Sesame Research, LLC

SERVING SESAME

FUNGI, OOMYCETES, BACTERIA, AND VIRUSES ASSOCIATED WITH SESAME (*Sesamum indicum* L.)

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Front cover: Phyllody on sesame plant. Photo: S. Boureima {Niger}

ABSTRACT

This book covers the sesame (*Sesamum indicum* L.) fungi, oomycetes, bacteria, and viruses that have been reported on sesame. The major diseases may seriously affect the yield or completely destroy fields and occur on all the continents. The major foliar diseases are on the leaves (which may spread to other parts of the plant) and include powdery mildew and the following leaf spots: Alternaria, Cercospora, Pseudomonas, and Xanthomonas. The following major soilborne diseases of sesame occur primarily on the roots and stems: Macrophomina, Phytophthora, and Fusarium. Other diseases affect the whole plant: Colletotrichum, Corynespora, phyllody, and Rhizoctonia. Some fungi produce toxins, reduce germination, and/or affect seed quality and are included in this work. This volume also includes species that have been used as biocontrols to combat infection and symptomology of pathogenic fungi. This volume is a part of other published volumes which cover the descriptors of sesame seedlings, roots and stems, plants, leaves, flowers, capsules, capsule zones, cycle, seeds, seed components, agronomic and administrative, invertebrates and fauna, and weeds. There is a volume still in draft on abiotic (physical) stresses. There is also a sesame bibliography. This series of documents are not intended to be read from front to back, but rather to be used like an encyclopedia. Data is repeated as appropriate, e.g., effects of *Trichoderma* spp. on *Fusarium* spp. will be under both *Trichoderma* spp. and *Fusarium* spp. for ease of use and to give the most complete information on a given topic. When a species is both a pathogen and a biocontrol, the data on the order, family, and genus is repeated in both sections.

KEYWORDS: sesame, *Sesamum indicum*, fungi, oomycetes, bacteria, virus, biocontrol, aflatoxin.

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For ease of finding, the glossary is on page ii.

There are two indices:

- The first index is in paragraph order and starts on page iv.
- The second index is in organism order and starts on page xii.

GLOSSARY

Acervuli: Cup shaped reproductive structures partially embedded in the substrate. These produce asexual spores (conidia) and may or may not have setae (whisker-like appendages sticking up from the acervulus) present.

Anamorph: An asexual reproductive stage (morph), often mold-like.

Anastomosis: a method for exchange of metabolic materials, hormones, genetic information, etc. that involves fusion (e.g., fusion of hyphae from two isolates of a given fungus, followed by exchange of the hyphae contents, including genetic material).

Anastomosis group (AG): Groupings based on the ability of hyphae of two different isolates to fuse and exchange materials.

Ascospores: A spore contained in an ascus or that was produced inside an ascus. This kind of spore is specific to fungi classified as ascomycetes. Ascospores are formed in ascus under optimal conditions. Typically, a single ascus will contain eight ascospores.

Basidiospores: Reproductive spores produced by Basidiomycete fungi, a grouping that includes mushrooms, shelf fungi, rusts, and smuts. Basidiospores typically each contain one haploid nucleus that is the product of meiosis, and they are produced by specialized fungal cells called basidia.

Basionym or basyonym: The original name of a species on which a new name is based.

Chasmothecia (plural of chasmothecium, previously cleistothecia): The sexual fruiting bodies produced by the powdery mildew organism. They only form on the surface of heavily diseased vine tissue and take about 90 days to fully mature. Immature chasmothecia are yellow, and gradually turn brown, then black.

Chlamydospores: Asexually produced thick-walled large resting spore of several kinds of fungi and oomycetes. It is the life-stage which survives in unfavorable conditions, such as dry or hot seasons.

Conidia (plural of conidium): Asexually produced microscopic spores of ascomycetes that occur in a variety of shapes and sizes, form on microscopic conidiophores of varying sizes and shapes (stalk like structures), or conidiogenous cells within various vase, cup, or other shaped structures (e.g., pycnidia, acervuli, etc.). The variation in shape, size, and color is instrumental in microscopic identification of these fungi and helpful in obtaining pure cultures via single spore isolation.

Conidiophore: A specialized hypha upon which conidia develop. Used in microscopic identification of fungi.

f. sp.: ***Forma specialis*** is an informal taxonomic grouping allowed by the International Code of Nomenclature for algae, fungi, and plants, that is applied to a parasite (most frequently a fungus) which is adapted to a specific host. This classification may be applied by authors who do not feel that a subspecies or variety name is appropriate, and it is therefore not necessary to specify morphological differences that distinguish this form. The literal meaning of the term is 'special form', but this grouping does not correspond to the more formal botanical use of the taxonomic rank of forma or form.

Gram-negative: Gram-negative bacteria do not retain the crystal violet stain used in the Gram staining method of bacterial differentiation into two broad categories according to their type of cell wall.

Gram-positive: Gram-positive bacteria give a positive result (retain the purple stain) in the Gram stain test, which is traditionally used to quickly classify bacteria into two broad categories according to their type of cell wall.

Heterotypic synonym: A synonym that comes into being when a taxon is reduced in status ("reduced to synonymy") and becomes part of a different taxon.

Holomorph: The whole fungus with respect to the life cycle, including anamorphs and teleomorphs.

Homotypic synonym: A synonym that comes into being through a nomenclatural act. when a taxon gets a new name, without being included in another taxon (of the same rank). The old name becomes a homotypic synonym of the new name.

Hyphae (plural of hypha): Long, branching filamentous structures of a fungus, oomycete, or actinobacterium. In most fungi, hyphae are the main mode of vegetative growth, and are collectively called a mycelium.

Inocula (plural of inoculum): A substance used for inoculation.

Macroconidia (plural of macroconidium): The larger of two different types of conidia produced by a fungus in the same manner, e.g., some Fusarium species produce micro- and macroconidia at the same time.

Microconidia (plural of microconidium): The smaller of two different types of conidia produced by a fungus in the same manner, e.g., some Fusarium species produce micro- and macroconidia at the same time.

Microsclerotia (plural of microsclerotium): A very small sclerotia, approx. half or less the size of a pin head, which is a durable long term survival structure of some fungi.

Oospore: A thick-walled sexual spore that develops from a fertilized oosphere in some algae, fungi, and oomycetes. They are believed to have evolved either through the fusion of two species or the chemically-induced stimulation of mycelia, leading to oospore formation.

Propagule: Any material that functions in propagating an organism to the next stage in its life cycle, such as by dispersal. The propagule is usually distinct in form from the parent organism.

pv.: A **pathovar** is a bacterial strain or set of strains with the same or similar characteristics, that is differentiated at infrasubspecific level from other strains of the same species or subspecies on the basis of distinctive pathogenicity to one or more plant hosts.

Pycnidia (plural of pycnidium): A variable and complex vase- or roughly circular shaped asexual reproductive structure, or fruiting body sometimes partially embedded in substrate. It bears spores (conidia) variously known as pycnidiospores, oidia, or spermatia. The spores are liberated through an opening (ostiole) in the pycnidium. Often brown or black in most species, though a few species produce lighter colors.

Sclerotia (plural of sclerotium): A compact mass of hardened fungal mycelium containing food reserves. One role of sclerotia is to survive environmental extremes, often for extended periods of time, even years. In some fungi, sclerotia become detached and remain dormant (often in the soil) until favorable growth conditions return. Sclerotia initially were mistaken for individual organisms and described as separate species until proved that sclerotia are only a stage in the life cycle of some fungi.

Seedborne: A pathogen that persists inside or on the seed; may serve as a source of inoculum in the field if pathogen remains viable until planting.

Setae: Dark brown, thick-walled, thorn like cystidia. Though mainly microscopic, the setae of some species may be sufficiently prominent to be visible with a hand lens.

Soilborne: A pathogen that persists in the soil.

sp. Single species within a genus.

Sporangia (plural of sporangium): Sac-like structures producing asexual spores endogenously by cytoplasmic cleavage.

Spore: A unit of sexual or asexual reproduction that may be adapted for dispersal and for survival, often for extended periods of time, in unfavorable conditions.

spp. Multiple species within a genus.

ssp.: The term **subspecies** refers to one of two or more populations of a species living in different subdivisions of the species' range and varying from one another by morphological characteristics.

Synanamorphs: When a single fungus produces multiple morphologically distinct anamorphs.

Teleomorph: The sexual reproductive stage (morph), typically a fruiting body.

Var.: V**ariety** is a taxonomic rank below that of species and subspecies, but above that of form. As such, it gets a three-part infraspecific name. It is sometimes recommended that the subspecies rank should be used to recognize geographic distinctiveness, whereas the variety rank is appropriate if the taxon is seen throughout the geographic range of the species.

Zoospore: A spore of certain algae, oomycetes, fungi, and protozoans, capable of swimming by means of a flagellum.

PARAGRAPH INDEX

TYPE of organism
- FNG = Fungus
- BAC = Bacteria
- OOM = Oomycetes
- VIR = Virus

The country column lists countries where the microorganism has been reported. There are many countries that have not done much research on microorganism or the references have not been found. For example, it does not make sense to have a species reported in Tanzania, Uganda, and Ethiopia, but not reported in Kenya. Or a report in West Bengal, India and not in Bangladesh. In the sections on biocontrols (E and F), the country list includes only the species that are not introduced for the experiments.

The following countries have reported microorganisms associated with sesame: International lists, Algeria, Argentina, Australia, Bangladesh, Bolivia, Brazil, Bulgaria, Burkina Faso, China, Colombia, Costa Rica, Cuba, Cyprus, Dominican Republic, Ecuador, Egypt, Ethiopia, Greece, Guatemala, Honduras, India, Iran, Iraq, Israel, Italy, Ivory Coast, Japan, Kenya, Macedonia, Malawi, Mexico, Myanmar, Nicaragua, Niger, Nigeria, Oman, Pakistan, Panama, Paraguay, Peru, Philippines, Republic of Korea, Republic of Moldova, Russia, Saudi Arabia, Senegal, Sierra Leone, Somalia, Sri Lanka, Sudan, Surinam, Syria, Taiwan, Tanzania, Thailand, Turkey, Uganda, Ukraine, United States, Uzbekistan, Venezuela, and Vietnam.

	Paragraph	Title	Type	Country
251	A5.1	Family: Erysiphaceae (Powdery mildew)	FNG	International lists, Australia, China, Ethiopia, Greece, India, Iraq, Israel, Japan, Malawi, Mexico, Myanmar, Nigeria, Pakistan, Somalia, Sri Lanka, Sudan, Tanzania, Thailand, Uganda, United States, and Venezuela
255	A5.1.1	*Oidium* spp.	FNG	International lists, Australia, China, Ethiopia, Greece, India, Israel, Japan, Mexico, Myanmar, Nigeria, Sri Lanka, Sudan, Tanzania, Uganda, United States, and Venezuela
258	A5.1.2	*Erysiphe* spp.	FNG	International lists, China, Ethiopia, India, Japan, Mexico, Sudan, Thailand, and Uganda
261	A5.1.3	*Leveillula* spp.	FNG	International lists, India, Italy, Japan, Mexico, Pakistan, United States, and Venezuela
264	A5.1.4	*Podosphaera* spp.	FNG	International lists, Australia, China, Ethiopia, India, Iraq, Japan, Malawi, Mexico, Somalia, Sudan, Tanzania, and Turkey
266	A5.1.5	*Pseudoidium* spp.	FNG	Japan and Republic of Korea
268	A6	Order: Cantharellales	FNG	
268	A6.1	Family: Ceratobasidiaceae	FNG	
268	A6.1.1	*Rhizoctonia* spp.	FNG	International lists, Australia, Bolivia, Brazil, China, Colombia, Costa Rica, Dominican Republic, Egypt, India, Iraq, Japan, Myanmar, Nicaragua, Pakistan, Panama, Republic of Korea, Uganda, United States, and Venezuela
276	A7	Order: Glomerellales	FNG	
276	A7.1	Family: Plectosphaerellaceae	FNG	
276	A7.1.1	*Verticillium* spp.	FNG	International lists, Australia, Bulgaria, China, Egypt, Ethiopia, India, Pakistan, Turkey, Uganda, United States, and Uzbekistan
279	A7.2	Family: Glomerellaceae	FNG	
279	A7.2.1	*Colletotrichum* spp.	FNG	International lists, China, India, Italy, Japan, Mexico, Myanmar, Nigeria, Paraguay, Republic of Korea, Thailand, Uganda, and United States
284	A8	Order: Helotiales	FNG	
284	A8.1	Family: Dermateaceae	FNG	
284	A8.1.1	*Cylindrosporium* spp.	FNG	International lists, Australia, Brazil, Costa Rica, Ethiopia, Guatemala, India, Kenya, Myanmar, Nigeria, Saudi Arabia, Sudan, Uganda, United States, and Venezuela
288	A8.1.2	*Gloeosporium* spp.	FNG	Italy
288	A8.2	Family: Sclerotiniaceae	FNG	
289	A8.2.1	*Sclerotinia* spp.	FNG	International lists, India, and Mexico
290	A9	Order: Atheliales	FNG	
290	A9.1	Family: Atheliaceae	FNG	
290	A9.1.1	*Athelia* spp.	FNG	International lists, China, Costa Rica, Greece, Honduras, India, Italy, Japan, Mexico, Nicaragua, Nigeria, Philippines, Sudan, United States, and Venezuela
294	A10	Order: Pezizales	FNG	
294	A10.1	Family: Rhizinaceae	FNG	
294	A10.1.1	*Phymatotrichopsis* spp.	FNG	United States
296	A11	Order: Trichosphaeriales	FNG	
296	A11.1	Family: Trichosphaeriaceae	FNG	
296	A11.1.1	*Nigrospora* spp.	FNG	China, Egypt, and Pakistan
298	A12	Order: Saccharomycetales	FNG	
298	A12.1	Family: Saccharomycetaceae	FNG	
298	A12.1.1	*Candida* spp.	FNG	India
298	A12.2	Family: Dipodascaceae	FNG	

	Paragraph	Title	Type	Country
378	C1.1.1	*Pseudomonas* spp.	BAC	International lists, Australia, Brazil, Bulgaria, Burkina Faso, China, Cuba, Ethiopia, Greece, Guatemala, India, Japan, Kenya, Macedonia, Malawi, Mexico, Myanmar, Nigeria, Pakistan, Paraguay, Republic of Korea, Somalia, Sudan, Tanzania, Thailand, Turkey, United States, and Venezuela
394	C2	Order: Burkholderiales	BAC	
394	C2.1	Family: Burkholderiaceae	BAC	
394	C2.1.1	*Ralstonia* spp.	BAC	International lists, China, India, Iraq, Japan, Mexico, Republic of Korea, Thailand, and United States
397	C2.2	Family: Comamonadaceae	BAC	
397	C2.2.1	*Acidovorax* spp.	BAC	Japan
398	C3	Order: Xanthomonadales	BAC	
398	C3.1	Family: Xanthomonadaceae	BAC	
398	C3.1.1	*Xanthomonas* spp.	BAC	International lists, Brazil, Burkina Faso, China, Ecuador, Ethiopia, Honduras, India, Japan, Malawi, Mexico, Myanmar, Nicaragua, Nigeria, Pakistan, Paraguay, Republic of Korea, Sudan, Turkey, United States, and Venezuela
414	C4	Order: Entomoplasmatales	BAC	
414	C4.1	Family: Spiroplasmataceae	BAC	
414	C4.1.1	*Spiroplasma* spp.	BAC	International lists, Iran, and Turkey
417	C5	Phyllody	BAC	International lists, Australia, Brazil, Burkina Faso, China, Egypt, Ethiopia, India, Iran, Iraq, Israel, Italy, Japan, Kenya, Malawi, Mexico, Myanmar, Niger, Nigeria, Oman, Pakistan, Paraguay, Philippines, Republic of Korea, Senegal, Sierra Leone, Sri Lanka, Sudan, Syria, Taiwan, Tanzania, Thailand, Turkey, Uganda, United States, Venezuela, and Vietnam. [Authors comment: In many countries, they have not determined the specific Phytoplasma species. This list includes the countries that have specified the Phytoplasma species.]
445	C6	Order: Acholeplasmatales	BAC	
445	C6.1	Family: Acholeplasmataceae	BAC	
445	C6.1.1	*Phytoplasma spp.*	BAC	See Phyllody above
462	C7	Order: Enterobacterales	BAC	
462	C7.1	Family: Erwiniaceae	BAC	
462	C7.1.1	*Erwinia* spp.	BAC	Ethiopia
462	C7.1.2	*Pantoea* spp.	BAC	Ethiopia, Japan
463	C7.2	Family: Enterobacteriaceae	BAC	
463	C7.2.1	*Salmonella* spp.	BAC	This does not come from the field. It may be picked up in the processing from the field to the consumer in any country.
464	C7.2.2	*Escherichia coli*	BAC	This does not come from the field. It may be picked up in the processing from the field to the consumer in any country.
466	C8	Order: Bacillales	BAC	
466	C8.1	Family: Bacillaceae	BAC	
466	C8.1.1	*Listeria* spp.	BAC	This does not come from the field. It may be picked up in the processing from the field to the consumer in any country.
466	C8.1.2	*Bacillus* spp.	BAC	Japan
468	D	Pest: Viruses	VIR	
470	D1	Order: Patatavirales	VIR	
470	D1.1	Family: Potyviridae	VIR	
470	D1.1.1	Genus: Potyvirus	VIR	
470	D1.1.1a	*Watermelon mosaic virus* (WMV)	VIR	China, Japan, and Republic of Korea

	Paragraph	Title	Type	Country
471	D1.1.1b	*Bean common mosaic virus* (BCMV)	VIR	China
472	D1.1.1c	*Zucchini yellow mosaic virus* (ZYMV)	VIR	International lists and China
472	D1.1.1d	*Cowpea aphid-borne mosaic virus* (CABMV)	VIR	International lists, Ivory Coast, Mexico, Paraguay, and United States
474	D1.1.1e	*Peanut stripe virus* (PSV)	VIR	International lists and China
475	D1.1.1f	*Turnip mosaic virus* (TuMV)	VIR	China and Japan
476	D1.1.1g	*Tobacco vein banding mosaic virus* (TVBMV)	VIR	China
476	D1.1.1h	*Peanut mottle virus* (PeMoV)	VIR	International lists
477	D2	Order: Geplafuvirales	VIR	
477	D2.1	Family: Geminividirae	VIR	
477	D2.1.1	Genus: Turncurtovirus	VIR	
477	D2.1.1a	*Sesame curly top virus* (SeCTV)	VIR	Iran
477	D2.1.2	Genus: Begomovirus	VIR	
478	D2.1.2a	*Tomato yellow leaf curl virus* (TYLCV)	VIR	Nigeria
478	D2.1.2b	*Tobacco leaf curl virus* (TLCV)	VIR	International lists, China, India, Mexico, Myanmar, Pakistan, Nigeria, Sierra Leone, Sudan, Tanzania, , and Venezuela
482	D3	Order: Martellivirales	VIR	
482	D3.1	Family: Virgaviridae	VIR	
482	D3.1.1	Genus: Tobamovirus	VIR	
482	D3.1.1a	*Pepper mild mosaic virus* (PMMoV)	VIR	China
482	D3.1.1b	*Tobacco mosaic virus* (TMV)	VIR	International lists and Nigeria
483	D3.2	Family: Bromoviridae	VIR	
483	D3.2.1	Genus: Alfamovirus	VIR	
483	D3.2.1a	*Alfalfa mosaic virus*	VIR	Unknown
484	D3.2.2	Genus: Cucumovirus	VIR	
484	D3.2.2a	*Cucumber mosaic virus* (CMV)	VIR	Not found naturally in fields
485	D4	Order: Mononegavirales	VIR	
485	D4.1	Family: Bunyaviridae	VIR	
485	D4.1.1	Genus: Tospovirus	VIR	
485	D4.1.1a	*Tomato spotted wilt virus* (TSWV)	VIR	Mexico
485	D4.1.1b	*Melon yellow spot virus* (MYSV)	VIR	Mexico
486	D4.1.1c	*Groundnut bud necrosis virus* (GBNV)	VIR	International lists, India
487	D5	Order: Picornavirales	VIR	
487	D5.1	Family: Secoviridae	VIR	
487	D5.1.1	Genus: Nepovirus	VIR	
487	D5.1.1a	*Tobacco ringspot virus* (TRSV)	VIR	Not found naturally in fields
487	D5.1.2	Genus: Sadwavirus	VIR	
488	D5.1.2a	*Satsuma dwarf virus* (SDV)	VIR	Not found naturally in fields
489	D6	Order: Tymovirales	VIR	
489	D6.1	Family: Alphaflexiviridae	VIR	
489	D6.1.1	Genus: Potexvirus	VIR	

ORGANISM INDEX

The following index lists all of the organisms (fungi, bacteria, oomycetes, and viruses) presently known to be associated with sesame. There are undoubtedly more organisms associated with sesame where the references were not found or will be researched in the future. **The organisms in black have been documented as a pathogen; as producing toxins; as affecting germination; as affecting seed quality; and/or have been tested as biocontrols. The organisms in blue have been reported on sesame but do not fall into the types above.** The columns are as follow:

- **Para** = Paragraph number in the document.
- **Organism** latin name. Initially, the common names were included, but the common names were different in different countries, or in some cases, the same common name was used on different organisms. *Syn = Synonym – see below.
- **Sdborne** = Has been reported on and/or inside the sesame seeds. Blank does not necessarily mean that the organism is not seedborne. There are only two known publications (Japan and United States) that searched for seedborne bacteria, and no known publications have searched for seedborne viruses.
- **Type** of organism
  - FNG = Fungus
  - BAC = Bacteria
  - OOM = Oomycetes
  - VIR = Virus
- **Func** = Function of organism
  - AQL = Affects seed quality
  - BIOC = Used as a biocontrol
  - BIOF = used as a biofertilizer
  - PATH = Pathogen
  - RGR = Reduces germination
  - TOX = Produces toxins
- **Synonym of** another organism. (Wikipedia, 6 Aug 2021) In botanical nomenclature, a synonym is a scientific name that applies to a taxon that (now) goes by a different scientific name. Unlike synonyms in other contexts, in taxonomy a synonym is not interchangeable with the name of which it is a synonym. In taxonomy, synonyms are not equals, but have a different status. The exception is that some names are reproductive forms (Teleomorph: the sexual reproductive stage [morph], typically a fruiting body. Anamorph: an asexual reproductive stage [morph], often mold-like. When a single fungus produces multiple morphologically distinct anamorphs, these are called synanamorphs. Holomorph: the whole fungus, including anamorphs and teleomorph) or a basionym (basionym or basyonym means the original name on which a new name is based; the author citation of the new name should include the authors of the basionym in parentheses.)

Para	Organism	Sdborne	Type	Func	Synonym of
H1.1	*Absidia corymbifera*	***	FNG		*Lichtheimia corymbifera*
E6.1.1a	*Acaulospora laevis*		FNG	BIOF	
E6.1.1	*Acaulospora* spp.		FNG	BIOF	
C2.2.1	*Acidovorax* spp.		BAC	PATH	
C2.2.1a	*Acidovorax valerianellae*		BAC	PATH	
I1.1	*Acinetobacter* spp.	***	BAC		
A1.3.1a	*Acremonium chrysogenum* *Syn: *Cephalosporium acremonium*	***	FNG	PATH	
A1.3.1	*Acremonium* spp. *Syn: *Cephalosporium* spp.	***	FNG	PATH	
A1.3.1b	*Acremonium strictum*	***	FNG	PATH	
D3.2.1a	*Alfalfa mosaic virus*		VIR	PATH	
D3.2.1	*Alfamovirus* spp.		VIR	PATH	
A3.1.1a	*Alternaria alternata* *Syn: *Alternaria tenuis*	***	FNG	PATH	
A3.1.1i	*Alternaria brassicae* *Syn: *Alternaria macrosporum*	***	FNG	PATH	

Para	Organism	Sdborne	Type	Func	Synonym of
A3.1.1l	*Alternaria brassicicola*	***	FNG	PATH	
A3.1.1	*Alternaria carthami*	***	FNG		
A3.1.1	*Alternaria chlamydospora*	***	FNG		
A3.1.1	*Alternaria cinerariae*	***	FNG		
A3.1.1g	*Alternaria citri*	***	FNG	PATH	
A3.1.1	*Alternaria dianthi*	***	FNG		
A3.1.1	*Alternaria dianthicola*	***	FNG		
A3.1.1	*Alternaria helianthi*	***	FNG		
A3.1.1	*Alternaria infectoria*	***	FNG		
A3.1.1f	*Alternaria japonica* *Syn: *Alternaria raphani*	***	FNG	PATH	
A3.1.1k	*Alternaria lini*		FNG	PATH	
A3.1.1	*Alternaria longipes*	***	FNG		
A3.1.1d	*Alternaria longissima*	***	FNG	PATH	
A3.1.1i	*Alternaria macrosporum*	***	FNG	PATH	*Alternaria brassicae*
A3.1.1n	*Alternaria mali*	***	FNG	PATH	
A3.1.1	*Alternaria pluriseptata*	***	FNG		
A3.1.1m	*Alternaria radicina*	***	FNG	PATH	
A3.1.1f	*Alternaria raphani*	***	FNG	PATH	*Alternaria japonica*
A3.1.1	*Alternaria seseamae*	***	FNG		
A3.1.1b	*Alternaria sesami* **Syn: Macrosporium sesami*	***	FNG	PATH	
A3.1.1c	*Alternaria sesamicola*	***	FNG	PATH	
A3.1.1e	*Alternaria simsimi*		FNG	PATH	
A3.1.1j	*Alternaria solani*	***	FNG	PATH	
A3.1.1	*Alternaria* spp. *Syn: *Macrosporium* spp.	***	FNG	PATH	
A3.1.1a	*Alternaria tenuis*	***	FNG	PATH	*Alternaria alternata*
A3.1.1h	*Alternaria tenuissima*	***	FNG	PATH	
A3.1.1	*Alternaria triticina*	***	FNG		
I2.1	*Aminivibrio* spp.	***	BAC		
A3.3.2	*Ascochyta gossypii*	***	FNG		
A3.3.2a	*Ascochyta sesami*		FNG	PATH	
A3.3.2b	*Ascochyta sesamicola*		FNG	PATH	
A3.3.2	*Ascochyta* spp.	***	FNG	PATH	
I3.1	*Asinibacterium* spp.	***	BAC		
A13.1.1n	*Aspergillus alba*	***	FNG	PATH	
A13.1.1	*Aspergillus amstelodami*	***	FNG		
A13.1.1	*Aspergillus caespitosus*	***	FNG		
A13.1.1i	*Aspergillus candidus*	***	FNG	TOX	
A13.1.1l	*Aspergillus carbonarius*	***	FNG	TOX	
A13.1.1p	*Aspergillus chevalieri*	***	FNG	PATH	
A13.1.1k E2.1.2c	*Aspergillus clavatus*	***	FNG	TOX BIOC	
A13.1.1m	*Aspergillus flavipes*		FNG	TOX	
A13.1.1a E2.1.2g	*Aspergillus flavus*	***	FNG	TOX BIOC	
A13.1.1h E2.1.2b	*Aspergillus fumigatus*	***	FNG	TOX BIOC	

Para	Organism	Sdborne	Type	Func	Synonym of
A13.1.1	*Aspergillus funiculosus*	***	FNG		
A13.1.1	*Aspergillus glaucus*	***	FNG		
A13.1.1	*Aspergillus montevidensis*	***	FNG		
E2.1.2f	*Aspergillus nidulans* *Syn: *Emericella nidulans*	***	FNG	BIOC	
A13.1.1b E2.1.2a	*Aspergillus niger*	***	FNG	TOX RGR AQL BIOC	
A13.1.1d	*Aspergillus nomius*		FNG	TOX	
A13.1.1e	*Aspergillus* ochraceus	***	FNG	TOX	
A13.1.1q	*Aspergillus oryzae*	***	FNG	PATH	
A13.1.1c	*Aspergillus parasiticus*	***	FNG	TOX	
A13.1.1g	*Aspergillus parvisclerotigenus*	***	FNG	TOX	
A13.1.1	*Aspergillus quadrilineatus* *Syn: *Emericella quadrilineata*	***	FNG		
A13.1.1	*Aspergillus repens*	***	FNG		
A13.1.1s	*Aspergillus ruber*	***	FNG	PATH	
A13.1.1j	*Aspergillus sacchari*	***	FNG	TOX	
A13.1.1 E2.1.2	*Aspergillus* spp.	***	FNG	TOX BIOC	
E2.1.2e	*Aspergillus sydowii*	***	FNG	BIOC	
A13.1.1f	*Aspergillus tamarii*	***	FNG	TOX	
A13.1.1r E2.1.2d	*Aspergillus terreus*	***	FNG	PATH BIOC	
A13.1.1	*Aspergillus tetrazonus*	***	FNG		
A13.1.1	*Aspergillus versicolor*	***	FNG		
A13.1.1o	*Aspergillus viridus*	***	FNG	PATH	
A9.1.1b	*Athelia arachnoidea* **Syn: Corticium centrifugum*		FNG	PATH	
A9.1.1a	*Athelia rolfsii* *Syn: *Pellicularia rolfsii* *Sclerotium rolfsii* *Botryobasidium rolfsii* *Corticium rolfsii*	***	FNG	PATH	
A9.1.1	*Athelia* spp.	***	FNG	PATH	
F4.1.1a	*Azospirillum brasilense*		BAC	BIOC	
F4.1.1	*Azospirillum* spp.		BAC	BIOC	
F1.1.2a	*Azotobacter chroococcum*		BAC	BIOF	
F1.1.2	*Azotobacter* spp.		BAC	BIOF	
F2.1.1d	*Bacillus amyloliquefaciens*		BAC	BIOC	
C8.1.2a F2.1.1c	*Bacillus cereus*		BAC	TOX BIOC	
F2.1.1a	*Bacillus megtella*		BAC	BIOC	
F2.1.1f	*Bacillus methylotrophicus*		BAC	BIOC	
F2.2.1a	*Bacillus polymyxa*		BAC	BIOC	*Paenibacillus polymyxa*
C2.1.1a	*Bacillus solanacearum*		BAC	PATH	*Ralstonia solanacearum*
C8.1.2 F2.1.1	*Bacillus* spp.	***	BAC	TOX BIOC	
F2.1.1b	*Bacillus subtillis*		BAC	BIOC	
F2.1.1g	*Bacillus thuringiensis*		BAC	BIOC	
F2.1.1e	*Bacillus velezensis*		BAC	BIOC	

Para	Organism	Sdborne	Type	Func	Synonym of
C1.1.1b	*Bacterium sesami*	***	BAC	PATH	*Pseudomonas syringae* pv. *sesami*
C1.1.1b	*Bacterium sesamicola*	***	BAC	PATH	*Pseudomonas syringae* pv. *sesami*
C2.1.1a	*Bacterium solanacearum*		BAC	PATH	*Ralstonia solanacearum*
D1.1.1b	*Bean common mosaic virus* (BCMV)		VIR	PATH	
E1.3.1a	*Beauveria bassiana*		FNG	BIOC	
E1.3.1	*Beauveria* spp.		FNG	BIOC	
D2.1.2	*Begomovirus* spp.		VIR	PATH	
H2.1	*Berkeleyomyces basicola* *Syn: *Chalara elegans*		FNG		
A9.1.1a	*Botryobasidium rolfsii*	***	FNG	PATH	*Athelia rolfsii*
A2.1.3a	*Botryosphaeria ribis*		FNG	PATH	
A2.1.3	*Botryosphaeria* spp.		FNG	PATH	
H3.1	*Botrytis* spp.	***	FNG		
A12.1.1	*Candida* spp.		FNG	PATH	
C6.1.1a	*Candidatus* Phytoplasma asteris (Group 16SrI)		BAC	PATH	
C6.1.1c	*Candidatus* Phytoplasma trifolii (Group 16SrVI)		BAC	PATH	
A1.3.1a	*Cephalosporium acremonium*	***	FNG	PATH	*Acremonium chrysogenum*
A1.3.1	*Cephalosporium* spp.	***	FNG	PATH	*Acremonium* spp.
A4.1.3a	*Cercoseptoria sesami*		FNG	PATH	
A4.1.3	*Cercoseptoria* spp.		FNG	PATH	
H4.1	*Cercospora bolleana*	***	FNG		*Mycosphaerella bolleana*
A4.1.1	*Cercospora chenopodii*	***	FNG		
H4.1	*Cercospora koepkei*	***	FNG		*Mycovellosiella koepkei*
A4.1.1a	*Cercospora sesami* *Syn: *Mycosphaerella sesami* *Mycosphaerella sesamicola* *Cercospora sesami* var. *somalensis*	***	FNG	PATH	
A4.1.1a	*Cercospora sesami* var. *somalensis*	***	FNG	PATH	*Cercospora sesami*
A4.1.1b	*Cercospora sesamicola*		FNG	PATH	
A4.1.1	*Cercospora* spp.	***	FNG	PATH	
A4.1.6	*Cercosporidium* spp.		FNG	PATH	
E4.1.2a	*Chaetomium bostrycoides*		FNG	BIOC	*Collariella bostrychodes*
E4.1.1	*Chaetomium elatum*	***	FNG		
E4.1.1	*Chaetomium funicolum*	***	FNG		
E4.1.1	*Chaetomium globosum*	***	FNG		
E4.1.1	*Chaetomium olivaceum*	***	FNG		
E4.1.1b	*Chaetomium penicilloides*		FNG	BIOC	
E4.1.1	*Chaetomium spirale*	***	FNG		
E4.1.1	*Chaetomium* spp.	***	FNG	BIOC	
H2.1	*Chalara elegans*		FNG		*Berkeleyomyces basicola*
A14.2.1a	*Choanephora cucurbitarum*		FNG	PATH	
A14.2.1	*Choanephora* spp.		FNG	PATH	
I4.1	*Chryseobacterium* spp.	***	BAC		
I6.1	*Chryseolinea* spp.	***	BAC		
A4.2.1e	*Cladosporium chlorocephalum*	***	FNG	PATH	
A4.2.1b	*Cladosporium cladosporioides*	***	FNG	PATH	
H5.1	*Cladosporium elatum*	***	FNG		*Ochrocladosporium elatum*

Para	Organism	Sdborne	Type	Func	Synonym of
A4.1.7	*Cladosporium fulvum*	***	FNG	PATH	*Passalora fulva*
A4.2.1c	*Cladosporium herbarum*	***	FNG	PATH	
A4.2.1d	*Cladosporium macrocarpum*	***	FNG	PATH	
A4.2.1a	*Cladosporium oxysporum*	***	FNG	PATH	
A4.2.1f	*Cladosporium sphaerospermum*	***	FNG	PATH	
A4.2.1	*Cladosporium* spp.	***	FNG	PATH	
A4.2.1g	*Cladosporium tenuissimum*	***	FNG	PATH	
A4.2.1h	*Cladosporium variabile*	***	FNG	PATH	
E5.2.1	*Claroideoglomus spp.*		FNG	BIOC	
E5.2.1a	*Claroideoglomus etunicatum*		FNG	BIOC	
E5.2.1b	*Claroideoglomus claroideum*		FNG	BIOC	
A3.1.5a	*Cochliobolus lunatus*	***	FNG	PATH	*Curvularia lunata*
A3.1.4a	*Cochliobolus sativus* *Syn: *Drechslera sorokiniana*		FNG	PATH	
A3.1.4b	*Cochliobolus spicifer*		FNG	PATH	
A3.1.4	*Cochliobolus* spp.		FNG	PATH	
E4.1.2a	*Collariella bostrychodes* *Syn: *Chaetomium bostrychodes*		FNG	BIOC	
E4.1.2	*Collariella* spp.		FNG	BIOC	
A7.2.1b	*Colletotrichum capsici*		FNG	PATH	*Colletotrichum truncatum*
A7.2.1a	*Colletotrichum gloeosporioides* *Syn: *Glomerella cingulata*		FNG	PATH	
A7.2.1c	*Colletotrichum sesamina* *Syn: *Vermicularia sesamina*		FNG	PATH	
A7.2.1	*Colletotrichum* spp.	***	FNG	PATH	
A7.2.1b	*Colletotrichum truncatum* *Syn: *Colletotrichum capsici*		FNG	PATH	
E2.1.3a	*Cordyceps fumosorosea* *Syn: *Isaria fumosorosea*		FNG	BIOC	
E2.1.3	*Cordyceps* spp.		FNG	BIOC	
A9.1.1b	*Corticium centrifugum*		FNG	PATH	*Athelia arachnoidea*
A9.1.1a	*Corticium rolfsii*	***	FNG	PATH	*Athelia rolfsii*
A3.2.1a	*Corynespora cassiicola*	***	FNG	PATH	
A3.2.1b	*Corynespora sesameum*		FNG	PATH	
A3.2.1	*Corynespora* spp.	***	FNG	PATH	
D1.1.1d	*Cowpea aphid-borne mosaic virus* (CABMV)		VIR	PATH	
D3.2.2a	*Cucumber mosaic virus* (CMV)		VIR	PATH	
D3.2.2	*Cucumovirus* spp.		VIR	PATH	
H1.2	*Cunninghamella elegans*	***	FNG		
A3.1.5c	*Curvularia fallax*		FNG	PATH	
A3.1.5a	*Curvularia lunata* *Syn: *Cochliobolus lunatus*	***	FNG	PATH	
A3.1.5b	*Curvularia macularis*		FNG	PATH	
A3.1.5d	*Curvularia neergaardii* *Syn: *Drechslera neergaardi*	***	FNG	PATH	
A3.1.5	*Curvularia richardiae*	***	FNG		
A3.1.5	*Curvularia* spp.	***	FNG	PATH	
A1.1.4	*Cylindrocladium* spp.		FNG	PATH	
A8.1.1a	*Cylindrosporium sesami*		FNG	PATH	
A8.1.1	*Cylindrosporium* spp.		FNG	PATH	

Para	Organism	Sdborne	Type	Func	Synonym of
A3.3.3a	*Didymella minuta*		FNG	PATH	
A3.3.3b	*Didymella rabiei* *Syn: *Mycosphaerella rabiei*		FNG	PATH	
A3.3.3	*Didymella* spp.		FNG	PATH	
H6.1	*Diplodia herbarum*	***	FNG		
A2.1.1a	*Dothiorella phillippinensis*	***	FNG	PATH	*Macrophomina phaseolina*
A3.1.3	*Drechslera ellisii*	***	FNG		
A3.1.3	*Drechslera halodes*	***	FNG		
A3.1.3	*Drechslera hawaiiensis*	***	FNG		
A3.1.5d	*Drechslera neergaardi*	***	FNG	PATH	*Curvularia neergaardii*
A3.1.3a	*Drechslera rostrata*		FNG	PATH	*Drechslera rostratum*
A3.1.3a	*Drechslera rostratum* *Syn: *Drechslera rostrata*		FNG	PATH	
A3.1.3b	*Drechslera sesami*		FNG	PATH	
A3.1.4a	*Drechslera sorokiniana*		FNG	PATH	*Cochliobolus sativus*
A3.1.3	*Drechslera spp.*	***	FNG	PATH	
A3.1.3	*Drechslera tetramera*	***	FNG		
E2.1.2f	*Emericella nidulans*	***	FNG	BIOC	*Aspergillus nidulans*
A13.1.1	*Emericella quadrilineata*	***	FNG		*Aspergillus quadrilineatus*
F7.1.1a	*Enterobacter cloacae*		BAC	BIOC	
F7.1.1	*Enterobacter* spp.		BAC	BIOC	
H11.1	*Eurotium* spp.	***	FNG		
C7.1.2a	*Erwinia herbicola*		BAC	PATH	*Pantoea agglomerans*
C7.1.1	*Erwinia* spp.		BAC	PATH	
A5.1.2c	*Erysiphe betae* *Syn: *Erysiphe polygoni*		FNG	PATH	
A5.1.2a	*Erysiphe cichoracearum* *Syn: Oidium acanthospermi*		FNG	PATH	
A5.1.2d	*Erysiphe communis*		FNG	PATH	*Erysiphe cruciferarum*
A5.1.2d	*Erysiphe cruciferarum* *Syn: *Erysiphe communis*		FNG	PATH	
A5.1.2b	*Erysiphe orontii*		FNG	PATH	
A5.1.2c	*Erysiphe polygoni*		FNG	PATH	*Erysiphe betae*
A5.1.2	*Erysiphe* spp.		FNG	PATH	
C7.2.2	*Escherichia coli*		BAC	PATH	
A3.1.6	*Exserohilum* spp. *Syn: *Setosphaeria* spp.	***	FNG	PATH	
I5.1	*Falsibacillus* spp.	***	BAC		
I4.2	Flavobacteriaceae	***	BAC		
E5.1.3a	*Funneliformis caledonium* *Syn: *Glomus caledonium*		FNG	BIOF	
E5.1.3b	*Funneliformis geosporum* *Syn: Glomus geosporum*		FNG	BIOF	
E5.1.3c	*Funneliformis mosseae* *Syn: *Glomus mosseae*		FNG	BIOF	
E5.1.3	*Funneliformis* spp.	***	FNG	BIOF	
A1.1.1j	*Fusarium acutatum*	***	FNG	PATH	
A1.1.1c	*Fusarium caeruleum*		FNG	PATH	
A1.1.1l	*Fusarium chlamydosporum*	***	FNG	TOX	
A1.1.1i	*Fusarium culmorum*		FNG	PATH	
A1.1.1	*Fusarium dimerum*	***	FNG		

Para	Organism	Sdborne	Type	Func	Synonym of
A1.1.1g	*Fusarium equiseti*	***	FNG	PATH	
A1.1.2a	*Fusarium fujikuroi*	***	FNG	PATH	*Gibberella fujikuroi*
A1.1.1	*Fusarium graminearum*	***	FNG		
A1.1.1e	*Fusarium incarnatum* *Syn: *Fusarium semitectum*	***	FNG	PATH	
A1.1.1m	*Fusarium longipes*		FNG	TOX	
A1.1.1h	*Fusarium merismoides*	***	FNG	PATH	
A1.1.2a	*Fusarium moniliforme*	***	FNG	PATH	*Gibberella fujikuroi*
A1.1.1	*Fusarium nygamai*		FNG		
A1.1.1a	*Fusarium oxysporum*	***	FNG	PATH TOX	
A1.1.1a.1	*Fusarium oxysporum* f. sp. *sesami*	***	FNG	PATH	
A1.1.1a.2	*Fusarium oxysporum* f. sp. *vasinfectum* *Syn: *Fusarium vasinfectum* *Fusarium vasinfectum* f. sp. *sesami*		FNG	PATH	
A1.1.1k	*Fusarium poae*		FNG	TOX	
A1.1.1b	*Fusarium proliferatum*	***	FNG	PATH	
A1.1.1	*Fusarium redolens*				
A1.1.1	*Fusarium reticulatum*				
A1.1.1	*Fusarium sambucinum*		FNG		
A1.1.1e	*Fusarium semitectum*	***	FNG	PATH	*Fusarium incarnatum*
A1.1.1d	*Fusarium solani*	***	FNG	PATH	
A1.1.1	*Fusarium* spp.	***	FNG	PATH	
A1.1.1	*Fusarium subglutinans*	***	FNG		
A1.1.1n	*Fusarium sulawesiensis*		FNG	PATH	
H8.1	*Fusarium tabacinum*	***	FNG		*Plectosphaerella cucumerina*
A1.1.1	*Fusarium tricinctum*		FNG		
A1.1.1a.2	*Fusarium vasinfectum*		FNG	PATH	*Fusarium oxysporum* f. sp. *vasinfectum*
A1.1.1a.2	*Fusarium vasinfectum* f. sp. *sesami*		FNG	PATH	*Fusarium oxysporum* f. sp. *vasinfectum*
A1.1.1f	*Fusarium verticillioides*	***	FNG	PATH	
A1.1.1	*Fusarium xylarioides*	***	FNG		
A12.2.1a	*Geotrichum candidum*	***	FNG	PATH	
A12.2.1	*Geotrichum* spp.	***	FNG	PATH	
A1.1.2a	*Gibberella fujikuroi* *Syn: *Fusarium moniliforme* *Fusarium fujikuroi*	***	FNG	PATH	
A1.1.2	*Gibberella* spp.	***	FNG	PATH	
A1.1.2b	*Gibberella zeae*		FNG	PATH	
E6.2.1a	*Gigaspora margarita*		FNG	BIOF	
E6.2.1	*Gigaspora* spp.		FNG	BIOF	
E1.1.3a	*Gliocladium penicillioides*		FNG	BIOC	*Sphaerostilbella aureonitens*
E1.1.2	*Gliocladium* spp.	***	FNG	BIOC	
E1.1.2	*Gliocladium roseum*	***	FNG		
A8.1.2a	*Gloeosporium macrophomoides*		FNG	PATH	
A8.1.2	*Gloeosporium* spp.		FNG	PATH	
A7.2.1a	*Glomerella cingulata*		FNG	PATH	*Colletotrichum gloeosporioides*
E5.1.1a	*Glomus austrae*		FNG	BIOF	

Para	Organism	Sdborne	Type	Func	Synonym of
E5.1.3a	*Glomus caledonium*		FNG	BIOF	*Funneliformis caledonium*
E5.1.4c	*Glomus clarum*		FNG	BIOF	*Rhizophagus clarus*
E5.1.4b	*Glomus fasciculatum*		FNG	BIOF	*Rhizophagus fasciculatus*
E5.1.3b	*Glomus geosporum*		FNG	BIOF	*Funneliformis geosporum*
E5.1.1b	*Glomus macrosporium*		FNG	BIOF	
E5.1.3c	*Glomus mosseae*		FNG	BIOF	*Funneliformis mosseae*
E5.1.1	*Glomus* spp.		FNG	BIOF	
D4.1.1c	*Groundnut bud necrosis virus* (GBNV)		VIR	PATH	
H9.1	*Haematonectria haematococca*		FNG		
H10.1	*Haplosporangium* spp.	***	FNG		
A16.1.1a	*Helicobasidium mompa*		FNG	PATH	
A16.1.1	*Helicobasidium* spp.		FNG	PATH	
A3.1.2d	*Helminthosporium gigasporum*		FNG	PATH	*Helminthosporium magnisporum*
A3.1.2b	*Helminthosporium halodes*		FNG	PATH	
A3.1.2d	*Helminthosporium magnisporum* *Syn: *Helminthosporium gigasporum*		FNG	PATH	
A3.1.2a	*Helminthosporium sesami*	***	FNG	PATH	
A3.1.2	*Helminthosporium* spp.	***	FNG	PATH	
A3.1.2c	*Helminthosporium tetramera*	***	FNG	PATH	
H9.2	*Hypocrea rufa*		FNG		
E2.1.3a	*Isaria fumosorosea*		FNG	BIOC	*Cordyceps fumosorosea*
E1.3.2a	*Lecanicillium leccani*		FNG	BIOC	
E1.3.2	*Lecanicillium* spp.		FNG	BIOC	
A5.1.3	*Leveillula* spp.		FNG	PATH	
A5.1.3a	*Leveillula taurica* *Syn: *Oidiopsis taurica*		FNG	PATH	
H1.1	*Lichtheimia corymbifera* *Syn: *Absidia corymbifera*	***	FNG		
C8.1.1	*Listeria* spp.	***	BAC	PATH	
A2.1.1a	*Macrophomina corchon*	***	FNG	PATH	*Macrophomina phaseolina*
A2.1.1a	*Macrophomina phaseoli*	***	FNG	PATH	*Macrophomina phaseolina*
A2.1.1a	*Macrophomina phaseoli* ssp. *sesamica*	***	FNG	PATH	*Macrophomina phaseolina*
A2.1.1a	*Macrophomina phaseolina* *Syn: *Macrophomina phaseoli* *Macrophomina phaseoli* ssp. *sesamica* *Sclerotium bataticola* *Macrophomina corchon* *Dothiorella phillippinensis* *Macrophomina phillippinensis* *Rhizoctonia bataticola* *Tiarosporella phaseolina*	***	FNG	PATH	
A2.1.1a	*Macrophomina phillippinensis*	***	FNG	PATH	*Macrophomina phaseolina*
A2.1.1	*Macrophomina* spp.	***	FNG	PATH	
A3.1.1b	*Macrosporium sesami*	***	FNG	PATH	*Alternaria sesami*
A3.1.1	*Macrosporium* spp.	***	FNG	PATH	*Alternaria* spp.
D4.1.1b	*Melon yellow spot virus* (MYSV)		VIR	PATH	
A1.2.2a	*Memnoniella echinata*	***	FNG	PATH	
A1.2.2	*Memnoniella sitophila*	***	FNG		

Para	Organism	Sdborne	Type	Func	Synonym of
A1.2.2	*Memnoniella* spp.	***	FNG	PATH	
E1.2.1b	*Metarhizium anisopliae*		FNG	BIOC	
E1.2.1	*Metarhizium* spp.		FNG	BIOC	
E1.2.1a	*Metarhizium rileyi* *Syn: *Nomuraea rileyi*		FNG	BIOC	
A14.1.2a	*Mucor hiemalis*		FNG	PATH	
A14.1.2	*Mucor mucedo*	***	FNG		
A14.1.2	*Mucor* spp.	***	FNG	PATH	
H4.1	*Mycosphaerella bolleana* *Syn: *Cercospora bolleana*	***	FNG		
H4.1	*Mycovellosiella koepkei* *Syn: *Cercospora koepkei*	***	FNG		
A3.3.3b	*Mycosphaerella rabiei*		FNG	PATH	*Didymella rabiei*
A4.1.1a	*Mycosphaerella sesami*	***	FNG	PATH	*Cercospora sesami*
A4.1.1a	*Mycosphaerella sesamicola*	***	FNG	PATH	*Cercospora sesami*
A1.2.3a	*Myrothecium roridum*	***	FNG	PATH TOX	*Paramyrothecium roridum*
A1.2.1	*Myrothecium* spp.	***	FNG	PATH	
A1.1.3	*Neocosmospora* spp.		FNG	PATH	
A1.1.3a	*Neocosmospora vasinfecta*		FNG	PATH	
D5.1.1	*Nepovirus* spp.		VIR	PATH	
E4.2.1a	*Neurospora sitophila*		FNG	BIOC	
E4.2.1	*Neurospora* spp.	***	FNG	BIOC	
E4.2.1	*Neurospora glabra*	***	FNG		
D2.1.2b	*Nicotinia 10 virus*		VIR	PATH	*Tobacco leaf curl virus* (TLCV)
A11.1.1b	*Nigrospora oryzae*		FNG	PATH	
A11.1.1a	*Nigrospora sphaerica*		FNG	PATH	
A11.1.1	*Nigrospora* spp.		FNG	PATH	
E1.2.1a	*Nomuraea rileyi*		FNG	BIOC	*Metarhizium rileyi*
F6.1.1	*Nostoc* spp.		BAC	BIOC	
FA1.1.1a	*Nuclear polyhedrosis virus* (NPV)		VIR	BIOC	
H5.1	*Ochrocladosporium elatum* *Syn: *Cladosprorium elatum*	***	FNG		
A5.1.3a	*Oidiopsis taurica*		FNG	PATH	*Leveillula taurica*
A5.1.2a	*Oidium acanthospermi*		FNG	PATH	*Erysiphe cichoracearum*
A5.1.4a	*Oidium erysiphoides*		FNG	PATH	*Podosphaera fuliginea*
A5.1.1a	*Oidium sesami*		FNG	PATH	
A5.1.1	*Oidium* spp. *Syn: *Oospora* spp.		FNG	PATH	
I7.1	*Okibacterium* spp.	***	BAC		
A5.1.1	*Oospora* spp.		FNG	PATH	*Oidium* spp.
H11.1	*Paecilomyces digitatum*	***	FNG		
H11.1	*Paecilomyces* spp.	***	FNG		
H11.1	*Paecilomyces variotii*	***	FNG		
F2.2.1a	*Paenibacillus polymyxa* *Syn: *Bacillus polymyxa*		BAC	BIOC	
F2.2.1	*Paenibacillus relictisesami*	***	BAC		
F2.2.1	*Paenibacillus* spp.	***	BAC	BIOC	
C7.1.2a	*Pantoea agglomerans* *Syn: *Erwinia herbicola*	***	BAC	PATH	
C7.1.2	*Pantoea dispersa*	***	BAC		

Para	Organism	Sdborne	Type	Func	Synonym of
C7.1.2	*Pantoea septica*	***	BAC		
C7.1.2	*Pantoea* spp.	***	BAC	PATH	
A1.2.3a	*Paramyrothecium roridum* *Syn: *Myrothecium roridum*	***	FNG	PATH TOX	
A1.2.3	*Paramyrothecium* spp.	***	FNG	PATH TOX	
A4.1.7a	*Passalora fulva* *Syn: *Cladosporium fulvum*	***	FNG	PATH	
A4.1.7	*Passalora* spp.	***	FNG	PATH	
D1.1.1h	*Peanut mottle virus* (PeMoV)		VIR	PATH	
D1.1.1e	*Peanut stripe virus* (PSV)		VIR	PATH	
C6.1.1b	Peanut witches' broom phytoplasma (Group 16SrII)		BAC	PATH	
A6.1.1a	*Pellicularia filamentosa*	***	FNG	PATH	*Rhizoctonia solani*
A9.1.1a	*Pellicularia rolfsii*	***	FNG	PATH	*Athelia rolfsii*
E2.1.1b	*Penicillium aurantiogriseum*		FNG	BIOC	
E2.1.1a	*Penicillium bilaiae*		FNG	BIOC	
A13.1.2h	*Penicillium brevicompactum*	***	FNG	TOX	
A13.1.2i E2.1.1c	*Penicillium chrysogenum*	***	FNG	AQL BIOC	
A13.1.2	*Penicillium citratum*	***	FNG		
A13.1.2b	*Penicillium citrinum*	***	FNG	RGR	
A13.1.2g E2.1.1d	*Penicillium crustosum*	***	FNG	TOX BIOC	
A13.1.2a	*Penicillium egyptiacum*	***	FNG	RGR	
A13.1.2	*Penicillium expansum*	***	FNG		
A13.1.2	*Penicillium herqui*	***	FNG		
A13.1.2	*Penicillium italicum*	***	FNG		
A13.1.2	*Penicillium janthinellum*	***	FNG		
A13.1.2	*Penicillium jensemi*	***	FNG		
A13.1.2	*Penicillium lanso-coerellum*	***	FNG		
A13.1.2	*Penicillium lilacinum*	***	FNG		
A13.1.2f	*Penicillium nordicum*	***	FNG	TOX	
A13.1.2	*Penicillium oxalicum*	***	FNG		
A13.1.2	*Penicillium paxilli*	***	FNG		
A13.1.2	*Penicillium purpurogenum*	***	FNG		
A13.1.2c	*Penicillium rubrum*	***	FNG	RGR	
A13.1.2 E2.1.1	*Penicillium* spp.	***	FNG	RGR BIOC	
E2.1.4	*Penicillium vermiculatum*	***	FNG		*Talaromyces flavus*
A13.1.2d	*Penicillium verrucosum*	***	FNG	TOX	
A13.1.2e	*Penicillium viridicatum*	***	FNG	TOX	
A13.1.2	*Penicillium waksmani*	***	FNG		
D3.1.1a	*Pepper mild mosaic virus* (PMMoV)		VIR	PATH	
A17.1	*Pestalotia macrotricha*	***	FNG		
A17.1.1a	*Pestalotiopsis mayumbensis*		FNG	PATH	
A17.1.1	*Pestalotiopsis* spp.		FNG	PATH	
A4.1.5a	*Phaeoisariopsis griseola*		FNG	PATH	
A4.1.5	*Phaeoisariopsis* spp.		FNG	PATH	
A3.3.1d	*Phoma exigua*		FNG	PATH	

Para	Organism	Sdborne	Type	Func	Synonym of
A3.3.1	*Phoma herbarum*	***	FNG		
A3.3.1b	*Phoma nebulosa*	***	FNG	PATH	
A3.3.1a	*Phoma sesami*		FNG	PATH	
A3.3.1c	*Phoma sesamina*		FNG	PATH	
A3.3.1	*Phoma sorghina*	***	FNG		
A3.3.1	*Phoma* spp.	***	FNG	PATH	
A3.3.1e	*Phoma variosporeae*		FNG	PATH	
C5	Phyllody		BAC	PATH	
A2.1.2a	*Phyllosticta sesami*		FNG	PATH	
A2.1.2	*Phyllosticta* spp.		FNG	PATH	
A10.1.1a	*Phymatotrichopsis omnivora* *Syn: *Phymatotrichum omnivorum*		FNG	PATH	
A10.1.1	*Phymatotrichopsis* spp.		FNG	PATH	
A10.1.1a	*Phymatotrichum omnivorum*		FNG	PATH	*Phymatotrichopsis omnivora*
C1.1.1b	*Phytomonas sesami*	***	BAC	PATH	*Pseudomonas syringae* pv. *sesami*
C1.1.1b	*Phytomonas sesamicola*	***	BAC	PATH	*Pseudomonas syringae* pv. *sesami*
B1.1.1b	*Phytophthora cactorum*		OOM	PATH	
B1.1.1f	*Phytophthora capsici*		OOM	PATH	
B1.1.1d	*Phytophthora drechsleri*		OOM	PATH	
B1.1.1c	*Phytophthora hibernalis*		OOM	PATH	
B1.1.1a	*Phytophthora nicotianae* *Syn: *Phytophthora nicotianae* var. *parasitica* *Phytophthora parasitica* *Phytophthora parasitica* var. *sesami*		OOM	PATH	
B1.1.1a	*Phytophthora nicotianae* var. *parasitica*		OOM	PATH	*Phytophthora nicotianae*
B1.1.1e	*Phytophthora palmivora*		OOM	PATH	
B1.1.1a	*Phytophthora parasitica*		OOM	PATH	*Phytophthora nicotianae*
B1.1.1a	*Phytophthora parasitica* var. *sesami*	***	OOM	PATH	*Phytophthora nicotianae*
B1.1.1	*Phytophthora* spp.	***	OOM	PATH	
B1.1.1g	*Phytophthora tropicalis*		OOM	PATH	
C6.1.1	*Phytoplasma* spp.		BAC	PATH	
C6.1.1d	*Pigeon pea witches' broom phytoplasma* (Group 16SrIX)		BAC	PATH	
I8.1	Planctomycetaceae	***	BAC		
H8.1	*Plectosphaerella cucumerina* *Syn: *Fusarium tabacinum*	***	FNG		
H5.2	*Pleospora* spp.	***	FNG		
A5.1.4a	*Podosphaera fuliginea* *Syn: *Sphaerotheca fuliginea* *Oidium erysiphoides* *Podosphaera xanthii*		FNG	PATH	
A5.1.4b	*Podosphaera fusca*		FNG	PATH	
A5.1.4	*Podosphaera* spp.		FNG	PATH	
A5.1.4a	*Podosphaera xanthii*		FNG	PATH	*Podosphaera fuliginea*
D6.1.1b	*Potato aucuba mosaic virus* (PAMV)		VIR	PATH	
D6.1.1a	*Potato virus X* (PVX)		VIR	PATH	
D6.1.1	*Potexvirus* spp.		VIR	PATH	
D1.1.1	*Potyvirus* spp.		VIR	PATH	

Para	Organism	Sdborne	Type	Func	Synonym of
F2.1.2a	*Priestia megaterium* *Syn: *Bacillus megaterium*		BAC	BIOC	
F2.1.2	*Priestia* spp.		BAC	BIOC	
A4.1.2a	*Pseudocercospora sesami*		FNG	PATH	
A4.1.2	*Pseudocercospora* spp.		FNG	PATH	
A4.1.4a	*Pseudocercosporella sesami*		FNG	PATH	
A4.1.4	*Pseudocercosporella* spp.		FNG	PATH	
A5.1.5a	*Pseudoidium pedaliacearum*		FNG	PATH	
A5.1.5	*Pseudoidium* spp.		FNG	PATH	
C1.1	Pseudomonadaceae	***	BAC		
F1.1.1d	*Pseudomonas aeruginosa*	***	BAC	BIOC	
C1.1.1	*Pseudomonas amygdali*	***	BAC		
C1.1.1	*Pseudomonas aptata*		BAC		
F1.1.1a	*Pseudomonas fluorescens*		BAC	BIOC	
F1.1.1b	*Pseudomonas putida* *Syn: *Pseudomonas striata*		BAC	BIOF	
C1.1.1b	*Pseudomonas sesami*	***	BAC	PATH	*Pseudomonas syringae* pv. *sesami*
C2.1.1a	*Pseudomonas solanacearum*		BAC	PATH	*Ralstonia solanacearum*
C1.1.1 F1.1.1	*Pseudomonas* spp.	***	BAC	PATH BIOC	
F1.1.1b	*Pseudomonas striata*		BAC	BIOF	*Pseudomonas putida*
C1.1.1a	*Pseudomonas syringae*		BAC	PATH	
C1.1.1b	*Pseudomonas syringae* pv. *sesami* *Syn: *Pseudomonas sesami* *Bacterium sesami* *Bacterium sesamicola* *Phytomonas sesami* *Phytomonas sesamicola*	***	BAC	PATH	
F1.1.1c	*Pseudomonas veronii*		BAC	BIOC	
A19.1.1	*Pseudothielavia* spp.		FNG	PATH	
A19.1.1a	*Pseudothielavia terricola* *Syn: *Thielavia terricola*		FNG	PATH	
B1.2.1c	*Pythium aphanidermatum*		OOM	PATH	
B1.2.1b	*Pythium debaryanum*		OOM	PATH	
B1.2.1d	*Pythium oligandrum*		OOM	PATH	
B1.2.1	*Pythium* spp.	***	OOM	PATH	
B1.2.1a	*Pythium ultimum*	***	OOM	PATH	
C2.1.1a	*Ralstonia solanacearum* *Syn: *Pseudomonas solanacearum* *Bacterium solanacearum* *Bacillus solanacearum*		BAC	PATH	
C2.1.1	*Ralstonia* spp.	***	BAC	PATH	
F3.1.1	*Rhizobium radiobacter*		BAC		
F3.1.1	*Rhizobium rhizogenes*		BAC		
F3.1.1	*Rhizobium* spp.		BAC	BIOC	
A2.1.1a	*Rhizoctonia bataticola*	***	FNG	PATH	*Macrophomina phaseolina*
A6.1.1a	*Rhizoctonia grisea*	***	FNG	PATH	*Rhizoctonia solani*
A6.1.1	*Rhizoctonia leguminicola*	***	FNG		
A6.1.1a	*Rhizoctonia solani* *Syn: *Rhizoctonia grisea*	***	FNG	PATH	

Para	Organism	Sdborne	Type	Func	Synonym of
	Pellicularia filamentosa *Thanatephorus cucumeris*				
A6.1.1	*Rhizoctonia* spp.	***	FNG	PATH	
A6.1.1	*Rhizoctonia stolonifer*	***	FNG		
E5.1.4c	*Rhizophagus clarus* *Syn: *Glomus clarum*		FNG	BIOF	
E5.1.4a	*Rhizophagus irregularis*		FNG	BIOF	
E5.1.4b	*Rhizophagus fasciculatus* *Syn: *Glomus fasciculatum*		FNG	BIOF	
E5.1.4	*Rhizophagus spp.*		FNG	BIOF	
A14.1.1b	*Rhizopus nigricans*	***	FNG	PATH	*Rhizopus stolonifer*
A14.1.1a	*Rhizopus oryzae*	***	FNG	PATH	
A14.1.1	*Rhizopus* spp.	***	FNG	PATH	
A14.1.1b	*Rhizopus stolonifer* *Syn: *Rhizopus nigricans*	***	FNG	PATH	
E3.1.1a	*Saccharomyces cerevisae*		FNG	BIOC	
I10.1	*Rosenbergiella* spp.	***	BAC		
E3.1.1	*Saccharomyces* spp.		FNG	BIOC	
D5.1.2	*Sadwavirus* spp.		VIR	PATH	
C7.2.1	*Salmonella* spp.		BAC	PATH	
D5.1.2a	*Satsuma dwarf virus* (SDV)		VIR	PATH	
E5.1.2a	*Sclerocystis coremioides* *Syn: *Sclerocystis dussi*		FNG	BIOF	
E5.1.2a	*Sclerocystis dussi*		FNG	BIOF	*Sclerocystis coremioides*
E5.1.2	*Sclerocystis* spp.		FNG	BIOF	
A8.2.1a	*Sclerotinia sclerotiorum*	***	FNG	PATH	
A8.2.1	*Sclerotinia* spp.	***	FNG	PATH	
A2.1.1a	*Sclerotium bataticola*	***	FNG	PATH	*Macrophomina phaseolina*
A9.1.1a	*Sclerotium rolfsii*	***	FNG	PATH	*Athelia rolfsii*
H2.2	*Scopulariopsis brevicaulis*	***	FNG		
H2.2	*Scopulariopsis* spp.	***	FNG		
I10.2	*Serratia* spp.	***	BAC		
D2.1.1a	*Sesame curly top virus* (SeCTV)		VIR	PATH	
A3.1.6	*Setosphaeria* spp.	***	FNG	PATH	*Exserohilum* spp.
A20.1.1a	*Sphaeronema sesami*		FNG	PATH	
A20.1.1	*Sphaeronema* spp.		FNG	PATH	
E1.1.3a	*Sphaerostilbella aureonitens* *Syn: *Gliocladium penicillioides*		FNG	BIOC	
E1.1.3	*Sphaerostilbella* spp.		FNG	BIOC	
A5.1.4a	*Sphaerotheca fuliginea*		FNG	PATH	*Podosphaera fuliginea*
C4.1.1a	*Spiroplasma citri*		BAC	PATH	
C4.1.1	*Spiroplasma* spp.		BAC	PATH	
H9.3	*Stachybotrys atra*	***	FNG		
H9.3	*Stachybotrys chartarum*	***	FNG		
H9.3	*Stachybotrys* spp.	***	FNG		
H5.2	*Stemphylium botryosum*	***	FNG		
H5.2	*Stemphylium* spp.	***	FNG		
I9.1	*Streptococcus* spp.	***	BAC		
F5.1.1a	*Streptomyces bikiniensis*		BAC	BIOC	
F5.1.1b	*Streptomyces rochei*		BAC	BIOC	

Para	Organism	Sdborne	Type	Func	Synonym of
F5.1.1	*Streptomyces* spp.		BAC	BIOC	
H1.3	*Syncephalastrum* spp.	***	FNG		
A18.1.1a	*Synchytrium sesami*		FNG	PATH	
A18.1.1b	*Synchytrium sesamicola*		FNG	PATH	
A18.1.1	*Synchytrium* spp.		FNG	PATH	
E2.1.4	*Talaromyces flavus* Syn: *Penicillium vermiculatum*	***	FNG		
E2.1.4a	*Talaromyces pinophilus*		FNG	BIOC	
E2.1.4	*Talaromyces* spp.	***	FNG	BIOC	
A6.1.1a	*Thanatephorus cucumeris*	***	FNG	PATH	*Rhizoctonia solani*
A19.1.1a	*Thielavia terricola*		FNG	PATH	*Pseudothielavia terricola*
A15.1.1a	*Thielaviopsis basicola*		FNG	PATH	
A15.1.1	*Thielaviopsis* spp.		FNG	PATH	
A2.1.1a	*Tiarosporella phaseolina*	***	FNG	PATH	*Macrophomina phaseolina*
D2.1.2b	*Tobacco leaf curl virus* (TLCV) *Syn: *Nicotinia 10 virus*		VIR	PATH	
D3.1.1b	*Tobacco mosaic virus* (TMV)		VIR	PATH	
D5.1.1a	*Tobacco ringspot virus* (TRSV)		VIR	PATH	
D1.1.1g	*Tobacco vein banding mosaic virus* (TVBMV)		VIR	PATH	
D3.1.1	*Tobamovirus* spp.		VIR	PATH	
D4.1.1a	*Tomato spotted wilt virus* (TSWV)		VIR	PATH	
D2.1.2a	*Tomato yellow leaf curl virus* (TYLCV)		VIR	PATH	
D4.1.1	*Tospovirus* spp.		VIR	PATH	
E1.1.1g	*Trichoderma arundinaceum*		FNG	BIOC	
E1.1.1	*Trichoderma aureoviride*		FNG		
E1.1.1h	*Trichoderma brevicompactum*		FNG	BIOC	
E1.1.1e	*Trichoderma hamatum*		FNG	BIOC	
E1.1.1b	*Trichoderma harzianum*	***	FNG	BIOC	
E1.1.1	*Trichoderma homingii*		FNG		
E1.1.1d	*Trichoderma koningii*		FNG	BIOC	
E1.1.1	*Trichoderma longibrachiatum*		FNG		
E1.1.1f	*Trichoderma pseudokoningii*		FNG	BIOC	
E1.1.1	*Trichoderma* spp.	***	FNG	BIOC	
E1.1.1c	*Trichoderma virens*		FNG	BIOC	
E1.1.1a	*Trichoderma viride*	***	FNG	BIOC	
H12.1	*Trichomerium jambosae*	***	FNG		
H9	*Trichothecium roseum*	***	FNG		
D1.1.1f	*Turnip mosaic virus* (TuMV)		VIR	PATH	
D2.1.1	*Turncurtovirus* spp.		VIR	PATH	
H7.1	*Typhula micans*	***	FNG		
H5.2	*Ulocladium atrum*	***	FNG		
H5.2	*Ulocladium lanuginosum*	***	FNG		
H5.2	*Ulocladium* spp.	***	FNG		
A7.2.1c	*Vermicularia sesamina*		FNG	PATH	*Colletotrichum sesamina*
A7.1.1a	*Verticillium albo-atrum*	***	FNG	PATH	
A7.1.1b	*Verticillium dahliae*	***	FNG	PATH	
A7.1.1	*Verticillium* spp.	***	FNG	PATH	

Para	Organism	Sdborne	Type	Func	Synonym of
D1.1.1a	*Watermelon mosaic virus* (WMV)		VIR	PATH	
C3.1.1c	*Xanthomonas axonopodis* pv. *ricini* *Syn: *Xanthomonas ricinicola*		BAC	PATH	
C3.1.1a	*Xanthomonas campestris*	***	BAC	PATH	*Xanthomonas euvesicatoria* pv. *sesami*
C3.1.1a	*Xanthomonas campestris* pv. *sesami*	***	BAC	PATH	*Xanthomonas euvesicatoria* pv. *sesami*
C3.1.1a	*Xanthomonas euvesicatoria* pv. *sesami* *Syn: *Xanthomonas campestris* pv. *sesami* *Xanthomonas sesami*	***	BAC	PATH	
C3.1.1b	*Xanthomonas ricinicola*		BAC	PATH	*Xanthomonas axonopodis* pv. *ricini*
C3.1.1a	*Xanthomonas sesami*	***	BAC	PATH	*Xanthomonas euvesicatoria* pv. *sesami*
C3.1.1	*Xanthomonas* spp.	***	BAC	PATH	
E7.1.1a	*Zoophthora radicans*		FNG	BIOC	
E7.1.1	*Zoophthora* spp.		FNG	BIOC	
D1.1.1c	*Zucchini yellow mosaic virus* (ZYMV)		VIR	PATH	

FOREWORD

D.R. Langham comments, 2021: I am not a plant pathologist; I have not taken a course in plant pathology; I do not have any textbooks on plant pathology; I do not have access to a scientific library. Most of the information in this document is based on the internet, which is not known for 100% accuracy. With the use of DNA, the taxonomic classifications of all living organisms will be changing considerably over the next 25 years. Thus, over time, there will be many modifications necessary. I am hoping to get feedback on errors. I have been working on this volume on and off since 2014, and full-time for the past 8 months. I have 89 more references that I could add, but I want to move on to new projects. I also did not reproof the entire document. I apologize for errors.

Over the last 60 years in the field, I have seen many diseases, but not all.

While growing up in Venezuela in the 1950s with sesame on our farm, there were few diseases because my father had bred tolerance to most of the local diseases.

I spent 9 months in India in 1967-68 studying sesame. I visited research stations and farmer fields all over the country and had nurseries in Coimbatore, Tamil Nadu, and Hyderabad, Telangana. I viewed thousands of hectares of sesame in most of the country and walked in hundreds of hectares. I was overwhelmed by phyllody (vectored by leafhoppers), and I saw many diseased leaves and dead plants. The one thing that struck me was that there were many reports of varietal tolerance to these scourges, but the diseases continue. Another major impression was that famers used seed from their previous crop to plant the new crop and did not have enough capital to use chemicals or biocontrols.

The Sesaco nurseries in the USA, have been primarily in areas with low humidity and low rainfall, and thus, there have been few leaf diseases and powdery mildew. However, root rots (*Phytophtora parasitica*, *Fusarium oxysporum*, and/or *Macrophomina phaseolina*) have destroyed fields. Unable to do inoculations, there was a nursery established in Uvalde, Texas, (west of San Antonio) where there was a 3 year rotation ensuring those pathogens were present for screening. Initially, we tried planting on the same spot, but there was too much carryover seed resulting in mixed populations. In each nursery known susceptible lines were planted to ensure the diseases were still present. After one full cycle, some susceptible lines died at emergence, and the rest did not survive to flowering. Lines that did not show tolerance were discarded, but in many segregating populations, surviving plants were carried forward. Some survivors died the following season, but others persisted. We found that tolerance could be passed down genetically, although we never tried to determine the number of genes involved. We developed tolerance by brute force by planting 7 to 10 thousand plots of around 3,000 lines. We did not use chemicals or biocontrols.

We did have satellite nurseries in other parts of the country. In the nurseries near Lubbock, TX, in years with considerable rain and cool nights, we did see leaf spots, which Ray Brigham from Texas A&M said were *Pseudomonas sesami*. However, soon thereafter with hot dry weather, the diseases would disappear. However, lines with more leaf spots were eliminated. It was interesting that lines with genes from Murray Kinman lines developed in the same area in the 1950/60s were tolerant.

We are all fortunate that sesame has not been homogenized like so many other crops. In travelling in the world, it is easy to see differences in just 4 basic traits – number of branches, number of capsules per leaf axil, days to harvest maturity, and seed color. In many countries, germplasm passed down through millennia is still used in some farms. I was taught a lasting lesson in India. In walking in a farmer field there were many phenotypes; one phenotype appeared superior to the others. I asked the farmer why he did not harvest just those plants for planting seed for the next year. He walked through his field and pointed out that in dry years, this phenotype was better; in wet years, this other phenotype was better; in years with the leaf roller, this other was better; in cool years, this other was better; in hot years, this other was better, etc. He said that if he knew at planting what the year was going to be like, he would select, but who can predict the weather in the coming 6 months with any certainty?

Sesame has been around for at least 5,500 years, and the variability of sesame is astounding. Dr. Sherwin Carlquist was one of my professors. He is a noted plant anatomist who was later recognized in his field by winning the Linnean Medal in 2002. While looking at my work with sesame, he said that sesame had one of the widest variation of any species he had seen or worked with. He wanted me to document some of the variability, and over the years I have identified variability on over 450 traits. Many countries have collected landraces and have developed core collections. However, in the new world of intellectual property, this germplasm is not shared across countries or even across institutions and companies within a country. My father exchanged all of his germplasm with anyone that requested it though the Sesamum Foundation. Twice, he lost his entire collection, first to a fire and later to rats.

Fortunately, he had sent many lines to Murray Kinman and John Martin in the United States, and they restocked his collection. I was fortunate to be able to plant and look at over 3,000 introductions from 67 countries. Many of these came from the USDA collection where they still share germplasm across country borders. We need to keep germplasm that has survived millennia because some will have tolerance to a disease that was present hundreds of years before, and the pathogen may reemerge.

Inspired by Dr. Carlquist, in 1966 I started accumulating data on the traits of sesame. Each trait had a descriptor which are presently divided into different volumes (see below). The Capsule zone descriptors combine stem, leaf, flower, and capsule descriptors when they overlap, e.g., *Capsules per leaf axil* involves the attachment of the capsules to the stem at the leaf axils. When they are first published, they are 'Working paper 1' (WP1) with subsequent updates as WP2, etc. However, presently when they are revised, they will become 'Revision 1' (Rev1), etc.

As the documents are completed, they have been placed on ResearchGate. Google "Ray Langham sesame" and click on https://www.researchgate.net/profiles/Derald-Langham. The volumes are as follow.

Volume name	**Release**
Sesame descriptor summary	WP1, Nov 2019
Descriptor index	WP1, Aug 2017
Sesame seedling descriptors (*Sesamum indicum* L.)	WP1, Aug 2017
Sesame plant descriptors (*Sesamum indicum* L.)	WP1, Jan 2020
Sesame root/stem descriptors (*Sesamum indicum* L.)	WP1, Jan 2018
Sesame leaf descriptors (*Sesamum indicum* L.)	WP2, Jul 2020
Sesame flower descriptors (*Sesamum indicum* L.)	WP1, Feb 2018
Sesame capsule descriptors (*Sesamum indicum* L.)	WP2, Feb 2020
Sesame capsule zone descriptors (*Sesamum indicum* L.)	WP1, Nov 2017
Sesame cycle descriptors (*Sesamum indicum* L.)	WP1, Apr 2018
Sesame seed descriptors (*Sesamum indicum* L.)	WP2, Jun 2020
Sesame seed composition descriptors (*Sesamum indicum* L.)	WP1, Oct 2020
Sesame agronomic and agronomic descriptors (*Sesamum indicum* L.)	WP1, May 2020
Sesame abiotic descriptors (*Sesamum indicum* L.)	WP1, draft
Sesame invertebrates and fauna (*Sesamum indicum* L.) with H.O. Sintim	Rev 1, Mar 2021
Fungi, oomycetes, bacteria, and viruses associated with sesame (*Sesamum indicum* L.) with K.A. Cochran	Dec 2021
Sesame weed control (*Sesamum indicum* L.) with W.J. Grichar and P.A. Dotray	WP1, Nov 2018
Sesame bibliography (*Sesamum indicum* L.)	WP8, Jan 2020

K.A. Cochran comments, 2021: I am a Plant Pathology Extension Specialist and Assistant Professor with Texas A&M University, located in Uvalde, Texas. When I began my current position in the fall of 2015, I quickly discovered that like many specialty crops, sesame producers needed diagnostic support and education regarding what diseases posed challenges to them and what plant disease management tools were available. I also quickly discovered that little documented information on sesame diseases in the USA was available in the scientific literature, and few treatment methods beyond agronomic techniques or lines thought to be tolerant to limited diseases were available to farmers. In the literature, data from international sources was available in a limited capacity, and few photos were available to observe symptoms of specific diseases. In my first season in Uvalde, I began what would eventually become a larger effort to define sesame diseases that affected USA production, starting with the Uvalde regional area with plans to expand. In the course of my efforts, I have published a first report to formally document *Rhizoctonia solani* on sesame and am in the process of preparing more to come. I am hopeful these will prove to be useful and serve the scientific community and future clientele well. In 2021, I organized and hosted an online International Sesame Research Symposium, a free online 2 day event to share scientific research and information with other scientists (day 1) and farmers/stakeholders (day 2). My thinking with offering this online was that individuals with limited resources could participate, which worked well in light of pandemic travel limitations as well. Going forward, I plan to expand my sesame program and provide education and applied pathology research for this growing industry to serve my local clients and those in the greater USA and abroad. Plant disease education and diagnostic support are integral parts of expanding production and markets of specialty crops, including sesame.

INTRODUCTION

This document is not intended to be the authority on fungi, bacteria, oomycetes, and viruses associated with sesame. In most cases, this is a summary of the over 1,000 references to guide a researcher to go to the original documents for more information. This document is not intended to be read from front to back, but rather to be used like an encyclopedia. Data is repeated as appropriate, e.g., effects of *Trichoderma* spp. on *Fusarium* spp. will be under both *Trichoderma* spp. and *Fusarium* spp. When a species is both a pathogen and a biocontrol, the data on the order, family, and genus is repeated in both sections.

Initially, there was a common name attached to the species; however, there was considerable variation in common names in different countries and even within countries for most species, and thus the common name is not in the indices. There has been no judgement as to whether an individual publication made a misidentification of a species. It was assumed the peer-review process handled the identification of the species.

This work is an introduction to disease concepts, a detailed review of sesame diseases, methodologies for disease resistance assessments, and geographic distribution of pathogens and disease events by country.

Sesame disease concepts

Plant diseases, caused by plant pathogens[1], are a challenge to production of sesame in many areas where sesame is produced. Many types of diseases affect sesame, all of which fall into two main types: soilborne and foliar diseases. These are all caused by pathogens (fungi, oomycetes (fungi-like, pronounced oh-oh my seets), bacteria, and viruses. Diseases should not be confused with abiotic, or non-living, causes of plant problems such as weather-related stresses or injury, herbicide injury, soil salinity/toxicity, or nutrition deficiencies. To have a plant disease event occur, three things must be present at the same point in time: a susceptible plant host, a pathogen capable of causing disease, and a favorable environment for that pathogen to cause the disease. While some plant pathogens do have an incredibly wide plant host range, others are specific to a single plant species. Various pathogens are active and thrive in specific environmental conditions. While there are commonalities, conditions vary by pathogen. Foliar diseases are becoming more commonplace as sesame production is expanding beyond traditional arid areas and into areas with higher annual rainfall or are grown under sprinkler irrigation. The lack of approved application regulations, limited availability, and financial costs of fungicide application make managing these diseases challenging. Additionally, most soilborne diseases, including those of sesame, are difficult to manage due to several factors, including longevity of inoculum in the soil for many of these pathogens, often having wide plant host ranges, and limited chemical management options.

In sesame, most especially persistent and problematic diseases are caused by soilborne[2] fungi and oomycetes. Foliar diseases can be very challenging but are typically do not have the persistent longevity of several of the challenging soilborne pathogens that affect sesame. While assessment of plant pathogens and the diseases they cause is ongoing, some of the most commonly encountered pathogens and the economically important diseases they cause are: *Macrophomina phaseolina* (Charcoal rot), *Rhizoctonia solani* (root and stem rot), *Phytophthora* spp.[3] (Phytophthora root rot), *Fusarium* spp. (Fusarium wilt and root rot), *Alternaria* spp. (Alternaria leaf spot, leaf blight), and *Cercospora* spp. (Cercospora leaf spot), *Pseudomonas* spp. (bacterial leaf spot and blight), *Xanthomonas* spp. (bacterial leaf spot and blight), and phyllody to name a few.

Plant diseases from seed to harvest

Seedling diseases and damping off can be caused by several fungi and oomycetes, or a complex of multiple species, which often include *Rhizoctonia solani*, *Pythium* spp., *Phytophthora* spp., *Fusarium* spp. Low seed vigor can be associated with not only damage or environmental stress during harvest or storage, but also seedborne or soilborne pathogens. Low vigor seed are more vulnerable to poor emergence and disease. Both poor vigor and soilborne seedling disease can cause poor emergence or damping off, which is seedling death after emergence. Many seedling diseases are associated with planting in temperatures that are sub-optimal for germination, often too early when soil temperatures are too low for rapid germination. Some soilborne pathogens thrive under warm conditions, such as *R. solani* and some species of oomycetes of Phytophthora and Pythium, while others thrive in cooler conditions, including other species of Phytophthora and Pythium. Seed treatments (as they are available by label), planting at

[1] **Pathogen:** A fungus, bacterium, oomycetes, virus, or other microorganism that can cause disease.
[2] **Soilborne:** A pathogen persists in the soil.
[3] **spp.:** Refers to multiple species within a genus, while '**sp.**' refers to a single species within a genus.

optimal times, and amending the planting site to promote ideal drainage can all help prevent seedling disease challenges.

Many diseases can occur mid-season, though foliar diseases are often the most obvious at this time. Many foliar diseases thrive under humid or frequently rainy conditions, and many have a minimum period of moisture required for successful infection. Typical foliar disease symptoms include leaf spots and blights, which come in various manifestations with respect to size, shape, and general appearance to the trained eye. Differentiating these accurately is difficult for those without plant pathology training. Leaf spots, or lesions, may have distinct sharp margins with pigment, may have yellow (chlorotic) halos around the spot, may be water-soaked or papery dry, be sunken, flush, or mounded, circular to irregularly shaped, and range in size from 2-3 to several mm. In some diseases, lesions can coalesce and cover large areas of the leaf. These characteristics paired with microscopy in a diagnostic lab can confirm the identity of a pathogen and the disease challenge.

In the later third of the season the full effects of unchecked foliar pathogens and the symptoms of many soilborne diseases become more evident. Problems noted in this part of the growing season include defoliation due to both foliar and soilborne diseases, stunting often due to soilborne diseases, and poor capsule set and development, or death of the plant. While many of these issues began earlier in the season, disease pressure due to increased pathogen populations and progression of symptom severity make them more apparent.

Seedborne[1] diseases are of concern with regard to reduced seed germination performance the next planting season, as well as possible food safety impacts or reductions to food-use seed or oil quality. Fungal seedborne pathogens can create mycotoxins, which have negative impacts on human and animal health.

Mechanisms of pathogen dissemination

Pathogen inocula[2] are propagules[3] of the pathogen with the ability to infect and cause disease on new host tissues. Inoculum can occur in many forms, depending on the type of pathogen being considered. These include spores[4], specialized fungal survival structures such as sclerotia[5], fungal hyphae[6], bacterial cells, and virus particles in sap or insect vectors. Some foliar diseases are primarily spread by wind (think fungal spores, or virus insect vectors), while others spread by water splash (often fungal spores and bacteria). Soilborne inocula can be spread by soil movement via water drainage, farm equipment, etc., or even via water flow through a field alone. The mechanism of dissemination is important to understand, in that this information influences the cultural control methods that would be helpful to implement.

Field scouting and rating tips

While disease diagnostics often require the assistance of a plant pathologist for confident diagnosis, the use of a high quality hand lens, field microscope, or digital microscopy with the use of phones and tablets paired with basic training can be helpful to make initial determinations. The following is a list of tips.

- Select a moderately symptomatic specimen for optimal sample quality.
  - Selecting particularly severe make observations more difficult because often older infections will lead to having decomposed fungi present.
- To spot soilborne disease hot spots, look for areas of the field with plants much smaller than expected for their age and growing conditions or areas of premature defoliation.
- Older leaves often start showing symptoms of foliar disease earlier than younger leaves, so they can be a good

[1] **Seedborne:** A pathogen that persists inside or on the seed; may serve as a source of inoculum in the field if pathogen remains viable until planting.
[2] **Inocula (plural of inoculum):** A substance used for inoculation.
[3] **Propagule:** Any material that functions in propagating an organism to the next stage in its life cycle, such as by dispersal. The propagule is usually distinct in form from the parent organism.
[4] **Spore:** A unit of sexual or asexual reproduction that may be adapted for dispersal and for survival, often for extended periods of time, in unfavorable conditions.
[5] **Sclerotia (plural of sclerotium):** A compact mass of hardened fungal mycelium containing food reserves. One role of sclerotia is to survive environmental extremes, often for extended periods of time, even years. In some fungi, sclerotia become detached and remain dormant (often in the soil) until favorable growth conditions return. Sclerotia initially were mistaken for individual organisms and described as separate species until proved that sclerotia are only a stage in the life cycle of some fungi.
[6] **Hyphae (plural of hypha):** Long, branching filamentous structures of a fungus, oomycete, or actinobacterium. In most fungi, hyphae are the main mode of vegetative growth, and are collectively called a mycelium.

place to start looking.
- Upon collection for taking to a specialist, keep samples cool to maintain viability of microbes and insect pests.
- When conducting a variety trial or screening lines, be sure to be confident of the disease symptomology for the pathogen of interest. A blanket rating of indiscriminate "leaf spot" or "root rot" is not as informative or valuable as data for specific disease symptoms.

Disease management basics

While fungicides and agronomic practices used to manage plant diseases can reduce the severity of plant disease symptoms or population of the pathogen, efforts do not eliminate the targeted pathogen. Disease management can be especially challenging if environmental conditions are highly favorable for disease development. Soilborne pathogens are particularly difficult to manage due to a lack of labelled management options and persistent longevity in many cases. Additionally, in the case of crops grown in developing areas, or simply by farmers on a tight budget, the financial costs of pesticides and additional agronomic activity (fuel, machinery investment, maintenance), can be a significant challenge in managing plant diseases. No matter the situation of the farmers, the best (cost, effort, etc) option is to develop varieties that are tolerant to the disease. While ideally sesame varieties could eventually be bred for dramatic and specific disease resistance using marker assisted selection, it is still likely to take many years and significant investment by breeding companies for such lines to become a reality. Additionally, for many pathogens that are problematic to sesame (e.g., *Macrophomina phaseolina* and *Rhizoctonia solani*) finding true resistance genes is a rare event in plants, which is evident by their extremely broad host ranges. In many plants, it is much more common to find 'tolerant' instead of 'resistant' plants that can survive despite pathogens still present in the field. In reviewing many publications, the common thread is that the local varieties, particularly in areas where sesame has been grown for centuries, are more tolerant than the introduced varieties, even if an introduced variety is tolerant in another area.

Plant diseases are managed in a variety of ways as part of an integrated pest management program. Methods focus on prevention of disease events and response once there is a problem. Preventative efforts include the use of resistant varieties, cultural methods to optimize plant health and discourage pathogen infection and proliferation, preventing pathogens from arriving in the field (primarily useful for soilborne pathogens or foliar pathogens with a short dispersal distance), and applying protectant products such as protectant fungicides or biological control products. Cultural control methods can include efforts to alter humidity or soil moisture such as limiting frequency of irrigation and watering deeply, reducing canopy humidity through increasing plant spacing or breeding for more upward growing varieties, optimizing field drainage to reduce standing water or dry spots, tillage to remove crop debris from the soil surface and prompt decomposition, and crop rotation. Response tactics include treatment with fungicides or similar products and eradication of a pathogen (seed sanitation, fumigation, etc). The best outcomes are usually achieved by utilizing more than one approach in tandem. It is important to understand that disease pressure will vary according to the amount of initial inoculum present, the vulnerability of the host, and ultimately the environmental conditions they are subjected to, which include those engineered through cultural control methods. When conducting variety trials, it is important to ensure cultural management practices are consistent year to year and location to location unless variability is intended as part of the trial.

Major fungi and oomycetes pathogens

Among biotic caused plant health issues, fungal and oomycete diseases are typically the most commonly encountered. True fungi (Alternaria, Cercospora, Colletotrichum, Corynespora, Fusarium, Macrophomina, Powdery mildew and Rhizoctonia genera) cause the majority of the sesame diseases. Oomycetes (Phytophthora) look very similar to true fungi but have some physiological and life cycle differences compared to true fungi. For the purposes of this work, they will be discussed together in alphabetical order.


Photo: S.U. Kim {Republic of Korea}


Photo: O.A. Enikuomehin {Nigeria}

Alternaria sesami (Synonym: *Macrosporium sesami*) and ***Alternaria alternata*** (Synonym: *Alternaria tenuis*) are major pathogens with worldwide distribution. It infects the stems, leaves, and green capsules causing considerable damage. When environmental conditions are favorable for disease development, the disease may occasionally be severe enough to kill seedlings and young plants. Symptoms are brown to dark-brown, spreading, water-soaked lesions which can often be observed the entire length of the stem. The lesions also occur on the midrib and even veins of leaves, which can be without the typical leaf-spots. In very severe attacks plants may be killed within a very short period after symptoms are first noticed, while milder symptoms cause defoliation. The pathogens are seedborne and soilborne. Favorable conditions for disease development are warm and high humidity or frequent rainfall. There are many other Alternaria species that have been documented as pathogenic to sesame: *A. brassicae*, *A. brassicicola*, *A. citri*, *A. japonica*, *A. lini*, *A. longissima*, *A. mali*, *A. redicina*, *A. sesamicola*, *A. simsimi*, *A. solani*, and *A. tenuissima.* There are also other species in the Pleosporaceae family that are pathogens: *Cochliobolus* spp., *Curvularia* spp., *Drechslera* spp., *Exserohilum* spp., and *Helminthosporium* spp. *Alternaria* spp. have been reported in international lists, Australia, Bolivia, Brazil, Burkina Faso, China, Costa Rica, Cuba, Egypt, Ethiopia, Greece, Guatemala, Honduras, India, Iran, Iraq, Israel, Japan, Kenya, Mexico, Myanmar, Nicaragua, Nigeria, Pakistan, Paraguay, Republic of Korea, Russia, Saudi Arabia, Sudan, Tanzania, Turkey, Uganda, Ukraine, United States, and Venezuela. For more information, see A3.1.1a and b.


Photo: K.A. Cochran {USA}


Photo: O.A. Enikuomehin {Nigeria}

Cercospora leaf spot is a major disease in sesame production globally, largely caused by ***Cercospora sesami*** (Synonyms: *Mycosphaerella sesami*, *Mycosphaerella sesamicola*, and *Cercospora sesami* var.[1] *somalensis*) and *C. sesamicola*. The disease manifests itself just before flowering, and the first symptoms are the appearance of small light brown spots on both surfaces of the leaves. In the beginning, the spots are roundish but later coalesce to form irregular patches varying from 5-15 mm in diameter. With the advance in age, the color of the spots darkens due to the formation of conidiophores[2] and conidia[3]. The number of spots vary from 100 to 400 per leaf under humid conditions resulting in premature defoliation. The disease, however, is less severe on the stem and the petiole, forming spots of varying lengths. These are light brown at first but gradually become darker in color. The capsules are also affected producing similar spots and quite often destroyed, resulting in poor yield. The fungus may infect the seed, leading to the potential for reduced seed quality and performance. Primary infection is seedborne and from infected debris. The secondary spread is through wind-borne conidia. It is suspected that other species of Cercospora occurring on other crops, such as soybean are pathogenic to sesame and have been observed in the United States. Even within a single species, spores can have a high degree of phenotypic variability with respect to length, which makes molecular identification of species

[1] **Var.:** V**ariety** is a taxonomic rank below that of species and subspecies, but above that of form. As such, it gets a three-part infraspecific name. It is sometimes recommended that the subspecies rank should be used to recognize geographic distinctiveness, whereas the variety rank is appropriate if the taxon is seen throughout the geographic range of the species.
[2] **Conidiophore:** A specialized hypha upon which conidia develop. Used in microscopic identification of fungi.
[3] **Conidia (plural of conidium):** Asexually produced microscopic spores of ascomycetes that occur in a variety of shapes and sizes, form on microscopic conidiophores of varying sizes and shapes (stalk like structures), or conidiogenous cells within various vase, cup, or other shaped structures (e.g., pycnidia, acervuli, etc.). The variation in shape, size, and color is instrumental in microscopic identification of these fungi and helpful in obtaining pure cultures via single spore isolation.

immensely helpful. Other fungi with similarly shaped spores (long and thin, borne on the end of a dark conidiophore) may be easily confused with *Cercospora* spp. particularly when using a hand lens, including *Corynespora* spp, and *Pseudocercospora* spp. There are also other species in the same family that are pathogens: *Pseudocercospora* spp., *Cercoseptoria* spp., *Pseudocercosporella* spp., *Phaeoisariopsis* spp., *Cercosporidium* spp., and *Passalora* spp. *Cercospora* spp. have been reported in international lists, Australia, Brazil, Burkina Faso, China, Colombia, Dominican Republic, Egypt, Ethiopia, Guatemala, Honduras, India, Israel, Italy, Japan, Kenya, Mexico, Myanmar, Nicaragua, Nigeria, Pakistan, Panama, Paraguay, Philippines, Somalia, Sri Lanka, Sudan, Surinam, Tanzania, Thailand, Turkey, Uganda, United States, and Venezuela. For more information, see A4.1.1a.

Acervuli sporulating on the stem.

Progressing lesion

Photos: K.A. Cochran {USA}

***Colletotrichum* spp.** has been reported to cause anthracnose on many crops, including sesame. Foliar symptoms can occur and may result in defoliation in serious cases. Medium to dark brown water soaked lesions may occur on leaves or stems. This pathogen has also been observed to cause stem lesions on lower portions of the stem progressing upward. Heavy sporulation can occur when conditions are favorable. Acervuli[1] with conidial ooze are typically about the size of a pinhead or slightly smaller and can be observed with a good quality loupe. Acervuli may or may not have setae[2], depending on the species of Colletotrichum present. As this fungus is readily spread in humid conditions with splashing water, areas at risk for significant disease development include irrigated fields, fields planted in areas with higher or more frequent rainfall, or areas late season rains are likely to occur prior to harvest. The pathogen is seedborne. Most publications classify Colletotrichum at the genus level, but there are some publications that have identified *C. gloeosporioides*, *C. sesamina*, and *C. truncatum*. *Colletotrichum* spp. have been reported in international lists, China, India, Italy, Japan, Mexico, Myanmar, Nigeria, Paraguay, Republic of Korea, Thailand, Uganda, and United States. For more information, see A7.2.1.

Photo: D.R. Langham {in China}

Photo: K.A. Cochran {USA}

The symptoms for ***Corynespora cassiicola*** are dark, irregularly shaped spots appear on the leaves; they enlarge, become brown with light centers, and coalesce forming a blotchy configuration. A concentric "target" pattern may be seen on lesions. Extensive defoliation occurs, and the affected plants often die. Infection on the stems is characterized by light-brown to reddish brown, elongated lesions which later spread over the entire stems, causing death of the plants. Affected stems are bent irregularly or swollen on the lesion affected area. Cankers of various sizes also appear on the stem and are often seen originating at the node near the pod base, or the crown of the plant. The pathogen has been reported to cause root rot and is likely associated with a crown rot. In immature plants, the infected stem cracks lengthwise and breadthwise, and these cracks

[1] **Acervuli:** Cup shaped reproductive structures partially embedded in the substrate. These produce asexual spores (conidia) and may or may not have setae (whisker-like appendages sticking up from the acervulus) present.
[2] **Setae:** Dark brown, thick-walled, thorn like cystidia. Though mainly microscopic, the setae of some species may be sufficiently prominent to be visible with a hand lens.

Side and front view of lesions.
Photos: K.A. Cochran {USA}

continue to expand if the plant manages to survive to maturity. Heavy, black to grey velvet-like sporulation is often observed on the crown area. Seedling infection has not been observed under field conditions, though it is seedborne. Capsules can be infected with symptoms appearing as sunken lesions that may be brown or with pale centers. Seeds may be infested and will appear shriveled and brown in severe cases, which can result in aborted seed or reduced seed quality. Symptoms usually appear and rapidly reach epiphytotic conditions as the plants reach maturity. The pathogen perpetuates through plant debris and is seedborne. *C. sesameum* is also a pathogen of sesame. *Corynespora* spp. have been reported in international lists, Australia, Brazil, China, Colombia, Costa Rica, Cuba, Ecuador, India, Japan, Mexico, Republic of Korea, United States, and Venezuela. For more information, see A3.2.1a.

Photo: L. Ayala et al. (2010)
{Paraguay}

Fusarium wilt and root rots are a common problem in sesame production areas. Symptoms of Fusarium wilt, caused by ***Fusarium oxysporum***, are typically most noticed starting mid-season and progress upward on the plant, increasing in severity as the season continues. Typical symptoms include yellowing, stunting, brownish vascular discoloration in the main stem, wilting and limp appearance of the leaves even after irrigation, drought like scorch looking symptoms on leaf margins, and papery dry dead leaf tissues on older leaves. Several species of Fusarium are associated with seedling disease and root rot, the symptoms of which are discoloration and lesions on roots, which may progress upward into the stem from the soil line. Infections in the seed germination or seedling stage are often associated with damping off. *Fusarium* spp. are soilborne and seedborne fungi and reproduce via macroconidia[1], microconidia[2], and long-lived hardy chlamydospores[3]. While macro- and microconidia are the main inoculum source in a single season, chlamydospores are concern for year-to-year inoculum carry over. There are two f. sp.[4]: *F. oxysporum* f. sp. *sesami* and *F. oxysporum* f. sp. *vasinfectum*. E.A. Weiss (1971) reported *F. oxysporum* f. sp. *sesami* can be devastating on susceptible varieties. Severe infection can cause the entire plant to become defoliated and dried. In less severe infections or when mature plants are infected, only one side of the plant may develop symptoms. Peeling off the epidermis of the lower stem or roots will reveal blackish streaks in plant tissues. If infected plants are uprooted, roots will be brittle and rotten, either wholly or partially corresponding with that side of the plants showing disease symptoms. If plants are infected early on in the season, poor capsule set occurs. When infection occurs in mature plants, capsules are formed but seeds are often shriveled and underdeveloped. An early Fusarium infection can destroy an entire field. Other Fusarium species are reported pathogens in sesame: *F. acutatum, F. caeruleum, F. chlamydosporum, F. culmorum, F. equiseti, F. incarnatum, F. longipes, F. merismoides, F. poae, F. proliferatum, F. solani, F. sulawesiensis,* and *F. verticillioides.* There are also other species in the Nectriaceae family that are pathogens: *Cylindrocladium* spp., *Gibberella* spp., and *Neocosmospora* spp. *Fusarium* spp. have been reported in international lists, Australia, Bangladesh, Brazil, Bulgaria, China, Colombia, Costa Rica, Cuba, Dominican Republic, Ecuador, Egypt, Ethiopia, Greece, Guatemala, Honduras, India, Iran, Iraq, Israel, Italy, Japan, Kenya, Malawi, Mexico, Nicaragua, Nigeria, Pakistan, Paraguay, Philippines, Republic of Korea, Saudi Arabia, Sierra Leone, Sudan, Tanzania, Thailand, Turkey, Uganda, Ukraine, United States, Uzbekistan, and Venezuela. For more information, see A1.1.1a.

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[1] **Macroconidia (plural of macroconidium):** The larger of two different types of conidia produced by a fungus in the same manner, e.g., some Fusarium species produce micro- and macroconidia at the same time.
[2] **Microconidia (plural of microconidium):** The smaller of two different types of conidia produced by a fungus in the same manner, e.g., some Fusarium species produce micro- and macroconidia at the same time.
[3] **Chlamydospores:** Asexually produced thick-walled large resting spore of several kinds of fungi and oomycetes. It is the life-stage which survives in unfavorable conditions, such as dry or hot seasons.
[4] **f. sp.:** ***Forma specialis*** is an informal taxonomic grouping allowed by the International Code of Nomenclature for algae, fungi, and plants, that is applied to a parasite (most frequently a fungus) which is adapted to a specific host.

Microsclerotia on stem in disease resistance assay

Microsclerotia on capsule

Photos: K.A. Cochran {USA}

Macrophomina phaseolina (Synonyms: *Dothiorella phillippinensis, M. corchon, M. phaseoli, M. phaseoli* ssp.[1] *sesamica, M. phillippinensis, Rhizoctonia bataticola, Sclerotium bataticola,* and *Tiarosporella phaseolina.*) causes one of the most important diseases of sesame worldwide - charcoal rot. The name charcoal rot is due to the ashy/charcoal discoloration caused by durable microsclerotia[2] embedded in plant tissues. Microsclerotia are approximately the size of a pin head or smaller abundantly present in the symptomatic stem tissue, which can include roots, stems, pods, and seeds. These can be visible embedded in the outside of the stem, or in the pith when cut lengthwise. The pathogen is soilborne and seedborne and can persist in the soil up to 15 years. The fungus thrives in the same conditions that are favorable for growing sesame - hot and dry. When conditions are favorable, the fungus produces asexual spores (conidia) in small round black structures (pycnidia[3]) that are apparent embedded on the surface of the stem. This pathogen has a very broad host range (over 500 plant host species) and can manifest in a variety of symptoms such as damping off, stem, root, and collar rots. The most commonly noticed symptoms include stunting, leaf yellowing, premature defoliation and dry down, rot progressing up the stem, and premature or non-typical pod dehiscence for a given variety. Symptoms are often noticed by producers mid to late season when they are most apparent, though infection often occurs earlier mid-season. Infections that occur earlier in the season often result in significant stunting and plant death by the end of the season. Microsclerotia can be spread field to field by seed transport, movement of microsclerotia infested soil on farm equipment, and within a field by equipment movement and flooding water carrying microsclerotia. Other genera in the Botryosphaericeae family that are pathogenic include *Botryosphaeria* spp. and *Phyllosticta* spp. *Macrophomina* spp. have been reported in international lists, Australia, Bangladesh, Brazil, China, Colombia, Cuba, Cyprus, Ecuador, Egypt, Ethiopia, Greece, Honduras, India, Iran, Iraq, Israel, Japan, Kenya, Mexico, Myanmar, Nicaragua, Nigeria, Pakistan, Paraguay, Republic of Korea, Sri Lanka, Sudan, Syria, Tanzania, Thailand, Turkey, Uganda, United States, and Venezuela. For more information, see A2.1.1a.

Photo: H.M. Miao {China}

Phytophthora nicotianae (Synonyms: *Phytophthora nicotianae* var. *parasitica, Phytophthora nicotianae* var. *sesami, Phytophthora parasitica.,* and *Phytophthora parasitica* var. *sesami.*) is a locally damaging disease. These microbes thrive in moist moderate to warm conditions, where disease epidemics can progress rapidly. Symptoms include water soaked spots on leaves and stems. Lesions on the leaves may coalesce and cause defoliation. Stem and branch lesions are initially brown and darken to black with age. The blackening of the stem is often most apparent near soil level. Affected branches produce poorly formed capsules with shriveled seeds, and affected plants show progressive wilting ending in death. Wet soils, rain, and warm temperatures favor the spread of the disease, and its incidence is higher

[1] **ssp.:** The term **subspecies** refers to one of two or more populations of a species living in different subdivisions of the species' range and varying from one another by morphological characteristics.

[2] **Microsclerotia (plural of microsclerotium):** A very small sclerotia, approx. half or less the size of a pin head, which is a durable long term survival structure of some fungi.

[3] **Pycnidia (plural of pycnidium):** A variable and complex vase- or roughly circular shaped asexual reproductive structure, or fruiting body sometimes partially embedded in substrate. It bears spores (conidia) variously known as pycnidiospores, oidia, or spermatia. The spores are liberated through an opening (ostiole) in the pycnidium. Often brown or black in most species, though a few species produce lighter colors.

on more clay heavy soils with poor drainage. Low areas in fields may be particularly affected. *Phytophthora* spp. typically overwinter as oospores[1] or chlamydospores, which can germinate sporangia[2]. Motile zoospores[3] are generated within sporangia, are released upon maturity, and can swim through water and subsequently infect new plant tissues. Inoculum can carry over in either soil or plant material. The pathogen may spread by being seedborne. Other *Phytophthora* species reported to be pathogenic on sesame, include *P. cactorum, P. capsici, P. drechsleri, P. hibernalis, P. palmivora*, and *P. tropicalis. Phytophthora* spp. have been reported in international lists, Argentina, China, Dominican Republic, Egypt, Guatemala, Honduras, India, Iran, Japan, Kenya, Malawi, Mexico, Nicaragua, Nigeria, Paraguay, Peru, Republic of Korea, Sri Lanka, Tanzania, Thailand, Turkey, United States, and Venezuela.

It should be noted that *Phytophthora* is actually an oomycete, not a true fungus, so it's always a good idea to double check fungicide labels for efficacy against it specifically prior to applying. Oomycetes are also known as water molds, which is quite telling regarding how much they thrive in water logged or moist conditions. *Phytophthora* spp. and other oomycetes have fairly interesting life cycles that include motile spores (zoospores) that can actually swim through even a thin film of water seeking out plant tissues to colonize utilizing chemotaxis. This unique characteristic is one part of why these pathogens spread so prolifically in moist conditions. Without moving water, zoospores could probably swim only a few cm at most, and soil particles may limit that distance. For more information, see B1.1.1a.

Photos: P. Venkata Ramana Rao et al. (2013) {India}

Powdery mildew is caused by many obligate biotrophic fungal species in the Erysiphaceae family (*Erysiphe* spp., *Leveillula* spp., *Podosphaera* spp., *Oidium* spp., and *Pseudoidium* spp.) While some species can infect many host plants, most are host specific. Powdery mildews produce asexual conidia as the main source of inoculum during the season. At the end of the season, sexual spores (ascospores[4]) are produced in tiny black generally spherical structures (chasmothecia[5], formerly cleistothecia) with clear to whitish-clear appendages. These are some of the most easily recognized features of powdery mildew, though they are not always present on symptomatic sesame. Chattopadhyay et al. (2019) reported symptoms start as small whitish spots on the upper surface of the leaves. The spots coalesce, finally covering the entire leaf surface with a pale grey to white fungal growth.

[1] **Oospore:** A thick-walled sexual spore that develops from a fertilized oosphere in some algae, fungi, and oomycetes. They are believed to have evolved either through the fusion of two species or the chemically-induced stimulation of mycelia, leading to oospore formation.

[2] **Sporangia (plural of sporangium):** Sac-like structures producing asexual spores endogenously by cytoplasmic cleavage.

[3] **Zoospore: A** spore of certain algae, oomycetes, fungi, and protozoans, capable of swimming by means of a flagellum.

[4] **Ascospores:** A spore contained in an ascus or that was produced inside an ascus. This kind of spore is specific to fungi classified as ascomycetes. Ascospores are formed in ascus under optimal conditions. Typically, a single ascus will contain eight ascospores.

[5] **Chasmothecia (plural of chasmothecium, previously cleistothecia):** The sexual fruiting bodies produced by the powdery mildew organism. They only form on the surface of heavily diseased vine tissue and take about 90 days to fully mature. Immature chasmothecia are yellow, and gradually turn brown, then black.

Powdery mildew (white patches) and bacterial leaf spot (black spots) on the same leaf. Photo: K.A. Cochran {USA}

The mildew is sometimes confined to the upper surface of the leaves, though it can be apparent on top and bottom in a highly favorable environment for disease development, which is humid and warm. Free water and hot temperatures are unfavorable for the pathogen. Much of the "powdery" substance on the leaf surface is conidiophores and conidia. In previous work, the disease caused a yield loss of 42%. The earlier onset of symptoms, the greater the likelihood of high incidence and severity of disease, leading to lower yields. The pathogens are seedborne and soilborne. Recently, taxonomy has been greatly revised using DNA analysis, while previous taxonomy relied primarily on morphology of teleomorph stages (Heffer et al., 2006). The following species have been reported to cause powdery mildew: *Erysiphe betae, E. cichoracearum, E. cruciferarum, E. orontii, Leveillula taurica, Oidium sesami, Podosphaera fuliginea, P. fusca,* and *Pseudoidium pedaliacearum.* Powdery mildew has been reported in international lists, Australia, China, Ethiopia, Greece, India, Iraq, Israel, Japan, Malawi, Mexico, Myanmar, Nigeria, Pakistan, Somalia, Sri Lanka, Sudan, Tanzania, Thailand, Uganda, United States, and Venezuela. For more information, see A5.1.

Seedlings killed by Rhizoctonia. Photo: B. Lyssy {USA}

Rhizoctonia solani crown and stem necrosis on sesame. Photo: K.A. Cochran {USA}

Rhizoctonia solani (Synonyms: *Pellicularia filamentosa* and *Rhizoctonia grisea*, teleomorph: *Thanatephorus cucumeris*) is a plant pathogenic fungus with a wide host range and worldwide distribution, which was discovered more than 100 years ago. Although it has a wide range of hosts, its main targets are herbaceous plants. The pathogen thrives in warm and moist conditions, though infection and symptoms can occur in a wide variety of environments. Symptoms can manifest in sesame as seedling disease/damping off, root rot, crown rot, and stem necrosis. Lesions are brown to dark-brown in color, often sunken and may circle the stem, girdling it. Diagnostic features are observed microscopically and include hyphae that are relatively large and have right angle branching with constrictions at the base of the branching. The fungus is easily cultured and sclerotia typically form readily in culture. Molecular identification (PCR) can be useful to confirm identity. This pathogen typically occurs as hyphae or sclerotia in the soil and in/on host plant material. Sclerotia are durable nugget-like pieces of modified hyphae (usually measuring from one to a few mm in diameter) that can live in the soil or plant debris for many years. This fungus doesn't typically sporulate sexually, but basidiospores[1] may occur on infected plant tissues. Asexual spores are not produced, though sclerotia serve in a similar capacity in the life cycle. *R. solani* isolates are categorized into anastomosis groups (AGs)[2], which is important to note in diagnostic efforts. AGs are determined by the ability of a given isolate to undergo hyphal fusion with a known AG isolate. Currently, only AG4 has been reported to be pathogenic to sesame in the US. Additional information is needed regarding what AGs are pathogenic to sesame globally. While it often infects its hosts when they are in early stages of development, such as seeds and seedlings, infection can occur later in the season. If infection occurs early in the season, and often results in stunting, root rot, and plant decline. Many infections are most apparent late in the season, when stunted and

[1] **Basidiospores:** Reproductive spores produced by Basidiomycete fungi, a grouping that includes mushrooms, shelf fungi, rusts, and smuts. Basidiospores typically each contain one haploid nucleus that is the product of meiosis, and they are produced by specialized fungal cells called basidia.

[2] **Anastomosis group (AG):** Groupings based on the ability of hyphae of two different isolates to fuse and exchange materials.

poorly developed plants are more vulnerable to lodging. Co-infection with *Macrophomina phaseolina* has been observed, and resulted in severe stunting, poor capsule set, and late season lodging. This pathogen is very difficult to manage, as it is very long lived in the soil, no resistant lines have been identified, and while chemical management regulations vary by country, labelled fungicides are generally not available. *Rhizoctonia* spp. have been reported in International lists, Australia, Bolivia, Brazil, China, Colombia, Costa Rica, Dominican Republic, Egypt, India, Iraq, Japan, Myanmar, Nicaragua, Pakistan, Panama, Republic of Korea, Uganda, United States, and Venezuela. For more information, see A6.1.1a.

Major bacteria pathogens

Plant pathogenic bacteria are a diverse group of microbes, with some being culturable, while others are difficult or impossible to culture. The major sesame diseases/pathogens are phyllody, Pseudomonas, and Xanthomonas. Some plant pathogenic bacteria are able to survive outside the host plant for a period of time, while others require being within a plant host or vector (typically insect) for survival. Bacteria gain entry to a plant through natural openings (e.g., stomata, lenticels), or injuries. Dissemination of bacterial pathogens can occur via water splash, movement of insect vectors, mechanical transmission, or via infected or infested seed. It should be noted that non-vector insect feeding activity often produces small wounds, are additional avenues for bacterial access. Copper based spray products are often used as protective applications but are of little use if plants are already symptomatic. Vector control is useful, particularly in the case of insect vectored diseases, such as phyllody, though this is not always feasible due to lack of product or equipment labelling or access, financial constraints, and simply extremely high insect populations.

Photo: K.P. Akhtar et al. (2009a) {Pakistan}

Photo: G.P. Rao et al. (2015) {India}

Arrow points to normal plant.
Photos: E.J.G. Junior et al. (2019) {Paraguay}

Phyllody is a significant disease of sesame globally. It is caused by phytoplasmas, which are bacteria lacking cell walls and are obligate intracellular parasites. Phyllody is a term typically used to describe symptoms including witches' brooming, shoot tip fasciation, floral virescence, reduced leaf size, malformed and discolored growth of tissues (leaves, capsules, flowers). Symptoms are dependent on the stage of crop growth at the time of infection. A plant infected in its early growth remains stunted to about two-thirds of normal plant size, and the entire plant may be symptomatic. The entire inflorescence is replaced by witches' broom symptoms (short, twisted leaves closely arranged on a stem with very short internodes). When infection occurs at later stages, normal capsules are formed on the lower portion of the plants, while phylloid flowers are present on the tops of the main branches and on the new shoots that are produced from the lower portions. The most characteristic symptom of the disease is virescence, which is when flower parts develop into green leaflike structures, followed by abundant vein clearing in different flower parts. A detailed description is as follows: the calyx becomes polysepalous and shows multicostate venation compared to its gamosepalous nature in healthy flowers. The sepals become leaf like but remain smaller in size. The phylloid flowers become actinomorphic in symmetry, and the corolla becomes polypetalous. The corolla may become deep green, depending upon the stage of infection. The veins of the flowers become thick and quite conspicuous. The stamens retain their normal shape, but they may become green in color. Sometimes, the filaments may, however, become flattened, showing its tendency to become leaf like. The anthers become green and contain abnormal pollen grains. In a normal flower, there are only four stamens, but a phylloid flower bears five stamens. The carpels are transformed into a leaf outgrowth, which forms a pseudosyncarpous ovary by their fusion at the margins. This false ovary

becomes very enlarged. Inside the ovary, instead of ovules, there are small petiole-like outgrowths, which later grow and burst through the wall of the false ovary producing small shoots. These shoots continue to grow and produce more leaves and phylloid flowers. The stalk of the phylloid flowers is generally elongated, whereas the normal flowers have very short pedicels. Increased IAA content appears to be responsible for proliferation of ovules and shoots. Sometimes, these symptoms are found to be accompanied with yellowing, cracking of seed capsule, germination of seeds in capsules, and formation of dark exudates on the foliage. Normal-shaped flowers may be produced on the symptomless areas of the plants, but such flowers are usually dropped before capsule formation, or the capsules are dropped later leaving the stalk completely bared.

The pathogen is now investigated to be phytoplasma (formerly referred to as mycoplasma-like organism—wall-less bacteria belonging to the class Mollicutes). In Sudan, red varieties of sesame have been found to be affected to the extent of 100%. Incidence and severity appear to vary by variety, with some varieties showing promising tolerance. Sesame phyllody is not transmitted mechanically or by seeds. The disease is transmitted from one plant to another by phloem-feeding leafhoppers. Nymphs of insect are incapable of transmitting the phytoplasma. The pathogen is transmitted by the following leafhopper vectors: *Circulifer haematoceps*, *Deltocephalus* spp., *Empoasca* spp., *Empoasca lybica, Empoasca motti, Hishimonus phycitis, Orosius albicinctus, Orosius argentatus, Orosius cellulosus,* and *Orosius orientalis.* The following phytoplasmas have been identified in sesame: *Candidatus* phytoplasma asteris (16SrI), *Peanut witches'-broom phytoplasma* (16SrII), *Candidatus* phytoplasma trifolii (16SrVI), and *Pigeon pea witches'-broom phytoplasma* (16SrIX). For more information, see C5.

Effect on leaves


Effect on stems and capsules

Photos: S.S. Firdous et al. (2014) {Pakistan}

Pseudomonas syringae* pv. *sesami (Synonyms: *Pseudomonas sesami, Bacterium sesami, Bacterium sesamicola, Phytomonas sesami,* and *Phytomonas sesamicola*) is a major disease with worldwide distribution and probably is the major cause of yield loss whenever it occurs in sesame plantings. It is most damaging under conditions of high rainfall or where high humidity persists for long periods, which are favorable for pathogen spread. Symptoms are light-brown, angular spots, with a darker, more purple margin. Spots may be water soaked initially and become drier as the infection progresses, though water-soaking may not be apparent if conditions become less humid. Spots are generally located between leaf veins, but may advance along the veins and petioles, when they become dark-brown to purple lesions with a shiny appearance. The spots themselves small, but often coalesce to form large necrotic areas on leaves. These later desiccate and disintegrate, giving the leaf a tattered appearance. Spots of the capsules are usually slightly sunken, shiny and purplish-brown in color. The bacteria are internally as well and externally seedborne and can persist in debris in the field. Wind and rain spread the pathogen. Collection and burning of infected plant debris after harvest and before ploughing will help control the spread in future years. However, the preferred method is to develop tolerant varieties. It has been suggested there is a relationship between *Pseudomonas sesami* and *Xanthomonas sesami*. Additional molecular analysis in the future may provide more insight to the relationship of pathogenic and epiphytic Pseudomonads of sesame and other hosts, as well as relationships with *Xanthomonas* pathogenic to sesame. The pathogen has been reported in international lists, Australia, Brazil, Bulgaria, Burkina Faso, China, Cuba, Ethiopia, Greece, Guatemala, India, Japan, Kenya, Macedonia, Malawi, Mexico, Myanmar, Nigeria, Pakistan, Paraguay, Republic of Korea, Somalia, Sudan, Tanzania, Thailand, Turkey, United States, and Venezuela.
For more information, see C1.1.1.

Photo: R. Felix-G et al. (2019) {Mexico}

Photos : H. Tadesse (1985) {Ethiopia}

Xanthomonas euvesicatoria* pv. *sesami (Synonyms: *X. campestris* pv. *sesami*, *X. campestris*, and *X. sesami*) has been reported to cause bacterial blight of sesame and can be difficult to distinguish from *Pseudomonas syringae* symptoms. Initial inoculum may be from seed or weed hosts near by. The bacteria gains entry via stomata and other openings, and secondary spread is by water splash from rain or irrigation. High temperature, high humidity, and rainy weather favor the disease. Peak conditions for seedling infection are soil temperatures of 20°C, while infection does not occur with hot conditions, with soil temperature of 40°C. Ideal soil moisture seem to be is 30-40% and relative humidity is 75-87%. Bacterial blight has been described as small, water-soaked, light-brown lesions with yellow (chlorotic) halos around the margin that will coalesce as the infection progresses. Lesions on the capsule and stem are also often present. Chattopadhyay et al. 2019) documented *X. euvesicatoria* pv. *sesami* first occuring on the margin of the cotyledon approximately 10-12 days after sowing. If environmental conditions are favorable lesions will spread, rapidly covering the entire cotyledons, then subsequently become dry. About 4% mortality due to the disease in 4-6 week-old seedlings has been reported. If the seedling survives, dark brown, water-soaked spotsalso appear on the true leaves. In a severe infection, the lesions extend to the stem through the petiole, leading to the formation of brown discoloration, resulting in systemic invasion and death of the plant. Seed can be infested with viable pathogen up to 16 months. The pathogen may also be found in weeds, such as *Acntospermum hispidum*, which may serve as a green bridge or weed host resevoir. In the case of *A. hispidum*, the pathogen may cause symptoms and harbor the bacterium in its dried leaves from year to year. The disease is known in Sudan as *Marad et Dum*, meaning the blood disease, due to the red color of infected plant tissue. There is another Xanthomonas species that is a pathogen in sesame: *X. axonopodis* pv. *ricini* (Syn. *X. ricinicola*). The pathogen has been reported in international lists, Brazil, Burkina Faso, China, Ecuador, Ethiopia, Honduras, India, Japan, Malawi, Mexico, Myanmar, Nicaragua, Nigeria, Pakistan, Paraguay, Republic of Korea, Sudan, Turkey, United States, and Venezuela. For more information, see C3.1.1a.

The following are 2 summary documents that provide an overview on disease control.

K.N. Gupta et al. (2018) summarized the cultural practices recommended to alleviate or control the major diseases of sesame.

S. No	Practice	Disease management
1	Pathogen free sites	All diseases
2	Sanitation	All diseases
3	Deep ploughing in summer	*Sclerotium rolfsi*, diseases caused by *phytopthora, Rhizoctonia and Fusarium*
4	Good drainage	Phytophthora blight, Fusarium root rot, vascular wilt, Macrophomina root rot/stem rot
5	Soil Solarization	*Macrophomina* stem/root rot, phytophthora blight
6	Manipulation in planting	
	A). shallow planting (1')	Rhizoctnia root rot *Macrophomina* stem and root rot
	B) Plant spacing	30x10 cm (3 lakh plants/ha) reduced Macrophomina stem/root rot and phyllody
	c) Early planting (immediately after onset of monsoon)	*Cercospora leaf* spot, *Alternaria leaf* spot and bacterial blght
	d) Late planting (about 3 weeks after onset of monsoon)	Macrophomina stem and root rot. Rhizoctonia root rot and phytophthora blight phyllody

7.	**Soil amendment**	
	Mustard cake	*Rhizoctonia and Fusarium* diseases
	Sesame cake (2000) kg/ha Neem cake (250 kg/ha)	Macrophomina stem and root rot
	a. Urea	*Rhizoctonia* diseases
	Urea (20 kg N/ha + FYM (20 kg N/ha)	do
	NPK (50,25,25)	do
	Wheat or soybean straw	do
	Nitrogen @45 kg/ha	Bacterial blight
8	Crop rotation	*Phytophthora blight, Fusarium wilt and Root rot Macrophomina root and stem rot, Corynespora* blight
9	Intercropping system	
	a)Sesame + Perl millet(4:1)	*Phytophthora blight and Cercospora leaf spot*
	b) Sesame + Mothbean (1:1 or 2:1)	*Macrophomina stem and root rot*
	c)Sesame +Pigeonpea (1:1)	*Phyllody*
	d)Sesame +sunflower (6:1)	*Macrophomina stem and root rot*
10	Mixed crop with Urd moong bean, Cowpea and Mothbean	*Fusarium and Rhizoctonia root rot*
11	Irrigation every 2 weeks (Whenever necessary)	*Macrophomina stem/root rot*
12	Removal and destruction of disease plant	*Wilt root disease and phyllody*
13	Destruction of collateral host	*Bacterial blight*

They also summarized the biocontrols and biopesticides recommended to alleviate or control the major diseases of sesame.

Practice	**Disease managed**
	Bio-control agent
Trichoderma sp.	*Rhizoctonia solani Macrophomina phaseolna*
Trichoderma viride	*Fusarium oxysporum* f. sp. *Rhizoctonia solani* Phytophthroa blight *Macrophomina* stem/root rot
Trichoderma harzianum	*Phytophthora* blight, *Macrophomina* stem/ root rot
Bacillus subtilis	Macrophomina stem/ root rot
T. harzianum	Sclerotium rolfsii
	Bio-pesticide
Neem oil 5% Neem seed karnel extract (3%)	Phyllody
Neem cake (250 kg/ha)+ *Trichoderma viride (2.5 kg/ha)* *Seed treatment with Trichoderma viridae @5g/kg seed+P. Fluorescens +Soil application of T.Viridae +Soil application of P.fluorescens @2.5kg/ha*	*Macrophomina* stem/ root rot
Foliar spray of neem oil 3% might be due to the presence of sulphur containing compounds viz., nimbidin and *azadirachtin*.	Powdery mildew

They also summarized the chemicals recommended to alleviate or control the major diseases of sesame.

Disease	Chemical	Mode of application
Root rots; Rhizoctonia root rot, collar rot, Macrophomina stem and root rot	Thiram (0.15%) + Captan (0.15%) (1:1) + Urea (2%)	2-3 time soil drenching along with the plant using sprayer without nozzle from the imitation of disease at 7 days interval
Fusarium root rot, Vascular wilt	Daconil (chlorothalonil)	Soil treatment
Phytophthora root rot	Ridomil Mz (0.25%)	Soil treatment
Foliar Diseases- Cercospora leaf spot	Topsin-M (0.1%) Mancozeb (0.25%) Difenoconazole (0.1%) Carbindazim 50wp+Mancozeb	3 sprays as and when disease appear at 15 days interval
Alternaria leaf spot	Carbindazim 50wp (0.1%); Mancozeb (0.25%) Carbindazim 50wp+mancozeb	3 sprays as and when disease appear at 15 days interval --do-- --do--
Corynespora blight	Zineb (0.25%)	---do--
Bacterial leaf spot	Agrimycin 100 (250 ppm) Cupervit 50 (0.5%) or Difolatan 80 (0.16%)	--do-- --do--
Powdery mildew	Sulfex (0.2%) Karathane (0.2%)	2 sprays starting from the imitation of disease at 10 days interval 2 spray at the beginning of flowering and fruiting
Phyllody and leaf curl	A) Phorate 10 g (10 kg/ha) Dimethoate (0.03%) Profenofas/sponosad	Soil application 2-3 foliar sprays

- V.P. Queiroga et al. (2016) provided the following overview of diseases.

  Pathogens can be found in several sources:
  - Seeds: The pathogen can go on or inside the seed.
  - Weeds: Weeds found around or within the field or farm of the culture, being hosts of the pathogen, can serve as a source of inoculum.
  - Insects: Some pathogens are able to survive in or on the body of the insect vector.
  - Stubble: The quality of the pathogen varies depending on the position of the stubble and the length of time to survive. In buried stubble, the decomposition of the residues leaves the pathogen without food.
  - Soil: The concentration of the pathogen occurs around the roots of plants. This is most common in association with crop residues.

  Diseases are disseminated, dispersed or spread in the field through the wind, rain, insects, seeds, animals, humans and agricultural implements.

  To identify the diseases, it is necessary to determine the number of plants with symptoms or incidence and the proportion of tissue with the symptom or severity.

  To manage the disease, actions must be found that break the development of the disease before sowing, at sowing time, during the establishment of the cultivation and after harvest.

  Measures before sowing:
  - Avoid transporting infected structures of the pathogen to planting sites.
  - Select the sowing date appropriately.
  - Select pathogen-free seed.
  - The seed must be treated.
  - Incorporate stubble to break the pathogen cycle.
  - Sow live barriers to reduce the possibility of inoculum entering with the
  - movement of the wind or with the movement of insects.
  - Sow strip crops to decrease inoculum.
  - Rotate cultures to reduce or eliminate inoculum.
  - Eliminate alternate hosts.

Measures at the time of sowing:
- Sow densities that allow light and air penetration.
- Plant disease tolerant or resistant varieties from the area.
- Trace the rows of the crop with the orientation to the sun, this allows more light and decreases pathogens.

Measures during the establishment of the crop:
- Make a good soil preparation.
- Monitoring of pests and diseases.
- Remove and destroy susceptible plants.
- Eliminate diseased plants.
- Measures after harvest:
- Rotate fields or crops.
- Incorporate stubble.

PROPOSED AND CURRENT DESCRIPTORS

This volume is primarily intended to establish a common method of describing diseases of sesame but has become more of a compendium of research on the organisms (fungi, bacteria, oomycetes, and viruses) that are associated with sesame. The invertebrates and other fauna are covered in volume 14.

PROPOSED DESCRIPTORS

The following is proposed to be used for level of tolerance to a pathogen:

Descriptor values: 0 to 9 for tolerance and letter descriptor for phase note taken. Date should also be taken since may take two sets of notes in the same phase.

- 0 = Segregating
- 1 = Zero disease in population
- 3 = High tolerance
- 5 = Medium tolerance
- 7 = Low tolerance
- 9 = All plants with disease
- V = Vegetative phase
- R = Reproductive phase
- M = Maturing phase
- D = Drying phase

The following is proposed to be used for effectiveness of a biocontrol:

Descriptor values: 0 to 9 for effectiveness.

- 0 = Segregating
- 1 = 100% reduction in disease
- 3 = 75% reduction in disease
- 5 = 50% reduction in disease
- 7 = 25% reduction in disease
- 9 = no reduction in disease

The following is proposed to be used for effectiveness of a biofertilizer:

Descriptor values: 0 to 9 for effectiveness

- 1 = 100% increase in yield
- 3 = 75% increase in yield
- 5 = 50% increase in yield
- 7 = 25% increase in yield
- 8 = no increase in yield
- 9 = decrease in yield

CURRENT DESCRIPTORS

The following are the descriptors used in international and national systems.

* Authors comment: One thing that needs to be straightened out is that some descriptors have the high values as being resistant or tolerant (NIAS, USA PVP) while others have the high values as being susceptible (This document, IPGRI, Paraguay, USA patent).

INTERNATIONAL

- Anon. (2004a) IPGRI descriptor: *10. Biotic stress susceptibility*

  In each case it is important to state the origin of the infestation or infection, i.e., natural, field inoculation, or laboratory. Also specify the causal organism and the corresponding symptoms. The susceptibility scale is as follows:
  - 1 = Very low or no visible sign of susceptibility
  - 3 = Low
  - 5 = Intermediate
  - 7 = High
  - 9 = Very high

The growth state, coded according to the list below at which each reaction was recorded should be appended to the record of that reaction.
- 1 = Seed
- 2 = Seedling
- 3 = Pre-flowering
- 4 = Early flowering
- 5 = Mid-flowering
- 6 = Late-flowering
- 7 = Maturity

The following diseases are included in IPGRI descriptors:
- 10.1 Insect: See D.R. Langham and H.O. Sintim (2021) Sesame invertebrate and fauna.
- 10.2 Fungi
  - 10.2.1 *Alternaria sesami* (Leaf spot and blight)
  - 10.2.2 *Cercospora sesami* (Leaf spot)
  - 10.2.3 *Colletotrichum* spp. (Anthracnose)
  - 10.2.4 *Fusarium vasinfectum* (Fusarium wilt)
  - 10.2.5 *Macrophomina phaseolina* (Root and stem rot)
  - 10.2.6 *Phytophthora parasitica* (Phytophthora stem rot/blight)
  - 10.2.7 *Erysiphe orontii* (Powdery mildew)
- 10.3 Bacteria
  - 10.3.1 *Pseudomonas sesami* (Bacterial black rot)
  - 10.3.2 *Xanthomonas campestris* pv. *sesami* (Bacterial blight)
- 10.4 Nematodes: See D.R. Langham and H.O. Sintim (2021) Sesame invertebrate and fauna books.
- 10.5 Virus and mycoplasma
  - 10.5.1 *Nicotinia 10* virus (Leaf curl)
  - 10.5.2 MLO transmitted by *Orosius albicinctus* (Phyllody)

BRAZIL

- N.H.C. Arriel et al. (n.d.) Brazil descriptor: *24. Doença*: identificar o agente causal da doença e contar o número de plantas afetadas de acordo com uma escala de notas (roteiro anexo). Solicitar a presença de fitopatologista se necessário. [Disease: Identify the causative agent of the disease and count the number of affected plants according to a grade scale. Request pathologist if necessary.] The following are the ratings to be used.
  - 1 : 0 to 5%
  - 2 : 6 to 25%
  - 3 : 26 to 50%
  - 4 : 51 to 75%
  - 5 : 76 to 100%

  The following diseases are listed in the document.
  - Mancha angular (*Cylindrosporium sesami*)
  - Cercosporiose (*Cercospora sesami*)
  - Podridao negra do caule (*Macrophomina phaseolina*)
  - Viroses (Viruses)
  - Filoidia (Phyllody)

CHINA

- Anon. (2006a) China descriptor: *8.x Resistance.* The following ratings are used.
  - 0 = Immune
  - 1 = High resistance (HR)
  - 3 = Resistance (R)
  - 5 = Susceptible (S)
  - 7 = High susceptibility (HS)

  The following diseases are listed in the Chinese descriptors:
  - *8.1 Resistance to charcoal rot*
  - *8.2 Resistance to Fusarium wilt*
  - *8.3 Resistance to Phytophthora blight*

- *8.4 Resistance to virus diseases*

They provide a methodology for artificial inoculations and observing in natural fields.

JAPAN

- Anon. (2015e) NIAS Genebank Japan descriptor: *3.x Disease resistance.* The following are the ratings to be used
  - 1 = Very low
  - 3 = Low
  - 4 = Slightly low
  - 5 = Intermediate
  - 6 = Slightly high
  - 7 = High
  - 9 = Very high
- The following diseases are listed in the NIAS descriptors:
  - 3.2 Phoma wilt resistance (*Phoma sesami*)
  - 3.3 Bacterial leaf spot resistance (*Alternaria sesamicola* Kawamura)
  - 3.4 Mosaic virus resistance (TUMV and UMV)
  - 3.5 Wilt disease resistance (*Fusarium oxysporum*)

PARAGUAY

- Anon. (2015a) Paraguay descriptor: *1.10 Incidencia de patogenos* [Incidence of pathogens]. The following ratings are used:
  - 0 = Sin informacion [No information]
  - 1 = Resistente [Resistant]
  - 2 = Medianamente resistente [Moderately resistant]
  - 3 = Medianamente susceptible [Moderately susceptible]
  - 4 = Susceptible [Susceptible]

  The following diseases are listed in the Paraguay descriptors:
  - *Pseudomonas sesami*
  - *Fusarium* sp.
  - *Cercospora sesami*
  - *Alternaria sesami*
  - *Phylodia* [Phyllody]
  - *Macrophomina*
- V. Espiniola et al. (2012) proposed the following rating system. [Authors comments: The publication implies that the rating is for all diseases but recommend using it for each specific disease. There are varieties that are susceptible to one disease and not susceptible to another. There are genetic and environmental conditions that also affect yield. There are also cases where a disease may be severe and not have a commensurate effect of yield, particularly if the disease becomes severe at the end of the cycle.]

Rating	Symptoms	Category
1	Absent	Highly resistant to the diseases. Germplasm can be used as a progenitor or a commercial variety. No symptoms visible. Excellent yield.
3	Weak	Resistant to the diseases. Germplasm can be used as a progenitor or a commercial variety. Weak symptoms with small lesions that may be chlorotic, wrinkled or deformed on about 10% of the plant. Good yield.
5	Intermediate	Intermediate resistant to the diseases. Germplasm can be used as a commercial variety. Symptoms with small lesions that may be chlorotic, wrinkled or deformed on about 25% of the plant with some economic damage. Intermediate yield
7	Severe	Susceptible to the diseases. Not useful as a progenitor or as a commercial variety. Symptoms with large lesions that may be chlorotic, wrinkled or deformed on about 50% of the plant causing considerable damage to yield or death of the plant. Poor yield.
9	Very severe	Highly susceptible to the diseases. Not useful as a progenitor or as a commercial variety. Symptoms with very large lesions that coalesce and may be chlorotic, wrinkled or deformed on about 75% or more of the plant causing considerable damage to yield or death of the plant. No yield.

They provided the following visible guide for the leaf diseases.


1 = no symptoms


3 = weak symptoms



5 = intermediate symptoms



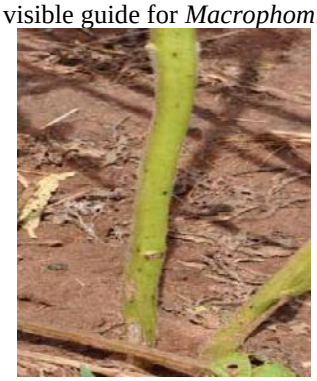
7 = severe symptoms



9 = very severe symptoms

They provided the following visible guide for *Macrophomina* and *Fusarium*.


1 = no symptoms


3 = weak symptoms



5 = intermediate symptoms



7 = severe symptoms



9 = very severe symptoms

They provided the following visible guide for phyllody.


1 = no symptoms


3 = weak symptoms



5 = intermediate symptoms



7 = severe symptoms



9 = very severe symptoms

UNITED STATES

- D.R. Langham (1966) descriptor 131. *Resistance to insects and diseases* as
  - Resistant
  - Medium
  - Susceptible
  - Resistance varies with the variety and climatic conditions under which it is grown. For example, drought will enhance the susceptibility to aphids.
- Anon. (2015c) USA PVP descriptor: *7. Diseases.* The following ratings are used:
  - 0 = Not tested
  - 1 = Susceptible
  - 2 = Low resistance
  - 3 = Moderate resistance
  - 4 = High resistance

  The following diseases are listed in the USA PVP, * = mandatory
  - *Bacterial* leaf spot *(Pseudomonas sesami)**
  - *Alternaria* leaf spot (*Alternaria sesami)**
  - *Cercospora* leaf spot (*Cercospora sesami)**
  - *Cercospora* leaf spot (*Cercospora sesamicola)*
  - *Verticilium* wilt (*Verticilium albo-atrum)*
  - *Phytophthora* blight or rot (*Phytophthora parasitica* var. *sesami)*
  - Powdery mildew (*Odium* spp.)*
  - *Fusarium* wilt (*Fusarium oxysporum)*
  - *Helminthosporium* blight (*Helminthosporium)*
  - Charcoal rot (*Macrophomina phaseoli)*
  - Southern blight (*Pellicularia rolfsii)*
  - Other
- D.R. Langham (2015b) USA patent descriptor:

Values: Average of a minimum of three plots of a subjective rating based on the following values: 0 to 8 scale of the % of infected plants (Intermediate values are used).
- 8 = Zero disease
- 7 = <10% infected
- 4 = 50% infected
- 1 = >90% infected
- 0 = all infected
- Intermediate values may be used
- NT = not tested
- NEC = no economic damage - not enough insects to do ratings

Ratings can be done in several ways:
- Take ratings after the disease is no longer increasing.
- Take ratings on consecutive weeks until the disease is no longer increasing and average ratings.
- Take periodic ratings and average ratings.

The following pests are listed in the USA patent descriptors:
- 34. Composite Kill Tolerance
- 35. Tolerance to *Fusarium* Wilt (*F. oxysporum*)
- 36. Tolerance to *Phytophthora* Stem Rot (*P. parasitica*)
- 37. Tolerance to *Charcoal Rot* (*Macrophomina phaseoli*)
- 38. Tolerance to *Bacterial Black Rot* (*Pseudomonas sesami*)

- D.R. Langham comments, 2021: The following descriptor was used in my nurseries. J.R. Mulkey (pers. comm. 1991) had been growing sesame in Uvalde, Texas, for several years, and he had observed root rots. Samples were sent to the Plant Disease Diagnostic Lab at Texas A&M University, where causal organisms of the diseases were identified as *Macrophomina phaseolina, Fusarium oxysporum*, and *Phytophthora parasitica*. It is likely that one pathogen will first penetrate the plant defenses to be followed by the other pathogens. By the time the symptoms are seen and samples taken, all three pathogens are present. The decision was made that it did not matter which pathogen killed the plant, tolerance needed to be developed for all three pathogens in the same line. Initially, ratings were taken at one time. However, it was noticed that the later maturing lines had higher ratings when the ratings were taken early. It was observed that as lines approach maturity, plant defenses likely began to wane, and the lines become more susceptible to the pathogens. Thus, the decision was made to take the ratings at physiological maturity of each plot followed by a rating 1 week later and then 2 weeks later. Within the USA, physiological maturity is defined as the point at which 3/4 of the capsules have seed with final color. In most lines, the seed will also have a seed line and tip that are dark. The following photo illustrates the difference between physiologically mature seed and seed about to mature (D.R. Langham et al., 2010c)

Within the green capsule, the S32 seed will change from a milky white color in the capsule to the left to the buff color in the capsule on the right when the seed is physiologically mature.

These S26 seeds are physiologically mature. Note the dark line (red arrow) and the dark tips (blue arrow) on the seeds. The line is only on one side of the seed. Note from the side view that the seeds are somewhat flat. S26 and S28 have lighter color than S32 seed

- D.R. Langham (2015b) USA patent descriptor: 34. *Composite kill tolerance*

- Definition: The amount of plants killed by root rots in the Sesaco nurseries.
- Values: Subjective rating (NNN for data taking and N.NN for means). Ratings are based on the number of plants killed in a population over a three week period, as follows:

  Before physiological maturity, the following ratings are used:
  - 1 = >90% kill before start of flowering
  - 2 = >90% kill between start of flowering and physiological maturity

  After physiological maturity, the following ratings are used:
  - 3 = > 90% kill
  - 4 = 50 to 89% kill
  - 5 = 25 to 49% kill
  - 6 = 10 to 24% kill
  - 7 = less than 10% kill
  - 8 = no kill
- Distribution: Based on lines in Sesaco Uvalde nursery in 2000-2001 (Total number of samples tested = 3045), low = 1.00; high = 8.00, avg. = 4.52, std = 1.49.
  - 1 = <1.6; 1.7%
  - 2 = <3.2; 16.7%
  - 3 = <4.8; 38.7%
  - 4 = <6.4; 31.2%
  - 5 = >6.3; 11.6%
- Methodology:
  - On the week a plot reaches physiological maturity, a rating is assigned. The ratings are then taken for 2 additional weeks. The three ratings are averaged for a final kill rating. For example, if a plot has a final kill of 766, the average for the plot will be 6.33. When a value of 1 or 2 is assigned, there are no additional ratings and there is no averaging.
  - There are three root diseases that affect sesame in Texas: *Fusarium oxysporum*, *Macrophomina phaseoli*, and *Phytophthora parasitica*. Between 1988 and the present, spores of these three have been accumulated in one small area (1 square km) north of Uvalde, and thus it is an excellent screening area for the diseases. Although each root rot attacks sesame in a different way with different symptoms, no effort is made to differentiate which disease is the culprit in each plot. Pathological screenings in the past have found all 3 pathogens present in dead plants.
  - Normally, the ratings will decrease a maximum of one value per week. There is an overlap between any two ratings, but this is overcome to a certain extent by using three ratings over 2 weeks.
- Comments:
  - In most years, *Fusarium* is the major cause of kill. When sesame is first introduced into a growing area, there are few disease problems, but over time the spores of these fungi accumulate and disease tolerance becomes important. When sesame was first introduced in Uvalde in 1988, the yields were high. As farmers planted on the same fields in subsequent years, the yields decreased.
  - *Composite kill tolerance* determines whether the plants can finish their cycle and have the optimum seed fill.
  - Lack of *Composite kill tolerance* can reduce *Seed weight – 100 seeds from the entire plant.*
  - Lack of *Composite kill tolerance* can reduce *Seed oil content.*
  - The amount of kill is usually increased with any type of stress to the plants. Drought can increase the amount of *Macrophomina*; too much water can increase the amount of *Phytophthora*; high temperatures and humidity can increase the amount of *Fusarium* and *Phytophthora*. High population can increase all three diseases.
  - The ratings for any one year can be used to compare lines grown in that year, but should not be used to compare lines grown in different years. The amount of disease in any one year is highly dependent on moisture, humidity, and temperatures.
  - In developing sesame varieties for the United States, there are eight characters that are desirable for successful crops: *Shaker shatter resistance, Improved non-dehiscent visual rating, Composite kill tolerance, Days to physiological maturity, Yield at drydown, Seed color, Seed weight – 100 seeds from the entire plant,* and *Seed oil content.* The first four characters contribute to *Yield at drydown*, which is the most important economic factor normally considered by a farmer in the selection of a variety. The last three characters determine the market value of the seed.

References:

- D.R. Langham (1998d) described the progress in developing root rot tolerances in Sesaco.
- D.R. Langham (1998e) reported that Sesaco took notes in most years on *"36. Kill from all stresses*. Critical for sesame becoming a crop in the US."

PHENOLOGY OF SESAME

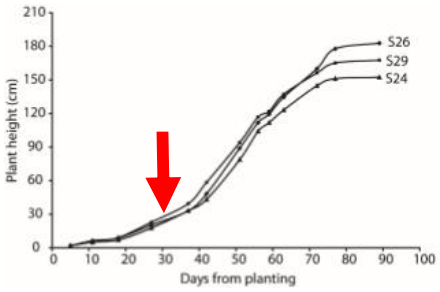
In taking data on diseases, it is important to note the phase/stage of the sesame at the date(s) the notes are taken.

This document uses the following phenology from D.R. Langham (2007a and 2008a), which breaks down the cycle in terms of phases (vegetative, reproductive, ripening, and drying) and each phase is broken into stages. The stages are delineated by an event that can be visually seen by the researcher or grower. The following table shows the range and mean number of days for each phase for lines that are acceptable for United States growing conditions.

	Days from planting		Length of phase, days	
Phase	**Range**	**Mean**	**Range**	**Mean**
Vegetative	33-53	40	33-53	40
Reproductive	56-114	81	27-52	38
Ripening	86-121	103	9-34	21
Drying	110-163	144	11-57	43

The following parameters use Sesaco 26 planted in Uvalde, Texas, planted in late-May. DAP = days after planting.

Stage	Stage parameters	Comments
VEGETATIVE PHASE		
Germination	- Start: Planting into moisture or water up - End: Emergence - DAP (Days after planting): 0-5 - Weeks: 1-	Germination is one of the most important stages because if there is a poor stand, no subsequent farmer action or weather condition can produce a high yield except to replant. See II Sesame seedling descriptors for more information on germination. Photo by A. Calderoni {Argentina}.
Seedling	- Start: emergence - End: 3rd pair true leaf length = 2nd - DAP: 6-25 - Weeks: 3-	The seedling stage is the most vulnerable stage to perils. At the beginning of the stage, leaf eating insects can destroy the plants, but towards the end, the plants can usually overcome the damage. There are many damping off diseases. High winds with blowing sand can sandblast the plants or cover the seedlings. Rains with running water can cover the seedlings. With no weed control, most weeds will outgrow the sesame plants and cover them.
Juvenile	- Start: 3rd pair true leaf length = 2nd - End: First buds - DAP: 26-37 - Weeks: 1	The photo is in the early juvenile stage. At about 30 days after planting, the plant growth increases dramatically. As shown in the graph, in the first 30 days, the plants reach a height of about 30 cm and in the next 30 days, the height quadruples to about 120 cm. From the start to the end of this stage, the crop can be cultivated. Towards the end of this stage, the first irrigation should be considered. Research has shown that between the start of the juvenile stage through the end of the full bloom stage, the plants need full moisture and fertility to maximize yield.



Stage	Stage parameters	Comments
Pre-reproductive	- Start: First buds - End: 50% open flowers - DAP: 38-44 - Weeks: 1	There is a continuing debate on whether the flowering date should be at the appearance of buds or at 50% open flowers. Both descriptors are provided; however, it is easier to see open flowers and that is the point where fertilization (reproduction) begins. Technically, the buds first appear inside the apical meristem, and one has to pull the new leaves back to see the first buds.

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REPRODUCTIVE PHASE

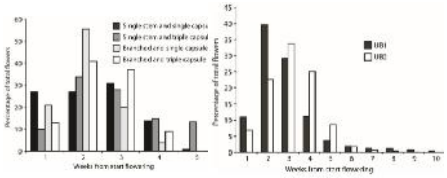
Early bloom

- Start: 50% open flower
- End: 5 node pairs of capsules
- DAP: 45-52
- Weeks: 1

Pollination normally takes place around the time the flowers open. In the afternoon, the corolla tubes drop off the flower, but the ovary that will form the capsule, stays on the plant. There are cultivar differences when the corolla will drop, and there are some lines where it does not drop and stays attached as the capsule forms. Within 3 days the capsule will be visible and will lengthen to about 2.5 cm within a week. There are varietal differences in the rate of elongation. The seeds form inside the capsules.

Mid Bloom

- Start: 5 node pairs of capsules
- End: Branches and minor plants stop flowering
- DAP: 53-81
- Weeks: 4



The beginning of this stage normally coincides with the branches starting to flower. This is the most critical stage for yield in that if the plants are stressed, they will drop whole flowers, including the ovary. The diagrams show that most of the flowers are produced in the 2nd and 3rd week after 50% flowers. The diagram at the far left is from the Republic of Korea and the close left is from Thailand.

Late bloom

- Start: Branches and minor plants stop flowering
- End: 90% of plants with no open flowers
- DAP: 82-90
- Weeks: 1+

The onset of this stage generally coincides with the plants running out of moisture and/or nutrients. This is a very difficult stage to determine because at times it is very abrupt and clear, and under other conditions, it stretches out over a long time as shown in the diagram of Thai flowering above.

Stage	Stage parameters	Comments

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RIPENING PHASE

Ripening

- Start: 90% of plants with no open flowers
- End: Physiological maturity (PM)
- DAP: 91-106
- Weeks: 2+

PM is the date at which 3/4 of the capsules on the main stem have seed with final color and a dark tip. In many lines, the seed will also have a dark seed line on one side. PM is when harvest aids can be applied. The PM definition was conceived after an experiment where plants were cut several days apart to determine the maximum yield. At that time, the lower capsules opened before the capsules at the top were mature. Basically, it was at the point where the increase in yield from the upper capsules equaled the loss of seed of yield from the bottom capsules. In most other countries the maturity date is when the first capsules are dry or when the plant changes to the appropriate color. This is the stage where the crop is most vulnerable to root diseases because it is the start of senescence.

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DRYING PHASE This phase applies only to crops that are harvented standing when the plants are dry and the seed is about 6% moisture.

Full maturity

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- Start: Physiological maturity (PM)
- End All seed mature
- DAP: 107-112
- Weeks: 1-

There was a debate as to whether this stage belonged in the ripening phase or the drying phase. The change has not been made because the additional week delay in cutting or applying harvest aids, pushes drydown into a cooler environment which delays drydown, and there are more rains later in the season. After cutting or applying harvest aids, the capsules above the PM ¾ line still make good seed, and all that is lost is the 2-3 node pair capsules at the top, which contribute little weight. There is basically less than a week between PM and full maturity. Bear in mind, there is no weather event that increases yield after maturity, but there are many weather events that decrease yield. Photo: A.A. Khalafalla {Sudan}

Stage	Stage parameters	Comments	
Initial drydown	- Start: All seed mature - End: 1st dry capsules - DAP: 113-126 - Weeks: 2	There are basically two drying patterns: many lines dry from the bottom up; some dry from the middle in both directions. In any sequence the lowest part of the plant between the lowest capsules and the root is the last to dry. For many years, there was selective pressure to develop varieties with a long initial drydown window. In most of the world there are 3 methods of harvest: plants are manually cut and shocked, cut with a binder and shocked, or cut with a swather and left in a windrow to dry. In large plantings or in weather, it is best to have a choice as to cutting time without any dry capsules that shed their seeds.	
Late drydown	- Start: 1st dry capsules - End: Full drydown - DAP: 127-146 - Weeks: 3	This is the most agonizing stage for the grower – waiting for harvest knowing that even with non-dehiscence, there will be seed falling out of the capsules. It can be accelerated by a frost or freeze in some northern latitudes.	
Full drydown	- End: Plants and capsules are dry enough to harvest.	In mechanized harvest, the seed is usually stored in silos after going through several augers. In order to maintain seed quality, the seed should be at 6% or less moisture. Storing seed at high moistures can lead to heating up and spoiling. The heating can lead to fires in the silo.	

FUNGI, OOMYCETES, BACTERIA, AND VIRUSES BY COUNTRY

INTERNATIONAL LISTS

- R.S. Vasudeva (1961) in A.B. Joshi (1961) reported the following pathogens: phytoplasma, Leaf curl, *Cercospora sesami, Cercospora sesamicola, Phytophthora parasitica, Phytophthora cactorum, Colletotrichum* sp., *Fusarium vasinfectum, Fusarium vasinfectum* var. *sesami, Fusarium oxysporum* var. *sesami, Neocosmospora vasinfecta* var. *sesami, Macrophomina phaseoli, Rhizoctonia bataticola, Rhizoctonia solani, Corticium solani, Rhizoctonia grisea, Xanthomonas sesami, Pseudomonas sesami, Bacterium sesami, Phytomonas sesami, Bacterium sesamicola, Phytomonas sesamicola, Alternaria* sp., *Alternaria sesamicola, Corynespora cassiicola, Phyllosticta sesami, Macrosporium sesami, Cylindrosporium sesami, Helminthosporium sesami, Helminthosporium gigasporum, Leveillula taurica, Sphaerotheca fuliginea, Oidium* sp., *Oidium erysiphoides, Fusarium caeruleum, Fusarium solani, Verticillium dahliae, Synchytrium sesami, Hypochnus centrifugus, Phoma* sp. and *Oospora* sp.
- J.R. Morschel (1964) reported the following pathogens in Australia and the world: *Alternaria sesami* (Leaf spot), *Cercospora sesami* (Leaf spot), *Corynespora cassiicola* (Leaf spot), *Macrophomina phaseolina* *** (Charcoal rot), *Fusarium oxysporum* (Wilt), *Macrosporium* spp. (Leaf spot)., *Oidium* spp. (Powdery mildew), *Pythium debaryanum* (Damping off), *Rhizoctonia solani* (Crown rot), *Verticilium dahliae* (Wilt), Mycoplasma-like organism (Witches broom and Big bud – phyllody). He added pathogens from outside Australia: *Alternaria sesamicola* (On stems), *Colletotrichum* spp. (anthracnose), *Helminthosporium sesami* *** (Leaf blotch), *Fusarium oxysporum* f. sp. *sesami* *** (Wilt), *Neocosmospora vasinfecta* var. *sesami, Phytophtora cactorum* (Stem canker), *Synchytrium sesamicola, Sphaerotheca fuliginea* (Sesame mildew), and *Pseudomonas sesami* *** (Wilt) {*** = seedborne}. [Cited by D.F. Beech, 1995a]
- E.A. Weiss (1971) reported is associated with the following organisms: *Pseudomonas sesami, Xanthomonas sesami, Cylindrosporium sesami, Alternaria sesami, Alternaria tenuis, Alternaria macrospora, Cercospora* spp., *Cercospora sesami, Cercospora sesamicola, Phytophthora parasitica, Fusarium oxysporum* f. sp. *sesami, Rhizoctonia* sp., *Helminthosporium sesami, Macrophomina phaseoli, Sclerotium bataticola, Rhizoctonia bataticola, Thielaviopsis basicola, Phymatotrichum omnivorum, Corynespora cassiicola, Colletotrichum* sp., *Oidium* sp., *Erysiphe cichoracearum, Curvularia macularis, Pellicularia rolfsii, Pythium aphanidermatum, Rhizoctonia* spp., *Sclerotium rolfsii, Sphaeronema sesami, Synchytrium sesamicola,* and *Pseudomonas aptata.*
- C. Wescott (1971) reported the following pathogens: bacterial leaf spot (*Pseudomonas sesami*), bacterial wilt (*Pseudomonas solanacearum*), blight (*Corynespora cassiicola*), leaf spots (*Alternaria sesami, Cercospora sesami, Cylindrocladium* spp., *Helminthosporium sesami*), charcoal rot (*Macrophomina phaseoli*) and wilt (*Verticillium albo-atrum*).
- P. Neergaard (1979) described seedborne diseases caused by *Alternaria sesami, Cercospora sesami, Corynespora cassiicola, Drechslera rostra, Drechslera sesami, Drechslera sorokiniana, Macrophomina phaseolina, Phytophthora nicotianae* var. *sesami, Pseudomonas sesami* and *Xanthomonas sesami* with losses caused, embryo/seed coat infection and control through seed treatment. [Cited by G.S. Saharan, 1989]
- M.O. Khidir (1981a) in a review of sesame in East Africa and the Near East reported the following diseases were a problem: *Pseudomonas sesami, Xanthomonas sesami, Cercospora sesami, Alternaria* spp., powdery mildew, leaf curl and phyllody.
- M.M. Satour (1981) compiled the following list of diseases during the Proceedings of Expert Consultation on Sesame in Rome, Italy, 8-12 December 1980.

Organism	IND	ISR	NIG	SUD	AUS	VEN	GRE	JAP	EGY	KEN	TAN	USA	MEX	BUK
Alternaria sesami	+	+		+	+	++		+	+	+	++	+	++	++
=*Macrosporium* sp.														
Cercospora sesami	+	+	+	+	+	+				+	++		++	++
Cylindrosporium sesami						+				+				
Corynespora cassiicola						+								
Fusarium oxysporum	+	+	+		+	++	+	++	++	+	+		+	+
Phytophthora parasitica	+		+			++			++		+		+	
Macrophomina phaseoli	+	+				++		+	++	+	+	+	+	
=*Sclerotium bataticola*														
=*Rhizoctonia bataticola*														
Oidium sp.	++	+	+	+	+	+								
Pythium debaryanum					+				+			+	+	
Rhizoctonia solani	+				+	+			+				+	+
Verticilium dahliae					+		+			+				
Helminthosporium sesami	+								+	+				
Colletotrichum sp.	+		+					+					+	
Mycoplasma	++	+			++	+			+	+	?			+

Organism	IND	ISR	NIG	SUD	AUS	VEN	GRE	JAP	EGY	KEN	TAN	USA	MEX	BUK
Xanthomonas sesami	+			+		++						+	+	+
Pseudomonas sesami				+		++				+	++		+	+

IND = India, ISR = Israel, NIG = Nigeria, SUD = Sudan, AUS = Australia, VEN = Venezuela, GRE = Greece, JAP = Japan, EGY = Egypt, KEN = Kenya, USA = United States, MEX = Mexico, and BUK = Burkina Faso.

- G.S. Saharan (1989) compiled the following sesame pathogens. (*** = seedborne)

Fungal pathogens

Alternaria sp. ***
Alternaria alternata ***
Alternaria lini
Alternaria longissima ***
Alternaria macrospora
Alternaria sesami ***
Alternaria sesamicola ***
Alternaria solani
Aspergillus niger ***
Botryobasiditun rolfsii
Botryosphaeria ribis
Cercospora spp. ***
Cercospora sesami ***
Cercospora sesami var. somalensis
Cercospora sesamicola
Cercoseptoria sesami
Choanephora cucurbitarum
Cladosporium spp. ***
Cladosporium cladosporioides
Cochliobolus lunatus ***
Cochliobolus specifer
Colletotrichum spp.
Colletotrichum capsici
Colletotrichum gloeosporioides
Corticium centrifugum
Corticitun rolfsii
Corynespora spp.
Corynespora cassiicola ***
Culvularia lunata ***
Culvularia macularis
Cylindrocladium spp.
Cylindrosporium spp.
Cylindrosporium sesami
Didymella minuta
Drechslera spp. ***
Drechslera neergaardi ***
Erysiphe cichoracearum
Erysiphe communis
Fusarium sp. ***
Fusarium equiseti ***
Fusarium moniliforme ***
Fusarium oxysporum ***
Fusarium oxysporum f. sp. *sesami* ***
Fusarium oxysporum f. sp. *vasinfectum*
Fusarium semitectum
Fusarium solani ***
Fusarium vasinfectum
Fusarium vasinfectum var. *sesami*
Gibberella fujikurio ***
Gibberella zeae
Gigaspora spp.
Gloeosporium macrophomoides
Glomerella cingulata
Helminthosporium gigesportun, sub sp. *javanicum*
Helminthosporium halodes
Helminthosporium sesami
Helminthosporium tetramera ***
Leveillula taurica
Macrophomina ssp.
Macrophomina corchon
Macrophomina phaseoli ***
Macrophomina phaseoli sub sp. *sesamica*
Macrophomina phaseolina ***
Macrophomina phillippinensis
Macrosporium sp.
Macrosporium sesami
Mycosphaerella rabiei
Mycosphaerella sesami
Mycosphaerella sesamicola
Myrothecium roridum
Neocosmopora vasinfecta var. *sesami*
Neurospora sitophila
Nigrospora oryzae
Oidium sp.
Oidium acanthospermi
Oidium erysiphoides
Oospora sp.
Pestalotiopsis mayumbensis
Phoma spp.
Phoma exiqua
Phoma nebulosa ***
Phoma sesamina
Phoma variosporeae
Phyllosticta sesami
Phytophthora sp. ***
Phytophthora cactorum
Phytophthora drechsleri
Phytophthora hibernalis
Phytophthora nicotianae
Phytophthora nicotianae var. *parasitica*
Phytophthora palmivora
Phytophthora parasitica
Phytophthora parasitica var. *sesami* ***
Pythium aphanidermatum
Pythium debaryanum
Pythium oligandrum
Pythium ultimum
Pseudocercosporella sesami
Rhizoctonia sp.
Rhizoctonia bataticola ***
Rhizoctonia solani ***
Rhizopus stolonifer
Sclerotium bataticola ***
Sclerotium rolfsii
Sphaeronema sesami
Sphaerotheca fuliginea
Synchytrium sp.
Synchytrium sesami
Synchytrium sesamicola
Thielavia terricola var. *minor*
Thielaviopsis basicola
Verticillium albo-atrum
Verticillium dahliae ***

Bacterial Pathogens

Bacillus solanacearum
Bacterium sesami
Bacterium sesamicola
Bacterium solanacearum
Erwinia spp.
Erwinia herbicola
Pseudomonas spp. ***
Pseudomonas sesami ***
Pseudomonas syringe pv. *sesami*
Pseudomonas solanacearum
Xanthomonas sp. ***
Xanthomonas axonopodis
Xanthomonas campestris pv. *sesami* ***
Xanthomonas sesami

Viral Pathogens

Alfalfa mosaic virus
Citrus dwarf virus
Cowpea mild mottle virus
Cucumber mosaic virus
Groundnut mottle virus
Peanut mottle virus
Potato aucuba mosaic virus
Potato virus x.
Satsuma dwarf virus
Sesamum leaf curl virus
Tobacco leaf curl virus
Watermelon mosaic virus

Mycoplasma Pathogens

Mycoplasma-like organism

Other seedborne fungi

Alternaria tenuis
Aspergillus spp.
Aspergillus amstelodami
Aspergillus candidus
Aspergillus chevalieri
Aspergillus fumigatus
Aspergillus funiculosus
Aspergillus montevidensis
Aspergillus ochraceus
Aspergillus repens
Aspergillus sydowi
Cephalosporium acremonium

Drechslera hawaiiensis
Drechslera tetramera
Myrothecium spp.
Penicillium chrysogenum
Penicillium citrium
Penicillium jensemi
Penicillium rubrum

Rhizosphere Fungi
Aspergillus spp.
Fusarium spp.
Fusarium oxysporum
Gigaspora spp.
Glomus spp.

Macrophomina phaseoli
Neocosmospora vasinfecta
Penicillium spp.
Sclerocystis spp.
Sclerotium bataticola
Streptanyces spp.

- Anon (2000a) is an organic grower guide for America. It describes the following pathogens/diseases and their recommended organic method of control: Phytophthora Blight, *Macrophomina phaseolina* and *Rhizoctonia bataticola* (Stem and root rot), *Fusarium oxysporum* (Fusarium wilt), Alternaria leaf spot, *Cercospora sesami* (White Spot), Powdery Mildew 4 pathogens: *Oidium erysiphoides, Sphaerotheca fuliginea, Leveillula taurica* and *Erysiphe cichoracearum*, and Corynespora Blight.
- C. Chattopadhyay et al. (2019) reported the major pathogens are *Phytophthora parasitica* (Dastur) var. *sesami* Prasad (*P. nicotianae* B. de Haan var. *parasitica* [Dastur] Waterh) (Phytophthora blight); *Macrophomina phaseolina* (Tassi) Goid. (Charcoal rot); *Fusarium oxysporum* (Schelt.) f. *sesami* Jacz (Fusarium wilt); *Alternaria sesami* (Kawamura) Mohanty and Behera (Alternaria leaf spot); *Cercospora sesami* Zimmerman (*Mycosphaerella sesamicola*) (White leaf spot or Cercospora leaf spot); and phytoplasma (Phyllody). Other pathogens are *Oidium erysiphoides* Fr., *Oidium sesami* Sreenivasulu et al., *Sphaerotheca* fuliginea (Schlecht) Pollacci, *Leveillula taurica* (Lav.) Truaud, and *Erysiphe cichoracearum* DC (Powdery mildew); *Corynespora cassiicola* (Berk. and Curt.) Wei (Corynespora blight); *Cylindrosporium sesami* Hansford (Brown angular leaf spot); *Cercospora sesamicola* Mohanty (Angular leaf spot); *Helminthosporium sesami* Miyake (Aerial stem rot); *Alternaria alternata* (Fr.) Keissier (Stem blight); *Xanthomonas campestris* (Pammel) Dawson pv. *sesami* (Sabet and Dowson) Dye (Bacterial blight); *Ralstonia solanacearum* (Bacterial blight), Leaf curl virus (Leaf curl); sesame mosaic virus (Mosaic disease); and Cowpea aphid-borne-mosaic virus (Cowpea aphid-borne-mosaic virus disease). [Authors comment: This chapter summarizes the research on the pathogens. In this volume in most cases, when a pdf or abstract of the cited authors is available, the information is under the author instead of in the summary.]
- CAB International (accessed 12 Apr 2021) reported sesame hosted the following organisms.
  - Major host of: *Candidatus phytoplasma trifolii* (clover proliferation phytoplasma); *Choanephora cucurbitarum* (Choanephora fruit rot); *Cowpea aphid-borne mosaic virus*; *Cylindrosporium sesami* (Angular leaf spot of sesame); *Macrophomina phaseolina* (Charcoal rot of bean/tobacco); *Peanut mottle virus* (Peanut mottle); *Pseudomonas syringae* pv. *sesami* (Bacterial: sesame leaf spot); *Rhizobium radiobacter* (Crown gall); *Rhizobium rhizogenes* (Gall); *Sclerotinia sclerotiorum* (Cottony soft rot); *Xanthomonas campestris* pv. *sesami* (Bacterial: sesame blight).
  - Minor host of: *Aspergillus flavus* (Aspergillus ear rot)*; Aspergillus niger* (Black mold of onion)*; Athelia rolfsii* (Sclerotium rot)*; Candidatus phytoplasma asteris* (yellow disease phytoplasmas)*; Chalara elegans* (Black root rot) [Synonym of *Berkeleyomyces basicola]; Fusarium oxysporum* f. sp. *vasinfectum* (Fusarium wilt)*; Haematonectria haematococca* (dry rot of potato)*; Leveillula taurica* (powdery mildew of cotton)*; Peanut stripe virus* (Groundnut stripe disease)*; Phytophthora nicotianae* (Black shank)*; Phytophthora tropicalis;* soybean phyllody phytoplasma (Soyabean phyllody)*; Tobacco leaf curl virus; Tobacco mosaic virus* (Tobacco mosaic)*; Xanthomonas axonopodis* (gummosis: grasses)*; Zucchini yellow mosaic virus.*
  - *Associated with (not a host): Bacillus subtilis*; *Hypocrea rufa* (Green mold of narcissus); *Spiroplasma citri* (Stubborn disease of citrus); *Trichoderma harzianum* (hyperparasite of *Rhizoctonia solani*).
  - Host of (source - data mining): *Alternaria alternata* (Alternaria leaf spot); *Alternaria sesami* (Blight of sesame); *Alternaria sesamicola* (Zonate: sesame leaf spot); *Cercospora sesami* (Leaf spot: sesame); *Corynespora cassiicola* (Target leaf spot of tomato); *Fusarium oxysporum* (Basal rot); *Fusarium oxysporum* f. sp. *sesami* (Wilt: sesame); *Groundnut bud necrosis virus*; *Oidium sesami*; *Phytoplasma aurantifolia* (lime witches' broom phytoplasma); *Podosphaera xanthii* (Powdery mildew of cucurbits).
- N. Ransingh et al. (2021) reported the major pathogens are *Macrophomina phaseolina* (Tassi.) Goid (Charcoal rot, dry rot, stem rot or root rot); *Alternaria sesame* Mohanty and Behera (Alternaria leaf spot); *Cercospora sesame* Zimmerman and *Cercospora sesamicola* Mohanty (Cercospora leaf spot); *Phytophthora parasitica* var. *sesame* (Phytophthora blight); various pathogens (Powdery mildew); *Pseudomonas syringae* pv. *sesami* (Bacterial leaf spot); and phytoplasma (Phyllody). [Authors comment: This chapter summarizes the research on the pathogens. In this volume in most cases, when a pdf or abstract of the cited authors is available, the information is under the author instead of in the summary.]

AUSTRALIA

- D.F. Beech (1995a) reported the following pathogens: *Alternaria sesami* (Leaf spot), *Cercospora sesami* (Leaf spot), *Corynespora cassiicola* (Leaf spot), *Macrophomina phaseolina* (Charcoal rot), *Fusarium oxysporum* (Wilt), *Macrosporium* spp. (Leaf spot)., *Oidium* spp. (Powdery mildew), *Pythium debaryanum* (Damping off), *Rhizoctonia solani* (Crown rot), *Verticilium dahliae* (Wilt), Mycoplasma-like organism (Witches broom and Big bud – phyllody).
- B.D. Conde (1995) reported the following pathogens: *Cercospora sesami* (imperfect state of *Mycosphaerella sesami*) (small Cercospora leaf spot), *Corynespora cassiicola* (Capsule/stem/leaf spot), *Macrophomina phaseolina* (Ashy stem blight, necrosis of lower leaves), *Pseudocercospora sesami* (imperfect state of *Mycosphaerella sesamicola*) (Large cercospora leaf spot), *Oidium* sp. (Powdery mildew), tomato big bud mycoplasma (Little leaf) (Transmitted by *Orosius argentatus*).

BANGLADESH

- M.D. Hosen and S. Shamsi (2017) isolated the following fungi from sesame seeds: *Aspergillus flavus, Aspergillus fumigatus, Aspergillus niger, Curvularia lunata, Fusarium merismoides, Mucor* sp., *Penicillium* sp., *Rhizopus stolonifer* and *Trichoderma viride.*

BOLIVIA

- B. Carreno L. et al. (n.d.) in a grower guide reported the following diseases: *Alternaria sesami* and *Rhizoctonia solani.*

BRAZIL

- N.E.M. Beltrao and E.C. Freire (1986) in a grower guide reported *Cercospora* sp., *Fusarium* sp., and *Cylindrosporium* sp. cause major diseases.
- N.H.C. Arriel et al. (2009) and N.E.M. Beltrao et al. (2013) reported the following pathogens: *Xanthomonas campestris* pv. *sesami, Macrophomina phaseolina, Alternaria sesami, Fusarium oxysporum, Cylindrosporium sesami, Cercospora sesami*, and phyllody.

CHINA

- L.L. Li (1988) reported the following fungi cause severe damage to sesame: *Fusarium vasinfectum* (Wilt), *Fusarium vasinfectum* var. *sesami* (Wilt), *Macrophomina phaseolina* (Stem necrosis), *Macrosporium sesami* (Purple blotch), *Phytophthora nicotianae* var. *sesami* (Blight), *Phytophthora. parasitica* var. *sesami* (Blight), and *Pseudomonas solanacearum* (Bacterial wilt). The following fungi cause major damage: *Pseudomonas sesami* (Angular leaf spot), Pepper mild mosaic virus (PMMV), and Turnip mosaic virus (TuMV). The following are cause minor diseases: *Alternaria sesamicola* (Black spot), *Ascochyta sesami* (Brown spot), *Ascochyta sesamicola* (Ring spot), *Cercospora sesami* (Leaf spot), *Colletotrichum* sp. (Anthracnose), *Corticium centrifugum*), *Corynespora sesameum* (Leaf necrosis), *Dothiorella phillippinensis, Erysiphe cichoracearum* (Mildew), *Helicobasidium mompa* (Purple root rot), *Helminthosporium sesami* (Leaf blight), *Oidium erysiphoides* (Mildew), *Phoma sesami* (Stem necrosis), *Rhizoctonia solani* (Rhizoctonia rot), *Thanatephorus cucumeris, Verticilium albo-atrum* (Yellow wilt), and *Xanthomonas ricinicola* (Bacterial wilt).
- H.M. Miao and H.Y. Liu (2010) reported the following pathogens: *Fusarium oxysporum* f. sp. *sesami, Macrophomina phaseoli, Rhizoctonia solani, Phytophthora nicotianae, Pseudomonas solanacearum, Sclerotium rolfsii, Ascochyta sesami, Ascochyta sesamicola, Alternaria sesami, Helminthosporium sesami, Cercospora sesami, Erysiphe cichoracearum, Pseudomonas syringae* pv. *sesami, Turnip mosaic virus* (TuMV), and mycoplasma-like organism (MLO).

COLOMBIA

- Anon. (2013c) in a grower guide reported *Macrophomina phaseolina, Fusarium oxysporum*, and *Cercospora sesami* cause major diseases.

COSTA RICA

- Anon (1991a) in a grower guide reported the following pathogens: *Rhizoctonia solani, Fusarium* spp., *Pythium* spp., *Sclerotium rolfsii, Alternaria* spp., and *Cylindrosporium* spp.

CUBA

- La Habana (2009) in a grower guide reported the following pathogens: *Alternaria alternata, Alternaria sesami, Corynespora cassiicola, Fusarium oxysporum, Macrophomina phaseolina, Drechslera sorokiniana, Myrothecium roridum, Aspergillus flavus, Cladosporium* sp., *Curvularia lunata, Phoma* sp., *Penicillium* sp. and *Pseudomonas sesami.*

ECUADOR

- M. Bustamonte (2001) in a grower guide reported the following pathogens: *Pseudocercospora sesami, Corynespora cassiicola, Macrophomina phaseolina,* and *Xanthomonas campestris.*

EGYPT

- I.A. El-Kady et al. (1986) reported isolating *Aspergillus ochraceus, Aspergillus sydowi, Aspergillus amstelodami, Aspergillus niger, Aspergillus montevidensis, Aspergillus repens, Penicillium chrysogenum* and *Penicillium jensemi* from market samples. [Cited by G.S. Saharan, 1989]
- M.M.I. Abdel-Hafez et al. (2012) examined the rhizosphere and rhizoplane of sesame with the following results:

Species	Rhizosphere	Rhizoplane
Fusarium spp.	x	x
Fusarium acutatum	x	
Fusarium chlamydosporum		x
Fusarium longipes		x
Fusarium nygamai	x	
Fusarium oxysporum	x	x
Fusarium poae	x	x
Fusarium sambucinum	x	
Fusarium semitectum	x	
Fusarium solani	x	x
Fusarium tricinctum	x	
Fusarium verticillioides	x	x

Species	Rhizosphere	Rhizoplane
Acremonium sp.	x	
Alternaria sp.	x	
Aspergillus spp.	x	x
Cladosporium spp.	x	
Gliocladium sp.	x	
Myrothecium sp.	x	
Penicillium spp.	x	x
Scopulariopsis spp.	x	
Setosphaeria spp.	x	x
Stachybotrys spp.	x	
Ulocladium sp.	x	

- M.M.I. Abdel-Hafez et al. (2014) took ten samples of sesame from local markets in Assiut city. They found the following: *Fusarium acutatum* Nirenberg & O' Donnell (a new species), *Fusarium chlamydosporum* Wollenw. & Reinking, *Fusarium graminearum* Schwabe, *Fusarium solani* (Mart.) Sacc., *Fusarium. subglutinans* (Wollenw. & Reinking) P. E. Nelson, Toussoun & Marasas, *Fusarium verticillioides* (Sacc.) Nirenberg, *Fusarium xylarioides* Steyaert, *Aspergillus ochraceus* Wilhelm, *Aspergillus terreus* Thom, *Aspergillus flavus* Link, *Aspergillus niger* van Tieghem, *Cladosporium* spp., *Eurotium* sp., *Gliocladium* sp., *Penicillium* spp., *Setosphaeria* spp., *Rhizopus* sp., and *Alternaria* spp. [Authors comment, 2021: Interesting that *F. oxysporum* was not found on the sesame, but it was common on the maize, sorghum, and lentils.]
- A. Hashem et al. (2014) collected 18 seed samples of sesame in Egypt (12 samples) and Saudi Arabia (6 samples). They identified the following mycoflora: *Alternaria alternata, Alternaria brassicae, Alternaria solani, Aspergillus caespitosus, Aspergillus nidulans, Aspergillus ochraceus, Aspergillus flavus, Aspergillus niger, Aspergillus oryzae, Aspergillus parasiticus, Aspergillus carbonarius, Aspergillus terreus, Aspergillus tetrazonus, Chaetomium elatum, Chaetomium globosum, Chaetomium spirale, Cladosporium cladosporioides, Drechslera ellisii, Emericella nidulans, Emericella quadrilineata* [Synonym of *Aspergillus quadrilineatus*], *Fusarium oxysporum, Fusarium chlamydosporum, Fusarium dimerum, Fusarium equiseti, Fusarium semitectum, Fusarium verticillioides, Penicillium brevicompactum, Penicillium citrinum, Penicillium chrysogenum, Penicillium crustosum, Penicillium nordicum, Penicillium oxalicum, Penicillium purpurogenum, Penicillium verrucosum, Penicillium viridicatum, Phoma sp., Phoma herbarum, Rhizoctonia solani, Pythium ultimum,* and *Sclerotium bataticola*. Ochratoxin A (OTA) is a secondary metabolite (mycotoxin) produced by some seedborne fungi belonging to *Aspergillus* and *Penicillium* genera. The total OTA contamination percent of the Egyptian samples were significantly less (16.7%) than those of the Saudi samples (83.3%).

Isolate code	Orginal location	Seedborne fungal isolates	Ochratoxin A production (µg/100 ml culture medium)
1	Bani Swief	*A. ochraceus*	122.4
2	Bani Swief	*A. ochraceus*	118.6
3	Bani Swief	*A. ochraceus*	120.7
4	Jizan	*P. viridicatum*	24.8
5	Bani Swief	*P. nordicum*	112.4
6	Holy Makkah	*P. verrucosum*	27.3
7	Ismailia	*A. niger*	14.5
8	Ismailia	*A. niger*	13.4
9	Jizan	*P. crustosum*	12.3
10	Sohag	*P. brevicompactum*	17.6
11	Sohag	*P. brevicompactum*	17.5
12	Sohag	*A. carbonarius*	147.5
13	Holy Makkah	*A. niger*	7.2
14	Jizan	*A. niger*	32.6
15	Holy Makkah	*A. ochraceus*	37.5
16	Jizan	*A. ochraceus*	36.4
17	Ismailia	*A. ochraceus*	10.4

ETHIOPIA

- T. Geremew et al. (2009 and 2012) reported the following diseases are a major problem: *Pseudomonas sesami* (Blight), *Xanthomonas sesami* (Blight), and phyllody. The following are a minor problem: *Fusarium oxysporum* (Wilt), *Verticillium* sp. (Wilt), *Alternaria sesami* (Leaf spot), *Cercospora sesamicola* (Leaf spot), *Cylindrosporium sesami* (Leaf spot), *Oidium* sp.(imperfect stage) (Powdery mildew), *Erysiphe* sp. (perfect stage) (Powdery mildew) and phyllody.
- B.K Yirga and B. Fiseha (2017a) reported the following pathogens: *Macrophomina phaseolina* (Stem and root rot), *Fusarium oxysporum* f. sp. *sesami* (Fusarium wilt), *Alternaria* spp. (Leaf spot), *Sphaerotheca fuliginea* (Powdery mildew), *Xanthomonas campestris* pv. *sesami* (Bacterial blight), and *Pseudomonas syringae* pv. *sesami* (Bacterial leaf spot).

GUATEMALA

- Anon. (1982a). A grower guide reported the following pathogens: *Phytophthora* sp., *Fusarium* sp., *Alternaria sesami; Cercospora* sp.; *Cylindrosporium sesami*; and *Pseudomonas sesami.*

HONDURAS

- V.P. Queiroga et al. (2016) reported the following diseases.

Pathogen	Part damaged	Age of the plant
Macrophomina phaseoli	Root, base of the stem and stem	Seedling
Fusarium sp.	Root, base of the stem and stem	Seedling
Sclerotium rofsii	Root and base of the stem	15 days after planting to the end
Phytophthora sp.	Root, stem, leaves, branches and capsules	35 days after planting to the end
Xanthomonas campestris pv. *sesami*	Leaves and capsules	15 days after planting to the end
Cercospora sesami	Leaves and capsules	15 days after planting to the end
Alternaria sp.	Leaves, stems, and capsules	15 days after planting to the end

INDIA

- O.P. Kadian (1972) reported in sesame seeds, species of *Alternaria* sp., *Phytophthora* sp., *Fusarium* sp., *Xanthomonas* sp., and *Pseudomonas* sp. were most commonly associated whereas species of *Cercospora* sp. and *Aspergillus* sp. were detected less frequently. Seven genera namely *Alternaria* spp., *Phytophthora* spp., *Fusarium* spp., *Cercospora* spp., *Aspergillus* spp., *Xanthomonas* spp. and *Pseudomonas* spp. were internally as well as externally seedborne and were also pathogenic. The seed infestations (%) with *Phytophthora* spp. and *Alternaria* spp. were comparatively higher than with other five genera. All these micro-organisms reduced seed germination and had adverse effect on the seedlings. [Cited by G.S. Saharan, 1989]
- T. Singh and D. Singh (1983) isolated 24 fungi: Of these, *Alternaria sesami, Cephalosporium acremonium, Fusarium oxysporum* f. sp. *sesami, Fusarium solani* and *Macrophomina phaseolina* were important pathogens. The presence of *Phytophthora parasitica* var. *sesami* was detected in microtome sections of seeds.
- K. Kumar et al. (1984a) reported 17 fungal species were found to be associated with the seeds of *Sesamum* varieties T-4 and T-12: *Aspergillus flavus, Aspergillus sacchari, Aspergillus candidus, Aspergillus terreus,*

Aspergillus niger, Aspergillus clavatus, Aspergillus fumigatus, Alternaria sesami, Curvularia lunata, Chaetomium sp., *Fusarium moniliforme, Helminthosporium tetramera, Memnoniella sitophila, Memnoniella echinata, Penicillium rubrum, Rhizopus nigricans,* and *Rhizoctonia bataticola.*

- S. Maiti et al. (1985 and 1986) reported phyllody is the most destructive disease in India. Leaf curl is also responsible for heavy losses when it infects at early growth stages of the crop. Bacterial leaf spot, *Pseudomonas syringae* pv. *sesami* causes considerable yield reduction whenever it infects the sesamum crop. Bacterial blight, *Xanthomonas campestris* pv. *sesami* is serious during the monsoon and to young plants. Among the fungal diseases, leaf blight, *Alternaria sesami* leafspot, *Cercospora* sp., and *Phytophthora nicotianae* pv. *parasitica* are important. Charcoal rot, *Macrophomina phaseolina* is widespread and destructive but difficult to control. Mildew is not a serious disease. A number of organisms have been reported to cause this disease. The following are considered minor pathogens. *Alternaria sesamicola* (Kaw.) Hans., *Corynespora cassiicola* (Berk and Curtis) Wei, *Cercoseptoria sesami* (Hansf) Deighton, *Botryosphaeria ribis* Gross and Dugg., *Cladosporium* sp., *Macrosporium* sp., *Phoma exigua* Desm., *Phoma variosporeae, Sphaeronema sesami* Sehgal and Daftari, *Choanephora cucurbitarum* (Berk and Rev.) Thaxt., *Fusarium equiseti* (Corda) Sacc., *Synchytrium sesami* Sinha and Gupta, *Synchytrium sesamicola* Lacy, *Colletotrichum* sp., *Thielavia terricola* (Gilman and Abboutt) Emmons, *Thielavia terricola* var. *minor* Rayas and Borutt, *Pythium aphanidermatum* (Eds) Filz., *Sclerotium rolfsii* Sacc., *Pellicularia filamentosa* (Pat) Rogers, and *Pseudomonas solanacearum* Smith.
- M.L. Verma (1985) reported the following pathogens: *Pythium aphanidermatum, Phytophthora parasitica, Rhizoctonia solani* (*Pellicularia filamentosa*), *Rhizoctonia bataticola* (*Macrophomina phaseoli*), *Sclerotium rolfsii* (*Corticium rolfsii*), *Fusarium caeruleum, F. oxysporum f. sp. sesami, F. vasinfectum, Phytophthora parasitica var. sesami* (*P. nicotianae var. parasitica*), *Corynespora cassiicola, Cercospora sesami, Cercospora sesamicola, Alternaria sesami* (*Macrosporium sesami*), *Erysiphe cichoracearum* (*Oidium erysiphoides*), *Sphaerotheca fuliginea, Pseudomonas sesami* (*Bacterium sesami*), *B. sesamicola, Xanthomonas campestris pv. sesami* (*Xanthomonas sesami*), *Nicotiana Virus-10, Mycoplasma*-like organism, *and Rickettsia*-like organism.
- Anon (1992a) in a grower guide reported the following pathogens: *Phytophthora sesami* (Seedling blight), *Xanthomonas campestris* pv. *sesami* (Bacterial blight), *Pseudomonas syringae* pv. *sesami* (Bacterial leaf spot), *Leveillula taurica* (Powdery mildew), *Cercospora sesami* (Cercospora leaf spot), *Alternaria sesami* (Alternaria leaf spot), *Rhizoctonia bataticola*/*Macrophomina phaseolina* (Stem and root rot), and *Mycoplasma* (Phyllody).
- N.O. Srikantappa et al. (2009) studied 28 samples of sesame taken from fields, farmers, retail shops and APMC markets from 5 areas. They found 34 four fungi: *Alternaria alternata, Alternaria sesamicola, Alternaria tenuis, Fusarium moniliforme, Fusarium oxysporum, Verticillium dahliae, Sclerotinia sclerotiorum, Sclerotium rolfsii, Cercospora sesami, Curvularia lunata, Macrophomina phaseolina, Cladosporium cladosporioides, Cladosporium herbarum, Cladosporium fulvum, Cladosporium chlorocephalum, Acremonium* sp., *Helminthosporium* sp., *Gliocladium roseum, Neurospora glabra, Cunninghamella elegans, Chaetomium globosum, Stachybotrys chartarum, Stachybotrys atra, Pestalotia macrotricha, Aspergillus niger, Aspergillus flavus, Aspergillus ochraceus, Aspergillus versicolor, Aspergillus terreus, Aspergillus candidus, Haplosporangium* sp., *Penicillium citratum, Rhizopus nigricans, Rhizopus stolonifer and Mycella sterilliae*. They tested the germination using two methods: sand and rolled paper towel. The differences in germination were significant as shown in the following tables. They recommended seed treatments are important to improve germination.

TABLE 3 : Effect of seed borne fungi on germination by Sand method

Place of collection	Germ (%)	Normal seedlings	Abnormal seedlings	Un germinated seedlings	Rotted seedlings	Fungal pathogens
Shivapura	92.0	62.0	30.0	5.0	3.0	*A. alternata, A. sesamicola, C. sesami, C. globosum, V. dahliae, M. phaseolina, C. cladosporioides, A. niger,*
Agasanakatti	88.0	50.0	38.0	10.0	2.0	*A. alternata, F. moniliforme, C. sesami, A. flavus, R. Stolonifer, A. sesamicola, M. phaseolina, A. ochraceus.*
Thumbigere	89.0	40.0	41.0	19.0	0	*A. alternata, F. moniliforme, C. sesami, A. flavus, R. Stolonifer, A. sesamicola, M. phaseolina, A. ochraceus.*
Duthidurga	91.0	53.0	37.0	8.0	2.0	*A. alternata, A. sesamicola, C. sesami, C. globosum, V. dahliae, M. phaseolina, C. cladosporioides, A. niger,*
Hulikatti	90.0	49.0	33.0	3.0	3.0	*A. alternata, F. moniliforme, C. sesami, A. flavus, R. Stolonifer, A. sesamicola, M. phaseolina, A. ochraceus.*
Mean	90	50.8	35.8	9	2	
SD	1.584	7.918	4.324	6.204	1.224	
SE	0.547	2.179	1.248	1.790	0.353	

TABLE 4 : Effect of seed borne fungi on germination by rolled paper towel method

Place of collection	Germ (%)	Normal seedlings	Abnormal seedlings	Un germinated seedlings	Rotted seedlings	Fungal pathogens
Shivapura	65.0	33.0	47.0	13.0	7.0	*A. alternata, F. moniliforme, C. sesami, A. flavus, R. Stolonifer, A. sesamicola, M. phaseolina, A. ochraceus.*
Agasanakatti	62.0	28.0	52.0	10.0	10.0	*A. alternata, A. sesamicola, C. sesami, C. globosum, V. dahliae, M. phaseolina, C. cladosporioides, A. niger,*
Thumbigere	69.0	37.0	43.0	8.0	12.0	*F. moniliforme, C. sesami, A. flavus, R. Stolonifer, A. sesamicola, M. phaseolina, A. ochraceus.*
Duthidurga	71.0	26.0	54.0	9.0	11.0	*F. moniliforme, C. sesami, A. flavus, R. Stolonifer, A. sesamicola, M. phaseolina, A. ochraceus.*
Hulikatti	74.0	29.0	51.0	3.0	17.0	*A. alternata, F. moniliforme, C. sesami, A. flavus, R. Stolonifer, A. sesamicola, M. phaseolina, A. ochraceus.*
Mean	68.2	30.6	49.4	8.6	11.4	
SD	4.764	4.393	4.393	3.646	3.646	
SE	1.375	1.268	1.268	1.052	1.053	

- V. Bharathi et al. (2013) collected sesame seeds from farmers in Andhra Pradesh. They tested the seeds for mycoflora, and the following fungi were found: *Alternaria alternata, Alternaria tenuissima, Alternaria terreus, Aspergillus flavus, Aspergillus fumigatus, Aspergillus niger, Macrophomina* spp., *Cephalosporium* spp., *Fusarium oxysporum, Rhizoctonia solani, Rhizopus stolonifer, Curvularia* spp., *Drechslera* spp., *Rhizopus* spp., *Cladosporium* spp., and *Penicillium* spp.
- P.L. Radha (2013) collected 18 cultivars from 7 districts in Karnataka and identified the following fungi: *Alternaria sesami*, *Colletotrichum* sp., *Fusarium* sp., *Macrophomina phaseolina*, *Aspergillus niger*, *Aspergillus flavus*, *Botrytis* sp., *Penicillium* sp., and *Mucor* sp.
- H.R. Aglave (2016) screened two varieties (CV.N-85 and CV. Phule-1) for seed mycoflora. Twenty-seven fungi were isolated from these varieties. Varietal variation was found during the investigation. The following fungi were present *Alternaria carthami*, *Aspergillus flavus*, *Chaetomium globosum*, *Fusarium oxysporum*, *Rhizopus stolonifer*, *Aspergillus niger*, *Rhizoctonia leguminicola*, *Absidia corymbifera* [This is a synonym of *Lichtheimia corymbifera*], *Mucor mucedo*, *Aspergillus versicolor*, and *Aspergillus terreus.*
- M.K. Naik et al. (2017) reported sesame production, particularly in India, has been declining since last decade and 'Leaf blight' caused by *Alternaria* spp. is reported to cause yield loss up to 30-40%. They investigated the fungal toxin produced by Alternaria and its pathogenicity. A total of 164 Alternaria strains (*A. alternata* [39], *A. brassicae* [10], *A. porri* [6], *A. tenuissima* [03], *A. sesami* [1] and *Alternaria* sp. [72]) were isolated on potato

dextrose agar media from the infected sesame leaves showing circular concentric rings with dark brown spots symptoms.

- B. Khamari et al. (2018e) collected 15 sesame seed samples from different localities of Odisha and analyzed their quality parameters to include mycoflora. Moisture content ranged from 8.18 to 10.30%. Physical purity ranged from 79.5 to 94.75%. Germination ranged from 71.5 to 89.5%. Seedling length ranged from 4.6 to 6.8 cm. Vigor index ranged from 325.35 to 611.83. Infested seed ranged from 4 and 18%. The main mycoflora included *Aspergillus flavus*, *Aspergillus niger*, *Penicillium* sp., *Alternaria* sp., *Fusarium* sp., *Macrophomina phaseolina*, *Curvularia* sp., *Helminthosporium* sp. and many other fungi. The infestations were as follow.

Table 3. Percent contribution of each seed mycoflora to the total number of seeds. Af : *Aspergillus flavus*, An : *Aspergillus niger*, Alt : *Alternaria* sp., Mp : *Macrophomina phaseolina*, Fus : *Fusarium* sp., Cur : *Curvularia* sp., Hel : *Helminthosporium* sp., Pen : *Penicillium* sp.

Sl. No.	Infes-tated seed (%)	Percent contribution of each mycoflora to the total seed sample taken									Total % of myco-flora
		Af	An	Alt	Mp	Fus	Cur	Hel	Pen	Others	
1	4	2	1	0.5	0.5	0.5	0.5	0.5	0.5	0	5.5
2	8	3	2.5	1	0	2	0	0	0	0	8.5
3	9	4	3.5	0	0.5	1.5	0	0	0	0	9
4	8	1.5	4.5	1	0	0.5	0.5	0	1	0	9
5	7	3.5	2.5	0	1.5	0.5	0	0	0	0	8
6	9	1.5	2.5	0	1	1.5	0	0	1.5	1	9
7	13	3	4.5	0.5	1	2.5	0.5	0.5	1.5	0	14
8	8.25	5.5	1	0.5	0	1	0	0	0	0.5	8.5
9	12	1	2.5	0	1.5	4	1	1	0.5	1	12.5
10	16	5.5	3.5	4	1	2.5	1.5	0.5	0	0	18.5
11	18	5	6.5	2.5	1	2	1	0	1	0.5	19.5
12	8	4	2.5	1	0	1	0	0	0.5	0	9
13	13	3.5	3	2	0	2	0	0	2.5	0	13
14	6	1	2	1	1	1	0.5	0.5	0	0	7
15	5	2	1	1	0	1	0.5	0	0	0	5.5

IRAN

- M. Gooya et al. (2000) reported during 1997/99 one seed samples of each 17 sesame cultivars from 10 locations resulted in 145 isolates, which included 34 species of 15 genera. The identified fungi were: 1. *Acremonium strictum*, 2. *Alternaria alternata*, 3. *Alternaria raphani*, 4. *Alternaria sesami*, 5. *Alternaria* sp., 6. *Aspergillus flavus*, 7. *Aspergillus niger*, 8. *Aspergillus ochraceus*, 9. *Aspergillus terreus*, 10. *Chaetomium elatum* 11. *Chaetomium funicolum*, 12. *Chaetomium olivaceum*, 13. *Cladosporium cladosporioides*, 14. *Cladosporium elatum* [This is a synomym of *Ochrocladosporium elatum*], 15. *Cladosporium herbarum*, 16. *Cladosporium macrocarpum*, 17. *Cladosporium oxysporum*, 18. *Fusarium moniliforme*, 19. *Fusarium oxysporum*, 20. *Paecilomyces variotii*, 21. *Paecilomyces sp.*, 22. *Penicillium brevicompactum*, 23. *Penicillium chrysogenum*, 24. *Penicillium citrinum*, 25. *Paecilomyces digitatum*, 26. *Rhizopus oryzae*, 27. *Scopulariopsis brevicaulis*, 28. *Stachybotrys chartarum*, 29. *Stemphylium botryosum*, 30. *Tiarosporella phaseolina*, 31. *Trichoderma harzianum*, 32. *Ulocladium atrum*, 33. *Ulocladium lanuginosum* and 34. *Ulocladium* sp. The fungi indicated by Nos. 1, 3, 12, 16, 17, 27, 33 were new for Iran, Nos. 1, 3, 5, 10, 11, 12, 13, 14, 15, 16, 17, 20, 21, 22, 23, 25, 26, 27, 28, 29, 31, 32, 33, 34 were reported from sesame seeds for the first time, and Nos., 2, 3, 6, 7 and 26 were dominant.

IRAQ

- F. Al-Refaee (2005) collected sesame seeds from 6 regions of Iraq and isolated fungi to determine which produced lipase. The following fungi were isolated: *Alternaria alternata*, *Alternaria sesami*, *Aspergillus flavus*, *Aspergillus niger*, *Fusarium* sp., *Macrophomina phaseolina*, *Penicillium* spp., *Rhizoctonia solani*, *Rhizoctonia stolonifer*, *Cladosporium* spp., *Cladosporium cladosporioides*.
- N.A. Saad et al. (2013) examined seed and found the following fungi: *Aspergillus niger*, *Aspergillus terreus*, *Aspergillus flavus*, *Penicillium* sp., *Chaetomium* sp., *Trichoderma* sp., *Cladosporium* spp., *Ulocladium* spp., *Macrophomina phaseolina*, *Rhizoctonia solani*, *Fusarium oxysporum*, *Fusarium moniliforme*, *Alternaria raphani*, *Alternaria alternata*, *Alternaria citri*, *Alternaria seseamae*, *Alternaria tenuissima*, and *Alternaria longipes*.

JAPAN

- K. Kato et al. (2021) purchased seed in local markets and identified the following bacteria: *Bacillus cereus, Pantoea dispersa, Pantoea septica, Pantoea agglomerans*, *Serratia spp*., *Pseudomonas spp., Xanthomonas spp.*, and *Rosenbergiella* spp. To prevent food poisoning caused by bacterial contamination, it is important to roast sesame seeds at a sufficiently high temperature, do not leave the cooked food with sesame at room temperature for a long time and avoiding cross-contamination from sesame to ready-to-eat food. [Authors comment: There is very little sesame grown in Japan, and there are multiple sources of the seed including Africa, America, Asia, and Australia.]
- T. Kuzuyuki (2021) reported the following pathogens: *Fusarium oxysporum* f. sp. *sesami* (Wilt), *Rhizoctonia solani* (Foliage rot), *Alternaria sesami* (Alternaria leaf blight), *Pseudoidium pedaliacearum* (Powdery mildew), *Oidium* sp. (Powdery mildew), *Phytophthora nicotianae* (Blight), and '*Candidatus phytoplasma* sp.' He also refers to the Database of Plant Diseases in Japan that adds the following sesame pathogens: *Macrophomina sesami* (Brown spot), *Acidovorax valerianellae* (Bacterial leaf spot), *Pseudomonas syringae* pv. *sesami*, *Xanthomonas* sp., Bacterium sesamicola, *Ralstonia solanacearum* (Bacterial wilt), *Cercospora sesami* (Cercospora leaf spot), *Corynespora sesameum* (Leaf blotch), *Alternaria sesamicola* (Leaf spot), *Turnip mosaic virus* (TuMV), *Watermelon mosaic virus* (WMV), *Sclerotium rolfsii* (Stem rot), and *Ascochyta sesami.*

KENYA

- B. Mazzani (1987) visited sesame growing regions of Kenya and reported the following major pathogens: *Phytophthora* spp., *Pythium* spp., *Fusarium* spp., and *Macrophomina* spp. He recommended treating the seeds prior to planting. Several foliar diseases were present, but the damages were scarcely important. The low humidity of the air at the sesame growing season and the well-known low susceptibility of African types to the more destructive air-borne pathogens limited the leaf diseases.

MALAWI

- W. Van Den Bos and C.J. Zee (2016) in a grower guide reported the following: *Xanthomonas sesami, Pseudomonas sesami, Fusarium oxysporum* f. *sesami*, and phyllody.

MEXICO

- J.R. Penaloza and D.R. Moctezuma (~1992) in a grower guide reported the following pathogens: *Pseudomonas sesami, Sclerotium rolfsii,* and *Macrophomina phaseolina.*
- E.C. Hernandez (2003) in a grower guide reported the following pathogens: *Alternaria* sp. (Mancha Alternaria), *Cercospora sesami* (Mancha redonda), *Phaeoisariopsis griseola* (Mancha angular), *Sclerotium bataticola* (Pudrición de carbón o marchitez), *Phytophthora* sp. (Pie negro o pata seca), *Pseudomonas sesami* (Bacteriosis), and *Leveillula taurica* (Moho polvoriento).
- Anon. (2010a) in a grower guide reported the following main pathogens: *Fusarium oxysporum, Sclerotium rolfsii, Alternaria alternata, Phytophthora nicotianae, Macrophomina phaseolina, Sclerotinia sclerotiorum,* and *Podosphaera xanthii.*
- L.A. Moraila (2015) and L.M. Tamayo in a grower guide reported the following serious pathogens: *Phytophthora* sp., *Fusarium* sp., *Macrophomina phaseoli*, and *Alternaria sesami.*
- Agrolytics.org (2021) reported sesame hosts the following: *Alternaria tenuissima, Alternaria longipes, Fusarium verticillioides, Ralstonia solanacearum, Pseudomonas amygdali, Pseudomonas aeruginosa, Alternaria simsimi, Alternaria sesami, Alternaria, Cercospora, Trichothecium roseum, Mycosphaerella sesami, Corynespora cassiicola, Pseudocercospora sesami, Didymella minuta, Diplodia herbarum, Erysiphe cichoracearum, Fusarium oxysporum f. sp. vasinfectum, Drechslera sesami, Corynespora sesameum, Leveillula taurica, Macrophomina phaseolina, Oidium, Phoma sesami, Phoma sesamina, Phyllosticta, Typhula micans, Sclerotinia, Sclerotium rolfsii, Synchytrium sesamicola, Synchytrium sesami, Trichomerium jambosae, Funneliformis, Xanthomonas, Pseudomonas syringae, Cowpea aphid-borne mosaic virus, Tomato spotted wilt virus, Melon yellow spot virus*.
  (https://www.agrolytics.org/specie/Sesamum_indicum/?DKrG8qYBQKa+FU+YI1dFKw==#hostOf, accessed 3 July 2021)

MYANMAR

- Y.Y. Min and K. Toyota (2019) reported the following pathogens: *Candidatus* Phytoplasma, *Macrophomina phaseolina, Alternaria* sp., *Oidium* sp., *Cercospora* sp., *Xanthomonas* sp., and leaf curl.

NICARAGUA

- R.A. Marenco M. et al. (1988) reported the most important diseases are those that rot the base of the stem, and this is most severe in soils with insufficient drainage. The principal causes of this fungal disease have been identified as being *Macrophomina* sp., *Fusarium* sp. and R*hizoctonia* sp. The only methods of control are to rotate crops and at the same time to avoid planting in soils with poor drainage.
- Anon. (1998b and 2009a) in grower guides reported *Alternaria* sp., *Cercospora sesami, Xanthomonas campestris* pv. *sesami, Macrophomina phaseoli, Phytophthora* sp., *Fusarium* sp., and *Sclerotium rolfsii* cause major diseases.

NIGERIA

- D. McDonald (1964) reported further studies on the sesame disease complex have shown that *Alternaria sesami, Cercospora sesamicola, Curvularia macularis, Colletotrichum gloeosporioides (Glomerella cingulata), Helminthosporium halodes, Fusarium semitectum, Macrophomina phaseoli* and *Pestalotiopsis mayumbensis* are closely associated with disease, their individual pathogenicity was established, the first three being the most virulent. None of the sesame strains tested showed complete resistance.
- H.A. Van Rheenen (1972) reported the following pathogens: *Alternaria sesami, Cercospora sesami, Curvularia lunata, Cylindrosporium sesami, Fusarium semitectum, Helminthosporium halodes, Macrophomina phaseoli, Oidium* sp., *Pestalotiopsis mayumbensis*, and *Pseudomonas sesami*. There is also phyllody and *Tobacco leaf curl virus* (vectored by *Bemisia tabaci*). The virus is the worst problem.
- J.E. Onyibe et al. (2005) in a grower guide reported the following pathogens: *Cercospora sesami, Xanthomonas campestris* pv. *sesami*, and *Tobacco leaf curl virus*.
- F.M. Afolagboye (2011) reported the following fungi from 4 sesame varieties (NCRIBEN 03L, NCRIBEN 01M, E8 and 530-6-1) at Abeokuta: *Aspergillus nidulans, Aspergillus fumigatus, Aspergillus glaucus, Cercospora sesami, Fusarium oxysporum, Penicillium* spp., *Alternaria sesami, Curvularia lunata and Rhizopus nigricans.* [Based on abstract]
- C.N. Ezekiel et al. (2014) isolated the following fungi on sesame seeds: *Alternaria* sp., *Aspergillus* sp., *Fusarium* sp., *Penicillium* sp., *Cercospora* sp., *Mucor* sp., *Rhizopus* sp., *Talaromyces* sp., and *Trichoderma* sp.. *Aspergillus* dominated (48.1%) followed by *Fusarium* (41.6%), *Cercospora* (5.0%), *Penicillium* (1.5%), *Alternaria* (0.7%) and others (3.1%). The *Aspergillus* were identified as *A. flavus, A. tamarii* and *A. parvisclerotigenus*.
- A.D. Ojochenemi et al. (2015) examined 46 samples of sesame for mycotoxicological concerns. Ten fungi genera were isolated from the samples, these include *Aspergillus* spp., *Alternaria* spp., *Fusarium* spp., *Cercospora* spp., *Curvularia* spp., *Macrophomina* spp., *Penicillium* spp., *Phoma* spp. and *Rhizopus* spp. The *Aspergillus* genera was further divided into: *A. flavus* (L-strain), *A. flavus* (S-strain), *A. niger*, *A. tamarii* and *A. parasiticus*. Members of *Aspergillus (A. flavus* (L-strain) and *A. flavus* (S-strain)), *Penicillium* and *Fusarium* where most predominant.

PAKISTAN

- A.S. Shakir and M. Ansar (1992) studied 25 samples of seed collected from various areas in Punjab and analyzed for the presence of mycoflora. They found the following fungi: *Alternaria sesami, Alternaria tenuis, Fusarium oxysporum, Fusarium semitectum, Fusarium moniliforme, Macrophomina phaseolina, Cephalosporium* spp., *Cladosporium* spp., *Drechslera halodes*, *Drechslera tetramera; Aspergillus* spp. and *Myrothecium roridum.*
- N. Altaf et al. (2004) tested 400 seeds from each of 10 cultivars for seedborne mycoflora. Eleven phytopathogenic fungi were found: *Alternaria brassicola, Alternaria redicina, Aspergillus alba, Aspergillus flavus, Aspergillus niger, Aspergillus viridus, Cephalosporium* sp., *Curvularia* sp., *Drechslera* sp., *Fusarium* sp., *and Penicillium* sp. Infection ranged from 0.53 to 53%. The percentage of the fungi varied with the seed as follows:

Table 2: Fungal infection percentage on seeds of ten cutivars of sesame

Fungus	Til-93	Til-89	Lateefi	Tabrezi	Nagari	Johi-1	Johi-2	Sehwani-1	Qallandari	P-37-40
Alternaria brassicola	13.00	9.25	4.25	5.00	1.25	1.50	3.75	0.00	0.00	0.25
Alternaria redicina	11.00	0.00	3.75	3.00	7.50	0.00	0.00	2.50	7.75	0.75
Aspergillus alba	29.00	28.25	25.50	53.00	24.50	22.50	33.00	25.30	25.50	28.80
Aspergillus flavus	3.75	9.50	6.25	12.30	0.00	12.30	15.00	3.25	0.00	6.75
Aspergillus niger	20.50	20.50	25.75	23.80	33.00	33.00	12.30	22.00	23.80	26.00
Aspergillus viridus	6.75	4.00	0.00	1.00	5.25	3.50	8.75	9.50	9.75	12.50
Cephalosporium sp.	0.00	10.00	0.25	0.25	3.75	7.50	8.25	0.00	0.00	1.25
Curvularia sp.	0.00	0.00	0.00	0.00	0.00	7.25	0.00	3.25	0.00	0.00
Drechslera sp.	0.00	0.00	0.00	0.00	0.00	0.00	2.00	0.50	0.00	0.00
Fusarium sp.	6.25	2.75	0.00	1.00	2.00	0.00	3.50	0.00	0.00	0.75
Penicillum sp.	5.00	3.00	4.75	3.25	2.25	0.00	7.50	3.50	0.00	1.25

- B.G. Nayyar et al. (2013) examined 15 samples of seed to detect fungi using 3 methods: agar plate, blotter, and deep freezing. The following were found: *Alternaria alternata*, *Alternaria chlamydospora*, *Alternaria cinerariae*, *Alternaria citri*, *Alternaria pluriseptata*, *Alternaria radicina*, *Alternaria triticina*, *Aspergillus flavus*, *Aspergillus niger*, *Cercospora* sp., *Cercospora bolleana* [Synonym of *Mycosphaerella bolleana*], *Cercospora chenopodii*, *Cercospora koepkei* [Synonym of *Mycovellosiella koepkei*], *Cladosporium herbarum*, *Cladosporium sphaerospermum*, *Cladosporium tenuissimum*, *Cladosporium variable*, *Curvularia richardiae*, *Drechslera hawaiiensis*, *Fusarium oxysporum*, *Fusarium proliferatum*, *Fusarium redolens*, *Fusarium reticulatum*, *Fusarium tabacinum* [Synonym of *Plectosphaerella cucumerina*], *Penicillium egyptiacum*, *Penicillium expansum*, *Penicillium herqui*, *Penicillium italicum*, *Penicillium janthinellum*, *Penicillium lanso-coerellum*, *Penicillium lilacinum*, *Penicillium paxilli*, *Penicillium vermiculatum* [Synonym of *Talaromyces flavus*], *Penicillium waksmani*, *Rhizopus oryzae* and *Verticillium albo-atrum*.
- B.G. Nayyar et al. (2017) analyzed a total of 428 *Alternaria* isolates obtained from 105 seed samples and grouped into 36 distinct taxonomic groups based on growth pattern and morphological characters and identified the following species: *Alternaria dianthi*, *Alternaria sesami*, *Alternaria citri*, *Alternaria longipes*, *Alternaria brassicicola*, *Alternaria solani*, *Alternaria raphani*, *Alternaria alternata*, *Alternaria dianthicola*, *Alternaria brassicae*, *Alternaria infectoria*, *Alternaria sesamicola*, *Alternaria helianthi*, *Alternaria longissimi*, *Alternaria tenuissima*, *Alternaria triticina*, *Alternaria radicina*, *Alternaria pluriseptata*, *Alternaria cinerariae*, and *Alternaria chlamydospora*.

PARAGUAY

- N. Lezcano (2006) in a grower guide reported the following pathogens: *Fusarium* sp., *Phytophthora* sp., *Alternaria* sp., *Cercospora* sp., *Pseudomonas* sp., and a disease called Ka'are. [The pathogen is the *Cowpea aphid-borne mosaic virus* (CABMV)]
- L.C. Rossi and A.L. Orrego (2007) identified the following fungi on sesame seeds: *Aspergillus* sp., *Fusarium* sp., *Alternaria* sp., *Macrophomina* sp., *Curvularia* sp., *Penicillium* sp., and *Colletotrichum* sp.
- L. Ayala et al. (2010, 2011, and 2013b) in grower guides reported the main pathogens are *Macrophomina phaseolina*, *Pseudomonas syringae*, *Fusarium oxysporum*, *Cercosporidium* spp., *Cercospora sesami*, *Alternaria sesami*, *Xanthomonas campestris*, and a virus that leads to Ka'are.

PHILIPPINES

- N.M. Tepora (1989 and 1993a) reported the following diseases: phyllody, Cercospora leaf spot, *Sclerotium rolfsii*, *Fusarium oxysporum*, and *Oidium* sp. (Powdery mildew).

REPUBLIC OF KOREA

- S.H. Yu (1981) reported the following fungi in sesame seed samples *Alternaria sesami*, *Alternaria sesamicola*, *Alternaria tenuis* (*Alternaria alternata*), *Corynespora cassiicola*, *Alternaria longissima*, *Fusarium oxysporum*, and *Macrophomina phaseolina*. All were controlled by pre-treatment with chlorine, except for *Corynespora cassiicola*. [Based on abstract and cited by G.S. Saharan, 1989]

SAUDI ARABIA

- A.H. Bahkali and M.A. Moslem (1996) reported five cultivars of sesame were screened for their seedborne mycoflora. *Alternaria* and *Aspergillus* were the predominant genera represented by 5 species each. Other genera isolated were *Chaetomium*, *Cladosporium*, *Curvularia*, *Drechslera*, *Fusarium*, *Helminthosporium*, *Mucor*, *Penicillium*, *Pleospora*, *Rhizopus*, *Setosphaeria*, *Stemphylium*, *Syncephalastrum*, *Trichoderma* and *Ulocladium*. [Based on abstract]
- A. Hashem et al. (2014) collected 18 seed samples of sesame in Egypt (12 samples) and Saudi Arabia (6 samples). See **EGYPT.**

SUDAN

- M.A.F. Khamees and E. Schlosser (1990) in testing of 165 Sudanese sesame seed samples recorded *Alternaria sesamicola*, *Macrophomina phaseolina*, *Aspergillus flavus*, *Phoma sorghina*, *Ascochyta gossypii*, and *Fusarium moniliforme* [*Gibberella fujikuroi*] . [Based on abstract]
- N.M.A. Hamid (2006) identified the following fungus from seed collected from 3 areas of Sudan: *Macrophomina phaseolina, Aspergillus niger, Aspergillus flavus, Alternaria sesami, Fusarium* sp., *Curvularia lunata, Alternaria alternata, Rhizopus* sp., *Ulocladium* sp., *Curvularia* sp., and *Drechslera rostrata*. [Based on abstract]
- H.I.H. Idriss (2016) collected farmer saved red and white sesame from 7 locations in Sudan. 14 different fungi representing ten genera were identified. These, in order of prevalence, were categorized as: a) predominant fungi (viz.: *Aspergillus flavus, Alternaria sesami, Phoma* sp., *Macrophomina phaseolina, Aspergillus niger*); b) less frequent fungal isolates (viz.: *Fusarium moniliforme, Alternaria alternata, Cercospora sesami*); and c) low frequency of occurrence fungi (viz.: *Drechslera* sp., *Alternaria solani, Rhizopus* sp., *Fusarium oxysporum, Curvularia lunata* and *Chaetomium* sp.). The rarely reported *Phoma* sp. warrants further etiological, ecological, and epidemiological investigations as well as analysis of pest risk assessment of this pathogen under sesame growing conditions in Sudan.
- A.R.C. Umaima (pers. comm. 2021): The following diseases are a problem: *Macrophomina phaseolina* and *Rhizoctonia bataticola* (Root rot or Stem rot or Charcoal rot), *Alternaria sesami* (Alternaria leaf blight), *Cercospora sesami* (Cercospora leaf spot), *Xanthomonas campestris* pv. *sesami* (Bacterial leaf spot), *Fusarium oxysporum* f. sp. *sesami* (Fusarium wilt), *Erysiphe cichoracearum* (Powdery mildew), and phyllody.

TANZANIA

- Kafiriti, E. and O. Mponda (n.d.) in a grower guide reported the following pathogens: *Cercospora sesami, Cercospora sesamicola, Macrophomina phaseolina, Alternaria* spp., *Pseudomonas sesami, Fusarium oxysporum* f. sp. *sesami, Phytophthora nicotianae* var. *sesami, Helminthosporium sesami*, and phyllody.

TURKEY

- F. Akdeniz and H. Sert (2019) reported the following pathogens from 75 sample plants from Manavgat city: *Alternaria sesami, Cercospora sesami, Macrophomina phaseolina, Fusarium oxysporum*, and *Podosphaera fusca.*
- N. Isler et al. (n.d.) reported the following pathogens: *Macrophomina phaseolina, Alternaria sesami, Cercospora sesami, Xanthomonas campestris* pv. *sesami, Phytophthora parasitica* var. *sesami, Sphaerotheca fuliginea, Leveillula* sp., *Rhizoctonia bataticola, Fusarium oxysporum* f. sp. *sesami*, and phyllody.

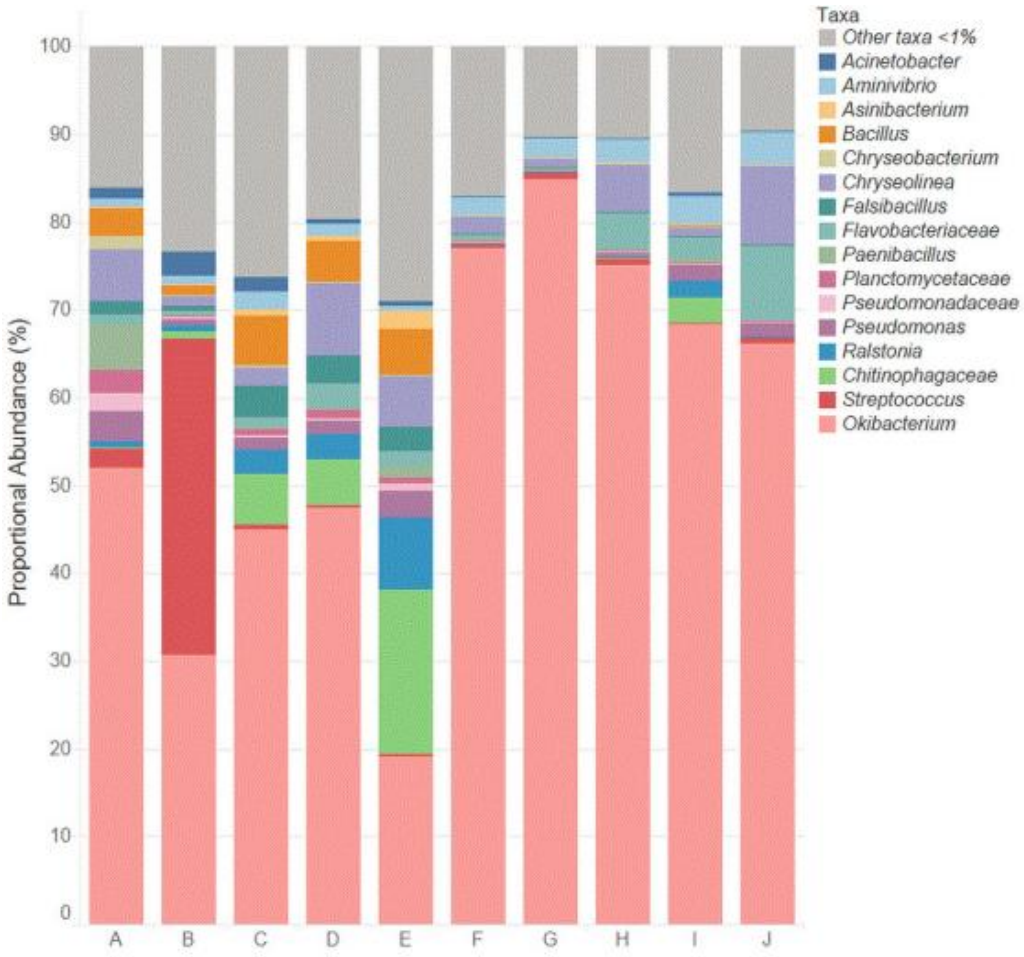
UGANDA

- C.G. Hansford (1931, 1938, 1939, 1940, and 1943) reported the following pathogens: *Alternaria sesamicola, Cercospora sesami, Cylindrosporium sesami,* Fusarium wilt, *Verticillium dahliae,* and *Rhizoctonia bataticola* (*Macrophomina phaseoli*). [Cited by G.S. Saharan, 1989]
- S.B. Mathur and F. Kabeer (1975) reported the following pathogens: *Alternaria sesami, Corynespora cassiicola, Cercospora sesami, Fusarium moniliforme* (*Gibberella fujikuroi*), *Fusarium oxysporum* and *Verticillium dahliae*.
- J.P. Egonyu (2005) reported the following pathogens: *Cercospora sesami, Cylindrosporium sesami, Verticillium dahliae, Fusarium oxysporum,* Nicotiana virus-10, *Erysiphe cichoracearum,* and *Sphaerotheca fuliginea.*

UNITED STATES

- D.T. Smith et al. (2000) reported the following pathogens: *Fusarium* sp., *Phytophthora* sp., *Rhizoctonia* sp., *Macrophomina* sp., *Alternaria sesami, Cercoseptoria sesami, Cercospora sesami, Helminthosporium sesami, Thielaviopsis basicola, Verticillium* sp., *Pseudomonas* sp., and powdery mildew.
- M. Fay et al. (2021) reported metagenomic analysis of food is becoming more routine and can provide important information pertaining to the shelf life potential and the safety of these products. They examined 10 sesame samples. The microbiomes of these seeds revealed that these products are dominated by environmental bacterial genera commonly isolated from soil, water, and plants; bacterial genera containing species known as commensal organisms were also identified. Although these species are placed under the United States, the seed probably was imported from another unidentified country. They identified the following bacteria: *Acinetobacter* spp., *Aminivibrio* spp., *Asinibacterium* spp., *Bacillus* spp., *Chryseobacterium* spp., *Chryseolinea* spp., *Falsibacillus* spp., Flavobacteriaceae, *Paenibacillus* spp., Planctomycetaceae, Pseudomonadaceae,

Pseudomonas spp., *Ralstonia* spp., Chitinophagaceae, *Streptococcus* spp., and *Okibacterium* spp. in the following proportions.



- K.A. Cochran comment, 2021: While sesame diseases that occur on modern varieties and geographic locations where sesame is grown in the United States are not well documented, there are common diseases that occur often. Foliar diseases such as bacterial blight (*Pseudomonas syringae* pv. *sesami* and *Xanthomonas euvesicatoria* pv. *sesami*), Alternaria leaf spot (*Alternaria sesami* and *A. alternata*), target spot (*Corynespora cassiicola*), and Cercospora leaf spot (*Cercospora sesami*) are all known to commonly occur in USA sesame. Soilborne diseases that are often problematic are: Charcoal rot (*Macrophomina phaseolina*), Rhizoctonia root and stalk rot (*Rhizoctonia solani*), Fusarium root and stalk rot (*Fusarium* spp.), Fusarium wilt (*F. oxysporum*), *Colletotrichum* spp., and Phytophthora root rot (*Phytophthora nicotianae*).

VENEZUELA

- G. Malaguti (1973) reported the following leaf diseases: round white spot (*Cercospora sesami*), angular brown spot (*Cylindrosporium sesami*), zonate leaf spot (*Alternaria sesamicola*) and bacterial leaf spot (*Xanthomonas sesami* and *Pseudomonas sesami.* [Cited by G.S. Saharan, 1989]
- C. Zambrano and O. Tortolero (1985) conducted studies on 540 sesame cultivars, and isolations from seedling rot and soil and reported the following pathogens: *Macrophomina phaseoli* (Mp), *Fusarium* (F), *Phytophthora hibernalis* (Ph), *Rhizoctonia* (R), *Sclerotium* (S), *Pythium oligandrum* (Po) [isolated for the first time from sesame seedlings], and *Trichoderma* (T). The incidence was related to precipitation and soil humidity. *M. phaseoli* caused heavier infection than *Phytophthora hibernalis* during dry conditions. The following table

shows the origin of the cultivars and the distribution of the pathogens.

Table 1: Pathogens isolated from different cultivars of sesame during three years in the field of FONALI, Portuguesa, Venezuela, and the numbers of varieties infected by the pathogens.

No. of varieties	Origin	Mp	F	Ph	R	S	Po	T
163	USA	146	62	31	17	8	3	-
8	Mexico	8	-	-	-	-	-	-
3	Sudan	1	-	1	-	1	-	-
2	Peru	2	-	-	-	-	-	-
4	Argentina	4	-	-	-	-	-	-
69	Africa	64	21	13	1	1	-	7
4	Senegal	4	-	-	-	-	-	-
2	Guatemala	2	1	1	-	-	-	-
1	Turkey	1	-	1	-	-	-	-
2	Brasil	2	-	-	-	-	-	-
1	Italy	1	-	-	-	-	-	-
3	Japan	3	-	-	-	-	-	-
15	China	15	8	2	2	1	-	-
14	India	13	1	1	-	-	1	-
27	Russia	27	10	3	2	-	-	1
170	Venezuela	142	45	51	10	11	3	11
52	Unknown	48	9	4	2	6	1	3

- A.M. Colmenares and L. Subero (1989a) reported the following pathogens: *Cercospora sesami, Corynespora cassiicola, Alternaria sesami, Pseudocercospora sesami, Fusarium oxysporum, Phytophthora parasitica, Macrophomina phaseolina*. Less relevant pathogens are *Sclerotium rolfsii* (Soft rot of the stem) and *Leveillula taurica* (Powdery mildew).
- Y. Martinez et al. (1991) in studying aflatoxin reported the following fungi on sesame: *Aspergillus niger, Aspergillus flavus, Mucor* sp., *Penicillium* sp., *Aspergillus ochraceus, Aspergillus glaucus, Aspergillus tamarii* and *Fusarium* sp. in the following percentages 96, 88, 50, 40, 30, 8, 6, 6, respectively. [Cited by B. Mazzani, 1999]
- B. Mazzani (1999) reported the following pathogens: *Macrophomina phaseolina, Phytophthora* sp., *Fusarium oxysporum, Cercospora sesami, Cercoseptoria sesami, Alternaria sesamicola, Pseudocercospora sesami, Cylindrosporium sesami, Alternaria tenuis, Corynespora cassiicola, Aspergillus, Penicillium,* and *Cladosporium.*

A Pest: Fungi

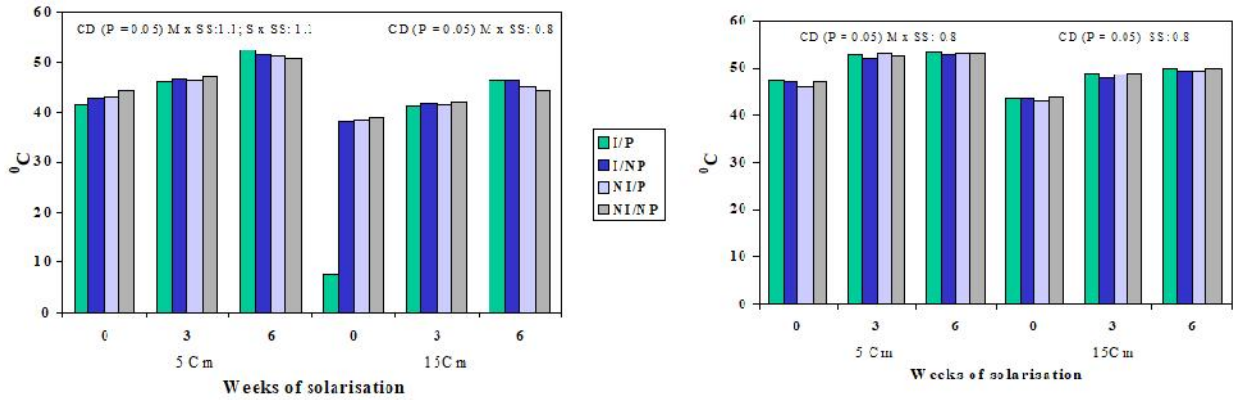
(Wikipedia, 21 Feb 2021) A **fungus** (plural: **fungi** or **funguses**) is any member of the group of eukaryotic organisms that includes microorganisms such as yeasts and molds, as well as the more familiar mushrooms. These organisms are classified as a kingdom, which is separate from the other eukaryotic life kingdoms of plants and animals.
A characteristic that places fungi in a different kingdom from plants, bacteria, and some protists is chitin in their cell walls. Fungi, like animals, are heterotrophs; they acquire their food by absorbing dissolved molecules, typically by secreting digestive enzymes into their environment. Fungi do not photosynthesize. Growth is their means of mobility, except for spores (a few of which are flagellated), which may travel through the air or water. Fungi are the principal decomposers in ecological systems. These and other differences place fungi in a single group of related organisms, named the *Eumycota* (*true fungi* or *Eumycetes*), which share a common ancestor (from a *monophyletic group*), an interpretation that is also strongly supported by molecular phylogenetics. This fungal group is distinct from the structurally similar myxomycetes (slime molds) and oomycetes (water molds). The discipline of biology devoted to the study of fungi is known as mycology (from the Greek μύκης *mykes*, mushroom). In the past, mycology was regarded as a branch of botany, although it is now known fungi are genetically more closely related to animals than to plants.

Abundant worldwide, most fungi are inconspicuous because of the small size of their structures, and their cryptic lifestyles in soil or on dead matter. Fungi include symbionts of plants, animals, or other fungi and also parasites. They may become noticeable when fruiting, either as mushrooms or as molds. Fungi perform an essential role in the decomposition of organic matter and have fundamental roles in nutrient cycling and exchange in the environment. They have long been used as a direct source of human food, in the form of mushrooms and truffles; as a leavening agent for bread; and in the fermentation of various food products, such as wine, beer, and soy sauce. Since the 1940s, fungi have been used for the production of antibiotics, and, more recently, various enzymes produced by fungi are used industrially and in detergents. Fungi are also used as biological pesticides to control weeds, plant diseases and insect pests. Many species produce bioactive compounds called mycotoxins, such as alkaloids and polyketides, that are toxic to animals including humans. The fruiting structures of a few species contain psychotropic compounds and are consumed recreationally or in traditional spiritual ceremonies. Fungi can break down manufactured materials and buildings and become significant pathogens of humans and other animals. Losses of crops due to fungal diseases (e.g., rice blast disease) or food spoilage can have a large impact on human food supplies and local economies.

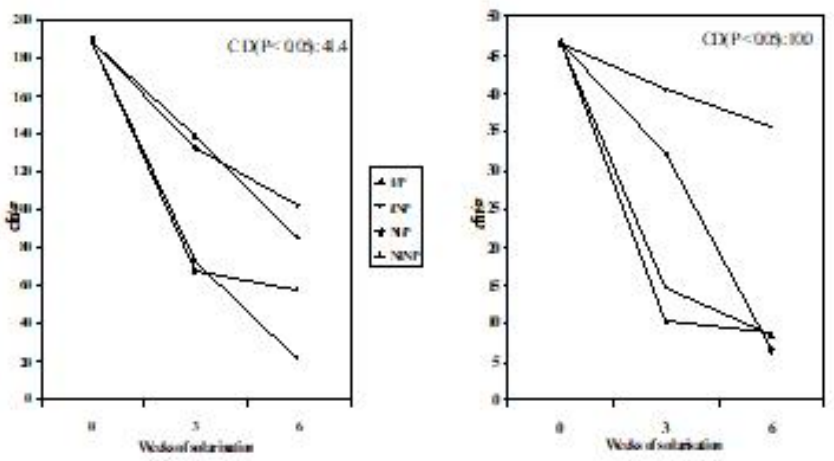
References:

INDIA

- C. Chattopadhyay and R. Kalpana Sastry (1999) studied the effect of soil solarization on the fungi population in 1995 and 1996 in Hyderabad (77.92E and 18.99N). Plots were irrigated to field capacity according to the design before they were covered with transparent polyethylene mulch of 50 µm thickness for 0, 3, or 6 weeks. The temperatures at 5 and 15 cm depth were as follow in the two years.



The effects on the total fungi population (cfu/g soil) were as follow.



A1 Order: Hypocreales Lindau 1897

Wikipedia (7 Apr 2021): The **Hypocreales** are an order of fungi within the class Sordariomycetes. In 2008, it was estimated that it contained some 237 genera, and 2647 species in seven families. Since then, a considerable number of further taxa have been identified, including an additional family, the Stachybotryaceae.

Species of Hypocreales are usually recognized by their brightly colored, perithecial ascomata, or spore-producing structures. These are often yellow, orange or red.

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A1.1 Family: Nectriaceae C. & L. Tulasne 1895

Wikipedia (7 Apr 2021): The **Nectriaceae** comprise a family of fungi in the order Hypocreales. It was circumscribed by brothers Charles and Louis René Tulasne in 1865.

The following species have been reported to cause diseases, produce a toxin, inhibit germination, or affect seed quality.

- A1.1.1 *Fusarium* spp.
- A1.1.1a *Fusarium oxysporum*
- A1.1.1a.1 *Fusarium oxysporum* f. sp. *sesami*
- A1.1.1a.2 *Fusarium oxysporum* f. sp. *vasinfectum* (*Syn: *F. vasinfectum* and *F. vasinfectum* f. sp. *sesami*)
- A1.1.1b *Fusarium proliferatum*
- A1.1.1c *Fusarium caeruleum*
- A1.1.1d *Fusarium solani*
- A1.1.1e *Fusarium incarnatum* (*Syn: *Fusarium semitectum*)
- A1.1.1f *Fusarium verticillioides*
- A1.1.1g *Fusarium equiseti*
- A1.1.1h *Fusarium merismoides*
- A1.1.1i *Fusarium culmorum*
- A1.1.1j *Fusarium acutatum*
- A1.1.1k *Fusarium poae*
- A1.1.1l *Fusarium chlamydosporum*
- A1.1.1m *Fusarium longipes*
- A1.1.1n *Fusarium sulawesiensis*
- A1.1.2 *Gibberella* spp.
- A1.1.2a *Gibberella fujikuroi* (*Syn: *Fusarium fujikuroi* and *F. moniliforme*)
- A1.1.2b *Gibberella zeae*
- A1.1.3 *Neocosmospora* spp.
- A1.1.3a *Neocosmospora vasinfecta*
- A1.1.4 *Cylindrocladium* spp.

There are species in this family associated with sesame, but not reported to cause diseases, produce a toxin, inhibit germination, or affect seed quality. See H9.1.

A1.1.1 *Fusarium* spp. (10 Dec 2021)

Family: Nectriaceae

Definition: Amount of tolerance to *Fusarium* spp. Link 1809.

Summary:

Photo: L. Ayala et al. (2010) {Paraguay}

Fusarium wilt and root rots are a common problem in sesame production areas. Symptoms of Fusarium wilt, caused by ***Fusarium oxysporum***, are typically most noticed starting mid-season and progress upward on the plant, increasing in severity as the season continues. Typical symptoms include yellowing, stunting, brownish vascular discoloration in the main stem, wilting and limp appearance of the leaves even after irrigation, drought like scorch looking symptoms on leaf margins, and papery dry dead leaf tissues on older leaves. Several species of Fusarium are associated with seedling disease and root rot, the symptoms of which are discoloration and lesions on roots, which may progress upward into the stem from the soil line. Infections in the seed germination or seedling stage are often associated with damping off. *Fusarium* spp. are soilborne and seedborne fungi and reproduce via macroconidia, microconidia, and long-lived hardy chlamydospores. While macro- and microconidia are the main inoculum source in a single season, chlamydospores are concern for year-to-year inoculum carry over. There are two f. sp.: *F. oxysporum* f. sp. *sesami* and *F. oxysporum* f. sp. *vasinfectum*. E.A. Weiss (1971) reported *F. oxysporum* f. sp. *sesami* can be devastating on susceptible varieties. Severe infection can cause the entire plant to become defoliated and dried. In less severe infections or when mature plants are infected, only one side of the plant may develop symptoms. Peeling off the epidermis of the lower stem or roots will reveal blackish streaks in plant tissues. If infected plants are uprooted, roots will be brittle and rotten, either wholly or partially corresponding with that side of the plants showing disease symptoms. If plants are infected early on in the season, poor capsule set occurs. When infection occurs in mature plants, capsules are formed but seeds are often shriveled and underdeveloped. An early Fusarium infection can destroy an entire field. Other Fusarium species are reported pathogens in sesame: *F. acutatum, F. caeruleum, F. chlamydosporum, F. culmorum, F. equiseti, F. incarnatum, F. longipes, F. merismoides, F. poae, F. proliferatum, F. solani, F. sulawesiensis,* and *F. verticillioides.* There are also other species in the Nectriaceae family that are pathogens: *Cylindrocladium* spp., *Gibberella* spp., and *Neocosmospora* spp. *Fusarium* spp. have been reported in international lists, Australia, Bangladesh, Brazil, Bulgaria, China, Colombia, Costa Rica, Cuba, Dominican Republic, Ecuador, Egypt, Ethiopia, Greece, Guatemala, Honduras, India, Iran, Iraq, Israel, Italy, Japan, Kenya, Malawi, Mexico, Nicaragua, Nigeria, Pakistan, Paraguay, Philippines, Republic of Korea, Saudi Arabia, Sierra Leone, Sudan, Tanzania, Thailand, Turkey, Uganda, Ukraine, United States, Uzbekistan, and Venezuela.

(Wikipedia, 7 Apr 2021) ***Fusarium*** is a large genus of filamentous fungi, part of a group often referred to as hyphomycetes, widely distributed in soil and associated with plants. Most species are harmless saprobes, and are relatively abundant members of the soil microbial community. Some species produce mycotoxins in cereal crops that can affect human and animal health if they enter the food chain. The main toxins produced by these *Fusarium* species are fumonisins and trichothecenes. Despite most species apparently being harmless (some existing on the skin as commensal members of the skin flora), some *Fusarium* species and subspecific groups are among the most important fungal pathogens of plants and animals. The name of *Fusarium* comes from Latin *fusus*, meaning a spindle.

The following species have been associated with sesame but there are known no reports of being a pathogen, producing a toxin, inhibiting germination, affecting seed quality, or being used as a biocontrol or biofertilizer.

- *Fusarium dimerum* [Egypt]
- *Fusarium graminearum* [Egypt]
- *Fusarium nygamai* [Egypt]
- *Fusarium redolens* [Pakistan]

- *Fusarium reticulatum* [Pakistan]
- *Fusarium sambucinum* [Egypt]
- *Fusarium subglutinans* [Egypt]
- *Fusarium tricinctum* [Egypt]
- *Fusarium xylarioides* [Egypt]

References:

AUSTRALIA
- D.F. Beech (1981a) reported the presence of *Fusarium* sp. (Wilt) in 1977.
- D.F. Beech (1981c) reported considerable progress has been made in developing resistance to *Fusarium* sp. through Aceitera and Glauca [Authors comment: These are Venezuelan varieties].

BRAZIL
- M.G.R. Faiad et al. (2002) examined seed from 416 accessions from 7 Brazilian states at 25°C under alternating black lights and darkness in a 12-hour photoperiod for 8 days. They found *Fusarium* spp. They then examined 31 seed samples that had been stored for 5 and 9 years at 8°C and 25% RH. They found *Fusarium* spp. They concluded the seed acts as a vehicle for pathogen dissemination.

BULGARIA
- S.G. Delikostadinov (1985) reported *Fusarium* sp. is a new problem. There are no plant sanitary measures except agrotechnical disease control.

CHINA
- X.R. Zhang et al. (2000) studied 4,251 genotypes (4,073 from China and 178 from other countries) using 14 traits that were genetically stable and agronomically important. They pre-selected a core of 884 accessions to grow in 3 locations for 2 years and finally selected a core of 453 accessions. They examined *Resistance to Fusarium wilt disease* and had the following distribution:
  - 1 = Highly resistant (12.4%)
  - 3 = Resistant (31.1%)
  - 5 = Susceptible (41.9%)
  - 7 = Highly susceptible (14.6%)
- Anon. (2006a) China descriptor: 8.2 (130) Resistance to *Fusarium wilt*. They provide a methodology for artificial inoculations and observing in natural fields. The following are the ratings to be used.
  - 0 = Immune
  - 1 = High resistance (HR)
  - 3 = Resistance (R)
  - 5 = Susceptible (S)
  - 7 = High susceptibility (HS)
  - H.Y. Zhang/H.M. Miao (pers. comm. 2016): This descriptor is used to describe new germplasm that is acquired by the Henan Sesame Research Center. It is also used in the breeding program.
  - X.R. Zhang/L.H. Wang (pers. comm. 2016): This descriptor is used in the breeding program by the Chinese Academy of Agricultural Sciences-Oil Crops Research Institute, Wuhan. It is also used to describe new germplasm that is acquired.

COLOMBIA
- V.C. Barcenas (1962) reported *Fusarium* sp. was identified on sesame. [Cited by G.S. Saharan, 1989]

COSTA RICA
- Anon (1991a) in a grower guide reported the following pathogen: *Fusarium* spp.

DOMINICAN REPUBLIC
- R. Ciferri (1930) reported *Fusarium* sp. was often associated with *Phytophthora parasitica*.

ECUADOR
- Anon. (1968) reported Aceitera and Oro were least susceptible to *Fusarium* sp. [Authors comment: Aceitera is a Venezuelan variety and Oro a USA variety]

EGYPT
- M.M.I. Abdel-Hafez et al. (2012) examined the soils around the roots of sesame and reported *Fusarium* spp. in the rhizosphere and rhizoplane.

- B.A. Sabry et al. (2016) in Egypt studied 28 sesame samples collected from food stores in different governates. They found the following fungi.

Governorate	NC/ TNS	Fungal load (log_{10} CFU/g)		Percentage occurrence of fungal genera				
		Range	Mean ± SD	*Alternaria*	*Aspergillus*	*Fusarium*	*Penicillium*	*Cladosporium*
Great Cairo	4/4	1.72 –2.32	1.91±0.77[a]	34.21	60.53	2.63	ND	2.63
Kalioubia	3/3	1.72 –2.32	1.97±1.03[a]	4.17	91.66	ND	4.17	ND
Alexandria	6/6	1.72 –2.67	1.99±1.63[a]	4.35	82.61	6.52	ND	6.52
El-Behera	5/5	1.72 –2.87	2.15±1.63[b]	ND	71.82	0.91	17.27	10.00
Kafr El-Sheik	5/5	1.72 –2.80	2.26±2.72[c]	3.96	60.40	1.98	17.82	15.84
Dakahlia	5/5	1.72 –3.02	2.52±0.70[d]	ND	79.68	1.59	6.37	12.35

NC: Number of contaminated samples; TNS: Total number of samples
Mean with different superscript letters are significantly different

GUATEMALA

- Anon (1982a) A grower guide reported *Fusarium* sp. causes black rot at the juncture of the stem and root. When the attack is late, it debilitates the plant, accelerates maturity, and reduces yield. When the attack is early, it kills the plants.

HONDURAS

- V.P. Queiroga et al. (2016) reported *Fusarium* sp. affects the base of the stem and the root, causing the death of the seedlings. There is a black coloration in the place damaged by the disease.

INDIA

- O.P. Kadian (1972) reported five common genera to include *Fusarium* spp., which reduced seed germination and had adverse effect on the seedlings. The seeds were internally as well as externally seedborne. [Cited by G.S. Saharan, 1989]
- K.R. Sharma and K.G. Mukerji (1974) reported a pathogenic *Fusarium* spp. on aging, senescing, and decaying leaves. [Cited by G.S. Saharan, 1989]
- N.D. Desai and S.N. Goyal (1981c) reported that TC-25, TC30, and TC45 (Punjab) and UT-43 (Gujarat) are resistant to *Fusarium* wilt in India.
- A.S. Reddy and S.M. Reddy (1983b) reported 36 fungal species were obtained from 105 seed samples of sesame. Several species of *Aspergillus*, *Fusarium* as well as *Penicillium citrinum* can produce a very wide range of mycotoxins. [Cited by G.S. Saharan, 1989]
- K. Bhattachary and S. Raha (2002) studied fungal infection, moisture content, germinability and deterioration of sesame in storage under natural conditions for a year. Different species of Aspergillus (*A. candidus*, A. *flavus, A. niger, A. terreus*, and *A. ruber*) were dominant followed by Rhizopus, Penicillium, Curvularia, Fusarium, Alternaria, etc. Seed moisture was maximum in the rainy season followed by a gradual decrease during longer storage. As storage proceeded, there was a gradual decrease in field fungi with simultaneous increase in storage fungi, and a reduction in germinability. A gradual loss of carbohydrate (both soluble and insoluble) content was recorded. A loss of protein content was recorded followed by a small increase. Oil content decreased in prolonged storage with simultaneous increase in fatty acid. [Based on abstract]
- P.L. Radha (2013) collected 18 cultivars from 7 districts in Karnataka and identified the following fungus: *Fusarium* sp.
- B.C. Becerra et al. (2016) studied the correlations between *Fusarium* sp. and the following weather parameters: maximum and minimum temperature, maximum and minimum relative humidity, rainfall, and bright sunshine hours. Minimum temperature, maximum relative humidity, rainfall, and bright sunshine hours were positively correlated to the disease development.
- B. Khamari et al. (2018c) conducted an intensive survey at flowering to ripening of capsule to record the incidence of sesame diseases in 10 agroclimatic zones of Odisha during rabi 2014-15 with the following results.

Sl. No.	Place	Variety	Mac (%)	Fus (%)	Alt (Grade)	PM (Grade)	Cer (Grade)	Phy (%)
1	Bheden	Bheden local	18.09	9.78	3	0	2	0
2	Balianta	VRI-1	23.8	8.0	4	3	2	2.3
3	Nuagaon	Nuagaon local	12.8	3.0	3	0	2	0.6
4	Papadahandi	Papdahandi local	15.2	4.1	2	0	2	1.0
5	Betanati	Betanati local	18.8	0.5	2	2	1	0
6	Kalimela	Kalimela local	11.3	0.8	3	1	2	0.8
7	Agarpada	Agarpada local	8.0	1.0	3	1	1	0.6
8	Kirei	Sundergarh local	15.8	3.9	2	0	1	1.4
9	Khajuripada	Phulbani local	10.5	2.9	3	3	1	0.0
10	Bhawanipatna	Narla local	19.2	4.8	4	0	2	1.4

Mac=*Macrophomina*, Fus= *Fusarium*, Alt= *Alternaria*, PM= Powdery Mildew, Cer= *Cercospora*, Phy= Phyllody

- K.N. Gupta et al. (2018) recommended cultural, chemical, and biocontrol practices to alleviate or control Fusarium wilt; refer to the introduction.
- B. Khamari et al. (2018e) collected 15 sesame seed samples from different localities of Odisha reported the infestation of *Fusarium* sp. ranged from 0.5 to 4.0%.

IRAQ

- F. Al-Refaee (2005) collected sesame seeds from 6 regions of Iraq and isolated *Fusarium* sp.

ISRAEL

- Ashri (1981a) reported the major diseases are soilborne *Fusarium* sp. and *Macrophomina* sp. The varieties Aceitera and Renner proved extremely susceptible.

JAPAN

- M. Terui (1933 and 1934) reported *Fusarium* as a wilt. [Cited by R.S. Vasudeva, 1961]

KENYA

- B. Mazzani (1987) visited sesame growing regions and reported the following major pathogen: *Fusarium* spp.

MEXICO

- L.A. Moraila (2015) in a grower guide reported *Fusarium* sp. (Wilt) can be prevented by using fields with good soil drainage. It is characterized by lesions that progress up the plant leading to death.

NICARAGUA

- R.A. Marenco M. et al. (1988) reported the most important diseases are those that rot the base of the stem, and this is most severe in soils with insufficient drainage. The principal causes of this fungal disease have been identified as being *Macrophomina* sp., *Fusarium* sp. and *Rhizoctonia* sp. The only methods of control are to rotate crops and at the same time to avoid planting in soils with poor drainage.
- Anon. (1998b and 2009a) in grower guides reported Black foot (*Fusarium* sp.). The base of the stem rots and turns black. The seedlings and mature plants die.

NIGERIA

- O.A. Enikuomehin (2010) evaluated the effectiveness of seedborne fungi control by plant extracts of leaves (*Azadirachta indica, Vernonia amygdalina, Musa paradisiaca* and *Anacardium occidentales*) and synthetic fungicides (Team [Carbendazin 12% + Mancozeb 63%] and Ridomil [Metalaxyl 60g + 60 g CuO_2]) using two sesame cultivars (530-6-1 and NCRIBEN-03L). All plant extracts significantly ($P \leq 0.05$) reduced the fungal infection of seeds. *A. indica* leaf extract was comparable to the synthetic fungicides in reducing fungal infection of seeds. Leaf extracts of *A. occidentales* and *M. parasitica* enhanced significant ($P \leq 0.05$) seedling emergence. *Alternaria sesamicola, Curvularia lunata* and *Fusarium* spp. were most sensitive to *A. indica* and *M. paradisiaca* leaf extracts. [Based on abstract]
- C.N. Ezekiel et al. (2014) isolated the following fungi on sesame seeds: *Fusarium* sp.
- A.D. Ojochenemi et al. (2015) examined 46 samples of sesame and reported *Fusarium* spp.
- S.T. Anjorin et al. (2016) studied the effects of 6 botanicals (baobab [*Adansonia digitate*] leaf powder, hot pepper [*Capsicum annum*] fruits, and ordeal tree [*Erythrophleum suaveolens*] bark and leaves, garlic bulbs and

ginger rhizomes) against fungi isolated from sesame seeds (*Aspergillus niger*, *Aspergillus flavus*, *Mucor* spp., *Fusarium* spp., *Alternaria* spp. and *Penicillium* spp.). The ginger, garlic, and ordeal bark were not effective. The results of the effective treatments were as follows.

Sesame seeds treated with plant extracts	*Aspergillusniger*	*Fusariumspp.*	*Aspergillusflavus* (cfug/ml)	*Penicillium* spp.	*MucorAlternaria* spp. spp.
Baobab leaf extract (100%)	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{b}	0.00^{b} 0.00^{b}
Baobab leaf extract (10%)	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{b}	0.00^{b} 0.00^{b}
Ordeal leaf extract(100%)	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{b}	0.00^{b} 0.00^{b}
Ordeal leaf extract(10%)	0.00^{c}	1.00^{bc}	0.00^{c}	1.00^{b}	0.00^{b} 0.00^{b}
Hot pepper fruit extract(100%)	4.00^{b}	2.00^{b}	0.00^{c}	4.00^{a}	1.00^{ab} 0.00^{b}
Hot pepper fruit extract(10%)	5.00^{b}	2.00^{b}	0.00^{c}	0.00^{b}	1.00^{ab} 0.00^{b}
Untreated sesame seed before storage	7.00^{a}	5.00^{a}	4.00^{a}	5.00^{a}	1.00^{ab} 2.00^{a}
Untreated sesame seed after storage	5.00^{b}	5.00^{a}	2.00^{b}	4.00^{a}	2.00^{a} 1.00^{b}

PAKISTAN

- H.N. Farhan et al. (2010) investigated the biological effects of *Pseudomonas putida* and *Pseudomonas fluorescens* as biocides to inhibit *Fusarium* fungi growth and as biofertilizers to improve growth characters of sesame crop grown in contaminated soil with *Fusarium* under field conditions compared with Dithen and Radiomil. The results were as follow.

Treatments	**Fusarium growth (mm)**	**% inhibition**
Pseudomonas putida 2 + Fusarium	4.80	94.2
Pseudomonas fluorescens 3+ Fusarium	4.43	94.6
P. putida2 + P. *fluorescens 3*+ Fusarium	0.0	100.0
Dithen Fungicide + Fusarium	29.0	64.9
Radiomil + Fusarium	33.0	60.1
Control (Fusarium only)	82.7	-
LSD at 5%	11.2	-

Treatments	Chlorophyll a+b (mg/gm)	% N	% P	% K
Pseudomonas putida 2 + Fusarium	2.29	3.82	0.35	2.23
Pseudomonas fluorescens 3+ Fusarium	2.17	3.06	0.23	3.11
P. putida2 + P. *fluorescens 3*+ Fusarium	3.21	4.18	0.44	3.87
Dithen Fungicide + Fusarium	1.78	2.70	0.27	3.06
No addition	1.86	3.03	0.18	3.31
Control (Fusarium only)	0.85	1.77	0.11	1.34
LSD at 5%	0.81	1.52	0.07	0.98

Treatments	Leaf no./plant	Pods no./plant	Grains no./pod
Pseudomonas putida 2 + Fusarium	297.3	101.3	51.2
Pseudomonas fluorescens 3+ Fusarium	374.7	106.0	52.8
P. putida2 + P. *fluorescens 3*+ Fusarium	428.3	146.7	69.1
Dithen Fungicide + Fusarium	269.3	88.3	47.0
No addition	272.3	94.0	49.3
Control (Fusarium only)	162.7	44.0	31.3
LSD at 5%	77.82	17.3	8.0

Treatments	Branch no./plant	Height of plant (cm)	Leaf area/plant (cm^2)
Pseudomonas putida 2 + Fusarium	32.9	105.7	41.2
Pseudomonas fluorescens 3+ Fusarium	34.6	106.7	43.2
P. putida2 + P. *fluorescens 3*+ Fusarium	45.8	151.7	59.7
Dithen Fungicide + Fusarium	23.6	104.0	41.2
No addition	27.4	105.3	40.5
Control (Fusarium only)	14.6	53.3	25.5
LSD at 5%	5.8	13.7	10.7

Treatments	Weight of 1000 grain (gm)	Total yield of grains per plot (gm)	% Oil in grains
Pseudomonas putida 2 + Fusarium	2.24	362.1	50.6
Pseudomonas fluorescens 3+ Fusarium	2.46	442.2	51.3
P. putida2 + P. *fluorescens 3*+ Fusarium	2.92	982.3	56.2
Dithen Fungicide + Fusarium	1.81	303.5	41.9
No addition	2.29	352.4	46.3
Control (Fusarium only)	0.94	112.4	26.6
LSD at 5%	0.38	49.0	10.5

- H.N. Farhan et al. (2011) investigated the biological activity of *Pseudomonas* bacteria as biocides to protect sesame crop from some fungi and to evaluate its efficiency as plant growth promoting. The first experiment investigated the effects of *Pseudomonas putida* (Pp) and *Pseudomonas fluorescens* (Pf) on germination and seedlings growth of sesame crop against Pythium, Alternaria, and Fusarium under plastic house conditions. The following are the results.

Treatments	Sterilized soil		Non sterilized soil	
	Germination (%)	Seedlings (cm)	Germination (%)	Seedlings (cm)
Pythium + Pp	80	4.0	70	3.2
Fusarium + Pp	84	3.5	85	2.5
Alternaria + Pp	86.7	4.5	82	3.3
Pythium + Pf	65	3.2	65.3	2.2
Fusarium + Pf	61.6	4.0	71	3.0
Alternaria + Pf	75.7	3.0	77	1.0
Pythium	0.0	0.0	21	2.0
Fusarium	2.0	0.0	10	0.5
Alternaria	0.0	0.0	19	2.0
Control (no addition)	38.3	1.9	49.3	2.4

The second experiment grew the plants to harvest.

Treatments	Germination percentage	Leaf no. per plant (cm^2/plant)	Leaf area/plant	Chlorophyll content (mg/gm)
Pp + Fusarium	89.7	27	22	3.27
Pp + Pythium,	84.0	28	20	2.29
Pp + Alternaria	86.7	25	18	1.28
Pf + Fusarium	70.7	22	19	3.23
Pf + Pythium	71.0	19	17	1.96
Pf + Alternaria	80.0	19	18	2.25
Fusarium	3.0	6	4	0.21
Pythium	2.3	4	4	0.32
Alternaria	0.0	0	0	0.00
Control (no addition)	52.0	11	9	0.76
LSD 5 %	10.9	3.98	5.12	0.167

Treatments	Height of plant (cm)	Branch no. per plant	Total dry weight of shoot gm/plant
Pp + Fusarium	76.7	5.3	6.9
Pp + Pythium	88.3	8.3	7.7
Pp + Alternaria	67.7	6.3	6.7
Pf + Fusarium	73.3	4.7	4.8
Pf + Pythium	69.7	4.3	5.7
Pf + Alternaria	62.3	5.7	5.6
Fusarium	37.3	1.3	0.23
Pythium	36.3	2.7	0.3
Alternaria	0.0	0.0	0.0
Control (no addition)	55.0	3.3	3.3
LSD 5%	11.4	1.78	1.26

Treatments	Seeds no. per pod per plant	Weight of 1,000 seeds per plant (gm)	Pods no. per plant
Pp + Fusarium	50.7	2.2	33.7
Pp + Pythium	64.0	2.5	37.3
Pp + Alternaria	53.7	2.1	35.9
Pf + Fusarium	53.3	1.9	35.0
Pf + Pythium	54.7	1.6	26.7
Pf + Alternaria	43.7	1.8	32.3
Fusarium	8.3	0.4	1.3
Pythium	13.0	0.7	1.0
Alternaria	0.0	0.0	0.0
Control (no addition)	35.3	1.2	19.0
LSD 5%	4.58	0.22	3.3

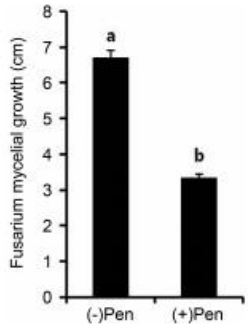
Treatments	N% in shoot	P% in shoot	K% in shoot	Oil% in seeds
Pp + Fusarium	0.55	0.67	4.73	43.3
Pp + Pythium,	0.72	0.85	5.53	48.0
Pp + Alternaria	0.63	0.73	4.30	45.0
Pf + Fusarium	0.40	0.61	4.43	42.7
Pf + Pythium	0.32	0.71	4.43	44.0
Pf + Alternaria	0.41	0.66	4.52	43.7
Fusarium	0.07	0.03	2.2	5.3
Pythium	0.06	0.04	1.43	4.7
Alternaria	0.0	0.0	0.0	0.0
Control (no addition)	0.21	0.42	3.05	27.7
LSD 5 %	0.033	0.042	0.576	3.11

PARAGUAY

- N. Lezcano (2006) in a grower guide reported the following pathogen: *Fusarium* sp.
- L.C. Rossi and A.L. Orrego (2007) identified the following fungus on sesame seeds: *Fusarium* sp.
- Anon. (2015a) Paraguay descriptor: *1.10 Incidence of Fusarium* sp. The following ratings are used:
  - 0 = Sin informacion [No information]
  - 1 = Resistente [Resistant]
  - 2 = Medianamente resistente [Moderately resistant]
  - 3 = Medianamente susceptible [Moderately susceptible]
  - 4 = Susceptible [Susceptible]

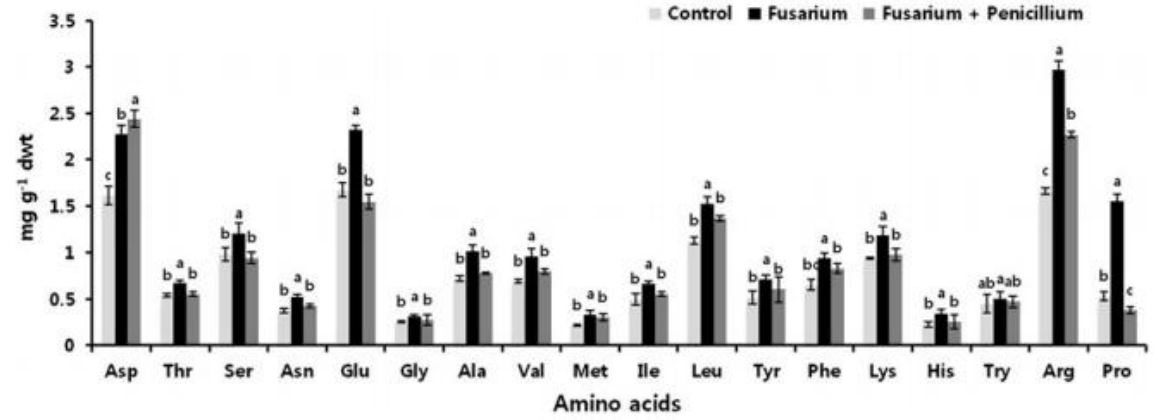
REPUBLIC OF KOREA

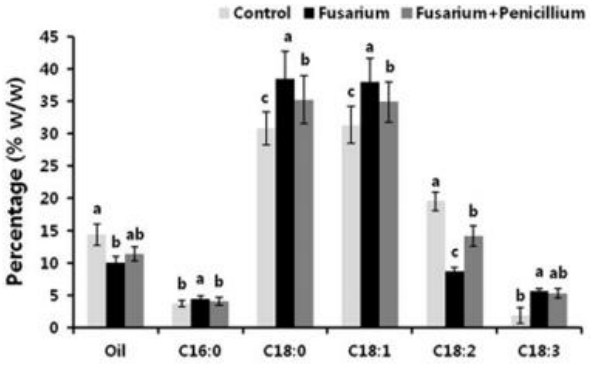
- J.I. Lee et al. (1985i) reported A new high-yielding sesame variety ‘Ansanggae’ was developed by mutation breeding of ‘Early Russian’. Ansanggae was moderately resistant to seedling blight including Rhizoctonia blights, and resistant to Corynespora leaf blight, Phytophthora blight, and Fusarium wilt. [Based on abstract]
- S.W. Kang and H.K Kim (1989) reported sesame seeds coated with conidia of *Gliocladium virens*, were sown in the field where sesame had been cultivated for five to six straight years. The antagonistic fungus was evaluated for biocontrol potentials over Benomyl fungicide against Damping-off and Fusarium wilt of sesame for two years with randomized block design with three replicates throughout the growing period of 1987 and 1988. Pathogenic fungi associated with sesame seedling disease in the field plot was predominantly *Fusarium* sp. and *Pythium* sp. at 32.9% and 27%, respectively. Disease incidence of Damping-off and Fusarium wilt at earlier growth stages was 20.1% in 1987 and 15.2% in 1988 for plots of seed-dusted with conidia of G. virens, which was far effective compared to the infection rate at average of 35.2% of the untreated plot. It was especially remarkable that *G. virens* seed-dusting was superior to fungicide seed treatment by Benomyl wp. [Based on abstract]
- R. Radhakrishnan et al. (2013a) reported *Penicillium* sp. is a potent plant growth promoting fungus that has the ability to ameliorate damage caused by *Fusarium* infection in sesame cultivation. The *in vitro* biocontrol activity of *Penicillium* sp. against *Fusarium* sp. was exhibited by a 49% inhibition of mycelial growth in a dual culture bioassay and by hyphal injuries as observed by scanning electron microscopy.



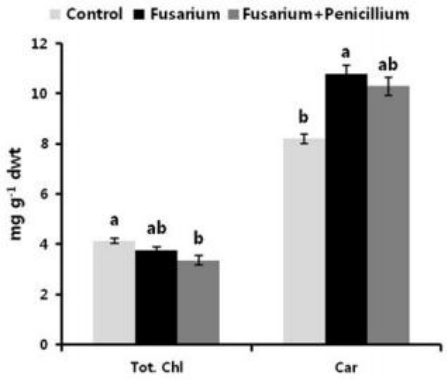
In addition, greenhouse experiments revealed that *Fusarium* inhibited growth in sesame plants by damaging lipid membranes and reducing protein content. Co-cultivation with *Penicillium* sp. mitigated *Fusarium*-induced oxidative stress in sesame plants by limiting membrane lipid peroxidation, and by increasing the protein concentration, levels of antioxidants such as total polyphenols, and peroxidase and polyphenoloxidase activities.

- R. Radhakrishnan et al. (2013b) studied the differences in amino acids and fatty acids between a control, *Fusarium* and *Fusarium* + *Penicillium*. Compared with healthy plants, *Fusarium*-infected plants accumulated higher concentrations of free amino acids, fatty acids, carotenoids, γ-Aminobutyric acid (GABA), and some lignans, and showed decreased concentrations of oil and chlorophyll. Furthermore, *Penicillium* treatment mitigated the *Fusarium*-induced changes in amino acids, fatty acids, carotenoids, and secondary metabolite contents in infected plants. The results were as follow.

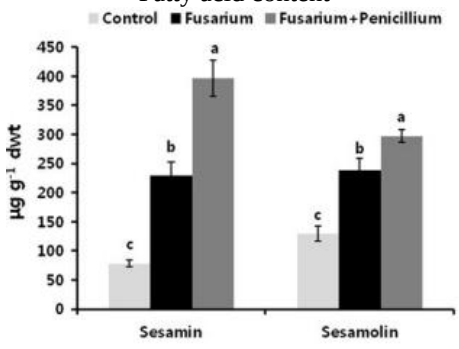




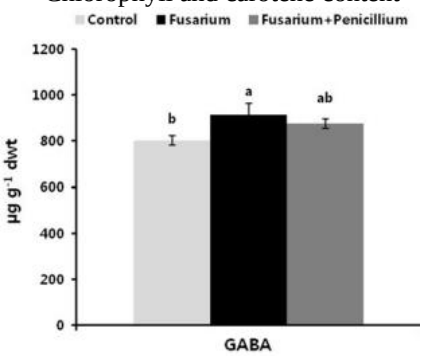
Fatty acid content



Chlorophyll and carotene content

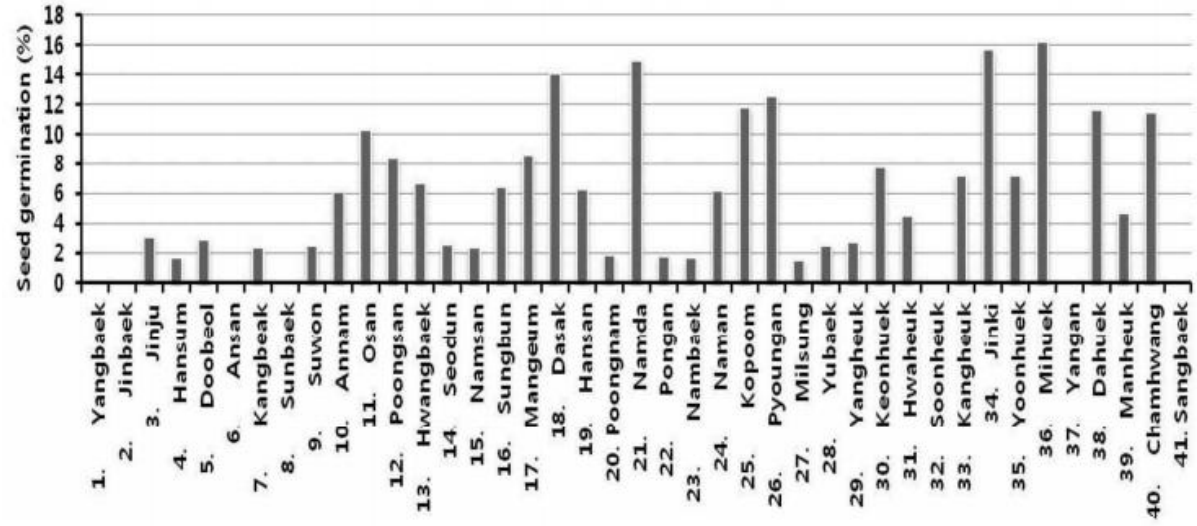


Sesamin and sesamolin content

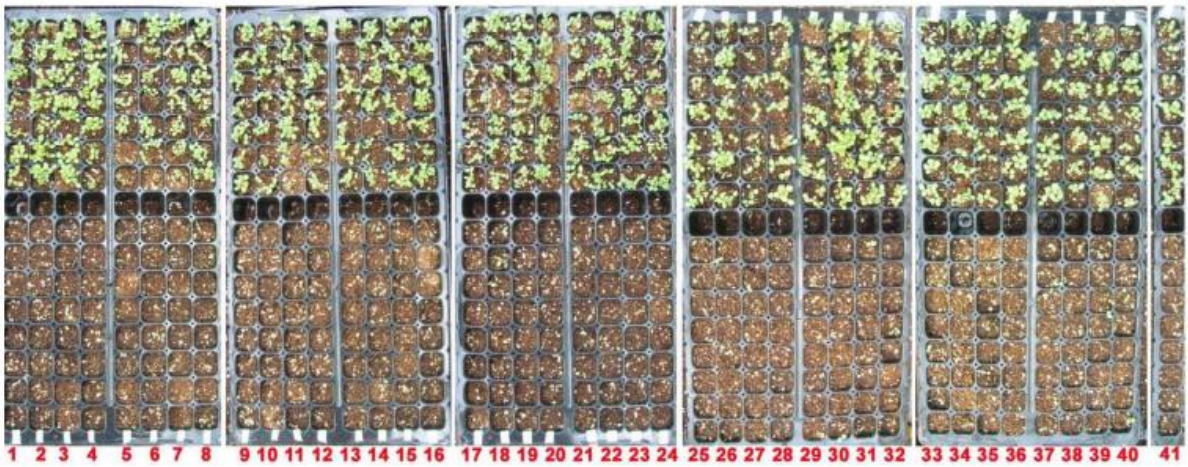


γ-Aminobutyric acid (GABA)

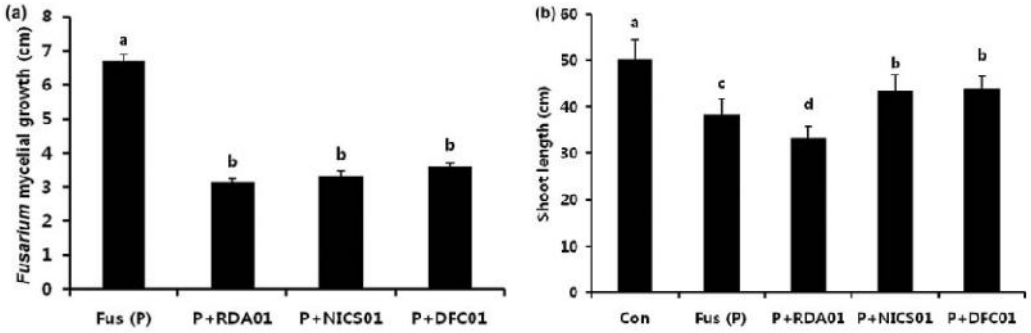
- R. Radhakrishnan et al. (2014a) screened 41 genotypes for resistance to *Fusarium* sp. *Fusarium* sp. 40240 isolate was cultured in potato dextrose broth for 3 weeks. The Fusarium culture filtrate with mycelium was mixed into pots. The pots treated with sterile water served as control. Sterilized seed was planted in the pots with the following rates of germination.



The following shows the control plots at the top and the *Fusarium* plots at the bottom for all 41 genotypes.



- R. Radhakrishnan et al. (2014b) evaluated the effects of 3 Penicillium species (RDA01, NICS01, and DFC01) on 3 cultivars (Pyeongang, Kangbaek, and 90 Day) on *Fusarium* sp. Seven-day-old RDA01, NICS01, DFC01 and *Fusarium* sp. cultures in PDB broth were applied to a 4-mm disc placed on the opposite side of Petri dishes containing potato dextrose agar (PDA) medium. The Petri dishes were incubated for 14 days at 28 ± 2°C and *Fusarium* mycelium growth was measured. The surface-sterilized seeds were sown in pots containing RDA01-, NICS01-, and DFC01-treated Baroker soil in a greenhouse. Fusarium culture was applied to the Penicillium-inoculated plants at 50 days. Shoot length was measured 15 days after the first appearance of wilting. The results were as follow.



- S.U. Kim (pers. comm. 2015): The following is a photo of *Fusarium* sp. on sesame in a greenhouse.

SAUDI ARABIA

- A.H. Bahkali and M.A. Moslem (1996) reported the following mycoflora on 5 cultivars: *Fusarium* sp.

SIERRA LEONE

- F.E. Jonsyn (1988) sampled the fungi in 4 different geographical areas and found three toxigenic Aspergillus species: *A. flavus* Link ex Fries, *A. ochraceus* Wilhelm, and *A. tamarii* Kita were common to all samples. *Penicillium citrinum* Thom and two Fusarium sp. were found in samples from two localities. The mycotoxins aflatoxin B_1 and G_1, ochratoxin A and B, and citrinin were positively identified. [Based on abstract]

SUDAN

- N.M.A. Hamid (2006) identified the following fungus from seed collected from 3 areas of Sudan: *Fusarium* sp.

THAILAND

- V. Benjasil (1985a) reported *Fusarium* sp. (Leaf and stem rot) causes losses in yield.

UGANDA

- C.G. Hansford (1931, 1938, 1939, 1940, and 1943) reported the following disease: Fusarium wilt. [Cited by G.S. Saharan, 1989]
- W.O. Anyanga (2019) reported Fusarium is one of the main diseases.

UNITED STATES

- G.M. Armstrong and J.K. Armstrong (1949) reported *Fusarium* on a benne farmer field in Georgia where the farmer reported the disease for the previous 15 years. He inoculated sesame in the greenhouse and found most lines susceptible, but one line (Sirigoma) was resistant.
- J.A. Martin (1949c) reported two of the breeding objectives are to develop tolerance to *Cercospora sesami* and *Fusarium* sp.
- R.D. Sears and S.A. Wingard (1951) reported Fusarium wilt in Virginia. [Cited by G.S. Saharan, 1989]
- J. A. Martin (1953a) reported the presence of *Fusarium* sp. in the US.
- D.R. Langham (1998e) reported that Sesaco took notes in most years on *"37a. Fusarium*. Critical data for sesame becoming a crop in the US."
- D.T. Smith et al. (2000) reported *Fusarium* wilt has been noted in Georgia and Texas. The pathogens can attack seedlings, cause damping off, reduce crop stands in cool, wet soils, and may attack the crop later in the growing season. Sesame seedlings may emerge, but seedling diseases may reduce stands 70% to 90%. Some varieties are very susceptible to *Fusarium* but breeding lines have shown some resistance. *rhh* may cause 80% yield loss with susceptible varieties. Fusarium wilt became the major problem in sesame in the Winter Garden area of Texas in the early 1990's, when sesame could be grown on set-aside ground. Repeated plantings resulted in a build-up of fungal spores. Fusarium shows up in earlier stages and kills the plant before seed is produced and reducing yields by 90% or more. Some lines, such as S-23, S-24, and S-25 show some resistance to this soil pathogen.

VENEZUELA

- D.G. Langham and M. Rodriguez (1945d) classified *Fusarium* sp. as a range: resistant (K_1), intermediate (K_2-K_4) and susceptible (K_5).
- G. Malaguti (1960) reported a sesame wilt caused by *Fusarium* sp. with symptoms similar to those of such wilts in other plants. Incidence was related to ambient conditions, the disease occurred when the water content of the soil was 17-27% of the dry weight. Nematodes, high air temperatures by day and low by night, and high soil temperatures to a depth of 5-10 cm during dry periods increased its incidence.
- B. Mazzani et al. (1973) introduced a new variety 'Maporal' which is especially adapted to conditions in which soilborne pathogens (*Phytophthora, Fusarium, Macrophomina*, and *Rhizoctonia*) are prevalent.

- B. Mazzani (1981a) reported *Fusarium* sp. (Wilt) is one of the major diseases.
- C. Zambrano and O. Tortolero (1985) conducted studies on 540 sesame cultivars, and isolations from seedling rot and soil and reported the following pathogen: *Fusarium* sp.
- Y. Martinez et al. (1991) in studying aflatoxin reported the following fungi on sesame: *Fusarium* sp.

A1.1.1a *Fusarium oxysporum* (7 Apr 2021)

Family: Nectriaceae

Definition: Amount of tolerance to *Fusarium oxysporum* Schlecht 1824.

(Wikipedia, 7 Apr 2021) ***Fusarium oxysporum*** (Schlecht as emended by Snyder and Hansen), an ascomycete fungus, comprises all the species, varieties and forms recognized by Wollenweber and Reinking within an infrageneric grouping called section Elegans.

Although their predominant role in native soils may be harmless or even beneficial plant endophytes or soil saprophytes, many strains within the *F. oxysporum* complex are pathogenic to plants, especially in agricultural settings.

These diverse and adaptable fungi have been found in soils ranging from the Sonoran Desert, to tropical and temperate forest, grasslands and soils of the tundra. *F. oxysporum* strains are ubiquitous soil inhabitants that have the ability to exist as saprophytes, and degrade lignin and complex carbohydrates associated with soil debris. They are pervasive plant endophytes that can colonize plant roots and may even protect plants or form the basis of disease suppression.

Because the hosts of a given *forma specialis* usually are closely related, many have assumed that members of a *forma specialis* are also closely related and descended from a common ancestor. However, results from research conducted on *Fusarium oxysporum* f. sp. *cubense* forced scientists to question these assumptions.

References:

INTERNATIONAL

- J.R. Morschel (1964) reported the following pathogen in the world: *Fusarium oxysporum* (Wilt). [Cited by D.F. Beech. 1995a]
- Anon (2000a) is an organic grower guide for America. It describes the following pathogen and its recommended organic method of control: *Fusarium oxysporum* (Fusarium wilt) is transmitted through seeds and soil. Indehiscent strains are less susceptible. In case of strong soil infection, sowing interval of minimum of 5 years.
- CAB International (accessed 12 Apr 2021) reported sesame was a host of *Fusarium oxysporum* (Basal rot).

AUSTRALIA

- D.F. Beech (1995a) reported the following pathogen: *Fusarium oxysporum* (Wilt).

BRAZIL

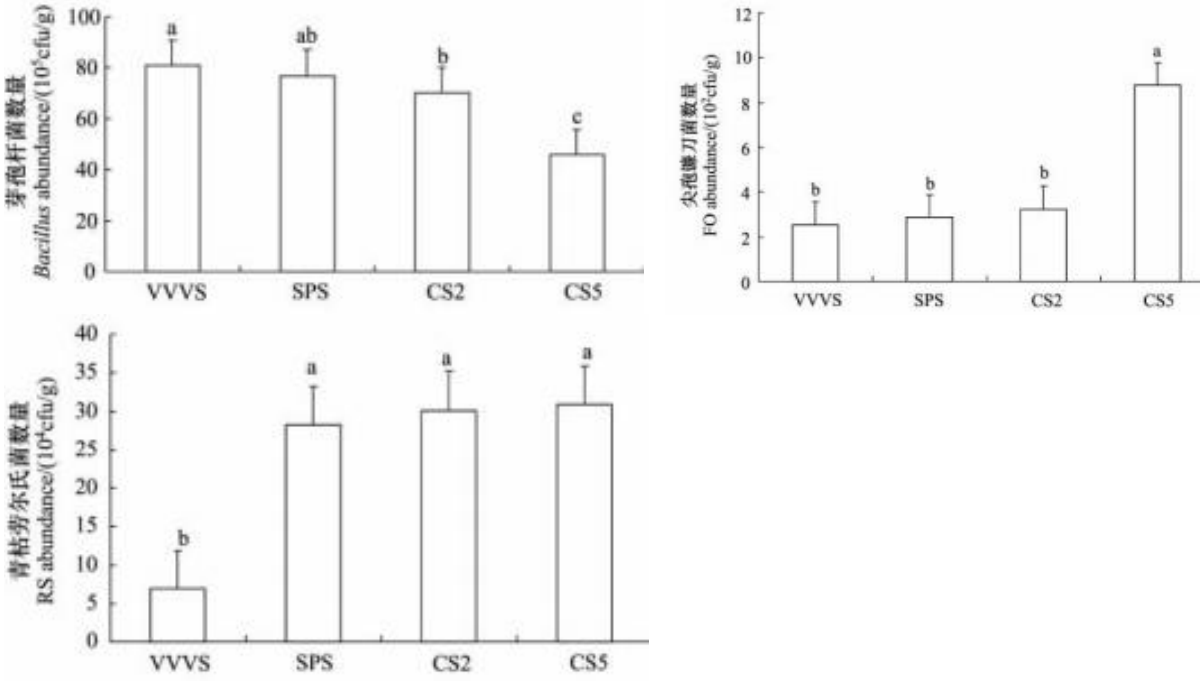
- V.P. Queiroga et al. (2010c and 2019) reported *Fusarium oxysporum.* For control, use resistant varieties (*Sesamum radiatum* or Delco). Rotate the crop and eliminate plant residues.

- N.E.M. Beltrao et al. (2013) reported *Fusarium oxysporum* It is characterized by sagging and wilting of the plant, which later it causes drought and consequently death. When making a cross section in the stem of the infected plant, there is blackening of the tissues of the vascular system. The disease affects any stage of the plant's life, from germination and seedling stage to its development and maturation (G. Malaguti, 1960). The

fungus survives in the soil in the form of spores, living saprophytically on crop residues. Its dissemination it is made by soil particles and water droplets (from rain and irrigation).

CHINA

- J.L. Hua et al. (2012) evaluated the effects of 4 normal crop rotations (vegetable crop (vegetable-vegetable-vegetable-sesame, VVVS), alternation of sesame with peanut (sesame-peanut-sesame, SPS), 2 year continuous sesame, CS2, and 5 year continuous sesame, CS5) on populations of *Bacillus* spp., *Fusarium oxysporum* (FO), and *Ralstonia solanacearum* (RS). The results were as follow.



It was clear that continuous cropping of sesame led to direct changes in the microbial composition of the rhizosphere. Bacteria and actinomycetes decreased in abundance, while fungi increased. When rhizospheric soil changes from "bacterial" to "fungal", its biological activity and fertility decline, and it is slower to recover from ecological fluctuations caused by external factors such as pathogens and waterlogging. Fusarium oxysporum and Ralstonia solanacearum continue to increase in abundance, causing worsening diseases. These factors eventually lead to continuous cultivation problems in sesame.

- D.H. Li et al. (2012) obtained 25 isolates of Fusarium species from wilted sesame grown on 25 farms from 22 regions of China. They identified *Fusarium oxysporum* and *Fusarium solani.*
- J.F. Wang et al. (2013) isolated 421 endophytic bacteria from 36 samples of healthy sesame roots growing in eastern Henan province. Antagonistic activity of these bacteria against *Fusarium oxysporum* was tested by the dural culture method. The result showed that 3 bacterial strains (A21, G20, G36) had significant antagonistic activity, and the biological control efficacies were 52%, 40%, 67% respectively. The detection of the enzyme production ability indicated that the 3 bacterial strains produced different cell wall degrading enzymes, and possibly had different bio-control mechanism. The test of physiological and biochemical characteristics of endophytic bacteria indicated that G36 belonged to Bacillus sp. [Based on abstract]
- X.B. Zhao et al. (2021a) studied the effects of *Penicillium bilaiae* on *Fusarium oxysporum.* Isolate 47M-1 was isolated from rhizosphere soil samples of tobacco and identified as Penicillium bilaiae. Isolate 47M-1 inhibited the mycelial growth of F. oxysporum by 81.3% and overgrew the colonies of F. oxysporum in co-cultures. In a potting test, the control efficiency of isolate 47M-1 against Fusarium wilt of sesame was 50%, which was superior to that of Bacillus subtilis ($P = 0.022$). There was no significant difference ($P = 0.068$) in the control of Fusarium wilt between treatment with the fungicide carbendazim and treatment with isolate 47M-1. The results also showed that isolate 47M-1 and its culture filtrate significantly promoted the growth of sesame. In conclusion, isolate 47M-1 can control Fusarium wilt of sesame via multiple mechanisms, including competition, production of inhibitory substances, promotion of plant growth and induction of disease resistance. [Based on abstract]

COLOMBIA

- Anon. (2013c) in a grower guide reported *Fusarium oxysporum* causes a major disease. It is transmitted in the seed and the soil.

CUBA

- La Habana (2009) in a grower guide reported the following pathogen: *Fusarium oxysporum.*

EGYPT

- A.K.A. El-Ghany et al. (1970) reported *Fusarium oxysporum, Rhizoctonia solani* and *Sclerotium bataticola* were isolated from diseased plants. Infection tests showed that vars. Introduction 51, Sharkya 57, 62 and 203 and especially Sharkya 79 were least susceptible. High soil moisture levels due to frequent irrigation increased infection. The best yields were obtained with irrigation every two weeks.
- A.K. Selim et al. (1976b) reported in 4 crosses between 3 local and 5 introduced sesame cvs. tolerance of *Fusarium oxysporum* in mature plants was governed by 1 or 2 dominant pairs of genes while in a 5th cross governed by 3 pairs of genes; tolerance was recessive.
- M.S. Serry (1981a and 1981b) reported the presence of *Fusarium oxysporum* is a major hazard. The variety Giza-25 is tolerant and now occupies 70% of the sesame area. Seed treatments with fungicides (Vitavax and Captan) proved to be effective in controlling seedling diseases. Studies using nematicides and *Trichoderma herzianum* have been initiated.
- M.B. Seoud et al. (1982) reported the most destructive diseases al sesame in Egypt are caused by *Fusarium oxysporum, Rhizoctonia solani* and *Sclerotium bataticola* (*Macrophomina phaseolina*). Seed treatment with Vitavax (carboxin) + Captan @ 4 g/ka seed and soil treatment with Daconil 2787 (chlorothalonil) at 3.75 kg/feddan gave the best control and highest yields.
- M.M. Satour (1984) reported one of the prevalent disease causal organisms was *Fusarium oxysporum*. [Cited by G.S. Saharan, 1989]
- M.S. El-Abyad et al. (1988) studied the effect of the herbicide prometryn on the metabolic activities of two formae speciales of Fusarium oxysporum. Prometryn at concentrations of 128 and 256 ppm significantly inhibited growth and respiration rates, reduced absorption of both sugar and nitrate, and reduced rates of synthesis of carbohydrates and organic nitrogenous compounds by both fungi. A concentration of 16 ppm did not significantly affect the metabolic activities of F. oxysporum f. sp. vasinfectum. [Based on abstract]
- H.A.H. Hasan (2002) reported *Fusarium oxysporum* was a pathogen in the rhizosphere and rhizoplane. [Cited by S.I.I. Abdel-Hafez, 2012]
- M.M.I. Abdel-Hafez et al. (2012) examined the soils around the roots of sesame and reported *Fusarium oxysporum* in the rhizosphere and rhizoplane.
- A. Hashem et al. (2014) collected 18 seed samples of sesame in Egypt (12 samples) and Saudi Arabia (6 samples). They identified the following mycoflora: *Fusarium oxysporum.*
- A.S. Anter and G.M. Samaha (2021) reported molecular marker analysis revealed eight markers linked to Fusarium wilt resistance (*Fusarium oxysporum*): they are seven positive markers (five RAPD and two ISSR), which were found in the line C3.8 and absent in the check variety.

ETHIOPIA

- T. Geremew et al. (2009 and 2012) reported the following diseases are a minor problem: *Fusarium oxysporum* (Wilt).

GREECE

- M.M. Satour (1981) reported the presence of *Fusarium oxysporum* (Wilt).

INDIA

- R.S. Vasudeva (1961) described the following symptoms of *Fusarium oxysporum*: The disease is characterized by yellowing, drooping, and withering of the leaves. The top of the stem gets dried up and bent over. A brown

discoloration in the wood gradually extends from the roots to the apex and ultimately leads to the death of the plant. The symptoms in general closely resemble with other wilt diseases caused by *Fusarium*.

- S.N. Bhargava and D.N. Shukla (1979a) reported seed coat leachates and seed extracts of sesame decreased spore germination of *Fusarium oxysporum*, *Fusarium solani* and *Curvularia lunata* (*Cochliobolus lunatus*). Culture filtrates of the fungi inhibited seed germination of the plants. [Cited by G.S. Saharan, 1989]
- S.N. Bhargava and D.N. Shukla (1980) reported the two most frequently encountered fungi, *Fusarium equiseti* and *Fusarium oxysporum* caused a slight reduction in oil content of seeds of sesame when incubated for 45 days. [Cited by G.S. Saharan, 1989]
- M.M. Satour (1981) reported the presence of *Fusarium oxysporum* (Wilt).
- B.K. Vaidehi et al. (1985) reported culture filtrates of *Fusarium oxysporum* reduced germination percentage and root and shoot elongation of sesame with the maximum on the 30th day. [Cited by G.S. Saharan, 1989]
- N.O. Srikantappa et al. (2009) studied 28 samples of sesame taken from fields, farmers, retail shops and APMC markets from 5 areas. They found 34 four fungi including *Fusarium oxysporum*. The fungi significantly reduced germination.
- R.B. Kakde and A.M. Chavan (2011) examined the effects of fungi on seeds in storage. Ten dominant fungi were isolated from seeds of groundnut, soybean, sesame, safflower, and sunflower. One hundred grams of seeds were inoculated with 10 ml of the fungi. The flasks were left at room temperature for 14 days and then analyzed for sugars, crude fat, and fiber. The results are as follow.

Table 1. Change in reducing sugar (g/100gm) due to seed-borne fungi

Fungi	Sunflower	Sesame	Groundnut	Soybean	Safflower
Alternaria dianthicola	5.2	4.8	1.1	1.1	1.3
Curvularia lunata	4.9	5.0	2.5	1.5	1.8
Curvularia pellescens	5.0	5.4	2.1	1.2	1.6
Fusarium oxysporum	4.7	4.4	1.8	1.7	1.1
Fusarium equiseti	4.6	4.8	1.6	1.2	1.0
Macrophomina phaseolina	5.8	3.5	2.2	2.0	2.2
Rhizopus stolonifer	6.1	5.0	1.1	1.8	2.1
Penicillium digitatum	5.5	4.6	1.9	1.7	1.4
Penicillium chrysogenum	5.2	4.9	2.0	1.6	1.6
Trichoderma viride	6.7	6.1	2.1	1.9	2.6
Control	7.2	6.9	3.1	2.4	2.8
C.D. at 0.05	0.52	0.62	1.21	0.24	0.21

Table 2. Change in crude fat (g/100gm) due to seed-borne fungi

Fungi	Sunflower	Sesame	Groundnut	Soybean	Safflower
Alternaria dianthicola	35.5	10.2	37.1	49.8	22
Curvularia lunata	43.5	14.3	32.5	48.2	26
Curvularia pellescens	45.5	10	41	49	27
Fusarium oxysporum	43	16.1	38	44	20
Fusarium equiseti	47	14.2	35	49.7	19
Macrophomina phaseolina	39	10.5	39.3	46.8	30
Rhizopus stolonifer	50	16.3	40.2	48.6	33
Penicillium digitatum	42	15.3	34.3	39	24
Penicillium chrysogenum	44	12.8	36.2	41	27
Trichoderma viride	46	17.5	40	46	35
Control	49	20	45	50	36
C.D. at 0.05	2.71	2.05	2.04	2.4	3.7

Table 3. Change in crude fiber (g/100) due to seed-borne fungi

Fungi	Sunflower	Sesame	Groundnut	Soybean	Safflower
Alternaria dianthicola	39.1	35.6	33.9	26.1	20.1
Curvularia lunata	52.3	30.6	38.8	34.5	21.8
Curvularia pellescens	46.1	41.1	42.3	31.1	21.6
Fusarium oxysporum	53.1	36.5	34.7	37.0	21.0
Fusarium equiseti	50.7	36.4	37.9	21.0	22.5
Macrophomina phaseolina	47.7	34.8	41.9	36.6	17.9
Rhizopus stolonifer	41.6	31.6	40.1	28.5	19.6
Penicillium digitatum	43.5	40.5	27.6	21.0	14.4
Penicillium chrysogenum	40.5	27.7	31.7	36.9	13.9
Trichoderma viride	47.5	35.1	38.3	37.0	19.8
Control	51.3	47.7	38.0	23.3	19.9
C.D. at 0.05	3.16	6.11	2.39	4.2	1.82

They also tested the effect of the following botanicals against the fungi: *Azadirachta indica, Polyalthia longifolia, Jatropha curcus, Santalum album, Withania somnifera, Datura strominum, Eucalyptus*

angophoroides, Vitex nigundo, Annona squamosal, Piper betel and *Murraya koenigii*. Most of the fungi tested are not normally found on sesame, but for those that are, *Azadirachta indica, Polyalthia longifolia, Murraya koenigii, Jatropha curcus, Withania somnifera* and *Datura strominum* showed antifungal activity against *Macrophomina phaseolina,* and *Eucalyptus angophoroides* against *Fusarium oxysporum.*

- A. Sharma et al. (2011) analyzed the metabolic alterations in sesame after infection with *Macrophomina phaseolina* and *Fusarium oxysporum* by estimating the levels of total phenolic compounds and the activities of phenylalanine ammonia lyase (PAL) of one week old plants. The PAL showed high activity in infected plants, revealing the active phase in the synthesis of secondary metabolites in the plant after infection. As a consequence, in infected plants the contents of polyphenols along with salicylic acid (SA) considerably exceeded when compared to control plants. This *in vivo* study of *M. phaseolina* and *F. oxysporum* infection reveals the differences of resistance levels in sesame against these two pathogens. The following shows the percentage increase in phenolics, PAL activity and defense related proteins in infected plants in comparison to control under *in vivo* and *in vitro* conditions in both 25 days 35 days old plants after 96 and 48 hours of inoculation.

	PAL				Salicylic acid				Total protein			
	A		B		A		B		A		B	
Varieties	25 days	35 days	25 days	35 days	25 days	35 days	25 days	35 days	25 days	35 days	25 days	35 days
RSG-931	5	8	5	12	31	25	9	33	10	23	24	24
RSG-945	10	12	5	7	21	29	21	20	40	19	44	18
RSG-896	10	28	11	14	32	31	32	23	42	24	59	28
CSJD-884	15	11	11	13	26	21	13	29	25	21	23	20

A-*In vivo*, B-*In vitro*.

- D.K. Maheshwari et al. (2012) evaluated the use of *Azotobacter chroococcum* TR2 against *Macrophomina phaseoli* and *Fusarium oxysporum* along with growth promoting attributes in conjunction with fertilizers. It caused degradation and digestion of cell wall components, resulting in hyphal perforations, empty cell (halo) formation, shrinking and lysis of fungal mycelia along with significant degeneration of conidia. The effects on the pathogens were as follow.

Fungal Pathogen	Incubation (h)	Growth in dual culture (mm)	Growth in control (mm)	Growth inhibition (%)
M. phaseolina	48	25.0 ± 0.03	48.2 ± 0.02	48.1
	72	28.3 ± 0.05	60.4 ± 0.05	53.1
	96	29.7 ± 0.01	70.7 ± 0.03	57.9
	120	30.9 ± 0.06	89.3 ± 0.02	65.3
F. oxysporum	48	28.0 ± 0.03	40.0 ± 0.07	30.0
	72	39.1 ± 0.02	65.5 ± 0.06	40.3
	96	41.0 ± 0.03	76.7 ± 0.11	46.5
	120	41.8 ± 0.07	88.1 ± 0.12	52.5

- V. Bharathi et al. (2013) collected sesame seeds from farmers in Andhra Pradesh. They tested the seeds for mycoflora, and the following fungus was found: *Fusarium oxysporum.*
- H.R. Aglave (2016) screened two varieties (CV.N-85 and CV. Phule-1) for seed mycoflora. Twenty-seven fungi were isolated from these varieties. Varietal variation was found during the investigation. The following fungus was present *Fusarium oxysporum.*

IRAN

- M. Gooya et al. (2000) took one seed samples of each 17 sesame cultivars from 10 locations leading to 145 isolates during 1997/99 They identified *Fusarium oxysporum.*

IRAQ

- K.M. Tamini and H.A. Hadwan (1985) reported the differences in the amount of inhibition of growth of a range of sesamum wilt causing fungi by gaseous metabolites from *Neurospora sitophila* and *Trichoderma harzianum* could be accounted for by differences in their ages. The highest level of growth inhibition from test fungi ever recorded was as follows: 3-day-old *N. sitophila* was 55% on virulent *Rhizoctonia solani,* 51% on a virulent *Rhizoctonia solani,* 48% on *Fusarium oxysporum* and 40% on *Macrophomina phaseoli*. *Other* soilborne fungi were less effective than *N. sitophila*. [Cited by G.S. Saharan, 1989]
- N.A. Saad et al. (2013) examined seed and found the following fungus: *Fusarium oxysporum.*

ISRAEL

- A.Z. Joffe and J. Palti (1964) reported of the nine *Fusarium spp*. identified in 79 isolates from soil and plant material in association with 18 different hosts, *F. oxysporum* (23 isolates) and *F. solani* (27) were most prevalent and affected hosts on many soils. Both the *F. solani* and *F. oxysporum* groups were associated with a serious wilt of sesame. [Cited by G.S. Saharan, 1989]
- M.M. Satour (1981) reported the presence of *Fusarium oxysporum* (Wilt).

JAPAN

- M.M. Satour (1981) reported the presence of *Fusarium oxysporum* (Wilt).

MALAWI

- E. Lawrence (1951) reported *Fusarium oxysporum* (Wilt) causes one of the more important diseases. [Cited G.S. Saharan, 1989]

MEXICO

- M.M. Satour (1981) reported the presence of *Fusarium oxysporum* (Wilt).
- Anon. (2010a) in a grower guide reported the following main pathogen: *Fusarium oxysporum.* For its control it is recommended to till the soil immediately after harvest, in order to expose the immature sclerotia to the sun; it also helps speed up the decomposition of organic matter by removing it at depths greater than those inhabited by the fungus. Avoid introduction of organic matter from other areas where the pathogen is suspected. In general, the most effective methods to control *F. oxysporum* include disinfection of the soil, free or treated seed and vegetative material with fungicidal chemicals, crop rotation with non-hosts of the fungus, or use of resistant cultivars.

NIGERIA

- M.M. Satour (1981) reported the presence of *Fusarium oxysporum* (Wilt).
- F.M. Afolagboye (2011) reported the following fungus from 4 sesame varieties (NCRIBEN 03L, NCRIBEN 01M, E8 and 530-6-1) at Abeokuta: *Fusarium oxysporum.*
- C.N. Ezekiel et al. (2012 and 2013) examined 17 samples of sesame from 4 markets and found *Fusarium oxysporum, Fusarium semitectum* and *Fusarium verticillioides*. They found no aflatoxins. Six randomly selected isolates were screened for their ability to produce mycotoxins in ofada rice culture, and the crude extracts of the mycotoxins were tested on week-old catfish (*Clarias gariepinus*) fingerlings with lethal effects. They isolated 6 toxic metabolites produced by the *Fusarium* in the rice culture: equisetin, fumonisin B_1, fumonisin B_2, methyl-equisetin, moniliformin, and zearalenone. They concluded sesame may be potential sources of toxigenic *Fusarium*.
- Enikuomehin (pers. comm., 2021) reported the causal pathogen of Fusarium Wilt and Fusarium leaf spot is *Fusarium oxysporum*. Fusarium wilt symptoms: Presents as gradual loss of turgor and drooping of above ground parts of the plant without any obvious sign of the pathogen on the soil surface or on the plant. Plants are more susceptible at almost all stages of growth, particularly when plant roots have wounds that provided access to the pathogen. Fusarium leaf spot appear as black, circular spots with less pronounced yellow halo. The spots readily coalesce to form black blotches on infected foliage.

PAKISTAN

- A.S. Shakir and M. Ansar (1992) studied 25 samples of seed collected from various areas in Punjab and found the following fungus: *Fusarium oxysporum.*
- K.H. Wagan et al. (2002) reported 4 species of seedborne fungi, that is *Alternaria sesami*, *A. sesamicola*, *Curvularia lunata* [*Cochliobolus lunatus*], and *Fusarium oxysporum* were isolated from infected seeds of sesame varieties PR-125, S-17, PR-19-9, and PR-14-2. The frequency of fungi was highest from PR-125 (25.63%) followed by S-17 (24.75%), PR-19-9 (23.13%) and PR-14-2 (22.5%). *A. sesami* was isolated as most predominant fungus according to its infection percentage (22.5-62.5). However, *C. lunata* was most frequently isolated from the variety PR-14-2. Maximum seed germination percentage (82.0) was obtained from the healthy seeds of PR-14-2 on filter paper followed by PR-125 (76.0), S-17 (67.0) and lowest from PR-19-9 (62.0). Vitigran blue [copper oxychloride] significantly (P=0.05) reduced the colony growth of the fungus followed by Liro-Manzeb [mancozeb], Dithane M-45 [mancozeb] and Topsin-M [thiophanate-methyl]. The number of spots on 2-month-old inoculated plants was significantly (P=0.05) reduced by spraying with Vitigran blue compared to Liro-Manzeb, Dithane M-45 and Topsin-M.
- B.G. Nayyar et al. (2013) examined 15 samples of seed to detect fungi using 3 methods: agar plate, blotter, and deep freezing and found *Fusarium oxysporum*.

- B.G. Nayyar et al. (2014) studied the effects of fungal pathogens on the germination of sesame. Seven prevalent fungal species viz. *Alternaria alternata, Aspergillus flavus*, *Aspergillus niger, Cercospora* sp., *Fusarium oxysporum, Penicillium egyptiacum* and *Rhizopus oryzae* associated with sesame seeds were selected for this study. Fungi associated with seeds affected the seed health and resulted in reduced seed germination, and seedling abnormality as shown in the table below.

Treatments	Normal seedlings %age	Abnormal seedlings %age	Un germinated seeds %age	Fungi isolated
Surface sterilized seeds	80	14	6	*Aspergillus flavus* *Aspergillus niger* *Fusarium oxysporum*
Naturally infected seeds	64	26	10	*Alternaria alternata* *Aspergillus flavus* *Aspergillus niger* *Fusarium oxysporum* *Penicillium egyptiacum*

The pathogenicity of the 7 fungi was tested with the following results.

S. No.	Fungi isolated	Pathogenic Effect	Healthy Plants
1	*A. alternata*	Infected root & stem, Weak stem, Reduced growth	55%
2	*A. flavus*	Reduced growth	70%
3	*A. niger*	Reduced growth, Infected roots, Weak stem	13%
4	*Cercospora* sp.	Infected stem, Weak stem, Reduced growth	40%
5	*P. egyptiacum*	Infected root, Weak stem	26%
6	*R. oryzae*	Reduced growth, Infected roots & stem, Weak stem	30%
7	*F. oxysporum*	Reduced growth, Leaves short & infected	32%

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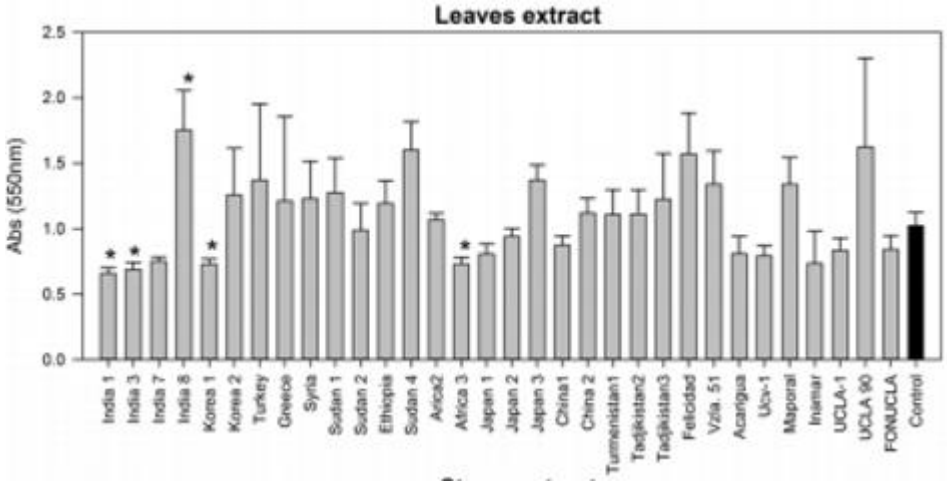
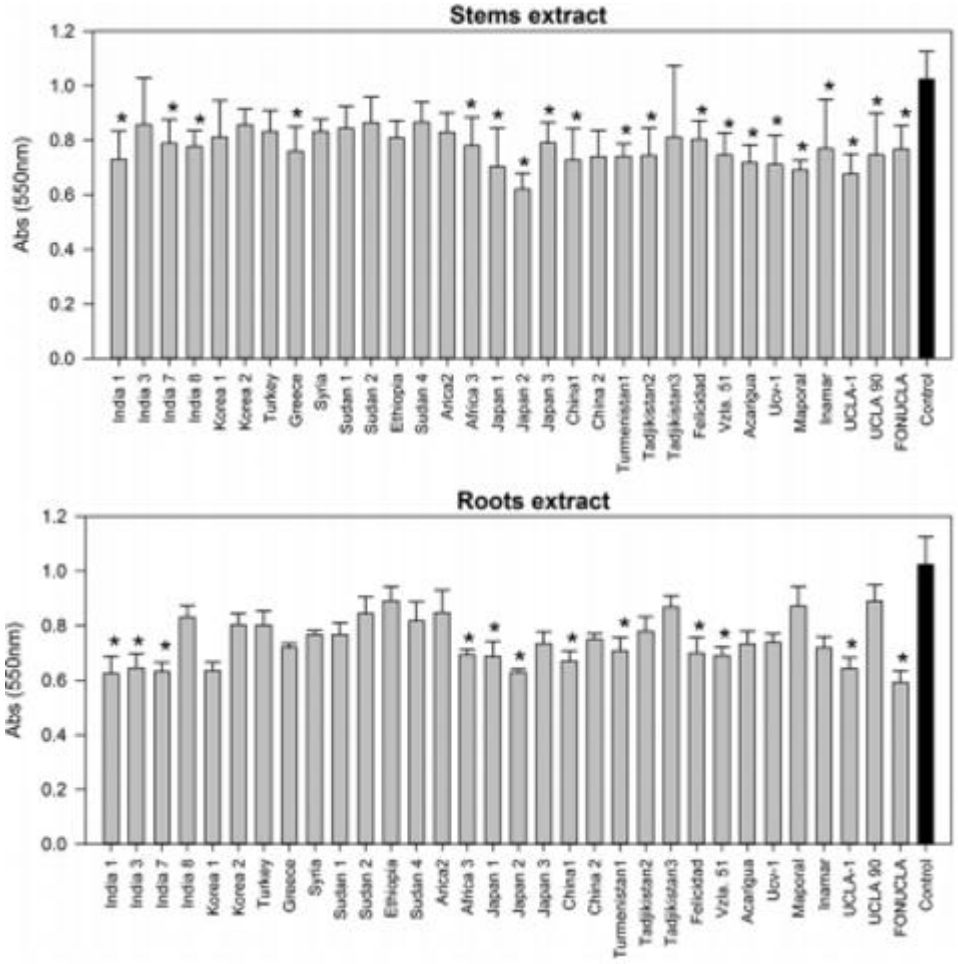
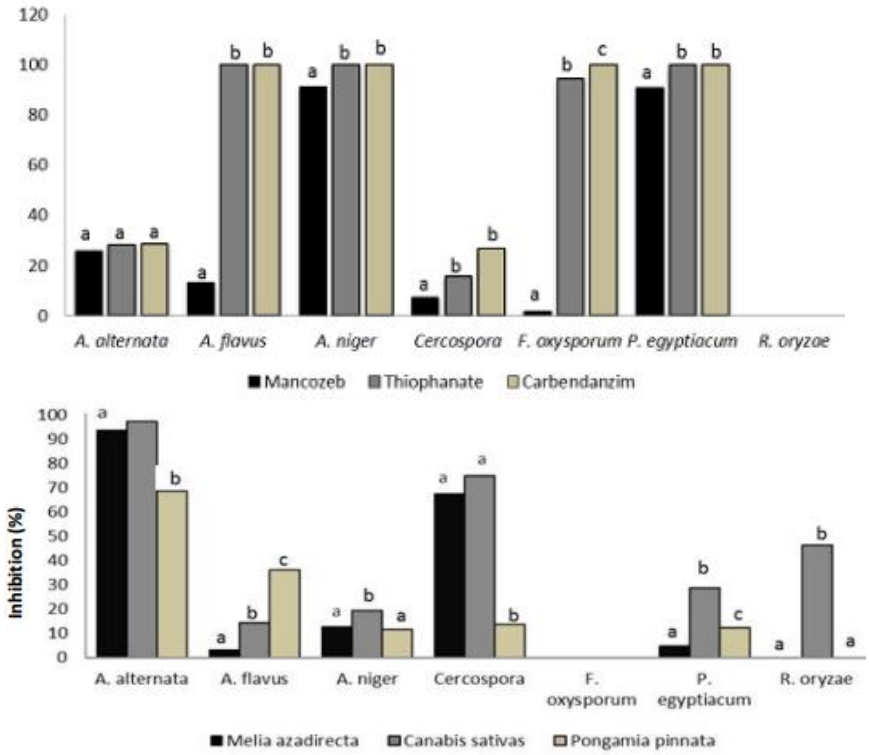
Abnormality rate of seedlings depends on the type of pathogens with which they are infected. There is also need for the management programs to control seedborne pathogens and reduce their impact on sesame production in Pakistan.

- R.N. Syed et al. (2015) evaluated leaf, stem, and root extracts from 32 lines with the aim of identifying genotypes with high content of metabolites potentially involved in resistance against fungal pathogens. The extract of the leaves and stems sprayed with $CuCl_2$ were the most inhibitory against *F. oxysporum.* The results for *Fusarium oxysporum* were as follow.





- B.G. Nayyar et al. (2016) evaluated different treatments to increase the germination and inhibit the fungi on sesame seeds: application of fungicides (Mancozeb, Thiophante Methyl, and Carbendazim) and plant extracts (*Melia azedarach*, *Cannabis sativa* and *Pongamia pinnata*). Seed germination was tested by following the protocol of International Seed Testing Association. Antifungal activity was tested by poisoned food technique. The results revealed that the germination increased effectively, due to thiophanate methyl up to 46%, followed by *Cannabis sativa* (37%). Out of 7 fungi tested against fungicides and plant extracts, 4 fungi, namely *Aspergillus flavus, Aspergillus niger, Fusarium oxysporum* and *Penicillium egyptiacum*, were inhibited up to 100% by Carbendazim and Thiophanate Methyl, while Mancozeb inhibited *Penicillium egyptiacum* (100%), only. *Cannabis sativa* inhibited *Alternaria alternata* (100%) and *Rhizopus oryzae* (55.6%). Overall treatment with fungicides gave best results but they were not eco-friendly. So, this study recommends the use of plant extracts and bioagents, which may increase seed germination and inhibit seedborne fungi without any harmful effect. The treatments had the following effects on specific fungi in terms of germination and inhibition: *Alternaria alternata, Aspergillus flavus, Aspergillus niger, Cercospora sp., Fusarium oxysporum, Penicillium egyptiacum* and *Rhizopus oryzae.*



- M. Ajmal et al. (2021) evaluated the incidence of mycobiota and contamination of AFB_1 in sesame seeds from rainfed and irrigated zones of the Punjab, Pakistan. *Aspergillus flavus* was the leading contaminant found in fresh and stored sesame seeds from rainfed and irrigated zone followed by *A. niger, Alternaria alternata* and *Fusarium oxysporum*. Least reported fungi were *Aspergillus ochraceus* and *Cladosporium oxysporum*. AFB_1 analysis revealed that 92% fresh and 99% stored samples were contaminated with AFB_1. 20% fresh and 100% stored samples from rainfed zone and 28% fresh and 60% stored samples from irrigated zone were tainted with AFB_1 levels above 20 ppb and not fit for human consumption.

PARAGUAY

- L. Ayala et al. (2010, 2011, and 2013b) in grower guides reported the following pathogen: *Fusarium oxysporum*. Prolonged rainfall and high temperatures favor *Fusarium oxysporum.*

PHILIPPINES

- N.M. Tepora (1993a) reported the following disease: *Fusarium oxysporum*. The nature of the damage is rotting and wilting of the infected plants. Control measures include seed treatment with Captan or Thiram before sowing.

REPUBLIC OF KOREA

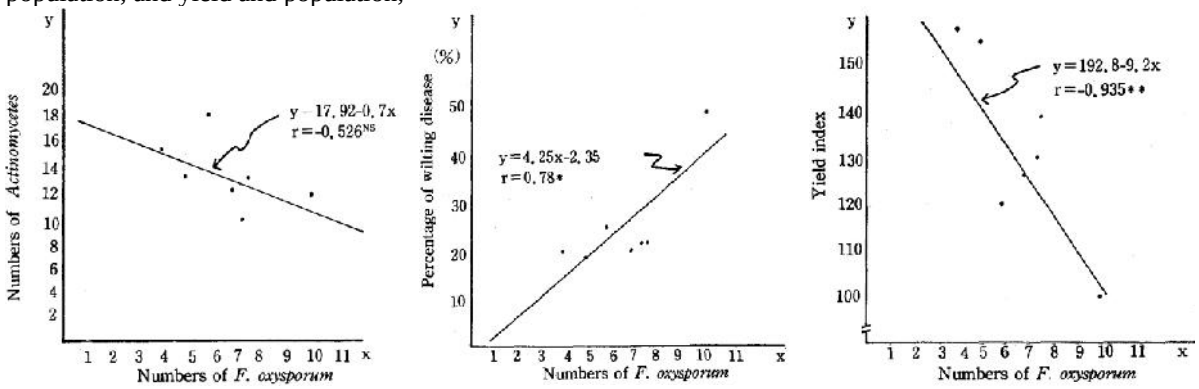
- S.H. Yu (1981) reported the following fungi in sesame seed samples *Alternaria sesami, Alternaria sesamicola, Alternaria tenuis* (*Alternaria alternata*), *Corynespora cassiicola, Alternaria longissima, Fusarium oxysporum,* and *Macrophomina phaseolina*. All were controlled by pre-treatment with chlorine, except for *Corynespora cassiicola*. [Based on abstract and cited by G.S. Saharan, 1989]
- J.I. Lee and B.H. Choi (1985h) reported that *Fusarium oxysporum* was reduced by planting under vinyl film.

- E.K. Cho and S.H. Choi (1987) reported *Fusarium* symptoms progressed from water-soaking continuous banding lesions on one side of the stem to producing abundant *Fusarium* growth on the lesion at late stage of pathogenesis. Although wilting of plants was most frequently observed in sesame seedlings when infected with *Fusarium oxysporum*, reproduction of the partial stem discoloration and rot was possible by soil inoculation and wound inoculation in old plants. The disease occurred from late July. Mycological characteristics of the isolate *Fusarium oxysporum* compared with those reported in sesame suggested that the isolate might be *F. oxysporum* f. sp. *sesami*.
- S.B. Paik et al. (1988) evaluated multiple rotations of sesame to determine the population of *Fusarium oxysporum* as shown below.

Field soil	Numbers of *F.oxysporum*/g of dry soil			
	May.30	June.30	July.30	August.30
A *	$10^3\times6.1$	$10^3\times10.1$	$10^3\times6.6$	$10^2\times7.3$
B	2.0	5.8	4.4	4.5
C	4.1	7.3	6.4	7.3
D	3.8	4.9	4.4	5.0
E	1.0	6.8	4.8	4.8
F	1.7	7.5	4.8	4.9
G	1.0	3.9	3.8	4.1

*A; Sesame, Sesame, Sesame, Sesame, Sesame. Replant
B; Sesame, Upland-rice, Sesame, Upland-rice, Sesame. Rotation
C; Sesame, Sesame, Upland-rice, Upland-rice, Sesame. Rotation
D; Sesame, Upland-rice, Upland-rice, Upland-rice, Sesame. Rotation
E; Sesame, Peanut, Sesame, Peanut, Sesame. Rotation
F; Sesame, Sesame, Peanut, Peanut, Sesame. Rotation
G; Sesame, Peanut, Peanut, Peanut, Sesame. Rotation

They also determined the relationships between *Fusarium oxysporum* and Actinomycetes, disease level and population, and yield and population,



SUDAN

- H.I.H. Idriss (2016) collected farmer saved red and white sesame from 7 locations in Sudan. 14 different fungi representing ten genera were identified. One of the low frequency fungi was *Fusarium oxysporum*.

TANZANIA

- M.M. Satour (1981) reported the presence of *Fusarium oxysporum* (Wilt).

TURKEY

- B. Uzun (pers. comm. 2016): He and M.I. Cagirgan used tolerance to *Fusarium oxysporum* in their breeding program at Adkeniz University.
- F. Akdeniz and H. Sert (2019) reported *Fusarium oxysporum* in sesame from 75 sample plants from Manavgat city.

UGANDA

- S.B. Mathur and F. Kabeer (1975) reported the following pathogen: *Fusarium oxysporum* in trace or moderate amounts in 4 genotypes.
- J.P. Egonyu (2005) reported two wilting pathogens: *Verticillium dahliae* and *Fusarium oxysporum.* The severity was significantly affected by time of planting with more wilting in later plantings as shown below.

Time of planting(WAO)	Leaf curl		Leaf spot		Wilt	
	Incidence (%)	Severity	Incidence(%)	Severity	Incidence(%)	Severity
0	16.4	3.05	84.8	2	17.1	3.62
2	29.4	4.05	70.7	1.1	29.9	1.62
4	11.5	3.76	42.1	1.	66.4	3.76
$LSD_{0.05}$	9.50	NS	9.02	0.3	7.29	0.539

WAO-Weeks after onset of rain.

The population did not have as much effect as shown below.

Density('000 plants/ha)	Leaf curl		Leaf spot		Wilt	
	Incidence (%)	Severity	Incidence(%)	Severity	Incidence(%)	Severity
40	25.7	4.4	47	2.5	55.4	4.7
50	15.4	4.7	31.8	3.3	60.6	5
60	14.3	3	50	2	71.4	4
70	23.1	5	49.3	3.3	68.7	4.7
80	22.3	3	34.3	1	56.1	5
90	30.6	5	48.9	2.8	53.8	4.3
140	16.9	4.5	50.1	1.5	56.9	5
150	26.7	5	33.3	3	73.3	5
160	26.7	3	60	2	46.7	4
170	27.7	5	56.9	2.5	55	4.5
200	26.9	4	30.8	2	61.5	5
210	15.4	4	61.2	2	34.6	5
220	36	4	52.2	1.5	31.9	4.5
410	60	5	56	4	40	5
$LSD_{0.05}$	NS	NS	NS	1.5	NS	NS

Intercropping did not have an effect as shown below.

Cropping pattern	Leaf curl		Leaf spot		Wilt	
	Incidence (%)	Severity	Incidence (%)	Severity	Incidence (%)	Severity
Sole sesame	35.4	5	41.2	2.75	52.4	4.75
Sesame + finger millet	23.4	4.33	47.7	2.45	56.4	4.64
$LSD_{0.05}$	11.3	0.63	NS	NS	NS	NS

UNITED STATES

- D.R. Langham et al. (2010c) reported sesame root rots (combination of *Fusarium oxysporum, Phytophthora parasitica*, and *Macrophomina phaseolina*) have been encountered mostly on fields where sesame is planted after sesame. The current varieties are tolerant but not resistant to the root rots. The best way to avoid sesame root rot is to rotate different crops every summer.
- D.R. Langham (2015b) USA patent descriptor: *35. Tolerance to Fusarium Wilt* (*F. oxysporum*)
  - Definition: Amount of tolerance to *Fusarium Wilt*.
  - Values: Average of a minimum of three plots of a subjective rating based on the following values: 0 to 8 scale of the % of infected plants (Intermediate values are used).
    - 8 = Zero disease
    - 7 = <10% infected
    - 4 = 50% infected
    - 1 = >90% infected
    - 0 = all infected
    - Intermediate values may be used
    - NT = not tested
    - NEC = no economic damage - not enough insects to do ratings

- Ratings can be done in several ways:
  - Take ratings after the disease is no longer increasing.
  - Take ratings on consecutive weeks until the disease is no longer increasing and average ratings.
  - Take periodic ratings and average ratings.
- Comments:
  - *Fusarium* has been a problem in South Texas, particularly on fields that have been planted with sesame before. Normally, only the *Composite Kill Tolerance* rating is taken.
  - There are three root diseases that affect sesame in Texas: *Fusarium oxysporum*, *Macrophomina phaseoli,* and *Phytophthora parasitica*. Between 1988 and the present, spores of these three have been accumulated in one small area (1 square km) north of Uvalde, and thus it is an excellent screening area for the diseases. Although each root rot disease attacks sesame in a different way and may result in different symptoms, no effort is made to definitively determine which disease is the etiological agent for the affected plants. Pathological screenings in the past have found all 3 pathogens present in dead plants.
  - The amount of kill is usually increased with any type of stress to the plants. Drought can increase the amount of *Macrophomina*; too much water can increase the amount of *Phytophthora*; high temperatures and humidity can increase the amount of *Fusarium* and *Phytophthora*. High population can increase all three diseases.
  - In most years, *Fusarium* is the major cause of kill. When sesame is first introduced into a growing area, there are few disease problems, but over time the spores of these fungi accumulate and disease tolerance becomes important. When sesame was first introduced in Uvalde in 1988, the yields were high. As farmers planted on the same fields in subsequent years, the yields decreased.

- D.R. Langham comments, 2021: My first encounter with *Fusarium oxysporum* was in 1991 in Uvalde, Texas. When moving the nurseries to Texas in 1988, J.R. Mulkey of Texas A&M reported that in his nurseries, he isolated *Macrophomina phaseolina, Phytophthora nicotianae* (known as *Phytophthora parasitica* back then), and *Fusarium oxysporum* in dead plants. He felt that probably only one of the pathogens had penetrated the plant defenses, but once that defensive line was broken, the others were able to enter the plant. He felt that *M. phaseolina* was the culprit when after starting with good moisture, a crop faced a drought. The symptoms appeared over several days. He felt that *P. nicotianae* appeared after an overirrigation or a heavy rain that resulted in puddling. The initial symptoms appeared overnight with a characteristic drooping of the top of the plant. The plant may or may partly recover. He did not have much experience with *F. oxysporum.* All 3 diseases are seedborne.

  It was 4 years before my first experience with *F. oxysporum.* I had a seed increase of Sesaco 11 in a field that had sesame 2 years before. Every day I saw more dead plants. In examining plants, the dead plants had brown streaks up the plant with a brown collar at soil level. Most plants could survive a streak up one side for a while but would eventually die. Texas A&M identified the pathogen as *Fusarium oxysporum.* My nursery was still on virgin ground, and I did not see the disease; however, the next year I went on a field that had my nursery 3 years before, and I found many lines were extremely susceptible. Here is where luck is involved. I had seed increases of Sesaco 12, which had an excellent yield and a beautiful, large seed that processors were anxious to have. There was no disease in the planting seed field, but in the nursery, Sesaco 12 died. Needless to say, the variety was never released so we never saw potentially hundreds of hectares dying.

  F. oxysporum is a more serious problem in that either too little or too much water will induce *M. phaseolina, P. nicotianae* due to a weakening of the defenses. *F. oxysporum* may attack the plants from seedlings to maturity without a weather event. Our advice to farmers was to rotate crops with at least 2 years between sesame crops, and this generally worked.

  I maintained nurseries in Uvalde within 100 meters of each other for 26 years. I would rotate the field each 3 years in order to create tremendous populations of *M. phaseolina, P. nicotianae,* and *F. oxysporum.* I would plant 'canary lines' that were very susceptible to the diseases to make sure there was pathogen pressure each year. I would discard any lines that were susceptible with the exception of crosses between tolerant and susceptible lines to move desirable traits from the susceptible line to the tolerant line. In those cases, the disease would appear in the F_1, but would often segregate in the F_2 and later generations. By the time that a variety was ready to be released, it was considered tolerant to the 3 diseases. Although this proved true for *P. nicotianae,* and *F. oxysporum*, it was not true for *M. phaseolina.* My nurseries did not provide a good screening for *M. phaseolina* because there was no drought to induce the disease.

  I feel fortunate that I have not seen large scale death from *F. oxysporum* on thousands of hectares. The screening methodology worked.

- K.A. Cochran comments, 2021: In the six years I have been in Uvalde, I have observed *F. oxysporum* is not the only Fusarium associated with sesame. After irrigation or rains, examination of plants for wilting with vascular discoloration are first steps to determine if the issue at hand is Fusarium wilt vs. another species causing root or stem rot. Further diagnostic efforts should be made with some degree of expertise utilizing microscopy, culturing, and likely DNA confirmation to ensure that the correct species is identified. Molecular identification efforts should include the most up to date primer selections from the scientific literature at the time. Genomic sequence based fungal taxonomy and resolution of genus specific genes within a database is continually improving. The soilborne nature of *F. oxysporum* can make it particularly difficult to manage, so care should be taken when moving equipment or vehicles from known infested fields to non-infested fields to prevent inadvertent spread of the pathogen. Some species of Fusarium have been recovered from seed during seed fungal assays, though it is unknown what the potential impacts of this on seedborne distribution.

VENEZUELA

- B. Mazzani et al. (1981b) reported the presence of *Fusarium oxysporum* is a permanent threat in the sesame producing regions. Such cultivars as Venezuela 51, Venezuela 52 and Caripucha were practically wiped out because of their susceptibility to *Fusarium* sp. Their place was taken by Aceitera which showed high tolerance.
- A.M. Colmenares and L. Subero (1989a) reported the following pathogen: *Fusarium oxysporum* (Fusarium wilt). The most common symptom is yellowing and wilting of the leaves on part of the plant. Necrotic bands appear afterwards in the wilted area of the plant.
- B. Mazzani (1999) reported the following pathogen: *Fusarium oxysporum.* B. Mazzani y G. Malaguti (1962d) observed resistance in *Sesamum radiatum* and Delco; some susceptibility in Aceitera, Indehiscente, and Glauca; very susceptible in Criollo, Inamar y Venezuela 52.

A1.1.1a.1 *Fusarium oxysporum* f. sp. *sesami* (7 Apr 2021)

Family: Nectriaceae

Definition: Amount of tolerance to *Fusarium oxysporum* f. sp. *sesami*.

(Anon. n.d.k) Wilt - *Fusarium oxysporum* f. sp. *sesami*

Symptoms: The disease appears as yellowing, drooping and withering of leaves. The plants gradually wither, show wilting symptoms leading to drying. The infected portions of root and stem show long, dark black streaks of vascular necrosis.

Pathogen: The fungus produces macroconidia, microconidia and chlamydospores. Macroconidia are falcate shape, hyaline and 5-9 celled. Microconidia are hyaline, thin walled, unicellular and ovoid. The dark walled chlamydospores are also produced.

Disease Cycle: The fungus survives in the soil in the infected plant debris. It is also seedborne and primary infection occurs through infected seeds or through chlamydospores in soil. The secondary infection may be caused by conidia disseminated by rain splash and irrigation water.

Management: Treat the seeds with Thiram or Carbendazim at 2g/kg; seed treatment with *Trichoderma viride* at 4g/kg; apply heavy doses of green leaf manure or farm yard manure.

References:

INTERNATIONAL

- J.R. Morschel (1964) reported the following pathogen in the world: *Fusarium oxysporum* f. sp. *sesami* (Wilt). [Cited by D.F. Beech. 1995a]
- E.A. Weiss (1971) reported *Fusarium oxysporum* f. sp. *sesami* can be devastating on susceptible varieties. The symptoms first appear on the terminal leaves, then progressively those lower down the stem. Leaves become yellowish, droop and desiccate. Severe infection can cause the entire plant to become defoliated and dried. In less severe infections or when mature plants are infected, only one side of the plant may develop symptoms. Peeling off the epidermis of the lower stem or roots will reveal blackish streaks in plant tissues. If infected plants are uprooted, roots will be rotten either wholly or partially corresponding with that side of the plants showing disease symptoms, When young plants are attacked little fruit is formed, but with more mature plants capsules are formed in which are many shriveled and underdeveloped seeds.
- C. Chattopadhyay et al. (2019) reported the following symptoms of *Fusarium oxysporum* f. sp. *sesami* (Fusarium wilt): Plants get infected at any stage of the crop development including the damping-off phase in the seedling stage. During later stages of the plant, yellowing of the leaves is the first noticeable symptom of the wilt in the field. Leaves become yellowish, droop, and desiccate. Sometimes such leaves show inward rolling of the edges and eventually dry up. The terminal portion dries up and becomes shrunken and bent over. In a severe infection, the entire plant becomes defoliated and dry. In a less severe infection or when mature plants are infected, only one side of the plant may develop symptoms, resulting in partial wilting, and a half stem rot symptom has been reported. A blackish discoloration in the form of streaks appears on infected plants. Discoloration of the vascular system is conspicuous in the roots. Roots in the later stages show rotting, wholly or partially corresponding with that side of the plant showing disease symptoms. Numerous pink pinhead-sized sporodochia (containing macroconidia of the fungus) may be seen scattered over the entire dried stem. The capsules of wilted plants also show numerous sporodochia.

  Seed treatment with benomyl or carboxin at 0.2% or with carbendazim (0.25%) or thiram (0.3%) results in significant control of the disease up to about 45 days after seed germination (Q. Ahmed et al. 1989 {Unknown}, S.I.M Shalaby 1997 {Egypt}). Balanced fertilization and insect pest control ensure good growth of the crop and help in the reduction of the disease. Trace elements such as copper, manganese, and zinc decrease the incidence of wilt of sesame (K.M.H. Abd-El-Moneem 1996 {Egypt}). In heavily infested soil, at least 5 years should elapse between two sesame crops. Cultivation of sesame in rotation with onion or wheat is helpful in the reduction of the Fusarium wilt in sesame (A. El-Kasim et al. 1991{Egypt}). Sanitation and clean cultivation and choice of sowing dates depending on the known prevailing local conditions are taken into practical use in disease management. For example, sowing the sesame crop around June 10 through hills-over-furrow and fertilizing the crop with NPK (65, 200, and 50 kg/feddan, respectively, in 0.42 ha) and giving one irrigation during the growing season in Egypt are a very useful cultural practice package for the management of the disease in sesame (O.Y.M Shalaby and A.T. Bakeer 2000 {Egypt}). Several microbial antagonists such as *Trichoderma viride* (Sangle and Bambawale 2004{India}, *Gliocladium virens* (Wuike et al. 1998 {Unknown} provide some control. Extracts of leaves of thyme, eucalyptus, and garlic reduce the incidence of Fusarium wilt disease of sesame. Extract of peppermint (*M.* x *piperita*) leaves not only reduces the wilt incidence but also increases the yield of sesame plant (A. Sidawi et al. 2010 {Unknown}).
- CAB International (accessed 12 Apr 2021) reported sesame was a host of *Fusarium oxysporum* f. sp. *sesami* (Wilt: sesame).

BRAZIL

- N.H.C. Arriel (2009) reported *Fusarium oxysporum* f. sp. *sesami*. The symptoms are characterized by the flaccidity and wilting of the plants, which later die and dry up. Through a cut transverse made on the stem of a diseased plant, it is possible to observe the blackening of the tissues of the vascular system. When the fungus establishes itself in the xylem vessels, it secretes pectolytic enzymes that act on pectic substances of vascular tissues, with the production of melanins from brown coloration that are absorbed by the lignified walls of the xylem vessels, giving way to the brown coloration that is characteristic of the presence of the disease. Fusarium is a soil fungus and lives saprophytically in debris of culture, being able to survive for long periods in the form of resistance spores (chlamydospores). Its dissemination occurs mainly through contaminated soil particles and through rainwater or irrigation; the spread over long distances is facilitated by the fact that pathogen infect seeds both internally and externally. The disease affects any stage of development, from the seedling stage to the ripening of the capsules. Low humidity, short days, less light intensity, soils poor in nitrogen and phosphorus, high potassium content and pH between 4.5 and 5.3 are factors that predispose the plant to attack by the pathogen. In addition to the use of resistant cultivars being the most efficient control, crop rotation,

disposal of crop residues, the application of dolomitic limestone, and the fertilization rich in nitrogen and phosphorus are measures that can help reduce the soil pathogen inoculum density.

CHINA

- H.M. Miao and H.Y. Liu (2010) reported the following pathogen: *Fusarium oxysporum* f. sp. *sesami.*
- Y.H. Duan et al. (2020) studied 69 *Fusarium oxysporum* isolates from the major sesame growing areas. Among these 54 isolates were pathogenic and 15 were nonpathogenic. For the pathogenic isolates, three *F. oxysporum* f. sp. *sesami* pathogenicity groups were defined based on the 3 differential sesame hosts for the first time. A translation elongation factor 1α gene tree was constructed to determine the genetic diversity of the *F. oxysporum* isolates but could not separate the pathogenic from the nonpathogenic isolates and other *F. oxysporum* formae speciales. Ten *secreted-in xylem* (*SIX*) genes (one family of effectors) were identified in *F. oxysporum* f. sp. sesami isolates by a search with the genome data and were subsequently screened in the 69 isolates. Compared with the *SIX* gene profiles in other *F. oxysporum* formae speciales, the presence and sequence variations of the *SIX* gene homologs directly correlated with the specific pathogenicity of *F. oxysporum* f. sp. *sesami* toward sesame. [Based on abstract]

EGYPT

- A.A. El-Deeb et al. (1985) reported cvs. Giza-25, Giza-24, Local-78 and Local 96 were susceptible to *Macrophomina phaseolina., Rhizoctonia solani, Fusarium* ox*ysporum* f. sp. *sesami* and *Verticilium albo-atrum*. [Cited by G.S. Saharan, 1989]
- A.A. El-Deeb (1989) studied the relationship between fertilizer levels and *Macrophomina phaseolina* (root-rot) and *Fusarium oxysporum* f. sp. *sesami* (wilt) with the following results.

Treatments			Sohag 1985				Sharkia 1986			
N	P	K	Root-rot	Wilt	Root-rot and wilt	Yield g/10 m^2	Root-rot	Wilt	Root-rot and wilt	Yield g/10 m^2
0.0	0.0	0.0	28.5	32.3	27.2	296	28.3	24.8	28.8	285
15	0.0	0.0	23.2	24.3	22.3	363	22.3	24.2	23.5	335
30	0.0	0.0	24.2	22.8	24.0	400	23.0	23.7	23.7	390
0.0	15	0.0	17.5	21.0	18.5	371	18.5	22.7	23.3	345
30	15	0.0	17.5	20.0	19.0	418	18.8	18.8	23.2	410
30	30	24	18.7	20.3	19.3	431	16.0	18.0	23.5	453
30	30	48	16.8	13.3	17.3	475	16.3	15.8	22.8	481
45	30	24	19.7	22.3	21.8	460	19.5	22.0	22.5	461
45	30	48	18.7	21.2	20.5	471	18.7	21.3	21.8	481
L.S.D. 5%			1.6	2.7	2.1	29	1.5	1.8	1.8	27

- E. Abdou et al. (2001) collected seed from several locations in Egypt. *Fusarium* was the most dominant fungi associated with the diseased sesame plants. Of 3 *Fusarium* species *Fusarium oxysporum* f. sp. *sesami* was the highest frequency, followed by *Macrophomina phaseolina, Mucor haemalis, Thielaviopsis basicola* (Wetn), and *Rhizoctonia solani*. Application of ascorbic acid or salicylic acid to seeds and/or plants reduced the number of the diseased sesame seedling plants. Treated seeds plus twice irrigation with either ascorbic acid or salicylic acid caused the best control against *F. oxysporum* f. sp. *sesami* infection as compared to the fungicide Benlate. Meantime, ascorbic and salicylic acids had less effect to control sesame damping-off and root rot wilt diseases caused by infection with *M. phaseolina, Mucor haemalis* or *Thielaviopsis basicola* as compared to Benlate. [Based on abstract]
- E. Abdou et al. (2004) reported both salicylic acid (SA) and yeast (*Saccharomyces cerevisiae*) seed treatments affected incidence of wilt and root rot of sesame incited by *Fusarium oxysporum* f. sp *sesami*, *Macrophomina phaseolina*, *Thielaviopsis basicola,* and *Mucor haemalis*. Also, yeast derivatives variously affected root rot/wilt severity. Combining SA with yeast or with its derivatives showed, in most cases, inhibition effects against the tested pathogenic fungi. [Based on abstract]
- M.A.S. El-Bramawy (2006a) screened lines of two generations (F_3 and F_4) from 15 crosses for two successive seasons (2004 and 2005) for their reaction to *Fusarium* wilt disease under natural infection by *Fusarium oxysporum* f. sp. *sesami*. Selection for both *Fusarium* wilt resistance and seed yield from these lines could be feasible and lead to resistant cultivars with seed yield potential. The results showed highly significant and positive correlations between lower infection in the F_4's and in F_3's through the two seasons. The highest significant correlation of the evaluated traits allowed the selection of some lines to be used in breeding programs.

- M.S. Abdel-Salam et al. (2007) reported *Enterobacter cloacae* and *Pseudomonas aeruginosa* control the soilborne plant pathogen *Fusarium oxysporum* f. sp. *sesami.*
- M.A.S. El-Bramawy et al. (2009a) posited that there may be a linkage between morphological traits and tolerance to *Macrophomina phaseolina* and *Fusarium oxysporum* f. sp. *sesami.* They evaluated 48 genotypes in 2005 and 20006 and determined there was a linkage between tolerance with medium branch number, medium maturity, and creamy seed color as shown below.

Variables	Infection percentage			
	2005		2006	
	regression equation	R^2	regression equation	R^2
F. oxysporum f.sp. *sesami*				
Branch number	$Y = 37.8 - 9.5\,X + 1.33\,X^2$	0.12^{*}	$Y = 21.0 - 5.0\,X + 1.0\,X^2$	0.27^{**}
Days to maturity	$Y = 526.3 - 8.4\,X + 0.04\,X^2$	0.01^{ns}	$Y = 692.9 - 11.4\,X + 0.05\,X^2$	0.04^{ns}
Seed colour	$Y = 53.8 - 35.5\,X + 9.4\,X^2$	0.20^{**}	$Y = 39.2 - 29.0\,X + 9.0\,X^2$	0.20^{**}
M. phaseolina				
Branch number	$Y = 35.2 - 7.2\,X + 0.9\,X^2$	0.07^{ns}	$Y = 20.8 - 3.1\,X + 0.6\,X^2$	0.06^{ns}
Days to maturity	$Y = 499.5 - 8.1\,X + 0.04\,X^2$	0.02^{ns}	$Y = 296.1 - 4.1\,X + 0.02\,X^2$	0.01^{ns}
Seed colour	$Y = 34.4 - 17.8\,X + 5.5\,X^2$	0.18^{*}	$Y = 22.2 - 10.8\,X + 4.2\,X^2$	0.14^{*}

- A.F. Sahab et al. (2010) studied the effects of sulphur on *Fusarium oxysporum* f. sp. *sesami*. In the lab, different concentrations of sulphur (62.5, 125, 250, 500, 1000, and 2000 ppm) slightly reduced both linear growth and sporulation than the control as shown below.

Characters	**Sulphur concentration (ppm)**						
	0	**62.5**	**125**	**250**	**500**	**1000**	**2000**
Linear growth (cm)	7.30 a	6.8 b	6.5 b	6.3 d	6.6 c	6.3 d	6.4 d
Conidia ($1x10^5$/cm²)	11.59 a	5.92 b	4.47 bc	3.23 c	2.56 d	2.65 d	2.04 d

In each row ,values followed by the same letter are not significantly different at *P≥0.05* according to Duncan's multiple test

In a pot experiment, addition of sulphur to infested soil before sowing at the rates of 62.5, 125, and 250 kg/feddan significantly reduced the percentage of wilted plants and disease severity than the control as shown below.

Sulphur	**Wilt incidenc**			**Morphological characters/plant**				
Kg/feddan	**Disease%**	**D. severity**		**Length (cm)**		**Dry weight (g)**		**No. of pods**
		shoot	**Root**	**shoot**	**Root**	**shoot**	**Root**	**/plant)**
0	**75.0 a**	**3.7 a**	**3.0 a**	**76.5 a**	**4.5 a**	**1.3c**	**0.18 b**	**1.3 c**
62.5	**32.5 d**	**1.6 c**	**1.3 d**	**67.7 a**	**4.5 a**	**2.3 a**	**0.39 a**	**2.5 a**
125	**52.5 c**	**2.6 b**	**2.1 c**	**72..3 a**	**4.5 a**	**1.68 b**	**0.20 b**	**1.6 b**
250	**65.0 b**	**2.9 b**	**2.5 b**	**73..9 a**	**4.0 b**	**1.58 b**	**0.38 a**	**1.3 c**

* In each row, values followed by the same letter are not significantly different at *P≥0.05* according to Duncan's multiple test .

In a field experiment, soil drenched with sulphur at rates of 62.5, 125, and 250 kg/feddan significantly decreased the percentage of wilt disease incidence as shown below.

Sulphur Kg/feddan	Disease %	Disease severity	Seed yield (ardab /feddan)
0	27.3 a	4.3 a	1.93 d
62.5	10.5 c	2.9 b	2.88 a
125	14.5 b	3.9 a	2.37 b
250	16.6 b	4.1 a	2.11 c

*In each column ,values followed by the same letter are not significantly different at $P \geq 0.05$ according to Duncan's multiple test

- M.A.S. El-Bramawy (2011) studied the relationship between tolerance to *Macrophomina phaseolina* and *Fusarium oxysporum* f. sp. *sesami* and levels of anti-nutritional factors (phytate, trypsin inhibitor and tannins) in 2009 and 2010 using 48 genotypes. He classified the lines in different groups (resistant, moderately resistant, moderately susceptible and susceptible) and determined the following regressions.

Sesame genotypes group	Anti-nutritional factors	
	2009	2010
	Regression equation (R^2)	Regression equation (R^2)
	Phytic acid	
Resistant (R)	0.62**	0.57**
Moderately resistant (MR)	0.11^{ns}	0.04^{ns}
Moderately susceptible (MS)	0.31**	0.29**
Susceptible (MS)	0.19*	0.12*
	Trypsin inhibitor	
Resistant (R)	0.22*	0.20*
Moderately resistant (MR)	0.21*	0.01^{ns}
Moderately susceptible (MS)	0.45**	0.39**
Susceptible (MS)	0.14*	0.16*
	Tannins	
Resistant (R)	0.52**	0.60**
Moderately resistant (MR)	0.25 *	0.21*
Moderately susceptible (MS)	0.61**	0.55**
Susceptible (MS)	0.42**	0.34**

- I.S. Elewa et al. (2011) evaluated the effects of *Bacillus subtilis* and *Trichoderma viride*, a virulent *Fusarium oxysporum*, and *Glomus* spp. (a Vesicular arbuscular mycorrhizae fungus [VAM]) isolates and a fungicide (Benlate) on *Fusarium oxysporum* f. sp. *sesami* and *Macrophomina phaseolina*. The results were as follow.

Soil infestation	Treatment	Wilt and root-rot	
	Transplants	Infection %	Disease severity
F. oxysporum	Control	37.5 a	1.87 a
	B. subtilis	33.3 b	1.66 b
	Avirulent *F. oxysporum*	24.9 c	1.25 c
	T. viride	24.9 c	1.25 c
	(VAM)	16.6 d	0.83 d
	Benlate (0.1%)	16.6 d	0.83 d
M. phaseolina	Control	33.3 a	1.66 ab
	B. subtilis	16.6 d	0.83 d
	Avirulent *F. oxsporum*	8.3 e	0.42 e
	T. viride	16.6 d	0.63 e
	(VAM)	12.5 d	0.62 e
	Benlate (0.1%)	16.6 d	0.83 d
F. oxysporum + *M. phaseolina*	Control	20.8 ab	1.04 bcd
	B. subtilis	12.5 d	0.62 e
	Avirulent *F. oxysporum*	12.5 d	0.62 e
	T. viride	16.6 d	0.83 d
	(VAM)	8.3 e	0.42 e
	Benlate (0.1%)	12.5 d	0.62 e

- E.H. Ziedan et al. (2011) evaluated the effects of *Bacillus subtilis* and *Trichoderma viride*, and *Glomus* spp. (a Vesicular arbuscular mycorrhizae fungus [VAM]) isolates on *Fusarium oxysporum* f. sp. *sesami* and *Macrophomina phaseolina*. The effects on *Fusarium oxysporum* f. sp. *sesami* in the pot experiments were as follow.

Treatments	Wilt disease incidence		Morphological characters/plant		
	% of diseased plants	disease severity	length [cm]	fresh weight [g]	No. of pods
Control	79.2 a	4.0 a	68.3 d	7.4 d	6.0 c
B. subtilis	66.7 ab	3.3 b	80.0 c	11.7 c	6.7 c
T. viride	50.0 b	2.5 c	103.8 ab	12.6 c	14.7 b
VAM	50.0 b	2.5 c	80.0 c	14.4 c	6.8 c
VAM + *B. subtilis*	29.2 d	1.5 d	115.6 a	18.7 b	19.0 a
VAM + *T. viride*	36.7 c	1.3 d	93.3 b	15.0 c	14.0 b
VAM + *B. subtilis* + *T. viride*	37.5 c	1.1 d	106.0 ab	25.3 a	20.0 a

The effects on *Macrophomina phaseolina* in the pot experiments were as follow.

Treatments	Root-rot incidence		Morphological characters /plant		
	% of diseased plants	disease severity	length [cm]	fresh weight [g]	No. of pods
Control	91.7 a	4.6 a	77.5 c	5.52 d	4.61 f
B. subtilis	50.0 c	2.5 c	101.9 a	19.4 a	12.6 b
T. viride	45.8 d	2.3 c	101.3 a	18.1 a	10.3 c
VAM	45.8 d	2.5 c	80.0 b	8.1 c	6.0 e
VAM + *B. subtilis*	45.8 d	2.4 c	104.4 a	18.2 a	9.8 d
VAM + *T. viride*	43.7 b	3.3 b	104.2 a	17.7 b	9.5 d
VAM + *B. subtilis* + *T. viride*	41.7 c	2.1 d	103.8 a	19.3 a	13.0 a

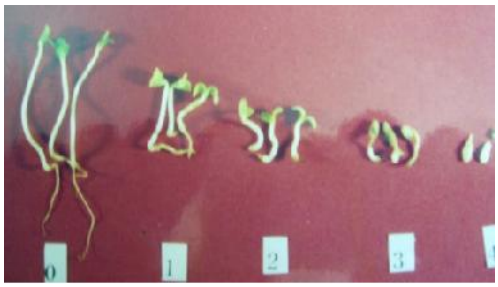
The effects from *Fusarium oxysporum* f. sp. *sesami* and *Macrophomina phaseolina* on seedlings in the field experiments were as follow.

Treatments	Wilt and root-rot incidence		
	% of survival plants	% of diseased plants	disease severity
Control	51.0 d	55.9 a	2.8 a
B.subtilis	54.1 c	50.0 b	2.5 b
T.viride	67.5 b	39.2 c	1.9 c
VAM	56.7 c	48.4 bc	2.4 b
VAM + *B. subtilis*	66.6 b	34.2 cd	1.7 c
VAM + *T. viride*	79.3 a	23.3 e	1.2 e
VAM + *B. subtilis*+ *T. viride*	76.0 a	30.9 d	1.5 cd

The effects from *Fusarium oxysporum* f. sp. *sesami* and *Macrophomina phaseolina* on the yield components in the field experiments were as follow.

Treatments	Shoot		Root size	Number/plant		Seed yield aradeb/ feddan	Oil [%]
	length [cm]	diameter [cm]		branches	pods		
Control	185.0 e	1.76 d	25.0 f	3.75 f	112.5 e	2.53 d	59.5
B. subtilis	196.3 c	1.99 b	50.0 b	5.3 e	197.5 c	4.55 c	56.9
T. viride	180.0 d	1.88 c	35.0 d	7.5 b	212.5 b	4.91 c	57.8
VAM	195.0 c	1.85 c	30.0 e	5.0 e	160.0 d	5.14 b	57.4
VAM + *B. subtilis*	210.0 a	1.77 d	35.0 c	6.75 c	196.3 c	4.95 c	57.1
VAM + *T. viride*	202.5 b	1.82 c	47.5 b	6.0 d	198.0 c	5.05 b	57.2
VAM + *B. subtilis* + *T. viride*	202.5 b	2.33 a	70.0 a	8.5 a	232.5 a	5.79 a	57.8

- E.H. Ziedan et al. (2012) evaluated the effects of biofertilizers (Phosphoren - *Bacillus megatherium*, *Azospirillium brasilense* - Cerialin, rhizobacterin and blue green algae) in combination with a fungicide (Topsin) on sesame as affected by *Fusarium oxysporum* f. sp. *sesami* using the following disease severity criteria.



The following were the results of the *in vitro* studies.

Treatment	Disease %	*D.severity
Control	85.0 a	3.4 a
Topsin	49.0 c	2.0 b
Blue green algae	49.0 c	2.0 b
Rhizobacteren	56.0 b	1.2 c
Cerialin	55.0 b	2.2 b
Phosphoren	38.0 d	1.5 bc
Cerialin + Topsin	25.0 e	1.0 c
Phosphoren + Topsin	44.0 c	1.8 b
Cerialin + phosphoren	09.0 f	0.4 d
Cerialin + phosphoren + Topsin	00.0 g	0.0 e

The following table shows the effects when the materials were transplanted to the field.

Treatment	Survival plant %	Wilt incidence	
		Infection %	D.severity
Seed cultivation			
Seed coated V./Captan	35.3 e	81.0 a	4.1 a
Transplanting cultivation			
Control	50.7 d	56.9 b	2.8 b
Topsin	63.7 c	45.6 c	2.3 b
Cerialin	67.9 c	36.0 d	1.8 c
Phosphoren	59.7 d	47.1 c	1.7 c
Cerialin + Topsin	74.8 b	29.8	1.5 c
Phosphoren + Topsin	70.0 b	33.6 d	1.3 cd
Cerialin + phosphoren	85.3 ab	19.1 e	1.0 d
Cerialin + phosphoren + Topsin	97.8 a	17.5 e	0.9 d

The following table shows the effects on yield components.

Treatment	Shoot lengh (cm)	No branch	No pods	Seed yield aradeb/ feddan
Seed cultivation				
Seed coated V./Captan	125.0	2.3 e	33.3 f	2.7 c
Transplanting cultivation				
Control	133.3	4.0 cd	70.0 e	2.7 c
Topsin	131.0	4.6 c	105.0 d	3.0 b
Cerialin	130.0	4.6	108.3	3.4 b
Phosphoren	135.0	5.0 bc	105.0 d	3.4 b
Cerialin + Topsin	135.0	5.7 a	108.0	4.1 a
Phosphoren + Topsin	133.3	4.3 d	138.7 c	4.2
Cerialin + phosphoren	135.0	6.0	147.0	4.4 ab
Cerialin + phosphoren + Topsin	128.3	6.3 b	203.3 a	4.6 b

- M.M. Amin et al. (2017) reported *Bacillus megaterium* var. *phosphaticum* (BMP) have been used to control sesame wilt disease caused by *Fusarium oxysporum* f. sp. *sesami* in the presence of different doses of calcium super phosphate (CSP) at two successive seasons (2014 and 2015) using Giza 32. CSP was added with soil preparation at the rate of 1, 2, 3 and 4 gm/pot and 50, 100, 150 and 200 kg/fed under greenhouse and field conditions, respectively. The greenhouse results were as follow, which includes the use of a fungicide – Topsin M-70%.

Treatment	2014	2015	Mean	Decrease (%)
BMP* + 1 gm CSP**	63.35	63.35	63.35	22.40
BMP + 2 gm CSP	60.02	56.67	58.35	28.53
BMP + 3 gm CSP	50.01	43.32	46.66	42.84
BMP + 4 gm CSP	40.00	36.64	38.32	53.06
4gm CSP	43.33	46.66	45.00	44.88
BMP	63.36	66.70	65.03	20.34
Topsin M-70%	40.00	43.32	41.66	48.97
Control	79.97	83.30	81.64	-
L.S.D. at 5%	11.53	10.76	-	-

BMP* *Bacillus megaterium var. phosphaticum*and as seed dressing, CSP** calcium super phosphate/pot

The field results were as follow.

Treatment	2014	2015	Mean	Decrease (%)
BMP* + 50 kgCSP**	41.40	42.70	42.04	26.85
BMP + 100 kgCSP	39.65	41.76	40.70	29.18
BMP + 150 kgCSP	38.25	40.70	39.48	31.31
BMP + 200 kgCSP	35.70	36.80	36.25	36.92
200 kgCSP	41.05	39.65	40.35	29.79
BMP	40.00	41.05	40.53	29.48
Topsin M-70%	26.60	27.50	27.05	52.93
Control	56.06	58.88	57.47	-
L.S.D. at 5%	1.17	1.63	-	-

BMP* *Bacillus megaterium var. phosphaticum*and as seed dressing, CSP** calcium super phosphate/fed

The yields and oil contents in the field were as follow. There is additional data on plant height, number of capsules/plant, number of branches/plant, and shoot content of N, P, and K.

Treatment	Seed yield (arddab/fed)				Oil content %			
	2014	2015	Mean	Increase (%)	2014	2015	Mean	Increase (%)
BMP* + 50 kgCSP**	3.00	3.20	3.10	18.10	52.00	54.00	52.99	4.56
BMP + 100 kgCSP	3.08	3.65	3.36	28.10	53.88	54.13	54.00	6.56
BMP + 150 kgCSP	3.50	3.83	3.66	39.52	56.20	55.88	56.04	10.58
BMP + 200 kgCSP	4.33	4.55	4.44	69.05	56.58	55.00	55.79	10.09
200 kgCSP	3.25	3.63	3.44	30.95	57.25	56.75	57.00	12.48
BMP	3.28	3.48	3.38	28.57	56.25	55.70	55.98	10.46
Topsin M-70%	3.05	3.25	3.15	20.00	53.63	52.30	52.96	4.51
Control	2.58	2.68	2.63	-	50.50	50.85	50.68	-
L.S.D. at 5%	0.38	0.25	-	-	1.53	1.41	-	-

BMP* *Bacillus megaterium var. phosphaticum*and as seed dressing, CSP** calcium super phosphate/fed

- A.F. Mahmoud and O.A. Abdalla (2018) evaluated the antagonistic capability of 24 isolates of *Trichoderma spp*. (*T. hamatum, T. harzianum, T. virens,* and *T. viride*) *in vitro* against *Fusarium oxysporum* f. sp. *sesami* (Fos).

Trichoderma strains	Bioagent No.	Colony diameter of *F. ox.* f.sp. *sesami* (cm)*	Inhibition of *F. ox.* f.sp. *sesami* growth (%)
Trichoderma hamatum	T1	4.15 ^{CDE}	53.88 ^{CDE}
	T2	3.85 ^{DE}	57.22 ^{DE}
	T3	3.77 ^{DE}	58.05 ^{DE}
	T4	4.40 ^{CD}	51.11 ^{CD}
	T5	3.82 ^{DE}	57.50 ^{DE}
Average		3.998	55.557
Trichoderma harzianum	T6	3.72 ^{DE}	58.61 ^{DE}
	T7	3.65 ^{DEF}	59.44 ^{DEF}
	T8	3.92 ^{DE}	56.38 ^{DE}
	T9	2.90 ^{FG}	67.77 ^{FG}
	T10	4.20 ^{CDE}	53.33 ^{CDE}
	T11	4.37 ^{CD}	51.38 ^{CD}
	T12	4.25 ^{CDE}	52.77 ^{CDE}
Average		3.858	57.09
Trichoderma virens	T13	4.32 ^{CD}	51.94 ^{CD}
	T14	4.75 ^{BC}	47.22 ^{BC}
	T15	4.77 ^{BC}	46.94 ^{BC}
	T16	4.12 ^{CDE}	54.16 ^{CDE}
Average		4.49	50.06
Trichoderma viride	T17	4.22 ^{CDE}	53.05 ^{CDE}
	T18	4.57 ^{BC}	49.16 ^{BC}
	T19	4.12 ^{CDE}	54.16 ^{CDE}
	T20	4.25 ^{CDE}	52.77 ^{CDE}
	T21	2.67 ^{G}	70.27 ^{G}
	T22	3.95 ^{DE}	56.11 ^{DE}
	T23	4.07 ^{CDE}	54.72 ^{CDE}
	T24	3.52 ^{EF}	60.83 ^{EF}
Average		3.921	56.38
Control		9.00 A	

*Means within the same column followed by different letters are significantly different at *5% significant level*.

Two strains of *T. harzianum* and *T. viride* had high antagonistic effect against *F. oxysporum* f. sp. *sesami in vitro* with inhibition percentage about 70 and 67%, respectively. These two isolates proved to have high ability to control Fusarium wilt disease under greenhouse conditions as shown below.

Bioagent	Application time	Seedling emergence (%)*	Increase in seedling emergence (%)	Disease severity (%)*	Reduction in disease severity (%)
Application of *T. harzianum* (T9)	7 days *before* challenging with Fos	87.25^{C}	54.42 ^{C}	22.50 ^{D}	74.71 ^{D}
	At the same time with Fos	79.50 ^{D}	40.70 ^{D}	35.25 ^{BC}	60.39 ^{BC}
	7 days *after* challenging with Fos	70.50 ^{E}	24.77 ^{E}	40.50^{B}	54.49 ^{B}
	Average	79.08	39.96	32.75	63.19
Application of *T. viride* (T21)	7 days *before* challenging with Fos	93.75^{B}	65.92 ^{B}	20.25 ^{D}	77.24^{D}
	At the same time with Fos	84.50 ^{C}	49.55 ^{C}	32.75 ^{C}	63.20 ^{C}
	7 days *after* challenging with Fos	80.75 ^{D}	42.92 ^{D}	38.00^{BC}	57.30 ^{BC}
	Average	86.33	52.79	30.33	65.91
Infected	Challenging with Fos	56.50^{F}	0.00 ^{F}	89.00^{A}	0.00 ^{A}
Healthy	Uninfected control	100^{A}	0.00 ^{A}	0.00 ^{E}	0.00 ^{E}

*Means within the same column followed by different letters are significantly different *at 5 % significant level*.

- M.G.A. Hegazy et al. (2019) evaluated the effects of biocontrols (*Alternaria alternate, Aspergillus* spp. and *Penicillium* spp.) on *Fusarium oxysporum* f. sp. *sesami* with the following results.

Isolate No.	Endophytic fungi isolate	Average of inhibition zone diameter (mm)
1	*Alternaria alternate*	1.5 ^{ef}
2	*Aspergillus clavatus*	9.2 ^{b}
3	*Aspergillus fumigatus*	0.8 ^{ef}
4	*Aspergillus niger*	11.6 ^{a}
5	*Aspergillus sydowii*	1.3 ^{ef}
6	*Aspergillus terreus* $_{(1)}$	2.3 ^{e}
7	*Aspergillus terreus* $_{(2)}$	5.9 ^{cd}
8	*Penicillium chrysogenum* $_{(1)}$	9.2 ^{b}
9	*Penicillium chrysogenum* $_{(2)}$	2.3 ^{e}
10	*Penicillium crustosum* $_{(1)}$	7.1 ^{bc}
11	*Penicillium crustosum* $_{(2)}$	8.2 ^{b}
12	*Penicillium crustosum* $_{(3)}$	2.8 ^{e}
13	Control	0.0 ^{f}

Means followed by the same letters (s) in a column are not significantly different at ($p \leq 0.05$) according to Duncan's multiple-range test.

The species with the highest levels of inhibition were further tested using different concentrations.

Endophytic fungi	Concentration (%)	Average of colony diameter (mm)	Inhibition (%)
Aspergillus niger	1	73.30	18.55 ^{i}
	2	69.30	23.00 ^{ghi}
	5	63.30	29.66 ^{fgh}
	10	57.00	36.66 ^{ef}
	20	45.00	50.00 ^{d}
Aspergillus terreus $_{(1)}$	1	68.30	24.11 ^{ghi}
	2	55.00	38.88 ^{e}
	5	45.00	50.00 ^{d}
	10	36.60	59.33 ^{bc}
	20	26.60	70.44 ^{a}
Aspergillus terreus $_{(2)}$	1	73.30	18.55 ^{i}
	2	65.30	27.44 ^{gh}
	5	56.60	37.11 ^{ef}
	10	43.30	51.88 ^{cd}
	20	33.30	63.00 ^{ab}
Penicillium chrysogenum $_{(1)}$	1	75.00	16.66 ^{i}
	2	70.00	22.22 ^{hi}
	5	62.00	31.11 ^{efg}
	10	55.00	38.88 ^{e}
	20	44.00	51.11 ^{cd}
Control		90.00	00.00 ^{j}

Means followed by the same letters (s) in a column are not significantly different at ($p \leq 0.05$) according to Duncan's multiple-range test.

The species were then used in the greenhouse with the following results.

Treatments	Disease Severity (%)	Plant growth parameters					
		Shoot			Root		Number of bods
		Plant height (cm)	Fresh weight (g)	Dry weight (g)	Fresh weight (g)	Dry weight (g)	
Aspergillus niger	36 ^{c}	73 ^{ab}	11.8 ^{b}	3.66 ^{b}	3.33 ^{c}	1.3 ^{c}	10 ^{c}
Aspergillus terreus $_{(1)}$	41 ^{bc}	83 ^{b}	19 ^{a}	4.66 ^{a}	7.83 ^{a}	3.43 ^{a}	16 ^{a}
Aspergillus terreus $_{(2)}$	52 ^{b}	96 ^{a}	10.3 ^{bc}	3 ^{c}	7.6 ^{a}	2.66 ^{b}	11 ^{b}
Penicillium chrysogenum $_{(1)}$	38.6 ^{bc}	85 ^{b}	10.6 ^{bc}	2.2 ^{d}	6.66 ^{ab}	1.46 ^{c}	10 ^{c}
Control (untreated)	94.3 ^{a}	56 ^{c}	9.6 ^{c}	2 ^{c}	4 ^{b}	1.16 ^{c}	9 ^{d}

Means followed by the same letters (s) in a column are not significantly different at ($p \leq 0.05$) according to Duncan's multiple-range test.

The species were then compared to using *Trichoderma* spp. alone or in combination with the following results.

Treatments	Disease Severity (%)	Growth parameters					
		Shoot			Root		Number of bods
		Shoot height (cm)	Fresh weight (g)	Dry weight (g)	Fresh weight (g)	Dry weight (g)	
A. niger + *Trichoderma* sp.	16 ^{c}	91.3 ^{b}	24.6 ^{c}	9.6 ^{b}	14.6 ^{b}	7.1 ^{b}	8 ^{c}
A. terreus $_{(1)}$ + *Trichoderma* sp.	25.3 ^{bc}	84 ^{c}	27 ^{b}	8.5 ^{c}	15.3 ^{b}	5.6 ^{c}	12 ^{b}
A. terreus $_{(2)}$ + *Trichoderma* sp.	46.6 ^{a}	84 ^{c}	27.5 ^{b}	7.6 ^{d}	13 c	5.4 ^{c}	6 ^{d}
P. chrysogenum $_{(1)}$ + *Trichoderma* sp.	36 ^{ab}	80 ^{d}	17.5 ^{d}	6 ^{e}	9.3 ^{d}	3.5 ^{d}	13 ^{a}
Control (*Trichoderma* sp. only)	13.3 ^{c}	98 ^{a}	42.3 ^{a}	12.6 ^{a}	25.6 ^{a}	14.3 ^{a}	12 ^{b}

- M.A.A. Hassan et al. (n.d.) evaluated the pathogenicity *in vivo* of 8 Fusarium isolates taken from infected sesame plants with the following results. [Authors comment: Assume *F. clmourum* is *F. culmorum.*]

Fungal isolates	Damping-off (%)		Survival plants (%)	Wilt disease		Root rot disease	
	Pre-	Post-		Incedance (%)	Severity (%)	Incedance (%)	Severity (%)
F. oxysporum							
1	7.50	17.50	75.00	48.16	34.75	8.00	3.7
2	10.00	25.00	65.00	88.09	61.35	12.00	5.9
3	5.00	17.50	77.50	58.48	38.75	9.50	3.3
F. solani							
1	32.50	15.00	52.50	10	5.1	27.5	10
2	30.50	14.00	55.50	7.5	3.9	15	17.3
3	31.50	13.00	55.50	19.1	4.3	22	15.8
F. climourum							
1	30.00	37.50	32.50	0.00	0.00	0.00	0.00
2	28.00	35.00	37.00	0.00	0.00	0.00	0.00
Control*	2.50	0.00	97.50	0.00	0.00	0.00	0.00
L.S.D. at 5%	7.90	7.90	12.41	13.51	5.37	12.46	4.25

*Non-infested plants, healthy plants. The significant differences between means compared by LSD at $p \leq 0.05$, NS, not significant

In another experiment, they reported the current study suggested that using the preceding onion and garlic plants could be used for eco-friendly reduction of damping-off and wilt disease of sesame.

Preceding crops	2019				2020				Mean			
	Damping-off %		Survival plants %	Wilt %	Damping-off %		Survival plants %	Wilt %	Damping-off %		Survival plants %	Wilt %
	Pre-	Post-			Pre-	Post-			Pre-	Post-		
Clover	19.26a	9.26a	71.48a	41.66a	22.57a	12.21a	65.22a	48.94a	20.92a	10.74a	68.35a	45.30a
White	14.45b	5.57b	79.98b	21.35b	16.49b	7.40b	76.11b	25.29b	15.47b	6.49b	78.05b	23.32b
Garlic	13.71bc	4.44bc	81.85bc	18.24bc	12.95bc	5.18bc	81.57bc	21.66bc	13.33bc	4.81bc	81.71bc	19.95bc
Onion	12.96c	4.07c	82.97c	16.15c	15.45c	5.55c	78.91c	19.78c	14.21c	4.81c	80.94c	17.96c

Values within columns followed by different lowercase letters are significantly different (LSD; $p < 0.05$).

In another experiment, they reported the antagonistic effect of *in vitro* biocontrol agents against *Fusarium oxysporum* f. sp. *sesami.*

Microorganism	Isolate No.	*Fusarium* growth (mm)	Reduction (%)
Bacillus subtilis	1	7.807a	11.93d
	2	6.889b	21.11b
	3	6.445b	25.55a
	4	7.361ab	16.39c
	5	7.028ab	19.72b
	Mean	**7.106**	**18.94**
Streptomyces rochei	1	6.838ab	21.62b
	2	7.415a	15.85c
	3	3.89b	51.10a
	Mean	**6.048**	**29.52**
Pseudomonas fluorescens		4.4	**45.8**
Trichoderma viride		2.3	**66.84**
Control		9	0.00
L.S.D. 0.05		4.49	

The significant differences between means compared by LSD at $p \leq 0.05$, NS, not significant

In another experiment, they reported the antagonistic effect of biocontrol agents against *Fusarium oxysporum* f. sp. *sesami* in the field.

Biocontrol agents	2019				2020				Mean			
	Damping-off (%)		SurvivalPlants	Wilt %	Damping-off(%)		Survival Plants	Wilt %	Damping-off (%)		Survival Plants	Wilt %
	Pre-	Post-			Pre-	Post-			Pre-	Post-		
B. subtilis	4.16	3.32	93.82	18.09	5.27	4.15	91.88	18.65	4.72	3.74	94.85a	18.37c
P. fluorescens	4.72	4.17	91.11	25.32	6.39	3.89	89.72	23.80	5.56	4.03	90.42b	24.56b
T. viride	3.06	2.22	94.72	16.99	4.17	3.05	92.78	17.55	3.62	2.64	93.75ab	17.27c
Control	18.61	26.39	55.00	57.96	22.22	29.17	48.61	67.00	20.42	27.78	51.81c	62.48a
L.S.D. at 5%	2.92	3.42	6.25	4.14	2.75	4.13	5.18	6.50	2.84	3.78	5.72d	5.32

Means with different lowercases indicate significant differences at $p \leq 0.05$

ETHIOPIA

- B.K Yirga and B. Fiseha (2017a) reported the following pathogen: *Fusarium oxysporum* f. sp. *sesami* (Fusarium wilt).
- B.K Yirga et al. (2018a) surveyed 10 locations representative low land areas of western zone of Tigray for 3 years (2015, 2016, and 2017). *Xanthomonas campestris* pv. *sesami* - bacterial blight (83.24%) recorded the

highest disease incidence followed by *Sphaerotheca fuliginea* - powdery mildew (78.13%), *Fusarium oxysporum* f. sp. *sesami* - fusarium wilt (78%), phyllody (72.01%) and *Alternaria* spp. - blight leaf spot (72%). Whereas blight leaf spot recorded highest severity (31.33%), followed by fusarium wilt (27.2%), phyllody (25.24%), bacterial blight (22.76%) and powdery mildew (22.6%). The phyllody is vectored by *Orosius albicinctus.*

- B.K. Yirga et al. (2018b) evaluated 17 sesame genotypes in northern Ethiopia during 2014-2015 main seasons against *Fusarium oxysporum* f. sp. *sesami* - fusarium wilt. Fusarium severity was recorded from 5%-100% range among genotypes. HuRC-2, Acc 227880, Setit -1, Hirhir, HuRC-3, HuRC-4 and ACC202514 were among the resistant (R) sesame genotypes. Whereas Gumero, Acc 202300, Kefif, Acc 111518, Land race Gumero were the highest susceptible (HS) genotypes for fusarium disease across the tested environments and years. HuRC-4 and HuRC3 genotypes were found resistant to bacterial blight, fusarium wilt and phyllody. Those genotypes could be used for diseases resistant breeding program across different locations.

GREECE

- C.C. Thanassoulopoulos (1963) reported *Fusarium oxysporum* f. *sesami* is newly recorded for Greece.

INDIA

- T. Singh and D. Singh (1983) isolated 24 fungi: Of these, *Fusarium oxysporum* f. sp. *sesami* was an important pathogens. [Cited by G.S. Saharan, 1989]
- M.L. Verma (1985) reported *Fusarium oxysporum* f. sp. *sesami* (Wilt) is a major disease with the following symptoms: Yellowing, drooping. Withering of first lower leaves then upper leaves. Top of stem bent down and dries. Brown discoloration on roots to tip, blackening of stem.
- A.R. Wasnikar et al. (1987) reported the influence of fungi varied for seed and soil contamination. Among four fungi, *Fusarium oxysporum* f. sp. *sesami* caused maximum mortality: seed = 72 and soil = 64%. [Based on abstract]
- A.R. Wasnikar et al. (1988) reported media were prepared with various C and N contents. In general, growth of *Alternaria sesami*, *Fusarium oxysporum* f. sp. *sesami*, *Helminthosporium sesami* and *Myrothecium roridum*, the most important pathogens of sesame, increased with C and N concentrations. [Based on abstract]
- K.S. Raghuwanshi et al. (1992a) evaluated the effects of 17 fungicides (Agrosan Gn, Aureofungin, Benlate, Delsan, Dithane M-45, Ridomil, Rovral, Thiran, Vitavax, Aliette, Bavistin, Captan, Delsan, Dithan Z-78, RH-124, Saprol, and Topsin) on *Fusarium oxysporum* f. sp. *sesami* using the poisoned food technique. Topsin, Aliette, Benlate, RH-24, and Bavistin were found considerably more effective in inhibiting mycelial growth. In field trials, Topsin, Rovral, Vitavax, Delsan, and Saprol reduced percent mortality.
- K.S. Raghuwanshi et al. (1992b) screened 47 germplasm entries under natural field conditions against *Fusarium oxysporum* f. sp. *sesami* using a 0-4 scale from no symptoms to susceptible. There were no immune lines, 11 were moderately resistant (1-10% infection), 23 field tolerance (11-20%), 11 moderately susceptible (21-50%), and 2 were susceptible (>50%).
- K.S. Raghuwanshi et al. (1992c) screened seeds from 21 varieties/cultivars for *Fusarium oxysporum* f. sp. *sesami* using the standard blotter method and inspecting the seeds 7 days after incubation at 27 ± 2°C using stereoscopic microscope. The amount ranged from 0 to 5% seed infection. They concluded the disease is seedborne.
- K.S. Raghuwanshi and C.D. Deokar (1993a) studied the effect of temperature on growth and sporulation of *Fusarium oxysporum* f. sp. *sesami*. The results were as follow.

	Colony dia (mm) after 7 days			Mean colony	
Temp. (°C)	**1**	**2**	**3**	**diameter (mm)**	**Sporulation**
5	0.0	0.0	0.0	0.0	-
10	9.0	8.5	8.5	8.7	+
15	22.5	16.0	16.5	13.3	+
20	27.5	47.5	45.0	40.0	++
25	60.0	57.5	50.0	53.8	++++
27	65.0	50.0	67.5	60.8	++++
30	62.5	57.5	53.5	57.8	+++
35	0.0	0.0	0.0	0.0	-
40	0.0	0.0	0.0	0.0	-

- no, + poor, ++ moderate, +++good, and ++++ abundant sporulation.

- K.S. Raghuwanshi and C.D. Deokar (1993a) studied the effect of pH on growth and sporulation of *Fusarium oxysporum* f. sp. *sesami*. The results were as follow.

pH	Weight of mycelium (mg)	Sporulation
4.5	1.01	-
5.0	1.08	+
5.5	1.15	++
6.0	0.90	-
6.5	1.28	++++
7.0	1.28	++++
7.5	1.20	+++
8.0	1.10	++
8.5	1.00	+
9.0	0.97	+

- no, + poor, ++ moderate, +++good, and ++++ abundant sporulation.

- S. Kumar et al. (2011) reported second most drastic disease is caused by Fusarium oxysporum f. sp. sesami (Zaprometoff) Castellani sesame wilt which causes drastic decline in sesame production. Management of Fusarium wilt is mainly through chemical soil fumigation and using resistant varieties. The broad-spectrum biocides used to fumigate the soil before planting also have negative impact on soil biota. Moreover, adverse effects of different groups of chemicals have been observed on sesame. Thus, development and use of resistant cultivars is effective, economical and eco-friendly for disease control. [Based on abstract]
- B. Jyothi et al. (2011) screened 35 genotypes for resistance to *Fusarium oxysporum* f. sp. *sesami.* All the accessions displayed some percent infection rate with a range of 13.1 to 98.1%, and none could be described as immune. Accessions NSKMS 260, NSKMS-267, NSKMS-261 and TMV-3 were found to be resistant with infection rates of 13.1, 14.6, 15.1 and 15.7% respectively.
- K. Satyagopal et al. (2014) in an IPM manual reported *Fusarium oxysporum* f. sp. *sesami* was a regional problem in Maharashtra and Rajasthan.
- B. Khamari et al. (2017a) reported stem and root rot and wilt diseases of sesame incited by *Macrophomina phaseolina* and *Fusarium oxysporum* f. sp. *sesami* respectively are serious biotic constraints for sesame production. Investigations were formulated on dual culture technique, cut stem inoculation experiment, and soil inoculation experiment in order to assess the interaction and combined effect of the 2 pathogens. Macrophomina did not showed any antagonistic effect towards Fusarium and vice versa in dual culture experiment. Inoculation of healthy sesame stem with Macrophomina, Fusarium and in combination of Macrophomina +Fusarium revealed the color of the stem changed from white to gray to black at different days of inoculations whereas the stem color was green throughout the experimental period in control. The vascular bundle converted to dark and hollow stem in case of Macrophomina and Macrophomina + Fusarium when split 30 days after inoculation. Soil inoculation study revealed inoculation of Macrophomina + Fusarium recorded as low as 26.00% seed germination due to pre emergence damping off followed by in Macrophomina alone (seed germination 34%). The control pot recorded as high as 82% germination. Macrophomina is fast growing fungus as compared to fusarium, but the combination of Macrophomina and Fusarium didn't yield any antagonistic effect and found both in association leading to disease severity as compared to alone. The progress of the disease on the outside of the stem were as follow.

Treatments	2 DAI		4 DAI		6DAI		10 DAI	
	Colour	Coverage	Colour	Coverage	Colour	Coverage	Colour	Coverage
Macrophomina	White	Medium	Grey	Medium + half stem	Dark grey	Medium + stem	Black	Medium + stem
Fusarium	White	Medium	White	Medium	Cream y white	Medium + 1/4th stem	Cream y white	Medium + stem
Macrophomina + Fusarium	White	Medium	White+ grey	Medium + 1/4th stem	Grey	Medium +½ stem	Grey	Medium + stem
Control	Green	-	Green	-	Green	-	Green	-

Comparisons of the outer and inner stem were as follow.

Treatments	30 days after Inoculation					
	Characteristics before splitting			Characteristics after splitting		
	Colour of medium	Colour of stem	Stem character	Colour of stem	Stem character	Microsclerotia
Macrophomina	Black	Black	Dark bark, fleshy, black growth on it	Black	Hollow VB	Present
Fusarium	Creamy white	Creamy white	Rotten, fleshy bark, whitish growth on it	White	Rotten VB	Absent
Macrophomina + Fusarium	Grey	Grey	Grey colour, fleshy	Grey	Hollow VB	Present
Control	Normal	Green	Green and normal	Light yellow	Normal VB	Absent

The effects of soil inoculation were as follow.

S. no	Treatments	Germination %	Pre emergence damping off
1	*Macrophomina*	34 (35.429)	66(54.534)
2	*Fusarium*	52 (46.311)	48(43.653)
3	*Macrophomina + Fusarium*	26 (27.586)	74(62.385)
4	Control	82 (65.332)	18(24.632)
SE(m) CD		5.020 15.179	5.022 15.186

- Anon. (n.d.k) reported *Fusarium oxysporum* f. sp. *sesami* (Wilt) causes a major disease.

IRAN

- T. Basirnia and Z. Banihashemi (20060 showed that *Fusarium oxysporum* f. sp. *sesami* is seedborne. [Based on abstract]
- A. Fallahpori et al. (2013) evaluated the effect of inoculating 10 species of several families with *Fusarium oxysporum* f. sp. *sesami*. Sesame was the only species with the disease symptoms. They monitored the peroxide activity at 2, 4, 6, 8, 10, and 12 days after inoculation. In the tolerant varieties, the peroxide activity rose through day 4 and then decreased, but in the susceptible varieties, the peroxide activity increased less than the tolerant varieties. They concluded the peroxide activity plays a probable role in tolerance.
- M. Najafiniya and A. Aien (2021) evaluated 24 genotypes against *Fusarium oxysporum* f. sp. *sesami* in the greenhouse, microplots, and the field. In the greenhouse and microplots, artificial inoculation was used while in field experiment, no artificial inoculum was used. The results showed 29.1% of the sesame genotypes (JL1, Jl14, JL10, JL11, JL13, Jl18 and Darab1) fell in resistant category and 37.5% of the genotypes (JL2, Varamin37, Local, Yekta, JL29, JL16, JL6, JL14-1 and Darab2) fell in moderately resistant group. The following photos show early and late infection.

ITALY

- E. Castellani (1950) reported in the summer of 1947, sesame plants growing at Florence developed wilt and trancheomycosis. The bottom leaves turned yellow, withered, and dropped. The leaves above became affected and top of stem dried up and bent over. A brown discoloration was present in wood and extended from the root to the apex. A strain of *Fusarium oxysporum* present in infected material was demonstrated by inoculation experiments to be specific to sesame and is therefore regarded as a new form *F. oxysporum* f. *sesami*. Artificial infection experiments showed that the most severe attacks occurred in sterilized soil and that the organism is carried on and in seed from diseased plants and lives in soil in the remains of infected plants. Control consists in the use of clean seed and resistant varieties. In one preliminary tests the var. Venezuela 25 showed marked resistance. [Cited by G.S. Saharan, 1989]

JAPAN

- Anon. (2015e) NIAS Genebank Japan descriptor: 3.5 Wilt disease resistance. Secondary essential character. Observation and measurement of a block. The degree of resistance to *Fusarium oxysporum* f. sp. *sesami* in field of in injection tests. The following are the ratings to be used
  - 1 = Very low
  - 3 = Low
  - 4 = Slightly low
  - 5 = Intermediate
  - 6 = Slightly high
  - 7 = High
  - 9 = Very high
- T. Kuzuyuki (2021) reported the following pathogen: *Fusarium oxysporum* f. sp. *sesami* (Wilt)

KENYA

- H.A. Van Rheenen (1981d) reported the goal of developing resistance to *Fusarium oxysporum* f. sp. *sesami.*

MALAWI

- W. Van Den Bos and C.J. Zee (2016) in a grower guide reported the following: *Fusarium oxysporum* f. sp. *sesami*. Terminal leaves turn yellowish, desiccate, and droop, the symptom progressing down to the stem. Mostly infection is patchy and when mature plants are attacked, only one side of the plant shows symptoms. When uprooted, roots will be wholly or partially rotten. Highly recommended practices are: field sanitation, crop rotation, no water logging conditions, and expose fungus to desiccation

REPUBLIC OF KOREA

- J.S. Park (1963) reported different sources and rates of N had a marked effect on the growth of *Fusarium oxysporum* f. sp. *vasinfectum* and or f. sp. *sesami* the common cause of cotton and sesame wilt in Korea. Nitrate N (best) and urea N had the most and ammonia N (either alone or in combination with other N compounds) the least effect. The latter produced effects similar to those induced by phenoxy compounds on other fungus.
- H.S. Chung and W.B. Choi (1992) reported the incidence of sesame damping off caused by *Rhizoctonia solani* and *Fusarium oxysporum* f. sp. *sesami* in Korea was reduced by coating seed with 3 isolates of *Trichoderma viride* or Benlate [benomyl] T (benomyl) in pot and field trials using naturally infested soils. When sesame seeds were treated with Benlate [benomyl] T or conidia (107/ml) of the antagonists, seedling emergence was significantly increased compared with the untreated control. The incidence of post-emergence damping off was significantly reduced compared with the control. Soil samples taken from the crown area of the sesame seedlings showed an increase in Trichoderma spp. populations during the growing season whereas those of *R. solani* and *F. oxysporum* decreased. However, no significant decline was found in the population of *F. oxysporum* from the rhizosphere at later stages. Mycoparasitism between the antagonists and the pathogens was observed after mycelial contact in dual culture. Coiling and penetration of the antagonists in the hyphae of the pathogens resulted in breaking, lysis and abnormal vacuolation.
- J.W. Hyun et al. (1999) reported *Bacillus polymyxa* (synonym of *Paenibacillus polymyxa*) was isolated as an antibiotic compound that was an antagonist against *Fusarium oxysporum* f. sp. *sesami.* Under greenhouse conditions *Bacillus polymyxa* was shown its minimum inhibitory concentrations were 12.8 µg/ml for *F. oxysporum* and *Alternaria mali,* 6.4 µg/ml for *Colletotrichum gloeosporioides* and *Rhizoctonia solani*, and 3.2 µg/ml for *Phytophthora capsici.*

SUDAN

- A.R.C. Umaima (pers. comm. 2021): *Fusarium oxysporum* f. sp. *sesami* (Fusarium wilt) is a current problem. The symptoms are yellowing, drooping, and withering of leaves then wilting and drying. Roots and stems show long, dark black streaks of vascular necrosis.

TANZANIA

- Kafiriti, E. and O. Mponda (n.d.) in a grower guide reported the following pathogen: *Fusarium oxysporum* f. sp. *sesami.*

TURKEY

- H. Kavak and E. Boydak (2006) screened 26 breeding lines from 3 provinces within the South-eastern Anatolia district against sesame wild disease caused by *Fusarium oxysporum* f. sp. *sesami* by planting them in a filed on an area known contaminated by Fusarium wilt for the last 5 years in 2002 and 2003. The most resistant line was Sanliurfa-63189 with a 6.6% infection rate. Half the lines had less than 20% infection and 5 were below 10%.
- H. Kavak and E. Boydak (2011) evaluated the effect of irrigation interval (5, 10, 15, and 20 days) on the infection of wilt caused by *Fusarium oxysporum* f. sp. *sesami* and *Macrophomina phaseolina* in 2008 and 2009 at Şanlıurfa (37.17N 38.80E). They found depending on delays in irrigation within irrigated crops grown in drought and hot regions, sudden wilt syndrome of sesame may increase. The causes of sudden wilt syndrome appear to be parasitic pathogens, drought stress, or the combined effect of both. The percentage of infections were as follow.

Year	5 days	10 days	15 days	20 days
2008	1.50	2.47	2.50	3.69
2009	1.85	1.90	2.12	2.27

- R.S. Silme and M.I. Cagirgan (2010) screened 19 genotypes, 4 mutants, and 2 cultivars for their reaction to *Fusarium oxysporum* f. sp. *sesami*. The evaluation was carried out during two successive seasons (2007 and 2008) in two soil conditions of an area known contaminated by a virulent isolate of the pathogen at Antalya. Birkan, Camdibi, WS-143, WS-313 were classified as resistant. Birkan should be used as a parent to pass resistance.
- N. Isler et al. (n.d.) reported the following pathogen: *Fusarium oxysporum* f. sp. *sesami.*

UGANDA

- Z.S. Mgamba et al. (2020a) reported Fusarium wilts (*Fusarium oxysporum* f. sp. *sesami*) is among of the most destructive soilborne disease of sesame in Uganda. The disease may cause yield loss of up to 100% if not controlled. Eight parental genotypes of sesame with different levels of resistance to Fusarium wilt pathogen were used in a full diallel to produce F_1 progenies. The eight parents and F_1 progenies were evaluated in the screen house under high pathogen pressure through artificial infection. The results revealed that additive and non-additive gene actions contributed to controlling resistance to Fusarium wilt. However non-additive were more predominant. Moreover, the study indicated that maternal effects have influence toward resistance to Fusarium wilt in sesame.
- Z.S. Mgamba et al. (2020b) reported *Fusarium oxysporum* f. sp. *sesami* incidence ranges from 17.1 to 73.3% in Uganda. In this study, 30 sesame genotypes that included released varieties, improved elite breeding lines, and introductions were screened in the screenhouse under high pathogen pressure following artificial infection using five isolates. The results revealed that sesame genotypes showed different response to the pathogen and thus disease development among the genotypes. No genotype was identified as being immune to the disease. Two genotypes (EM15-1-5 and Sesim 2) were identified and rated moderately resistant to *Fusarium* wilt (37.3 and 33.8%), respectively.

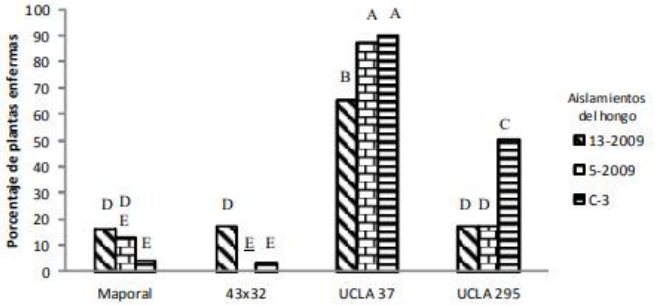

UNITED STATES

- M.L. Kinman and J.A. Martin (1954) reported the presence of *Fusarium oxysporum* f. *sesami* in a few locations in the USA. It is apparently specific to sesame. “Sirogoma” was highly resistant or immune to it.

- M.L. Kinman (1955) reported Fusarium wilt (*Fusarium oxysporum* f. sp. *sesami*) has attacked sesame at a few locations in the USA, and this species is apparently specific to sesame.
- G.W. Rivers et al. (1965b) reported the following:
  - Some of the 568 strains and varieties grown during the 1961-1964 on wilt infected soil were resistant to *Fusarium oxysporum* f. *sesami* in every year except 1964 when there was a severe epidemic, but reactions were inconsistent.
  - *Fusarium* is not a serious threat to sesame in the USA at present but may become one.
  - When planted in June, the symptoms appear in early August.
  - Strains that seem resistant to this are: Dulce (S146), T5318 sel (S189), and Delco (S177).
- Anon. (2015c) USA PVP descriptor: *7. Diseases – Fusarium wilt (Fusarium oxysporum* f. sp. *sesami*). The following ratings are used:
  - 0 = Not tested
  - 1 = Susceptible
  - 2 = Low resistance
  - 3 = Moderate resistance
  - 4 = High resistance

VENEZUELA

- G. Malaguti and B. Mazzani (1962) isolated 3 strains of *Fusarium oxysporum* f. sp. *sesami* and tested them against Venezuela 52, Acarigua, Inamar, Morada, Indehiscente, Fam. 37 and Criollo. Although morphologically the strains had some differences, they showed the same pathogenic behavior in the plants.
- B. Mazzani (1964b) reported *Sesamum radiatum* could be used as a source of resistance to *Fusarium oxysporum* f. sp. *sesami.*
- B. Mazzani et al. (1975) reported a new Aceitera variety resistant to *Phytophthora nicotianae* var. *parasitica, Macrophomina phaseoli,* and *Fusarium oxysporum* f. sp. *sesami* was obtained by backcrossing with the African var. Ajioo Atar 55 resistant to *Phytophthora* and *Macrophomina*. The yield and vegetative characteristics of the new variety resemble those of the original Aceitera which is resistant to *Fusarium*.
- I. Herrera and H. Laurentin (2012) reported one of the most effective strategies for fungi control is to obtain resistant cultivars, but for that, it is necessary an efficient inoculation protocol to identify resistant germplasm and also to get initial propagule enough. The objectives of this research were to evaluate spore production of *Fusarium oxysporum* f. sp. *sesami* on two culture media, and two inoculation methods of the fungus on sesame. Inoculation methods were i. confronting plantlets to fungus spores, and ii. confronting plantlets to fungus (mycelia and spores) mixed with soil. Spore production was 4, 5 and 2 times larger on potato dextrose agar than on SNA (low nutrients agar) for chlamydospores, macroconidia and microconidia respectively. The first inoculation method resulted in 100% incidence and 91% of severity, which was measured as the relation lesion length/plantlet length expressed as percentage. The second method resulted in 50% incidence and 68% severity. The second method was considered the most suitable for screening sesame germplasm to the fungus.
- I. Herrera and H. Laurentin (2014) screened 4 varieties (Maporal, 43 x 32, UCLA 37, and UCLA 295) against *Fusarium oxysporum* f. sp. *sesami.* They inoculated the plants with isolates taken in 3 different locations (13-2009, 5-2009, and C3). The % of plants infected were as follow/



The severity indices were as follow.

Genotipos de ajonjolí	Aislamientos		
	13-2009	5-2009	C-3
Maporal	0,16^{D}	0,26^{D}	0,04^{E}
43 x 32	0,34^{D}	0,00^{E}	0,03^{E}
UCLA37	1,30^{B}	2,61^{A}	2,70^{A}
UCLA295	0,34^{D}	0,17^{D}	1,00^{C}

- P. Fernandez and H.E. Laurentin (2016) evaluated the effect of sesame root and stem extracts of the three sesame cultivars (Fonucla, INIA, and UCLA295) on the growth of *Fusarium oxysporum* f. sp. *sesami*. It was evaluated by means of the record of *in vitro* growth in ELISA microplates cells in presence of 0.2 mL of sesame root or stem extracts. Each cell contained 0.2 mL of spore suspension (200 conidia mL-1) in potato dextrose broth and one of the treatments. Optical density was recorded each 12 h during 192 h. Root extracts had the trend of inhibiting fungus growth, however only extracts coming from cultivar INIA had statistical differences ($P<0.05$); it inhibited up to 25% of fungus growth. On the contrary, stem extracts had the trend of stimulating fungus growth, but only INIA cultivar had a significant effect ($P<0.05$) as compared to the control treatment, reaching to promote up to 20% of growth. The data was as follows (* = statistical difference of $P<0.05$ from the control.

Root extract data

Horas de incubación	Genotipo o cultivar		
	Fonucla	INIA	UCLA295
24	0.0379	0.1074	0.0366
36	0.0987	0.1203	0.0335
48	0.1279	0.0842	0.0254
60	0.1642	0.0943	0.0440
72	0.1743	0.0559	0.0651
84	0.1626	0.0110	0.0560
96	0.0265	-0.1677	-0.0784
108	0.0099	-0.2127*	-0.0339
120	0.0101	-0.2222*	-0.0551
132	0.0242	-0.2457*	-0.0554
144	0.0433	-0.2625*	-0.0747
156	0.0426	-0.2815*	-0.0779
168	-0.0048	-0.3282*	-0.0917
180	-0.0095	-0.3472*	-0.0660
192	-0.0105	-0.3589*	-0.0534

Stem extract data

Horas de incubación	Genotipo o cultivar		
	Fonucla	INIA	UCLA295
24	0.1411	0.2471*	0.0678
36	0.1255	0.2378*	0.1273
48	0.1405	0.2478*	0.0850
60	0.1256	0.2828*	0.1409
72	0.0986	0.2861*	0.1535
84	0.0993	0.2323*	0.1424
96	-0.0152	0.0572	0.0130
108	-0.0352	0.0465	-0.0025
120	0.0025	0.0013	-0.0021
132	0.1010	-0.0025	-0.0004
144	0.0107	-0.0043	0.0000
156	0.0372	0.0084	-0.0034
168	-0.0624	0.0330	-0.0503
180	0.0741	0.0833	-0.0653
192	0.0099	0.0789	-0.0691

A1.1.1a.2 *Fusarium oxysporum* f. sp. *vasinfectum* (7 Apr 2021)

Synonyms: *Fusarium vasinfectum* and *Fusarium vasinfectum* f. sp. *sesami*

Family: Nectriaceae

Definition: Amount of tolerance to *Fusarium oxysporum* f. sp. *vasinfectum* W.C. Snyder & H.N. Hansen 1940.

INTERNATIONAL

- R.S. Vasudeva (1961) reported the wilt of sesamum has been known to occur almost in all parts of the world wherever sesame is cultivated. The disease is characterized by yellowing, drooping, and withering of the leaves. The top of the stem gets dried up and bent over. A brown discoloration in the wood gradually extends from the roots to the apex and ultimately leads to the death of the plant.
- Anon. (2004a). IPGRI descriptor: 10.2.4. Biotic stress susceptibility to *Fusarium vasinfectum.* (*Fusarium* wilt).
  - In each case it is important to state the origin of the infestation or infection, i.e., natural, field inoculation, or laboratory. Also specify the causal organism and the corresponding symptoms. The susceptibility scale is as follows:
    - 1 = Very low or no visible sign of susceptibility
    - 3 = Low
    - 5 = Intermediate
    - 7 = High
    - 9 = Very high
  - The growth state, coded according to the list below at which each reaction was recorded should be appended to the record of that reaction.

- 1 = Seed
- 2 = Seedling
- 3 = Pre-flowering
- 4 = Early flowering
- 5 = Mid-flowering
- 6 = Late-flowering
- 7 = Maturity

- CAB International (accessed 12 Apr 2021) reported sesame was a minor host of *Fusarium oxysporum* f. sp. *vasinfectum* (Fusarium wilt).

CHINA

- L.C. Tu (1985a and 1985b) reported *Fusarium vasinfectum* f. sp. *sesami* (Wilt) in Henan province with a damage level of 1 out of possible 3.
- L.L. Li (1988) reported *Fusarium vasinfectum* and *Fusarium vasinfectum* var. *sesami* (Wilt) cause severe damage to sesame. Plants may be infected at any stage of plant development. In the seedling stage, infected seedlings may be seen with the appearance of damping-off and withered seedlings. In the last stage, symptoms of the affected plants appear on one side of the root system as red-brown withered stripe, and the leaves of the infected side wilt, turn into yellow color, wither and fall from bottom to top. The vascular bundle of the diseased stem becomes brown. Capsules on affected branches are smaller, precocious, easily dehiscing, and they contain thin and shriveled seeds. The pathogen has two sorts of conidium, and the macroconidia are sickle-shaped and 3-5 septate. The microconidia are ovoid to ellipsoid, and unicellular. It grows at the temperature range of 10 to 35°C with an optimum temperature of 30°C. It grows at the temperature range of 10 to 35°C with an optimum temperature of 30°C. The pathogen is reported to be seed- soil- and plant debris-borne. It is quite evident that the fungus penetrates the host through the root tip and wound of seedlings and also infects the healthy root directly. Then, it enters into the vessel and finally extends upwards into all parts of plants. Continuous cropping, high soil moisture and barren sandy loam are favorable for the development of the disease. The disease could be controlled by using 3 to 5 years crops rotation, use of non-diseased seed or seed treatment with 0.5% copper sulphate preparations for half an hour as an effective control method of the disease.

INDIA

- E.J. Butler (1926) provided a detailed description of artificial inoculation of seedlings of both the hosts with organisms isolated from wilted plants, the results of which together with the morphological and cultural features of the pathogens led the author to consider that the wilt producing fungi attacking cotton, sesame and pigeon pea (*Cajanus indicus*) in India are specialized strains of *Fusarium vasinfectum*, the American cotton wilt organism.
- M.L. Verma (1985) reported *Fusarium vasinfectum* (Wilt) is a major disease with the following symptoms: Yellowing, drooping. Withering of first lower leaves then upper leaves. Top of stem bent down and dries. Brown discoloration on roots to tip, blackening of stem.

EGYPT

- M.S. El-Abyad et al. (1988) studied the effect of the herbicide prometryn on the metabolic activities of two formae speciales of *Fusarium oxysporum*. Prometryn at concentrations of 128 and 256 ppm significantly inhibited growth and respiration rates, reduced absorption of both sugar and nitrate, and reduced rates of synthesis of carbohydrates and organic nitrogenous compounds by both fungi. A concentration of 16 ppm did not significantly affect the metabolic activities of *F. oxysporum* f. sp. *vasinfectum*. [Based on abstract]

JAPAN

- T. Mutsuo (1934) reported in 1932 sesame plants in Sapporo were attacked by a wilt disease characterized by wrinkling, dropping and blackish brown discoloration of the leaves and by the eventual death of plants. The causal organism (*Fusarium vasinfectum*) was readily isolated al a number of standard media. Making the best growth at about 30°C and was inoculated into sesame plants with positive results. It produced branched conidiophores bearing a head of mostly non-septate ovoid to ellipsoid, hyaline micro conidia, 5 to 23.5 by 2.5 to 5.5 µ and also formed cinnamon buff colored macro conidia, 3-4 or 5 septate measuring 20.8 to 44.2 by 2.6 to 4.5 µ, 36.4 to 49.4 by 3 to 5 µ and 41. 6 to 52 by 4 to 5 µ respectively. Apical or intercalary chlamydospores were produced.

MEXICO

- Agrolytics.org (2021) reported sesame hosts *Fusarium oxysporum f. sp. vasinfectum.*

REPUBLIC OF KOREA

- J.S. Park (1963) reported different sources and rates of N had a marked effect on the growth of *Fusarium oxysporum* f. sp. *vasinfectum* and or f. sp. *sesami* the common cause of cotton and sesame wilt in Korea. Nitrate N (best) and urea N had the most and ammonia N (either alone or in combination with other N compounds) the least effect. The latter produced effects similar to those induced by phenoxy compounds on other fungus. [Cited by G.S. Saharan, 1989]
- C.Y. Choi (1964) reported most of the 10 culture filtrates of *Fusarium oxysporum* f. sp. *vasinfectum* (which is known to produce a toxin – fumaric acid) tested inhibited or retarded germination or growth of the seedling. The inhibitory capacity varied considerably. In general sesame seeds were highly susceptible. [Based on abstract]
- J.S. Park (1964) reported culture filtrates of *Fusarium oxysporum* f. *vasinfectum* strongly or weakly inhibited the germination and brought about necrosis accompanying black discoloration of sesame seeds, probably due to fusaric acid (wilt toxin). There were no varietal differences. Five strains used in this study differ greatly in the toxicity of culture filtrates inhibiting the germination of sesame seeds. In the seedling bed added with culture filtrates, the growth of shoot as well as root system of sesame seedlings are notably inhibited, and necrotic black discoloration appear on both shoot and root system. But in the seedling beds added with weaker concentration of culture filtrates (10%) the growth of shoot is slightly promoted. In culture of sesame seedlings with Knop's solution containing 1 to 3 per cent culture filtrates, the growth of shoot as well as root system are slightly retarded and till the time of development of the third leaves the whole stem and leaf petiole tissue are weakened so that they become thread like accompanying brown discoloration, interveinal light brown area appear in the second leaves, and the third leaves curl from both sides towards the middle with necrotic brown discoloration, especially symptoms of injury on the third leaves are nearly similar to that of the leaves of wilted sesame in the field. [Based on abstract]
- C.W. Kang et al. (1985f) reported Sesame Fusarium wilt (*Fusarium oxysporum* f. *vasinfectum*) lesions on the lower part of the stem are enlarged slowly or rapidly from seedling stage to late maturing stage. It therefore reduces sesame yield greatly. Seven chemicals were applied three times from late June to the middle of July after inoculating with artificially cultured sesame Fusarium wilt fungi. Oxydong 50% WP (sprayed three times at ten day intervals 1,000X solution of 1.2 t/ha) was the most effective in controlling Fusarium wilt. The incidence rate in the treated material was 13% compared to 6l% in the unsprayed control. The treated plants had a few more capsules per plant (100 vs. 91), and their yields were 12% higher. [Based on abstract]
- C.W. Kang et al. (1985i) reported the incidence of wilt caused by *Fusarium oxysporum* f. sp. *vasinfectum* in cv. Kwangsan was considerably influenced by sowing date and mean air temperature in the field. [Based on abstract]
- J.I. Lee and B.H. Choi (1985h) reported that vinyl mulching helped escape infections of *Fusarium oxysporum* f. sp. *vasinfectum*, which severely attacked young seedlings in Korea. The disease occurs nearly wherever sesame is cultivated in Korea. The variety "Ahnsanggae" is fairly resistant. They also recommend crop rotation, using healthy seed, and spraying at one week intervals with Benlate-T and Benoram WP at the seedling stage. At later stages they recommended Cuper (Coside) or Oxidong fungicide applications. When there is damping off, 70% of the time it is *Fusarium oxysporum* f. sp. *vasinfectum*, 20% *Rhizoctonia solani*, and 10% *Phoma sesami.*
- B.K. Chung and K.S. Hong (1991) and B.K. Chung and S.O. Ser (1992) isolated *Streptomyces bikiniensis* and reported it is antagonistic to *Phytophthora nicotianae* var. *parasitica* and *Fusarium oxysporum* f. sp. *vasinfectum.*

UKRAINE

- I.V. Bohovik (1936) reported *Fusarium vasinfectum.* [Cited by G.S. Saharan, 1989]

UNITED STATES

- J.K. Armstrong and G.M. Armstrong (1950 and 1953) reported sesame wilt, caused by a species of *Fusarium* was observed in 1948 on a plantation in S. Georgia. In inoculation experiments most of the varieties and breeding lines tested proved susceptible with the exception of Sirigoma which was highly resistant. The sesame Fusarium could not be differentiated from *F. vasinfectum* morphologically or culturally but was quite distinct from pathogenicity, failing to cause wilting of any other plant inoculated. Fusarium isolates from 10 other hosts did not attack sesame. It is suggested that the use of the names *F. vasinfectum* and *Fusarium vasinfectum* var. *sesami* for the sesame fungus is misleading and should be discontinued.

UZBEKISTAN

- N.G. Zaprometoff (1925) reported *Fusarium vasinfectum* var. *sesami.* [Cited by R.S. Vasudeva, 1961, and G.S. Saharan, 1989]

A1.1.1b *Fusarium proliferatum* (22 Apr 2021)

Family: Nectriaceae

Definition: Amount of tolerance to *Fusarium proliferatum* (Matsush.) Nirenberg ex Gerlach & Nirenberg 1982.

(Wikipedia, 22 Apr 2021) ***Fusarium proliferatum*** is a fungal plant pathogen infecting asparagus.

References:

IRAN

- M. Torabi et al. (2014) reported the first record of *Fusarium proliferatum* on sesame in Iran. Colonies were fast growing, forming abundant aerial mycelium, with colorless to dark purple appearance on colony reverse. On CLA, club-shaped and single-celled microconidia were formed in chains and in conidial heads arising from mono-phialides and poly-phialides, the macroconidia were slender, almost straight, and usually 3-5 septate. Chlamydospores were absent.

PAKISTAN

- B.G. Nayyar et al. (2013) examined 15 samples of seed to detect fungi using 3 methods: agar plate, blotter, and deep freezing. They found *Fusarium proliferatum.*
- B.G. Nayyar et al. (2018) collected 105 sesame seed samples from different locations in the Punjab from which 520 isolates of *Fusarium* spp. were recovered. These isolates were initially grouped and identified based on morphological characteristics. The identities of representatives of the three most frequently isolated groups (strains designated F01, F98, F153) were identified as *Fusarium proliferatum*, on the basis of the sequencing of ITS of rDNA and translation elongation factor (TEF-1α) gene regions. Culture filtrates of F01 reduced sesame seed germination (to 40%) and vigor (to 16.5%) of sesame seedlings. This baseline study suggests that F. proliferatum infection of sesame seeds could be a major source of yield loss in the Punjab. [Based on abstract]

A1.1.1c *Fusarium caeruleum* (28 Apr 2021)

Family: Nectriaceae

Definition: Amount of tolerance to *Fusarium caeruleum* Libert ex Saccardo 1886.

References:

INDIA

- N. Prasad (1944) reported *Fusarium caeruleum* caused a disease in sesame. [Cited by R.S. Vasudeva, 1961]
- M.L. Verma (1985) reported *Fusarium caeruleum* (Wilt) is a major disease with the following symptoms: Yellowing, drooping. Withering of first lower leaves then upper leaves. Top of stem bent down and dries. Brown discoloration on roots to tip, blackening of stem.

A1.1.1d *Fusarium solani* (8 May 2021)

Family: Nectriaceae

Definition: Amount of tolerance to *Fusarium solani* (Mart.) Saccardo 1881.

(Wikipedia, 8 May 2021) ***Fusarium solani*** is a species complex of at least 26 closely related filamentous fungi in the division Ascomycota, family Nectriaceae. It is the anamorph of *Nectria haematococca*. It is a common soil fungus and colonist of plant materials. *Fusarium solani* is implicated in plant disease as well as human disease notably infection of the cornea of the eye.

References:

CHINA

- D.H. Li et al. (2012) obtained 25 isolates of Fusarium species from wilted sesame grown on 25 farms from 22 regions of China. They identified *Fusarium oxysporum* and *Fusarium solani.*

EGYPT

- M.M.I. Abdel-Hafez et al. (2012) examined the soils around the roots of sesame and reported *Fusarium solani* in the rhizosphere and rhizoplane.
- H.A.H. Ahmed et al. (2013) studied biological control of *Fusarium solani* and *Macrophomina phaseolina* causing wilt and charcoal rot diseases *in vitro* as well as under pot conditions. Culture technique showed that the addition of intact *Nostoc* sp. SAG2306 or its sonicate inhibited the radial mycelial growth of the test pathogens. Application of *Nostoc* sonicates resulted in the lowest infection percentage (11.1% and 17.8% of *Fusarium* and *Macrophomina* respectively) whereas in the control it was 95.6% and 97.7%. Under pot conditions, plant height, fresh and dry weight of plants increased significantly as a result of the inhibition of fungal by *Nostoc*. Similar results were observed in chlorophyll (ch.la & ch.lb) content of the treated plants. Infection enhanced proline accumulation that was lowered upon *Nostoc* addition, indicating alleviation of infection ascribed stress. The effect of sonicated (NS) or intact (NI) *Nostoc* sp 2306 cells on seed infection of sesame *in vitro* was as follow.

Treatements	*F. solani*	*M.Phaseolina*
NS	11.11	17.78
NI	26.67	33.34
Control	95.55	97.7

The effects in pots in the greenhouse in 2010 and 2011 seasons was as follow.

Treatments	*F.solani*				*M.phaseolina*			
	Percentage of infected plants				Percentage of infected plants			
	Root-rot		Wilt		Root-rot		Charcoal	
	2010	2011	2010	2011	2010	2011	2010	2011
*N.*sonicated	16.66	20	16.66	16.66	16.66	20	20	16.66
*N.*intact	26.66	26.66	20	23.33	20	23.33	23.33	20
Control	36.66	33.33	56.66	60	33.33	33.33	60	63.33

- M.M.I. Abdel-Hafez et al. (2014) took ten samples of sesame from local markets in Assiut city. They found *Fusarium solani* (Mart.) Sacc.
- M.A.A. Hassan et al. (n.d.) evaluated the pathogenicity *in vivo* of 8 Fusarium isolates taken from infected sesame plants with the following results. [Authors comment: Assume *F. clmourum* is *F. culmorum.*]

Fungal isolates	Damping-off (%)		Survival plants (%)	Wilt disease		Root rot disease	
	Pre-	Post-		Incedance (%)	Severity (%)	Incedance (%)	Severity (%)
F. oxysporum							
1	7.50	17.50	75.00	48.16	34.75	8.00	3.7
2	10.00	25.00	65.00	88.09	61.35	12.00	5.9
3	5.00	17.50	77.50	58.48	38.75	9.50	3.3
F. solani							
1	32.50	15.00	52.50	10	5.1	27.5	10
2	30.50	14.00	55.50	7.5	3.9	15	17.3
3	31.50	13.00	55.50	19.1	4.3	22	15.8
F. clmourum							
1	30.00	37.50	32.50	0.00	0.00	0.00	0.00
2	28.00	35.00	37.00	0.00	0.00	0.00	0.00
Control*	2.50	0.00	97.50	0.00	0.00	0.00	0.00
L.S.D. at 5%	7.90	7.90	12.41	13.51	5.37	12.46	4.25

*Non-infested plants, healthy plants. The significant differences between means compared by LSD at $p \leq 0.05$, NS, not significant

INDIA

- L.N. Daftari and O.P. Verma (1973) found that seed treatment with aureofungin (20 ppm) for 1 hour was effective for checking seedling infection by seedborne *Fusarium solani* by 90.2% in a susceptible variety and increased vigor in two varieties of sesame. [Cited by M.L. Verma, 1985, and G.S. Saharan, 1989]
- D.N. Shukla and S.N. Bhargava (1977) reported *Fusarium solani* was associated with seed of sesame and pathogenic to seedlings of the crop. Growth and sporulation were best at pH 5.5-6.5 and at 22-28°C. Agrosan (Phenylmercury acetate), Benlate (Benanyl), Blitox 50 (Copper oxychloride), Ceresan (Mathoxy ethylmercury chloride), Kirticopper, Plantvax (Oxycarboxin), Thiram and Vitavax (Carboxin) inhibited growth of fungus in culture. [Cited by G.S. Saharan, 1989]

- S.N. Bhargava and D.N. Shukla (1979a) reported seed coat leachates and seed extracts of sesame decreased spore germination of *Fusarium oxysporum*, *Fusarium solani* and *Curvularia lunata* (*Cochliobolus lunatus*). Culture filtrates of the fungi inhibited seed germination of the plants. [Cited by G.S. Saharan, 1989]
- S.N. Bhargava et al. (1981b) reported during a survey of the diseases of pulses and oil crops in and around Allahabad a seedling blight of sesamum caused by *Fusarium solani* (Mart.) Sacc. was observed. [Cited by G.S. Saharan, 1989]
- M.N. Reddy and D.S. Rao (1981) reported a new record of *Fusarium solani.*
- T. Singh and D. Singh (1983) isolated 24 fungi: Of these, *Fusarium solani* was an important pathogens. [Cited by G.S. Saharan, 1989]
- R.K.S. Chauhan and B.M. Kulshrestha (1984b) reported the diffusate obtained from the fruit cavities of sesame inoculated with a spore suspension of *Alternaria sesami* was inhibitory to the germination of spores of *Fusarium solani.*

IRAQ

- N.A. Ramadan (2009) reported The effect of the concentrations 0, 1, 2, 3, and 4 mg/ml of alcoholic extracts of cress seeds (*Lipidium sativum*) on the growth and dry weight of root–rot fungi of sesame plants, *Pythium aphanidermatum*, *Fusarium solani* and *Macrophomina phaseolina* indicated high significant inhibitory affect as compared to the control. *M. phaseolina* was mostly inhibited than other fungi when 4mg/ml w, 86.66 and 78.26% respectively. Antagonistic test of the bacterial biocontrol agent *Bacillus cereus* showed high inhibiting effect on all tested pathogens with the maximum inhibition 80.8% on *M. phaseolina*. Culture filtrate of *B. cereus* also showed a highly inhibiting efficiency to the growth and dry weight of the biomass of all pathogenic fungi with the increase of concentrations 10%, 20%, 30% and 40% (v l v) with the 40% was mostly effective on *M. phaseolina* by the ratio of 72.22% and 83.90%, respectively. The best inhibition was achieved with the use of combination of 4 mg/ml of alcoholic extract of Cress seeds and 40% of culture filtrate of *Bacillus cereus*. It showed synergistic inhibitory effect on all pathogenic fungi used, that exceeded the effect of each of the plant extract or culture filtrate of the bacteria separately. [Based on abstract]

ISRAEL

- A.Z. Joffe and J. Palti (1964) reported of the nine *Fusarium spp*. identified in 79 isolates from soil and plant material in association with 18 different hosts, *F. oxysporum* (23 isolates) and *F. solani* (27) were most prevalent and affected hosts on many soils. Both the *F. solani* and *F. oxysporum* groups were associated with a serious wilt of sesame. [Cited by G.S. Saharan, 1989]

TURKEY

- E. Bremer (1944) reported the sesame wilt presents a close parallel with that of tobacco both as regards symptomology, time of development, and the favoring influence of drought. Moreover, *Macrophomina phaseoli* and *Fusarium solani* were isolated from most of the specimens of diseased material, presumably in a secondary capacity since inoculation experiments were again unsuccessful. [Cited by G.S. Saharan, 1989]

A1.1.1e *Fusarium incarnatum* (12 May 2021)

Synonym: *Fusarium semitectum*

Family: Nectriaceae

Definition: Amount of tolerance to *Fusarium incarnatum* (Desm.) Sacc. 1886.

(Wikipedia, 12 May 2021) ***Fusarium incarnatum*** is a fungal plant pathogen.

References:

EGYPT

- M.M.I. Abdel-Hafez et al. (2012) examined the soils around the roots of sesame and reported *Fusarium semitectum* in the rhizosphere.
- A. Hashem et al. (2014) collected 18 seed samples of sesame in Egypt (12 samples) and Saudi Arabia (6 samples). They identified the following mycoflora: *Fusarium semitectum.*

NIGERIA

- D. McDonald (1964) reported *Fusarium semitectum*.
- H.A. Van Rheenen (1972) reported the following pathogen: *Fusarium semitectum.*

- C.N. Ezekiel et al. (2012 and 2013) examined 17 samples of sesame from 4 markets and found *Fusarium oxysporum, Fusarium semitectum* and *Fusarium verticillioides*. They found no aflatoxins. Six randomly selected isolates were screened for their ability to produce mycotoxins in ofada rice culture and the crude extracts of the mycotoxins were tested on week-old catfish (*Clarias gariepinus*) fingerlings with lethal effects. They isolated 6 toxic metabolites produced by the *Fusarium* in the rice culture: equisetin, fumonisin B_1, fumonisin B_2, methyl-equisetin, moniliformin, and zearalenone. They concluded sesame may be potential sources of toxigenic *Fusarium*.

PAKISTAN
- A.S. Shakir and M. Ansar (1992) studied 25 samples of seed collected from various areas in Punjab and analyzed for the presence of mycoflora. They found the following fungus: *Fusarium semitectum.*

A1.1.1f *Fusarium verticillioides* (12 May 2021)

Family: Nectriaceae

Definition: Amount of tolerance to *Fusarium verticillioides* (Sacc.) Nirenberg 1976.

(Wikipedia, 12 May 2021) ***Fusarium verticillioides*** is the most commonly reported fungal species infecting maize (*Zea mays*). *Fusarium verticillioides* is the accepted name of the species, which was also known as *Fusarium moniliforme*. The species has also been described as mating population A of the *Fusarium fujikuroi* species complex (formally known as *Gibberella fujikuroi* species complex). *F. verticillioides* produces the mutagenic chemical compound fusarin C. *F. verticillioides* produces a group of disease-causing mycotoxins—fumonisins—on infected kernels.

References:

EGYPT
- M.M.I. Abdel-Hafez et al. (2012) examined the soils around the roots of sesame and reported *Fusarium verticillioides* in the rhizosphere and rhizoplane.
- M.M.I. Abdel-Hafez et al. (2014) took ten samples of sesame from local markets in Assiut city. They found the following: *Fusarium verticillioides* (Sacc.) Nirenberg.
- A. Hashem et al. (2014) collected 18 seed samples of sesame in Egypt (12 samples) and Saudi Arabia (6 samples). They identified the following mycoflora: *Fusarium verticillioides.*

MEXICO
- Agrolytics.org (2021) reported sesame hosts *Fusarium verticillioides.*

NIGERIA
- C.N. Ezekiel et al. (2012 and 2013) examined 17 samples of sesame from 4 markets and found *Fusarium oxysporum, Fusarium semitectum* and *Fusarium verticillioides*. They found no aflatoxins. Six randomly selected isolates were screened for their ability to produce mycotoxins in ofada rice culture, and the crude extracts of the mycotoxins were tested on week-old catfish (*Clarias gariepinus*) fingerlings with lethal effects. They isolated 6 toxic metabolites produced by the *Fusarium* in the rice culture: equisetin, fumonisin B_1, fumonisin B_2, methyl-equisetin, moniliformin, and zearalenone. They concluded sesame may be potential sources of toxigenic *Fusarium*.

A1.1.1g *Fusarium equiseti* (19 May 2021)

Family: Nectriaceae

Definition: Amount of tolerance to *Fusarium equiseti* (Corda) Sacc. 1886

References:

EGYPT
- A. Hashem et al. (2014) collected 18 seed samples of sesame in Egypt (12 samples) and Saudi Arabia (6 samples). They identified the following mycoflora: *Fusarium equiseti.*

INDIA

- S.N. Bhargava and D.N. Shukla (1980) reported the two most frequently encountered fungi, *Fusarium equiseti* and *Fusarium oxysporum* caused a slight reduction in oil content of seeds of sesame when incubated for 45 days. [Cited by G.S. Saharan, 1989]
- S.N. Bhargava et al. (1981b) reported during survey of diseases of pulses and oil crops, in and around Allahabad, a new seedling rot (*Fusarium equiseti*) of sesamum was observed. Pathogenicity tests were performed, and sesame seedling showed brown to black discoloration at the basal portion. Both pre and post emergence damping off was observed. Preemergence rot was as high as up to 40 to 60%. Seedlings killed at early stage were generally necrotic and commonly covered with profuse fungal growth. [Cited by G.S. Saharan, 1989]
- S. Maiti et al. (1985 and 1986) reported the following minor pathogen: Seedling rot *Fusarium equiseti* (Corda) Sacc.
- R.B. Kakde and A.M. Chavan (2011) examined the effects of fungi on seeds in storage. Ten dominant fungi were isolated from seeds of groundnut, soybean, sesame, safflower, and sunflower. One hundred grams of seeds were inoculated with 10 ml of the fungi. The flasks were left at room temperature for 14 days and then analyzed for sugars, crude fat, and fiber. The results are as follow.

Table 1. Change in reducing sugar (g/100gm) due to seed-borne fungi

Fungi	Sunflower	Sesame	Groundnut	Soybean	Safflower
Alternaria dianthicola	5.2	4.8	1.1	1.1	1.3
Curvularia lunata	4.9	5.0	2.5	1.5	1.8
Curvularia pellescens	5.0	5.4	2.1	1.2	1.6
Fusarium oxysporum	4.7	4.4	1.8	1.7	1.1
Fusarium equiseti	4.6	4.8	1.6	1.2	1.0
Macrophomina phaseolina	5.8	3.5	2.2	2.0	2.2
Rhizopus stolonifer	6.1	5.0	1.1	1.8	2.1
Penicillium digitatum	5.5	4.6	1.9	1.7	1.4
Penicillium chrysogenum	5.2	4.9	2.0	1.6	1.6
Trichoderma viride	6.7	6.1	2.1	1.9	2.6
Control	7.2	6.9	3.1	2.4	2.8
C.D. at 0.05	0.52	0.62	1.21	0.24	0.21

Table 2. Change in crude fat (g/100gm) due to seed-borne fungi

Fungi	Sunflower	Sesame	Groundnut	Soybean	Safflower
Alternaria dianthicola	35.5	10.2	37.1	49.8	22
Curvularia lunata	43.5	14.3	32.5	48.2	26
Curvularia pellescens	45.5	10	41	49	27
Fusarium oxysporum	43	16.1	38	44	20
Fusarium equiseti	47	14.2	35	49.7	19
Macrophomina phaseolina	39	10.5	39.3	46.8	30
Rhizopus stolonifer	50	16.3	40.2	48.6	33
Penicillium digitatum	42	15.3	34.3	39	24
Penicillium chrysogenum	44	12.8	36.2	41	27
Trichoderma viride	46	17.5	40	46	35
Control	49	20	45	50	36
C.D. at 0.05	2.71	2.05	2.04	2.4	3.7

Table 3. Change in crude fiber (g/100) due to seed-borne fungi

Fungi	Sunflower	Sesame	Groundnut	Soybean	Safflower
Alternaria dianthicola	39.1	35.6	33.9	26.1	20.1
Curvularia lunata	52.3	30.6	38.8	34.5	21.8
Curvularia pellescens	46.1	41.1	42.3	31.1	21.6
Fusarium oxysporum	53.1	36.5	34.7	37.0	21.0
Fusarium equiseti	50.7	36.4	37.9	21.0	22.5
Macrophomina phaseolina	47.7	34.8	41.9	36.6	17.9
Rhizopus stolonifer	41.6	31.6	40.1	28.5	19.6
Penicillium digitatum	43.5	40.5	27.6	21.0	14.4
Penicillium chrysogenum	40.5	27.7	31.7	36.9	13.9
Trichoderma viride	47.5	35.1	38.3	37.0	19.8
Control	51.3	47.7	38.0	23.3	19.9
C.D. at 0.05	3.16	6.11	2.39	4.2	1.82

A1.1.1h *Fusarium merismoides* (25 May 2021)

Family: Nectriaceae

Definition: Amount of tolerance to *Fusarium merismoides* Corda 1838.

(Wikipedia, 25 May 2021) ***Fusarium merismoides*** is a fungal plant pathogen.

References:

BANGLADESH

- M.D. Hosen and S. Shamsi (2017) isolated the following fungus from sesame seeds: *Fusarium merismoides.* They evaluated the effects of fungicides (Bavistin DF, Capvit 50 WP, Dithane M-45, Ridomil Gold MZ 68 WG and Tilt 250 EC at 100, 200, 300, 400 and 500 ppm) and plant extracts (*Allium sativum* L. (bulb), *Azadirachta indica* A. Juss. (leaf), *Citrus limon* (L.) Burm. f. (leaf), *Mangifera indica* L. (leaf) and *Psidium guajava* L. (leaf) at 5, 10, 15 and 20%) against both *Aspergillus niger* and *Fusarium merismoides*. The results of the fungicides were as follow.

Name of fungicides	% inhibition of radial growth at different concentrations (ppm)				
	100	200	300	400	500
Bavistin DF	100^{a}	100^{a}	100^{a}	100^{a}	100^{a}
Capvit 50 WP	0.0^{NS}	0.0^{NS}	0.0^{NS}	0.0^{NS}	0.0^{NS}
Dithane M-45	43.82^{a}	52.62^{a}	56.18^{a}	57.30^{a}	60.67^{a}
Ridomil MZ Gold	47.75^{a}	53.37^{a}	70.00^{a}	100^{a}	100^{a}
Tilt 250 EC	87.08^{a}	88.76^{a}	92.70^{a}	97.75^{a}	98.88^{a}

The results of the plant extracts were as follow.

Name of plant	% inhibition of radial growth of the pathogen at different conc. (%)			
	5	10	15	20
Allium sativum	100^{a}	100^{a}	100^{a}	100^{a}
Azadirachta indica	64.04^{a}	66.29^{a}	67.42^{a}	82.02^{a}
Citrus limon	74.16^{a}	78.65^{a}	79.78^{a}	80.90^{a}
Mangifera indica	0.0^{NS}	67.98^{a}	70.79^{a}	74.16^{a}
Psidium guajava	0.0^{NS}	0.0^{NS}	0.0^{NS}	75.84^{a}

A1.1.1i *Fusarium culmorum* (13 Jul 2021)

Family: Nectriaceae

Definition: Amount of tolerance to *Fusarium culmorum* Corda 1838.

(Wikipedia, 13 Jul 2021) ***Fusarium culmorum*** is a fungal plant pathogen and the causal agent of seedling blight, foot rot, ear blight, stalk rot, common root rot and other diseases of cereals, grasses, and a wide variety of monocots and dicots. In coastal dunegrass (*Leymus mollis*), *F. culmorum* is a nonpathogenic symbiont conferring both salt and drought tolerance to the plant.

References:

EGYPT

- M.A.A. Hassan et al. (n.d.) evaluated the pathogenicity *in vivo* of 8 Fusarium isolates taken from infected sesame plants with the following results. [Authors comment: Assume *F. clmourum* is *F. culmorum.*]

Fungal isolates	Damping-off (%)		Survival plants (%)	Wilt disease		Root rot disease	
	Pre-	Post-		Incedance (%)	Severity (%)	Incedance (%)	Severity (%)
F. oxysporum							
1	7.50	17.50	75.00	48.16	34.75	8.00	3.7
2	10.00	25.00	65.00	88.09	61.35	12.00	5.9
3	5.00	17.50	77.50	58.48	38.75	9.50	3.3
F. solani							
1	32.50	15.00	52.50	10	5.1	27.5	10
2	30.50	14.00	55.50	7.5	3.9	15	17.3
3	31.50	13.00	55.50	19.1	4.3	22	15.8
F. climourum							
1	30.00	37.50	32.50	0.00	0.00	0.00	0.00
2	28.00	35.00	37.00	0.00	0.00	0.00	0.00
Control*	2.50	0.00	97.50	0.00	0.00	0.00	0.00
L.S.D. at 5%	7.90	7.90	12.41	13.51	5.37	12.46	4.25

*Non-infested plants, healthy plants. The significant differences between means compared by LSD at $p \leq 0.05$, NS, not significant

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A1.1.1j *Fusarium acutatum* (26 Jul 2021)

Family: Nectriaceae

Definition: Amount of tolerance to *Fusarium acutatum* Nirenberg & O'Donnell 1998.

(Wikipedia, 26 Jul 2021) ***Fusarium acutatum*** is a fungus species of the genus *Fusarium*. *Fusarium acutatum* can cause gangrenous necrosis on the feet from diabetic patients. *Fusarium acutatum* produces fumonisin B1, fumonisin B2, fumonisin B3 and 8-O-Methyl-fusarubin.

References:

EGYPT

- M.M.I. Abdel-Hafez et al. (2012) examined the soils around the roots of sesame and reported *Fusarium acutatum* in the rhizosphere.
- M.M.I. Abdel-Hafez et al. (2014) took ten samples of sesame from local markets in Assiut city. They found the following: *Fusarium acutatum* Nirenberg & O'Donnell (a new species).

A1.1.1k *Fusarium poae* (26 Jul 2021)

Family: Nectriaceae

Definition: Amount of tolerance to *Fusarium poae* (Peck) Wollenw. 1913.

(S.A. Stenglein, 2009) *Fusarium poae* is a fungus of increasingly recognized important, which has been associated with human and animal toxicoses as its strains produce aurofusarin, beauvericin, culmorin, cyclonerodiol, enniatins, fusarin, moniliformin, and trichothecenes of types A and B.

References:

EGYPT

- M.M.I. Abdel-Hafez et al. (2012) examined the soils around the roots of sesame and reported *Fusarium poae* in the rhizosphere and rhizoplane.

A1.1.1l *Fusarium chlamydosporum* (26 Jul 2021)

Family: Nectriaceae

Definition: Amount of tolerance to *Fusarium chlamydosporum* Wollenweber & Reinking 1925.

References:

EGYPT

- M.M.I. Abdel-Hafez et al. (2012) examined the soils around the roots of sesame and reported *Fusarium chlamydosporum* is in the rhizoplane.

- M.M.I. Abdel-Hafez et al. (2014) took ten samples of sesame from local markets in Assiut city. They found the following: *Fusarium chlamydosporum* Wollenw. & Reinking.
- A. Hashem et al. (2014) collected 18 seed samples of sesame in Egypt (12 samples) and Saudi Arabia (6 samples). They identified *Fusarium chlamydosporum.*

A1.1.1m *Fusarium longipes* (26 Jul 2021)

Family: Nectriaceae

Definition: Amount of tolerance to *Fusarium longipes* Wollenweber & Reinking 1925.

References:

EGYPT

- M.M.I. Abdel-Hafez et al. (2012) examined the soils around the roots of sesame and reported *Fusarium longipes* is in the rhizoplane.

A1.1.1n *Fusarium sulawesiensis* (28 Aug 2021)

Family: Nectriaceae

Definition: Amount of tolerance to *Fusarium sulawesiensis* Xia et al. 2019.

References:

PAKISTAN

- M. Kamram et al (2019) observed diseased plants with the following symptoms: mature sesame plants (cv. TS-5) were found wilting in a field. The leaves became brown and necrotic and rotten areas were observed on the cortical region of the stems. Eventually infected plants died. The disease incidence exceeded 75% in some plots depending upon the date of sowing. The pathogen was identified as *Fusarium sulawesiensis.*

A1.1.2 *Gibberella* spp. (11 May 2021)

Family: Nectriaceae

Definition: Amount of tolerance to *Gibberella* spp.

(Wikipedia, 11 May 2021) ***Gibberella*** is a genus of fungi in the family Nectriaceae. In 1926, Japanese scientists observed that rice plants infected with *Gibberella* had abnormally long stems ("foolish seedling disease"). A substance, gibberellin, was derived from this fungus. Gibberellin is a plant hormone that promotes cell elongation, flower formation, and seedling growth.

A1.1.2a *Gibberella fujikuroi* (11 May 2021)

Synonyms: *Fusarium moniliforme* and *Fusarium fujikuroi.*

Family: Nectriaceae

Definition: Amount of tolerance to *Gibberella fujikuroi* (Sawada) Wollenw 1931.

(Wikipedia, 11 May 2021) ***Gibberella fujikuroi*** is a fungal plant pathogen. It causes *bakanae* disease in rice seedlings. Another name is foolish seedling disease. It gets that name because the seeds can be infected, leading to disparate outcomes for the plant. There are not many diseases that initiate similar symptoms as bakanae.

References:

INDIA

- K. Kumar et al. (1984a) reported *Fusarium moniliforme* was found to be associated with the seeds of varieties T-4 and T-12. The species was pathogenic and reduced germination by causing seed rot under laboratory

conditions and produced brown necrotic lesions on roots and later became a seedling invader to cause root rot and seedling blight.
- B.K. Singh (1987) reported *Fusarium moniliforme* was found frequently on sesame seeds. [Cited by G.S. Saharan, 1989]
- N. Saxena and D. Karan (1991) reported on seeds of sesame cv. T-85 collected in Andhra Pradesh contained *Fusarium moniliforme* [*Gibberella fujikuroi*].
- N.O. Srikantappa et al. (2009) studied 28 samples of sesame taken from fields, farmers, retail shops and APMC markets from 5 areas. They found 34 four fungi to include: *Fusarium moniliforme*. The fungi significantly reduced germination.

IRAN
- M. Gooya et al. (2000) reported during 1997/99 one seed samples of each 17 sesame cultivars from 10 locations resulted in 145 isolates, which included 34 species of 15 genera to include *Fusarium moniliforme.*

IRAQ
- N.A. Saad et al. (2013) examined seed and found the following fungi: *Fusarium moniliforme.*

NIGERIA
- A.O. Esan et al. (2020) purchased 60 sesame samples from markets in Nasarawa states during 2 seasons (wet and dry) in order to determine the safety for human consumption. They identified the following fungi: *Aspergillus* section *candidi*, *Aspergillus* section *flavi* (*A. flavus* and *A. tamarii*), *Aspergillus* section *nigri*, *Cladosporium* sp., *Fusarium fujikuroi, Penicillium* spp., and Didymellaceae. [For the toxins found refer to section G1 Toxin producing mycoflora.]

PAKISTAN
- A.S. Shakir and M. Ansar (1992) studied 25 samples of seed collected from various areas in Punjab and found the following fungus: *Fusarium moniliforme.*

SUDAN
- M.A.F. Khamees and E. Schlosser (1990) in testing of 165 Sudanese sesame seed samples recorded *Fusarium moniliforme* [*Gibberella fujikuroi*] . [Based on abstract]
- H.I.H. Idriss (2016) collected farmer saved red and white sesame from 7 locations in Sudan. 14 different fungi representing ten genera were identified. Among the less frequent fungal isolates was *Fusarium moniliforme.*

UGANDA
- S.B. Mathur and F. Kabeer (1975) reported the following pathogen: *Fusarium moniliforme* (*Gibberella fujikuroi*) in trace or moderate amounts in 4 genotypes.

A1.1.2b *Gibberella zeae* (8 Jul 2021)

Family: Nectriaceae

Definition: Amount of tolerance to *Gibberella zeae* (Schwein.) Petch 1936.

(Wikipedia, 8 Jul 2021) ***Gibberella zeae***, also known by the name of its anamorph ***Fusarium graminearum***, is a fungal plant pathogen which causes fusarium head blight, a devastating disease on wheat and barley. The pathogen is responsible for billions of dollars in economic losses worldwide each year. Infection causes shifts in the amino acid composition of wheat, resulting in shriveled kernels and contaminating the remaining grain with mycotoxins, mainly deoxynivalenol, which inhibits protein biosynthesis; and zearalenone, an estrogenic mycotoxin. These toxins cause vomiting, liver damage, and reproductive defects in livestock, and are harmful to humans through contaminated food. Despite great efforts to find resistance genes against *F. graminearum*, no completely resistant variety is currently available. Research on the biology of *F. graminearum* is directed towards gaining insight into more details about the infection process and reveal weak spots in the life cycle of this pathogen to develop fungicides that can protect wheat from scab infection.

References:

REPUBLIC OF KOREA
- H.W. Chung et al. (1966) reported in inoculation tests, sesamum was resistant to *Gibberella zeae.*

A1.1.3 *Neocosmospora* spp. (29 Aug 2021)

Family: Nectriaceae

Definition: Amount of tolerance to *Neocosmospora* spp. E.F. Smith.

(Wikipedia, 29 Aug 2021) ***Neocosmospora*** is a genus of fungi in the family Nectriaceae.

A1.1.3a *Neocosmospora vasinfecta* (19 May 2021)

Family: Nectriaceae

Definition: Amount of tolerance to *Neocosmospora vasinfecta* E.F. Smith 1899.

(Wikipedia, 19 May 2021) ***Neocosmospora vasinfecta*** is a fungal plant pathogen.

References:

INTERNATIONAL

- C. Moreau and M. Moreau (1950) present an account of *Neocosmospora vasinfecta* including its geographical distribution, host range, symptoms, morphology, biological characters and control. Since the organism can live as a saprophyte in soil, new plantings should not be made for several years in areas where diseased plants have been found; soil disinfection is also advised. *Neocosmospora vasinfecta* var. *sesami* occurs sesame. [Cited by G.S. Saharan, 1989]
- J.R. Morschel (1964) reported the following pathogen in the world: *Neocosmospora vasinfecta* var. *sesami*. [Cited by D.F. Beech. 1995a]

UZBEKISTAN

- N.G. Zaprometoff (1925) reported *Neocosmospora vasinfecta* on sesame. [Cited by G.S. Saharan, 1989]

A1.1.4 *Cylindrocladium* spp. (20 Jul 2021)

Family: Nectriaceae

Definition: Amount of tolerance to *Cylindrocladium* spp. Morgan 1892.

(Wikipedia, 20 Jul 2021) ***Cylindrocladium*** is a genus of ascomycete fungi in the family Nectriaceae. Many species within this genus are synonymous with the genus *Calonectria*.

References:

INTERNATIONAL

- C. Wescott (1971) reported the following pathogen: leaf spots (*Cylindrocladium* spp.).

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A1.2 Family: Stachybotryaceae L. Lombard & Crous 2014

(Wikipedia, 22 Apr 2021) The **Stachybotryaceae** are a family of fungi in the order Hypocreales; the genera it contains have been described as "hyper-diverse".

The following species have been reported to cause diseases, produce a toxin, inhibit germination, or affect seed quality.

- A1.2.1 *Myrothecium* spp.
- A1.2.2 *Memnoniella* spp.
- A1.2.2 *Memnoniella echinata*
- A1.2.3 *Paramyrothecium* spp.
- A1.2.3a *Paramyrothecium roridum* (*Syn: *Myrothecium roridum*)

There are species in this family associated with sesame, but not reported to cause diseases, produce a toxin, inhibit germination, or affect seed quality. See H9.3.

A1.2.1 *Myrothecium* spp. (22 Apr 2021)

Family: Stachybotryaceae

Definition: Amount of tolerance to *Myrothecium* spp. Tode 1790.

(Wikipedia, 22 Apr 2021) ***Myrothecium*** is a genus of fungi in the order Hypocreales and is now placed in the family Stachybotryaceae.

References:

EGYPT

- M.M.I. Abdel-Hafez et al. (2012) examined the soils around the roots of sesame and reported *Myrothecium* sp. in the rhizosphere.

INDIA

- R.K.S. Chauhan and S. Chauhan (1984a) evaluated the pathogenic potentials of Myrothecium in relation to seed viability, germination, and formation of seedlings. The toxic metabolites produced by the pathogen in culture filtrate had phytotoxic effect on seeds and healthy plants. [Cited by G.S. Saharan, 1989]

A1.2.2 *Memnoniella* spp. (2 Jun 2021)

Family: Stachybotryaceae

Definition: Amount of tolerance to *Memnoniella* spp. Hohn 1923

The following species has been associated with sesame but there are no known reports of being a pathogen, producing a toxin, inhibiting germination, affecting seed quality, or being used as a biocontrol or biofertilizer.

- *Memnoniella sitophila* [India]

A1.2.2a *Memnoniella echinata* (2 Jun 2021)

Family: Stachybotryaceae

Definition: Amount of tolerance to *Memnoniella echinata* (Rivolta) Galloway 1933.

(mold-answers.com, 2 Jun 2021) ***Memnoniella echinata*** is a common form of mold found all around the world. It used to be called *Stachybotrys echinata*, and it is very similar to another common type of mold *Stachybotrys chartarum*. *Stachybotrys chartarum* is sometimes referred to as black mold, since it is black in color, or toxic mold, because it produces mycotoxins.

References:

INDIA

- K. Kumar et al. (1984a) reported *Memnoniella echinata* was found to be associated with the seeds of varieties T-4 and T-12. The species was pathogenic and reduced germination by causing seed rot under laboratory conditions.

A1.2.3 *Paramyrothecium* spp. (2 Oct 2021)

Family: Stachybotryaceae

Definition: Amount of tolerance to *Paramyrothecium* spp. L. Lombard & Crous 2016.

A1.2.3a *Paramyrothecium roridum* (2 Oct 2021)

Synonym: *Myrothecium roridum*

Family: Stachybotryaceae

Definition: Amount of tolerance to *Paramyrothecium roridum* (Tode) L. Lombard & Crous, 2016.

(Wikipedia, 22 Apr 2021) ***Myrothecium roridum*** is a fungal plant pathogen. Mycotoxin B has been isolated from it.

References:

CUBA
- La Habana (2009) in a grower guide reported the following pathogen: *Myrothecium roridum*.

INDIA
- D.B. Singh and H.S. Srivastava (1967) reported a new record of a leaf spot disease: *Myrothecium roridum.* [Cited by G.S. Saharan, 1989]
- A.R. Wasnikar et al. (1987) reported the influence of fungi varied for seed and soil contamination: *Myrothecium roridum*: 32 and 16%. [Based on abstract]
- A.R. Wasnikar et al. (1988) reported media were prepared with various C and N contents. In general, growth of *Alternaria sesami*, *Fusarium oxysporum* f. sp. *sesami*, *Helminthosporium sesami* and *Myrothecium roridum*, the most important pathogens of same, increased with C and N concentrations. [Based on abstract]

PAKISTAN
- A.S. Shakir and M. Ansar (1992) studied 25 samples of seed collected from various areas in Punjab and found the following fungus: *Myrothecium roridum*.

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A1.3 Family: Hypocreaceae De Notaris 1844

(Wikipedia, 27 Jun 2021) The **Hypocreaceae** are a family within the class Sordariomycetes. Species of Hypocreaceae are usually recognized by their brightly colored, perithecial ascomata, typically yellow, orange or red. The family was proposed by Giuseppe De Notaris in 1844. According to the *Dictionary of the Fungi* (10th edition, 2008), the family has 22 genera and 454 species.

The following species have been reported to cause diseases, produce a toxin, inhibit germination, or affect seed quality.
- A1.3.1 *Acremonium* spp. (*Syn: *Cephalosporium* spp.)
- A1.3.1a *Acremonium chrysogenum* (**Syn: Cephalosporium acremonium*)
- A1.3.1b *Acremonium strictum*

A1.3.1 *Acremonium* spp. (27 Jun 2021)

Synonym: *Cephalosporium* spp.

Family: Hypocreaceae

Definition: Amount of tolerance to *Acremonium* spp. Link 1809.

(Wikipedia, 27 Jun 2021) ***Acremonium*** is a genus of fungi in the family Hypocreaceae. It used to be known as ***Cephalosporium***.

References:

EGYPT
- M.M.I. Abdel-Hafez et al. (2012) examined the soils around the roots of sesame and reported *Acremonium* sp. in the rhizosphere.

INDIA
- N.O. Srikantappa et al. (2009) studied 28 samples of sesame taken from fields, farmers, retail shops and APMC markets from 5 areas. They found *Acremonium* sp. The fungi significantly reduced germination.

- V. Bharathi et al. (2013) collected sesame seeds from farmers in Andhra Pradesh. They tested the seeds for mycoflora, and reported *Cephalosporium* spp.

PAKISTAN

- A.S. Shakir and M. Ansar (1992) studied 25 samples of seed collected from various areas in Punjab and analyzed for the presence of mycoflora. They found the following fungus: *Cephalosporium* spp.
- N. Altaf et al. (2004) tested 400 seeds from each of 10 cultivars for seedborne mycoflora. Eleven phytopathogenic fungi were found to include *Cephalosporium* sp.

A1.3.1a *Acremonium chrysogenum* (2 Oct 2021)

Synonym: *Cephalosporium acremonium*

Family: Hypocreaceae

Definition: Amount of tolerance to *Acremonium chrysogenum*.

(https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5640796/, 2 Oct 2021) *Acremonium chrysogenum*, belongs to Filamentous fungi, is an important industrial microorganism. One of its metabolites, cephalosporin C (CPC), is the major resource for production of 7-amino cephalosporanic acid (7-ACA), an important intermediate for manufacturing of many first-line anti-infectious cephalosporins-antibiotics, in industry.

References:

INDIA

- T. Singh and D. Singh (1983) isolated 24 fungi: Of these, *Cephalosporium acremonium* was an important pathogens. [Cited by G.S. Saharan, 1989]

A1.3.1b *Acremonium strictum* (2 Oct 2021)

Family: Hypocreaceae

Definition: Amount of tolerance to *Acremonium strictum* W. Gams 1971.

(Wikipedia, 24 Jul 2021) ***Acremonium strictum*** is an environmentally widespread saprotroph species found in soil, plant debris, and rotting mushrooms. Isolates have been collected in North and Central America, Asia, Europe and Egypt. *A. strictum* is an agent of hyalohyphomycosis and has been identified as an increasingly frequent human pathogen in immunosuppressed individuals, causing localized, disseminated and invasive infections. Although extremely rare, *A. strictum* can infect immunocompetent individuals, as well as neonates. Due to the growing number of infections caused by *A. strictum* in the past few years, the need for new medical techniques in the identification of the fungus as well as for the treatment of human infections has risen considerably.

A. strictum has been shown to be involved in some myoparasitic relationships, as well as a wide range of plant endophytic and parasitic relationships, and further studies are required to determine *A. strictum's* use as a biological control agent and role as a parasite that reduces crop yields. *A. strictum* exhibits metabolism of many products that imply future agricultural and pharmaceutical significance.

References:

IRAN

- M. Gooya et al. (2000) reported during 1997/99 one seed samples of each 17 sesame cultivars from 10 locations resulted in 145 isolates, which included 34 species of 15 genera. The identified *Acremonium strictum.*

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A2 Order: Botryosphaeriales C.L. Schoch, Crous & Shoemaker 2007

(Wikipedia, 8 Apr 2021) The **Botryosphaeriales** are an order of sac fungi (Ascomycetes), placed under class Dothideomycetes. Some species are parasites, causing leaf spot, plant rot, die-back or cankers, but they can also be saprophytes or endophytes. They occur world-wide on many hosts.

The order was originally defined in 2006 to have only one family, Botryosphaeriaceae, but new taxonomic studies have added at least seven other families.

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A2.1 Family: Botryosphaeriaceae Theiss. & H. Sydow 1918

(Wikipedia, 8 Apr 2021) The **Botryosphaeriaceae** are a family of sac fungi (Ascomycetes), which is the type representative of the order Botryosphaeriales. According to a 2008 estimate, the family contains 26 genera and over 1500 species.

The following species have been reported to cause diseases, produce a toxin, inhibit germination, or affect seed quality.

- A2.1.1 *Macrophomina* spp.
- A2.1.1a *Macrophomina phaseolina* (*Syn: *Dothiorella phillippinensis, M. corchon, M. phaseoli, M. phaseoli* ssp. *sesamica, M. phillippinensis, Rhizoctonia bataticola , Sclerotium bataticola,* and *Tiarosporella phaseolina*)
- A2.1.2 *Phyllosticta* spp.
- A2.1.2a *Phyllosticta sesami*
- A2.1.3 *Botryosphaeria* spp.
- A2.1.31a *Botryosphaeria ribis*

There are species in this family associated with sesame, but not reported to cause diseases, produce a toxin, inhibit germination, or affect seed quality. See H6.1.

A2.1.1 *Macrophomina* spp. (8 Apr 2021)

Family: Botryosphaeriaceae

Definition: Amount of tolerance to *Macrophomina* spp. Petr. 1923

Summary:

Microsclerotia on stem in disease resistance assay

Microsclerotia on capsule

Photos: K.A. Cochran {USA}

Macrophomina phaseolina (Synonyms: *Dothiorella phillippinensis, M. corchon, M. phaseoli, M. phaseoli* ssp. *sesamica, M. phillippinensis, Rhizoctonia bataticola, Sclerotium bataticola,* and *Tiarosporella phaseolina.*) causes one of the most important diseases of sesame worldwide - charcoal rot. The name charcoal rot is due to the ashy/charcoal discoloration caused by durable microsclerotia embedded in plant tissues. Microsclerotia are approximately the size of a pin head or smaller abundantly present in the symptomatic stem tissue, which can include roots, stems, pods, and seeds. These can be visible embedded in the outside of the stem, or in the pith when cut lengthwise. The pathogen is soilborne and seedborne and can persist in the soil up to 15 years. The fungus thrives in the same conditions that are favorable for growing sesame - hot and dry. When conditions are favorable, the fungus produces asexual spores (conidia) in small round black structures (pycnidia) that are apparent embedded on the surface of the stem. This pathogen has a very broad host range (over 500 plant host species) and can manifest in a variety of symptoms such as damping off, stem, root, and collar rots. The most commonly noticed symptoms include stunting, leaf yellowing, premature defoliation and dry down, rot progressing up the stem, and premature or non-typical pod dehiscence for a given variety. Symptoms are often noticed by producers mid to late season when they are most apparent, though infection often

occurs earlier mid-season. Infections that occur earlier in the season often result in significant stunting and plant death by the end of the season. Microsclerotia can be spread field to field by seed transport, movement of microsclerotia infested soil on farm equipment, and within a field by equipment movement and flooding water carrying microsclerotia. Other genera in the Botryosphaericeae family that are pathogenic include *Botryosphaeria* spp. and *Phyllosticta* spp. *Macrophomina* spp. have been reported in international lists, Australia, Bangladesh, Brazil, China, Colombia, Cuba, Cyprus, Ecuador, Egypt, Ethiopia, Greece, Honduras, India, Iran, Iraq, Israel, Japan, Kenya, Mexico, Myanmar, Nicaragua, Nigeria, Pakistan, Paraguay, Republic of Korea, Sri Lanka, Sudan, Syria, Tanzania, Thailand, Turkey, Uganda, United States, and Venezuela.

(Wikipedia, 8 Apr 2021) ***Macrophomina*** is a genus of fungi in the family Botryosphaeriaceae. There are two species, *Macrophomina limbalis* and *Macrophomina phaseolina*.

References:

AUSTRALIA

- M.R. Bennett (1986-1997). In his sesame development program in the Northern Territories of Australia between 1986 and 1997, he took data on 'Susceptibility to *Macrophomina*'. In the 1993-94 wet season he took data on 200 plants, and the data ranged from 2 to 157 plants with the disease. His ideotype included tolerance to this disease.

CHINA

- X.R. Zhang et al. (2000) studied 4,251 genotypes (4,073 from China and 178 from other countries) using 14 traits that were genetically stable and agronomically important. They pre-selected a core of 884 accessions to grow in 3 locations for 2 years and finally selected a core of 453 accessions. They examined *Resistance to charcoal rot disease* and had the following distribution:
  - 1 = Highly resistant (5.7%)
  - 3 = Resistant (24.9%)
  - 5 = Susceptible (50.3%)
  - 7 = Highly susceptible (19.0%)
- Anon. (2006a) China descriptor: 8.1 (129) Resistance to *charcoal rot* (CCCC). They provide a methodology for artificial inoculations and observing in natural fields. The following are the ratings to be used.
  - 0 = Immune
  - 1 = High resistance (HR)
  - 3 = Resistance (R)
  - 5 = Susceptible (S)
  - 7 = High susceptibility (HS)
  - H.Y. Zhang/H.M. Miao (pers. comm. 2016): This descriptor is used to describe new germplasm that is acquired by the Henan Sesame Research Center. It is also used in the breeding program.
  - X.R. Zhang/L.H. Wang (pers. comm. 2016): This descriptor is used in the breeding program by the Chinese Academy of Agricultural Sciences-Oil Crops Research Institute, Wuhan. It is also used to describe new germplasm that is acquired.

INDIA

- K.R. Sharma and K.G. Mukerji (1974) reported a pathogenic *Macrophomina* spp. on aging, senescing, and decaying leaves. [Cited by G.S. Saharan, 1989]
- N.D. Desai and S.N. Goyal (1981b) reported that TMV1, TMV3, KRR-1, KRR-2, and G-5 are resistant to *Macrophomina*.
- V. Bharathi et al. (2013) collected sesame seeds from farmers in Andhra Pradesh. They tested the seeds for mycoflora, and the following fungus was found: *Macrophomina* spp.
- C. Jeyalakshmi et al. (2013) evaluated integrated disease management practices to combat major diseases (Alternaria leaf blight, *Macrophomina* root rot, and Powdery mildew) and to increase the seed yield of sesame during summer 2009 and 2010 using at Karaikal (10.93N 79.84E). The treatments were as follow.
  - M1: Soil application of neem cake @ 250 kg /ha+ seed treatment with thiram (0.2%) + carbendazim (0.1%) + foliar spray of mancozeb (0.25%) + endosulfan (0.07%) at 30 and 45 DAS.
  - M2: Seed treatment with *Trichoderma viride* (0.4 %) + soil application of *T. viride* @ 2.5 kg/ha + foliar spray of mancozeb (0.25%) + endosulfan (0.07%) at 30 and 45 DAS.
  - M3: Soil application of neem cake @ 250 kg /ha + seed treatment with *T. viride* (0.4 %) + soil application of *T. viride* @ 2.5 kg/ha + foliar spray of azadirachtin (0.03%) @ 3 mL/L on 30 and 45 DAS.

- M4: Farmer's practices (control)

The results were as follow.

Module	2009*				2010*			
	Root rot (%)	Powdery mildew (PDI)	Seed yield (kg/ha)	C:B ratio	Root rot (%)	*Alternaria* blight (PDI)	Seed yield (kg/ha)	C:B
M1	8.28[b]	5.10[b]	680[c]	1:1.03	8.80[b]	5.44[b]	708[c]	1:1.18
M2	7.05[b]	4.22[b]	690[b]	1:1.13	6.90[b]	6.16[b]	720[b]	1:1.28
M3	3.04[a]	2.01[a]	760[a]	1:1.20	2.54[a] (9.13)	2.48[a]	766[a]	1:1.32
M4	17.7[c]	11.95[c]	545[d]	1:1.00	18.60[c]	19.40[c]	495[d]	1:0.98

- B. Khamari et al. (2018c) conducted an intensive survey at flowering to ripening of capsule to record the incidence of sesame diseases in 10 agroclimatic zones of Odisha during rabi 2014-15 with the following results.

Sl. No.	Place	Variety	Mac (%)	Fus (%)	Alt (Grade)	PM (Grade)	Cer (Grade)	Phy (%)
1	Bheden	Bheden local	18.09	9.78	3	0	2	0
2	Balianta	VRI-1	23.8	8.0	4	3	2	2.3
3	Nuagaon	Nuagaon local	12.8	3.0	3	0	2	0.6
4	Papadahandi	Papdahandi local	15.2	4.1	2	0	2	1.0
5	Betanati	Betanati local	18.8	0.5	2	2	1	0
6	Kalimela	Kalimela local	11.3	0.8	3	1	2	0.8
7	Agarpada	Agarpada local	8.0	1.0	3	1	1	0.6
8	Kirei	Sundergarh local	15.8	3.9	2	0	1	1.4
9	Khajuripada	Phulbani local	10.5	2.9	3	3	1	0.0
10	Bhawanipatna	Narla local	19.2	4.8	4	0	2	1.4

Mac=*Macrophomina*, Fus= *Fusarium*, Alt= *Alternaria*, PM= Powdery Mildew, Cer= *Cercospora*, Phy= Phyllody

ISRAEL

- Ashri (1981a) reported the major diseases are soilborne *Fusarium* sp. and *Macrophomina* sp. The varieties Aceitera and Renner proved extremely susceptible. [Authors comment: Aceitera is a Venezuelan variety and Renner is a United States variety.]

JAPAN

- T. Kuzuyuki (2021) cited the following pathogen *Macrophomina sesami* (Brown spot) is listed in the Database of Plant Diseases in Japan.

KENYA

- B. Mazzani (1987) visited sesame growing regions and reported the following major pathogen: *Macrophomina* spp.

MYANMAR

- D. Myint (2020) reported charcoal rot is a serious disease.

NICARAGUA

- R.A. Marenco M. et al. (1988) reported the most important diseases are those that rot the base of the stem, and this is most severe in soils with insufficient drainage. The principal causes of this fungal disease have been identified as being *Macrophomina* sp., *Fusarium* sp. and *Rhizoctonia* sp. The only methods of control are to rotate crops and at the same time to avoid planting in soils with poor drainage.

NIGERIA

- A.D. Ojochenemi et al. (2015) examined 46 samples of sesame and reported *Macrophomina* spp.

PARAGUAY

- L.C. Rossi and A.L. Orrego (2007) identified the following fungus on sesame seeds: *Macrophomina* sp.
- Anon. (2015a) Paraguay descriptor: 1.10 Incidence of *Macrophomina*. The following ratings are used:

- 0 = Sin informacion [No information]
- 1 = Resistente [Resistant]
- 2 = Medianamente resistente [Moderately resistant]
- 3 = Medianamente susceptible [Moderately susceptible]
- 4 = Susceptible [Susceptible]

REPUBLIC OF KOREA

- S.W Kang and H.K. Kim (1989) reported *Macrophomina* sp. is frequently encountered in the soils. [Based on abstract]

THAILAND

- V. Benjasil (1985a) reported *Macrophomina* sp. and *Sclerotium* sp. (Root and stem rot) causes losses in yield.

UNITED STATES

- J. A. Martin (1953a) along with M.L. Kinman and J.A. Martin (1954) reported the presence of *Macrophomina* in the USA under drought conditions.
- D.R. Langham (1998e) reported that Sesaco took notes in most years on *"37c. Macrophomina.* Important in South Texas."
- D.T. Smith et al. (2000) reported Charcoal rot was observed on sesame in Texas and California on young seedlings and in mid-season. Charcoal rot attacks roots, crowns, and lower stems when sesame is planted after other susceptible crops. The stem rots just above the soil line and results in severe stand reductions. Early sesame breeders in Texas (Kinman) and Arizona (Yermanos) worked on resistance to charcoal rot and it is rarely a problem now.

VENEZUELA

- D.G. Langham et al. (1961c) used the following symbology in the Sesamum Foundation: *Resistencia a marchitez* [Macrophomina]
  - K1 = Resistant
  - K2-K4 = Intermediate
  - K5 = Susceptible
- B. Mazzani et al. (1973) introduced a new variety 'Maporal' which is especially adapted to conditions in which soilborne pathogens (*Phytophthora*, *Fusarium, Macrophomina*, and *Rhizoctonia*) are prevalent.

A2.1.1a *Macrophomina phaseolina* (8 Apr 2021)

Synonyms: *Dothiorella phillippinensis*, *M. corchon*, *M. phaseoli*, *M. phaseoli* ssp. *sesamica*, *M. phillippinensis, Rhizoctonia bataticola*, *Sclerotium bataticola*, and *Tiarosporella phaseolina*

Family: Botryosphaeriaceae

Definition: Amount of tolerance to *Macrophomina phaseolina* (Tassi) Goid. 1947

(Wikipedia, 8 Apr 2021) ***Macrophomina phaseolina*** is a Botryosphaeriaceae plant pathogen fungus that causes damping off, seedling blight, collar rot, stem rot, charcoal rot, basal stem rot, and root rot on many plant species.

One of the most harmful seed and soilborne pathogens, *Macrophomina phaseolina* is a fungus that infects nearly 500 plant species in more than 100 families. The identification of isolates of *M. phaseolina* is usually based on morphology and efforts to divide the pathogen into subspecies, but because there are wide intraspecific variations in the phenotype of the isolates, these criteria are often not reliable. The failure to correctly detect and identify *M. phaseolina* using conventional culture-based morphological techniques has led scientists to develop nucleic acid-based molecular approaches, such as highly sensitive and specific polymerase chain reaction-based methods. Researchers have also recently created species-specific oligonucleotide primers and digoxigenin-labeled probes in hopes of better identifying and detecting *M. phaseolina*.

The pathogen *M. phaseolina* affects the fibrovascular system of the roots and basal internodes of its host, impeding the transport of water and nutrients to the upper parts of the plant. As a result, progressive wilting, premature dying, loss of vigor, and reduced yield are characteristic symptoms of *M. phaseolina* infection. The fungus also causes many diseases like damping off, seedling blight, collar rot, stem rot, charcoal rot, basal stem rot, and root rot. Although brown lesions may form on the hypocotyls or emerging seedlings, many symptoms occur during or after flowering, including grey discoloration of the stem and taproots, shredding of plant tissue in the stem and top of the

taproot, and hollowing of the stem. Small black dots may form beneath the epidermis of the lower stem and in the taproot, giving the stems and roots a charcoal-sprinkled appearance. When the epidermis is removed, small and black microsclerotia (a sign of the disease) may be so numerous that they give a greyish-black tint to the plant tissue. In addition, reddish-brown discoloration and black streaks can form in the pith and vascular tissues of the root and stem.

The *M. phaseolina* fungus has aggregates of hyphal cells, which form microsclerotia within the taproots and stems of the host plants. The microsclerotia overwinter in the soil and crop residue and are the primary source of inoculum in the spring. They have been shown to survive in the soil for up to three years. They are black, spherical or oblong structures that allow the persistence of the fungus under poor conditions, such as low soil nutrient levels and temperatures above 30° C. However, in wet soils, microsclerotia survival is significantly lower, often surviving no more than 7 to 8 weeks, and mycelium cannot survive more than 7 days. Additionally, infected seeds can carry the fungus in their seed coats. These infected seeds either do not germinate or produce seedlings that die soon after emergence.

Macrophomina phaseolina is a heat- and drought-favoring disease, producing large quantities of microsclerotia under relatively low water potentials and relatively high temperatures. In soybeans especially, charcoal rot typically occurs when the plants are experiencing significant drought stress.

When conditions are favorable, hyphae germinate from these microsclerotia. Germination of the microsclerotia occurs throughout the growing season when temperatures are between 28 and 35° C. Microsclerotia germinate on the roots' surface, and germ tubes on the end of the microsclerotia form appresoria that penetrate the hosts' epidermal cell walls using turgor pressure or through natural openings.

The hyphae infect the roots of the host plant. Initially, the hyphae enter the cortical tissue and grow intercellularly, then infect the roots and the vascular tissue. Within the vascular tissue, mycelia and sclerotia are produced and plug the vessels. This causes the greyish-black color often observed in plants infected by *M. phaseolina*, and it also prevents water and nutrients from being transported from the roots to the upper parts of the plant. Thus, due to this systemic infection, diseased plants often wilt and die prematurely.

(Anon. n.d.k) Root rot or stem rot or charcoal rot - *Macrophomina phaseolina* (Sclerotial stage: *Rhizoctonia bataticola*)
Symptoms: The disease symptom starts as yellowing of lower leaves, followed by drooping and defoliation. The stem portion near the ground level shows dark brown lesions and bark at the collar region shows shredding. The sudden death of plants is seen in patches. In the grown-up plants, the stem portion near the soil level shows large number of black pycnidia. The stem portion can be easily pulled out leaving the rotten root portion in the soil. The infection when spreads to pods, they open prematurely, and immature seeds shriveled and become black in color. Minute pycnidia are also seen on the infected capsules and seeds. The rotten root as well as stem tissues contains a large number of minute black sclerotia. The sclerotia may also be present on the infected pods and seeds.

Pathogen: The pathogen produces dark brown, septate mycelium showing constrictions at the hyphal junctions. The sclerotia are minute, dark black and 110-130m in diameter. The pycnidia are dark brown with a prominent ostiole. The conidia are hyaline, elliptical and single celled.

Favorable Conditions: Day temperature of 30˚C and above; prolonged drought followed by copious irrigation.

Disease cycle: The fungus remains dormant as sclerotia in soil as well as in infected plant debris in soil. The infected plant debris also carries pycnidia. The fungus primarily spreads through infected seeds which carry sclerotia and pycnidia. The fungus also spreads through soilborne sclerotia. The secondary spread is through the conidia transmitted by wind and rain water.

Management: Seed treatment with carbendazim + thiram (1:1) at 2g/kg seed; treat the seeds with *Trichoderma viride* at 4g/kg; apply farm yard manure or green leaf manure at 10t/ha or neem cake 150 kg/ha. Spot drench with Carbendazim at 1.0 g/l.

References:

INTERNATIONAL

- R.S. Vasudeva (1961) in a review of sesame diseases stated *Macrophomina phaseoli* is one of the major diseases in the world. The root rot has dark brown or black discoloration at the base of the stem which frequently breaks off at the ground level. The disease may travel along the stem up to 30 cm or so. On the surface of the affected parts of the stem, abundant dot-like black structures are formed representing the pycnidial stage of the fungus. Inside the affected portion of the roots and stem there are numerous sclerotia characteristic of *Rhizoctonia bataticola*. The pycnidia and sclerotia may also be present on the capsules and seeds. Humid weather conditions at the time of maturity may results in severe attack on the capsules due to a secondary infection. The infected capsules open prematurely. The immature seeds thus exposed also get infected and as a result, shrivel up.
- J.R. Morschel (1964) reported the following pathogen in the world: *Macrophomina phaseoli* (Charcoal rot) which is seedborne. [Cited by D.F. Beech. 1995a]
- E.A. Weiss (1971) reported *Macrophomina phaseolina* (the sterile state, which is known as *Sclerotium* or *Rhizoctonia bataticola*) has been recorded on 293 species of plants in different parts of the world. The pathogen attacks the stems causing them to become characteristically black and rotten. In the early sates of infection plants make poor growth and remain stunted, and numbers may eventually die. Capsules are also affected, and seeds with the small black sclerotia can be found in the capsules. High soil temperature and moisture favor the spread and increase its severity. It is also spread in irrigation water. Periods of drought between heavy rainstorms are thought to favor spread. The very wide range of host plants makes control almost impossible, and the infection is soil- and seedborne. The fungus can survive the heat of tropical dry seasons in the soil and reinfect subsequent crops.
- C. Wescott (1971) reported the following pathogen: charcoal rot (*Macrophomina phaseoli*).
- P. Neergaard (1979) reported the following pathogen caused a disease in sesame: *Macrophomina phaseolina*. [Cited by G.S. Saharan, 1989]
- Anon (2000a) is an organic grower guide for America. It describes the following pathogens and their recommended organic method of control: *Macrophomina phaseolina* and *Rhizoctonia bataticola* (Stem and root rot) – The contagion is transmitted through seeds and soil. Green manure and stimulation of antagonists (mature compost). Use of resistant or less susceptible varieties (e.g., varieties with purple capsules).
- Anon. (2004a) IPGRI descriptor: 10.2.5. Biotic stress susceptibility to *Macrophomina phaseolina*. (Root and stem rot)
  - In each case it is important to state the origin of the infestation or infection, i.e., natural, field inoculation, or laboratory. Also specify the causal organism and the corresponding symptoms. The susceptibility scale is as follows:
    - 1 = Very low or no visible sign of susceptibility
    - 3 = Low
    - 5 = Intermediate
    - 7 = High
    - 9 = Very high
  - The growth state, coded according to the list below at which each reaction was recorded should be appended to the record of that reaction.
    - 1 = Seed
    - 2 = Seedling
    - 3 = Pre-flowering
    - 4 = Early flowering
    - 5 = Mid-flowering
    - 6 = Late-flowering
    - 7 = Maturity
- C. Chattopadhyay et al. (2019) described the following symptoms of *Macrophomina phaseolina:* Sesame plants may be attacked immediately after sowing. The germinating seeds may become brown and rot. In the seedling stage, the roots may become brown and rot, resulting in the death of the plants. If the plants survive, the older plants are affected at the base of the stem indicating the formation of lesion that later spreads to the middle portion of the stem and becomes ashy, causing drooping of leaves and top of the plants. Such plants make poor growth and remain stunted. The mycelium of the fungus progresses upward in the stem, and as the stem dries, pycnidia are formed as minute black dots. The stem may break off, and the blackening may extend upward on

the stem. The capsules are also affected. Such capsules open prematurely, exposing shriveled and discolored seeds. Seeds may show the presence of sclerotia on the surface.

Seedling mortality due to seedborne infection aggravates the disease problem by reducing the plant stand per unit area, resulting in low yield. About 5%–100% yield loss due to the disease is reported. An estimated yield loss of 57% at about 40% disease incidence is reported (S. Maiti et al. 1988). If the disease appears simultaneously with Phytophthora blight or with Fusarium wilt, the losses in yield usually are very high. The response of the sesame crop to stress conditions has been found to be of significant importance in epidemiology, and irrigation reduces infection by reducing drought stress. Periods of drought between heavy rains favor the development of the disease in Africa.

Seed treatment with carbendazim (0.1%–0.3%) gives complete control of seedborne infection of *M. phaseolina* when used as seed treatment fungicide (C.S. Choudhary et al. 2004 {India}, R.A. Shah et al. 2005 {Pakistan}, P. John et al. 2010 {India}). Other seed treatment fungicides are thiophanate methyl (P. John et al. 2010 {India}), Benlate or Rizolex T at 3 g/kg seed (A.A. El-Deeb et al. 1985 {Egypt}), mancozeb (P.J. Mudingotto et al. 2002 {India}), thiram, captan, and carboxin (M.L. Verma et al. 2005 {India}). Aminobutylic acid and potassium salicylate can effectively control charcoal rot in sesame by induction of host resistance against *M. phaseolina* and increasing plant height, indole acetic acid (IAA) content, and peroxidase (PO) activity (I.M.S. Shalaby et al. 2001 {Egypt}). Soaking sesame seeds in indole butyric acid at 100 ppm or salicylic acid at 4 mM produce healthy stand of plants.

The average charcoal rot incidence can be lowered down by choice of sowing date and levels and time of irrigation depending on the local conditions in a particular geographical area. Early sowing by June 10 in Egypt and following hills-over-furrows method of sowing and giving only one irrigation during the whole growing season to a crop fertilized with N at 65 kg, P at 200 kg, and K at 50 kg/feddan (0.42 ha) resulted in significant reduction in charcoal rot incidence (O.Y.M. Shalaby and A.T. Bakeer 2000 {Egypt}). It is noteworthy that green gram (mung) and black gram plant extracts are inhibitory to the growth of *M. phaseolina* (S.J. Kolte and P.A. Shinde 1973 {India}).

Effect of antagonistic fungi and bacteria isolated from the rhizosphere of sesame is reported to be efficiently more effective in controlling the root rot and stem rot of sesame caused by *M. phaseolina*. Sesame seed treatment with (a) *Trichoderma viride* at 4 g/kg of seed (T.S. Rajpurohit 2004a {India}, H.Z.A. Hafedh et al. 2005 {Iraq}, (b) *Trichoderma harzianum* (Cardona and Rodriguez 2002 {Venezuela}, A.M.H. Sattar et al. 2006 {Unknown}; S. Moi and P. Bhattacharyya 2008 {India}), (c) *Pseudomonas fluorescens* (S. Moi and P. Bhattacharyya 2008 {India}), and (d) *Bacillus subtilis* has been found effective in the control of charcoal rot disease. Seed treatment with *Azotobacter chroococcum* and seed + soil treatment with *Azospirillum* also reduce the disease by about 30% (M.L. Verma et al. 2005 {India).

Extracts of *Thevetia neriifolia* (A.A. Bayounis and M.A. Al-Sunaidi 2008b {Unknown}, and *Helichrysum* flower (I.M.S. Shalaby et al. 2001 {Egypt}) show inhibitory effect on the growth of *M. phaseolina*, indicating their potential use in the control of the disease. The extracts of Eucalyptus (*Eucalyptus rostrata, E. camaldulensis*), peppermint (*Mentha piperita*), and thyme (*Thymus serpyllum*), when used in sand culture or under *in vitro* conditions in growth media and inoculated with *M. phaseolina*, have been found to show increase in sesame seed germination despite the presence of *M. phaseolina* in the culture, indicating potential usefulness of these extracts (A. Sidawi et al. 2010 {Unknown}).

- CAB International (accessed 12 Apr 2021) reported sesame was a major host of *Macrophomina phaseolina* (Charcoal rot of bean/tobacco).
- N. Ransingh et al. (2021) described the following symptoms of *Macrophomina phaseolina* (Tassi.) Goid (Charcoal rot, dry rot, stem rot or root rot): Stem and root rot is a devastating disease which affects all the stages of plant. It leads to poor seedling establishment, reduction of vigor, discoloration of plant, dry root rot, and finally wilting of the plant which reduces the productivity (B. Khamari et al. 2016 {India}). The disease affects the seed at the initial stage, causing seed rot leading to improper germination and rotting of young seedlings and resulting into poor plant population in the field (S.H. Yu and J.S. Park 1980 {Republic of Korea}; M.C. Gonzalez and M.L. Subero 1984 {Venezuela}; I.K. Das et al. 2015 {India}; B. Khamari et al. 2016 {India}). In the later stages, small brownish-colored lesions appear on the stem regions. It gradually spreads in both the directions affecting the whole plant (B. Khamari et al. 2016 {India}). Affected plants turn black due to the presence of microsclerotia (Y.A. Abdou et al., 1980a {India}; B. Khamari et al. 2016 {India}). It also attacks the below-ground resulting in poorly developed secondary roots (B. Khamari et al. 2016 {India}). In the advanced stage, it deforms and rots the roots. Finally, the whole plant wilts, which leads to poor development of capsule and ultimately a significant reduction in total plant yield. Being systemic in nature, the pathogen moves

through xylem vessel and totally degrades the vascular tissue. The infected vascular bundle turns to black color. Hence, there is blockage in the flow of nutrients, which results in wilting and death of plant in later stages (B. Khamari et al. 2016 {India}). The disease severity occurs in drought stress as the defense system of the plant becomes weak, and the pathogenic activity may increase several-fold.

The pathogen attacks more than 500 plant species and survives in soil as well as in seed. It exists in the form of microsclerotia in the absence of host. These microsclerotia persist in soil for a very long period of time (2–15 years depending upon environmental conditions and host residues). These are potent resting structure having the potential to germinate quickly from each and every cell and produce a germ tube which finally infects the susceptible host, acting as the source of primary inoculum. These resting structures are adapted to a wide range of environmental conditions, such as moisture, temperature, or nutrient stresses. It requires temperature, ranging from 28-35°C for germination. These microsclerotia produce appressoria after germination, which helps in penetration of the host epidermis by secreting various cell wall degrading enzymes. The pathogen may also penetrate through natural openings or wounds. These mycelia colonize in vascular tissue by entering the xylem vessels. It clogs the vascular system and restricts the conduction process resulting in wilting of plant. The pathogen produces various enzymes and toxins which may help in the development of characteristic symptoms of rotting, wilting, and blight, etc.

The severity of the disease depends on microsclerotia density or pathogen inoculum present in the field (B. Khamari et al., 2019 {India}). The pathogen also survives in seed apart from soil. Seeds produced from infected plants when sown in the field rot and do not germinate. Even if it germinates, after few days, the stems become brownish, thin, wire-like and toppled down from that point though the upper portion remain green (B. Khamari et al., 2016 {India}). The rate of disease development and disease severity is directly related to the pathogen propagules present in the soils, as well as the mode of pathogen invasion (B. Khamari et al., 2019 {India}). The disease is more common at the maturity stage of the plant in dry weather. The pathogenic ability increases with water stress and rise in temperature between 28 and 35°C (A.C. Jain and S.N. Kulkarni 1965 {India}; R. Cardona 2006 {Venezuela}; K.P. Akhtar et al., 2011 {India}; B. Khamari et al., 2018b {India}). The disease incidence depends mostly on age of plant, atmospheric temperature, and soil humidity (M. Rodriguez and C. Zambrano 1985 {Venezuela}). Soil temperature of 27-35°C for 2 to 3 weeks favors development of disease. The disease incidence is positively related to temperature but negatively correlated with relative humidity (P. Deepthi et al., 2014 {India}).

Management of this disease is a bit tough as well as not economical as the pathogen is soilborne, highly variable and affects a wide range of plant species. The management strategies should be formulated after proper knowledge on biology as well as survival of the pathogen and stage of the crop. It can be managed in various ways like cultural methods, use of organic products, biocontrol agents, chemicals, use of resistant varieties, or their combinations. It is the safest method to manage the disease by altering cultural practices. It is not only ecofriendly but also pocket friendly. Modifications in cultural practices can save the crop from deadly diseases. It may be field preparation, choosing the right cropping system, collection of healthy seed material, proper sowing time, spacing, timely irrigation, fertilization, timely harvest, and proper storage. There are several methods to manage sesame diseases. Intercropping of sesame with other crops can reduce disease incidence. Inter or mixed cropping of sesame with moth bean or mung bean may minimize the stem and root rot disease incidence. Mixed cropping of sesame with urd (*Phaseolus mungo* L.), cowpea (*Vigna sinensis*), moong (*Phaseolus aureus*), guar (*Gramopsis tetragonoloba*) and moth (*Phaseolus aconitifolius*) also reduce root and stem rot disease of sesame (L.N. Daftari and O.P. Verma 1975 {India}). Rotation of sesame crop with non-host crop is effective against the diseases as the pathogen survives in soil. Small grain and corn be used for this. The effectiveness of this method depends on the type of crop and field where it is grown. As the pathogen is seedborne in nature, the use of clean and disease-free seeds are mandatory. Treatment of seeds before sowing provides a good plant population in the field by protecting the seedlings from disease. Soil solarization is also an important component for the management of soilborne disease. The propagules of *M. phaseolina* effectively reduced by soil solarization up to 20% as compared to unsolarized soil after 30 days. Soil solarization solely or mixed with *Trichoderma pseudokoningii* and *Emericella nidulans* solely or in consortium reduces incidence of disease (M.E. Ibrahim and A.M. Abdel-Azeem 2015 {Egypt}). Combination of soil amended with powder form of eucalyptus leaves and soil solarization has synergistic effect, which increase the number of healthy plants by reducing disease (M.E. Ibrahim and A.M. Abdel-Azeem 2015 {Egypt}). Transplanting of sesame can protect plants for a long time against soilborne diseases than seed treatment (I.S. Elewa et al. 1994 {Egypt}; E.H. Ziedan, 1998 {Egypt}; A.F. Sahab et al. 2001 {Egypt}; M.H. Mostafa et al. 2003 {Egypt}; B. Alasee 2006 {Unknown}). Stem and root rot disease is more severe if it is grown in stress conditions such as high

temperatures, drought or poor fertility, etc. Therefore, such cultural practices should be chosen that minimizes plant stress and reduce the risk of charcoal rot. Reduction in plant populations, proper spacing, timely irrigation, and optimization of fertility levels, especially phosphorus can reduce stress in plant. It may not control charcoal rot but can reduce the risk and finally reduce disease impact on yield. Cultural methods are more effective and economical against the soilborne pathogen. However, it takes a long time to manage the diseases. Again, due to a high degree of variability, competitive saprophytic ability, as well as polyphagous nature of pathogen, cultural methods like crop rotation are inefficient.

Biocontrols are used in many crops to reduce *Macrophomina phaseolina*. Some of the ones listed below have worked for sesame, and others (i.e., *Trichoderma polysporum*) should work for sesame. It is a method to manage the disease with living organisms. Different species of Trichoderma such *T. viride, T. harzianum*, and *T. polysporum* are reported not only to reduce stem and root rot disease incidence but also enhance germination and boost plant growth in different crops to an appreciable level both *in vitro* as well as *in vivo* conditions. *T. viride* as seed treatment is effective for management of root rot fungus *M. phaseolina* in various crops. Application of *T. harzianum* as both seed treatment as well as soil application significantly brought down the disease incidence) and enhanced grain yield. Soil application of *T. viride* @ 2.5 kg/ha is effective and economical for the management of root and stem rot disease of sesame (K.N. Gupta et al., 2018 {India}). The use of biological agents such as *T. harzianum, T. viride, Bacillus subtilis* and *Pseudomonas fluorescens* to manage soilborne pathogenic fungi is an attractive possibility (S.W. Kang and H.K. Kim, 1989 {Republic of Korea}; J.W. Hyun et al., 1999 {Republic of Korea}). *T. viride* coils around and penetrates into hyphae of another soilborne pathogen, i.e., *Fusarium oxysporum* f. sp. *sesami* which causes wilt disease of sesame (I.S. Elewa et al. 2011 {Egypt}). There are many bacterial biocontrol agents such as *Bacillus subtilis* and *P. fluorescens* which are effective against stem and root rot pathogen (T.S. Rajpurohit 1999 {India}; V.A. Savaliya et al. 2016 {India}). *Bacillus subtilis* has the capacity to reduce growth, sporulation, and sclerotial formation of pathogen (I.S. Elewa et al. 2011 {Egypt}). Bacterial antagonists are found to be more effective biocontrol over *Trichoderma spp*. (V.A. Savaliya et al. 2016 {India}). Combination of both fungal as well as bacterial antagonist as seed treatment as well as soil treatment provides more promising results in terms of seed germination, growth, plant stand, and total harvested produce. Treatment of seed and soil application with *Trichoderma viride* and *P. fluorescens* @5 g/kg of seed and 2.5 kg/ha respectively is effective against the disease (K.N. Gupta and A.R.G. Ranganatha 2014 {India}).

The association of mycorrhiza in roots of a sesame plant can reduce the colonization of fungal pathogens in the rhizosphere. Application of *Glomus spp*. in sesame not only reduces colonization of fungal pathogens in sesame rhizosphere but also diminishes their virulence and enhances lignin contents in root system of the plant (M.M.A. Khalifa 1997 {Egypt}; A.F. Sahab et al. 2001 {Egypt}; A.I.I. El-Fiki et al. 2004a {Egypt}; E.H. Ziedan 1998 {Egypt}; M.H. Mostafa et al. 2003 {Egypt}; E.H. Ziedan et al. 2010, 2011 {Egypt}). Vesicular arbuscular mycorrhizae fungi (VAM) improve resistance of plants by increasing antifungal chitinase enzymes in roots. Another mycorrhiza, i.e., *Lums spp*. (VAM) significantly increases biometric parameters of plants such as plant height, number of branches, and number of pods. Treatment with mycorrhiza stimulates colonization of selective bacteria such as bacteria belonging to the Bacillus group in the sesame rhizosphere which shows antagonistic potential to fungal pathogens (E.H. Ziedan et al. 2011 {Egypt}). Application of mycorrhizae and biocontrol agent such as *Trichoderma viride* or *Bacillus subtilis* in consortium are more effective than the individual for controlling Macrophomina disease incidences and increase morphological characters and seed yield of sesame (E.H. Ziedan et al. 2011 {Egypt}). *Trichoderma spp*. along with VAM (Glomus spp.) not only protected sesame plant from wilt and root-rot disease but also significantly increased seed yield (M.M.A. Khalifa 1997 {Egypt}; A.F. Sahab et al. 2001 {Egypt}). Mycorrhiza along with bacterial biocontrol agent such as *Bacillus subtilis* is also effective (A.F. Sahab et al. 2001 {Egypt}).

Application of organic products such as oil cake, farmyard manure, green manure, and vermicompost (VC) may reduce harmful microorganisms from the rhizosphere by promoting growth of antagonistic microorganisms. Beside this, these organic products are rich in alkaloids which suppress the pathogens. Mustard cake, neem cake, groundnut cake and sesame cake are few of the oil cakes which are effective against the disease (B. Khamari and C. Patra 2018a {India}). Among which mustard cake gives better performance (P.D. Gemawat and O.P. Verma 1971 {India}). Apart from oil cakes, different manures like farmyard manure, VC, and goat manure can also used in the field for reduction of disease incidence (B. Khamari and C. Patra 2018a {India})

Extracts of many commonly available plants which have effectiveness against the disease can be a possible alternative to the hazardous chemicals as it is easily available in our localities, environment friendly, and suits to the pockets of farmers. It neither disturbs the ecosystem nor leaves residues in the final product. Garlic,

onion, acacia, ginger, neem, turmeric, datura, and Karanj are commonly available plants which are effective against the pathogen *in vitro* (V.A. Savaliya, 2015 {India}). The aqueous extracts of *Cymbopogon citratus* and Powder of *Datura fastulosa* have been used against *M. phaseolina* in pots.

Essential oils isolated from various sources have fungicidal as well as bactericidal properties as it provides a barrier between pathogen and host. Oils are reported to suppress much air-borne, seedborne as well as a soilborne pathogens. Actinidine isolated from *Nepeta clarkei* was found to be quite effective *in vitro* against *M. phaseolina*. Garlic oil, neem oil, palmarosa oil, and clove oil are reported effective against *M. phaseolina* (B. Khamari et al., 2018d {India}). Neem oil is more or equally effective as compared to benomyl and carbendazim. Oils can be utilized as seed dresser for effective management of disease.

A combination of Neem cake (250 kg/ha) and *Trichoderma viride* (2.5 kg/ ha) can also give good results against the disease incidence. The combined application of neem cake and Trichoderma viride at the rate of 250 kg/ha and 2.5 kg/ha, respectively, works well against the disease (T.S. Rajpurohit 2008 and 2013 {India}). The use of *Pseudomonas fluorescens* as seed treatment and soil amendment with mustard cake, VC, and FYM successfully reduced Macrophomina root rot. Soil application of $ZnSO_4$ followed by combined application of *T. viride* + $ZnSO_4$ significantly reduces root rot incidence.

As there is little resistant germplasm against virulent pathogen, utilization of systemic fungicides is a potential approach to reduce the inoculum density of this soilborne disease. It is relatively cheap and more effective. There are many fungicides that were reported to be effective against *Macrophomina phaseolina* both *in vitro* and *in vivo*. They reduce the disease incidence as well as sclerotia production. *Macrophomina phaseolina* is a virulent pathogen of sesame which can be managed by seed treatments before sowing (B.G. Nayyar et al. 2014 {Pakistan}). Seeds treated with carbendazim, captan, etc., boost germination of seed by reducing disease incidence (B.N. Shukla and B.P. Singh 1974 {India}). Seed dressing (Benomyl @5 g/kg seed) combined with or without chlorothalonil or dicloran (5 kg/feddan) as soil treatment reduces sesame diseases (El-Deeb et al. 1985 {Egypt}). $ZnSO_4$ significantly reduces root rot incidence. Carbendazim, Captan, thiram, mancozeb, indofil M-45, Tebuconazole, propiconazole, and vitavax or raxil are effective against the disease and reduce root rot incidence (B. Khamari and C. Patra 2018a {India}). The new generation chemicals like Tebuconazole 2DS as seed treatment and tebuconazole 25.9 EC as soil drenching are most effective against charcoal rot incidence and increase yield (A.I.I. El-Fiki et al. 2004a {Egypt}; K. Choudhary et al. 2018 {India}; B. Khamari and C. Patra 2018a {India}). Combination of VC with bavistin reduces the root rot incidence in pots conditions. A new generation combination fungicide, i.e., Nativo (Trifloxystrobin 25% + Tebuconazole 50%) disrupts the metabolism of pathogen and hampers their growth and development. It forms a covalent bond with sclerotia and interrupts its ionic concentration (A.I.I. El-Fiki et al. 2004a {Egypt}; B. Khamari and C. Patra 2018a {India}). Application of combination fungicide such as Carbendazim 12% + mancozeb 63% WP also found effective against the disease (B. Khamari and C. Patra 2018a {India}). The plants protected with fungicides gave more number of capsules per plant, more number of seeds per capsule, and finally increase the yield (P. Deepthi et al., 2014 {India})

AUSTRALIA

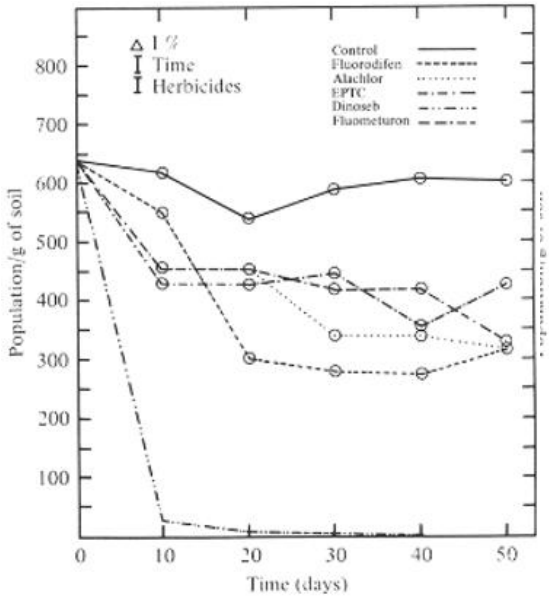
- D.F. Beech (1995a) reported the following pathogen: *Macrophomina phaseolina* (Leaf spot).
- B.D. Conde (1995) reported the following pathogen: *Macrophomina phaseolina* (Ashy stem blight, necrosis of lower leaves) is a soilborne fungus with a wide host range. The characteristic symptom is a girdling at or slightly above the soil line. Other symptoms include wilting and the eventual death of plants which turn brown and remain upright. Charcoal rot is associated with plants under stress or insect-injured plants. Although charcoal rot has been of concern overseas, this has not been the case in the Northern Territories.
- M.R. Bennett and B. Conde (2003) reported *Macrophomina phaseolina.* The characteristic symptom is a girdling at or slightly above the soil line. Other symptoms include wilting with eventual death of plants which turn brown and remain upright. The presence of small black microsclerotia in the plant tissue, especially towards the base of the plant, is diagnostic of the casual fungus. To date, charcoal rot has not been a serious disease of sesame.

BANGLADESH

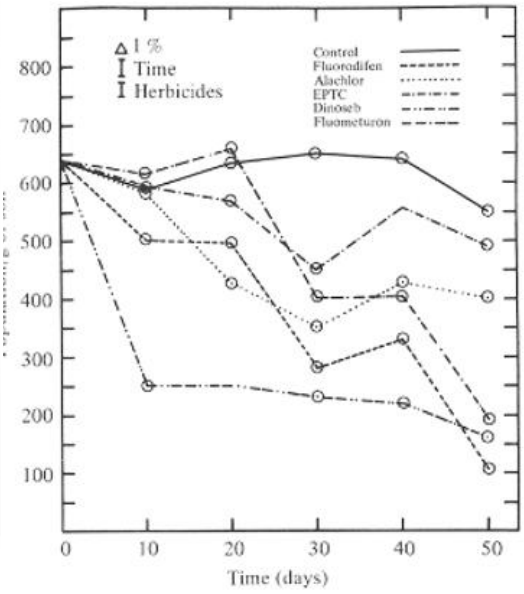
- A.L. Khan et al. (1977) reported in seedling pot-tests sesame was susceptible to *Macrophomina phaseolina*. The pycnidial structure was more pathogenic than the sclerotial one. [Cited by G.S. Saharan, 1989]

BRAZIL

- E.S. Filho and O.D. Dhingra (1980) studied the effects of herbicides (fluorodifen, alachlor, EPTC, dinoseb, and fluometuron) on *Macrophomina phaseolina* – one of the major diseases of sesame. Two types of soil were infested with 500 mg of dry sclerotia. Then, 100 g of the soil were used to apply the herbicides at the commercially recommended rates: fluorodifen at 0.03 ml a.i./100 g, alachlor at 0.08 ml a.i./100 g, EPTC at 0.02 ml a.i./100g, dinoseb at 0.07 ml a.i./100g, and fluometuron at 0.03 ml a.i/100 g. The populations of *M. phaseolina* were determined at 10, 20, 30, 40, and 50 DAA. The results were as follow.



Results in sandy-clay-loam soils



Results in sandy-loam soil.

- M.G.R. Faiad et al. (2002) examined seed from 416 accessions from 7 Brazilian states at 25°C under alternating black lights and darkness in a 12-hour photoperiod for 8 days. They found *Macrophomina phaseolina.* They then examined 31 seed samples that had been stored for 5 and 9 years at 8°C and 25% RH. They found *Macrophomina phaseolina.* They concluded the seed acts as a vehicle for pathogen dissemination.
- N.H.C. Arriel et al. (2007a) studied 108 accessions from Brazil and the world. They used *Stem black rot – Macrophomina phaseolina* as one of the descriptors. They showed the following correlations with other plant traits.

CP	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
1	1.00	-0.15	-0.09	-0.04	-0.10	0.00	-0.13	-0.10	0.27	-0.01	-0.04	-0.10	0.00	-0.04	0.01	-0.24	-0.02	-0.02	0.01	-0.02	-0.06	-0.10	-0.10	0.08	0.07	-0.15	-0.02	-0.19	-0.09	0.16
2		1.00	0.39	0.15	-0.14	0.60	0.36	-0.02	-0.44	-0.03	-0.19	0.56	0.43	-0.21	0.03	0.22	0.11	0.04	-0.10	0.05	0.04	0.05	0.10	-0.09	-0.06	0.32	0.32	-0.10	0.48	-0.19
3			1.00	0.05	-0.23	0.52	0.21	-0.09	-0.36	0.04	0.10	0.35	0.77	-0.23	-0.05	0.24	0.00	-0.20	0.02	0.00	-0.05	-0.08	0.07	-0.33	-0.20	0.24	0.25	0.19	0.31	0.06
4				1.00	0.23	0.27	0.24	0.53	-0.38	0.20	0.29	0.35	-0.03	0.17	0.05	-0.01	-0.07	-0.16	-0.13	-0.03	-0.06	-0.11	-0.02	0.23	0.08	0.06	-0.08	0.11	0.33	0.12
5					1.00	-0.26	0.10	0.42	-0.01	-0.02	0.21	-0.03	-0.14	0.15	-0.08	0.15	-0.06	-0.03	-0.10	-0.04	-0.14	-0.06	-0.10	0.42	0.25	-0.11	-0.40	-0.27	-0.01	-0.18
6						1.00	0.20	-0.17	-0.32	0.01	-0.11	0.42	0.49	-0.31	-0.14	0.06	0.11	-0.14	-0.04	0.12	0.19	-0.09	0.10	-0.07	0.00	0.31	0.17	-0.07	0.36	-0.02
7							1.00	0.17	-0.52	0.04	0.13	0.58	0.17	0.16	0.19	0.13	0.05	-0.14	-0.13	0.00	-0.04	-0.05	-0.03	0.23	-0.01	0.33	0.17	0.06	0.50	-0.03
8								1.00	-0.23	0.09	0.34	0.16	-0.25	0.30	-0.07	0.07	0.02	0.03	-0.18	0.01	-0.22	0.05	0.00	0.05	0.10	-0.17	-0.14	0.17	0.14	-0.05
9									1.00	-0.05	-0.10	-0.87	-0.31	-0.18	-0.04	-0.29	-0.05	0.00	0.27	-0.04	0.10	-0.10	0.06	-0.19	0.00	-0.50	-0.06	0.03	-0.75	-0.11
10										1.00	0.14	0.00	0.01	0.19	-0.14	-0.24	-0.01	-0.37	0.07	-0.03	0.07	-0.08	0.08	0.04	0.01	-0.08	-0.02	0.10	0.01	0.07
11											1.00	0.05	-0.09	0.24	-0.02	-0.05	-0.04	0.11	-0.09	-0.02	-0.16	0.04	0.05	0.13	-0.08	-0.14	-0.22	0.20	0.05	0.10
12												1.00	0.31	0.11	0.01	0.22	0.02	0.03	-0.30	0.01	-0.09	0.05	-0.08	0.18	-0.01	0.58	0.14	-0.13	0.86	0.13
13													1.00	-0.24	0.02	0.33	0.03	-0.18	-0.07	0.02	0.01	-0.11	-0.02	-0.13	-0.13	0.21	0.11	-0.08	0.27	0.00
14														1.00	0.16	-0.05	-0.08	-0.03	-0.04	-0.05	-0.22	0.33	-0.42	0.24	0.01	0.02	-0.08	0.10	0.10	-0.04
15															1.00	0.00	-0.01	-0.01	0.02	0.00	-0.20	-0.02	-0.12	0.10	0.00	0.02	0.13	0.06	0.01	-0.03
16																1.00	-0.15	0.17	-0.12	-0.10	0.00	0.13	0.02	-0.09	0.09	0.13	-0.02	0.05	0.19	-0.12
17																	1.00	-0.02	-0.13	0.70	0.06	-0.03	-0.05	0.00	0.00	0.03	0.04	-0.05	0.02	-0.04
18																		1.00	-0.30	-0.01	-0.14	0.45	-0.18	-0.06	0.09	0.00	-0.10	-0.13	0.03	-0.13
19																			1.00	-0.21	0.00	-0.10	0.39	-0.20	-0.07	-0.22	0.10	0.21	-0.33	-0.08
20																				1.00	0.04	-0.02	-0.12	0.10	0.00	0.02	-0.07	-0.14	0.01	-0.03
21																					1.00	-0.06	0.21	-0.14	0.02	0.26	0.03	0.08	-0.07	0.09
22																						1.00	-0.21	-0.05	0.07	0.07	0.10	0.02	0.04	-0.31
23																							1.00	-0.31	0.06	-0.22	0.12	0.20	-0.07	0.07
24																								1.00	0.14	0.13	-0.46	-0.57	0.15	0.03
25																									1.00	0.05	0.04	-0.01	-0.01	0.06
26																										1.00	0.13	-0.18	0.50	0.13
27																											1.00	0.24	0.12	-0.03
28																												1.00	-0.11	0.14
29																													1.00	0.13
30																														1.00

*1-Flowering; 2- plant height; 3- insertion height of the 1st capsule; 4- no. of capsules/plant ; 5- capsule length; 6-no. of branches; 7-stand; 8-grain yield; 9-cycle; 10-weight of 1000 seeds; 11- no. of capsules/axil; 12-plant growth; 13- capsule insertion; 14- angular leaf spot; 15- black rot; 16-pests; 17-stem shape; 18-stem pilosity; 19-branch color; 20-branch; 21-leaf color; 22-leaf pilosity; 23- leaf position; 24- leaf shape; 25-leaf size; 26- basal leaf shape; 27- V- pigmentation of the flower; 28- flower color; 29- capsule dehiscence; 30-seed color.

- N.H.C. Arriel et al. (2009) reported *Macrophomina phaseolina*, with the sclerotial stage of *Sclerotium bataticola*. This illness can occur between 25 and 29 days after the germination. The fungus mainly affects the stem and branches of the plant, which have light brown lesions and which can surround these organs or extend within them longitudinally, reaching the terminal bud of the plant. In adult plants, as the damage progresses, branches, capsules and leaves dry. Affected plants wither and die. In the necrotic area, several black punctuations can be observed, which correspond to the pathogen's sclerotia and pycnidia. The sclerotia (reproductive structures of the fungus) allow the pathogen to be transmitted from diseased plants to healthy plants and enable the survival of the fungus from one year to another in hosts or on the ground (up to 3 years), with or without crop residues. Since the fungus reaches the seed, it can be transported and transmitted by it. In the cultivated area, dissemination also occurs through irrigation water or rain and soil particles.
- V.P. Queiroga et al. (2010c and 2019) reported *Macrophomina phaseolina.* For control use resistant varieties (Arawaca, Venezuela 52, Ajimo Atar, or Adong Acol) and clean seed. Application of a green manure stimulates antagonistic fungi. [Authors comment: Arawaca and Venezuela 52 are Venezuelan varieties.]

- N.E.M. Beltrao et al. (2013) reported *Macrophomina phaseolina* is one of the major diseases since seed infection and seedling mortality lead to losses in production. Two distinct lines form pycnidia and sclerotia. This fungus can survive in soil and sesame seeds. Plants can be attacked immediately after sowing. The fungus mainly affects the stem and branches of seedlings, causing lesions that are light brown in color or extend longitudinally, and may reach the terminal bud. The attacked seedlings grow little, remaining atrophied, the roots and the stem can rot, and the parts upper ones are darkened (F.X.R. Vale and L. Zambolim, 1997). In lesions, fungi can form sclerotia and pycnidia. The plants affected wither, may dry up, and die. In the case of the capsules these are also affected, opening prematurely and causing wilt and browning in the seeds. The growth and formation of sclerotia of the fungus can decrease below 15 and above 40ºC. Dissemination occurs

through water (irrigation or rain), by particles of the infected soil and seeds, as well as high temperatures, low humidity of the soil, favor the appearance of this pathogen (N.A. Wulff and S.F. Pascholati, 2005).

- N.H.C. Arriel et al. (n.d.) Brazil descriptor: PODRIDÃO NEGRA DO CAULE [Black stem rot] (*Macrophomina phaseolina*): Symptoms are characterized by the presence of light brown lesions on the stems and branches of the plant. These may surround the stem or branch or extend longitudinally and may reach close to the apex of the plant. The attacked plants wither and may later dry and die. The lesions have several black scores, which are the pathogen pycnidia and sclerotia. The following are the ratings to be used.
  - 1 : 0 to 5%
  - 2 : 6 to 25%
  - 3 : 26 to 50%
  - 4 : 51 to 75%
  - 5 : 76 to 100%

CHINA

- L.C. Tu (1985a and 1985b) reported *Macrophomina phaseoli* (Black stalk) in Henan province with a damage level of 3 out of possible 3.
- L.L. Li (1988) reported *Macrophomina phaseolina* (Stem necrosis) causes severe damage to sesame. This disease is common all over the major sesame growing areas, and it can cause significant yield loss on sesame. The incidence of the disease is often from 10% to 20%, but seriously over 80% in a few years in some districts, resulting in 10% to 15% loss in seed yield and reduced oil content from 1-12%. Only a few affected plants are found in a seedling stage 1 it causes seed rot and seedling dies. A lot of infected plants are seen in flowering and fruiting stage. The first symptoms appear on root and stem basal portion. The root becomes brown with small, blackish sclerotia in the cortex. Water-soaked, yellow-brown spots appear, then become dark-brown, and lastly turn into silver color at the middle part of the spots. There are many black pycnidia and small sclerotia on the surface of the diseased stem. The leaves of the diseased plant curl and wilt from bottom to top and the severely diseased plants die. The diseased seed, the soil and the diseased plant refuse all can spread the disease. Primary infection results from the mycelium produced on sclerotia under high soil moisture and over 25°C soil temperature. The incubation period is about 5 to 10 days. The spores from infected plants are widely distributed by wind and spattering rains so that numerous secondary infections occur. The secondary infected plants are about 46%. Sclerotia may remain alive in soil for two years. A three-years rotation with non-host crops offers an effective method of control. Non-diseased seed application and seed treatment with 55°C water for ten minutes or 60°C water for five minutes have been reported to be effective in the control of the disease. He also reported this pathogen as *Dothiorella phillippinensis*, which causes minor or regional damage to sesame.
- X.Y. Feng (1988) reported *Macrophomina phaseolina* is one of the most common and serious diseases of sesame in the major sesame producing areas in China. The lower incidence of the disease was 10-15% and the higher incidence was 60-80%. The 1000-seed weight of an infected plant was reduced by 4-14%. The yield per unit area was less (19-81%) and the oil content was decreased by 1-10%. A few varieties of higher resistance to the disease have been selected by naturally and artificially induced identification. Among these, the wild sesame from Congo was immune to the disease.
- H.M. Miao and H.Y. Liu (2010) reported the following pathogen: *Macrophomina phaseoli.*
- H. Zhao et al. (2012) evaluated resistance to *Macrophomina phaseolina* using 129 genotypes in 2010-2011. There was no immune type. A total of 6 varieties uniformly showed resistance in the two years: ZZM 0565, ZZM 0570, Xiangcheng dazibai, Xincai xuankang, Shangshui farm species, and KKU3.

COLOMBIA

- Anon. (2013c) in a grower guide reported *Macrophomina phaseolina* causes a major disease. It is transmitted in the seed and the soil.

CUBA

- La Habana (2009) in a grower guide reported the following pathogen: *Macrophomina phaseolina.*

CYPRUS

- R.M. Nattrass (1934) reported *Macrophomina phaseoli* caused a disease in sesame. [Cited by R.S. Vasudeva, 1961]

ECUADOR

- M. Bustamonte (2001) in a grower guide reported the following pathogens: *Macrophomina phaseolina.* The incidence of the disease is directly proportional to the density of the inoculum and is affected by the number of

sclerotia. Each sclerotia can produce 10 germination tubes. The pathogen has between 130 to 248 hosts. The pathogen causes a carbonaceous rot at the stem level that causes lodging of the plants and prevents mechanized harvest. It is recommended to not sow sesame in fields where cultures of the host species have previously been established. In a field that has been infested with *Macrophomina* it is necessary to practice crop rotation with non-hosts such as some cereals, cabbage, onion, celery and carrot. This author recommends stopping cultivating the field with sesame or host species of *Macrophomina* at least for 5 years to achieve a significant reduction of the inoculum present in the soil. Another way to prevent the incidence of this disease by using seed from fields that do not have the inoculum. This author also recommends as prevention measures to avoid the transfer of seed from regions where sesame is grown in the rainy season since the seeds harvested there would be carriers of other pathogens, especially *Alternaria* and *Pseudocercospora*. He also suggests that seed be produced in the dry season or, if done in rainy season, which is in regions far from those with commercial sowings.

EGYPT

- A.K.A. El-Ghany et al. (1970) reported *Fusarium oxysporum, Rhizoctonia solani* and *Sclerotium bataticola* were isolated from diseased plants. Infection tests showed that vars. Introduction 51, Sharkya 57, 62 and 203 and especially Sharkya 79 were least susceptible. High soil moisture levels due to frequent irrigation increased infection. The best yields were obtained with irrigation every two weeks.
- M.S. Serry (1981a and 1981b) reported the presence of *Sclerotium bataticola* is a major hazard.
- M.B. Seoud et al. (1982) reported the most destructive diseases al sesame in Egypt are caused by *Fusarium oxysporum, Rhizoctonia solani* and *Sclerotium bataticola* (*Macrophomina phaseolina*). Seed treatment with Vitavax (carboxin) + Captan @ 4 g/ka seed and soil treatment with Daconil 2787 (chlorothalonil) at 3.75 kg/feddan gave the best control and highest yields.
- M.M. Satour (1984) reported one of the prevalent disease causal organisms was *Sclerotium bataticola* (*Macrophomina phaseoli*) [Cited by G.S. Saharan, 1989]
- A.A. El-Deeb et al. (1985) reported cvs. Giza-25, Giza-24, Local-78 and Local 96 were susceptible to *Macrophomina phaseolina., Rhizoctonia solani, Fusarium* ox*ysporum* f. sp. *sesami* and *Verticilium albo-atrum*. [Cited by G.S. Saharan, 1989]
- S. Shafshak et al. (1985) reported out of three crosses, N.A. 372-6 x Giza 25 (tolerant x tolerant) N.A. 342-6 x Margo and Giza-25 x Margo (tolerant x susceptible) tolerance to *Sclerotium bataticola* was partially dominant (13T:3S) in first cross and complete dominance of susceptibility (1T:3S) in other two crosses. 1-2 gene pairs control the difference between the parents in their reaction *S. bataticola.* [Authors comment: Margo is a United States variety]
- A.A. El-Deeb (1989) studied the relationship between fertilizer levels and *Macrophomina phaseolina* (root-rot) and *Fusarium oxysporum* f. sp. *sesami* (wilt) with the following results.

Treatments			Sohag 1985				Sharkia 1986			
N	P	K	Root-rot	Wilt	Root-rot and wilt	Yield g/10 m^2	Root-rot	Wilt	Root-rot and wilt	Yield g/10 m^2
0.0	0.0	0.0	28.5	32.3	27.2	296	28.3	24.8	28.8	286
15	0.0	0.0	23.2	24.3	22.3	363	22.3	24.2	23.5	335
30	0.0	0.0	24.2	22.8	24.0	400	23.0	23.7	23.7	390
0.0	15	0.0	17.5	21.0	18.5	371	18.5	22.7	23.3	346
30	15	0.0	17.5	20.0	19.0	418	18.8	18.8	23.2	410
30	30	24	18.7	20.3	19.3	431	16.0	18.0	23.5	453
30	30	48	16.8	13.3	17.3	475	16.3	15.8	22.8	481
45	30	24	19.7	22.3	21.8	460	19.5	22.0	22.5	461
45	30	48	18.7	21.2	20.5	471	18.7	21.3	21.8	481
L.S.D. 5%			1.6	2.7	2.1	29	1.5	1.8	1.8	27

- M.R. Gabr et al. (1998) reported that the germinating seed and seedlings stimulate normal sclerotial germination of *Macrophomina phaseolina* and attract developing mycelium to the host roots. Entry may occur directly through the cuticle and epidermis, infection cushions and appressoria are also reported to be formed on sesame plants prior to infection, and the pathogen produces cell-wall-degrading pectolytic and cellulolytic enzymes. The most aggressive isolate produces more cell-wall-degrading enzymes than the less aggressive isolates. [Cited by C. Chattopadhyay et al., 2019]
- E. Abdou et al. (2001) collected seed from several locations in Egypt. *Fusarium* was the most dominant fungi associated with the diseased sesame plants. Of 3 *Fusarium* species *Fusarium oxysporum* f. sp. *sesami* was the highest frequency, followed by *Macrophomina phaseolina, Mucor haemalis, Thielaviopsis basicola* (Wetn), and *Rhizoctonia solani*. Application of ascorbic acid or salicylic acid to seeds and/or plants reduced the number

of the diseased sesame seedling plants. Treated seeds plus twice irrigation with either ascorbic acid or salicylic acid caused the best control against *F. oxysporum* f. sp. *sesami* infection as compared to the fungicide Benlate. Meantime, ascorbic and salicylic acids had less effect to control sesame damping-off and root rot wilt diseases caused by infection with *M. phaseolina, Mucor haemalis* or *Thielaviopsis basicola* as compared to Benlate. [Based on abstract]

- E. Abdou et al. (2004) reported both salicylic acid (SA) and yeast (*Saccharomyces cerevisiae*) seed treatments affected incidence of wilt and root rot of sesame incited by *Fusarium oxysporum* f. sp *sesami*, *Macrophomina phaseolina*, *Thielaviopsis basicola*, and *Mucor haemalis*. Also, yeast derivatives variously affected root rot/wilt severity. Combining SA with yeast or with its derivatives showed, in most cases, inhibition effects against the tested pathogenic fungi. [Based on abstract]
- A.I.I. El-Fiki et al. (2004a) studied the effects of using certain seed treatments to control *Macrophomina phaseolina* Tassi (Goid). The seeds were planted in pots in the greenhouse and then took percentages as follows: % pre-emergence = damping off within 15 days, % post-emergence = damping off within 45 days, % charcoal rot = diseased at 90 days, and % healthy plants at 90 days. The results with antagonistic fungi were as follow.

Antagonistic fungi and bacteria	% Disease incidence			
	At seedling stage		At maturity stage	
	Pre-emergence	Post-emergence	Charcoal rot	Healthy plants
B. megtella *	16.7	16.7	23.3	43.3
Bacillus sp 3 **	13.3	10.0	23.3	53.3
Bacillus subtillus *	10.0	13.3	20.0	56.7
Chaetomium bostrycoides *	0.0	3.3	6.7	90.0
Gliocladium penicilloides *	16.7	20.0	26.7	36.7
T. hamatum *	6.7	6.7	6.7	80.0
T. viride *	16.7	6.7	6.7	70.0
Trichoderma harzianum *	0.0	0.0	3.3	96.7
Trichoderma sp 10 **	23.3	26.7	20.0	30.0
Trichoderma sp 2 **	13.3	13.3	13.3	60.0
Trichoderma sp 3 **	16.7	23.3	16.7	43.3
Trichoderma sp 5 **	6.7	0.0	10.0	83.3
Trichoderma sp 6 **	13.3	6.7	10.0	70.0
Trichoderma sp 8 **	16.7	20.0	20.0	43.3
Trichoderma sp 9 **	20.0	6.7	16.7	56.7
Control	30.0	26.7	26.7	16.7
LSD. at 5%	8.17	9.05	7.96	9.53

* Obtained from Biological Control and Onion and Oil Crops Res. Dept Agric., Res. Center Giza, Egypt.
** Isolated from rhizosphere of healthy sesame plants.

Fresh plant parts of garlic (cloves), thyme and marjoram (herbs) and dried plant parts of clove (flower buds), roselle (sepals), ginger and rhubarb (roots), anise, fennel, and cumin (seeds), eucalyptus and azedrach (leaves) were tested with the following results. There were two methodologies: filtered extracts and autoclaved extracts.

Source of plant extract	Sterilization method of extracts							
	Filtered extracts "F"				Autoclaved extracts "A"			
	% Pre-emergence	% Post-emergence	% Charcoal rot *	% Healthy plants **	% Pre-emergence	% Post-emergence	% Charcoal rot *	% Healthy plants **
Cumin	10.0	13.3	10.0	66.7	0.0	6.7	6.7	86.7
Ginger	13.3	23.3	16.7	46.7	13.3	13.3	16.7	56.7
Marjoram	10.0	6.7	6.7	76.7	13.3	23.3	20.0	43.3
Garlic	3.3	10.0	3.3	83.3	20.0	26.7	20.0	33.3
Rhubarb	6.7	3.3	6.7	83.3	3.3	13.3	3.3	80.0
Eucalyptus	10.0	16.7	23.3	50.0	16.7	10.0	13.3	60.0
Thyme	3.3	3.3	6.7	86.7	16.7	20.0	23.3	40.0
Anise	10.0	6.7	10.0	73.3	6.7	6.7	10.0	76.7
Rosselle	6.7	16.7	20.0	56.7	6.7	6.7	6.7	80.0
Fennel	16.7	20.0	20.0	43.3	13.3	20.0	16.7	50.0
Azedrach	13.3	16.7	13.3	56.7	0.0	6.7	6.7	86.7
Clove	10.0	16.7	16.7	56.7	6.7	6.7	6.7	80.0
Control	23.3	26.7	23.3	26.7	23.3	26.7	23.3	26.7
Mean	**10.5**	**13.9**	**13.6**	**62.1**	**10.8**	**14.4**	**13.3**	**61.6**

L.S.D. at 5% for:	Pre-	Post-	Rot	Healthy
Sterilization method	n.s.	n.s.	n.s.	n.s.
Source of extract	6.92	6.47	5.82	6.61
Interaction	9.79	9.16	8.23	9.35

Chemical agents were used in three concentrations as follows.

Table 1: List of the tested systemic resistant inducing agents and their concentrations.

Tested compound	Tested concentrations
Salicylic acid (SA)	2.0, 4.0 and 8.0 mM
Bion 500 WG *	2.0, 4.0 and 8.0 mM
Indole acetic acid (IAA)	100, 200 and 400 ppm
Indole butyric acid (IBA)	100, 200 and 400 ppm
Hydrogen peroxide (H_2O_2)	1.0, 2.0 and 4%
Potassium chloride (KCl)	1.0, 2.0 and 4%

* [50% Acibenzolar-5 methyl (lysoprosall), chemical name: benzol (1,2,3) thiadiazol-7-carbothioic acid 5-methyl ester (BTH)]

The results with chemical agents were as follow.

Agents	% Pre-emergence			% Post-emergence			% Charcoal rot			% Healthy plants		
	* I	II	III	* I	II	III	* I	II	III	* I	II	III
H_2O_2	23.3	20.0	26.7	16.7	13.3	23.3	13.3	16.7	13.3	46.7	50.0	36.7
KCl	16.7	16.7	10.0	20.0	13.3	3.3	20.0	13.3	16.7	43.3	56.7	70.0
IAA	6.7	13.3	16.7	3.3	3.3	10.0	3.3	10.0	13.3	86.7	73.3	60.0
IBA	0.0	3.3	3.3	0.0	0.0	6.7	0.0	6.7	6.7	100.0	90.0	83.3
SA	3.3	0.0	10.0	3.3	3.3	0.0	3.3	0.0	0.0	90.0	96.7	90.0
Bion	23.3	20.0	26.7	13.3	10.0	16.7	10.0	13.3	16.7	53.3	56.7	40.0
Control	26.7	26.7	26.7	23.3	23.3	23.3	23.3	23.3	23.3	26.7	26.7	26.7
Mean	14.3	14.3	17.2	11.4	9.5	11.9	10.5	11.9	12.9	63.8	64.3	58.1

* The tested concentrations of each compound were shown in Table (1).

LSD. at 0.05 for:	Pre	Post	Charcoal	Healthy plants
Chemical agents (A):	4.10	4.23	3.95	5.94
Concentrations (C):	2.90	N.S.	n.s.	4.20
A x C	8.19	8.45	7.90	11.87

They also tested inoculating pathogen-infested soil with different soil preparations of vesicular arbuscular-mycorrhizal (VAM) fungi.

VAM soil preparation	% Disease incidence			
	At seedling stage		At mature plant stage	
	% Pre-emergence	% Post-emergence	% Charcoal rot	% Healthy plants
G. macrocarpum [G1]	3.3	10.0	10.0	76.7
G. australe [G2]	23.3	16.7	16.7	43.3
Glomus sp. [G3]	20.0	13.3	13.3	53.3
Malti VAM [G4]	13.3	10.0	13.3	63.3
G1 + G2	20.0	16.7	16.7	46.7
G1 + G3	16.7	16.7	13.3	53.3
G1 + Malti VAM [G4]	16.7	13.3	10.0	60.0
G2 + G3	13.3	13.3	10.0	63.3
G2 + Malti VAM [G4]	10.0	16.7	13.3	60.0
G3 + Malti VAM [G4]	6.7	10.0	13.3	70.0
G1+G2 + G3 + [G4]	0.0	6.7	6.7	86.7
Control	23.3	20.0	20.0	36.7
LSD. At 5%	9.63	n.s.	n.s.	8.55

- A.A. El-Fiki et al. (2004b) evaluated several fungicides to reduce the disease brought on by *Macrophomina phaseolina* with the following results.

Fungicides and bioagents	Method of application	% Disease incidence			
		At seedling stage		At maturity stage	
		% Pre-	% Post-	% Rotted plants	% Healthy plants
Rizolex-T	Seed	3.3	6.7	6.7	83.3
	Soil	23.3	16.7	13.3	46.7
Vitavax-T	Seed	13.3	10.0	13.3	63.3
	Soil	20.0	23.3	13.3	43.3
Benlate	Seed	0.0	3.3	3.3	93.3
Maxim	Seed	6.7	13.3	10.0	70.0
Plant guard	Seed	16.7	3.3	16.7	63.3
Rhizo-N	Seed	16.7	16.7	13.3	53.3
Amconil	Soil	13.3	16.7	20.0	50.0
Control		**26.7**	**23.3**	**23.3**	**26.7**

	Pre-	Post-	Rot	Healthy
L.S.D at 0.05:	8.61	9.53	9.29	11.77

They also tested 30 genotypes resulting in different tolerances to the disease and understandably different amounts of protection from the fungicides.

- M.A.S. El-Bramawy and O.A.A. Wahid (2006b) studied two segregating generations (F_3 and F_4) from 6 × 6 half-diallel crosses of a sesame breeding program exposed to natural infection by the root rot pathogen (*Macrophomina phaseolina*) in two successive seasons (2004 and 2005). The level of infection in 2004 ranged from 2.63-52.42% in the F_3 and from 1.28- 51.78% in the F_4. There was a high correlation of tolerance from the F_3 to the F_4 indicating that tolerance is inherited and can be used in developing tolerant lines.
- M.E. Ibrahim and A.M. Abdel-Azeem (2007) evaluated soil solarization in combination with fungal antagonists and soil amendments as a potential disease management strategy for the control of charcoal rot of sesame caused by *Macrophomina phaseolina*. Solarization alone or in combination with *Trichoderma pseudokoningii* and *Emericella nidulans* singly or in mixed inocula reduced disease incidence from 30% (control) to 80%, 91%, 82% and 85% respectively. It is noted that while pairing improved the biocontrols potentiality of *E. nidulans* by increasing the number of healthy plants in both unsolarized and solarized soils it leads to decrease in the biocontrol potentiality of *T. pseudokoningii*. On the other hand, the combination of solarization with soil amendment with Eucalyptus powdered leaves showed a synergistic effect by increasing number of healthy plants from 65% in amended unsolarized soil to 77% in amended solarized soil.
- M.A.S. El-Bramawy et al. (2009a) posited that there may be a linkage between morphological traits and tolerance to *Macrophomina phaseolina* and *Fusarium oxysporum* f. sp. *sesami*. They evaluated 48 genotypes in 2005 and 2006 and determined there was a linkage between tolerance with medium branch number, medium maturity, and creamy seed color as shown below.

Variables	Infection percentage			
	2005		2006	
	regression equation	R^2	regression equation	R^2
F. oxysporum f.sp. *sesami*				
Branch number	$Y = 37.8 - 9.5\,X + 1.33\,X^2$	0.12^{*}	$Y = 21.0 - 5.0\,X + 1.0\,X^2$	0.27^{**}
Days to maturity	$Y = 526.3 - 8.4\,X + 0.04\,X^2$	0.01^{ns}	$Y = 692.9 - 11.4\,X + 0.05\,X^2$	0.04^{ns}
Seed colour	$Y = 53.8 - 35.5\,X + 9.4\,X^2$	0.20^{**}	$Y = 39.2 - 29.0\,X + 9.0\,X^2$	0.20^{**}
M. phaseolina				
Branch number	$Y = 35.2 - 7.2\,X + 0.9\,X^2$	0.07^{ns}	$Y = 20.8 - 3.1\,X + 0.6\,X^2$	0.06^{ns}
Days to maturity	$Y = 499.5 - 8.1\,X + 0.04\,X^2$	0.02^{ns}	$Y = 296.1 - 4.1\,X + 0.02\,X^2$	0.01^{ns}
Seed colour	$Y = 34.4 - 17.8\,X + 5.5\,X^2$	0.18^{*}	$Y = 22.2 - 10.8\,X + 4.2\,X^2$	0.14^{*}

- H.A.M. Ahmed (2010) collected seed from different locations in Egypt, and *Macrophomina phaseolina* was found on the seed. The obtained isolates were different in their virulence on the tested sesame cultivars. Also, they differed in their growth nature including colony color and sclerotial production. The color of colonies of the pathogen seems to be correlated with density of sclerotial formation. Aqueous extracts of Majorna, Wild chamomile, Geranium oil and Nees plants were highly toxic to tested isolates of *M. phaseolina*, *in vitro*. On the other hand, the rest of the tested aqueous extracts had no effect. Soaking seeds of sesame before sowing in aqueous extracts of Eucalyptus, Nerium, Ocimum and Rosemary plants decreased the disease incidence. Aqueous extracts of Eucalyptus and Ocimum were the most effective treatment. Dipping sesame seeds in hot water at 60°C for 5 minutes increased seed germination of Giza 32 and Shandawel-3 cvs. followed by 55°C, 50°C, and 45°C, while 40°C treatment resulted the lowest seed germination rate Dipping sesame seeds in hot water at different temperature before planting decreased seed, seedling, and charcoal rots. Soaking seeds in hot water at 60°C increased greatly plant height and decreased seed, seedling rot and charcoal rot followed by 55°C and 50°C, under greenhouse condition.

Table 3. Effect of certain aqueous plant extracts on mycelial growth of *M. phaseolina*, *in vitro*

Plants extracts	Reduction of linear growth (%)
Majorana (*Origanum majoranum*)	52.22 a
Rosemary (*Rosemarinus officinalis*)	0.00 d
Basil (*Ocimum basilicum*)	0.00 d
Spear mint (*Mentha spicata*)	0.00 d
Wild chomanile (*Matricaria chomamilla*)	40.73 b
Caraway (*Carum carvi*)	0.00 d
Anise (*Pimpinella anisum*)	0.00 d
Fruetus cumini (*Cuminum cyminum*)	0.00 d
Fennel (*Foeniculum vulgare*)	0.00 d
Wild celery (*Apium grayeolens*)	0.00 d
Coriander (*Coriandrum sativum*)	0.00 d
Geranium (*Pelargonium graveolens*)	5.92 c
Henna (*Lowsonia inermis*)	0.00 d
Halfa gar (*Cymbopogon proximus*)	0.00 d
Black cumin (*Nigella sativa*)	0.00 d
Nerium (*Nerium oleander*)	0.00 d
Liquorice (*Glycirrhiza glabra*)	0.00 d
Fenugreek (*Trigonella foenum graecum*)	0.00 d
Tamarind (*Tamarindus maica*)	0.00 d
Nees (*Cinnamonum cassia*)	5.37 c
Roselle (*Hibiscus sabdariffa*)	0.00 d
Blue gum (*Eucalyptus globulus*)	0.00 d
Caster bean (*Ricinus communis*)	0.00 d
Dill (*Anethum graveolens*)	0.00 d
Parsley (*Petroselinum sativum*)	0.00 d
Distilled water control	0.00 d

Table 4. Effect of seed treatments of Giza 32 and Shandawel-3 sesame cultivars with four medicinal plant extracts on incidence of seed rot, seedling rot and charcoal rot caused by *M. phaseolina* in 2005 and 2006 seasons

Plant Extracts	2005 Season						2006 season					
	Seed rot %		Seedling rot %		Charcoal rot %		Seed rot %		Seedling rot %		Charcoal rot %	
	Giza 32	Shan-dawel-3	Giza 32	Shan-dawel-3	Giza 32	Shan-dawel-3	Giza 32	Shan-dawel-3	Giza 32	Shan-dawel-3	Giza 32	Shan-dawel-3
Nerium	25 b	15 b	20 d	15 d	30 f	30 f	25 h	15 i	25 k	15 k	30 m	40 n
Ocimum	30 a	20 b	20 d	15 d	25 f	20 g	25 h	20 h	20 l	15 k	20 n	15 o
Eucalyptus	20 b	15 b	10 e	10 e	20 g	20 g	15 h	15 i	20 l	5 l	20 n	10 o
Rosmary	30 a	5 c	10 e	10 e	30 f	20 g	15 h	5 j	20 l	10 m	30 m	20 n
Control	40 a	30 a	25 d	30 d	35 f	35 f	35 h	30 k	30 k	30 k	35 m	35 n

Table 5. Effect of hot water seed treatment on seed germination of two sesame cultivars, *in vitro*

Temperature (°C)	Germination (%)		
	Giza 32	Shandawel-3	Mean
60	95.00 g	93.33 g	94.16 a
55	86.66 h	83.33 h	85.00 a
50	81.66 i	80.00 i	80.33 b
45	80.00 l	73.33 j	76.66 b
40	65.00 k	65.00 k	65.00 c
Control (25°C)	20.00 l	18.33 l	19.16 d
Mean	71.38 e	68.88 f	

Table 6. Effect of treating sesame seeds with hot water on the plant growth of Giza 32 and Shandawel-3 cultivars

Temperature (°C)	Plant height (cm)			
	2005 season		2006 season	
	Giza 32	Shandawel-3	Giza 32	Shandawel-3
60	132 a	129 d	134 f	128 h
55	105 a	112 d	105 f	113 h
50	96 b	116 d	81 f	110 h
Control (25°C)	26 c	30 e	23 g	34 i

- M.A.S. El-Bramawy (2011) studied the relationship between tolerance to *Macrophomina phaseolina* and *Fusarium oxysporum* f. sp. *sesami* and levels of anti-nutritional factors (phytate, trypsin inhibitor and tannins) in 2009 and 2010 using 48 genotypes. He classified the lines in different groups (resistant, moderately resistant, moderately susceptible and susceptible) and determined the following regressions.

Sesame genotypes group	Anti-nutritional factors	
	2009	2010
	Regression equation (R^2)	Regression equation (R^2)
	Phytic acid	
Resistant (R)	0.62**	0.57**
Moderately resistant (MR)	0.11^{ns}	0.04^{ns}
Moderately susceptible (MS)	0.31**	0.29**
Susceptible (MS)	0.19*	0.12*
	Trypsin inhibitor	
Resistant (R)	0.22*	0.20*
Moderately resistant (MR)	0.21*	0.01^{ns}
Moderately susceptible (MS)	0.45**	0.39**
Susceptible (MS)	0.14*	0.16*
	Tannins	
Resistant (R)	0.52**	0.60**
Moderately resistant (MR)	0.25 *	0.21*
Moderately susceptible (MS)	0.61**	0.55**
Susceptible (MS)	0.42**	0.34**

- I.S. Elewa et al. (2011) evaluated the effects of *Bacillus subtilis* and *Trichoderma viride*, a virulent *Fusarium oxysporum*, and *Glomus* spp. (Vesicular arbuscular mycorrhizae fungus - VAM) isolates and a fungicide (Benlate) on *Fusarium oxysporum* f. sp. *sesami* and *Macrophomina phaseolina*. The results were as follow.

Soil infestation	Treatment	Wilt and root-rot	
	Transplants	Infection %	Disease severity
F. oxysporum	Control	37.5 a	1.87 a
	B. subtilis	33.3 b	1.66 b
	Avirulent *F. oxysporum*	24.9 c	1.25 c
	T. viride	24.9 c	1.25 c
	(VAM)	16.6 d	0.83 d
	Benlate (0.1%)	16.6 d	0.83 d
M. phaseolina	Control	33.3 a	1.66 ab
	B. subtilis	16.6 d	0.83 d
	Avirulent *F. oxsporum*	8.3 e	0.42 e
	T. viride	16.6 d	0.63 e
	(VAM)	12.5 d	0.62 e
	Benlate (0.1%)	16.6 d	0.83 d
F. oxysporum + *M. phaseolina*	Control	20.8 ab	1.04 bcd
	B. subtilis	12.5 d	0.62 e
	Avirulent *F. oxysporum*	12.5 d	0.62 e
	T. viride	16.6 d	0.83 d
	(VAM)	8.3 e	0.42 e
	Benlate (0.1%)	12.5 d	0.62 e

- E.H. Ziedan et al. (2011) evaluated the effects of *Bacillus subtilis* and *Trichoderma viride*, and *Glomus* spp. (a Vesicular arbuscular mycorrhizae fungus [VAM]) isolates on *Fusarium oxysporum* f. sp. *sesami* and *Macrophomina phaseolina*. The effects on *Fusarium oxysporum* f. sp. *sesami* in the pot experiments were as follow.

Treatments	Wilt disease incidence		Morphological characters/plant		
	% of diseased plants	disease severity	length [cm]	fresh weight [g]	No. of pods
Control	79.2 a	4.0 a	68.3 d	7.4 d	6.0 c
B. subtilis	66.7 ab	3.3 b	80.0 c	11.7 c	6.7 c
T. viride	50.0 b	2.5 c	103.8 ab	12.6 c	14.7 b
VAM	50.0 b	2.5 c	80.0 c	14.4 c	6.8 c
VAM + *B. subtilis*	29.2 d	1.5 d	115.6 a	18.7 b	19.0 a
VAM + *T. viride*	36.7 c	1.3 d	93.3 b	15.0 c	14.0 b
VAM + *B. subtilis* + *T. viride*	37.5 c	1.1 d	106.0 ab	25.3 a	20.0 a

The effects on *Macrophomina phaseolina* in the pot experiments were as follow.

Treatments	Root-rot incidence		Morphological characters /plant		
	% of diseased plants	disease severity	length [cm]	fresh weight [g]	No. of pods
Control	91.7 a	4.6 a	77.5 c	5.52 d	4.61 f
B. subtilis	50.0 c	2.5 c	101.9 a	19.4 a	12.6 b
T. viride	45.8 d	2.3 c	101.3 a	18.1 a	10.3 c
VAM	45.8 d	2.5 c	80.0 b	8.1 c	6.0 e
VAM + *B. subtilis*	45.8 d	2.4 c	104.4 a	18.2 a	9.8 d
VAM + *T. viride*	43.7 b	3.3 b	104.2 a	17.7 b	9.5 d
VAM + *B. subtilis* + *T. viride*	41.7 c	2.1 d	103.8 a	19.3 a	13.0 a

The effects from *Fusarium oxysporum* f. sp. *sesami* and *Macrophomina phaseolina* on seedlings in the field experiments were as follow.

Treatments	Wilt and root-rot incidence		
	% of survival plants	% of diseased plants	disease severity
Control	51.0 d	55.9 a	2.8 a
B.subtilis	54.1 c	50.0 b	2.5 b
T.viride	67.5 b	39.2 c	1.9 c
VAM	56.7 c	48.4 bc	2.4 b
VAM + *B. subtilis*	66.6 b	34.2 cd	1.7 c
VAM + *T. viride*	79.3 a	23.3 e	1.2 e
VAM + *B. subtilis*+ *T. viride*	76.0 a	30.9 d	1.5 cd

The effects from *Fusarium oxysporum* f. sp. *sesami* and *Macrophomina phaseolina* on the yield components in the field experiments were as follow.

Treatments	Shoot		Root size	Number/plant		Seed yield aradeb/ feddan	Oil [%]
	length [cm]	diameter [cm]		branches	pods		
Control	185.0 e	1.76 d	25.0 f	3.75 f	112.5 e	2.53 d	59.5
B. subtilis	196.3 c	1.99 b	50.0 b	5.3 e	197.5 c	4.55 c	56.9
T. viride	180.0 d	1.88 c	35.0 d	7.5 b	212.5 b	4.91 c	57.8
VAM	195.0 c	1.85 c	30.0 e	5.0 e	160.0 d	5.14 b	57.4
VAM + *B. subtilis*	210.0 a	1.77 d	35.0 c	6.75 c	196.3 c	4.95 c	57.1
VAM + *T. viride*	202.5 b	1.82 c	47.5 b	6.0 d	198.0 c	5.05 b	57.2
VAM + *B. subtilis* + *T. viride*	202.5 b	2.33 a	70.0 a	8.5 a	232.5 a	5.79 a	57.8

- H.A.H. Ahmed et al. (2013) studied biological control of *Fusarium solani* and *Macrophomina phaseolina* causing wilt and charcoal rot diseases *in vitro* as well as under pot conditions. Culture technique showed that the addition of intact *Nostoc* sp. SAG2306 or its sonicate inhibited the radial mycelial growth of the test pathogens. Application of *Nostoc* sonicates resulted in the lowest infection percentage (11.1% and 17.8% of Fusarium and Macrophomina respectively) whereas in the control it was 95.6% and 97.7%. Under pot conditions, plant height, fresh and dry weight of plants increased significantly as a result of the inhibition of fungal by *Nostoc*. Similar results were observed in chlorophyll (ch.la & ch.lb) content of the treated plants. Infection enhanced proline accumulation that was lowered upon *Nostoc* addition, indicating alleviation of infection ascribed stress. The effect of sonicated (NS) or intact (NI) *Nostoc* sp 2306 cells on seed infection of sesame *in vitro* was as follow.

Treatements	*F. solani*	*M.Phaseolina*
NS	11.11	17.78
NI	26.67	33.34
Control	95.55	97.7

The effects in pots in the greenhouse in 2010 and 2011 seasons was as follow.

Treatments	*F.solani*				*M.phaseolina*			
	Percentage of infected plants				Percentage of infected plants			
	Root-rot		Wilt		Root-rot		Charcoal	
	2010	2011	2010	2011	2010	2011	2010	2011
*N.*sonicated	16.66	20	16.66	16.66	16.66	20	20	16.66
*N.*intact	26.66	26.66	20	23.33	20	23.33	23.33	20
Control	36.66	33.33	56.66	60	33.33	33.33	60	63.33

- A. Hashem et al. (2014) collected 18 seed samples of sesame in Egypt (12 samples) and Saudi Arabia (6 samples). They identified the following mycoflora: *Sclerotium bataticola.*
- S.G. Amen et al. (2020) compared 3 biofumigant crops (radish - *Raphanus sativus*, cauliflower - *Brassica oleracea* var. *botrytis*) and rocket - *Eruca sativa*) versus the fungicide Rhizolex-T on mycelial growth of *Macrophomina phaseolina in vitro* and compared to soil solarization *in vivo*. The obtained data in this study demonstrated that brassica crops may be successfully applied as a safe and economical control measure for sesame charcoal root rot disease as shown below (*in vitro* on the left and *in vivo* on the right).

	Linear growth (cm)		
	Days after incubation		
Treatments	7	14	Reduction (%)
First season (2017)			
Rocket	7.525^{b}	8.247^{a}	9.188^{c}
Cauliflower	5.525^{c}	6.698^{bc}	26.12^{ab}
Radish	7.170^{b}	7.935^{ab}	12.63^{bc}
Rhizolex-T	1.033^{d}	5.485^{c}	39.50^{a}
Control	8.658^{a}	9.083^{a}	0^{c}
LSD 0.05	1.057	1.272	13.89
First season (2018)			
Rocket	7.525^{ab}	7.842^{ab}	10.40^{bc}
Cauliflower	5.797^{b}	6.965^{b}	20.15^{b}
Radish	7.122^{ab}	7.412^{ab}	14.81^{bc}
Rhizolex-T	0.9475^{c}	5.360^{c}	38.79^{a}
Control	8.330^{a}	8.770^{a}	0^{c}
LSD 0.05	1.724	1.558	17.72

*Means in column followed by the same alphabetical letter are not significantly different at 5% level according to LSD, *Each figure represents the mean of four replicate

	Disease severity index	
	Days after transplanting	
Treatments	60	80
First season (2017)		
Rocket-biofumigation	1.750^{a}	3.500^{a}
Cauliflower-biofumigation	1.750^{a}	2.000^{b}
Radish- biofumigation	1.500^{a}	3.000^{a}
Control	2.500^{a}	3.500^{a}
Rhizolex-T	2.000^{a}	2.000^{b}
Soil solarization	1.750^{a}	3.000^{a}
LSD 0.05	1.238	0.9266
Second season (2018)		
Rocket-biofumigation	1.500^{bcd}	3.250^{a}
Cauliflower-biofumigation	2.000^{b}	2.000^{b}
Radish-biofumigation	1.250^{cd}	2.000^{b}
Control	3.000^{a}	3.250^{a}
Rhizolex-T	1.750^{bc}	2.500^{ab}
Soil solarization	1.000^{d}	2.500^{ab}
LSD 0.05	0.5066	0.8405

*Means in column followed by the same alphabetical letter are not significantly different at 5% level according to LSD, *Each figure represents the mean of four replicates*

ETHIOPIA

- B.K Yirga and B. Fiseha (2017a) reported the following pathogen: *Macrophomina phaseolina* (Stem and root rot).

GREECE

- J.A. Sarejanni and C.B. Cortzas (1935) reported *Macrophomina phaseoli* caused a disease in sesame. It appears to be identical with that reported on sesame from the Philippines by Petrak as *Macrophomina phillippinensis*. [Cited by R.S. Vasudeva, 1961, and G.S. Saharan, 1989]

HONDURAS

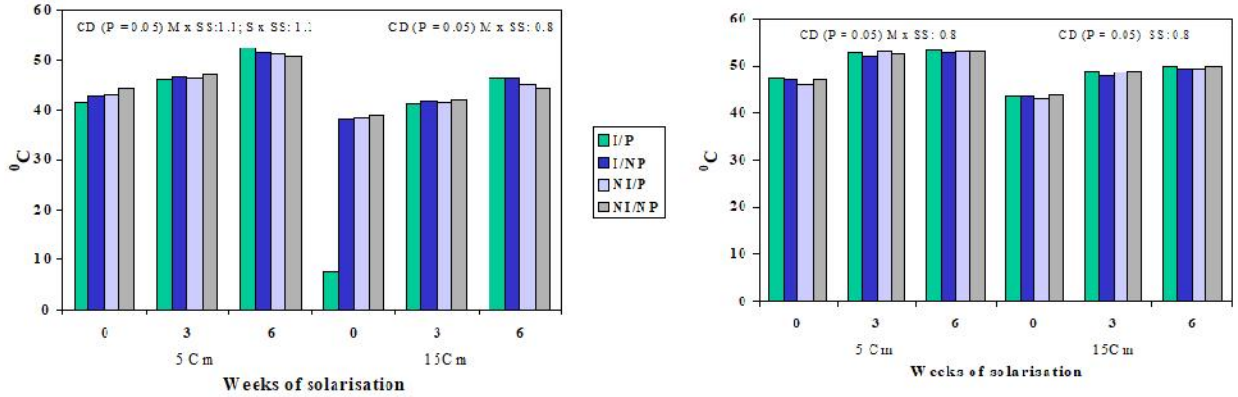
- V.P. Queiroga et al. (2016) reported *Macrophomina phaseoli* (Pata negra) symptoms are the base of the stem rots and turns black, and the plants die.

INDIA

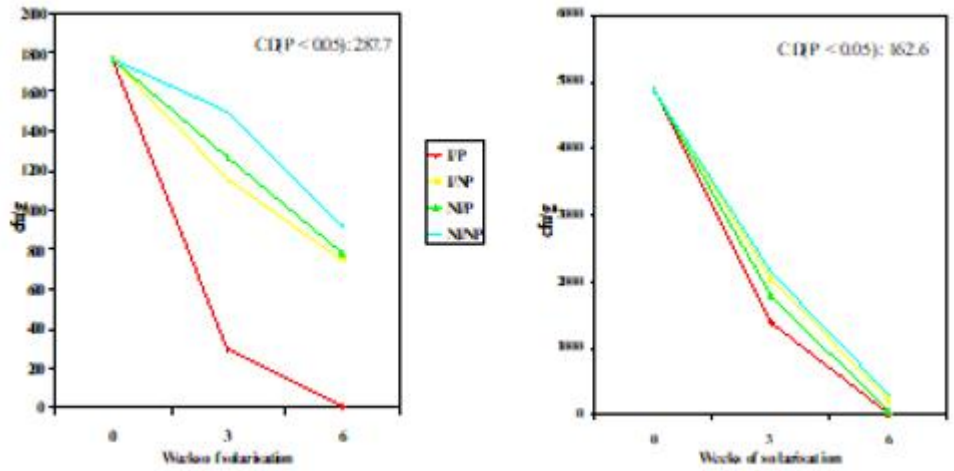
- R.T. Pearl (1923) reported *Macrophomina phaseoli* caused a disease in sesame. [Cited by R.S. Vasudeva, 1961]
- W. McRae (1930) reported *Sclerotium bataticola* readily attacked wounded plants, which soon collapsed. The infected plants were blackened and bore numerous pycnidia of *Macrophomina phaseoli*. [Cited by G.S. Saharan, 1989]
- S. Sundararaman (1931 and 1932) reported the yield from the affected plots with 36.6% infection of *Macrophomina phaseoli* is only 43% of the normal. [Cited by R.S. Vasudeva, 1961]

- P.R. Mehta (1951) reported *Macrophomina phaseoli* caused a disease in sesame. [Cited by R.S. Vasudeva, 1961]
- A.C. Jain and S.N. Kulkarni (1965) reported in Madhya Pradesh (*Macrophomina phaseoli*) remained viable in the soil during the severe summer heat, grew best in the lab at 25-35°C with maximum sclerotial production at 35°C, and caused more disease at 100% than at 60% soil moisture holding capacity. The disease may be minimized by lowering the soil temperature and ensuring proper drainage. Of 13 sesame vars. tested, St-58 and Gwalior-5 were most resistant. [Cited by G.S. Saharan, 1989]
- N.B. Kulkarni and B.C. Patil (1966) reviewed relevant literature, and they concluded that an isolate studied from sesame should be classified under *Macrophomina phaseoli* ssp. *sesamica*. [Cited by G.S. Saharan, 1989]
- L.N. Daftari and O.P. Verma (1972) reported efficacy of seven fungicides were tested for eradication of *Macrophomina phaseoli* on sesamum seeds under laboratory condition. Captan and Agrosan G.N. (2 gm/kg seed), Mercuric chloride, Ceresan wet (0.1% for 3 minutes), and Aureofungin (20 ppm for one hour) gave the complete control of seedborne infection in affected seeds. In addition to disease control, Captan also induced maximum germination of seeds and vigor of the seedlings. [Cited by G.S. Saharan, 1989]
- B.P. Singh et al. (1972) reported infected seeds invariably yielded *Macrophomina phaseoli* . The oil content was greatly reduced. Protein and carbohydrate values were also somewhat lower. [Cited by G.S. Saharan, 1989]
- O.P. Verma and L.M. Daftari (1974) reported the amount of *Macrophomina phaseoli* seedborne inoculum (number of sclerotia on seed surface) affects the seedling mortality and growth. Depending upon number of sclerotia per seed, seedling mortality of three varieties viz. Ex-116, G-5 and Limbdi-93 were 19-56%, 7-26%, and 26-53% respectively. [Cited by G.S. Saharan, 1989]
- A.K. Selim et al. (1976a) reported mature plant reaction in 4 crosses between six local and introduced sesame cvs. indicated that susceptibility to *Sclerotium bataticola* (*Macrophomina phaseolina*) was dominant over tolerance and was controlled by 1, 2, or 3 pairs of genes. [Based on abstract]
- K.K. Kushi and M.N. Khare (1979a) reported among 26 samples, *Macrophomina phaseolina* was associated with 23, *Corynespora cassiicola* with 11 and *Alternaria sesami* with 10. Isolates of all 3 were pathogenic, resulting in seed rot, pre- and post-emergence losses, stem rot and leaf spots.
- S.M. Jani and M.R. Siddiqui (1981) reported *Macrophomina phaseolina* was predominant in 23 of the 26 samples examined, particularly in untreated seeds in the blotter test. [Cited by M.L. Verma, 1985]
- M.M. Satour (1981) reported the presence of *Macrophomina phaseoli* (Black stalk, stem rot).
- S.C. Vyas (1981) reported crop losses from 5 to 100% from *Macrophomina phaseoli*. [Cited by P. Deepthi, 2012, and T. Ezhilarasi, 2021]
- A.S. Reddy and S.M. Reddy (1982b) studied the activity of alkaline and acid phosphatase, esterase, peroxidase, and polyphenol oxidase in sesamum seed under the influence of *Macrophomina phaseolina* and *Phoma nebulosa*. [Cited by G.S. Saharan, 1989]
- T. Singh and D. Singh (1982) reported using seed from infected plants, the presence of *Macrophomina phaseolina* was confirmed in the next generation in infected but healthy-looking sesame seedlings. After 8 weeks, almost every surviving plant developed pale yellow to brown circular or oval concentric spots on leaves, stem, and capsules. Mycelium and microsclerotia were observed in the peripheral region of lesions. Inter and intracellular mycelium was demonstrated in cortex, xylem, and pith cells. Infection in the capsule was recorded on inner wall, septum, placenta, and seed spreading from base to apex. [Cited by G.S. Saharan, 1989]
- A.S. Reddy and S.M. Reddy (1983a) reported fungal succession on sesame seeds with different moisture levels was analyzed monthly. Incidence varied with moisture content. *Alternaria alternata* was abundant only in the initial stages. *Aspergillus flavus* predominated while *Macrophomina phaseolina* and *Rhizoctonia solani* were associated only with seeds of high moisture content. The seed mycoflora at first increased with storage time but subsequently decreased. Seed germination increased with storage time. [Cited by G.S. Saharan, 1989]
- T. Singh and D. Singh (1983) isolated 24 fungi: Of these, *Macrophomina phaseolina* was an important pathogens. [Cited by G.S. Saharan, 1989]
- K. Kumar et al. (1984a) reported *Rhizoctonia bataticola* was found to be associated with the seeds of varieties T-4 and T-12. The species was pathogenic and reduced germination by causing seed rot under laboratory conditions and produced brown necrotic lesions on roots and later became a seedling invader to cause root rot and seedling blight.
- E.A. Abuewasim and A.B. Zeidan (1985) reported pycnidia of *Macrophomina phaseolina* were observed after 4 days on the wheat leaf bits. They appeared as raised, grey to black bodies, erumpt, oval to globular with a distinct ostiole with average dimensions 140 x 135µ. [Cited by G.S. Saharan, 1989]
- S. Maiti et al. (1985) reported charcoal rot, *Macrophomina phaseolina* is widespread and destructive but difficult to control.

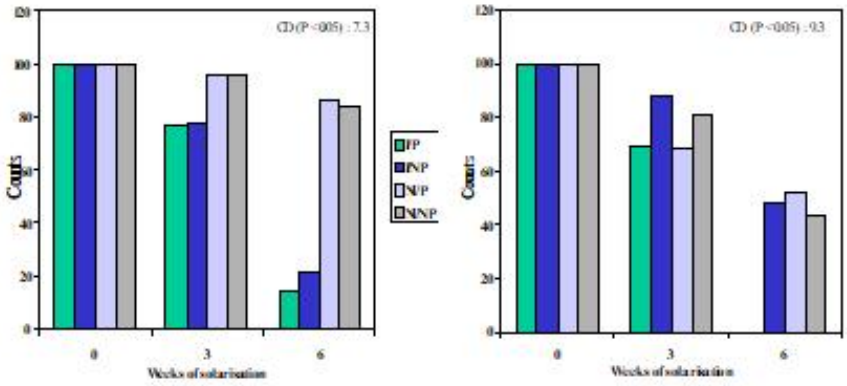
- M.L. Verma (1985) reported *Rhizoctonia bataticola* (*Macrophomina phaseoli*) (Root and stem rot) is a major disease with the following symptoms: Wilting of seedlings. Blackening of basal/ upper portion of stem.
- C.D. Kaushik et al. (1986) screened 175 genotypes over 3 years (1983 to 1985) against phyllody (MLO), root rot (*Macrophomina phaseoli*), and leaf curl (virus). There were other diseases: Bacterial leaf blight (*Xanthomonas* sp.), powdery mildew (*Erysiphe* sp.) and Phytophthora blight. Out of 175 germplasm lines/varieties 16, 51 and 65 lines were resistant to leaf curl, phyllody and root rot; 49, 41, and 14 were moderately susceptible and rest of the lines were susceptible to these diseases. Although there are reports on the evaluation of germplasm lines/varieties of Sesamum against different diseases, no one has indicated-multiple disease resistant sources in sesame.
- I.J. Gupta and H.S. Cheema (1990) reported. the number of microsclerotia of *Macrophomina phaseolina* present on sesame seeds was positively correlated with plant infection and negatively correlated with seed germination, dry matter production and root and shoot length of seedlings. Treatment with thiram, captan or Bavistin [carbendazim] increased seed germination by 16-40% compared with an untreated control, increased shoot length by 0.6-28.5% and decreased incidence of disease by 14-70%. Seed yields were also increased. Treatment with activated clay (attapulgite dust) or seed coating with *Trichoderma viride* increased germination by 30% and 16%, respectively, and increased seed yield by 32 and 46%.
- A. Singh et al. (1990) evaluated the effect of soil amendments with inorganic (urea) and organic (neem cake, mustard cake and farm yard manure - FYM) nitrogen sources and their combinations on sesame root rot (caused by *Macrophomina phaseolina*). Urea and FYM were the most effective combined treatment. Disease incidence was 9 and 7.5% (% plants killed) and seed yield was 88 and 60 g in 1982 and 1983, respectively, compared with 41.3 and 37.6% disease and 29 and 39 g seed for the control in 1982 and 1983, respectively. The next best combination was urea plus mustard cake followed by urea plus neem cake.
- Anon (1992a) in a grower guide reported *Rhizoctonia bataticola*/*Macrophomina phaseolina* (Stem and root rot) appears from the seedling to maturity. Sudden wilting is seen when the plant gets rot near soil surface, it starts up and down. The rotted portion turns black, and a charcoal appearance is exhibited. The plant later droops down from the point of infection and dies prematurely.
- S.P. Sinhamahapatra and S.N. Das (1992) reported combining ability analysis of a 9 x 9 diallel set of sesame genotypes grown in a sick plot infested with *Macrophomina phaseolina* revealed that the dominance component played a major role in controlling resistance to charcoal rot. Only two genotypes showed significant gca effects, one having resistance and the other having susceptible reaction.
- D. Dinakaran et al. (1996a) evaluated the effects of different soil amendments (Farmyard manure @ 12.5 t/ha, Press mud @ 12.5 t/ha, Decomposed coconut coir pith @ 12.5 t/ha, Sunn hemp green leaf manure @ 12.5 t/ha, Poultry manure @ 1.0 t/ha, and neem cake @ 150 kg/ha) to manage *Macrophomina phaseolina* in inoculated pots and under field condition in rabi 1994/95 using TMV 3 in Tamil Nadu. Carbendazim and untreated were also included. The soil incorporation of neem cake recorded a significantly lower incidence of root rot both under artificial (25.1%) and field conditions (6.9%) than the control with artificial (85.7%) and field conditions (27.8%).
- D. Dinakaran et al. (1996b) screened 44 sesame genotypes under field condition during the 1995 rainy season against root rot (*Macrophomina phaseolina*) and phyllody in Tamil Nadu. Three genotypes (IVT 21, IVT 22, and IVT 23) were found to be completely free from both disease and three genotypes (IVT 14, AVT 11and HT 1) were found to be free from phyllody alone. The high incidence of the root rot was 94.4% with a mean of 35.5%, while for phyllody the high was 36.5% with a mean of 10.7%.
- C. Chattopadhyay and R. Kalpana Sastry (1999) studied the effect of soil solarization on the sesame (stem root-rot pathogen (*Macrophomina phaseolina*) population in 1995 and 1996 in Hyderabad (77.92E and 18.99N). The experiment was laid out in split-split plot design in 3 replications with irrigated (I) and non-irrigated (NI) as main (M) plots, ploughed (P) and unploughed (NP) as sub (S) plots and 0, 3 and 6 weeks of solarization as sub-sub (SS) levels of treatment. Plots were irrigated to field capacity according to the design before they were covered with transparent polyethylene mulch of 50 µm thickness. The temperatures at 5 and 15 cm depth were as follow in the two years.



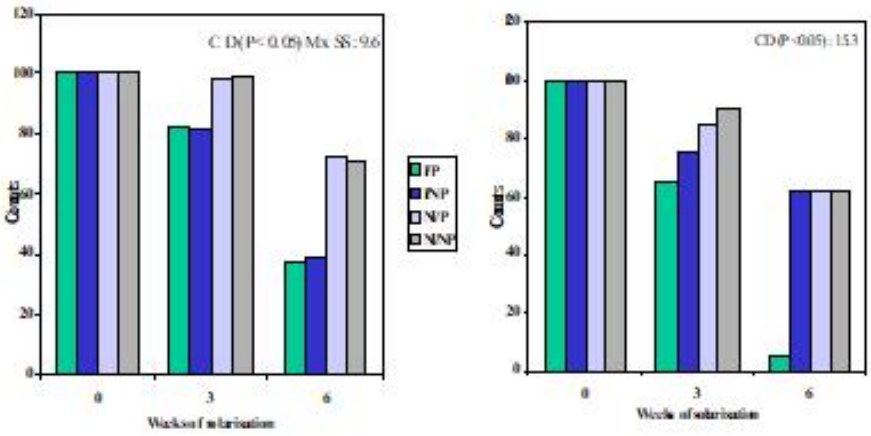
The effects on soil populations of *Macrophomina phaseolina* (cfu/g soil) were as follow.



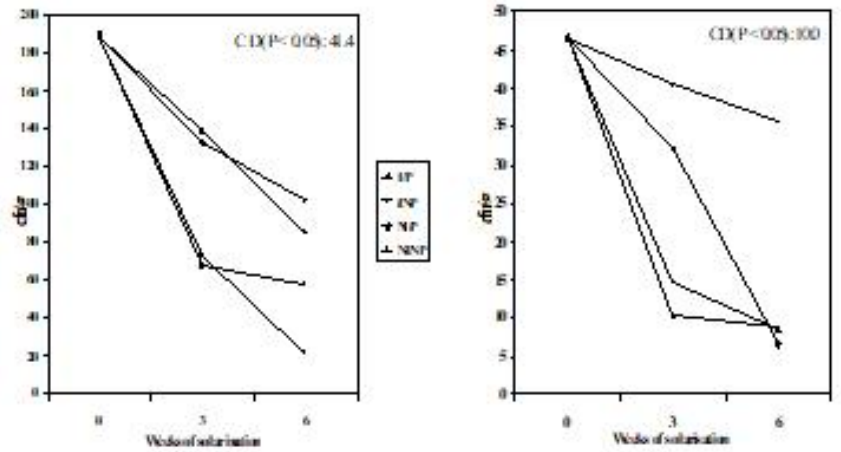
The effects on artificial inoculum of *Macrophomina phaseolina* placed at 5 cm soil depth were as follow.



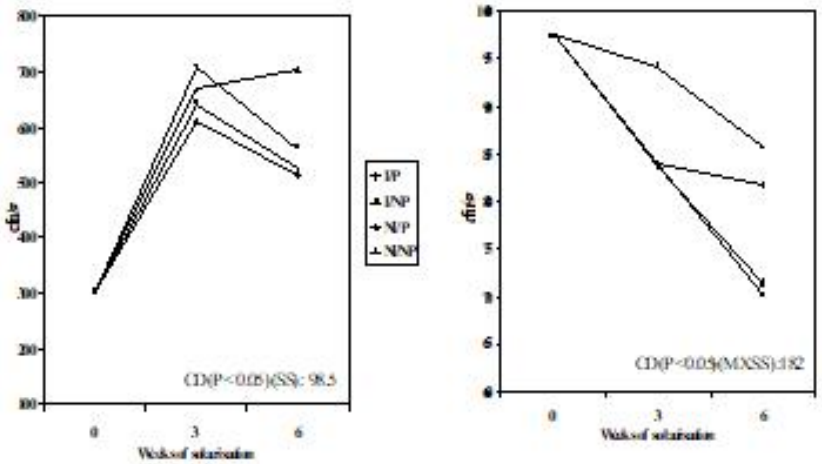
The effects on artificial inoculum of *Macrophomina phaseolina* placed at 15 cm soil depth were as follow.



The effects on the total fungi population (cfu/g soil) were as follow.



The effects on the total bacteria population (cfu/g soil) were as follow.



- K. Karunanithi et al. (1999) evaluated the efficacy of spraying KCl at several concentrations (0, 0.25, 0.5, 0.75, 1.0, 1.25, and 1.5) at 3 intervals (30, 45, and 60 DAS) to control *Macrophomina phaseolina.* Dry root-rot of sesame caused by *M. phaseolina* is the most serious disease affecting the crop at later stages of growth and it causes yield loss up to the extent of 30-40% in Tamil Nadu (A.N. Buldeo et al., 1979). They concluded spraying of 1.0% at 45 DAS is the best combination which caused disease reduction from 75% to 52.5%. Potassium chloride spray also enhanced the rhizosphere populations of fungi and bacteria and decreased that of actinomycetes.

Foliar spray of KCl (% concentration)	Root rot incidence (%)*			
	DAS			
	30	45	60	Mean
0.25	72.5 (58.4)	70.0 (56.8)	75.0 (59.9)	72.67 (58.4)
0.5	72.5 (58.3)	67.5 (55.2)	72.5 (58.4)	70.83 (57.3)
0.75	65.0 (53.7)	60.0 (50.8)	67.5 (55.2)	64.17 (53.2)
1.0	60.0 (50.7)	52.5 (46.4)	62.5 (52.3)	58.33* (49.8)
1.25	57.5 (49.3)	50.0 (45.0)	62.5 (52.2)	56.67 (48.8)
1.5	57.5 (49.4)	50.0 (45.0)	60.0 (50.8)	55.83 (48.4)
Control (no foliar spray)	75.0 (60.0)	75.0 (60.0)	77.5 (61.7)	75.83 (60.6)
Mean	65.7 (64.2)	60.7 (51.3)	68.2 (55.8)	

CD(P = 0.05): Concentration = 1.46; Spray (DAS) = 1.41; Interaction = 2.72
* Mean of four replications.
Figures in parentheses are mean transformed values.

- R. Krishan et al. (1999a) evaluated the effects of edaphic factors and moisture regime on the incidence of root rot disease caused by *Rhizoctonia bataticola*, which is the most devastating in North-Western parts of India. Due to severe infections the stem becomes black causing break off or blackening may extent upward and ultimately defoliation occurs. They used 4 soils (sandy, sandy loam, clay loam and clay) with different N levels (0, 15, 30, and 45 kg N/ha – N_0 to N_3 respectively) and different irrigation intervals (1, 2, 5, and & days). The following were the results.

Type of soil	Per cent			Disease incidence (%)
	Sand	Silt	Clay	
Sandy soil	96.0	2.5	1.50	66.66 (54.76)
Sandy loam soil	70.0	18.0	12.0	78.33 (62.24)
Clay loam soil	53.5	19.5	27.0	56.66 (48.55)
Clayey soil	14.2	24.3	61.3	51.66 (45.97)
C.D. at 5%				5.56

Figures in parenthesis are angular transformed values

Nitrogen levels (kg ha^{-1})	Disease incidence (%)
N_0	66.66 (54.76)
N_1	68.33 (55.73)
N_2	75.00 (60.00)
N_3	88.33 (70.00)
C.D. at 5%	5.80

Figures in parenthesis are angular transformed values

Irrigation after days of interval	Disease incidence (%)
1	6.66 (14.89)
2	16.66 (23.34)
5	36.66 (37.29)
7	48.33 (44.03)

Figures in parenthesis are angular transformed values

- R. Krishan et al. (1999b) evaluated the management effects of biological controls (using *Trichoderma harzianum*) on the seed and the soil, different levels of N (0, 30, and 45 N kg/ha), and seeds treated with different fungicides (Benomyl, Carboxyn, and Carbendazim) on *Rhizoctonia bataticola*. The results of using the *T. harzianum* conidia on the seed was as follow.

T. harzianum conidia g kg^{-1} seed (w/w)	Per cent disease incidence*
0	66.66 (54.76)
1.5	45.00 (42.13)
2.5	40.00 (39.23)
3.5	35.00 (36.27)
4.5	30.00 (33.21)
C.D. at 5%	6.93

*Figures in parentheses are angular transformed values

The results of using the *T. harzianum* in the soil and at different levels of N were as follow.

Level of N kg ha^{-1}	*T. harzianum* g kg^{-1} soil (w/w)	Per cent disease incidence*
30	0	75.00 (60.70)
	2	66.66 (54.75)
	4	56.66 (48.81)
	6	50.00 (45.00)
	8	46.66 (43.08)
	10	40.00 (39.21)
45	0	88.33 (70.50)
	2	78.33 (62.48)
	4	71.66 (57.86)
	6	63.33 (52.74)
	8	55.00 (47.88)
	10	45.00 (42.12)
Control	-	64.20 (53.25)
C.D. at 5%		7.51

*Figures in parentheses are angular transformed value

The results of using the *T. harzianum* on the seed with different fungicides were as follow.

Conidia g kg^{-1} seed (w/w)	Fungicide at 2%, W/V	Disease incidence (%)*
2.5	Benomyl	8.33 (16.60)
	Carboxyn	10.00 (18.05)
	Carbendazim	11.66 (19.89)
	No fungicide	42.50 (40.69)
3.5	Benomyl	5.00 (12.92)
	Carboxyn	6.66 (14.76)
	Carbendazim	6.66 (14.76)
	No fungicide	36.00 (36.87)
Control	-	66.66 (54.76)
C.D. at 5%		2.31

*Figures in parenthesis are angular transformed value

The results of using the *T. harzianum* in the soil with different fungicides were as follow.

Mycelial suspension of *T. harzianum* (g kg^{-1} soil)	Fungicide at 2% W/W	Disease incidence (%)*
4	Benomyl	8.93 (17.36)
	Carboxyn	3.58 (10.94)
	Carbendazim	7.15 (15.45)
	No fungicide	26.66 (31.11)
6	Benomyl	7.15 (15.45)
	Carboxyn	1.79 (7.71)
	Carbendazim	0.00
	No fungicide	21.66 (27.76)
Control		64.66 (50.55)
C.D. at 5%		1.37

*Figures in parenthesis are angular transformed value

- C. Chattopadhyay and R.K. Sastry (2000) evaluated methods to screen for *Macrophomina phaseolina* tolerance. They concluded for the first tier screening to use the blotter paper technique (seedlings grown on autoclaved sand were dipped in a suspension of *Macrophomina phaseolina* for 1 minute and placed on a folded blotter paper at 35°C for 10 days before observing the reaction). For the second tier screening they recommended the pot culture method (5 g of *Macrophomina phaseolina* in sorghum seed meal was mixed into 100 g of autoclaved soil. Seedlings from seeds sown in the pot were observed for the reaction).
- K. Jayashree et al. (2000) reported *Pseudomonas fluorescens* strain Pf1, effectively inhibited the mycelial growth of *Macrophomina phaseolina*, the pathogen causing dry root-rot in sesame. Application of Pf1 as a seed treatment (10g/kg seed) followed by soil application (2.5 kg/ha) effectively supported higher plant growth and grain yield. Sclerotial number and root rot incidence were also greatly reduced. The rhizosphere soil recorded a higher number of Pf1 population. The germination percentage were as follow.

ST - Pf 1	92.0^{cd}
ST + SA - Pf 1	97.5^{c}
SA - Pf 1	89.0^{bc}
ST - Carbendazim	90.2^{bcd}
ST + SD - Carbendazim	94.2^{d}
SD - Carbendazim	86.8^{ab}
ST - Pf 1 + SD - Carbendazim	93.5^{d}
ST – Carbendazim + SA - Pf 1	92.5^{cd}
Control	82.5^{a}

ST = seed treatment, SA = soil application, SD = soil drenching

The data at 30 days after sowing was as follow.

	Root length (cm)	Shoot length (cm)	*Pseudomonas* population / 100 g of soil	Sclerotia/ g of soil
ST - Pf 1	6.0 e	41.4 e	30.5 f	12.42 b
ST + SA - Pf 1	7.5 I	48.6 h	61.7 I	7.03 a
SA - Pf 1	5.3 c	35.0 c	54.3 h	26.11 d
ST – Carbendazim	5.7 d	40.5 d	7.5 d	14.32 b
ST + SD – Carbendazim	7.0 h	44.2 g	3.2 c	8.97 a
SD – Carbendazim	4.9 b	31.8 b	3.0 d	26.12 d
ST - Pf 1 + SD – Carbendazim	6.8 g	42.7 f	24.5 e	16.00 bc
ST – Carbendazim + SA - Pf 1	6.4 f	41.1 e	46.8 g	18.35 c
Control	4.2 a	25.6 a	2.6 a	35.66 e

ST-Seed Treatment; SA-Soil Application; SD-Soil Drenching

The final results were as follow.

	Root rot incidence (%)	Grain yield (kg / ha)
ST - Pf 1	38.5^{c}	320^{b}
ST + SA - Pf 1	23.2^{a}	1200^{g}
SA - Pf 1	35.4^{bc}	680^{e}
ST – Carbendazim	40.3^{c}	400^{bc}
ST + SD – Carbendazim	26.8^{ab}	820^{f}
SD – Carbendazim	37.1^{c}	460^{cd}
ST - Pf 1 + SD – Carbendazim	27.9^{ab}	900^{f}
ST – Carbendazim + SA - Pf 1	31.2^{abc}	560^{d}
Control	58.3^{d}	190^{a}

- C. Chattopadhyay and R.K. Sastry (2001) evaluated the effect of solarization on *Macrophomina phaseolina* for 2 years in Hyderabad (77.92E and 18.99N) in sandy to clay loam *alfisol* type soil. The solarization was done

with transparent polyethylene mulch of 50 µm thickness during the historically hottest 6 weeks with 0, 3, and 6 weeks of cover. Six weeks of soil solarization of infested crop field sites in the summer months result in good sesame seed germination and better disease management under Indian conditions as shown below.

Table 1. Effect of soil solarization on initial plant stand of sesame*

Weeks of solarization	I/P		I/NP		NI/P		NI/NP	
	First year	Second year	First year	Second year	First year	Second year	First year	Second year
0	322.6 (−4.1)	332.0 (19.7)	322.0 (−4.3)	317.4 (14.4)	320.6 (4.7)	315.4 (13.7)	336.6	277.4 –
3	354.0 (5.1)	314.0 (13.2)	356.0 (5.8)	272.6 (−1.7)	373.4 (10.9)	283.4 (2.2)	372.6 (10.7)	330.0 (19.0)
6	466.0 (38.4)	450.6 (62.4)	431.4 (28.2)	278.6 (0.4)	417.4 (24.0)	260.6 (−6.0)	426.6 (26.7)	261.4 (5.8)
C D ($P<0.05$)	First year (sub sub)			14.8				
	Second year (main x sub x sub–sub)			102.6				

*Mean of three replicates at 21 days after sowing
I: Irrigated; NI: Unirrigated; P: Ploughed; NP: Unploughed; Figures in parentheses are % increase over control.

Table 2. Effect of soil solarization on incidence of stem–root rot disease in sesame*

Weeks of solarization	I/P		I/NP		NI/P		NI/NP	
	First year	Second year	First year	Second year	First year	Second year	First year	Second year
0	41.6 (44.6)	59.2 (73.6)	38.7 (29.0)	68.7 (86.7)	32.6 (39.2)	67.7 (85.3)	45.9 (51.6)	73.4 (91.5)
3	35.9 (34.9)	45.7 (51.3)	31.2 (28.8)	57.8 (37.6)	32.4 (26.8)	33.6 (30.7)	28.4 (22.7)	41.8 (44.4)
6	5.2 (0.6)	4.0 (0.0)	26.0 (16.2)	28.2 (22.5)	23.7 (19.3)	29.6 (24.4)	23.2 (15.6)	32.7 (29.6)
C D ($P<0.05$)	First year (main x sub x sub sub)			8.8				
	Second year (main x sub x sub–sub)			7.4				

*Mean of three replicates at 100 days after sowing
Figures in parentheses are actual percent disease incidence and others are angular transformed values.
I: Irrigated; NI: Unirrigated; P: Ploughed; NP: Unploughed.

- D. Dinakaran and S.E.N. Mohammed (2001) screened 3 entries of sesame (ORM 7, ORM 14 and ORM 17) along with check varieties (TMV 3, Co 1, and VRI 1) at fortnightly intervals from June 1997 to May 1998 in Tamil Nadu against *Macrophomina phaseolina* (Root rot disease). All 3 cultures were found to be resistant (less than 10% incidence) to root rot disease under natural field conditions recording a mean incidence of 4.99, 5.17 and 4.14%, respectively. These 3 accessions were also screened under artificially inoculated pot culture conditions during rabi 1999-2000 showing also resistant reaction under these conditions, with a mean incidence of 10.0, 9.1 and 8.3%, respectively, whereas the susceptible varieties TMV 3, Co 1 and VRI 1 recorded the maximum incidence of 66.7, 70.0 and 91.7%, respectively.
- C. Chattopadhyay and R.K. Sastry (2002) evaluated the effects of chemicals, extracts, biocontrols, and agronomic practices in controlling *Macrophomina phaseolina* with the following *in vitro* results.

Treatment	Mycelial growth (mm)* in different fungicidal concentrations						Control	L.S.D. ($P<0.01$)
	1 ppm	5 ppm	10 ppm	25 ppm	50 ppm	100 ppm		
Carbendazim	17.7	14.0	9.3	0.0	0.0	0.0	43.0	2.5
Benomyl	20.0	15.7	14.7	5.3	2.3	0.0	43.0	1.1
Captan	42.7	42.0	33.7	21.7	18.0	12.3	43.0	3.3
Thiram	33.7	12.7	11.3	10.3	7.3	0.0	43.0	2.2
Copper-oxychloride	42.7	42.0	28.3	27.7	25.7	17.7	43.0	1.2
Control	43.0	43.0	43.0	43.0	43.0	43.0		
C.D. ($P<0.01$)	1.2	3.0	3.0	2.8	1.8	0.8		

*mean of five replicates after 7 days at 27±1°C

Treatment	Mycelial growth (mm)*	% Reduction in mycelial growth
Salicylic acid	0.0	100.0
Garlic bulb extract	9.5	78.4
Neem leaf extract	30.7	30.2
Azadirachtin[a]	43.0	2.3
AFF[y]	44.0	0.0
Control	44.0	-
C.D. (P < 0.01)	2.8	

*mean of five replications after 7 days on PDA at 27±1°C [a]neem formulation

Treatment	Mycelial growth (mm)*	% Reduction in mycelial growth
Trichoderma viride	21.6	71.3
T. harzianum	36.2	52.0
Gliocladium virens	14.2	80.9
Control	75.4	-
C.D. (P < 0.01)	6.5	

*mean of five replications after 7 days on PDA at 27±1°C

The following were the results in pots.

Treatment	% seed germination*		Radicle length (mm)*	Shoot length (cm)[$]	% disease incidence [$]	
Trichoderma viride	97.3	(82.1)	50.5	40.4	20.0	(25.7)
T. harzianum	88.0	(70.5)	31.0	24.6	55.0	(47.9)
Gliocladium virens	96.0	(80.5)	35.5	35.4	53.3	(47.4)
Garlic bulb extract	53.3	(46.9)	12.0	28.0	85.0	(67.6)
Neem leaf extract	92.0	(73.9)	29.5	33.9	45.0	(41.5)
Azadirachtin[a]	72.0	(58.1)	14.0	29.2	80.0	(64.4)
AFF[y]	0.0	(4.0)	0.0	30.2	61.6	(52.1)
Salicylic acid	88.0	(69.9)	26.0	37.5	60.0	(51.0)
Carbendazim	92.0	(73.6)	29.5	30.0	51.6	(45.9)
Copper-oxychloride	84.0	(66.5)	11.7	27.5	68.3	(56.3)
Thiram	78.7	(62.5)	9.7	26.6	65.0	(53.8)
Captan	84.0	(66.5)	8.0	26.9	50.0	(44.9)
Inoculated Control	81.3	(64.4)	13.7	14.9	100.0	(90.0)
Uninoculated Control	-	-	-	32.2	-	-
C.D. (P < 0.05)	7.2		4.8	6.3	13.7	

*mean of three replicates 3 days after sowing [a]neem formulations
Figures in parentheses are angular transformed values

Treatment	% Disease incidence*		% Disease reduction	Shoot length(cm)*	%Increase in shoot length
P 20 kg ha^{-1}	60.0	(50.8)	40.0	27.7	-14.0
P 40 kg ha^{-1}	58.3	(50.1)	41.7	31.0	-3.7
P 60 kg ha^{-1}	71.7	(58.3)	28.3	26.8	-16.8
K 15 kg ha^{-1}	73.3	(59.0)	26.7	21.7	-32.6
K 30 kg ha^{-1}	65.0	(53.9)	35.0	29.1	-9.6
K 45 kg ha^{-1}	60.0	(51.6)	40.0	23.1	-28.3
K 1 % foliar spray	80.0	(66.8)	20.0	21.7	-32.6
Inoculated control	100.0	(89.4)	-	14.9	-53.7
Uninoculated control	-	-	-	32.2	-
C.D. (P < 0.05)	14.6			7.2	

*mean of four replicates 12 weeks after sowing
Figures in parentheses are angular transformed values

[Authors comment: Notice that on *Trichoderma viride* they also used an induced mutation.]

Treatment	% Disease incidence*		Shoot length (cm)*	cfu (x 10^3) g^{-1} soil*
P @ 20 kg ha^{-1}	61.7	(51.8)	25.3	57.3
K @ 15 kg ha^{-1}	73.3	(58.9)	25.7	50.7
Carbendazim @ 0.1% a.i	51.7	(46.0)	34.3	42.7
Salicylic acid @ 1% (w/v)	61.7	(51.8)	27.3	48.0
Neem leaf extract @ 1% (w/v)	61.7	(51.8)	32.3	49.0
Trichoderma viride (wild)	23.3	(28.9)	36.7	19.3
Trichoderma viride (Mut)	31.7	(34.2)	37.0	29.0
P + K	50.0	(45.0)	28.3	47.0
Carbendazim + P	46.7	(43.1)	34.3	44.0
Carbendazim + K	43.3	(44.0)	34.7	40.3
Carbendazim + P + K	36.7	(38.2)	35.3	38.0
Salicylic acid + P	53.3	(46.9)	27.7	43.3
Salicylic acid + K	51.7	(46.0)	28.0	40.7
Salicylic acid + P + K	48.3	(44.0)	30.3	43.3
Neem leaf extract + P	55.0	(47.9)	33.7	50.3
Neem leaf extract + K	53.3	(46.9)	34.3	46.0
Neem ;eaf extract + P + K	50.0	(45.0)	34.7	48.0
Trichoderma viride (wild) + P	23.3	(28.9)	36.7	19.3
Trichoderma viride (wild) + K	21.7	(27.7)	36.7	19.3
Trichoderma viride (wild) + P + K	20.0	(26.6)	37.0	19.0
Trichoderma viride (Mut) + P	30.0	(33.2)	37.3	27.0
Trichoderma viride (Mut) + K	28.3	(32.1)	37.3	26.3
Trichoderma viride (Mut) + Carbendazim	26.7	(31.1)	38.3	31.3
T. viride (Mut) + P + Carbendazim	20.0	(26.6)	38.7	19.3
T. viride (Mut) + K + Carbendazim	20.0	(26.6)	39.7	20.0
T. viride (Mut) + P + K	23.3	(28.8)	39.0	25.3
T viride (Mut) + P + K + Carbendazim	8.3	(16.6)	41.7	18.0
Inoculated control	100.0	(90.0)	13.3	58.3
Uninoculated control	-	-	33.7	-
C.D. ($P < 0.01$)	4.7		1.6	3.4

*mean of three replicates 12 weeks after sowing
Figures in parentheses are angular transformed values

- T.S. Rajpurohit (2002) evaluated the effects of intercropping (sole sesame compared to 1:1 and 2:1 of sesame and green gram, mothbean, and pearl millet) on *Macrophomina phaseolina* and yield. Sesame or intercropped with green gram in 1:1 gave less incidence of stem and root rot and also provided a higher sesame seed yield equivalent as compared to sole sesame and this may be recommended for cultivation in an arid region of Rajasthan.
- K. Thiyagu et al. (2007a) evaluated 15 genotypes and 36 of their F_1s for tolerance to *Macrophomina phaseolina*. The genotypes namely ORM 7, ORM 14, and ORM 17 were identified as resistant to root rot which could be used as cultivars or used in hybridization program. The F_1s obtained by crossing the three resistant genotypes (as testers) with twelve susceptible genotypes (as lines) found to be susceptible which indicated that the resistance trait may be governed by the recessive gene.
- D.B. Ahuja et al. (2009) reported adoption of IPM technology comprising intercropping of sesame with greengram and spray of 9 ppm azadirachtin at flowering stage reduced the incidence of major pests such as *Antigastra catalaunalis* and *Macrophomina phaseolina* from 24.79 and 16.88 in unprotected treatment to 13.04 and 6.25, respectively. [Based on abstract]
- S.U. Rani et al. (2009) reported use of *Trichoderma viride* (seed treatment) 4g/kg, soil application 5 kg/ha with FYM managed *Macrophomina phaseolina* causing root rot in sesame.
- N.O. Srikantappa et al. (2009) studied 28 samples of sesame taken from fields, farmers, retail shops and APMC markets from 5 areas. They found 34 four fungi including *Macrophomina phaseolina*. The fungi significantly reduced germination.
- R. Narayanaswamy and B. Gokulakumar (2010) studied 5 varieties grown in different trial plots with three treatments (control, chemical fertilizer, and organic manure. Diseased and healthy roots were collected. The roots were subjected to ICP-AES analysis and the elemental status of the diseased and healthy roots were estimated. Based on the comparison between healthy and diseased roots, lowering the concentration of Ca, Na, Mg and Fe and increasing the concentration of K, Cu and Zn in the soil may reduce root rot disease occurrence caused by *Macrophomina phaseolina* . [Based on abstract and cited by C. Chattopadhyay, 2019]
- J. Priya et al. (2010) reported thiophanate-methyl and carbendazim were most effective against the mycelial growth of *Rhizoctonia bataticola* followed by carboxin and Captan under *in vitro* conditions, whereas under screenhouse conditions thiophanate-methyl, carbendazim and carboxin were found effective against charcoal-

rot of sesame incited by *R. bataticola*. Seed treatment proved more effective than soil drenching with fungicides.

- R.B. Kakde and A.M. Chavan (2011) examined the effects of fungi on seeds in storage. Ten dominant fungi were isolated from seeds of groundnut, soybean, sesame, safflower, and sunflower. One hundred grams of seeds were inoculated with 10 ml of the fungi. The flasks were left at room temperature for 14 days and then analyzed for sugars, crude fat, and fiber. The results are as follow.

Table 1. Change in reducing sugar (g/100gm) due to seed-borne fungi

Fungi	Sunflower	Sesame	Groundnut	Soybean	Safflower
Alternaria dianthicola	5.2	4.8	1.1	1.1	1.3
Curvularia lunata	4.9	5.0	2.5	1.5	1.8
Curvularia pellescens	5.0	5.4	2.1	1.2	1.6
Fusarium oxysporum	4.7	4.4	1.8	1.7	1.1
Fusarium equiseti	4.6	4.8	1.6	1.2	1.0
Macrophomina phaseolina	5.8	3.5	2.2	2.0	2.2
Rhizopus stolonifer	6.1	5.0	1.1	1.8	2.1
Penicillium digitatum	5.5	4.6	1.9	1.7	1.4
Penicillium chrysogenum	5.2	4.9	2.0	1.6	1.6
Trichoderma viride	6.7	6.1	2.1	1.9	2.6
Control	7.2	6.9	3.1	2.4	2.8
C.D. at 0.05	0.52	0.62	1.21	0.24	0.21

Table 2. Change in crude fat (g/100gm) due to seed-borne fungi

Fungi	Sunflower	Sesame	Groundnut	Soybean	Safflower
Alternaria dianthicola	35.5	10.2	37.1	49.8	22
Curvularia lunata	43.5	14.3	32.5	48.2	26
Curvularia pellescens	45.5	10	41	49	27
Fusarium oxysporum	43	16.1	38	44	20
Fusarium equiseti	47	14.2	35	49.7	19
Macrophomina phaseolina	39	10.5	39.3	46.8	30
Rhizopus stolonifer	50	16.3	40.2	48.6	33
Penicillium digitatum	42	15.3	34.3	39	24
Penicillium chrysogenum	44	12.8	36.2	41	27
Trichoderma viride	46	17.5	40	46	35
Control	49	20	45	50	36
C.D. at 0.05	2.71	2.05	2.04	2.4	3.7

Table 3. Change in crude fiber (g/100) due to seed-borne fungi

Fungi	Sunflower	Sesame	Groundnut	Soybean	Safflower
Alternaria dianthicola	39.1	35.6	33.9	26.1	20.1
Curvularia lunata	52.3	30.6	38.8	34.5	21.8
Curvularia pellescens	46.1	41.1	42.3	31.1	21.6
Fusarium oxysporum	53.1	36.5	34.7	37.0	21.0
Fusarium equiseti	50.7	36.4	37.9	21.0	22.5
Macrophomina phaseolina	47.7	34.8	41.9	36.6	17.9
Rhizopus stolonifer	41.6	31.6	40.1	28.5	19.6
Penicillium digitatum	43.5	40.5	27.6	21.0	14.4
Penicillium chrysogenum	40.5	27.7	31.7	36.9	13.9
Trichoderma viride	47.5	35.1	38.3	37.0	19.8
Control	51.3	47.7	38.0	23.3	19.9
C.D. at 0.05	3.16	6.11	2.39	4.2	1.82

They also tested the effect of the following botanicals against the fungi: *Azadirachta indica, Polyalthia longifolia, Jatropha curcus, Santalum album, Withania somnifera, Datura strominum, Eucalyptus angophoroides, Vitex nigundo, Annona squamosal, Piper betel* and *Murraya koenigii*. Most of the fungi tested are not normally found on sesame, but for those that are, *Azadirachta indica, Polyalthia longifolia, Murraya koenigii, Jatropha curcus, Withania somnifera* and *Datura strominum* showed antifungal activity against *Macrophomina phaseolina*, and *Eucalyptus angophoroides* against *Fusarium oxysporum.*

- A. Sharma et al. (2011) analyzed the metabolic alterations in sesame after infection with *Macrophomina phaseolina* and *Fusarium oxysporum* by estimating the levels of total phenolic compounds and the activities of phenylalanine ammonia lyase (PAL) of one week old plants. The PAL showed high activity in infected plants, revealing the active phase in the synthesis of secondary metabolites in the plant after infection. As a consequence, in infected plants the contents of polyphenols along with salicylic acid (SA) considerably exceeded when compared to control plants. This *in vivo* study of *M. phaseolina* and *F. oxysporum* infection reveals the differences of resistance levels in sesame against these two pathogens. The following shows the percentage increase in phenolics, PAL activity and defense related proteins in infected plants in comparison to

control under *in vivo* and *in vitro* conditions in both 25 days 35 days old plants after 96 and 48 hours of inoculation.

	PAL				Salicylic acid				Total protein			
	A		B		A		B		A		B	
Varieties	25 days	35 days	25 days	35 days	25 days	35 days	25 days	35 days	25 days	35 days	25 days	35 days
RSG-931	5	8	5	12	31	25	9	33	10	23	24	24
RSG-945	10	12	5	7	21	29	21	20	40	19	44	18
RSG-896	10	28	11	14	32	31	32	23	42	24	59	28
CSJD-884	15	11	11	13	26	21	13	29	25	21	23	20

A-*In vivo*, B-*In vitro*.

- P. Deepthi (2012 and 2014) studied the effects of temperature and relative humidity on *Macrophomina phaseolina* in a field study using 1 variety (TGK-22) in 2011/12 at Raipur, Chhattisgarh (21.25N 81.63E). The control seeds were treated with Penflufen + Trifloxystrobin along with one foliar application of carbendazim. The correlations with the weather were as follow.

(a) Correlation coefficient between weather parameters and lesion length of charcoal rot of sesame

	Length	Max temp	Min temp	RH
Length	1			
Max. temp	0.6257641	1		
Min. temp	0.0439474	0.1036966	1	
RH	-0.777863	-0.366525	-0.512541	1

(a) Correlation coefficient between weather parameters and lesion width of charcoal rot of sesame

	Width	Max temp	Min temp	RH
Width	1			
Max temp	0.729714	1		
Min temp	0.060163	0.103697	1	
RH	-0.73122	-0.36652	-0.51254	1

The effects on yield components were as follow.

S. No	Nature of observation	Unprotected	Protected	% Reduction
1	No. of capsules per plant	31	46	32.61
2	No. of seeds per capsule	29	45	35.55
3	1000 seed wt. (g) (healthy capsule seed)	2.50	2.91	14.08
4	1000 seed wt. (g) (infected capsule seed)	1.83	2.20	16.81

- D.K. Maheshwari et al. (2012) evaluated the use of *Azotobacter chroococcum* TR2 against *Macrophomina phaseoli* and *Fusarium oxysporum* along with growth promoting attributes in conjunction with fertilizers. It caused degradation and digestion of cell wall components, resulting in hyphal perforations, empty cell (halo) formation, shrinking and lysis of fungal mycelia along with significant degeneration of conidia. The effects on the pathogens were as follow.

Fungal Pathogen	Incubation (h)	Growth in dual culture (mm)	Growth in control (mm)	Growth inhibition (%)
M. phaseolina	48	25.0 ± 0.03	48.2 ± 0.02	48.1
	72	28.3 ± 0.05	60.4 ± 0.05	53.1
	96	29.7 ± 0.01	70.7 ± 0.03	57.9
	120	30.9 ± 0.06	89.3 ± 0.02	65.3
F. oxysporum	48	28.0 ± 0.03	40.0 ± 0.07	30.0
	72	39.1 ± 0.02	65.5 ± 0.06	40.3
	96	41.0 ± 0.03	76.7 ± 0.11	46.5
	120	41.8 ± 0.07	88.1 ± 0.12	52.5

- P.L. Radha (2013) collected 18 cultivars from 7 districts in Karnataka and identified the following fungus: *Macrophomina phaseolina*.
- K. Satyagopal et al. (2014) in an IPM manual reported *Rhizoctonia bataticola* (Dry root rot) symptoms were as follows:
  - The fungus attacks young seedling, their stems become water soaked soft and incapable of supporting the seedling which falls over and dies.
  - On older seedlings elongated brownish black lesions appear which increase in length and width girdling the stem and plant dies.

  The pathogen survives in seed and soil. High soil temperatures and moisture stress conditions favor the development of the pathogen.

  Cultural control: Avoid planting overlapping crops in adjacent area. Crop rotations, viz., sesame-maize, cabbage, okra-sesame-maize, maize-sesame-maize and sesame- finger millet-egg plant are reported effective in reducing disease incidence. Crop rotation with non-host crops, particularly with paddy. Provide good drainage.

Seed treatment: Treatment with *Trichoderma* sp. @ 4 g/Kg of seed, *Pseudomonas fluorescens* @ 2 g/Kg seed, or *Bacillus subtilis* @ 2 g/Kg seed or NSKE 4%.

- S. Kumar et al. (2011) reported charcoal rot of sesame caused by *Macrophomina phaseolina* (Tasi) Goid is the most devastating disease, causing up to 50% or more disease incidence in field resulting in heavy yield losses. The pathogen survives as sclerotia in the soil and in host tissue for varying periods. Due to its soilborne nature, practically no effective field control is available so far. [Based on abstract]
- K.N. Gupta and A.R.G. Ranganatha (2014) reported among the fungal diseases, charcoal rot of sesame caused by *Macrophomina phaseolina* is the most devastating, causing up to 55% or more disease incidence in field resulting in heavy yield losses. The pathogens survive as sclerotia in the soil and in host tissue for varying periods. The pathogen attacks plant at all growth stages and causes pre emergence rotting in seeds, soft rot in emerging seedlings, and charcoal rot in mature plants. Due to soilborne nature, practically no effective field control and no resistance variety is available so far. Thus, management of charcoal rot by fungicides is expensive and not eco-friendly. Biological control of plant disease is cost effective and environmentally safe. A field experiment was conducted on sesame during Kharif 2013 to find out the effect of *Trichoderma viride* on incidence of charcoal rot disease in sesame. On the basis of number of capsule/plant, yield/plot/ha and 1000-seed weight, it was concluded that seed treatment with *Trichoderma viride* (5g/kg seed) and before sowing mix in soil (2.5 kg/ha) were found effective and economical for the management this disease. [Based on abstract]
- V.A. Savaliya et al. (2015) evaluated the efficacy of various botanicals against *Macrophomina phaseolina* using the poison food technique with the following results.

Phytoextract	Concentration (%)	Sclerotial formation	Per cent inhibition over control	Mean
Allium sativum L.(Garlic)	2	+	75.18	77.65
	5	+	77.03	
	10	+	80.73	
*Allium cepa*L.(Onion)	2	+	73.33	77.15
	5	+	76.66	
	10	+	81.47	
Ocimum sanctum L.(Tulsi)	2	++++	43.70	52.21
	5	+++	51.84	
	10	++	61.10	
Azadirachta indica A. Juss. (Neem)	2	++++	40.73	47.52
	5	++	48.88	
	10	++	52.96	
Curcuma longa L. (Turmeric)	2	++++	32.95	42.46
	5	++++	41.10	
	10	+++	53.33	
*Adhatoda vasica*Ness. (Ardusi)	2	++++	36.29	41.23
	5	++++	42.21	
	10	++++	45.18	
*Jatropha curcas*L.(Jatropha)	2	++++	33.70	35.79
	5	++++	35.18	
	10	++++	38.51	
Lantana camara L. (Lantana)	2	++++	29.99	34.56
	5	++++	31.10	
	10	++++	42.58	
Zingiber officinale Rosc. (Ginger)	2	++++	21.10	32.34
	5	++++	35.55	
	10	++++	40.36	
Control	-		-	
	Phytoextract (P)	Concentration (C)	P x C	
S. Em. ±	**0.895**	**0.490**	**1.550**	
CD at 5%	**2.532**	**1.387**	**4.386**	
CV %		**6.09**		

*** sclerotial formation: ++++ = abundant; +++ = good; ++ = moderate; + = scanty; - = no sclerotial formation**

- B. Khamari et al. (2016) reported the first symptoms of *Macrophomina phaseolina* were seed rot, poor seedling stand, pre- and post-emergence damping off, and reduced vigor. The pathogen gradually affected the fibro-vascular system and base internodes resulting in loss of vigor, progressive wilting, and premature dying. The growth of the secondary toot system was greatly reduced. The root system as a whole was poorly developed in diseased plants. The characteristic symptom appeared after flowering as browning to grayish discoloration of the plant and hallowing of the stem resulting in reduction in stem girth and heigh of the plant. Finally, the

whole plant withered giving blackish appearance due to death of the plant and presence of numerous microsclerotial bodies. The following is a comparison between healthy (H) and diseased (D) plants.

Plants	Root length (cm)		Stem diameter(cm)		No of roots		Root length(cm)		Plant height (cm)		Girth of transition zone(cm)	
	H	D	H	D	H	D	H	D	H	D	H	D
1	12	10.9	1.12	0.86	48	31	4.5	3.2	125	115	6.5	4.9
2	15	9.5	0.7	1.06	52	24	5	2	138	86	5.1	5.2
3	17	16.5	1.2	1.03	59	22	5.6	2.9	135	127	5.3	4.0
4	14	12.5	1.3	0.93	42	20	4.5	2.2	130	98.5	5.1	5.5
5	13	15.0	1.8	0.9	39	18	5.3	2.7	124	105	4.5	4.4
Mean	14.2	12.88	1.22	0.96	48	23	4.93	2.6	130.4	106.3	5.3	4.8

- V.A. Savaliya et al. (2016) evaluated biocontrols against *Macrophomina phaseolina in vitro* with the following results.

Biocontrol agents	Sclerotial formation	Per cent inhibition over control
Bacillus subtilis	+	87.03
T. viride	+ +	71.48
T. hamatum	+ + +	70.00
T. koningii	+ + +	68.14
Trichoderma harzianum	+ +	67.40
Pseudomonas fluorescens	+ +	64.07
Control		-
S. Em. ±	1.602	
CD at 5%	4.862	
CV %	4.54	

Biocontrol agents	Per cent disease incidence	Yield (kg / ha)
Bacillus subtilis	18.93(10.53)	680
Trichoderma konigii	25.43(18.44)	585
T. hamatum	26.90(20.48)	609
T. viride	28.42(22.65)	579
T. harzianum	30.02(25.02)	510
Pseudomonas fluorescens	30.93(26.42)	537
Control	32.96(29.61)	507
S. Em. ±	1.30	28.36
C.D. at 5%	3.89	87.38
C.V.%	10.46	8.59

- B. Khamari et al. (2017a) reported stem and root rot and wilt diseases of sesame incited by *Macrophomina phaseolina* and *Fusarium oxysporum* f. sp. *sesami* respectively are serious biotic constraints for sesame production. Investigations were formulated on dual culture technique, cut stem inoculation experiment, and soil inoculation experiment in order to assess the interaction and combined effect of the 2 pathogens. Macrophomina did not showed any antagonistic effect towards Fusarium and vice versa in dual culture experiment. Inoculation of healthy sesame stem with Macrophomina, Fusarium and in combination of Macrophomina +Fusarium revealed the color of the stem changed from white to gray to black at different days of inoculations whereas the stem color was green throughout the experimental period in control. The vascular bundle converted to dark and hollow stem in case of Macrophomina and Macrophomina + Fusarium when split 30 days after inoculation. Soil inoculation study revealed inoculation of Macrophomina + Fusarium recorded as low as 26.00% seed germination due to pre emergence damping off followed by in Macrophomina alone (seed germination 34%). The control pot recorded as high as 82% germination. Macrophomina is fast growing fungus as compared to fusarium, but the combination of Macrophomina and Fusarium didn't yield any antagonistic effect and found both in association leading to disease severity as compared to alone. The progress of the disease on the outside of the stem were as follow.

Treatments	2 DAI		4 DAI		6DAI		10 DAI	
	Colour	Coverage	Colour	Coverage	Colour	Coverage	Colour	Coverage
Macrophomina	White	Medium	Grey	Medium + half stem	Dark grey	Medium + stem	Black	Medium + stem
Fusarium	White	Medium	White	Medium	Cream y white	Medium + 1/4th stem	Cream y white	Medium + stem
Macrophomina + Fusarium	White	Medium	White+ grey	Medium + 1/4th stem	Grey	Medium +½ stem	Grey	Medium + stem
Control	Green	-	Green	-	Green	-	Green	-

Comparisons of the outer and inner stem were as follow.

Treatments	**30 days after Inoculation**					
	Characteristics before splitting			**Characteristics after splitting**		
	Colour of medium	Colour of stem	Stem character	Colour of stem	Stem character	Microsclerotia
Macrophomina	Black	Black	Dark bark, fleshy, black growth on it	Black	Hollow VB	Present
Fusarium	Creamy white	Creamy white	Rotten, fleshy bark, whitish growth on it	White	Rotten VB	Absent
Macrophomina + Fusarium	Grey	Grey	Grey colour, fleshy	Grey	Hollow VB	Present
Control	Normal	Green	Green and normal	Light yellow	Normal VB	Absent

The effects of soil inoculation were as follow.

S. no	Treatments	Germination %	Pre emergence damping off
1	*Macrophomina*	34 (35.429)	66(54.534)
2	*Fusarium*	52 (46.311)	48(43.653)
3	*Macrophomina + Fusarium*	26 (27.586)	74(62.385)
4	Control	82 (65.332)	18(24.632)
SE(m) CD		5.020 15.179	5.022 15.186

- B. Khamari et al. (2017b) evaluated the inhibitory effect of 30 commonly available plant products on growth of *Macrophomina phaseolina in vitro.* Maximum inhibition was recorded in garlic followed by onion at all the concentrations in methanol as well as in aqueous extract. Garlic registered maximum mean per cent inhibition of 77.93%, 87.20, 92% and 100% followed by onion giving 70.22%, 85.80%, 92.67% and 98.73% at 5%, 10%, 15% and 20% concentrations respectively in aqueous extract. Methanolic extract of garlic witnessed mean per cent inhibition of 85.32%, 92.67%, 96.33% and 100% followed by onion with mean per cent inhibition of 72.25%, 89.47%, 92.67% and 100% at concentration of 5, 10, 15 and 20%. Besides garlic and onion, neem, bitter gourd, karanj and carrot grass had good reduction in mycelial growth at all concentrations. Lantana recorded least effective among all the plant extracts.
- K. Choudhary et al. (2018) evaluated chemicals (Tebuconazole, Carbendazim, and Mancozeb) and biocontrols (*Trichoderma harzianum* and *Pseudomonas fluorescens*) to reduce the incidence of *Macrophomina phaseolina* with the following results in terms of disease incidence and yield.

Treatments	Disease incidence (%)	Disease control (%)	Yield (kg ha^{-1})
T_1 -Tebuconazole 2DS ST @ 1.5 g kg $^{-1}$	16.16 (23.70)*	73.06	435.00
T_2 - Carbendazim 12% + Mancozeb 63% WP ST @ 2 g kg $^{-1}$	18.16 (25.22)	69.73	420.10
T_3 - *T. harzianum* ST @ 10 g kg $^{-1}$	31.00 (33.83)	48.10	378.00
T_4 - *P. fluorescens* ST @ 10 g kg $^{-1}$	33.50 (35.36)	44.16	370.00
T_5 - Tebuconazole 25.9 EC SA @ 1.5 ml Lt^{-1}	19.51 (26.21)	67.48	410.00
T_6 - Carbendazim 12% + Mancozeb 63% WP SA @ 2 g Lt^{-1}	22.50 (28.32)	62.50	405.00
T_7 -*T. harzianum* SA @ 10 kg ha^{-1}	35.80 (36.64)	40.33	350.00
T_8 - *P. fluroescens* SA @ 10 kg ha^{-1}	40.00 (39.23)	33.33	330.10
T_9 - Tebuconazole 2DS ST@ 1.5 g kg $^{-1}$ + Tebuconazole 25.9 EC SD @ 1.5 ml Lt^{-1}	9.52 (17.97)	84.13	480.60
T_{10} - Carbendazim 12% ST @ 2 g kg $^{-1}$+ Mancozeb 63% WP + SD @ 2 g Lt^{-1}	13.50 (21.56)	77.50	450.00
T_{11} -*T. harzianum* ST @ 10 g kg $^{-1}$ + SA @ 10 kg ha^{-1}	23.50 (29.00)	60.83	392.00
T_{12} - *P. fluroescens* ST @ 10 g kg $^{-1}$ + SA @ 10 kg ha^{-1}	26.55 (31.01)	55.75	385.30
T_{13} - Control (without treatment)	60.00 (50.77)	-	250.00
SEm ± CD P=0.05 CV(%)	1.58 4.63 10.23		22.93 66.94 10.21
*Figures in parentheses are angular transformed values			

ST= Seed treatment, SA= Soil application, SD=Soil drenching

- K.N. Gupta et al. (2018) reported stem and root rot are caused by *Macrophomina phaseolina*. The symptoms were produced at ground level stem becomes black, which extends upward rupturing the stem and black dots appear on the infected stem. The roots will become brittle. In disease infected plants, black capsules are seen which open prematurely exposing shriveled seed. The diversity of host species and the geographic range have suggested that *M. phaseolina* is quite heterogeneous. Its variability has been confirmed by reports demonstrating differences in pathogen city of isolates obtained from both a single plant and a single host species (B.K. Babu et al. 2010 {India}). Despite having a wide host range, only one species is recognized within Macrophomina. The disease also causes severe losses right from seedling to maturity of the crop. Intercropping of sesame + mothbean (1:1 or 2:1) is helpful for controlling stem and root rot. For recommendations on cultural, chemical, and biocontrol practices to alleviate or control the disease refer to the introduction.
- C.S. Karibasappa et al. (2018) surveyed the disease incidence of root rot of sesame caused by *Macrophomina phaseolina* in the major sesame growing areas of Telangana in 2017 in 21 locations. The percentage infections ranged from 0-18%.

Plate 1: a: healthy plant b: diseased plant at maturity

Plate 2: Black coloured sclerotial bodies on pod (left) and on stem portion of the diseased plants

- B. Khamari and C. Patra (2018a) screened 15 chemicals *in vitro* at four concentrations such as 100 ppm, 250 ppm, 500 ppm and 1000 ppm employing poison food technique against *Macrophomina phaseolina* with the following results.

Treatments	Trade name	Systemic / contact	Mean per cent of mycelia inhibition			
			100 ppm	250 ppm	500 ppm	1000 ppm
Carbendazim 50% WP	Dhanustin 50% WP	Systemic	64.00 (53.11)	82.23 (65.04)	100.00 (90.00)	100.00 (90.00)
Carbendazim 63%w/w + Mancozeb 12% w/w	Saaf	Systemic & contact	70.10 (56.83)	86.27 (68.22)	100.00 (90.00)	100.00 (90.00)
Validamycin 3L	Sheathmar 3L	Systemic	45.27 (42.27)	64.50 (53.41)	80.72 (63.94)	94.78 (77.03)
Azoxystrobin 23 SC	One star	Systemic	34.83 (36.16)	46.27 (42.84)	61.04 (51.38)	92.57 (74.19)
Hexaconazole 5% EC	Contaf 5E	Systemic	45.03 (42.13)	78.49 (62.35)	100.00 (90.00)	100.00 (90.00)
Difenconazole 25 EC	Score	Systemic	54.63 (47.64)	72.70 (58.48)	96.58 (79.33)	99.60 (87.88)
Propiconazole 25% EC	Tilt	Systemic	66.80 (54.79)	80.56 (63.82)	100.00 (90.00)	100.00 (90.00)
Thiophenate methyl 70% WP	Roko	Systemic	70.00 (56.77)	84.61 (66.88)	100.00 (90.00)	100.00 (90.00)
Propineb 70% WP	Antracol	Contact	44.83 (42.02)	76.57 (61.03)	98.79 (86.33)	100.00 (90.00)
Chlorothalonil	Kavach	Contact	54.43 (47.52)	68.49 (55.83)	94.78 (76.89)	95.18 (77.56)
Carboxin 37.5%WP+ Thiram 37.5%	Vitavax power	Systemic & contact	65.33 (53.90)	72.65 (58.44)	100.00 (90.00)	100.00 (90.00)
Tebuconazole + Trifloxystrobin	Nativo 75 WG	Systemic	54.63 (47.64)	84.61 (66.88)	99.60 (87.88)	100.00 (90.00)
Cyamoxanil 8% + Mancozeb 64%	Curzate M8	Systemic & contact	42.63 (40.74)	62.63 (52.30)	93.17 (77.67)	99.60 (87.88)
Fenamidon + Mancozeb	Sectin 60WG	Systemic & contact	42.57 (40.71)	72.88 (58.60)	89.16 (70.76)	89.96 (71.50)
Tebuconazole 25% W/W	Folicure	Systemic	62.65 (52.30)	75.00 (59.98)	99.20 (87.01)	100.00 (90.00)
Control	-	-	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
SE(m)± CD(0.01)			0.221 0.640	0.364 1.054	2.138 6.187	1.041 3.013

- B. Khamari et al. (2018b) studied the influence of physiological parameters like temperature, pH and light period on growth and sporulation *in vitro* of *Macrophomina phaseolina*. The effects of pH were as follow.

Sl. No.	pH	Dry myeclia weight(mg)
1	3.0	196.00
2	3.5	197.00
3	4.0	204.00
4	4.5	226.50
5	5.0	230.00
6	5.5	238.00
7	6.0	275.25
8	6.5	285.80
9	7.0	278.00
10	7.5	260.00
11	8.0	257.00
12	8.5	246.00
13	9.0	240.25
14	9.5	217.00
15	10.0	210.00
SE(m)± CD(0.05)		14.957 45.495

The effects of temperature were as follow.

Sl no.	Temperature (^{0}C)	Mean (mm)
1	5	0.00
2	10	0.00
3	15	0.70
4	20	4.57
5	25	4.90
6	30	8.57
7	35	9.00
8	40	7.80
9	45	7.23
10	50	5.83
CD(0.05) SE(m)±		0.567 0.191

The effects of daylight were as follow.

Sl no	Treatments	Radial diameter	
		3rd day of inoculation	5th day of inoculation
1	24 hours light	3.98	7.34
2	24 hours dark	3.89	5.54
3	12 hours light and 12 hours dark	4.55	7.69
4	16 hours light and 8 hours dark	4.20	7.48
5	8 hours light and 16 hours dark	3.73	7.67
SE(m)±		0.369	0.212
CD		N.S.	0.645

- B. Khamari and C. Patra (2018d) evaluated different plant oils, several locally available oil cakes, and manures at different concentrations *in vitro* using poison food technique against *Macrophomina phaseolina*. The results with oil were as follow.

S. no	Treatments	Mean mycelia inhibition		
		2% conc	3% conc	5% conc
1	Karanj oil	70.50 (57.08)	76.47 (61.50)	85.87 (67.95)
2	Neem oil	72.57 (58.39)	81.86 (64.87)	88.60 (70.28)
3	Eucalyptus oil	34.31 (34.9)	56.05 (48.45)	78.49 (62.34)
4	Clove oil	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)
5	Sesame oil	25.98 (30.58)	51.73 (45.97)	73.25 (58.84)
6	Olive oil	10.07 (18.33)	40.77 (39.66)	57.46 (49.27)
7	Mustard oil	71.82 (57.91)	77.94 (62.51)	87.47 (69.25)
8	Control	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
SE(m) ±		3.189	2.604	0.733
CD(0.01)		9.642	7.873	2.217

*Data in parenthesis represents transformed values

The results with cake and manures were as follow.

S. no	Treatments	Mean mycelia inhibition*		
		3% conc	4% conc	5% conc
1	Mustard cake	58.20(49.70)	68.89(56.07)	93.73(75.50)**
2	Neem cake	60.00(50.74)	76.57(61.02)	93.73(75.50)
3	Karanj cake	46.43(42.93)	63.65(59.90)	82.23(65.04)
4	Mahua cake	51.53 (45.86)	68.49(55.83)	87.13(68.95)
5	Sesame cake	46.43(42.93)	65.70(54.12)	83.71(66.16)
6	Poultry manure	43.49(41.24)	52.83(46.60)	72.78(58.53)
7	Goat manure	50.00(44.98)	60.00(50.74)	76.57(61.02)
8	Control	0.00(0.00)	0.00(0.00)	0.00(0.00)
SE(m)±		0.211	0.273	0.534
CD(0.01)		0.647	0.824	1.615

*Mean of 3 replications ** Data in the paraenthesis represents the transformed value

- B. Khamari et al. (2018e) collected 15 sesame seed samples from different localities of Odisha reported the infestation of *Macrophomina phaseolina* ranged from 0 to 1.5%.
- A.K. Satpathi and N.M. Gohel (2018) studied the influence of various meteorological factors viz. bright sunshine hours, wind speed, temperature, relative humidity and rainfall on the development of *Macrophomina phaseolina*. Sesame variety Gujarat Til 2 was sown on five different dates at seven days intervals from 07 July during Kharif 2016. The stem and root rot were more progressive during 37th and 39th standard meteorological week when the bright sunshine (8.7 and 9.1 hrs) and maximum temperature (34.5 and 33.3°C) increased, minimum temperature (24.9 and 24.2°C) and relative humidity decreased (90.7 and 93.6%), respectively and there was no rainfall as shown below.

Sr. No	Date of Observations	SMW	Disease incidence (%)*					BSS (hr)	WS (km/hr)	Rainfall (mm)	Atmospheric Temperature (°C)			Relative humidity (%)	
			D_1	D_2	D_3	D_4	D_5				Max.	Min.	Mean	Rh_1	Rh_2
1	7th Jul. 2016	27th	0	-	-	-	-	3.20	7.40	13.20	34.40	26.00	30.20	89.00	69.70
2	14th Jul. 2016	28th	0	0	-	-	-	2.40	6.10	30.40	33.40	26.20	29.80	91.10	71.40
3	21st Jul. 2016	29th	0	0	0	-	-	2.30	6.10	17.80	32.20	25.60	28.90	88.10	74.30
4	28th Jul. 2016	30th	0	0	0	0	-	2.30	4.80	19.20	33.50	25.60	29.55	91.40	72.10
5	04th Aug. 2016	31st	0	0	0	0	0	1.80	5.70	73.20	31.50	25.20	28.35	97.40	79.40
6	11th Aug. 2016	32th	0	0	0	0	0	1.0	6.00	96.80	30.00	24.50	27.25	95.60	85.00
7	18th Aug. 2016	33th	0	0	0	0	0	5.60	6.40	2.80	32.50	24.70	28.60	92.10	66.10
8	25th Aug. 2016	34th	0.41	0	0	0	0	1.10	5.50	49.60	29.50	24.90	27.20	94.70	90.10
9	01st Sept. 2016	35th	4.58	1.66	0.83	0	0	2.70	4.30	19.60	31.70	25.40	28.55	97.40	77.70
10	08th Sept. 2016	36th	10.41	6.25	4.58	0.41	0	8.80	5.80	8.20	32.40	23.70	28.05	94.60	60.40
11	15th Sept. 2016	37th	22.50	15.41	12.08	2.50	2.08	8.70	4.40	0.00	34.50	24.90	29.70	90.70	54.10
12	22nd Sept. 2016	38th	26.66	18.33	15.41	5.00	4.16	4.10	4.00	159.60	32.30	23.70	28.00	93.60	76.90
13	29th Sept. 2016	39th	38.75	28.75	24.58	10.83	9.58	9.10	5.70	0.00	33.30	24.20	28.75	93.60	64.90
Yield (kg/ha)			651	702	553	482	433								

*Mean of four replications, Rh_1-Relative humidity (Morning), Rh_2- Relative humidity (Evening)
SMW = Standard Meteorological Week, BSS = Bright sunshine hour, WS = Wind Speed

- B. Khamari and S.K. Hasmi (2019a) reported stem and root rot is a destructive disease of sesame which cause huge economic yield loss and brought on by *Macrophomina phaseolina* (a soilborne as well as seedborne pathogen with heterogenous host specificity). It affects all the stages and all the parts of the plant. At initial stage, pre emergence and post emergence damping off symptoms are very common. Appearance of water soaked lesion on the stem is the first symptom in the standing crop which spread in both the direction and attacks both the foliar parts as well as roots. The plant become black in color, dry up and finally wilts. The capsules are poorly developed containing poor quality seeds with no market value. Hence, the production of the crop decreases drastically. High temperature, less rainfall, poor or less fertile and light texture soil is favorable for the disease. Several bio control agents like Trichoderma, Pseudomonas, Bacillus are commonly used bio control agents as seed treatment as well as soil application. As this a soilborne disease application of organic products like oil cakes, farm yard manure, mycorrhiza as well as vermicompost in soil is also an effective way of management.
- B. Khamari et al. (2019b) evaluated the impact of *Macrophomina phaseolina* inoculum load as well as duration of exposure to the pathogen on disease incidence. The effects of g/kg of the pathogen were as follow.

Treatments (g/kg)	Germination (%)	% reduction over control	Seed rot (%)	Seedling mortality (%)	Survival (%)	% reduction over control
2	27.5 (31.38)	65.62	72.5 (58.58)	20.0 (25.65)	7.5 (13.82)*	90.62
5	25.0 (29.72)	68.75	75.0 (60.24)	20.0 (26.55)	5.0 (6.64)	93.75
8	17.5 (21.20)	78.12	82.5 (68.76)	15.0 (16.59)	2.5 (4.61)	96.87
10	12.5 (17.88)	84.37	87.5 (72.08)	12.5 (17.88)	0.0 (0.00)	100
Control	80 (63.78)	-	20 (26.18)	0 (0.00)	80 (63.78)	-
SE(m)± CD(0.05)	5.094 15.493		5.098 15.508	5.570 16.944	4.374 13.304	

*Data in the parenthesis indicates the transformed values

The effects of time of seen soaking were as follow.

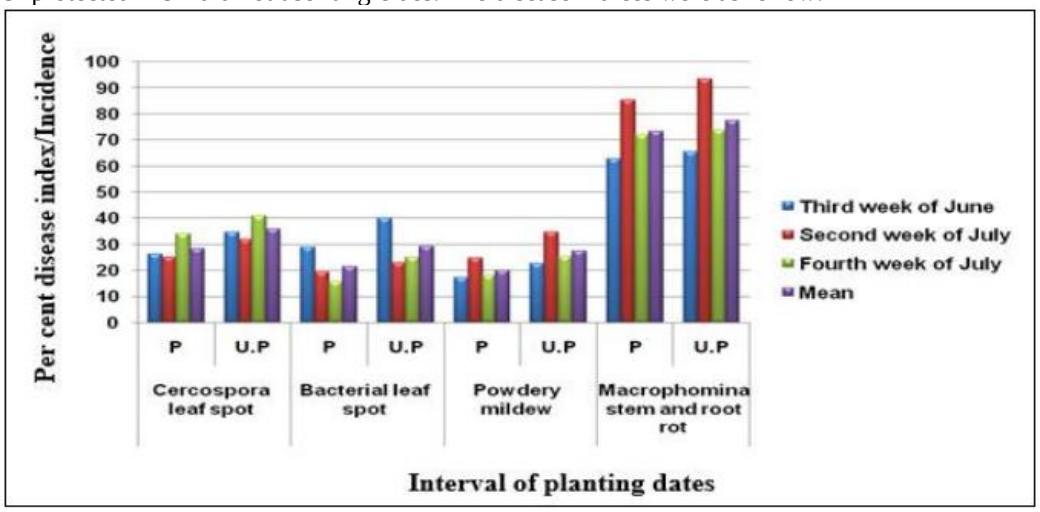
Sl no	Time of seed soaking (hr)	Germination (%)	Diseased seed (%)	Seedling length (cm)	Vigour index
1	Control	81.0	2.0	6.2	504.2
2	4	11.0	86.0	5.9	64.0
3	8	10.0	85.0	5.6	53.9
4	12	8.0	88.0	5.0	41.5
5	16	8.0	90.5	4.8	38.9
6	20	6.0	94.0	4.0	23.6
7	24	5.0	95.0	3.8	18.6
SE(m)± CD(0.01)		1.874 5.547	2.246 6.650	0.344 1.017	21.118 62.526

- T.K. Babu et al. (2020) evaluated the use of *Trichoderma viride* and *Pseudomonas fluorescens* in combination with neem to control *Macrophomina phaseolina* with the following results.

Treatment	Pooled data (*Kharif*, 2014, 2015 and 2015)			Pooled (Summer, 2015 and 2018)	
	Root Rot (%)	Phyllody %)	Yield (kg/ha)	Root Rot (%)	Yield (Kg/ha)
T1-Seed treatment *T. viride* @ 4 g/kg + soil application of *Tv* @ 2.5 kg/ha enriched in 100 kg of FYM at sowing.	18.5 (25.1)	21.3 (26.8)	231	11.9 (19.6)	664
T2-Seed treatment *P. flourescens* @ 10 g/kg + Soil application of Pf @ 2.5 kg/ha enriched in 100 kg of FYM at sowing.	24.0 (28.8)	22.4 (27.7)	204	12.9 (19.9)	654
T3-Seed treatment *T. viride* @ 4 g/kg + soil application of *Tv* @ 2.5 kg/ha enriched in 100 kg of FYM + neem cake @ 250 kg/ha at sowing.	23.1 (28.4)	25.0 (29.3)	226	6.8 (14.1)	611
T4-Seed treatment *P. fluorescens* @ 10 g/kg + soil application of Pf @ 2.5 kg/ha enriched in 100 kg of FYM + neem cake 250 kg/ha at sowing.	22.6 (27.6)	23.4 (28.3)	261	16.1 (23.4)	672
T5-Seed treatment Tv + Pf @ 10 g /kg + Soil application of Pf @ 2.5 kg/ha + Tv @ 2.5 kg/ha enriched in 100 kg of FYM + neem cake @ 250 kg/ha at sowing.	13.0 (20.9)	17.8 (24.7)	304	9.3 (15.8)	769
T6-Seed treatment Carbendazim @ 2 g/kg + soil drenching with Carbendazim @ 1 g/ l.	33.4 (35.1)	19.8 (25.9)	183	13.5 (21.2)	561
T7-Untreated check	41.7 (40.1)	27.8 (31.6)	127	27.7 (31.7)	473
S.Em ±	2.7	2.2	17.1	3.1	70.1
CV%	18.7	17.0	13.6	23.5	19.3
LSD (5%)	7.7	6.3	49.0	9.0	204

*mean of 3 repiications; figures in parenthesis are angular transformed values

- M.G. Palakshappa et al. (2020b) evaluated the date of planting (3rd week of June, 2nd week of July, and 4th week of July) on diseases from 2014 to 2017 at Dharwad, Karnataka (15.46N 75.01E). The main constraint for the low productivity of this crop is due to severe outbreak of various fungal stem and root rot of sesame (*Macrophomina phaseolina*), Alternaria leaf spot (*Alternaria sesami*), Powdery mildew (*Leveillula taurica*), Cercospora leaf spot (*Cercospora sesamicola*), Bacterial leaf spot (*Pseudomonas syringae* pv. *sesam*i), viral and phytoplasma diseases. The control (Protected – P) used fungicides viz., Carbendazim @ 0.1% and combi product (Tebuconazole 50% + Trifloxistrobin 25% WG) @ 0.05% were sprayed at 15 days intervals and the Unprotected – UP did not use fungicides. The disease indices were as follow.



The effects on yield were as follow.

Planting intervals	Yield q/ha								Mean yield q/ha	
	Kharif- 2014		*Kharif*- 2015		*Kharif* -2016		*Kharif*- 2017			
	P	UP	P	UP	P	UP	P	UP	P	UP
Third week of June	11.80	4.30	9.70	5.75	5.45	4.62	5.40	3.04	8.08	4.42
Second week of July	7.00	2.60	7.10	4.00	6.89	3.64	2.69	1.86	5.92	3.02
Fourth week of July	4.10	1.30	4.40	3.35	1.12	0.47	1.92	0.62	2.88	1.44
Mean	7.63	2.73	7.06	5.03	4.48	3.57	3.33	1.84	5.62	3.29

Third week of June sowing | Second week of July sowing | Fourth week of July sowing

- P. Renganathan et al. (2020a) examined the *in vitro* effect of extracts of locally available different organic oil cake extracts (neem, groundnut, gingelly, mahua, and coconut) at different concentrations (10, 20, 30 , 40, and 50%) on the mycelial growth and mycelial dry weight of *Macrophomina phaseolina* (Tassi) Goid. The results for the mycelial growth were as follow.

S.No	Source	Mycelial growth (mm) of *M. phaseolina*					Per cent inhibition				
		Concentration (%)					Concentration (%)				
		10	20	30	40	50	10	20	30	40	50
1	Mahua cake	60.24	32.12	24.15	19.35	15.70	33.06	64.31	73.16	78.50	82.55
2	Sesame cake	86.00	79.64	64.19	60.32	46.59	04.44	79.64	28.67	32.97	48.23
3	Groundnut cake	85.74	75.52	63.17	54.93	42.67	04.73	75.52	29.81	38.96	52.58
4	Neem cake	72.51	52.00	47.32	39.17	27.56	19.43	52.00	47.42	56.47	69.37
5	Coconut cake	87.23	82.52	74.28	63.45	49.86	03.07	82.52	2.270	29.50	44.60
6	Control	90.00	90.00	90.00	90.00	90.00	-	-	-	-	-
	S. Ed	0.68	1.12	0.12	0.51	0.43	-	-	-	-	-
	CD (p=0.05)	1.45	2.54	0.25	1.10	0.98	-	-	-	-	-

The results of the mycelial weight were as follow.

S.No	Source	Mycelial dry weight (mg) of *M. phaseolina*					Per cent inhibition over control				
		Concentration (%)									
		10	20	30	40	50	10	20	30	40	50
1	Mahua cake	100.00	93.65	79.28	61.27	50.36	67.77	69.82	74.45	80.25	83.77
2	Sesame cake	206.17	198.52	191.06	183.67	169.90	33.57	36.03	38.44	40.82	45.25
3	Groundnut cake	192.75	174.36	160.21	168.35	120.59	37.89	43.82	41.69	45.76	61.14
4	Neem cake	169.85	154.52	136.27	123.97	97.80	45.27	50.21	48.31	60.05	68.48
5	Coconut cake	280.16	210.46	204.82	200.64	184.95	9.73	32.18	34.00	35.35	72.62
6	Control	310.36	-	-	-	-	-	-	-	-	-
	S. Ed	0.51	1.01	0.74	0.97	0.85	-	-	-	-	-
	CD (p=0.05)	1.21	2.09	1.76	1.99	1.78	-	-	-	-	-

The results of present study suggest that among the organic amendments mahua oil cake effectively managed the *M. phaseolina* induced charcoal root rot disease.

- P. Renganathan et al. (2020b) reported *Macrophomina phaseolina* attacks at different stages of plant growth and causes complex disease syndromes like root rot, seedling blight, charcoal rot, ashy stem blight, wilt, collar rot, dry rot, capsule rot, and seed rot. The fungus is not only soilborne, but also seedborne and infects plants from seedling to maturity. The inhibition of seed germination is brought about by Phaseolinone, a metabolite isolated from the culture filtrate. The diseases plants showed yellow to brown concentric spots on leaves, stem, and capsules. Infection was also noticed in capsule inner wall, septum, and placenta of the seed. The stem near the soil level showed discoloration and shedding of the bark. Premature opening of capsules and discolorations of the seeds were other symptoms. The production of hydrolytic enzymes have been reported to play a crucial role in the development of the disease. Phaseoline appears to be the most important of the toxins that include aspirin, phomalactone, phaseolinic acid, and phenomenon. The pathogen is both externally and internally seedborne. The hyphae were inter and intracellular in the tissues of the seed coat, endosperm and embryo. It has been reported that the dry rainfed conditions favored higher root rot. The disease incidence was greater in sandy loam as compared to clay loam.

  Many *Trichoderma* species are regarded as growth promoters by increasing fresh weight, height, and flowering while inhitbiting pathogen growth. *T. viride* and *T. harzianum* inhibited the growth and caused sclerotial lysis of

M. phaseolina in vitro. *Pseudomonas fluorescens* was also effective using various modes of action especially rhizosphere colonization, antibiotic production, and induction of systemic resistance.

- K. Vinothini et al. (2020a) collected samples of *Macrophomina phaseolina* in 15 locations in Tamil Nadu. The amount of incidence in the fields ranged from 17.2 to 32.6%. In general, the crop grown under rainfed conditions showed more root rot incidence when compared with the crops grown under irrigated conditions. In respect of soil type, sandy soil had more root rot incidence than clay and clay loam soil.

S. No.	Isolates	Village	Soil type	District	Situation	Variety	Root rot incidence (%)
1	MP_1	Andiyur	Red sandy loam	Krishnagiri	Irrigated	TMV 4	18.70 (25.62)
2	MP_2	Maganoorpatti	Sandy loam	Krishnagiri	Rainfed	TMV 3	32.57(34.79)
3	MP_3	Mathur	Sandy loam	Krishnagiri	Irrigated	Local	29.90(33.14)
4	MP_4	Pochampalli	Clay loam	Krishnagiri	Rainfed	Local	24.40(29.60)
5	MP_5	Harur	Clay	Krishnagiri	Irrigated	Local	17.20(24.50)
6	MP_6	Eggoor	Sandy loam	Krishnagiri	Rainfed	TMV 3	36.25(37.01)
7	MP_7	Singarapettai	Clay loam	Krishnagiri	Irrigated	Local	28.82(32.46)
8	MP_8	Karapattu	Sandy loam	Krishnagiri	Rainfed	TMV 4	20.50(26.92)
9	MP_9	Vadakkumangudi	Clay	Cuddalore	Rainfed	Local	27.25(31.46)
10	MP_{10}	Sivapuri	Clay loam	Cuddalore	Rainfed	TMV 4	17.90(25.02)
11	MP_{11}	Annuvampattu	Clay loam	Cuddalore	Rainfed	Local	23.65(29.09)
12	MP_{12}	Theithampalayam	Sandy loam	Cuddalore	Rainfed	Local	25.80(30.52)
13	MP_{13}	Pudhuchathiram	Sandy loam	Cuddalore	Rainfed	TMV 3	31.45(34.11)
14	MP_{14}	Koththa	Clay loam	Cuddalore	Irrigated	Local	19.30(26.06)
15	MP_{15}	Periyapattu	Sandy loam	Cuddalore	Rainfed	TMV 4	22.98(28.64)

The isolates collected from different locations showed varied levels of pathogenicity in pot experiments as follow.

SI. No	Isolates	Root rot incidence (%)				Mean
		45 DAS	60 DAS	75 DAS	At harvest	
1	MP_1	14.98 (22.77)	25.47 (30.30)	35.79 (36.74)	52.45 (46.40)	32.17
2	MP_2	29.79 (33.07)	46.96 (43.25)	57.69 (49.42)	75.93 (60.61)	52.59
3	MP_3	25.60 (30.39)	36.25 (37.01)	49.52 (44.72)	67.75 (55.39)	44.65
4	MP_4	21.04(27.30)	30.64 (33.60)	45.46 (42.39)	62.93 (52.49)	40.04
5	MP_5	14.35 (22.26)	25.29 (30.19)	34.92 (36.22)	48.30 (44.02)	30.71
6	MP_6	32.45 (34.72)	49.96 ()44.97	65.69 (54.14)	79.93 (63.38)	57.07
7	MP_7	27.79 (31.81)	43.28 (41.13)	55.69 (48.26)	67.24 (55.08)	50.17
8	MP_8	17.72 (24.89)	29.07 (32.62)	40.09 (39.28)	60.04 (50.79)	36.73
9	MP_9	23.00 (28.65)	34.53 (35.98)	49.35 (44.62)	64.82 (53.62)	43.65
10	MP_{10}	15.17 (22.92)	26.52 (30.99)	39.25 (38.79)	49.82 (44.89)	33.50
11	MP_{11}	20.15 (26.67)	32.78 (34.92)	45.87 (42.63)	61.83(50.79)	40.43
12	MP_{12}	22.60 (28.38)	35.06 (36.30)	47.60 (43.62)	63.05 (52.56)	42.52
13	MP_{13}	26.21 (30.79)	37.28 (37.63)	50.82 (45.46)	73.93(59.29)	45.66
14	MP_{14}	16.36 (23.85)	27.27 (31.48)	39.72 (39.06)	53.07 (46.76)	33.95
15	MP_{15}	18.52 (25.48)	31.20 (33.95)	42.02 (40.40)	61.05 (51.38)	38.20

All the fifteen isolates of the root rot pathogen showed variations with regard to mycelia growth, number of sclerotia, and sclerotial size.

S. No.	Isolates	Mycelial character	Mycelial growth(mm)	No. of. Sclerotia	Sclerotial size (µ)
1	MP_1	Blackish grey, profuse aerial growth	76.46	168.26	91.90
2	MP_2	Deep black, fluffy growth	90.00	184.34	102.27
3	MP_3	Greyish white, fluffy growth	86.57	180.25	100.32
4	MP_4	Blackish grey, profuse aerial growth	81.45	177.36	97.52
5	MP_5	Greyish white, flat growth	73.95	165.20	90.50
6	MP_6	Blackish grey, flat aerial growth	90.00	186.50	105.75
7	MP_7	Greyish white, fluffy growth	85.83	179.31	99.65
8	MP_8	Blackish grey, slightly fluffy growth	78.43	169.72	93.41
9	MP_9	Black profuse, aerial growth	84.70	178.62	98.90
10	MP_{10}	Greyish white, flat growth	74.86	167.75	91.34
11	MP_{11}	Blackish scanty, aerial growth	81.30	176.09	95.23
12	MP_{12}	Deep black, flat growth	82.25	178.20	98.10
13	MP_{13}	Blackish grey, profuse aerial growth	87.82	183.72	101.20
14	MP_{14}	Medium black, flat growth	77.85	168.53	92.50
15	MP_{15}	Blackish grey, flat growth	80.47	176.10	94.65

- K. Vinothini et al. (2020b) evaluated 5 native *Trichoderma viride* (Tv) and *Pseudomonas fluorescens* (Pf) antagonists isolated from healthy sesame rhizosphere soil in different regions for their ability to reduce the growth of *Macrophomina phaseolina* as well as sclerotial germination. The results with the dual culture technique were as follow.

S. No.	Isolates	*T. viride*(Tv_3) Mycelial growth of *M. phaseolina* (mm)	*T. viride*(Tv_3) Percent inhibition over control	Isolates	*P. fluorescens* (Pf_5) Mycelial growth of *M. Phaseolina* (mm)	*P. fluorescens* (Pf_5) Per cent inhibition over control	*P. fluorescens* (Pf_5) Inhibition zone (mm)
1	Tv_1	20.53	77.18	Pf_1	27.33	69.63	7.53
2	Tv_2	30.56	65.93	Pf_2	28.19	68.67	6.75
3	Tv_3	18.69	79.23	Pf_3	24.38	72.91	9.26
4	Tv_4	35.42	60.64	Pf_4	26.40	70.66	8.42
5	Tv_5	23.56	73.82	Pf_5	22.30	75.22	10.04
6	Control	90.00	—	Control	90.00	-	-
	S. Ed	0.51		S. Ed	0.13		
	CD (p=0.05)	1.21	—	CD (p=0.05)	0.28	—	—

The results with the poison food technique were as follow.

S. No.	Concentration of cultural filtrates	*T. viride* (Tv_3) Mycelial growth (mm)	*T. viride* (Tv_3) Percent inhibition over control	*T. viride* (Tv_3) Mycelial dry weight (mg)	*T. viride* (Tv_3) Percent inhibition over control	*P. fluorescens* (Pf_5) Mycelial growth (mm)	*P. fluorescens* (Pf_5) Percent inhibition over control	*P. fluorescens* (Pf_5) Mycelial dry weight (mg)	*P. fluorescens* (Pf_5) Percent inhibition over control
1	10	24.33	72.96	200.86	36.10	29.57	65.84	176.96	43.50
2	20	19.46	78.37	120.95	61.52	17.39	75.23	154.92	50.54
3	30	10.13	88.74	49.93	84.12	12.64	80.37	57.65	81.60
4	40	NG	100.00	1.68	99.46	NG	100.00	1.32	99.57
5	50	NG	100.00	1.25	99.60	NG	100.00	1.05	99.67
6	Control	90.00	-	314.34	-	90.00	—	313.25	—
	S. Ed	0.54		0.98		0.49		0.52	
	CD (p=0.05)	1.96	—	2.13	—	1.11	—	1.45	—

NG-Nil Growth

The effects on number, size and sclerotial germination were as follow.

S. No.	Isolates	No. of. Sclerotia	Per cent inhibition	Sclerotial size (m)	Per cent reduction	Sclerotial germination(%)	Per cent inhibition	No. of. Germ tube per Sclerotium^{-1}	Percent reduction
1	Tv_1	94.90	44.13	75.11	37.50	49.46(44.69)	45.73	7.05	49.17
2	Tv_2	105.73	37.75	88.32	26.51	64.85(53.63)	30.22	9.39	32.29
3	Tv_3	74.21	56.31	70.24	41.55	42.62(40.75)	54.14	4.92	64.52
4	Tv_4	134.92	20.56	102.13	15.01	68.78(56.03)	25.99	10.03	27.68
5	Tv_5	102.02	39.93	85.79	28.92	56.09(48.49)	39.64	6.85	50.61
6	Control	169.86	-	120.18	-	92.94(74.59)	-	13.87	-
	S. Ed	0.42		0.62		0.45		0.12	
	CD (p=0.05)	1.091	—	1.65	—	0.99	—	0.28	—

S. No.	Isolates	No. of. Sclerotia	Percent inhibition	Sclerotial size (m)	Percent reduction	Sclerotial germination(%)	Percent inhibition	No. of. Germ tube per sclerotium^{-1}	Percent reduction
1	Pf_1	80.33	49.55	77.46	28.91	51.03 (45.59)	43.79	10.14	37.62
2	Pf_2	84.25	47.09	79.74	26.85	54.86 (47.78)	39.61	12.94	20.32
3	Pf_3	72.91	52.33	70.06	35.70	45.02 (42.14)	50.44	7.01	56.83
4	Pf_4	81.25	48.97	78.95	27.54	51.96 (46.12)	42.80	9.94	38.79
5	Pf_5	64.78	59.65	63.91	41.35	39.63 (39.01)	56.37	5.09	68.65
6	Control	159.25	-	108.97	-	90.85 (72.39)	-	16.24	-
S. Ed				0.12		0.11		0.13	
CD (p=0.05)		0.150.45	—	0.26	—	0.23	—	0.28	—

- T. Ezhilarasi et al. (2021) reported *Macrophomina phaseolina* (Tassi) Goidanich causes root rot disease in sesame. S.C. Vyas (1981) reported it is very serious and destructive pathogen in all sesame growing areas and causes 5-100% yield loss. Thus, the new variety VIR 3 (VS 07 023) was screened and compared to the current varieties and proved to be moderately resistant as shown below with a mean of 15% infection.

S. No	Entries	*Rabi* 2013-14	Summer 2013-14	*Rabi* 2014-15	Summer 2015-15	Mean
1	VS 07 023	14	15	16	15	**15**
2	SVPR 1	18	20	22	20	**20**
3	TMV (SV) 7	24	22	20	22	**22**

- P. Mahalakshmi and P.A. Devi (2021) Studied the effects of biological controls (*Trichoderma viride* and *Pseudomonas fluorescens*) and a fungicide (Carbendazim) on *Macrophomina phaseolina* in 2016 and 2017 at Vridhachalam ,Tamil Nadu (11.56N 79.33E). The results for 2016 were as follow (ST = seed treatment, SA = soil application).

Module No	Treatments	Disease incidence (%)	Yield (Kg /ha)	C:B ratio
M_1	ST with *T. viride* + SA of *T. viride* 2.5 Kg /*ha* enriched in 100 Kg FYM	28.80 (32.45)	578	1.29
M_2	ST with *P. fluorescens* +SA of *P. fluorescens* 2.5 Kg /*ha* enriched in 100 Kg FYM	25.15 (30.10)	561	1.48
M_3	ST with *T. viride* + SA of *T. viride* 2.5 Kg /*ha* enriched in 100 Kg FYM +Neem cake@250Kg/ha	18.56 (25.51)	621	2.00
M_4	ST with *P. fluorescens* +SA of *P. fluorescens* 2.5 Kg /*ha* enriched in 100 Kg FYM+ Neem cake@250Kg/ha	22.21 (28.11)	615	1.68
M_5	ST *T. viride*+ *P. fluorescens*+ SA of *T. viride*+ SA of *P. fluorescens* enriched in 100 Kg FYM +Neem cake@250Kg/ha	14.75 (22.58)	648	2.60
M_6	ST Carbendazim 2g/Kg +Soil drenching with Carbendazim 1g/l	14.32 (22.23)	651	2.62
M_7	Untreated check	37.21 (37.59)	454	
S.Ed		0.56	7.98	
CD(*P*=0.05)		1.11	17.40	

The results for 2017 were as follow.

Tr. No	Treatments	Root rot (%)	Yield (kg/ha)	C:B ratio
T_1	ST with *T. viride* + SA of *T. viride* 2.5 Kg /*ha* enriched in 100 Kg FYM	22.64 (28.41)	635	1.46
T_2	ST with *P. fluorescens* +SA of *P. fluorescens* 2.5 Kg /*ha* enriched in 100 Kg FYM	27.36 (31.53)	625	1.44
T_3	ST with *T. viride* + SA of *T. viride* 2.5 Kg /*ha* enriched in 100 Kg FYM +Neem cake@250Kg/ha	17.28 (24.56)	610	1.41
T_4	ST with *P. fluorescens* +SA of *P. fluorescens* 2.5 Kg /*ha* enriched in 100 Kg FYM+ Neem cake@250Kg/ha	23.71 (29.13)	595	1.37
T_5	ST *T. viride*+ *P. fluorescens*+ SA of *T. viride*+ SA of *P. fluorescens* enriched in 100 Kg FYM +Neem cake@250Kg/ha	11.15 (19.50)	651	1.5
T_6	ST Carbendazim 2g/Kg +Soil drenching with Carbendazim 1g/l	11.03 (19.39)	659	1.52
T_7	Untreated check	37.45 (37.73)	432	
SEd		1.31	2.92	
CD(P=0.05)		2.86	6.36	

- Anon. (n.d.k) reported *Macrophomina phaseolina* (Sclerotial stage: *Rhizoctonia bataticola*) (Root rot or stem rot or charcoal rot) causes a major disease.

IRAN

- M. Gooya et al. (2000) reported during 1997/99 one seed samples of each 17 sesame cultivars from 10 locations resulted in 145 isolates, which included 34 species of 15 genera. The identified *Tiarosporella phaseolina*.

IRAQ

- H.Y. Al-Ani et al. (1970) reported *Sclerotium bataticola* (*Macrophomina phaseoli*) causes serious infection of sesame at all stages of growth. None of the 22 vars. tested was resistant. Temperatures of 30-3S°C favored fungal growth.
- K.K. Al-Hassan et al. (1973) reported all 22 vars. tested were susceptible to *Sclerotium bataticola* (*Macrophomina phaseoli*). American 48, American 71, and Giza 24 showed relatively high tolerance when inoculated in May but little tolerance when inoculated in June.
- W.S. El-Shamma (1976) reported natural infection (by *Macrophomina phaseolina*) on local vars. in Iraq was studied in 1968-69. Red sesame had the highest yield and the lowest percentage of infection at all 3 seeding dates. For all vars. there was a significant negative correlation between seed yield and percentage of infection.
- Y.A. Abdou et al. (1980a) reported *Macrophomina phaseoli* is a destructive pathogen of sesame, causing typical wilt with dry root rot associated with discoloration of infected tissues due to sclerotial formation. Seeds of infected plants carry the fungus on and inside the testa as sclerotia and stromatic mycelium. Infected and healthy seeds were indistinguishable. Normal germination occurred at first in infected seed, but seedling deterioration followed and pycnidia were abundant. [Cited by G.S. Saharan, 1989]
- Y.A. Abdou et al. (1980b) reported *Macrophomina phaseoli* sclerotia remained dormant in soil treated only with distilled water in the absence of the host. Ihe presence of germinating sesame seeds and seedlings stimulated normal sclerotial germination and attraction of developing mycelium to host roots. Infection cushions and appressoria were also formed prior to infection. Remnants of PDA in soil stimulated limited sclerotial germination without subsequent development or infection. The results suggest that sclerotial germination and behavior depended on nutrients. [Cited by G.S. Saharan, 1989]
- K.M. Tamini and H.A. Hadwan (1985) reported the differences in the amount of inhibition of growth of a range of sesamum wilt causing fungi by gaseous metabolites from *Neurospora sitophila* and *Trichoderma harzianum* could be accounted for by differences in their ages. The highest level of growth inhibition from test fungi ever recorded was as follows: 3-day-old *N. sitophila* was 55% on virulent *Rhizoctonia solani*, 51% on a virulent *Rhizoctonia solani*, 48% on *Fusarium oxysporum* and 40% on *Macrophomina phaseoli*. *Other* soilborne fungi were less effective than *N. sitophila*. [Cited by G.S. Saharan, 1989]
- F. Al-Refaee (2005) collected sesame seeds from 6 regions of Iraq and isolated *Macrophomina phaseolina*.
- N.A. Ramadan (2009) reported The effect of the concentrations 0, 1, 2, 3, and 4 mg/ml of alcoholic extracts of cress seeds (*Lipidium sativum*) on the growth and dry weight of root–rot fungi of sesame plants, *Pythium aphanidermatum*, *Fusarium solani* and *Macrophomina phaseolina* indicated high significant inhibitory affect as compared to the control. *M. phaseolina* was mostly inhibited than other fungi when 4mg/ml w, 86.66 and 78.26% respectively. Antagonistic test of the bacterial biocontrol agent *Bacillus cereus* showed high inhibiting effect on all tested pathogens with the maximum inhibition 80.8% on *M. phaseolina*. Culture filtrate of *B. cereus* also showed a highly inhibiting efficiency to the growth and dry weight of the biomass of all pathogenic fungi with the increase of concentrations 10%, 20%, 30% and 40% (v l v) with the 40% was mostly effective on *M. phaseolina* by the ratio of 72.22% and 83.90%, respectively. The best inhibition was achieved with the use of combination of 4 mg/ml of alcoholic extract of Cress seeds and 40% of culture filtrate of *Bacillus cereus*. It showed synergistic inhibitory effect on all pathogenic fungi used, that exceeded the effect of each of the plant extract or culture filtrate of the bacteria separately. [Based on abstract]
- N.A. Saad et al. (2013) examined seed and found the following fungus: *Macrophomina phaseolina*.

ISRAEL

- I. Reichert (1930) reported *Rhizoctonia bataticola* has so far been isolated from 35 plants in Palestine, the greatest damage being caused to sesame. [Cited by G.S. Saharan, 1989]
- A. Meiri and Z. Solel (1963) reported experiments using commercial sesame var. Renner 15 demonstrated *Sclerotium bataticola* (*Macrophomina phaseoli*) to which this var. is very susceptible is seedborne and a high degree of seed infection may account for the poor field germination. [Cited by G.S. Saharan, 1989]
- M.M. Satour (1981) reported the presence of *Macrophomina phaseoli* (Black stalk, stem rot).

JAPAN

- M.M. Satour (1981) reported the presence of *Macrophomina phaseoli* (Black stalk, stem rot).

KENYA

- H.A. Van Rheenen (1981d) reported the goal of developing resistance to *Macrophomina phaseoli*.

MEXICO

- M.M. Satour (1981) reported the presence of *Macrophomina phaseoli* (Black stalk, stem rot).
- I.C. Joaquin Torres (1985) reported that *Macrophomina phaseoli* affects the Mexican crop and reduced yields.
- J.R. Penaloza and D.R. Moctezuma (~1992) in a grower guide reported: *Macrophomina phaseolina.*
- E.C. Hernandez (2003) in a grower guide reported the following pathogen: *Sclerotium bataticola* (Pudrición de carbón o marchitez). Symptoms are brown area in the stem from base to upper part. The foliage withers and the plant dies. Recommend rotation with crops not susceptible, regulation of water on the ground, and resistant or tolerant varieties.
- Anon. (2010a) in a grower guide reported the following main pathogen: *Macrophomina phaseolina.* Causal agent of charcoal rot with a wide host range that occurs in regions with climates varied from arid to tropical. In Mexico it has been observed that it causes significant damage, mainly in common beans, sesame, sorghum and soybeans. Attacks bean seedlings in dry conditions in pre and post-emergence or reduces adult plant vigor and seed yield.
- L.A. Moraila (2015) in a grower guide reported *Macrophomina phaseoli* (Stem rot) causes black rot on roots and stems. In early attacks it causes a delay in the development of the crop, and if the environmental conditions are favorable, the plant dies. The disease is difficult to control requiring resistant varieties.
- Agrolytics.org (2021) reported sesame hosts *Macrophomina phaseolina*.

MYANMAR

- W. Small (1927a) reported *Macrophomina phaseoli* caused a disease in sesame. [Cited by R.S. Vasudeva, 1961]
- Y.Y. Min and K. Toyota (2019) surveyed diseases in 10 farmer fields and interviewed 25 farmers. They reported the following pathogen: *Macrophomina phaseolina*. The disease incidence ranged from 10% to 30% and was reported in 80% of the fields. The yield losses ranged from 10 to 75%.

NICARAGUA

- Anon. (1998b and 2009a) in grower guides reported Black foot (*Macrophomina phaseoli*). The base of the stem rots and turns black. The characteristic symptoms are black colorations at the base of the stem and root, which rot at the end of the disease cycle. As a result of the disease, the seedlings die. The adult plants wilt and have a premature death.
- Anon. (2008a) in a grower guide reported Black foot (*Macrophomina phaseoli*) was one of the major diseases. It is known as root and stem rot. It can appear in any stage of development, but primarily in drought. In the seedling stage, there is wilting, yellowing, and then death. During flowering through physiological maturity, it manifests in the roots and then advances to the aerial portion and leads to flower loss. When it attacks the stem, it takes on a black color as far up as 20 cm leading to defoliation and damaged seed in the capsules. If there is a strong infestation, recommend a 2 year gap and sorghum should also not be planted since it can increase the pathogen. The main method of control is crop rotation, use of resistant varieties, and assured good drainage.

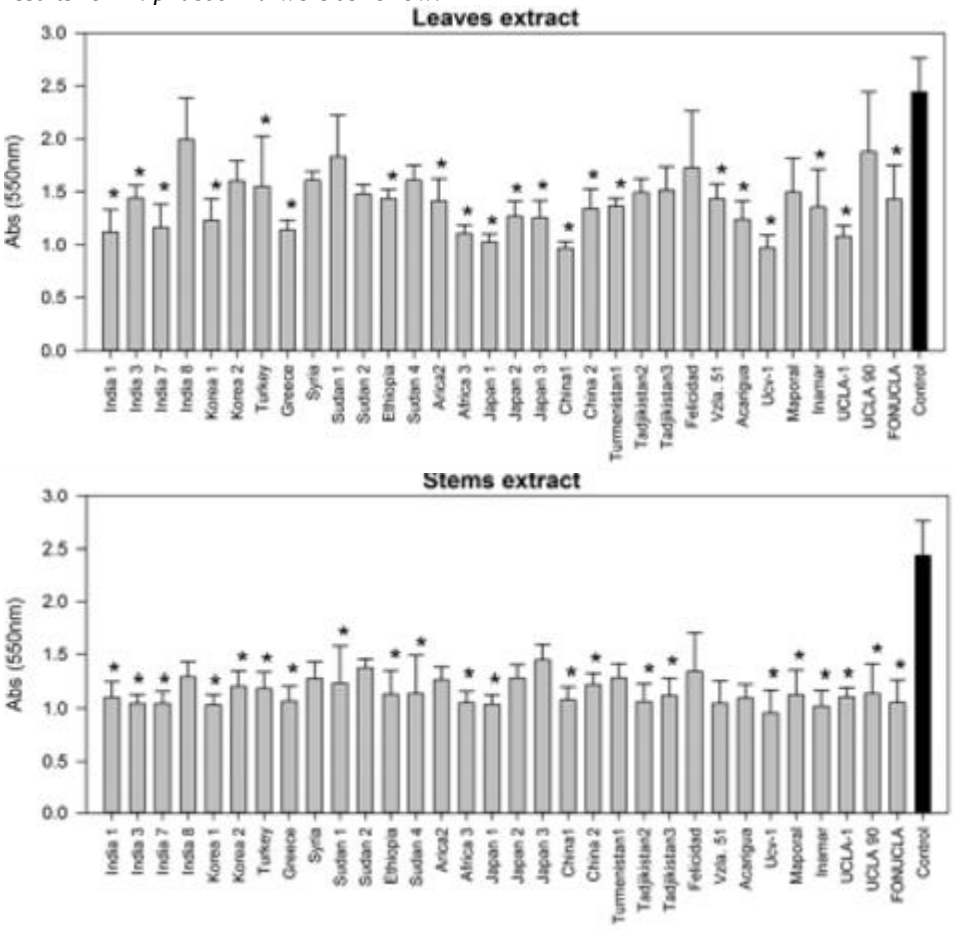
NIGERIA

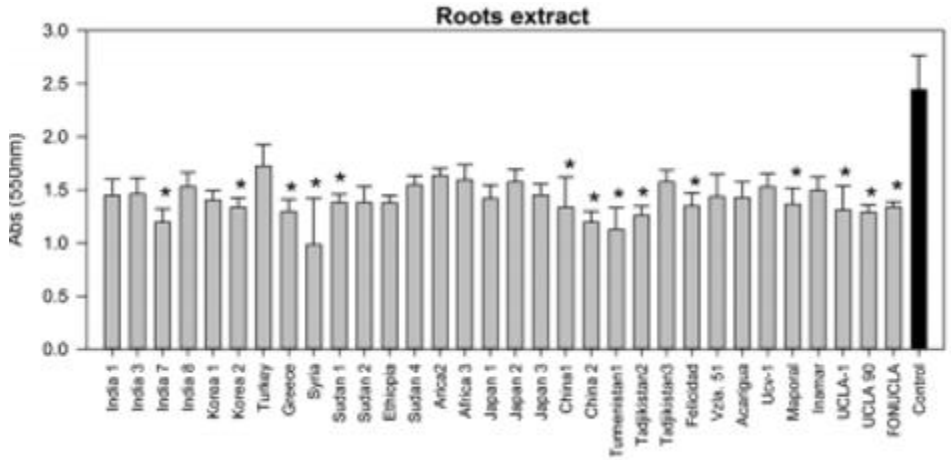
- D. McDonald (1964) reported *Macrophomina phaseoli*.
- H.A. Van Rheenen (1972) reported the following pathogen: *Macrophomina phaseoli.*
- M. Elaigwu et al. (2017) tested the *in vivo* effectiveness of the plant extracts (*Prosopis africana, Azadirachta indica, Eucalyptus globulus, Vitex doniana, Tridax procumbens, Mangifera indica, Eucalyptus camaldulensis, Ocimum gratissimum, Cymbopogon citratus, Morinda lucida, Jasminum dichotonum, Citrus aurantifolia, Carica papaya, Chromolaena odorata, Nauclea latifolia, Musa sapientum, Gmelina arborea, Daniella oliveri, Psidium guajawa, Lophira lanceolata, Bridelia ferruginae, Gardenia florida, Thevetia peruviana, Lawsonia inermis, Vernonia amygdalina, Amaranthus spinosus, Delonix regia, Annona senegalensis, Newbouldia laevis* and *Anacardium occidentale*) against *Macrophomina phaseolina* (Tassi) Goid using fresh and dried leaves. The present findings indicate that plant products, particularly extracts of fresh leaves of *Anacardium occidentale, Prosopis africana* and seed treatment with fresh extracts of *Prosopis africana* offer a potential and environmentally safe alternative for use as fungicides and could be exploited for effective management of root rot diseases of sesame caused by *Macrophomina phaseolina.*

PAKISTAN

- N. Prasad (1944) reported *Macrophomina phaseoli* caused a disease in sesame. [Cited by R.S. Vasudeva, 1961]

- N. Ali and A. Beg (1985) reported *Macrophomina phaseoli* (Root rot) is a common and destructive disease. They recommend planting disease resistant varieties, field sanitation (crop rotation and removal of all crop residues after the harvest) and early planting.
- M. Sharif (1985) reported *Macrophomina phaseoli* (Root and stem rot) is a major disease.
- A.S. Shakir and M. Ansar (1992) studied 25 samples of seed collected from various areas in Punjab and found the following fungus: *Macrophomina phaseolina.*
- D.A. Shambharkar et al. (1997) evaluated 30 genotypes from 9 countries for tolerance to *Alternaria sesami, Leveillula taurica, Macrophomina phaseolina,* and phyllody. The *Macrophomina phaseolina* incidence ranged from 0 to 16.5%. The genotypes SIK-113 and SIK-104 from Kenya exhibited better tolerance under high as well as low input conditions. Other good genotypes were Krishna, Padma, and Tapi. These genotypes should be used for breeding programs.
- K.P. Akhtar et al. (2011) subjugated a *Macrophomina phaseolina* sesame isolate to a growth rate test at 10, 15, 20, 25, 30, 35 and 40°C. The optimum temperature for fungal growth and microsclerotia production was found to be 30-35°C. *M. phaseolina* was found to be pathogenic against all the 18 tested plant species (sesame, sorghum, sunflower, maize, cotton, castor, wheat, lentil, mungbean, urdbean, chickpea, tomato, chili, tobacco, rice, ladyfinger, brassica and cucumber) and this pathogenicity proved its necrophytic behavior. Seed infection efficiency of *M. phaseolina* was 100% with significant reduction in seed index. They identified some sesame mutants with some tolerance to *M. phaseolina*.
- R.N. Syed et al. (2015) evaluated leaf, stem, and root extracts from 32 lines with the aim of identifying genotypes with high content of metabolites potentially involved in resistance against fungal pathogens. The extract of the leaves sprayed with $CuCl_2$ were the most inhibitory against *Macrophomina phaseolina*. The results for *M. phaseolina* were as follow.





- M.R. Bashir et al. (2017) evaluated new fungicides (Antracol, Topsin-M, Mancozeb, Score, Topas, Nativo) at various rates (150, 250, and 350 ppm) against *Macrophomina phaseolina* both *in vitro* and in the field. The *in vitro* results were as follow.

Treatments	Colony growth (cm)
Antracol	2.0444
Topsin-M	1.4222
Mancozeb	1.7778
Score	1.1444
Topass	2.3333
Nativo	0.9333
Control	6.5000
LSD	0.0304

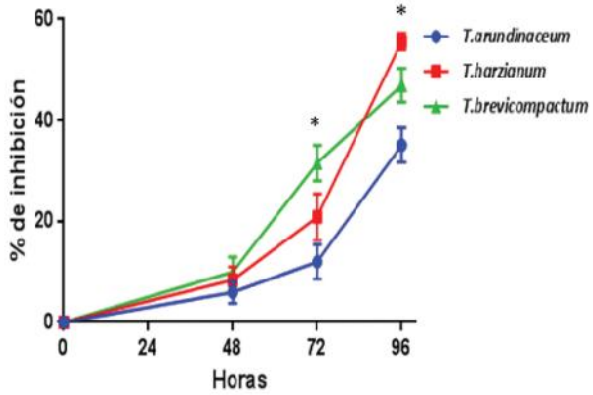
The field results in terms of disease incidence were as follow.

Treatments	**Mean DI (%)
Antracol	52.453C
Topsin-M	32.333E
Mancozeb	44.324D
Score	16.466F
Topass	62.393B
Nativo	12.557G
Control	77.217A

PARAGUAY

- L. Ayala et al. (2010, 2011, and 2013b) in grower guides reported one of the main pathogens is *Macrophomina phaseolina*. It forms highly branched primary and secondary mycelia, in addition to numerous black sclerotia found in necrotic tissues on stems and primary roots. The fungus attacks the plant in the base of the stem showing a dark color, which can move towards the aerial part of the plant, causing a withering and may die in short time. The optimum temperature of growth and formation of sclerotia is between 28 and 32°C. The fungus grows better and produces more sclerotia in conditions of continuous light than in the dark. It also causes damage from the seedling to the adult stage. The largest infestations have been observed more frequently in long periods of drought, as well as in late sowings that are subject to soil drought when the rains. Therefore, it is very important to establish the cultivation according to the recommended sowing dates. There is evidence the fungus can survive in soils between 3 months and 3 years in sclerotial form. Crop rotation with non-host crops such as maize, cotton, sorghum, sugarcane, or soybeans reduce the pathogen over 2 years.

- D.D. Ruiz et al. (2017) evaluated the effects of *Trichoderma arundinaceum, T. harzianum,* and *T. pseudokoningii* on *Macrophomina phaseolina*. The % inhibition across 96 hours is shown below.



REPUBLIC OF KOREA

- S.H. Yu and J.S. Park (1980) tested 12 samples of sesame seeds and found *Macrophomina phaseolina* on 7 of the samples. *M. phaseolina* caused heavy reduction in seed germination and seedling stand. It was also detected on over wintered plant debris and diseased seedlings in the field.
- S.H. Yu (1981) reported the following fungi in sesame seed samples *Alternaria sesami, Alternaria sesamicola, Alternaria tenuis* (*Alternaria alternata*), *Corynespora cassiicola, Alternaria longissima, Fusarium oxysporum,* and *Macrophomina phaseolina*. All were controlled by pre-treatment with chlorine, except for *Corynespora cassiicola*. [Based on abstract and cited by G.S. Saharan, 1989]

SRI LANKA

- W. Small (1927b) reported *Macrophomina phaseoli* caused a disease in sesame. [Cited by R.S. Vasudeva, 1961]

SUDAN

- M.A.F. Khamees and E. Schlosser (1990) reported testing of 165 Sudanese sesame seed samples showed that although seedborne pathogens such as *Alternaria sesamicola* and *Macrophomina phaseolina* were widespread in the country, their incidence was generally only at a low level. [Based on abstract]
- N.M.A. Hamid (2006) identified the following fungus from seed collected from 3 areas of Sudan: *Macrophomina phaseolina*.
- H.I.H. Idriss (2016) collected farmer saved red and white sesame from 7 locations in Sudan. 14 different fungi representing ten genera were identified. One of the predominant fungi was *Macrophomina phaseolina*.
- A.R.C. Umaima (pers. comm. 2021): *Macrophomina phaseolina and Rhizoctonia bataticola* (Root rot or Stem rot or Charcoal rot) is a current problem. The symptoms are yellowing of lower leaves, drooping and defoliation. The stem near the collar region shows dark brown lesions and bark shows shredding then sudden death of plants in patches.

SYRIA

- M. Al-Ahmad and A. Saidawi (1988) reported the first record of charcoal root rot of sesame in Syria in surveying 12 sites. Laboratory isolation revealed that *Macrophomina phaseolina* was the causal organism of root rot, stalk rot, blight, and wilt symptoms on infected plants. The pathogen was isolated from root bark and stem pith, sclerotia and rarely pycnidia were formed on these parts of infected plant. Local varieties showed a relatively low rate of susceptibility (12-24%), while most of the introduced ones were highly susceptible. *Macrophomina phaseolina* spreads by the movement of soil and crop debris and through the sesame seeds. The sesame seed has been found to carry the fungus on and inside the testa as sclerotia or as stromatic mycelium. Pathogenicity test proved that the pathogen induced typical symptoms to artificially infected plants. [Based on abstract and cited by C. Chattopadhyay et al., 2019]

TANZANIA

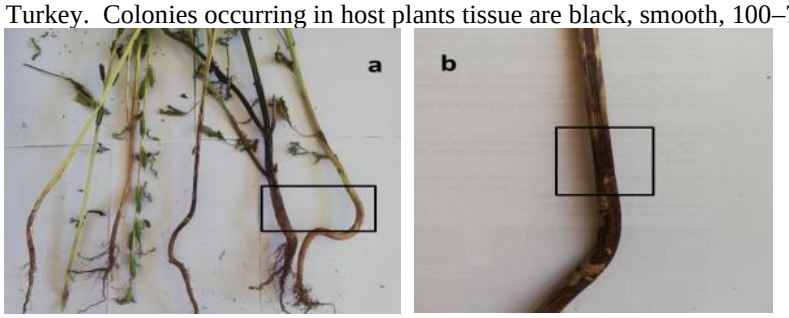
- Kafiriti, E. and O. Mponda (n.d.) in a grower guide reported the following pathogen: *Macrophomina phaseolina.*

THAILAND

- S. Maneekao et al. (1999b) screened 120 new and 33 existing cultivars against *Macrophomina phaseolina* and *Pseudomonas solanacearum*. They identified MR 13 (red seed) and MR 36 (Black seed) were more tolerant to the pathogens than the existing major cultivars (UB 1 and MK 60).
- N. Worasatit et al. (2003a) evaluated the resistance to *Macrophomina phaseolina* (Charcoal rot) using 90 genotypes in 1999 and 2000 at Ubon. Pots were grown in the greenhouse and inoculated 1 month after sowing. Sesame lines UCR 3 x No.585, Yuzhi No. 5, Sesamum 25 [DRL comment: Sesaco 25], Yori x No. 585, MKS-I-84001 x MKS-I-84013, No. 585 x MK60, and Yori x MK60 were considered resistant with the following percentages of infection: 19.0, 16.7, 19.2, 16.7, 13.4, 0, and 0, respectively.

TURKEY

- E. Bremer (1944) reported the sesame wilt presents a close parallel with that of tobacco both as regards symptomology, time of development, and the favoring influence of drought. Moreover, *Macrophomina phaseoli* and *Fusarium solani* were isolated from most of the specimens of diseased material, presumably in a secondary capacity since inoculation experiments were again unsuccessful. [Cited by G.S. Saharan, 1989]
- P. Sagir et al. (2010) studied the effect of sowing time and irrigation on yield, yield components and Charcoal rot disease (*Macrophomina phaseolina*). The average charcoal rot diseases percentage of sesame lines changed according to sowing time and irrigation conditions. The lowest disease percentage were recorded from B-60 line (40.6%), and the highest from C-36 line (%49.0). When all factors were evaluated, the lowest disease percentage were recorded from irrigated (27.6%) and late sowing time (34.7%), the highest from in dry condition (58.0%) and early sowing time (50.8%). [Based on abstract]
- F. Akdeniz and H. Sert (2019) reported *Macrophomina phaseolina* is one of the main disease of sesame in Turkey. Colonies occurring in host plants tissue are black, smooth, 100–750 µm diam.



- N. Isler et al. (n.d.) reported the following pathogens: *Macrophomina phaseolina* and *Rhizoctonia bataticola.* For control, use fungicides, plant in October, and have good drainage.

UGANDA

- S.F. Ashby (1927) reported as a result of careful morphological and cultural comparison of material, Macrophomina from a dry fruit of sesame from Uganda, is identical with sclerotial fungus, *Rhizoctonia bataticola*. He agrees with Petark's suggestion that pycnidial forms devoid of stroma and ·with long thin-walled elliptical spores that remain hyaline and continuous should be included is latter's qenus Macrophomina.
- J.D. Snowden (1927) reported a mildew (*Oidium* sp.) on sesame in same plot where the sclerotia and pycnidia of *Macrophomina corchon* (*Macrophomina phaseoli*) were found is thought to have made the leaves more susceptible to attack by the latter. [Cited by G.S. Saharan, 1989]
- C.G. Hansford (1931, 1938, 1939, 1940, and 1943) reported the following pathogen: *Rhizoctonia bataticola* (*Macrophomina phaseoli*). [Cited by G.S. Saharan, 1989]

UNITED STATES

- M.L. Kinman (1955) reported Charcoal rot (*Macrophomina phaseoli*) will cause a stem rot of sesame; this disease is favored by droughty conditions.
- M.M. Satour (1981) reported the presence of *Macrophomina phaseoli.*
- D.R. Langham et al. (2010c) reported sesame root rots (combination of *Fusarium oxysporum*, *Phytophthora parasitica*, and *Macrophomina phaseolina*) have been encountered mostly on fields where sesame is planted

after sesame. The current varieties are tolerant but not resistant to the root rots. The best way to avoid sesame root rot is to rotate different crops every summer.

- Anon. (2015c) USA PVP descriptor: 7. Diseases – Charcoal rot (*Macrophomina phaseoli).* The following ratings are used:
  - 0 = Not tested
  - 1 = Susceptible
  - 2 = Low resistance
  - 3 = Moderate resistance
  - 4 = High resistance
- D.R. Langham (2015b) USA patent descriptor: 37. Tolerance to Charcoal rot (*Macrophomina phaseoli*)
  - Definition: Amount of tolerance to Charcoal rot.
  - Values: Average of a minimum of three plots of a subjective rating based on the following values: 0 to 8 scale of the % of infected plants (Intermediate values are used).
    - 8 = Zero disease
    - 7 = <10% infected
    - 4 = 50% infected
    - 1 = >90% infected
    - 0 = all infected
    - Intermediate values may be used
    - NT = not tested
    - NEC = no economic damage - not enough insects to do ratings
  - Ratings can be done in several ways:
    - Take ratings after the disease is no longer increasing.
    - Take ratings on consecutive weeks until the disease is no longer increasing and average ratings.
    - Take periodic ratings and average ratings.
  - Comments:
    - *Macrophomina* has been a problem in Arizona and Texas, particularly on fields that go into a drought. Normally, only the Composite Kill Tolerance rating is taken.
    - There are three root diseases that affect sesame in Texas: *Fusarium oxysporum*, *Macrophomina phaseoli*, and *Phytophthora parasitica*. Between 1988 and the present, spores of these three have been accumulated in one small area (1 square km) north of Uvalde, and thus it is an excellent screening area for the diseases. Although each root rot disease attacks sesame in a different way and may result in different symptoms, no effort is made to definitively determine which disease is the etiological agent for the affected plants. Pathological screenings in the past have found all 3 pathogens present in dead plants.
    - The amount of kill is usually increased with any type of stress to the plants. Drought can increase the amount of *Macrophomina*; too much water can increase the amount of *Phytophthora*; high temperatures and humidity can increase the amount of *Fusarium* and *Phytophthora*. High population can increase all three diseases
- K.A. Cochran (2020) evaluated the tolerance of 50 varieties to *Macrophomina phaseolina.* Symptoms include stunting, defoliation, reduction in yield, and possibly plant death. In the southwest Texas area, production losses have been reported to be over 30% in severely affected fields. This pathogen is particularly difficult to manage due to its soilborne nature and longevity in the soil. Additionally, the often utilized cultural control method of supplemental irrigation is not always appropriate for drought tolerant crops such as sesame. Of the varieties analyzed, 9 had average stem symptom progression of less than 5% of the total stem length, while varieties thought to be relatively susceptible in other research efforts had symptom progression of over 60% of the stem length. [Based on abstract]
- D.R. Langham comments, 2021: My first encounter with *Macrophomina phaseolina* was in 1981 in Yuma, Arizona, when an irrigation ditch broke, and a 5 acre field could not be irrigated for several weeks. All of the plants died. The University of Arizona identified the pathogen. Other fields within 10 meters on two sides did not have any dead plants. When moving the nurseries to Texas in 1988, J.R. Mulkey of Texas A&M reported that in his nurseries, he isolated *Macrophomina phaseolina, Phytophthora nicotianae,* and *Fusarium oxysporum* in dead plants. He felt that probably only one of the pathogens had penetrated the plant defenses, but once that defensive line was broken, the others were able to enter the plant. He felt that *M. phaseolina* was the culprit when after starting with good moisture, a crop faced a drought. The symptoms appeared over several days. He felt that *P. parasitica* appeared after an overirrigation or a heavy rain that resulted in puddling. The initial

symptoms appeared overnight with a characteristic drooping of the top of the plant. The plant may or may partly recover. He did not have much experience with *F. oxysporum.*

Over the years, I have seen the same pattern for *M. phaseolina* in many commercial fields over thousands of hectares. In years when there is enough marginal moisture to geminate a crop, the plants will grow and produce a low yielding crop, but the plants will not die. However, when planting with a full moisture and fertility profile, if there is no rain (or irrigation), the plants will die from the disease. In another case, there was a year with no moisture in the soil when a 25 mm rain allowed planting 250 ha. The seedlings were healthy, but when the moisture evaporated, the plants died from the pathogen. In the Coastal Bend of Texas, there are very heavy soils that retain winter rains, resulting in a healthy crop, but then a high pressure system will prevent rain for as much as 6 weeks resulting in death from the pathogen. There are years when a grower will plant the dry corners of a circular pivot field because there have been good winter rains. If the soil moisture in the dry corners is marginal at planting, the crop will grow with a poor yield (will flower and mature earlier than the sesame under the pivot). However, if the soil moisture in the dry corners is very good at planting time, then the plants will die unless there is sufficient rain through the season. It is dramatic to see a circle of healthy plants with dead plants outside the circle dead. It is rarely a perfect circle because winds may carry irrigation water for some meters into the dry corner. The prevalent winds in Uvalde are from the southeast and so the northwest dry corner will have more live plants at harvest.

I maintained nurseries in Uvalde within 100 meters of each other for 26 years. I would rotate the field each 3 years in order to create tremendous populations of *M. phaseolina, P. nicotianae,* and *F. oxysporum.* I would plant 'canary lines' that were very susceptible to the diseases to make sure there was pathogen pressure each year. I would discard any lines that were susceptible with the exception of crosses between tolerant and susceptible lines to move desirable traits from the susceptible line to the tolerant line. In those cases, the disease would appear in the F_1, but would often segregate in the F_2 and later generations. By the time that a variety was ready to be released, it was considered tolerant to the 3 diseases. Although this proved true for *P. nicotianae,* and *F. oxysporum*, it was not true for *M. phaseoli*. In retrospect, it was probably because the nurseries had full irrigation for the entire season, and thus there was no *M. phaseolina* pressure. When the disease appeared in the Coastal Bend, I realized that I really did not know which lines were susceptible to *M. phaseolina*, and thus did not have 'canary lines.'

- K.A. Cochran comments, 2021: *M. phaseolina* is one of the most widespread and persistently problematic plant diseases that challenge sesame production. This is in part due to the fact that both sesame and this fungus thrive in hot and dry conditions. In my experience in the case of extreme cases located in the southwest Texas area, production losses have been reported to be over 30% in severely affected dryland fields. This pathogen is particularly difficult to manage due to its soilborne nature and longevity in the soil combined with a lack of effective and suitably labelled fungicides. Additionally, the often utilized cultural control method of supplemental irrigation is not always appropriate for drought tolerant crops such as sesame. Genetic tolerance or resistance would be incredibly useful, though resistance to this pathogen in crops is rare. Since *M. phaseolina* is endemic and has a very broad host range, repeated plantings of susceptible crops can lead to buildup of pathogen populations in fields, even if crops are rotated. I see this in many cases in the Uvalde region where sesame is produced. I have noted this pathogen is especially problematic in cotton-sesame rotated fields in arid production areas. This disease is mitigated using irrigation, but this is not always possible in dryland production. I suspect subsistence and small scale farmers in developing countries who may lack resources for supplemental irrigation might be especially vulnerable to crop losses from this disease. In such situations, genetic tolerance to this pathogen would be invaluable to meet the nutritional needs of the farmers and their communities.


Microsclerotia on stem in disease resistance assay


Microsclerotia on capsule

UNKNOWN

- A.A. Bayounis and M.A. Al-Sunaidi (2008a) showed the effect of some powder plant materials (*Azadarichta indica* seed, *Datura stramonium* seed, *Nerium oleander* leaves, *Eucalyptus camaldulensis* leaves) on the control of *Macrophomina phaseolina*. The powder plant material powder was used as 60, 40, 20g/kg of soil. Sesame seeds showed the highest germination rate in the soils treated with *A. indica* seeds powder. Germination rate in the soils treated with *A. indica* seeds powder reached about 69%, whereas germination rate for control was about 4%. The study has also indicated that the highest percentage of infected seeds under the soils treated with Eucalyptus leaves powder was 84.8%, while percentage infected seeds under *A. indica* treated soils was about 25%. All treatments with different concentrations of plant powder have shown inhibition effects on *Macrophomina phaseolina* growth. The highest percentage of inhibition was seen under the treatment with *A. indica* seed powder (73.9%) , whereas Eucalyptus leaves treatment powder was about 11.4%.

VENEZUELA

- B. Mazzani et al. (1975) reported a new Aceitera variety resistant to *Phytophthora nicotianae* var. *parasitica*, *Macrophomina phaseoli*, and *Fusarium oxysporum* f. sp. *sesami* was obtained by backcrossing with the African var. Ajioo Atar 55 resistant to *Phytophthora* and *Macrophomina*. The yield and vegetative characteristics of the new variety resemble those of the original Aceitera which is resistant to *Fusarium*.
- B. Mazzani et al. (1981b) reported the presence of *Macrophomina phaseoli* is a permanent threat in the sesame producing regions. All of the common cultivars were very sensitive to Black stalk, but the tolerance of several African varieties was incorporated into Aceitera.
- C. Zambrano and O. Tortolero (1985) conducted studies on 540 sesame cultivars, and isolations from seedling rot and soil and reported the following pathogen: *Macrophomina phaseoli. M. phaseoli* caused heavier infection than *Phytophtora hibernalis* during dry conditions.
- J.B. Pineda and J.M. Avila (1988a) evaluated the use of herbicides (Alachlor applied and not applied) and fungicides (Propineb [Antracol 70%], Dicarboximida [Captan], Iprodione [Rovral] and Carboxin [Vitavax]) to manage *Macrophomina phaseolina.* They reported high temperatures, associated with low soil moisture, double the severity of the disease; the maximum infection occurs when the soil is dry, affecting the crop, both in the seedling stage and when the plants are maturing; the disease becomes more severe in sandy soils due to their low water storage capacity. The results were as follow.

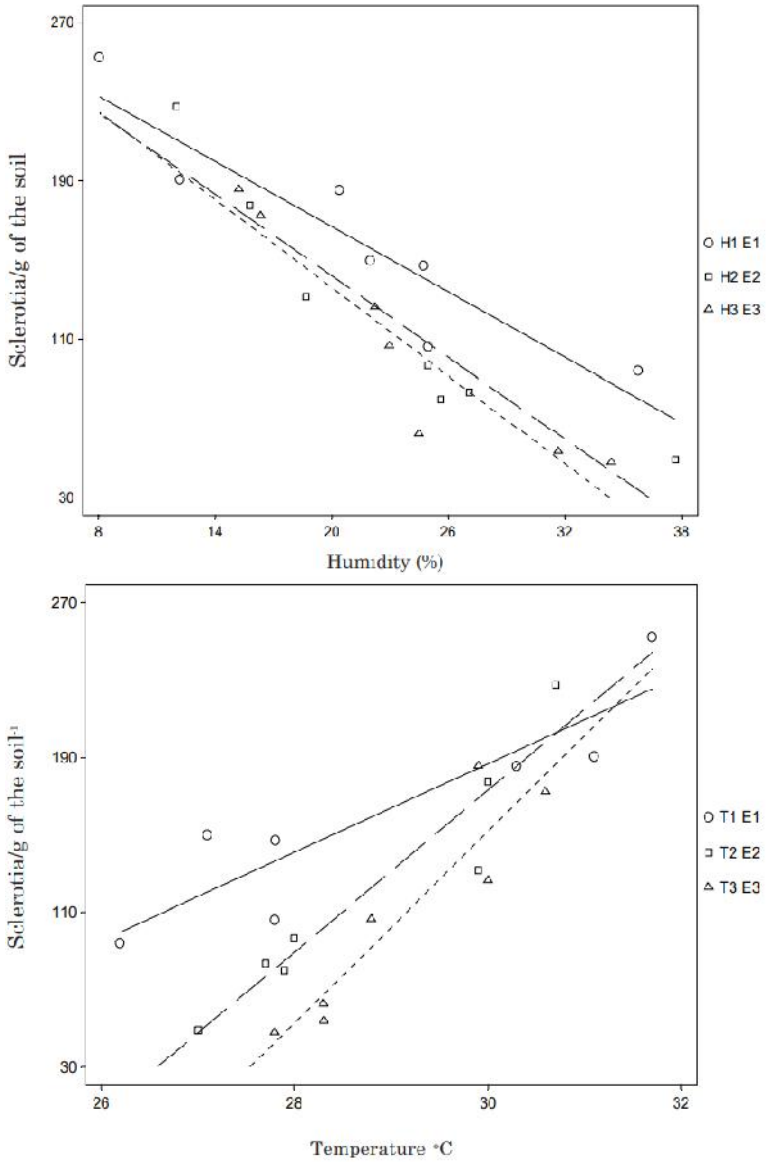
Treatment	**Yield (kg/ha)**
Antracol + Alachor	1,031
Antracol	964
Captan	927
Rovral	905
Control + Alachor	871
Control	855
Captan + Alachor	845
Rovral + Alachor	782
Vitavax	671

Treatment	Yield (kg/ha)
Vitavax + Alachor	654

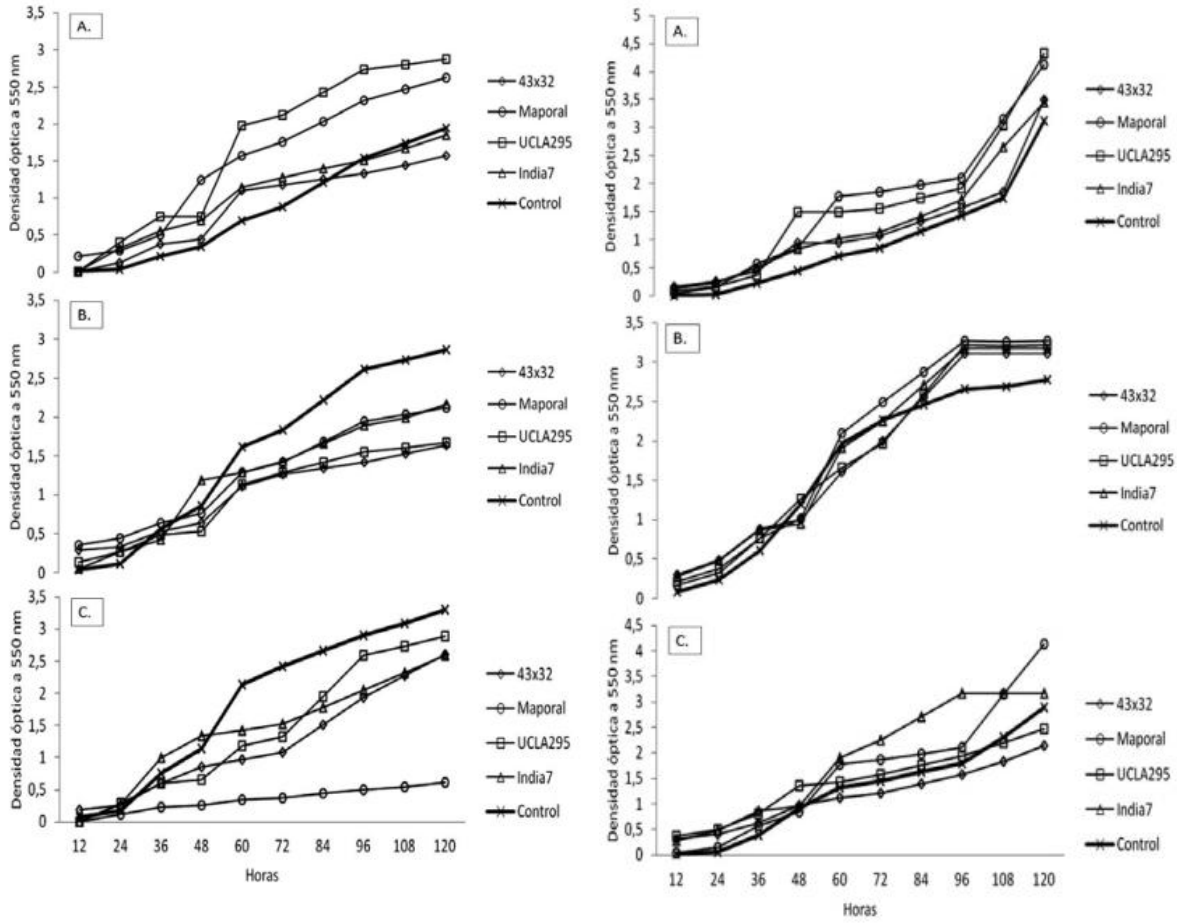
- M. Rodriguez and C. Zambrano (1985) reported several studies. They evaluated the development of *Macrophomina phaseoli* using various inoculation methods. Indole acetic acid (IAA) was the most effective in inducing sclerotial germination on *M. phaseoli*. The first 3 weeks of the cultivar Aceitera M were the critical plant age for infection and disease development. The effectivity of fungicides was tested *in vitro* with Benlate and Captan being effective and Brasicol and Ridomil were not effective. Ten different sesame cultivars were tested for susceptibility. The most resistant were Maporal, Arawaca, and 439. Benlate and Captan were tested as seed protectants, and both showed no significant difference. Captan can be of use in protecting the initial growth of sesame. [Based on abstract]
- J.B. Pineda and E.R. Glonnella (1988b) isolated 12 different cultures of fungi from soil samples collected in El Playon (7.47N 73.20W) and Turen (9.33N 69.11W) where some locations showed a low incidence of dry stem disease (*Macrophomina phaseolina*). The isolates were 8 *Aspergillus* spp., 2 *Trichoderma* spp., 1 *Cladosporium* sp. and 1 *Pythium* sp. These organisms were tested against one isolate of *Macrophomina phaseolina* (Tassi) Gold, pathogenic in sesame. They determined 2 *Aspergillus* spp. and 2 *Trichoderma* spp. could inhibit the growing and sclerotia production of this pathogen. Under natural field conditions, *Trichoderma* I and *Aspergillus* 1 were highly effective in reducing sesame dead plant percentage by *M. phaseolina* until 72 days after planting, indicating a good control.
- A.M. Colmenares and L. Subero (1989a) reported the following pathogen: *Macrophomina phaseolina* (Black stem). The symptoms of this disease appear in the root and then advance to the stem. It is possible to observe a necrosis which goes from the root to the top of the plant. Initially, the necrosis is light brown and later changes to black of charcoal color because of the numerous pycnidia and sclerotia formed. Stem necrosis is hard and dry. Recently, in the eastern part of the country, new symptoms have been reported. These consist in extensive watery spots on the leaves which advance towards the petiole though the rings. Necrosis occur in the stem, weakening and bending the plant until it falls over.
- J. Avila M. and J.P. Pineda (1996b) evaluated 10 varieties against *Macrophomina phaseolina* in 3 seasons (1986-89) in Turen (9.33N 69.11W) and El Aji (9.22N 69.05W). Although the soils contain both *Macrophomina phaseolina* and *Fusarium oxysporum*, the dry conditions lead to higher incidence of *M. phaseolina*. Arawaca (5.8%) and LP 8 (9.3%) were the most tolerant with a mean for all lines of 19.3% and a high of 30.5%.
- B. Mazzani (1999) reported the following pathogen: *Macrophomina phaseolina.* Mazzani (1983) reported minor susceptibility in Ajimo Atar, Adong Acol, and *Sesamum radiatum* and major susceptibility in Aceitera, Acarigua, Caripucha, and Venezuela 52.
- J.B. Pineda (2001) evaluated using *Trichoderma harzianum* in different forms (clayey soil granules impregnated with conidia of *T. harzianum* and 5% sucrose, rice grains inoculated with *T. harzianum*, sesame seed coated with conidia of *T. harzianum*, and no treatment) to control *Macrophomina phaseolina* in Turen (9.33N 69.11W). The results were as follow.

Treatment	Dead plants (%)	Reduction of mortality (%)
Clayey soil granules impregnated with conidia of *T. harzianum* and 5% sucrose	2.8 a	69.5
Sesame seed coated with conidia of *T. harzianum*	4.3 ab	53.3
rice grains inoculated with *T. harzianum*	6.8 bc	26.1
No treatment	9.2 c	0

- R. Cardona and H. Rodríguez (2006a) studied the effects of *Trichoderma harzianum* on *Macrophomina phaseolina* using 3 methods: application on the seed; application in clay granules, and application in rice grains versus a control with no application. Across 3 years, These results do not show any difference of *T. Harzianum* on the incidence of the charcoal rot, also evidenced the necessity of evaluating cultural practices that might improve the environmental conditions that allows the fungus *T. Harzianum* to develop all its antagonist capacity.
- R. Cardona (2006b) studied the vertical distribution of *Macrophomina phaseolina* sclerotia versus the influence of the temperature and humidity on a soil infested naturally with the following results. (E1: Sclerotia from 0 to 5 cm of depth. E2: sclerotia from 5-10 cm of depth. E3: Sclerotia from 10-20 cm of depth. H1: Temperature from 0- 5 cm of depth. H2: Temperature from 5-10 cm of depth. H3: Temperature from 10-20 cm of depth.)



- R. Cardona (2008) studied the effects of *Trichoderma harzianum* and green manure of *Crotalaria spp.* on the number of sclerotia/g of soil (SG) of *Macrophomina phaseolina* and the incidence of charcoal rot in sesame with 3 treatments: a) green manure (GM) and absolute control (AC); b) GM, green manure + *Trichoderma* (GMT) and c) GM, GMT and AC. The results indicates that the GM slows down the *M. phaseolina* development at the beginning, but when advancing the crop cycle the levels of inoculums reaches equal values to the AC; whereas the GMT treatment showed diminution in the SG throughout the cycle in comparison with the treatment GM. In the third essay, a high significant difference ($P \leq 0.01$) in the incidence of charcoal rot with the GMT treatment constitutes a viable alternative for controlling *M. phaseolina* in sesame.
- A. Martinez-Hilders and H. Laurentin (2012) and A. Martinez-Hilders et al. (2013) studied 7 isolates of *Macrophomina phaseolina* characterized by means of growth velocity, microsclerotia production, mycelium color, aerial mycelium presence, and RAPD markers. These results indicate it is difficult to manage charcoal rot by means of obtaining resistant cultivars because of the fungus variability found in all the levels evaluated.
- Y. Mendoza and H. Laurentin (2012) evaluated the effect of sesame root and stem extracts from 4 varieties on 3 isolates of *Macrophomina phaseolina*. There was some suppression of mycelial growth from the root extracts but little from the stems as shown below.



There was no correlation between suppression of mycelial growth and the alkaloid, flavonoid, and phenol in the extracts as shown below.

	Grupo de metabolitos en raíz			Grupo de metabolitos en tallo		
Genotipo de ajonjolí	Alcaloides	Flavonoides	Fenoles -mg mL^{-1}-	Alcaloides	Flavonoides	Fenoles
43 x 32	103,44 a	0,00 c	0,00	0,00 b	74,28 a	0,00
India 7	103,63 a	63,87 a	0,00	61,11 a	93,80 a	0,00
Maporal	0,00 c	25,71 b	0,00	0,00 b	32,25 b	<25
UCLA 295	62,85 b	52,50 a	0,00	0,00 b	0,00 c	<25

- D. Peraza and H. Laurentin (2013) evaluated 3 methods of inoculating sesame with *Macrophomina phaseolina*: For the first method, sesame plantlets were put into Petri dishes containing microsclerotia suspension; for the second method plantlets were put into Petri dishes containing the fungus growing on potato dextrose agar medium, and for the third, plantlets were grown into substrate mixed with the fungus growing into a Petri dish. Lesion length on plantlets and germination percentage were quantified in the three methods. All methods were successful for causing disease, however, second method was difficult to manage due to contamination problems, for that, data was not registered. Germination percentage was the only variable showing differences among sesame genotypes when third method was used. Third method is proposed as routine protocol for measuring sesame germplasm reaction to *M. phaseolina*.

A2.1.2 *Phyllosticta* spp. (2 Jul 2021)

Family: Botryosphaeriaceae

Definition: Amount of tolerance to *Phyllosticta* spp. Pers. 1818.

(Wikipedia, 2 Jul 2021) ***Phyllosticta*** is a genus of fungi. Many of the species in this genus are common and important plant pathogens. They typically infect the foliage and cause tannish-gray leaf spots with dark brown to purple borders. However, *Phyllosticta* may also infect fruit and stems. Yield loss is a common consequence of *Phyllosticta* infection.

References:

MEXICO

- Agrolytics.org (2021) reported sesame hosts *Phyllosticta* spp.

A2.1.2a *Phyllosticta sesami* (2 Jul 2021)

Family: Botryosphaeriaceae

Definition: Amount of tolerance to *Phyllosticta sesami* Bohovik 1936.

References:

UKRAINE

- I.V. Bohovik (1936) reported *Phyllosticta sesami* caused a light outbreak of a whitish, rounded or irregular leaf spot with a brown margin up to 1 cm in diameter. There were emergent brown, mostly globose pycnidia, 30 to 100 µ in diameter and hyaline, continuous, elongated spores rounded at both ends and 6 to 13 by 2 to 4 µ. [Cited by R.S. Vasuveda, 1961, and G.S. Saharan, 1989]

A2.1.3 *Botryosphaeria* spp. (28 Apr 2021)

Family: Botryosphaeriaceae

Definition: Amount of tolerance to *Bostryosphaeria* spp. Cesati & De Notaris 1863.

(Wikipedia, 4 Jun 2021) ***Botryosphaeria*** is a genus of pathogenic fungi in the family Botryosphaeriaceae. There are 193 species, many of which are important disease-causing agents of various important agricultural crops.

A2.1.3a *Botryosphaeria ribis* (28 Apr 2021)

Family: Botryosphaeriaceae

Definition: Amount of tolerance to *Bostryosphaeria ribis* Grossenb. & Duggar 1911.

(Wikipedia, 28 Apr 2021) ***Botryosphaeria ribis*** is a fungal plant pathogen that infects many trees causing cankers, dieback and death.

References:

INDIA

- B.N. Shukla and S.C. Vyas (1977) reported leaf blight (*Bostryosphaeria ribis*) of sesamum caused brown or black irregular marginal leaf spots and brown sunken capsule spots; stem and flowers are also affected; seeds turn brown.
- S. Maiti et al. (1985 and 1986) reported the following minor pathogen: Blight *Botryosphaeria ribis* Gross. and Dugg.
- M.L. Verma (1985) reported *Botryosphaeria ribis* (Leaf blight) is a minor disease with the following symptoms: Brown black irregular marginal leaf spots. Brown, sunken, pod spots. Stem, leaves and flowers affected. Seeds turn brown.

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A3 Order: Pleosporales Luttr. Ex M.E. Barr 1987

(Wikipedia, 8 Apr 2021) The Pleosporales is the largest order in the fungal class Dothideomycetes. By a 2008 estimate it contains 23 families, 332 genera and more than 4700 species. The majority of species are saprobes on decaying plant material in fresh water, marine, or terrestrial environments, but several species are also associated with living plants as parasites, epiphytes or endophytes. The best studied species cause plant diseases on important agricultural crops. Some species of Pleosporales occur on animal dung and a small number occur as lichens and rock-inhabiting fungi.

There are species in this order associated with sesame, but not reported to cause diseases, produce a toxin, inhibit germination, or affect seed quality. See H5.

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A3.1 Family: Pleosporaceae Nitschke 1869

(Wikipedia, 8 Apr 2021) **Pleosporaceae** is a family of sac fungi. The taxonomic relationship of this family to associated genera is still not determined.

The following species have been reported to cause diseases, produce a toxin, inhibit germination, or affect seed quality.

- A3.1.1 *Alternaria* spp. (*Syn: *Macrosporium* spp.)
- A3.1.1a *Alternaria alternata* (**Syn: *Alternaria tenuis*)
- A3.1.1b *Alternaria sesami* (*Syn: *Macrosporium sesami*)
- A3.1.1c *Alternaria sesamicola*
- A3.1.1d *Alternaria longissima*
- A3.1.1e *Alternaria simsimi*
- A3.1.1f *Alternaria japonica* (*Syn: *Alternaria raphani*)
- A3.1.1g *Alternaria citri*
- A3.1.1h *Alternaria tenuissima*
- A3.1.1i *Alternaria brassicae* (*Syn: *Alternaria macrosporum*)
- A3.1.1j *Alternaria solani*
- A3.1.1k *Alternaria lini*
- A3.1.1l *Alternaria brassicola*
- A3.1.1m *Alternaria radicina*
- A3.1.1n *Alternaria mali*
- A3.1.2 *Helminthosporium spp.*
- A3.1.2a *Helminthosporium sesami*
- A3.1.2b *Helminthosporium halodes*
- A3.1.2c *Helminthosporium tetramera*
- A3.1.2d *Helminthosporium magnisporum* (*Syn: *Helminthosporium gigasporum*)
- A3.1.3 *Drechslera* spp.
- A3.1.3a *Drechslera rostratum* (*Syn: *Drechslera rostrata*)
- A3.1.3b *Drechslera sesami*
- A3.1.4 *Cochliobolus* spp.
- A3.1.4a *Cochliobolus sativus* (*Syn: *Drechslera sorokiniana*)
- A3.1.4b *Cochliobolus spicifer*
- A3.1.5 *Curvularia* spp.
- A3.1.5a *Curvularia lunata* (*Syn: *Cochliobolus lunatus*)
- A3.1.5b *Curvularia macularis*
- A3.1.5c *Curvularia fallax*
- A3.1.5d *Curvularia neergaardii* (*Syn: *Drechslera neergaardi*)
- A3.1.6 *Exserohilum* spp. (Syn: *Setosphaeria* spp.)

There are species in this family associated with sesame, but not reported to cause diseases, produce a toxin, inhibit germination, or affect seed quality. See H5.2.

A3.1.1 *Alternaria* spp. (10 Dec 2021)

Synonym: *Macrosporium* spp.

Family: Pleosporaceae

Definition: Amount of tolerance to *Alternaria* spp. Nees 1817.

Summary:

Photo: S.U. Kim
{Republic of Korea}

Photo: O.A. Enikuomehin
{Nigeria}

Alternaria sesami (Synonym: *Macrosporium sesami*) and ***Alternaria alternata*** (Synonym: *Alternaria tenuis*) are major pathogens with worldwide distribution. It infects the stems, leaves, and green capsules causing considerable damage. When environmental conditions are favorable for disease development, the disease may occasionally be severe enough to kill seedlings and young plants. Symptoms are brown to dark-brown, spreading, water-soaked lesions which can often be observed the entire length of the stem. The lesions also occur on the midrib and even veins of leaves, which can be without the typical leaf-spots. In very severe attacks plants may be killed within a very short period after symptoms are first noticed, while milder symptoms cause defoliation. The pathogens are seedborne and soilborne. Favorable conditions for disease development are warm and high humidity or frequent rainfall. There are many other Alternaria species that have been documented as pathogenic to sesame: *A. brassicae*, *A. brassicicola*, *A. citri*, *A. japonica*, *A. lini*, *A. longissima*, *A. mali*, *A. redicina*, *A. sesamicola*, *A. simsimi*, *A. solani*, and *A. tenuissima*. There are also other species in the Pleosporaceae family that are pathogens: *Cochliobolus* spp., *Curvularia* spp., *Drechslera* spp., *Exserohilum* spp., and *Helminthosporium* spp. *Alternaria* spp. have been reported in international lists, Australia, Bolivia, Brazil, Burkina Faso, China, Costa Rica, Cuba, Egypt, Ethiopia, Greece, Guatemala, Honduras, India, Iran, Iraq, Israel, Japan, Kenya, Mexico, Myanmar, Nicaragua, Nigeria, Pakistan, Paraguay, Republic of Korea, Russia, Saudi Arabia, Sudan, Tanzania, Turkey, Uganda, Ukraine, United States, and Venezuela.

Alternaria spp. and *Cercospora spp.* often occur on the same plant/leaf. Alternaria leaf spot (irregular tan/light brown lesions, mostly on top half of leaf) and Cercospora leaf spot (reddish-brown margins, small circular lesions; see edges of leaf especially). Photo: K.A. Cochran {USA}

(Wikipedia, 8 Apr 2021) ***Alternaria*** is a genus of [Deuteromycetes] fungi. *Alternaria* species are known as major plant pathogens. They are also common allergens in humans, growing indoors and causing hay fever or hypersensitivity reactions that sometimes lead to asthma. They are present in the human mycobiome and readily cause opportunistic infections in immunocompromised people such as AIDS patients.

There are 299 species in the genus; they are ubiquitous in the environment and are a natural part of fungal flora almost everywhere. They are normal agents of decay and decomposition. The spores are airborne and found in the soil and water, as well as indoors and on objects. The club-shaped spores are single or form long chains. They can grow thick colonies which are usually green, black, or gray.

At least 20% of agricultural spoilage is caused by *Alternaria* species; most severe losses may reach up to 80% of yield, though. Many human health disorders can be caused by these fungi, which grow on skin and mucous membranes, including on the eyeballs and within the respiratory tract. Allergies are common, but serious infections are rare, except in people with compromised immune systems. However, species of this fungal genus are often prolific producers of a variety of toxic compounds. The effects most of these compounds have on animal and plant health are not well known. Many species of *Alternaria* modify their secondary metabolites by sulfoconjugation, however the role of this process is not yet understood. The terms *alternariosis* and *alternariatoxicosis* are used for disorders in humans and animals caused by a fungus in this genus.

Not all *Alternaria* species are pests and pathogens; some have shown promise as biocontrol agents against invasive plant species. Some species have also been reported as endophytic microorganisms with highly bioactive metabolites.

The genus is now known to be polyphyletic.

The following species have been associated with sesame but there are no known reports of being a pathogen, producing a toxin, inhibiting germination, affecting seed quality, or being used as a biocontrol or biofertilizer.

- *Alternaria carthami* [India]
- *Alternaria chlamydospora* [Pakistan]
- *Alternaria cinerariae* [Pakistan]
- *Alternaria dianthi* [Pakistan]
- *Alternaria dianthicola* [Pakistan]
- *Alternaria helianthi* [Pakistan]
- *Alternaria infectoria* [Pakistan]
- *Alternaria longipes* [Mexico and Pakistan]
- *Alternaria pluriseptata* [Pakistan]
- *Alternaria seseamae* [Iraq]
- *Alternaria triticina* [Pakistan]

References:

INTERNATIONAL

- M.O. Khidir (1981a) in a review of sesame in East Africa and the Near East reported the following disease was a problem: *Alternaria* spp.
- Anon (2000a) is an organic grower guide for America. It describes the following disease and its recommended organic method of control: Alternaria leaf spot is transmitted through seeds, therefore resort to resistant varieties. Totally hairy varieties seem to be more resistant. They recommended a copper product, but it was banned in Europe in 2002.

AUSTRALIA

- D.F. Beech (1981a) reported the presence of *Alternaria* sp. (leaf spot) in 1964 and 1973 and *Macrosporium* sp. in 1941.

COSTA RICA

- Anon (1991a) in a grower guide reported the following pathogen: *Alternaria* spp.

EGYPT

- M.M.I. Abdel-Hafez et al. (2012) examined the soils around the roots of sesame and reported *Alternaria* sp. in the rhizosphere.
- M.M.I. Abdel-Hafez et al. (2014) took ten samples of sesame from local markets in Assiut city. They found *Alternaria* spp.
- B.A. Sabry et al. (2016) in Egypt studied 28 sesame samples collected from food stores in different governates. They found the following fungi.

Governorate	NC/TNS	Fungal load (log_{10} CFU/g)		Percentage occurrence of fungal genera				
		Range	Mean ± SD	*Alternaria*	*Aspergillus*	*Fusarium*	*Penicillium*	*Cladosporium*
Great Cairo	4/4	1.72 –2.32	1.91±0.77[a]	34.21	60.53	2.63	ND	2.63
Kalioubia	3/3	1.72 –2.32	1.97±1.03[a]	4.17	91.66	ND	4.17	ND
Alexandria	6/6	1.72 –2.67	1.99±1.63[a]	4.35	82.61	6.52	ND	6.52
El-Behera	5/5	1.72 –2.87	2.15±1.63[b]	ND	71.82	0.91	17.27	10.00
Kafr El-Sheik	5/5	1.72 –2.80	2.26±2.72[c]	3.96	60.40	1.98	17.82	15.84
Dakahlia	5/5	1.72 –3.02	2.52±0.70[d]	ND	79.68	1.59	6.37	12.35

NC: Number of contaminated samples; TNS: Total number of samples
Mean with different superscript letters are significantly different

ETHIOPIA

- B.K Yirga and B. Fiseha (2017a) reported the following pathogen: *Alternaria* spp. (Leaf spot).
- B.K Yirga et al. (2018a) surveyed 10 locations representative low land areas of western zone of Tigray for 3 years (2015, 2016, and 2017). *Xanthomonas campestris* pv. *sesami* - bacterial blight (83.24%) recorded the highest disease incidence followed by *Sphaerotheca fuliginea* - powdery mildew (78.13%), *Fusarium oxysporum* f. sp. *sesami* - fusarium wilt (78%), phyllody (72.01%) and *Alternaria* spp. - blight leaf spot (72%). Whereas blight leaf spot recorded highest severity (31.33%), followed by fusarium wilt (27.2%), phyllody (25.24%), bacterial blight (22.76%) and powdery mildew (22.6%). The phyllody is vectored by *Orosius albicinctus.*

HONDURAS

- V.P. Queiroga et al. (2016) reported *Alternaria* sp. (Mancha circular zonada) symptoms are spots on the leaves, stem and capsules. These are circular in shape with irregular, whitish contours with purplish edges and concentric inner areas with purplish borders.

INDIA

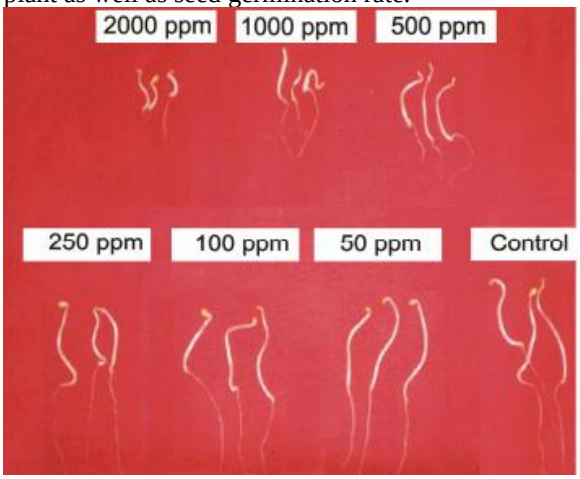
- J.H. Mitter and R.N. Tandon (1930) reported *Macrosporium* sp. caused a disease in sesame. [Cited by R.S. Vasudeva, 1961]
- O.P. Kadian (1972) reported five common genera to include *Alternaria* spp., which reduced seed germination and had adverse effect on the seedlings. The seeds were internally as well as externally seedborne. The seed infestations (%) with *Alternaria* spp. were comparatively higher than with other five genera. [Cited by G.S. Saharan, 1989]
- K.R. Sharma and K.G. Mukerji (1974) reported a pathogenic *Alternaria* spp. on aging, senescing, and decaying leaves. [Cited by G.S. Saharan, 1989]
- T.S. Rajpurohit et al. (1983) reported maximum growth (mycelial mat) of *Alternaria* sp. was observed in case of glucose followed by sucrose, fructose, lactose, and maltose with excellent sporulation except in case of maltose. The fungus is widely adaptable in utilizing various forms of nitrogen for its growth.
- S. Maiti et al. (1985 and 1986) reported the following minor pathogen: Blight *Macrosporium* sp.
- K. Bhattachary and S. Raha (2002) studied fungal infection, moisture content, germinability and deterioration of sesame in storage under natural conditions for a year. Different species of Aspergillus (*A. candidus*, A. *flavus*, *A. niger*, *A. terreus*, and *A. ruber*) were dominant followed by Rhizopus, Penicillium, Curvularia, Fusarium, Alternaria, etc. Seed moisture was maximum in the rainy season followed by a gradual decrease during longer storage. As storage proceeded, there was a gradual decrease in field fungi with simultaneous increase in storage fungi, and a reduction in germinability. A gradual loss of carbohydrate (both soluble and insoluble) content was recorded. A loss of protein content was recorded followed by a small increase. Oil content decreased in prolonged storage with simultaneous increase in fatty acid. [Based on abstract]
- C. Jeyalakshmi et al. (2013) evaluated integrated disease management practices to combat major diseases (Alternaria leaf blight, *Macrophomina* root rot, and Powdery mildew) and to increase the seed yield of sesame during summer 2009 and 2010 using at Karaikal (10.93N 79.84E). The treatments were as follow.
  - M1: Soil application of neem cake @ 250 kg /ha+ seed treatment with thiram (0.2%) + carbendazim (0.1%) + foliar spray of mancozeb (0.25%) + endosulfan (0.07%) at 30 and 45 DAS.
  - M2: Seed treatment with *Trichoderma viride* (0.4 %) + soil application of *T. viride* @ 2.5 kg/ha + foliar spray of mancozeb (0.25%) + endosulfan (0.07%) at 30 and 45 DAS.

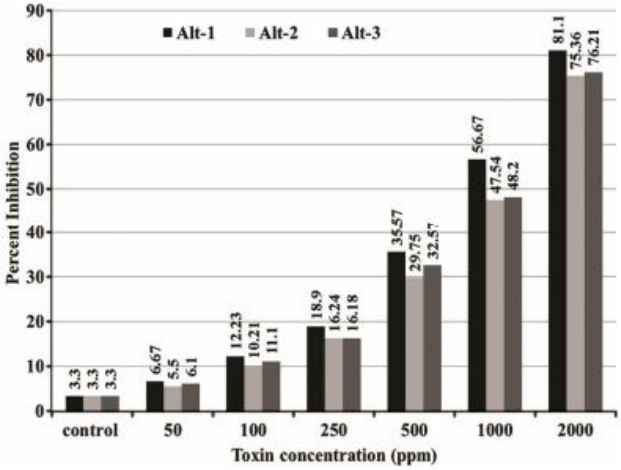
- M3: Soil application of neem cake @ 250 kg /ha + seed treatment with *T. viride* (0.4 %) + soil application of *T. viride* @ 2.5 kg/ha + foliar spray of azadirachtin (0.03%) @ 3 mL/L on 30 and 45 DAS.
- M4: Farmer's practices (control)

The results were as follow.

Module	2009*				2010*			
	Root rot (%)	Powdery mildew (PDI)	Seed yield (kg/ha)	C:B ratio	Root rot (%)	*Alternaria* blight (PDI)	Seed yield (kg/ha)	C:B
M1	8.28[b]	5.10[b]	680[c]	1:1.03	8.80[b]	5.44[b]	708[c]	1:1.18
M2	7.05[b]	4.22[b]	690[b]	1:1.13	6.90[b]	6.16[b]	720[b]	1:1.28
M3	3.04[a]	2.01[a]	760[a]	1:1.20	2.54[a] (9.13)	2.48[a]	766[a]	1:1.32
M4	17.7[c]	11.95[c]	545[d]	1:1.00	18.60[c]	19.40[c]	495[d]	1:0.98

- N. Ranasingh and T. Samal (2013) reported soil application of neem cake @ 250 kg/ha + Seed Treatment with (Thiram 0.2%) + Carbendazim 0.1%) + spray of mancozeb 0.25% + Profenofos 50 EC @ 2ml/l of water at 30 and 45 Days after sowing recorded least incidence of *Alternaria* sp. and *Cercospora* sp. (leaf spot) and capsule borer attack. Spraying of quintal 0.1% (Carbendazim + Iprodione) or Iprodione (Rovral) 0.2% two times (30 and 45 Days) was also effective against *Alternaria* sp. and *Cercospora* sp.
- M.K. Naik et al. (2017) reported sesame production, particularly in India, has been declining since last decade and 'Leaf blight' caused by *Alternaria* spp. is reported to cause yield loss up to 30-40%. They investigated the fungal toxin produced by Alternaria and its pathogenicity. A total of 164 Alternaria strains (*A. alternata* [39], *A. brassicae* [10], *A. porri* [6], *A. tenuissima* [03], *A. sesami* [1] and *Alternaria* sp. [72]) were isolated on potato dextrose agar media from the infected sesame leaves showing circular concentric rings with dark brown spots symptoms. All the isolates were screened for cultural and morphological characters. Color of the fungus was grey to dark brown, formed smooth, raised, fluffy, and regular to irregular margins. Among 164 isolates, 23 showed toxigenicity, varied from highly toxigenic (*A. alternata*) to least toxigenic (*A. brassicae*). Pathogenicity of the isolates showed that they were highly virulent to less virulent when tested by the detached leaf method. Based on the toxigenicity, the toxin was partially purified, and brown colored paste was recovered. Chemistry of the toxin was confirmed based on the IR, UV, NMR and mass spectra analyses, and it resembled the structure of alternariol mono methyl ether and altenuene which are mycotoxins in nature. Further, bioassay of toxin was carried out at different concentrations (50 to 2000 ppm) on seeds and seedlings of sesame. Maximum inhibition of seed germination of 81.1% was observed at 2000 ppm and the least was 6.67% at 50 ppm. With the increase in the concentration of toxin, the manifestation of the symptom was conspicuous and quick such as marginal, veinal necrosis, drooping, and yellowing with lesion formation. From the present study, it is found that the species of Alternaria are responsible for the cause of blight disease symptoms, and the toxicity of toxin produced by the pathogen was very high. The Alternaria toxin could inhibit the growth of the plant as well as seed germination rate.





- B. Khamari et al. (2018c) conducted an intensive survey at flowering to ripening of capsule to record the incidence of sesame diseases in 10 agroclimatic zones of Odisha during rabi 2014-15 with the following results.

Sl. No.	Place	Variety	Mac (%)	Fus (%)	Alt (Grade)	PM (Grade)	Cer (Grade)	Phy (%)
1	Bheden	Bheden local	18.09	9.78	3	0	2	0
2	Balianta	VRI-1	23.8	8.0	4	3	2	2.3
3	Nuagaon	Nuagaon local	12.8	3.0	3	0	2	0.6
4	Papadahandi	Papdahandi local	15.2	4.1	2	0	2	1.0
5	Betanati	Betanati local	18.8	0.5	2	2	1	0
6	Kalimela	Kalimela local	11.3	0.8	3	1	2	0.8
7	Agarpada	Agarpada local	8.0	1.0	3	1	1	0.6
8	Kirei	Sundergarh local	15.8	3.9	2	0	1	1.4
9	Khajuripada	Phulbani local	10.5	2.9	3	3	1	0.0
10	Bhawanipatna	Narla local	19.2	4.8	4	0	2	1.4

Mac=*Macrophomina*, Fus= *Fusarium*, Alt= *Alternaria*, PM= Powdery Mildew, Cer= *Cercospora*, Phy= Phyllody

- B. Khamari et al. (2018e) collected 15 sesame seed samples from different localities of Odisha reported the infestation of *Alternaria* sp. ranged from 0 to 4%.
- K. Divya et al. (2020) screened 133 genotypes for tolerance to phyllody, Alternaria leaf spot, Cercospora leaf spot, and downy mildew. There were no genotypes that were resistant to the leaf spots.

IRAN

- M. Gooya et al. (2000) took one seed samples of each 17 sesame cultivars from 10 locations leading to 145 isolates during 1997/99 They identified *Alternaria* sp.

KENYA

- H.A.E W'Opindi (1981) reported the presence of *Alternaria* sp.

MEXICO

- I. Torres (1985) reported that *Alternaria* sp. affects the crop and reduces yields.
- E.C. Hernandez (2003) in a grower guide reported the following pathogen: *Alternaria* sp. (Mancha Alternaria). Lesions or dark brown spots that increase in size with concentric circles. For control, use tolerant varieties and rotate crops.
- Agrolytics.org (2021) reported sesame hosts *Alternaria* spp.

MYANMAR

- D. Myint (2020) reported *Alternaria* sp. is a serious disease.
- Y.Y. Min and K. Toyota (2019) surveyed diseases in 10 farmer fields and interviewed 25 farmers. They reported the following pathogen: *Alternaria* sp. The disease incidence ranged from 5 to 40%.

NICARAGUA

- S.C. Litzenberger and J.A. Stevenson (1957) reported *Alternaria* sp. caused a disease in sesame. [Cited by R.S. Vasudeva, 1961]
- Anon. (1998b and 2009a) in grower guides reported zoned circular spot (caused by *Alternaria* sp.). Symptoms are spots on leaves, stem and capsules. The spots are circular with irregular contours and whitish with purplish edges and inner areas concentric with purplish borders.

NIGERIA

- O.A. Enikuomehin et al. (2008) evaluated the effects of different row arrangements on incidence and severity of Cercospora leaf spot (CLS) and Alternaria leaf blight (ALB) diseases and seed health of sesame intercropped with maize. Row arrangements were sesame intercropped with maize in alternate pair of rows (2:2), two rows of sesame intercropped with one row of maize (2:1), sesame intercropped with maize in single alternate rows

(1:1) with sole sesame as control. Intercropping maize with sesame reduced the incidence and severity of diseases. Sesame intercropped with maize in a (1:1) ration recorded a significantly lower number of infected leaves by CLS and ALB incidence than other row arrangements. ALB lesion number was between 17 and 20 in the (1:1) arrangement relative to 65–104 and 28–43 in the sole crop and other row arrangements, respectively. ALB lesion size was also reduced in the (1:1) than other row arrangements. Fungal infection of harvested sesame seeds was significantly reduced in the intercrop relative to the sole crop. CLS incidence was significant and negatively correlated with seed weight while defoliation was significant and positively correlated with ALB or CLS incidence. Rainfall was significant and positively correlated with CLS or ALB incidence while intercropping induced microclimatic effects that influenced disease incidence. Grain yield, weight of 1000-seed, number of capsules/plant and weight of seed/plant were significantly higher in the (1:1) row arrangement than the sole crop or other row arrangements. The study demonstrates that intercropping sesame with maize in a single alternate row (1:1) arrangement can be used to reduce foliar diseases of sesame. [Based on abstract]

- O.A. Enikuomehin et al. (2008) evaluated the effect of different population densities of sesame intercropped with maize, in a single alternate row (1:1) arrangement on the incidence and severity of foliar diseases of sesame during the early and late cropping seasons of 2006 and 2007, respectively. The experiment comprised four treatments, namely sesame planted at 266,666, 177,777 and 133,333 plants/ha intercropped with maize (53,000 plants/ha) and sole sesame at 266,666 plants/ha. Sesame at 133,333 plants/ha + maize showed a lower incidence of *Cercospora* leaf spot (CLS) and *Alternaria* leaf blight (ALB) disease and also produced a higher grain yield than the other treatments. The incidence of normal or discolored seeds was not influenced by sesame population density. Significant negative correlations existed between foliar disease incidence and proportion of normal or white/cream colored seeds. Foliar disease incidence was negatively correlated with incidence of abnormal or discolored seeds. Intercropping did not influence maize agronomic characteristics and grain yields. [Based on abstract]
- C.N. Ezekiel et al. (2014) isolated the following fungi on sesame seeds: *Alternaria* sp.
- A.D. Ojochenemi et al. (2015) examined 46 samples of sesame and reported *Alternaria* spp.
- S.T. Anjorin et al. (2016) studied the effects of 6 botanicals (baobab [*Adansonia digitate*] leaf powder, hot pepper [*Capsicum annum*] fruits, and ordeal tree [*Erythrophleum suaveolens*] bark and leaves, garlic bulbs and ginger rhizomes) against fungi isolated from sesame seeds (*Aspergillus niger, Aspergillus flavus, Mucor* spp., *Fusarium* spp., *Alternaria* spp., and *Penicillium* spp.). The ginger, garlic, and ordeal bark were not effective. The results of the effective treatments were as follow.

Sesame seeds treated with plant extracts	*Aspergillusniger*	*Fusarium*spp.	*Aspergillusflavus* (cfug/ml)	*Penicillium* spp.	*MucorAlternaria* spp. spp.
Baobab leaf extract (100%)	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{b}	0.00^{b} 0.00^{b}
Baobab leaf extract (10%)	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{b}	0.00^{b} 0.00^{b}
Ordeal leaf extract(100%)	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{b}	0.00^{b} 0.00^{b}
Ordeal leaf extract(10%)	0.00^{c}	1.00^{bc}	0.00^{c}	1.00^{b}	0.00^{b} 0.00^{b}
Hot pepper fruit extract(100%)	4.00^{b}	2.00^{b}	0.00^{c}	4.00^{a}	1.00^{ab} 0.00^{b}
Hot pepper fruit extract(10%)	5.00^{b}	2.00^{b}	0.00^{c}	0.00^{b}	1.00^{ab} 0.00^{b}
Untreated sesame seed before storage	7.00^{a}	5.00^{a}	4.00^{a}	5.00^{a}	1.00^{ab} 2.00^{a}
Untreated sesame seed after storage	5.00^{b}	5.00^{a}	2.00^{b}	4.00^{a}	2.00^{a} 1.00^{b}

- M. Jimoh et al. (2016) evaluated the effect of foliar spray of aqueous extracts of *Tithonia diversifolia* or *Ocimum gratissimum* on Cercospora leaf spot (CLS) and Alternaria leaf blight (ALB) diseases of sesame intercropped with maize. The spraying regime was at 2 weeks interval from 3 to 12 weeks after planting. Extracts of *T. diversifolia* or *O. gratissimum* reduced the incidence and severity of both diseases. CLS incidence and severity as well as defoliation was significantly ($p < 0.05$) reduced below what obtained in the unsprayed intercrop. ALB lesion size was significantly ($p < 0.05$) reduced by *T. diversifolia* extract at 8.0% (w/v) from 154.7 mm^2 (sole crop) or 13.4 mm^2 (unsprayed intercrop) to 4.9 mm^2 (sprayed intercrop). *T. diversifolia* extract at 8.0% (w/v) enhanced higher values of grain yield/plant and incidence of normal seeds, and lower incidence of fungal infection of seeds than in the unsprayed intercrop. [Based on abstract]

PAKISTAN

- H.N. Farhan et al. (2011) investigated the biological activity of *Pseudomonas* bacteria as biocides to protect sesame crop from some fungi and to evaluate its efficiency as plant growth promoting. The first experiment investigated the effects of *Pseudomonas putida* (Pp) and *Pseudomonas fluorescens* (Pf) on germination and seedlings growth of sesame crop against Pythium, Alternaria, and Fusarium under plastic house conditions. The following are the results.

Treatments	Sterilized soil		Non sterilized soil	
	Germination (%)	Seedlings (cm)	Germination (%)	Seedlings (cm)
Pythium + Pp	80	4.0	70	3.2
Fusarium + Pp	84	3.5	85	2.5
Alternaria + Pp	86.7	4.5	82	3.3
Pythium + Pf	65	3.2	65.3	2.2
Fusarium + Pf	61.6	4.0	71	3.0
Alternaria + Pf	75.7	3.0	77	1.0
Pythium	0.0	0.0	21	2.0
Fusarium	2.0	0.0	10	0.5
Alternaria	0.0	0.0	19	2.0
Control (no addition)	38.3	1.9	49.3	2.4

The second experiment grew the plants to harvest.

Treatments	Germination percentage	Leaf no. per plant (cm^2/plant)	Leaf area/plant	Chlorophyll content (mg/gm)
Pp + Fusarium	89.7	27	22	3.27
Pp + Pythium,	84.0	28	20	2.29
Pp + Alternaria	86.7	25	18	1.28
Pf + Fusarium	70.7	22	19	3.23
Pf + Pythium	71.0	19	17	1.96
Pf + Alternaria	80.0	19	18	2.25
Fusarium	3.0	6	4	0.21
Pythium	2.3	4	4	0.32
Alternaria	0.0	0	0	0.00
Control (no addition)	52.0	11	9	0.76
LSD 5 %	10.9	3.98	5.12	0.167

Treatments	Height of plant (cm)	Branch no. per plant	Total dry weight of shoot gm/plant
Pp + Fusarium	76.7	5.3	6.9
Pp + Pythium	88.3	8.3	7.7
Pp + Alternaria	67.7	6.3	6.7
Pf + Fusarium	73.3	4.7	4.8
Pf + Pythium	69.7	4.3	5.7
Pf + Alternaria	62.3	5.7	5.6
Fusarium	37.3	1.3	0.23
Pythium	36.3	2.7	0.3
Alternaria	0.0	0.0	0.0
Control (no addition)	55.0	3.3	3.3
LSD 5%	11.4	1.78	1.26

Treatments	Seeds no. per pod per plant	Weight of 1,000 seeds per plant (gm)	Pods no. per plant
Pp + Fusarium	50.7	2.2	33.7
Pp + Pythium	64.0	2.5	37.3
Pp + Alternaria	53.7	2.1	35.9
Pf + Fusarium	53.3	1.9	35.0
Pf + Pythium	54.7	1.6	26.7
Pf + Alternaria	43.7	1.8	32.3
Fusarium	8.3	0.4	1.3
Pythium	13.0	0.7	1.0
Alternaria	0.0	0.0	0.0
Control (no addition)	35.3	1.2	19.0
LSD 5%	4.58	0.22	3.3

Treatments	N% in shoot	P% in shoot	K% in shoot	Oil% in seeds
Pp + Fusarium	0.55	0.67	4.73	43.3
Pp + Pythium,	0.72	0.85	5.53	48.0
Pp + Alternaria	0.63	0.73	4.30	45.0
Pf + Fusarium	0.40	0.61	4.43	42.7
Pf + Pythium	0.32	0.71	4.43	44.0
Pf + Alternaria	0.41	0.66	4.52	43.7
Fusarium	0.07	0.03	2.2	5.3
Pythium	0.06	0.04	1.43	4.7
Alternaria	0.0	0.0	0.0	0.0
Control (no addition)	0.21	0.42	3.05	27.7
LSD 5 %	0.033	0.042	0.576	3.11

PARAGUAY

- N. Lezcano (2006) in a grower guide reported the following pathogen: *Alternaria* sp.
- L.C. Rossi and A.L. Orrego (2007) identified the following fungus on sesame seeds: *Alternaria* sp.

REPUBLIC OF KOREA

- S.W Kang and H.K. Kim (1989) reported *Alternaria* sp. is frequently encountered in the soils. [Based on abstract]
- S.U. Kim (pers. comm. 2015): The following is a photo of *Alternaria* sp.on sesame in a greenhouse.

RUSSIA

- E.S. Kvashnina (1928) reported *Alternaria* sp. forms on the upper surface of leaves of sesame rounded or irregular frequently confluent brown spots paling towards the margins and measuring 1.5 to 5 mm. The conidiophores are olive-brown, 1- to 4- septate and 26 to 48 by 4.4 to 5.2 µ, the spores vary in shape from flask shaped with very short beak to clavate with a very long beak (5 to 6 times the length of spore itself); they are olive-brown with 1 to 14 transverse and 1 to 4 longitudinal septa, and measure 28 to 362 {including the beak) by 5.2 to 24 µ [Cited by R.S. Vasudeva, 1961, and G.S. Saharan, 1989]

SAUDI ARABIA

- A.H. Bahkali and M.A. Moslem (1996) reported the following mycoflora on 5 cultivars: *Alternaria* sp.

SENEGAL

- M.N. Beko (pers. comm., 2021): The following photos show “Altenariose” in her research fields.

TANZANIA

- A.K. Auckland (1981a) reported the goal of developing resistance to *Alternaria* sp.
- Kafiriti, E. and O. Mponda (n.d.) in a grower guide reported the following pathogen: *Alternaria* spp.

UNITED STATES

- J. A. Martin (1953a) and M.L. Kinman and J.A. Martin (1954) reported *Alternaria* sp. The development is favored by excessive rainfall and high humidity. The organism is seedborne. They felt they could not completely control it with seed treatments since *Alternaria* sp. has other hosts. They found that Sirogoma and Venezuela 51 were moderately resistant. Widespread disease in 1952 allowed evaluation of resistance and several lines were selected in this respect.
- M.L. Kinman (1955) reported at least two fungi (*Cercospora sesami* and *Alternaria* spp.), and a bacterium (*Pseudomonas sesami*) are known to cause leaf spot diseases. The development of these leaf troubles is favored by excessive rainfall and high humidity. The causal organisms can be seedborne. It may be possible to control the leaf spots by the use of disease-free seed or by appropriate seed treatment. The *Alternaria* spp. may not be subject to complete control by these methods, since it appears to spread from other hosts. Disease-free seed can be grown in the desert under irrigation. Hot water seed treatment or treatment with the antibiotic Streptomycin will eliminate seed-born bacterial leaf spot.

- Anon (1959) reported *Alternaria* sp. and *Cylindrosporium* sp. were the main diseases in Florida nurseries. *Cercospora* sp. and *Helminthosporium* sp. are minor problems.
- C.A. Thomas (1959b) reported leaf spots or blights caused by species of Alternaria, Cercospora, Corynespora, Helminthosporium, and other fungi appear to be the chief diseases limiting production in areas of high rainfall and humidity. Observations over a period of years and in a number of locations will tell us what levels of resistance are sufficient for satisfactory production in an average year in a particular area. Whether or not lines can be found that possess higher resistance than our present ones remains a question. It would appear, however, that the discovery and use of such lines is necessary before commercial production can be profitable in some areas.
- S.Z. Berry (1960) reported:
  - Epiphytotics (*Alternaria* sp.) are associated with excessive rainfall and high humidity.
  - Symptoms are brownish-red annular lesions on the cotyledons of emerging seedlings. Lesions are found to develop on the lower true leaves and then on the upper leaves. Under epiphytotic conditions, leaf drop may be premature and accompanied by lesions on the stems and capsules.
  - Rio, T53264-B-48-1-2-B, T53264-3-25-1-1-B, and T53178-2-10-3-11-1-b also showed a certain amount of resistance (in addition to V51).
  - This species of *Alternaria* was once classified as *Macrosporium sesami* Kawamura.
- C.A. Thomas (1959a) reported plants grown for seed became infected with bacterial leaf spot and *Alternaria* before harvest. When these seeds were planted, *Alternaria* spots developed on the cotyledons and was usually severe by flowering time. Orthocide gave good protection against both diseases. Seed treatment is of much value under these conditions, but it may not be sufficient under more severe conditions. Control of *Alternaria* and bacterial leaf spot can be done by using clean seed and rotating crops.

VENEZUELA

- B. Mazzani (1953c) reported a new variety ‘Morada’ was tolerant to *Alternaria* spp. (Irregular stain) and *Cercospora sesami* (Round stain). Although the diseases show up, they are of low intensity and late in the cycle resulting in little effect on the plants.
- D.G. Langham et al. (1961c) used the following symbology in the Sesamum Foundation: *Resistencia a Alternaria* (D1-D5).
  - D1 = Resistant
  - D2-D4 = Intermediate
  - D5 = Susceptible
- M. Barboza et al. (1966) screened 10 varieties for tolerance to *Cercospora sesami* and *Alternaria* spp. All of the varieties were affected with a 15.7 to 55.2% loss in yield. [Cited by G.S. Saharan]
- B. Mazzani (1981a) reported *Alternaria* sp. (Leaf spot) is one of the major diseases.

A3.1.1a *Alternaria alternata* (10 Dec 2021)

Synonym: *Alternaria tenuis*

Family: Pleosporaceae

Definition: Amount of tolerance to *Alternaria alternata* (Fr.) Keiss 1912.

(Wikipedia, 8 Apr 2021) ***Alternaria alternata*** is a fungus which has been recorded causing leaf spot and other diseases on over 380 host species of plant. It is an opportunistic pathogen on numerous hosts causing leaf spots, rots and blights on many plant parts. It can also cause upper respiratory tract infections and asthma in humans with compromised immunity. *Alternaria alternata* has many different hosts depending on its forma specialis.

In order to survive, *Alternaria alternata* needs a moist warm environment. It is often found in areas with humid climates, or where there has been significant rainfall. The fungus lives in seeds and seedlings and is also spread by spores. This disease flourishes in dead plants that have been left in gardens over winter. Additionally, when dead infected debris is added to compost pile it can spread to other vegetables throughout the garden.

There are no insect vectors for this disease. This means that using insecticides has no effect on the spread of this pathogen. However, there are several cultural practices that can be followed to suppress this fungal pathogen's impact. The disease first occurs in the host's exposed leaves.

References:

INTERNATIONAL

- EA. Weiss (1971) reported *Alternaria tenuis* causes a similar leaf-spot disease to *Alternaria sesami.*
- C. Chattopadhyay et al. (2019) described the following symptoms for *Alternaria alternata*: Blighting of the stem is the major symptom. Chemical control: Seed treatment with Captan at 3 g/kg seed and foliar spray with copper oxychloride (0.3%) at 20, 40, and 60 days after sowing.
- CAB International (accessed 12 Apr 2021) reported sesame was a host of *Alternaria alternata* (Alternaria leaf spot).
- N. Ransingh et al. (2021) reported 3 species of Alternaria (*A. longissima, A. alternata* and *A. sesamicola*) infect sesame, inducing symptoms such as foliage blight, stem necrosis, and spots on capsules. All 3 species also reduced seed germination and seedling stand.

CHINA

- H.S. Cheng et al. (2021) reported a blight sesame fruit in a field in Lianing province. Initial disease symptoms consisted of brown or dark brown spots on the capsule. With time, lesions coalesced and the whole fruit turned dark brown or black. Most of the diseased capsules had thin and small, deformed, necrotic, hardened cracked epidermal lesions. Lesions were also produced on stem and petioles leading to leaf abscission. They identified causal pathogen as *Alternaria alternata.*

CUBA

- La Habana (2009) in a grower guide reported the following pathogen: *Alternaria alternata.*

EGYPT

- A. Hashem et al. (2014) collected 18 seed samples of sesame in Egypt (12 samples) and Saudi Arabia (6 samples). They identified the following mycoflora: *Alternaria alternata.*
- M.G.A. Hegazy et al. (2019) evaluated the effects of biocontrols (*Alternaria alternata, Aspergillus* spp. and *Penicillium* spp.) on *Fusarium oxysporum* f. sp. *sesami*, but as shown below, *Alternaria alternata* was not effective.

Isolate No.	Endophytic fungi isolate	Average of inhibition zone diameter (mm)
1	*Alternaria alternate*	1.5 ^{ef}
2	*Aspergillus clavatus*	9.2 ^{b}
3	*Aspergillus fumigatus*	0.8 ^{ef}
4	*Aspergillus niger*	11.6 ^{a}
5	*Aspergillus sydowii*	1.3 ^{ef}
6	*Aspergillus terreus* $_{(1)}$	2.3 ^{e}
7	*Aspergillus terreus* $_{(2)}$	5.9 ^{cd}
8	*Penicillium chrysogenum* $_{(1)}$	9.2 ^{b}
9	*Penicillium chrysogenum* $_{(2)}$	2.3 ^{e}
10	*Penicillium crustosum* $_{(1)}$	7.1 ^{bc}
11	*Penicillium crustosum* $_{(2)}$	8.2 ^{b}
12	*Penicillium crustosum* $_{(3)}$	2.8 ^{e}
13	Control	0.0 ^{f}

Means followed by the same letters (s) in a column are not significantly different at ($p \leq 0.05$) according to Duncan's multiple-range test.

INDIA

- A.S. Reddy and S.M. Reddy (1983a) reported fungal succession on sesame seeds with different moisture levels was analyzed monthly. Incidence varied with moisture content. *Alternaria alternata* was abundant only in the initial stages. *Aspergillus flavus* predominated while *Macrophomina phaseolina* and *Rhizoctonia solani* were associated only with seeds of high moisture content. The seed mycoflora at first increased with storage time but subsequently decreased. Seed germination increased with storage time. [Cited by G.S. Saharan, 1989]
- V.U. Rani et al. (1984) reported sesamum plants infected with *Alternaria alternata* (Fr.) Keissler Wiltshire showed stem bend at infection site after formation of an elliptical lesion with a dark reddish brown halo. Dark brown spots on leaves coalesce to cause blighting. Flowers and fruits also get infection. Infected fruits show hypertrophy. [Cited by G.S. Saharan, 1989]
- M.L. Verma (1985) reported *Alternaria alternata* (Leaf spot) is a minor disease with the following symptoms: Leaf spot, leaf spot water soaked, brown, later with yellow halo.
- N.O. Srikantappa et al. (2009) studied 28 samples of sesame taken from fields, farmers, retail shops and APMC markets from 5 areas. They found 34 four fungi including *Alternaria alternata* and *A. tenuis.* The fungi significantly reduced germination.
- N. Saxena and D. Karan (1991) reported seeds of sesame cv. T-85 collected in Andhra Pradesh had *Alternaria alternata.* Seed protein and carbohydrate contents were analyzed before and 10, 20 and 30 days after

inoculation. The fungi decreased protein and carbohydrate contents. It is suggested that the fungi contain a protein hydrolyzing enzyme, and the carbohydrate is consumed and converted into carbon dioxide and water. [Based on abstract]

- V. Bharathi et al. (2013) collected sesame seeds from farmers in Andhra Pradesh. They tested the seeds for mycoflora, and the following fungus was found: *Alternaria alternata.*
- A.S. Savitha et al. (2013) obtained 14 isolates of *Alternaria* spp. from Raichur, Gulbarga, Dharwad, Bidar, Bangalore, Hyderabad and Coimbatore districts comprising of eight isolates *Alternaria alternata* and six isolates of *Alternaria sesami*. They were studied for cultural, morphological, physiological, pathogenic and genetic variability.
- M.K. Naik et al. (2017) reported sesame production, particularly in India, has been declining since last decade and 'Leaf blight' caused by *Alternaria* spp. is reported to cause yield loss up to 30-40%. They investigated the fungal toxin produced by Alternaria and its pathogenicity. A total of 164 Alternaria strains (*A. alternata* [39], *A. brassicae* [10], *A. porri* [6], *A. tenuissima* [03], *A. sesami* [1] and *Alternaria* sp. [72]) were isolated on potato dextrose agar media from the infected sesame leaves showing circular concentric rings with dark brown spots symptoms. Among 164 isolates, 23 showed toxigenicity, varied from highly toxigenic (*A. alternata*) to least toxigenic (*A. brassicae*). [For more information see Naik in *Alternata* spp. above]

IRAN

- M. Gooya et al. (2000) took one seed samples of each 17 sesame cultivars from 10 locations leading to 145 isolates during 1997/99 They identified *Alternaria alternata.*

IRAQ

- F. Al-Refaee (2005) collected sesame seeds from 6 regions of Iraq and isolated *Alternaria alternata*.
- N.A. Saad et al. (2013) examined seed and found *Alternaria* fungi were the most prevalent, and *Alternaria alternata*, *Alternaria raphani*, *Alternaria citri*, and *Alternaria tenuissima* killed the following percentages of seed: 62, 59, 66, and 60% compared to the control of 0%.

MEXICO

- Anon. (2010a) in a grower guide reported the following main pathogen: *Alternaria alternata*. Losses caused by this pathogen can be minimized by following a regular spray schedule, as well as the application of postharvest treatments using maneb, mancozeb, difenoconazole or tebuconazole. Seed treatment: Chemical treatment with captan in doses of 600 g of powder wettable per 100 kg of seeds, or the application of carboxim + is recommended thiram at a rate of 200-300 ml of aqueous solution per 100 kg of seed. The use of seeds certified free of the disease. The fumigation of the seedlings and planting beds, drastically reduce the incidence of the disease, in addition to being a preventive treatment in subsequent years. The quarantine treatment guide for Mexico does not refer to any specific treatment for this pathogen, since is widely distributed.

NIGERIA

- C.A. Amienyo et al. (2015) studied the effect of mycoflora collected from 5 markets on the deterioration of lipid content of seed. Visually healthy seeds were inoculated with spores of each of the nine fungi isolated from diseased seeds and incubated at 25+20°C for 7days. The healthy and fungal infected seeds were analyzed for their lipid content. The percentage incidence at the 5 locations is shown below.

Fungi incidence	Location				
	A	B	C	D	E
Alternaria alternate	6.6	3.6	3.2	2.0	0.0
Aspergillus chevalieri	10.3	4.2	5.0	0.0	0.0
Aspergillus niger	0.0	6.1	7.4	2.6	5.2
Aspergillus oryzae	3.3	4.0	0.0	0.0	0.0
Aspergillus flavus	3.9	3.1	2.7	0.0	0.0
Aspergillus terreus	4.8	11.2	2.4	13.0	0.0
Cochliobolus Spp.	9.5	0.0	0.0	0.0	0.0
Geotrichum candidum	0.0	0.0	0.0	0.0	3.5
Phoma Spp.	5.9	2.0	0.0	0.0	0.0

Fungi utilize basic compounds of the seeds for their metabolism and growth and may affect the germination rate of the seed. The uninoculated seed had 49.35% lipid. The following shows the lipid content after 7 days of infection.

Fungi	Lipid content (%)
Aspergillus chevalieri	42.40
Aspergillus oryzae	43.50
Aspergillus niger	45.00
Aspergillus terreus	45.45
Alternaria alternata	47.80
Cochliobolus Spp	48.10
Aspergillus flavus	48.70
Phoma Spp.	49.15
Geotrichum candidum	49.40

PAKISTAN

- A.S. Shakir and M. Ansar (1992) studied 25 samples of seed collected from various areas in Punjab and found the following fungus: *Alternaria tenuis.*
- B.G. Nayyar et al. (2013) examined 15 samples of seed to detect fungi using 3 methods: agar plate, blotter, and deep freezing and found *Alternaria alternata*.
- B.G. Nayyar et al. (2014) studied the effects of fungal pathogens on the germination of sesame. Seven prevalent fungal species viz. *Alternaria alternata, Aspergillus flavus*, *Aspergillus niger, Cercospora* sp., *Fusarium oxysporum, Penicillium egyptiacum* and *Rhizopus oryzae* associated with sesame seeds were selected for this study. Fungi associated with seeds affected the seed health and resulted in reduced seed germination, and seedling abnormality as shown in the table below.

Treatments	Normal seedlings %age	Abnormal seedlings %age	Un germinated seeds %age	Fungi isolated
Surface sterilized seeds	80	14	6	*Aspergillus flavus* *Aspergillus niger* *Fusarium oxysporum*
Naturally infected seeds	64	26	10	*Alternaria alternata* *Aspergillus flavus* *Aspergillus niger* *Fusarium oxysporum* *Penicillium egyptiacum*

The pathogenicity of the 7 fungi was tested with the following results.

S. No.	Fungi isolated	Pathogenic Effect	Healthy Plants
1	*A. alternata*	Infected root & stem, Weak stem, Reduced growth	55%
2	*A. flavus*	Reduced growth	70%
3	*A. niger*	Reduced growth, Infected roots, Weak stem	13%
4	*Cercospora* sp.	Infected stem, Weak stem, Reduced growth	40%
5	*P. egyptiacum*	Infected root, Weak stem	26%
6	*R. oryzae*	Reduced growth, Infected roots & stem, Weak stem	30%
7	*F. oxysporum*	Reduced growth, Leaves short & infected	32%

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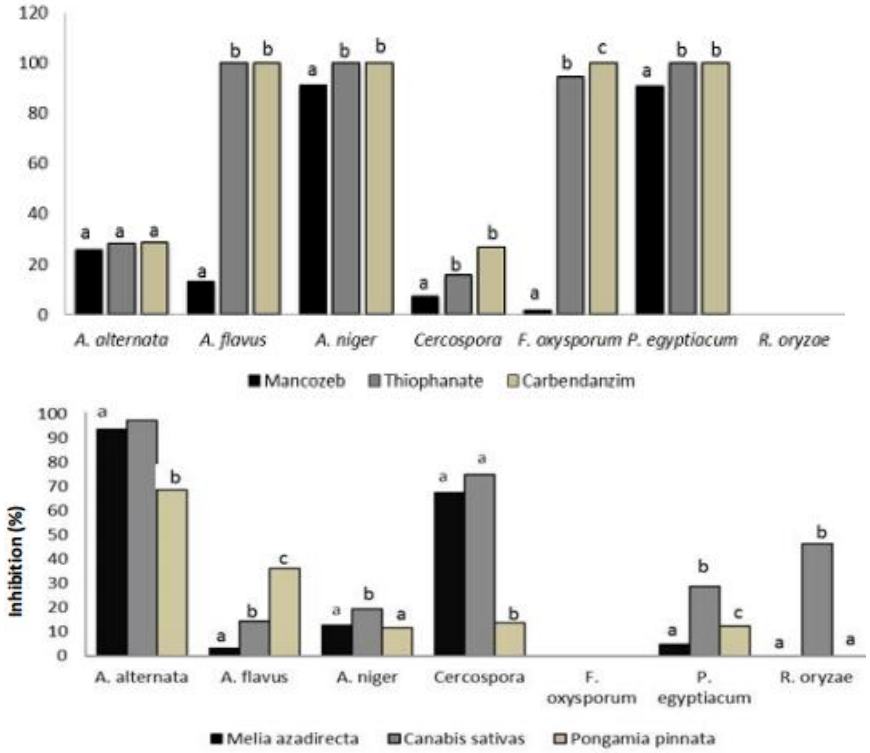
Abnormality rate of seedlings depends on the type of pathogens with which they are infected. There is also need for the management programs to control seedborne pathogens and reduce their impact on sesame production in Pakistan.

- M. Ajmal et al. (2016) studied the histopathology of three varieties of sesame (TS 3, TS 5, and SG 27) infected with *Alternaria alternata* to understand the mechanism of fungal infection and penetration in sesame plant as well as to determine the histological manifestation in sesame cells by light microscopy. Microscopic examination of sesame stem showed that the fungus was present in epidermis, hypodermis and cortical parenchyma tissue as the symptoms became visible by naked eye ten days after inoculation. As the disease progressed, the fungus moved from cortical parenchyma to vascular bundle, xylem and phloem. Later on, it completely overlapped the vascular bundle and entered in pith. When necrotic lesion appeared, fungus was present abundantly in epidermis, hypodermis, cortical parenchyma, vascular bundles and in pith. Due to its excessive growth and complete overlapping of cells, disorganization or destruction of cells of sesame took place. It was concluded that the *Alternaria alternata* was not a tissue limited pathogen instead of this it spread in to all tissues of stem from epidermis to pith.
- B.G. Nayyar et al. (2016) evaluated different treatments to increase the germination and inhibit the fungi on sesame seeds: application of fungicides (Mancozeb, Thiophante Methyl, and Carbendazim) and plant extracts (*Melia azedarach*, *Cannabis sativa* and *Pongamia pinnata*). Seed germination was tested by following the protocol of International Seed Testing Association. Antifungal activity was tested by poisoned food technique.

The results revealed that the germination increased effectively, due to thiophanate methyl up to 46%, followed by *Cannabis sativa* (37%). Out of 7 fungi tested against fungicides and plant extracts, 4 fungi, namely *Aspergillus flavus, Aspergillus niger, Fusarium oxysporum* and *Penicillium egyptiacum*, were inhibited up to 100% by Carbendazim and Thiophanate Methyl, while Mancozeb inhibited *Penicillium egyptiacum* (100%), only. *Cannabis sativa* inhibited *Alternaria alternata* (100%) and *Rhizopus oryzae* (55.6%). Overall treatment with fungicides gave best results but they were not eco-friendly. So, this study recommends the use of plant extracts and bioagents, which may increase seed germination and inhibit seedborne fungi without any harmful effect. The treatments had the following effects on specific fungi in terms of germination and inhibition: *Alternaria alternata, Aspergillus flavus, Aspergillus niger, Cercospora sp., Fusarium oxysporum, Penicillium egyptiacum* and *Rhizopus oryzae.*



- B.G. Nayyar et al. (2017) analyzed a total of 428 *Alternaria* isolates obtained from 105 seed samples and grouped into 36 distinct taxonomic groups based on growth pattern and morphological characters and identified the following species.

Isolate code	Name of fungi	Origin (city)	Non sterilized seeds			Surface sterilized seeds		
			No. of isolates	*Fr*	*RD*	No. of isolates	*Fr*	*RD*
A6	*Alternaria dianthi*	Sialkot	5	10	2.14	4	6	2.06
A13	*Alternaria sesami*	Sialkot	58	24	24.79	32	40	16.49
A19	*Alternaria citri*	Sialkot	13	18	5.56	5	8	2.58
A47	*Alternaria longipes*	Gujranwala	17	78	7.26	19	40	9.79
A91	*Alternaria dianthicola*	Gujranwala	17	24	7.26	7	10	3.61
A166	*Alternaria brassicicola*	Gujranwala	6	8	2.56	32	40	16.49
A181	*Alternaria solani*	Gujranwala	7	10	2.99	3	2	1.55
A183	*Alternaria raphanin*	Gujranwala	0	0	0.00	1	2	0.52
A196	*Alternaria alternata*	Gujranwala	13	18	5.56	5	6	2.58
A203	*Alternaria dianthicola*	Hafizabad	16	22	6.84	4	6	2.06
A215	*Alternaria brassicae*	Hafizabad	18	26	7.69	30	26	15.46
A217	*Alternaria citri*	Hafizabad	2	2	0.85	0	0	0.00

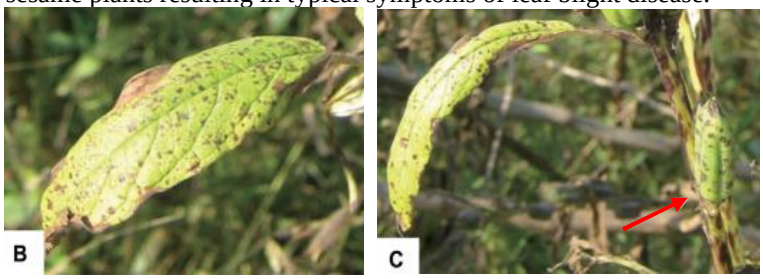
A218	*Alternaria infectoria*	Hafizabad	3	4	1.28	0	0	0.00
A220	*Alternaria sesamicola*	Gujrat	17	24	7.26	6	8	3.09
A221	*Alternaria helianthi*	Gujrat	9	12	3.85	6	8	3.09
A228	*Alternaria longissimi*	Gujrat	10	14	4.27	3	4	1.55
A236	*Alternaria raphanin*	Gujrat	4	4	1.71	1	2	0.52
A239	*Alternaria tenuissima*	Attock	7	10	2.99	0	0	0.00
A249	*Alternaria triticina*	Attock	0	0	0.00	19	26	9.79
A261	*Alternaria radicina*	Mandi Bahuddin	4	4	1.71	4	8	2.06
A263	*Alternaria pluriseptata*	Mandi Bahuddin	3	6	1.28	2	2	1.03
A267	*Alternaria cinerariae*	Mandi Bahuddin	2	4	0.85	5	8	2.58
A272	*Alternaria chlamydospora*	Mandi Bahuddin	3	4	1.28	6	6	3.09

Fr = Isolation frequency; *RD* = relative density.

Further molecular analysis of the three most frequent isolates showed the predominant species as *Alternaria alternata.*

Isolate code	Origin (city)	Morphological identification	Molecular identification		NCBI accession no.	
			ITS	*Alt a 1*	ITS	*Alt a 1*
A13	Sialkot	*Alternaria sesami*	*Alternaria* sp.	*Alternaria alternata*	KY190101	KY124234
A47	Gujranwala	*Alternaria longipes*	*Alternaria* sp.	*Alternaria alternata*	KY190102	KY124235
A215	Hafizabad	*Alternaria brassicae*	*Alternaria* sp.	*Alternaria alternata*	KY190103	KY124236

The pathogenicity and virulence of these isolates of *Alternaria alternata* was confirmed in inoculations of sesame plants resulting in typical symptoms of leaf blight disease.



Leaf symptoms Capsule symptoms

- M. Ajmal et al. (2021) evaluated the incidence of mycobiota and contamination of AFB_1 in sesame seeds from rainfed and irrigated zones of the Punjab, Pakistan. *Aspergillus flavus* was the leading contaminant found in fresh and stored sesame seeds from rainfed and irrigated zone followed by *Aspergillus niger*, *Alternaria alternata* and *Fusarium oxysporum*. Least reported fungi were *Aspergillus ochraceus* and *Cladosporium oxysporum*. AFB_1 analysis revealed that 92% fresh and 99% stored samples were contaminated with AFB_1. 20% fresh and 100% stored samples from rainfed zone and 28% fresh and 60% stored samples from irrigated zone were tainted with AFB_1 levels above 20 ppb and not fit for human consumption.

REPUBLIC OF KOREA

- S.H. Yu (1981) reported the following fungi in sesame seed samples *Alternaria sesami, Alternaria sesamicola, Alternaria tenuis* (*Alternaria alternata*), *Corynespora cassiicola*, *Alternaria longissima*, *Fusarium oxysporum*, and *Macrophomina phaseolina*. All were controlled by pre-treatment with chlorine, except for *Corynespora cassiicola*. [Based on abstract and cited by G.S. Saharan, 1989]
- Y.H. Yu et al. (1982) reported *Alternaria sesami, A. sesamicola, A. tenuis*, and *A. longissima* were detected in Korean seed samples of *Sesamum indicum* L. *A. sesamicola* was the predominant species, seed infection in some samples ranging between 30 and 68%. *A. sesami* and *A. longissima* were recorded only in low percentages of 1–3%. Based on the original descriptions and the isolates studied, it is concluded that *A. sesami* and *A. sesamicola* are two distinct species. *A. sesami* and *A. sesamicola* caused severe symptoms; seed germination and seedling stand was adversely affected. [Based on abstract]

REPUBLIC OF MOLDOVA

- G. Lupascu et al. (2019) screened 40 sesame genotypes in the treatment of the seeds with culture filtrate (CF) of the *Alternaria alternata* fungus. Of these, genotypes L1, Cubaneț 57 and Liano have the highest indices for such important agronomic characteristics as the number of capsules per plant (95-135) and the 1,000-seed

weight (3.01-3.91 g), which indicates the association of some valuable agronomic characters with resistance to pathogen, thus being quite attractive for breeding programs.

SUDAN

- N.M.A. Hamid (2006) identified the following fungus a from seed collected from 3 areas of Sudan: *Alternaria alternata.*
- H.I.H. Idriss (2016) collected farmer saved red and white sesame from 7 locations in Sudan. 14 different fungi representing ten genera were identified. One of the less frequent fungi was *Alternaria alternata*.

UNITED STATES

- E.E. Leppik and G. Sowell (1964) reported *Alternaria tenuis* had similar symptoms in sesame as *Alternaria sesami.* It attacks seedlings, stems of young plants, leaves, and green pods, causing considerable damage to plants and fruits. Occasionally seedlings and young plants are killed. From infected pods, it can penetrate into seed coats, where it remains viable until germination of the seed.
- K.A. Cochran comments, 2021: Many assume that any Alternaria on sesame in the USA must be *A. sesami.* However, *A. alternata* and other species of Alternaria may be the predominant species present depending on the region, environmental conditions, and other alternate host crops grown nearby. Beak length and other features of the spores is useful to differentiate species, though the resolution of these efforts can be limited when species are highly similar. In those cases, DNA identification is useful.

VENEZUELA

- B. Mazzani (1999) reported the following pathogen: *Alternaria tenuis.*

A3.1.1b *Alternaria sesami* (10 Dec 2021)

Synonym: *Macrosporium sesami*

Family: Pleosporaceae

Definition: Amount of tolerance to *Alternaria sesami* (E. Kawam.) Mohanty & Behera

(Anon. n.d.k) Leaf blight - *Alternaria sesami*

- Symptoms: Initially small, circular, reddish brown spots (1-8mm) appear on leaves which enlarge later and cover large area with concentric rings. The lower surfaces of the spots are greyish brown in color. In severe blighting defoliation occurs. Dark brown lesions can also be seen on petioles, stem and capsules. Infection of capsules results in premature splitting with shriveled seeds.
- Pathogen: The mycelium of the fungus is dull brown and septate and produce large number of pale grey-yellow conidiophores which are straight or curved. The conidia are light olive colored with transverse and longitudinal septa. These are around 3-5 septate and conidia are borne in chain over short conidiophore.
- Favorable Conditions: Low temperature (20-25˚C); high relative humidity; cloudy weather.
- Disease Cycle: The fungus is seedborne and also soilborne as it remains dormant in the infected plant debris.
- Management: Treat the seeds with thiram or Carbendazim at 2g/kg; spray Mancozeb at 2kg/ha or Iprodion 1L/ha.

(CAB International, 8 Apr 2021)

- Symptoms: Brown to black, round to irregular and often zonate lesions measuring up to 1 cm diam. are produced on the leaves and in severe attacks the leaves dry out and fall off. Stem lesions are either in the form of dark brown spots or streaks. Dark brown, circular lesions are produced on the capsules which can cause the capsule to drop. The most visible symptoms are the leaf spots which are dark, irregular patches mostly on the edges and tips of the leaves, but the stem rots can be more significant. *A. sesami* can cause seed rot, pre- and post-emergence losses as well as stem rot and leaf spots.
- As a predominantly seedborne disease the most important sanitary methods are to ensure that the seed is free of infection.
- All investigations into resistance to infection by *A. sesami* in sesame have found that no variety or cultivar is totally resistant, although some were more resistant than others.
- The mechanism of resistance has also been examined. A comparison between susceptible and resistant cultivars and found that wax, phenol and chlorophyll contents were higher, and reducing sugars and soluble nitrogen were lower, in resistant plants than in susceptible ones. Phytoalexins also appear to have a role. Aqueous leaf extract of neem (Azadirachta indica Juss.) provided the control of Alternaria leaf spot pathogen (Alternaria

sesami) of sesame. Treatment with this extract led to the changes in plant metabolism as leaves of the treated plants exhibited significantly high level of enzymes phenylalanine ammonialyase (PAL), peroxidase (PO) and content of phenolic compounds.

- Although considered an important fungal disease of sesame, there is little information about actual economic impact of *A. sesami*. Most of the common diseases of sesame cause yield losses of 20-40%. This yield loss is caused by the premature defoliation of the plants leading to smaller capsules and loss of capsules due to infection. Yield losses in Karnataka, India, due to Alternaria blight were 0.1-5.7g/100 fruits.

References:

INTERNATIONAL

- J.R. Morschel (1964) reported the following pathogen in the world: *Alternaria sesami* (Leaf spot) and *Macrosporium sesami*. [Cited by D.F. Beech, 1995a]
- E.A. Weiss (1971) reported *Alternaria sesami* is a major disease with worldwide distribution. It attacks the stems, leaves, and green capsules causing considerable damage, and my occasionally be severe enough to kill seedlings and young plants. Symptoms are dark-brown, spreading, water-soaked lesions which can often be traced the entire length of the stem. The lesions also occur on the midrib and even veins of leaves, which can be without the typical leaf-spots. In very severe attacks plants may be killed within a very short period after symptoms are first noticed, while milder attacks cause defoliation. It is seedborne. The incidence has been associated with high humidity.
- C. Wescott (1971) reported the following pathogen: leaf spots (*Alternaria sesami*).
- P. Neergaard (1979) reported the following pathogen caused a disease in sesame: *Alternaria sesami*. [Cited by G.S. Saharan, 1989]
- Anon. (2004a) IPGRI descriptor: 10.2.1. Biotic stress susceptibility to *Alternaria sesami.* (Leaf spot and blight)
  - In each case it is important to state the origin of the infestation or infection, i.e., natural, field inoculation, or laboratory. Also specify the causal organism and the corresponding symptoms. The susceptibility scale is as follows:
    - 1 = Very low or no visible sign of susceptibility
    - 3 = Low
    - 5 = Intermediate
    - 7 = High
    - 9 = Very high
  - The growth state, coded according to the list below at which each reaction was recorded should be appended to the record of that reaction.
    - 1 = Seed
    - 2 = Seedling
    - 3 = Pre-flowering
    - 4 = Early flowering
    - 5 = Mid-flowering
    - 6 = Late-flowering
    - 7 = Maturity
- C. Chattopadhyay et al. (2019) reported the following symptoms of *Alternaria sesami* (Alternaria leaf spot): The disease appears mainly on leaf blades as small, brown, round-to-irregular spots, varying from 1 to 8 mm in diameter. The spots later become larger and darker with concentric zonations demarcated with brown lines inside the spots on the upper surface. On the lower surface, the spots are lighter brown in color. Such spots often coalesce and may involve large portions of the blade, which become dry and are shed. Dark brown, spreading, water-soaked lesions can be seen on the entire length of the stem. The lesions also occur on the midrib and even on veins of leaves. In very severe attacks, plants may be killed within a very short period after symptoms are first noted, while milder attacks cause defoliation. Occasionally, seedlings and young plants are killed exhibiting pre- and postemergence damping-off.

  A. sesami may survive through seed up to 11 months, and it can also perpetuate in infected debris for nearly 11 months under field conditions (P.C. Agarwal et al. 2006 {India}, M.K. Naik et al. 2007 {India}). From infected capsules, A. sesami can penetrate into the seed coat, where it remains viable until germination of seed. The spores of the fungus attached to the seeds or capsule may serve to carry and disseminate the pathogen. The disease becomes most severe on plants established from seeds with 8% infection, and the disease severity increases with increased seed infection level (P.S. Ojiambo et al. 1999b, 2000b, 2003 {Kenya}). Though the infection process appears to be similar to other Alternaria species, culture filtrate from *A. sesami* reveals the

presence of a toxin, the tenuazonic acid (N.R. Rao and M. Vijayalakshmi 2000 {India}). Excessive rainfall favors the development of the disease. The fungus is restricted to sesame in its pathogenicity. Distinct physiological races have not been identified, although differential virulence among isolates of *A. sesami* has been described from India and the United States.

Two sprays of mancozeb at 0.25% (P.J. Mudingotto et al. 2002 {India}, T.S. Rajpurohit 2003 {India}) or a combination of mancozeb at 0.25% plus methyldemeton at 1 mL/L (T.S. Rajpurohit 2004b {India}) or mancozeb at 0.25% plus streptocycline at 0.025% (G. Shekharappa and P.V. Patil 2001a {India}) have been found to be effective in the management of Alternaria leaf spot of sesame with increase in yield of sesame crop.

- CAB International (accessed 12 Apr 2021) reported sesame was a host of *Alternaria sesami* (Blight of sesame).
- N. Ransingh et al. (2021) reported the following symptoms of *Alternaria sesame* Mohanty and Behera (Alternaria leaf spot): Brown colored spots of round to irregular shape varying from 1 to 8 mm in diameter are observed on leaf blade (U.N. Mohanty and N.N. Behera 1958 {India}). In the early stages of infection, minute brown spots appear on the leaf blade, which later became darker in color with concentric zonations demarcated with brown lines inside the spots on the upper surface. On the under surface, the spots are grayish-brown in color. These spots coalesce, including the leaf blade, and leads to drying and dropping off of the leaves. In the advance stage, shot holes appeared and the leaf blade breaks in an irregular manner. Spots on the stem and petioles are elongated. Affected floral buds fail to open, shriveled, and dried up. In the early stages, the effect of infection by the fungus includes a decline in photosynthetic area due to leaf damage. Damping-off is very common in the seedling stage (S.Z. Berry 1960 {United States}). Seedborne infection of pathogen may result in pre-emergence damping-off (G.S. Samuel et al. 1972b {India}). Premature defoliation affects growth and yield of plant adversely. Severe infection caused complete defoliation (S.J. Kolte 1985 {India})

  The pathogen survives in seeds and serves as primary inoculum for subsequent crops (P. Neergaard 1979 {Great Britain}). Due to a lack of commercial certified seeds, farmers plant their own seeds from previous harvests. The temperature of 25.9-33.7°C, relative humidity between 89 and 95% and a sufficient intermittent rainfall (1.2–12.8 mm in a meteorological week) is conducive for disease development. Prolonged high humidity and frequent rain favored spore's dispersal, infection, and development of leaf blight disease (P.S. Ojiambo et al. 1998, {Kenya}).

  Botanicals are an ecofriendly approach of management of disease. Bulb extract of garlic is a wonder for reducing this foliar disease. *Calotropis gigantia* (Crown flower) and *Ocimum sanctum* (Tulsi) plant extracts also works well in mycelial inhibition of *A. sesami* (Hemalatha 2006 {India}). Intercropping with maize minimizes the incidence of Alternaria leaf spot.

  Application of neem cake and Trichoderma viride in soil at the rate of 250 kg/ha and 2.5 kg/ha respectively along with seed treatment of *Trichoderma viride* followed by foliar spray of Azadirachtin @ 3 ml/l on 30 and 45 days after sowing is very effective.

  Spraying of fungicides against this disease is quite common. It is cheap, easy, and well accepted by farmers. Foliar Spraying of Mancozeb @ 0.2% and Propiconazole (0.1%) is highly effective against the disease. Systemic fungicide like carbendazim @ 0.2% or combination fungicide like Carbendazim + mancozeb @ 0.2% also works well.

AUSTRALIA

- D.F. Beech (1981c and 1995a) reported the presence *Alternaria sesami* (Alternaria leaf spot) and *Macrosporium sesami*.

BOLIVIA

- B. Carreno L. et al. (n.d.) in a grower guide reported *Alternaria sesami*. It primarily attacks the leaves, but is sometimes found on the petioles, stem, and seeds. The symptoms are dark stains that may join and form a large stain. At times they can cover 50% of the foliar area. Depending on the variety, the stains can change color from light brown to dark brown.

BRAZIL

- M.G.R. Faiad et al. (2002) examined seed from 416 accessions from 7 Brazilian states at 25°C under alternating black lights and darkness in a 12-hour photoperiod for 8 days. They found *Alternaria sesami.* They then examined 31 seed samples that had been stored for 5 and 9 years at 8°C and 25% RH. They found *Alternaria sesami.* They concluded the seed acts as a vehicle for pathogen dissemination.
- N.H.C. Arriel et al. (2009) reported *Alternaria sesami.* Symptoms are characterized by the presence of irregular brown spots on the leaves with concentric rings of necrotic tissue up to 2 cm in diameter and chlorotic halos at around the infection. These spots can coalesce, forming large areas of necrotic tissue. When the incidence is severe, they affect capsules and seeds, and the plant can be completely defoliated. That disease can also cause the death of young plants. Temperatures between 20 and 30°C and relative humidity of 85% are ideal conditions for the growth of the pathogen, which can be transmitted through the seed. The use of healthy seeds from fields free of pathogen, can contribute to reducing the incidence of this disease. Rotation and disposal of crop residues can reduce the disease incidence There is no information in the literature about the existence of sesame genotypes with significant levels of resistance to this disease.
- N.E.M. Beltrao et al. (2013) reported *Alternaria sesami.* This pathogen is restricted to sesame (N.A. Wulff and S.F. Pascholati, 2005). The disease occurs in tropical and subtropical regions, and the severity of the disease dependent on the plant's growth stage and environmental conditions. This fungus survives on seeds and can colonize them internally (E.J.B.N. Cardoso, 1968). They are characterized by the presence of brown, circular or irregularities in the leaves and stems, which can coalesce and lead to the area affected to necrosis, causing defoliation and plant death. At the capsules, when affected, often present concentric rings of necrotic tissue with a diameter of up to 2 cm (A.A. Cook, 1981).

BURKINA FASO

- M.M. Satour (1981) reported the presence of *Alternaria sesami* (Leafspot).

CHINA

- L.C. Tu (1985b) reported *Alternaria sesami* (Leaf spot).in Henan province with a damage level of 1 out of possible 3.
- L.L. Li (1988) reported *Macrosporium sesami* causes severe damage to sesame.
- H.M. Miao and H.Y. Liu (2010) reported the following pathogen: *Alternaria sesami.*

CUBA

- La Habana (2009) in a grower guide reported the following pathogen: *Alternaria sesami.*

EGYPT

- M.M. Satour (1981) reported the presence of *Alternaria sesami* (Leafspot).

ETHIOPIA

- T. Geremew et al. (2009) reported the following diseases are a minor problem: *Alternaria sesami* (Leaf spot).
- R.A. Bayisa (2020) evaluated the impact of *Bacillus velezensis* AR1 on *Alternaria sesami*. There were a total of 4 treatments (control - *A. sesami* alone, *Bacillus velezensis* AR1, dithianon (fungicide), and *Bacillus velezensis* with dithianon). The sole and alternate application of AR1 with fungicide reduced disease severity to less than 10%. Plant physiological traits also improved due to the plant growth promoting AR1. Induced plant defense-related biochemicals, i.e., total phenolic and flavonoid contents, were maximum in the plant subjected to AR1 and a fungicide. In addition, the concentration of leaf amino acid proline was doubled due to AR1 compared to the control. The concentration of the plant growth-regulating hormones gibberellic acid and indole acetic acid (IAA), as well as leaf chlorophyll, total nitrogen and phosphorus contents were also significantly increased by 203.86, 7.79, 0.31 mg gFW^{-1}, 0.15 and 0.13%, respectively, due to the treatments. Furthermore, postharvest soil

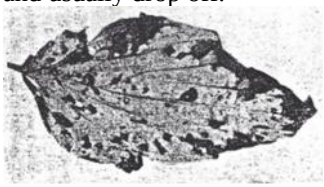
chitinase, cellulase and 1,3-β-glucanase activity results indicated the biological control and rapid soil colonization trends of AR1.

GUATEMALA

- Anon (1982a) A grower guide reported *Alternaria sesami* Kaw (Mancha de hoja) attacks the foliage.

INDIA

- N.N. Mohanty and B.C. Behera (1958a) reported *Alternaria sesami* (Sesame blight) is widespread in India and under moist conditions causes considerable damage. The pathogen closely resembles *Macrosporium sesami* with the difference that the conidia occur in chains. The disease manifests mainly on the leaf blade as brown, round to irregular spots varying from 1 to 8 mm in diameter. In early stages of infection, minute brown spots appear on the leaf blade which later become darker in color with concentric zonations demarcated with brown lines inside the spots on the upper surface. On the undersurface, the spots are greyish brown in color. In severe infections, several spots coalesce together involving a major portion of the leaf blade and the affected leaves dry and usually drop off.



- G.S. Samuel and C.V. Govindaswamy (1972a) reported vitamins tested did not have significant effect on the growth of *Alternaria sesami*. Good mycelial growth and sporulation was between 4-8 pH. 5 pH was best for mycelial growth and pH 7 for sporulation. [Cited by G.S. Saharan, 1989]
- E.V. Abraham et al. (1976) studied the effects of 2 foliar sprays of various insecticides were applied 40 and 60 days after sowing. In the kharif season (August-November), combinations of 0.2% Dithane M-45 (a mixture of maneb and zineb containing 16% manganese and 2% zinc) with endosulfan or fenthion at 0.5 kg/ha were effective in controlling powdery mildew (*Oidium sp*.), leaf blight (*Alternaria sesami*), *Aphis gossypii* Glov. and *Asphondylia sesami* Felt. In the rabi season (February-May), when the incidence of powdery mildew was high, combinations of 0.25% Miltox (a mixture of copper oxychloride and zineb) with endosulfan or fenthion at 0.5 kg were the best, followed by those of 0.2% Dithane M-45 with carbaryl at 1 kg/ha, or endosulfan or fenthion at 0.5 kg/ha. [Based on abstract]
- P.R. Mehta and B.N. Prasad (1976) reported sesame varieties. M3-2, NP 6, TMV-2, T 12 and Punjab til No.1 were susceptible *Alternaria sesami*, and typical symptoms were found on plants at all stages under highly humid conditions. Conidial morphology and germination studies are described. Oatmeal agar was the best solid and Richard's the best liquid medium at 25°C and the fungus grew best in the dark. Tillex and cuman effectively inhibited *in vitro* spore germination even at 0.1%. [Based on abstract]
- K.K. Kushi and M.N. Khare (1979a) reported among 26 samples, *Macrophomina phaseolina* was associated with 23, *Corynespora cassiicola* with 11 and *Alternaria sesami* with 10. Isolates of all 3 were pathogenic, resulting in seed rot, pre- and post-emergence losses, stem rot and leaf spots.
- N.D. Desai and S.N. Goyal (1981b) reported that No. 128 is resistant to *Alternaria sesami*.
- A.L. Siddaramaiah et al. (1981a) reported pathogenic isolates of *Alternaria sesami* from sesame leaves differed those from capsules in their growth on different media. Cultural characters suggested the occurrence of physiological strains of the fungus. [Cited by G.S. Saharan, 1989]
- A.L. Siddaramaiah et al. (1981b) reported sesame losses in Karnataka due to *Alternaria sesami* were 0.1-5.7 g/100 fruits. The number of shriveled seeds depended on disease severity. The fungus greatly reduced germination. JT-63-117, A-6-5, JT-66-276, Anand-9, JT-62-10, VT-43 and Anand-74 are resistant cultivars. [Cited by G.S. Saharan, 1989]
- A.L. Siddaramaiah et al. (1981c) studied the effects of sulphur and phosphorus compounds on growth and sporulation of *Alternaria sesami* and *Alternaria lini.* Potassium dihydrogen phosphate supported maximum growth followed by disodium hydrogen phosphate and dipotassium hydrogen orthophosphate. Maximum sporulation was supported by dipotassium hydrogen arthophosphate and disodium hydrogen phosphate.
- T. Singh and D. Singh (1983) isolated 24 fungi: Of these, *Alternaria sesami* was an important pathogens. [Cited by G.S. Saharan, 1989]
- R.K.S. Chauhan and B.M. Kulshrestha (1984b) reported the diffusate obtained from the fruit cavities of sesame inoculated with a spore suspension of *Alternaria sesami* was inhibitory to the germination of spores. It inhibited the spore germination of *Aspergillus niger, Cladosporium cladosporioides, Colletotrichum capsici, Curvularia*

lunata, Fusarium solani, Helminthosporium tetramera, Mycosphaerella rabiei, and *Rhizopus stolonifer*. No inhibition was caused by the extracts of healthy uninoculated fruits.

Fungus	Per cent inhibition in spore germination*		Inhibition over control %
	Phytoalexin	Control	
Alternaria sesami	88	25	63
Aspergillus niger	80	11	69
Cladosporium cladosporioides	85	44	41
Colletotrichum capsici	100	12	88
Curvularia lunata	69	0	69
Fusarium solani	82	17	65
Helminthosporium tetramera	100	0	100
Mycosphaerella rabiei	100	22	78
Rhizopus stolonifer	85	39	46

*Spore germination value is mean of 100 observations.

- U.V. Dolis and R.K. Hegde (1984b) reported visible symptoms of *Alternaria sesami* were apparent 3 days after germination, and disease development reached its peak when the crop was 35 days old. Evening RH and max. temp. were significant in disease development. Of 22 cultivars tested under conditions of natural infection, X-7732/10-2 developed the least disease (10.4%). In field trials the best control was achieved with Dithane M-45 [mancozeb] at 0.3%, applied 30, 45 and 60 days after sowing. [Based on abstract]
- K. Kumar et al. (1984a) reported *Alternaria sesami* was found to be associated with the seeds of varieties T-4 and T-12. The species was pathogenic and reduced germination by causing seed rot under laboratory conditions and produced brown necrotic spots on leaves.
- P.P. Gupta et al. (1985) in India studied wax, total phenols, reducing sugars, total soluble nitrogen, and chlorophyll content in relation the susceptibility to *Alternaria sesami* (Kaw) Mohanty and Behera. They used susceptible varieties (Pd Til No.1 and HRT-I) and tolerant varieties (RT-4-6 and HT-24). The samples were collected at 20 and 35 days (before disease appearance) and at 50 and 65 days (after disease appearance). In all the varieties, wax and phenols decreased while reducing sugars and nitrogen increased with the age of the plants. However, depending upon the plants' age and variety, the wax content was higher (1,480 to 1,600 ug/g) in the tolerant group as compared to the susceptible group (424 to 520 ug/g). Similarly, the phenol content in the tolerant group was also higher than in the susceptible while the levels of reducing sugars and total soluble nitrogen were found to be lower in the tolerant group than in the susceptible group. The total chlorophyll content was also observed to be higher (1,143 to 1,221 ug/g) in the tolerant group as compared to the susceptible group (931 to 1,068 ug/g). The results indicate the presence of higher amounts of wax and phenolics on the leaf surfaces probably resist the penetration and establishment of the pathogen. [Based on abstract]
- S. Maiti et al. (1985) reported leaf blight, *Alternaria sesami* is important.
- B.K. Vaidehi et al. (1985) reported culture filtrates of *Alternaria sesami* reduced germination percentage and root and shoot elongation of sesame with the maximum on the 30th day. [Cited by G.S. Saharan, 1989]
- M.L. Verma (1985) reported *Alternaria sesami* (*Macrosporium sesami*) (Alternaria leaf blight) is a major disease with the following symptoms: Black, round spots with concentric rings.
- B.M. Kulshrestha and R.K.S. Chauhan (1987 and 1988) studied some physico-chemical properties of the phytoalexin (Rf 0.14) produced by capsules of sesame in response to *Alternaria sesami* and its chemical induction. They showed they were fungicidal to conidia of *A. sesami*. The phytoalexin was inactivated by exposure to UV radiation but not by high temperatures. Its production could be induced by the addition of a range of chemicals. [Cited by G.S. Saharan, 1989, and CABI, 2021]
- A.R. Wasnikar et al. (1987) reported the influence of fungi varied for seed and soil contamination: *Alternaria sesami*: 58 and 60%. [Based on abstract]
- A.R. Wasnikar et al. (1988) reported media were prepared with various C and N contents. In general, growth of *Alternaria sesami*, *Fusarium oxysporum* f. sp. *sesami*, *Helminthosporium sesami* and *Myrothecium roridum*, the most important pathogens of sesame, increased with C and N concentrations. [Based on abstract]
- Anon (1992a) in a grower guide reported *Alternaria sesami* (Alternaria leaf spot) appears when the crop is nearly one month old. Small brown spots with concentric rings are formed on the leaves; later increase in size and number causing defoliation.

- P. Kumar and U.S. Mishra (1992) reported sesame diseases were monitored in Uttar Pradesh. In 1987, 12 diseases were recorded and in 1988 powdery mildew [*Oidium sesami*] was also recorded. Leaf and stem spot caused by *Corynespora cassiicola* was the predominant disease (28%) followed by leaf spots caused by *Cercospora sesami* [*Mycosphaerella sesamicola*], *Xanthomonas* [*campestris* pv.] *sesami* and *Alternaria sesami* (11-18%). The remaining diseases reached disease intensities of 10%. Disease intensity was higher in 1987 than in 1988 due to drought. A new leaf spot disease caused by *Curvularia fallax* was recorded for the first time in India. Most of the common diseases of sesame caused yield losses of 20-40%. [Based on abstract]
- D. Dinakaran et al. (1994) screened 27 genotypes against *Alternaria sesami* and phyllody under field conditions. The genotypes IET 4, IET 6, AVT 3, VS 350, and VS 9104 were moderately resistant to Alternaria blight ranging from 17.3 to 23.3% incidence. The high incidence was 81.3%. Ten genotypes showed toleration to phyllody ranging from 13.5 to 20.0% with the high incidence of 35.7%. Only 1 genotype showed tolerance to both Alternaria blight and phyllody: VS350.
- D.A. Shambharkar et al. (1997) evaluated 30 genotypes from 9 countries for tolerance to *Alternaria sesami*, *Leveillula taurica*, *Macrophomina phaseolina*, and phyllody. The *Alternaria sesami* incidence ranged from 6.5 to 33.7%. The genotypes SIK-113 and SIK-104 from Kenya exhibited better tolerance under high as well as low input conditions. Other good genotypes were Krishna, Padma, and Tapi. These genotypes should be used for breeding programs.
- S. Guleria and A. Kumar (2000) reported induced resistance is an important component of disease-resistance response of plants and is accompanied by increased capability for activating defense responses upon pathogen ingress or elicitor treatment. Aqueous leaf extract of neem (*Azadirachta indica* Juss.) provided the control of Alternaria leaf spot pathogen (*Alternaria sesami*). Treatment with this extract led to the changes in plant metabolism as leaves of the treated plants exhibited significantly high level of enzymes phenylalanine ammonia lyase (PAL), peroxidase (PO) and content of phenolic compounds. Germination of *A. sesami* spores was not significantly inhibited by neem extract. It is therefore, suggested that protection of sesame plants against *A. sesami* by neem extract might be due to stimulation of plants natural defense response.
- T.S. Rajpurohit (2004b) evaluated the effects of plant extracts [Neem gold (0.3%) and Neem leaf extract (2%)] fungicides [Mancozeb (0.2%), Propiconazole (0.1%), Difenconazole (0.1%) and Penconazole (0.1%)] and in combination with an insecticide (Mancozeb at 0.25% + Methyl demeton at 1 ml/l) against *Alternaria sesami*, leaf curl, and phyllody in 2001 and 2003. Two years of pooled results indicated that all the treatments reduced significantly Alternaria blight (*Alternaria sesami*), phyllody and leaf curl (Nicotinia virus-10) diseases and increased seed yield as compared to the control. Two foliar sprays of Mancozeb at 0.25% + methyl demeton at 1 ml/l. reduced Alternaria blight from 39.35 to 10.1%, phyllody and leaf curl from 5.24 to 0.83% and increased seed yield from 416 to 721 kg/ha.
- M.K. Naik et al. (2007) collected seed and plant debris from plants infected with *Alternaria sesami*. The percent of seed infected declined over time but persisted until 59 weeks after harvest. The plant debris was kept in the laboratory and the fungus persisted for 18 months, in refrigerated conditions for 21 months, and in the field for 11 months. Since crops are normally replanted within 11 months, it would be expected that the fungi would persist and attack the subsequent sesame crop.

Table 1. Determination of seed borne nature of *A. sesami* in sesame seeds by Agar plate method

Sl No.	Weeks	Per cent seeds infected	Weeks	Per cent seeds infected
1	1st	34.13	32nd	07.50
2	2nd	33.46	33rd	07.20
3	3rd	32.10	34th	07.00
4	4th	33.17	35th	06.67
5	5th	32.15	36th	06.23
6	6th	30.70	37th	06.03
7	7th	28.10	38th	05.80
8	8th	26.93	39th	05.34
9	9th	25.71	40th	05.34
10	10th	26.43	41st	05.34
11	11th	23.17	42nd	05.34
12	12th	20.53	43rd	05.34
13	13th	18.47	44th	05.34
14	14th	17.10	45th	05.04
15	15th	15.33	46th	04.85
16	16th	15.10	47th	04.60
17	17th	12.74	48th	04.02
18	18th	10.17	49th	03.85
19	19th	11.40	50th	03.60
20	20th	09.43	51st	03.20
21	21st	09.70	52nd	03.01
22	22nd	09.31	53rd	02.80
23	23rd	09.23	54th	02.60
24	24th	09.10	55th	02.00
25	25th	09.10	56th	01.80
26	26th	09.08	57th	01.20
27	27th	08.86	58th	00.80
28	28th	08.84	59th	00.00
29	29th	08.04	60th	00.00
30	30th	08.00	61st	00.00
31	31st	07.80	32nd	07.50

Table 2. Detection of *A. sesami* in infected plant debris under three different Environments

Sl No.	Date	Recovery of fungus from the infected debris under different conditions		
		Field	Laboratory	Refrigerator
1	15	Present	Present	Present
2	15	Present	Present	Present
3	15	Present	Present	Present
4	15	Present	Present	Present
5	15	Present	Present	Present
6	15	Present	Present	Present
7	15	Present	Present	Present
8	15	Present	Present	Present
9	15	Present	Present	Present
10	15	Present	Present	Present
11	15	Present	Present	Present
12	15	Absent	Present	Present
13	15	Absent	Present	Present
14	15	Absent	Present	Present
15	15	Absent	Present	Present
16	15	Absent	Present	Present
17	15	Absent	Present	Present
18	15	Absent	Present	Present
19	15	Absent	Absent	Present
20	15	Absent	Absent	Present
21	15	Absent	Absent	Present
22	15	Absent	Absent	Absent
23	15	Absent	Absent	Absent

- A.S. Savitha et al. (2011) evaluated several isolates against *Alternaria sesami.* Among two *Trichoderma* isolates, maximum inhibition was noticed in *T. harzianum* to the extent of 87% followed by *T. viride*. Among four bacterial bioagents, an exogenous *Pseudomonas fluorescens* (Pf-E) was most efficient with 80% inhibition. Salicylic acid at 1% was found to be effective in suppressing the pathogen and resulted in higher vigour index (1138.28), followed by *P. fluorescens* (E) with good germination and vigour index of 97.75% and 1029.85, respectively. The higher vigour index is mainly due to increased germination, higher root and shoot growth by the systemic resistance inducing agents. [Based on abstract]
- A.S. Lubaina and K. Murugan (2012) reported induction of plant defense against pathogen attack is regulated by a complex network of different signals. The oxidative burst or rapid and transient production of large amount of reactive oxygen species (ROS) belongs to the fastest and earliest active defense responses to microbial infection known in plants. The aim of this study was to investigate the intensity and timing of the ROS formation, lipid peroxidation and expression of antioxidant enzymes as initial response of sesame against *Alternaria sesami*. The concentration of hydrogen peroxide (H_2O_2) was 384 times higher at 72 h post-inoculation and lipid peroxidation was 5.5 times higher at 72 h post-inoculation in the extracts of inoculated leaves than in the control. An increase in total phenolic content was also detected in inoculated leaves. The activities of the antioxidative enzymes, viz., superoxide dismutase (SOD, EC 1.15.1.1), catalase (CAT, EC 1.11.1.6), guaiacol peroxidase (GPX, EC 1.11.1.7) and ascorbate peroxidase (APX, EC 1.11.1.11), increased in response to pathogen inoculation. SOD activity at 72 h post-inoculation in leaves was 92 times than the control. CAT activity also showed a decrease after 24 hpi and the increase in activities of GPX and APX was insignificant after 24 h post-inoculation in the inoculated leaves. The oxidative burst generated in the interaction between sesame and *Alternaria sesami* may be an early first line of defense mounted against the invading pathogen. However, seemingly less efficient antioxidative system (particularly the decrease of CAT activity after 24 hour post-inoculation) leading to sustained accumulation of ROS and the observed higher rate of lipid peroxidation indicate that the biochemical events are largely in favor of the pathogen, thus making this

host–pathogen interaction a compatible combination. The oxidative burst served as a weapon for the pathogen because the antioxidative system was not significant enough to impede the pathogen ingress in the host.

- A.S. Savitha et al. (2012) reported *Alternaria sesami* (the incitant of leaf blight of sesame) produced toxic metabolite in culture. The toxin produced necrotic symptoms on sesame and tomato seedlings at various concentrations. The maximum inhibition of seed germination and shoot and root length was noticed at 2,000 ppm concentration. Least inhibition of root and shoot length was observed at 50 ppm concentration. Different resistance inducing chemicals were tested for inhibition of growth and induction of resistance. Among them, salicylic acid (10 mM) was effective in inhibiting the mycelial growth of *A. sesami* (68.8%). The least inhibition of mycelial growth was observed in potassium nitrate (55.81%). The resistance inducing chemicals, plant extracts and bioagents when tested *in vivo*, with challenge inoculation of *A. sesami*, salicylic acid at 1% concentration was found to be effective in suppressing the pathogen and resulted in higher vigor index (1138.28), which was followed by *Pseudomonas fluorescens* (E) with good germination per cent of 97.35 and vigor index of 1029.85. The higher vigor index obtained in these treatments is mainly due to their support for increased germination, good root and shoots growth by the systemic resistance inducing agents. [Based on abstract]
- R. Goudappagoudar et al. (2013) studied the inheritance of Alternaria blight (*Alternaria sesami*) resistance in sesame using straight and reciprocal crosses between RT-273 (resistant) and Gulbarga local black (susceptible) during Kharif-2007. Screening of F_2 and F_3 progenies against Alternaria blight, and segregation analysis showed that resistance is governed by single dominant gene. Further screening of F_4 families under field condition during Kharif-2010 confirmed the single dominant gene governing the Alternaria blight resistance in cultivated sesame.
- A.S. Lubaina and K. Murugan (2013a) evaluated the fungicidal effects of *Senna alata* aqueous leaf extracts *in vivo* and *in vitro* on *Alternaria sesami*. Both pot and field experimental condition evaluated disease severity and incidence, changes in the activity of defense related enzymes such as phenylalanine ammonia lyase (PAL), peroxidase (POX), polyphenol oxidase (PPO) and total phenolic content after 24 h from the last spray. Two fold increase in activities of these defense related enzymes was observed in sesame after *S. alata* leaf extract treatments. Both field and pot culture aqueous extract treatment of *S. alata* decreased the incidence and severity of disease in sesame. The results were as follow.

	Field data				Pot culture			
	Disease Incidence	Disease incidence	Disease severity	Disease severity	Disease Incidence	Disease incidence	Disease severity	Disease severity
Year	2011	2012	2011	2012	2011	2012	2011	2012
Senna	18.90 [b]	17.73 b	7.10 [b]	6.13 [b,c]	17.77 [c]	16.00 [b]	5.60 [c]	6.27 [c,d]
Mancozeb	11.20 [a]	10.77 [a]	3.20 [a]	2.73 [a]	10.33 [a]	10.57 [a]	3.53 [a]	2.97 [a]
Control	54.83 [c]	58.23 [d]	34.10 [d]	35.43 [e]	57.23 [d]	57.10 [c]	32.50 [c]	31.47 [d]
F	206.07	274.4	279.4	359	178.4	240.4	364.4	621.1
p-value	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

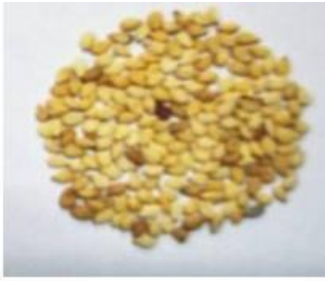
The values of the defense related enzymes were as follow.

Hour		Pot study					Field study				
		24	48	72	96	120	24	48	72	96	120
POX U g^{-1} fresh weight	T	16.4a	18.1a	21.5c	20.4c	19.6b	15.6a	17.2b	21.3d	19.9c	19.2c
	C	7.2a	8.3b	10.1c	9.8c	9.0b	7.4a	8.6b	11.1d	9.4c	8.9b
PPO U mg^{-1} protein	T	6.3a	8.4a	9.9b	9.1b	8.6a	10.1b	14.3d	12.5c	9.4a	8.2a
	C	3.5a	3.9b	4.4c	3.8b	3.9b	4.0a	4.5c	5.1c	4.1b	3.7a
PAL nmole cinnamic acid g^{-1} fresh weight	T	223a	239b	252d	243c	224a	288c	321d	384d	292c	246b
	C	108a	119b	128d	121c	113b	119a	131c	157d	140d	125b
Phenol µg gallic acid g^{-1} fresh wt	T	1238a	1315c	1301c	1298d	1264b	1332a	1421c	1386c	1334c	1264b
	C	548a	571b	607d	589c	578b	557a	578b	621d	594c	583a

- A.S. Lubaina and K. Murugan (2013b) studied conidium germination, inoculation, penetration and colonization of *Alternaria sesami* on plant surfaces. Multiple germ tubes from the conidium spread in all directions across the leaf surfaces. Penetration occurred through the epidermis or via stomata with or without appressoria formation. Hyphal penetration continued through the substomata cavity and some of the hyphal branches grew in the intercellular space of mesophyll tissue. Hyphal toxin caused cell and cell wall damages. There were structural changes in the chloroplast. There were changes in the chemical composition.
- P.L. Radha (2013) collected 18 cultivars from 7 districts in Karnataka, and identified the following fungi: *Alternaria sesami, Colletotrichum* sp., *Fusarium* sp., *Macrophomina phaseolina, Aspergillus niger, Aspergillus*

flavus, *Botrytis* sp., *Penicillium* sp., and *Mucor* sp. Apparently healthy and artificially inoculated (surface sterilized and apparently healthy seed) seed samples of sesame (cv. E-8) were used to demonstrate the effect of different seed inoculum levels on per cent leaf spot severity and to prove seed to plant transmission of *Alternaria sesami* in a glass house.

Infected seeds



Apparently Healthy seeds

(cv. E-8)

Germinations were measured at 25 ± 2ºC for six days with 12 hours light, 12 days. Seedling roots and shoots were measured to determine the vigor index (Seed germination % × seedling length [shoot +root length in cm]). The results were as follows.

Sl. No.	Treatment	Per cent germination	Per cent leaf spot	
			20DAS	30DAS
1.	T_1- Un-inoculated (Apparently healthy seeds)	88.75 (70.47)*	7.75 (16.14)*	11.25 (19.57)*
2.	T_2- Seeds soaked in $5x10^6$ conidia/10 ml	12.75 (20.86)	100.00 (90.00)	100.00 (90.00)
3.	T_3- Seeds soaked in $5x10^5$ conidia/10 ml	25.25 (30.10)	95.00 (78.93)	98.25 (84.73)
4.	T_4- Seeds soaked in $5x10^4$ conidia/10 ml	38.75 (38.47)	60.00 (50.78)	87.50 (69.82)
5.	T_5- Seeds soaked in $5x10^3$ conidia/10 ml	50.00 (44.99)	3.00 (9.90)	6.50 (14.76)
SEm±		1.21	1.86	1.96
CD @ 1%		5.04	7.78	8.16

* Arcsine transformed values

The antagonistic micro-organisms like *Trichoderma harzianum* Rifai., *Trichoderma viride* Pers., *Trichoderma koningii* Qudem., *Trichoderma virens* Miller., *Pseudomonas fluorescens* Migula., and *Bacillus subtilis* Cohn. were evaluated for their antagonistic effect under *in vitro* condition against *A. sesami* by dual culture technique. The results were as follows.

Bioagents	Per cent inhibition
Trichoderma harzianum	77.50 (61.66)*
Trichoderma viride	75.14 (60.07)
Trichoderma koenigii	73.19 (58.79)
Trichoderma virens	71.53 (57.73)
Pseudomonas fluorescens	36.22 (36.98)
Bacillus subtilis	52.02 (46.15)
S.Em±	0.90
CD at 1 %	2.51

* Arcsine transformed values

Efficacy of fungicides, botanicals and bio-agents were tested against seedborne fungal infections of sesame (variety E-8). The results were as follows.

Sl. No.	Treatments	Percent seed Infection	Percent seed germination	Vigour index
1.	Garlic	30.33 (33.43)*	70.00 (56.82)	517
2.	Ginger	26.67 (31.11)	74.33 (59.59)	591
3.	Hexaconazole	13.33 (21.42)	89.33 (70.97)	1208
4.	Tebuconazole	30.67 (33.65)	72.00 (58.08)	697
5.	Propiconazole	26.33 (30.89)	74.00 (59.37)	729
6.	*T. harzianum*	21.33 (27.52)	80.67 (63.95)	515
7.	*P. fluoroscencs*	25.00 (30.00)	75.33 (60.03)	828
8.	Avatar72WP (Hexazconazole 4% + Zineb 68%)	14.00 (21.89)	87.67 (69.48)	1027
9.	Taqat75WP(Captan70+Hexaconazole 5%)	25.00 (30.00)	78.33 (62.34)	429
10	Control (untreated seeds)	42.00 (40.41)	57.33 (49.24)	318
	S.Em±	**0.46**	**0.78**	**13.95**
	CD at 1 %	**2.16**	**3.71**	**69.38**

* Arcsine transformed values

- A.S. Savitha et al. (2013) obtained 14 isolates of *Alternaria* spp. from Raichur, Gulbarga, Dharwad, Bidar, Bangalore, Hyderabad and Coimbatore districts comprising of eight isolates *Alternaria alternata* and six isolates of *Alternaria sesami*. They were studied for cultural, morphological, physiological, pathogenic and genetic variability.
- K. Satyagopal et al. (2014) in an IPM manual reported *Alternaria sesami* symptoms were as follows:
  - The pathogen attacks all parts of the plant at all stages.
  - Small, dark brown water soaked, round to irregular lesions, with concentric rings, 1-8 mm in diameter appear on the leaves and under excessive atmospheric and soil humidity the spot increases in size and number.
  - The lesions may also appear on the midrib and veins of the leaves.
  - Milder attacks cause only defoliation, in severe cases the plant may die.

  The pathogen is seedborne. Temperature of 20-30° C and high humid conditions favor the disease.
  Cultural control: Avoid planting overlapping crops in adjacent area. Crop rotations, viz., sesame-maize, cabbage, okra-sesame-maize, maize-sesame-maize and sesame- finger millet-egg plant are reported effective in reducing disease incidence. Crop rotation with non-host crops, particularly with paddy. Provide good drainage. Seed treatment: Treatment with *Trichoderma* sp. @ 4 g/Kg of seed, *Pseudomonas fluorescens* @ 2 g/Kg seed, or *Bacillus subtilis* @ 2 g/Kg seed or NSKE 4%.
- K.N. Gupta et al. (2018) reported the disease caused by (*Alternaria sesami*) is one of the most common and economically important foliar diseases of sesame. It affects the plants at all stages and symptoms produce are small dark brown water soaked, round to irregular lesions with concentric rings varying from 1-8 mm in diameter. In severe infections several spots involving major portions of leaf blade and later drop off from the plants. The plants were observed to be most susceptible at 8-10 week's age. Dark brown spots are developed on cotyledons, water soaked circular or irregular brown spots on leaves, and brown stripes are formed on stem by the fungus. Resistant varieties are the best option for managing Alternaria blight. The disease may be alleviated by intercropping of sesame + pearl millet (3:1); early planting (immediately after onset of monsoon); and spraying Carbindazim 50wp (0.1%), Mancozeb (0.25%), or Carbindazim 50wp + Mancozeb 3 times when disease appear at 15 days interval.
- Anon. (n.d.k) reported *Alternaria sesami* (Leaf blight) causes a major disease.

IRAN

- M. Gooya et al. (2000) took one seed samples of each 17 sesame cultivars from 10 locations leading to 145 isolates during 1997/99 They identified *Alternaria sesami.*

IRAQ

- F. Al-Refaee (2005) collected sesame seeds from 6 regions of Iraq and isolated *Alternaria sesami.*

ISRAEL

- M.M. Satour (1981) reported the presence of *Alternaria sesami* (Leafspot).

JAPAN

- E. Kawamura (1931) reported *Macrosporium sesami* caused a leaf disease in sesame. [Cited by R.S. Vasudeva, 1961, and G.S. Saharan, 1989]
- M.M. Satour (1981) reported the presence of *Alternaria sesami* (Leafspot).
- T. Kuzuyuki (2021) reported the following pathogen: *Alternaria sesami* (Alternaria leaf blight).

KENYA

- H.A. Van Rheenen (1981d) reported the goal of developing resistance to *Alternaria sesami.*
- P.S. Ojiambo et al. (1997) reported the blotter oatmeal agar method was a better way to detect *Alternaria sesami* than the roll paper towel and the blotter methods.
- P.S. Ojiambo et al. (1998) evaluated six infection levels (0-8%) to determine the effect of transmission of the fungus by seed on disease severity in 1996 and 1997. They collected *Alternaria sesami* samples in Busia, Kakamega and Siay with the level of infection ranging from 9.0 to 24.2%. Disease was most severe on plants from seeds with highest infection level of 8% and least on plants from seeds with no infection. Severity of the disease increased with increase in seed infection. The following shows the mean area under disease progress curves for % leaf area blighted (AUDPC-DL) and % defoliation (AUDPC-DF).

	Season I March-June 1996		Season II July-October 1996	
Inoculum level (%)	AUDPC-DL	AUDPC-DF	AUDPC-DL	AUDPC-DF
0	0.18cde	0.35de	0.10bcde	0.20cde
2	0.35bcde	0.56bcde	0.33bcde	0.35bcde
4	0.59bcd	0.60abcde	0.60bcd	0.40abcd
5	1.41abc	0.80abc	1.39bc	0.48abc
7	1.95ab	0.89ab	1.59ab	0.55ab
8	2.30a	0.99a	2.26a	0.66a
Mean	1.13	0.70	1.04	0.44

- P.S. Ojiambo et al. (1999b) evaluated the effects of *Alternaria sesami* based on inoculation ages (4, 6, 8, 10, and 12 weeks after sowing) on the amount of leaf area and defoliation. The following shows the mean area under disease progress curves for % leaf area blighted (AUDPC-DL) and % defoliation (AUDPC-DF).

	Season 1		Season 2	
Plant age (weeks)	AUDPC-DL	AUDPC-DF	AUDPC-DL	AUDPC-DF
4	1.13cd	3.97bcd	0.98cd	2.16d
6	1.68cd	4.00bcd	1.20bcd	2.24bcd
8	3.86abc	4.73abc	2.55abc	3.34bc
10	6.29a	4.83ab	5.08a	3.38ab
12	5.45ab	5.30a	4.40ab	3.81a
Mean	3.68	4.56	2.84	2.98
C.V. (%)	35.10	29.70	45.30	32.50

- P.S. Ojiambo et al. (2000a and 2000b) evaluated the effects of six infection levels (0-8%) to determine the effect of transmission of *Alternaria sesami* by seed on yield and yield components. Disease severity was negatively correlated with seed yield, 1000-seed weight and seeds per capsule.

Seed infection (%)	Severity (AUDPC–DL)‡	Yield loss (%)	Yield (kg ha^{-1})	1000-seed weight (g)	Seeds per capsule	Capsules per plant
0	0.14	0	312.50	3.97	60.5	42.8
2	0.34	4	300.10	3.82	58.8	38.6
4	0.60	7	290.60	3.71	55.1	39.4
5	1.40	10	283.70	2.70	51.1	40.3
7	1.77	18	255.10	2.20	50.7	37.8
8	2.28	25	234.90	2.10	45.4	39.4
Mean			279.50	3.10	53.6	39.7
s.e.			4.90	0.35	2.3	0.7
Correlation coefficient (r)§			−0.81*	−0.89**	−0.86*	−0.37
Correlation coefficient (r)¶			0.81*	0.80*	0.58	

- P.S. Ojiambo et al. (2003) evaluated disease incidence caused by *Alternaria sesami* and seed infection on 6 varieties planted in March and October 1995 during the first and second rainy seasons. The results were as follow.

Accession	First season		Second season	
	Disease incidence (%)[a]	Seed infection (%)[b]	Disease incidence (%)	Seed infection (%)
SPS SIK 013	98a[c]	11.3a	92a	12.2a
SPS SIK 110	98a	11.2a	86a	7.6c
SPS SIK 121	100a	9.6ab	86a	9.8b
SPS SIK 130	100a	6.4b	69a	7.2c
SPS SIK 212	16b	0.0c	5b	0.0d
SPS SIK 238	0b	0.0c	0b	0.0d

MEXICO

- M.M. Satour (1981) reported the presence of *Alternaria sesami* (Leafspot).
- L.A. Moraila (2015) in a grower guide reported *Alternaria sesami* (Leaf spot) causes lesions on the leaves that present as sunken dark brown areas with concentric circles. At times they are also on the stem. It causes serious damage when there is high relative humidity.
- Agrolytics.org (2021) reported sesame hosts *Alternaria sesami.*

NIGERIA

- D. McDonald (1964) reported *Alternaria sesami* was one of the most virulent pathogens.
- H.A. Van Rheenen (1972) reported the leaf pathogen *Alternaria sesami* had the following symptoms: Brown spots of about 5 mm diameter occur on the stems, petioles, and leaves. Typical is the brown coloring of the vein pattern and the drooping of the leaves.
- F.M. Afolagboye (2011) reported the following fungus from 4 sesame varieties (NCRIBEN 03L, NCRIBEN 01M, E8 and 530-6-1) at Abeokuta: *Alternaria sesami.*
- O.A. Enikuomehin (pers. comm., 2021) reported the causal pathogen of Alternaria leaf blight is *Alternaria sesami*. Symptoms: Lesions appear as light to dark brown necrotic areas with yellow boarders on the leaf and could extend up to 12 mm in diameter at advanced stage. At early stages, necrotic lesions are delineated by leaf veins. Extensive blighting causes rapid defoliation. In most instances, both Cercospora leaf spot and Alternaria leaf blight may be found on the same infected plant.


PAKISTAN

- A.S. Shakir and M. Ansar (1992) studied 25 samples of seed collected from various areas in Punjab and found the following fungus: *Alternaria sesami.*
- K.H. Wagan et al. (2002) reported 4 species of seedborne fungi, that is *Alternaria sesami*, *A. sesamicola*, *Curvularia lunata* [*Cochliobolus lunatus*], and *Fusarium oxysporum* were isolated from infected seeds of sesame varieties PR-125, S-17, PR-19-9, and PR-14-2. The frequency of fungi was highest from PR-125 (25.63%) followed by S-17 (24.75%), PR-19-9 (23.13%) and PR-14-2 (22.5%). *A. sesami* was isolated as most predominant fungus according to its infection percentage (22.5-62.5). However, *C. lunata* was most frequently isolated from the variety PR-14-2. Maximum seed germination percentage (82.0) was obtained from the healthy seeds of PR-14-2 on filter paper followed by PR-125 (76.0), S-17 (67.0) and lowest from PR-19-9 (62.0). Vitigran blue [copper oxychloride] significantly (P=0.05) reduced the colony growth of the fungus followed by Liro-Manzeb [mancozeb], Dithane M-45 [mancozeb] and Topsin-M [thiophanate-methyl]. The number of spots

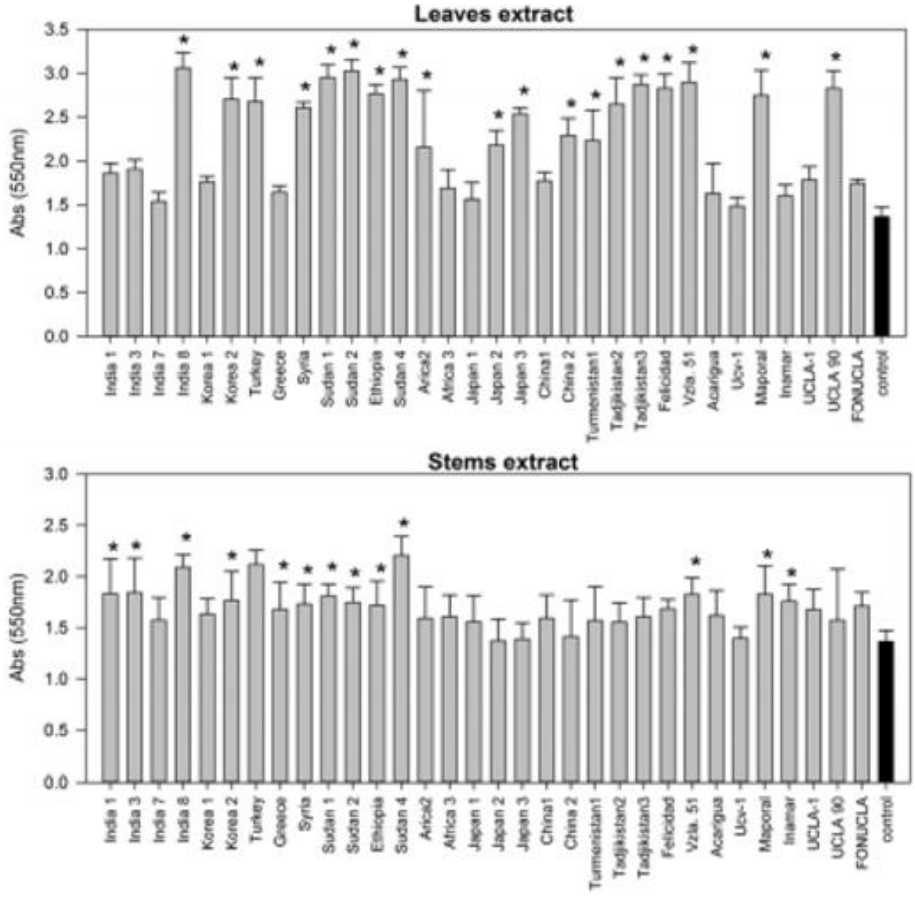
on 2-month-old inoculated plants was significantly (P=0.05) reduced by spraying with Vitigran blue compared to Liro-Manzeb, Dithane M-45 and Topsin-M.

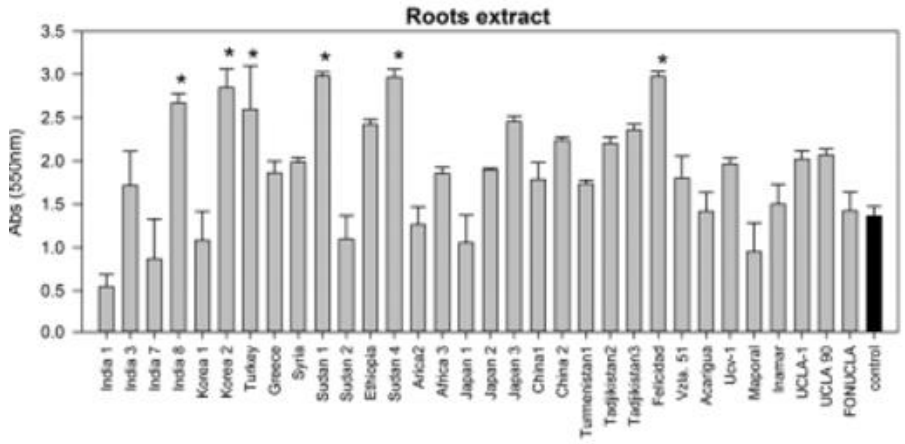
- N.R. Marri et al. (2012) evaluated 4 varieties (S-122, S-117, S-131 and Latifi) in pots and in the field in 2010 at Roze Din Marri (25.42N 68.58E). S-122 was highly resistant to *Alternaria sesami* in both experiments.
- A. Jan et al. (2014b) evaluated the effect of planting date (20th June, 10th and 30th July) and nitrogen (0, 40, 80 and 120 kg N/ha) on Alternaria leaf blight (*Alternaria sesami*) incidence and severity using a local white and a local black lines in 2012 at Peshawar (34.02N 71.52E). The results were as follow.

Treatment	*Alternaria leaf blight* incidence (%)	*Alternaria leaf blight* severity (%)	Oil content (%)	Oil yield (kg ha^{-1})	Seed yield (kg ha^{-1})	NUE
Sowing dates						
20th June	15 c	6 c	46	522 a	1135 a	19 a
10th July	77 a	45 a	45	195 b	433 b	7 b
30th July	34 b	22 b	45	138 c	306 c	5 c
LSD (0.05)	8.86	6.86	Ns	27.89	56.68	0.87
Sesame cultivars						
Local White	46 a	28 a	45 b	249 b	554 b	9 b
Local Black	37 b	20 b	47 a	335 a	696 a	12 a
Nitrogen(kg ha^{-1})						
0	34 d	18 d	40 d	136 d	339 d	-
40	39 c	23 c	44 c	268 c	609 c	15 a
80	45 b	27 b	48 b	345 b	718 b	9 b
120	49 a	31 a	52 a	433 a	833 a	7 c
LSD (0.05)	1.90	1.77	0.06	12.48	24.35	0.17

NUE = Nitrogen use efficiency

- R.N. Syed et al. (2015) evaluated leaf, stem, and root extracts from 32 lines with the aim of identifying genotypes with high content of metabolites potentially involved in resistance against fungal pathogens. The results for *Alternaria sesami* were as follow.





- B.G. Nayyar et al. (2017) – See this reference in *Alternaria alternata*, which reported that isolates identified as *Alternaria sesami* using morphological characterization were identified as *Alternaria alternata* using molecular analysis.

PARAGUAY

- L. Ayala et al. (2010, 2011, and 2013b) in grower guides reported the following pathogen: *Alternaria sesami.*
- Anon. (2015a) Paraguay descriptor: 1.10 Incidence of *Alternaria sesami.* The following ratings are used:
  - 0 = Sin informacion [No information]
  - 1 = Resistente [Resistant]
  - 2 = Medianamente resistente [Moderately resistant]
  - 3 = Medianamente susceptible [Moderately susceptible]
  - 4 = Susceptible [Susceptible]

REPUBLIC OF KOREA

- S.H. Yu (1981) reported the following fungi in sesame seed samples *Alternaria sesami, Alternaria sesamicola, Alternaria tenuis* (*Alternaria alternata*), *Corynespora cassiicola*, *Alternaria longissima*, *Fusarium oxysporum,* and *Macrophomina phaseolina*. All were controlled by pre-treatment with chlorine, except for *Corynespora cassiicola*. [Based on abstract and cited by G.S. Saharan, 1989]
- Y.H. Yu et al. (1982) reported *Alternaria sesami, A. sesamicola, A. tenuis*, and *A. longissima* were detected in Korean seed samples of *Sesamum indicum* L. *A. sesamicola* was the predominant species, seed infection in some samples ranging between 30 and 68%. *A. sesami* and *A. longissima* were recorded only in low percentages of 1–3%. Based on the original descriptions and the isolates studied, it is concluded that *A. sesami* and *A. sesamicola* are two distinct species. *A. sesami* and *A. sesamicola* caused severe symptoms; seed germination and seedling stand was adversely affected. [Based on abstract]

SUDAN

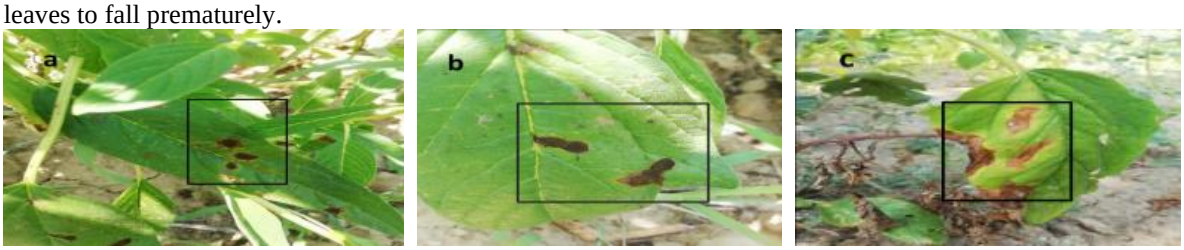
- M.M. Satour (1981) reported the presence of *Alternaria sesami* (Leafspot).
- N.M.A. Hamid (2006) identified the following fungus from seed collected from 3 areas of Sudan: *Alternaria sesami*.
- H.I.H. Idriss (2016) collected farmer saved red and white sesame from 7 locations in Sudan. 14 different fungi representing ten genera were identified. One of the predominant fungi was *Alternaria sesami*.
- A.R.C. Umaima (pers. comm. 2021): *Alternaria sesami* (Alternaria leaf blight) is a current problem. The symptoms are small, circular, reddish brown spots (1-8 mm) appear on leaves which enlarge later and cover large area with concentric rings and yellow hollow.

TANZANIA

- M.M. Satour (1981) reported the presence of *Alternaria sesami* (Leafspot).

TURKEY

- M. Esentepe et al. (1972) reported *Alternaria sesami* was isolated from diseased plants in Aydm. Seed infection was 16.5 to 63.5%. [Cited by G.S. Saharan, 1989]
- F. Akdeniz and H. Sert (2019) reported *Alternaria sesami* attacked leaves, seedlings, and stems of young plants. There were circular concentric rings with brown to dark brown color around the infection on the leaves. There were round or irregular, often zonate spots up to 3-6 mm diameter and frequently coalescing, often causing the leaves to fall prematurely.



- N. Isler et al. (n.d.) reported the following pathogen: *Alternaria sesami.* For control, plant early, remove residue, weed the crop.

UGANDA

- S.B. Mathur and F. Kabeer (1975) reported the following pathogen: *Alternaria sesami* had an infestation of 67-87% in the four genotypes.

UKRAINE

- I.V. Bohovik (1936) reported *Macrosporium sesami* caused a disease in sesame. [Cited by R.S. Vasuveda, 1961, and G.S. Saharan, 1989]

UNITED STATES

- M.M. Satour (1981) reported the presence of *Alternaria sesami* (Leafspot).
- T.W. Culp and C.A. Thomas (1964b) reported the following observations on *Alternaria sesami*:
  - Large, irregular-shaped, concentrically-zoned, light lesions which later coalesce and cause defoliation. Infection on the stem is characterized by light-brown, elongated lesions which later spread over the entire stems, causing death of the plants.
  - Usually occurs late in the season in Mississippi. The amount of damage is dependent on the stage of growth and environmental conditions at the time of the disease attack.
  - Ven 51 shows some resistance in that it is not attacked until mature.
  - Usually not possible to separate from *Corynespora cassiicola* under field conditions. Both diseases can occur on the same plant.
  - This and *Corynespora cassiicola* were believed to be beneficial because it got rid of the leaves at maturity, but then it attacked earlier producing immature seed (seed transmits the disease) and reducing yield in 5 varieties by an average of 49.5%.
  - Excessive rainfall and high humidity favor the blights, but dry years can hurt just as much since under moisture stress the plants become more susceptible. Additional irrigation may help.
  - The fungus is transferred by the seed. Seed treatments and crop rotation should be used.
- E.E. Leppik and G. Sowell (1964) reported the world trade of sesame seedborne fungi such as *Alternaria sesami* to be introduced into other countries. To prevent further spread of these diseases, quarantine regulations of international scope are needed. Existing quarantine measures, according to the present study, including seed

fumigation at the port of entry, are not adequate to prevent the entrance of these pathogens. *Alternaria sesami* attacks seedlings, stems of young plants, leaves, and green pods, causing considerable damage to plants and fruits. Occasionally seedlings and young plants are killed. From infected pods, it can penetrate into seed coats, where it remains viable until germination of the seed. Its spores, attached to seeds or included in wrapping material, may carry and disseminate the pathogen. Seed treatment with chemicals reduces the number of spores on seed but does not eliminate the infections inside the seed. Such treatment may help reduce the disease in commercial plantings but is not sufficiently effective for quarantine purposes.

- D.T. Smith et al. (2000) reported the following pathogen: *Alternaria sesami.*
- Anon. (2015c) USA PVP descriptor: 7. Diseases – Alternaria leaf spot (*Alternaria sesami)* – Mandatory. The following ratings are used:
  - 0 = Not tested
  - 1 = Susceptible
  - 2 = Low resistance
  - 3 = Moderate resistance
  - 4 = High resistance
- D.R. Langham comments, 2021: Most of my experience in sesame in the USA has been in Arizona, Texas, and Oklahoma in the areas where there was little rainfall and low humidity. Leaf spots did show up occasionally, but they were not an economic problem, and so I never bothered to determine if they were from *Alternaria sesami* or *Cercospora sesami*, even though C. Stichler once showed me the difference. When I did find lines with many leaf spots, I eliminated them from the breeding program.
- K.A. Cochran comments, 2021: Many assume that any Alternaria on sesame in the USA must be *A. sesami.* However, *A. alternata* and other species of Alternaria may be the predominant species present depending on the region, environmental conditions, and other alternate host crops grown nearby. Beak length and other features of the spores is useful to differentiate species, though the resolution of these efforts can be limited when species are highly similar. In those cases, DNA identification is useful.

VENEZUELA

- B. Mazzani et al. (1981b) reported the presence of *Alternaria sesami* (Zonate leaf spot) is one of the major diseases.
- A.M. Colmenares and L. Subero (1989a) reported the following pathogens: *Alternaria sesami* (Irregular spot). It produces irregular or rounded dark brown spots with concentric rings on the leaves. The stem and capsules are also affected by this disease where elongated and hollow brown spots appear.

A3.1.1c *Alternaria sesamicola* (8 Apr 2021)

Family: Pleosporaceae

Definition: Amount of tolerance to *Alternaria sesamicola* Kawamura 1931.

References:

INTERNATIONAL

- J.R. Morschel (1964) reported the following pathogen in the world: *Alternaria sesamicola* (On stems). [Cited by D.F. Beech. 1995a]
- CAB International (accessed 12 Apr 2021) reported sesame was a host of *Alternaria sesamicola* (Zonate: sesame leaf spot).
- N. Ransingh et al. (2021) reported 3 species of Alternaria (*A. longissima, A. alternata* and *A. sesamicola*) infect sesame, inducing symptoms such as foliage blight, stem necrosis, and spots on capsules. All 3 species also reduced seed germination and seedling stand.

CHINA

- L.L. Li (1988) reported *Alternaria sesamicola* (Black spot) causes minor or regional damage to sesame.

INDIA

- P.K. Dey (1948) reported *Alternaria sesamicola* caused a disease in sesame. [Cited by R.S. Vasudeva, 1961]
- D. Singh et al. (1980) found dormant mycelia of *Alternaria sesamicola* in the sub-epidermal layer of the seed coat and occasionally in the endosperm and embryo. In severely infected seeds, it was found to enter the seed

through the hilum and invaded all parts of the seed and even sporulated within the seed. The thick inner cuticle of seed coat and the outer cuticle of endosperm appeared to resist its inward penetration. [Based on abstract]

- S. Maiti et al. (1985 and 1986) reported the following minor pathogen: Leaf spot blight *Alternaria sesamicola* (Kaw.) Hans.
- M.L. Verma (1985) reported *Alternaria sesamicola* (Leaf spot) is a minor disease with the following symptoms: Leaf spot, leaf spot water soaked, brown, later with yellow halo.
- N.O. Srikantappa et al. (2009) studied 28 samples of sesame taken from fields, farmers, retail shops and APMC markets from 5 areas. They found 34 four fungi including *Alternaria sesamicola.* The fungi significantly reduced germination.

JAPAN

- E. Kawamura (1931) reported *Alternaria sesamicola* caused a disease in sesame. [Cited by R.S. Vasudeva, 1961]
- Anon. (2015e) NIAS Genebank Japan descriptor: 3.3 Bacterial leaf spot resistance. Secondary essential character. Observation and measurement of a block. The degree of resistance to *Alternaria sesamicola* Kawamura in field of in injection tests. The following are the ratings to be used
  - 1 = Very low
  - 3 = Low
  - 4 = Slightly low
  - 5 = Intermediate
  - 6 = Slightly high
  - 7 = High
  - 9 = Very high
- T. Kuzuyuki (2021) cited the following pathogen *Alternaria sesamicola* (Leaf spot) is listed in the Database of Plant Diseases in Japan.

NIGERIA

- O.A. Enikuomehin (2010) evaluated the effectiveness of seedborne fungi control by plant extracts of leaves (*Azadirachta indica, Vernonia amygdalina, Musa paradisiaca* and *Anacardium occidentales*) and synthetic fungicides (Team [Carbendazin 12% + Mancozeb 63%] and Ridomil [Metalaxyl 60g + 60 g CuO_2]) using two sesame cultivars (530-6-1 and NCRIBEN-03L). All plant extracts significantly ($P \leq 0.05$) reduced the fungal infection of seeds. *A. indica* leaf extract was comparable to the synthetic fungicides in reducing fungal infection of seeds. Leaf extracts of *A. occidentales* and *M. parasitica* enhanced significant ($P \leq 0.05$) seedling emergence. *Alternaria sesamicola, Curvularia lunata* and *Fusarium* spp. were most sensitive to *A. indica* and *M. paradisiaca* leaf extracts. [Based on abstract]

PAKISTAN

- K.H. Wagan et al. (2002) reported 4 species of seedborne fungi, that is *Alternaria sesami*, *A. sesamicola*, *Curvularia lunata* [*Cochliobolus lunatus*], and *Fusarium oxysporum* were isolated from infected seeds of sesame varieties PR-125, S-17, PR-19-9, and PR-14-2. The frequency of fungi was highest from PR-125 (25.63%) followed by S-17 (24.75%), PR-19-9 (23.13%) and PR-14-2 (22.5%). *A. sesami* was isolated as most predominant fungus according to its infection percentage (22.5-62.5). However, *C. lunata* was most frequently isolated from the variety PR-14-2. Maximum seed germination percentage (82.0) was obtained from the healthy seeds of PR-14-2 on filter paper followed by PR-125 (76.0), S-17 (67.0) and lowest from PR-19-9 (62.0). Vitigran blue [copper oxychloride] significantly (P=0.05) reduced the colony growth of the fungus followed by Liro-Manzeb [mancozeb], Dithane M-45 [mancozeb] and Topsin-M [thiophanate-methyl]. The number of spots on 2-month-old inoculated plants was significantly (P=0.05) reduced by spraying with Vitigran blue compared to Liro-Manzeb, Dithane M-45 and Topsin-M.
- B.G. Nayyar et al. (2017) analyzed a total of 428 *Alternaria* isolates obtained from 105 seed samples and grouped into 36 distinct taxonomic groups based on growth pattern and morphological characters and identified the following species: *Alternaria sesamicola.*

REPUBLIC OF KOREA

- S.H. Yu (1981) reported the following fungi in sesame seed samples *Alternaria sesami, Alternaria sesamicola, Alternaria tenuis* (*Alternaria alternata*), *Corynespora cassiicola*, *Alternaria longissima*, *Fusarium oxysporum*, and *Macrophomina phaseolina*. All were controlled by pre-treatment with chlorine, except for *Corynespora cassiicola*. *Alternaria sesamicola* produced mild to severe leaf spotting and blight when conidial suspensions were sprayed on plants. [Based on abstract and cited by G.S. Saharan, 1989]

- Y.H. Yu et al. (1982) reported *Alternaria sesami, A. sesamicola, A. tenuis*, and *A. longissima* were detected in Korean seed samples of *Sesamum indicum* L. *A. sesamicola* was the predominant species, seed infection in some samples ranging between 30 and 68%. *A. sesami* and *A. longissima* were recorded only in low percentages of 1–3%. Based on the original descriptions and the isolates studied, it is concluded that *A. sesami* and *A. sesamicola* are two distinct species. *A. sesami* and *A. sesamicola* caused severe symptoms; seed germination and seedling stand was adversely affected. [Based on abstract]
- CAB International (accessed 12 Apr 2021) reported *Alternaria sesamicola* is present in the Republic of Korea.

SUDAN
- M.A.F. Khamees and E. Schlosser (1990) reported testing of 165 Sudanese sesame seed samples showed that although seedborne pathogens such as *Alternaria sesamicola* and *Macrophomina phaseolina* were widespread in the country, their incidence was generally only at a low level. [Based on abstract]

UGANDA
- C.G. Hansford (1931, 1938, 1939, 1940, and 1943) reported the following pathogen: *Alternaria sesamicola.* [Cited by G.S. Saharan, 1989 and R.S. Vasuveda, 1961]
- D. Singh et al. (1983) reported seed infection with *Alternaria sesamicola* caused pre and post emergence loss of young seedlings and death of older plants. In a test sample of infested seed, those which failed to germinate were covered with conidia of the fungus. The pathogen was isolated from normal appearing as well as stunted plants indicating that it can invade the whole plant system without showing symptoms, and that seed from symptomless plants are not necessarily pathogen free. Stunted plants with brown-black lesions bore no flowers. [Cited by G.S. Saharan, 1989]

VENEZUELA
- G. Malaguti et al. (1972) reported inoculation with *Alternaria sesamicola* resulted in a severe foliage blight and stem canker or necrosis in addition to the characteristic of zonate leaf spots. Of 10 cultivars tested, Venezuela 51 was the least susceptible. [Cited by G.S. Saharan, 1989]
- G. Malaguti (1973) reported the following leaf disease: zonate leaf spot (*Alternaria sesamicola*). [Cited by G.S. Saharan, 1989]
- B. Mazzani (1999) reported the following pathogen: *Alternaria sesamicola.* He reported minor susceptibility in Maporal, Morada id, Acarigua, and Inamar.

A3.1.1d *Alternaria longissima* (8 Apr 2021)

Family: Pleosporaceae

Definition: Amount of tolerance to *Alternaria* longissima Deighton & MacGarvie 1968.

References:

INTERNATIONAL
- N. Ransingh et al. (2021) reported 3 species of Alternaria (*A. longissima, A. alternata* and *A. sesamicola*) infect sesame, inducing symptoms such as foliage blight, stem necrosis, and spots on capsules. All 3 species also reduced seed germination and seedling stand.

PAKISTAN
- B.G. Nayyar et al. (2017) analyzed a total of 428 *Alternaria* isolates obtained from 105 seed samples and grouped into 36 distinct taxonomic groups based on growth pattern and morphological characters and identified the following species: *Alternaria longissimi.*

REPUBLIC OF KOREA
- S.H. Yu (1981) reported the following fungi in sesame seed samples *Alternaria sesami, Alternaria sesamicola, Alternaria tenuis* (*Alternaria alternata*), *Corynespora cassiicola*, *Alternaria longissima*, *Fusarium oxysporum*, and *Macrophomina phaseolina*. All were controlled by pre-treatment with chlorine, except for *Corynespora cassiicola*. *Alternaria longissima* produced mild to severe leaf spotting and blight when conidial suspensions were sprayed on plants. [Based on abstract and cited by G.S. Saharan, 1989]
- Y.H. Yu et al. (1982) reported *Alternaria sesami, A. sesamicola, A. tenuis*, and *A. longissima* were detected in Korean seed samples of *Sesamum indicum* L. *A. sesamicola* was the predominant species, seed infection in some samples ranging between 30 and 68%. *A. sesami* and *A. longissima* were recorded only in low percentages

of 1–3%. Based on the original descriptions and the isolates studied, it is concluded that *A. sesami* and *A. sesamicola* are two distinct species. *A. sesami* and *A. sesamicola* caused severe symptoms; seed germination and seedling stand was adversely affected. [Based on abstract]

A3.1.1e *Alternaria simsimi* (8 Apr 2021)

Family: Pleosporaceae

Definition: Amount of tolerance to *Alternaria simsimi* Simmons 2004.

References:

MEXICO

- Agrolytics.org (2021) reported sesame hosts *Alternaria simsimi*.

REPUBLIC OF KOREA

- Y.P. Choi et al. (2014) reported the first record of *Alternaria simsimi* caused spot symptoms on leaves and stems of sesame plants 2 weeks after artificial inoculation, which were similar to those observed in the field in 2009 and 2010.


A3.1.1f *Alternaria japonica* (2 Oct 2021)

Synonym: *Alternaria raphani*

Family: Pleosporaceae

Definition: Amount of tolerance to *Alternaria japonica* Yoshii 1941.

(Wikipedia, 2 Oct 2021) ***Alternaria japonica*** is a fungal plant pathogen. It is a cause of black spot disease in cruciferous plants. It is not a major source of crop loss but is considered dangerous for plants during the seedling stage.

References:

IRAN

- M. Gooya et al. (2000) took one seed samples of each 17 sesame cultivars from 10 locations leading to 145 isolates during 1997/99 They identified *Alternaria raphani*.

IRAQ

- N.A. Saad et al. (2013) examined seed and found *Alternaria* fungi were the most prevalent, and *Alternaria alternata*, *Alternaria raphani*, *Alternaria citri*, and *Alternaria tenuissima* killed the following percentages of seed: 62, 59, 66, and 60% compared to the control of 0%.

PAKISTAN

- B.G. Nayyar et al. (2017) analyzed a total of 428 *Alternaria* isolates obtained from 105 seed samples and grouped into 36 distinct taxonomic groups based on growth pattern and morphological characters and identified the following species: *Alternaria raphani*.

A3.1.1g *Alternaria citri* (28 Apr 2021)

Family: Pleosporaceae

Definition: Amount of tolerance to *Alternaria citri* Ellis & N. Pierce 1902.

(Wikipedia, 28 Apr 2021) *Alternaria citri* is an ascomycete fungal plant pathogen that causes black rot in citrus plants. Specifically, certain lemon, lime, orange, mandarin and grapefruit species are susceptible hosts for this pathogen. The host is more susceptible to disease under ideal environmental conditions consisting of dry, warm summers and cool, moist winters. One symptom of the pathogen is the black rot that is produced. The black hyphae that forms on the surface of the plant is a sign of the actual pathogen. While healthy and uninfected fruits will display a particular hue, a plant infected by *A. citri* will possess atypical and usually more brightly colored fruits which signifies presence of the pathogen. Little research on the specific disease cycle of *Alternaria citri* has been conducted because its life cycle is so similar to *Alternaria alternata.*

References:

IRAQ

- N.A. Saad et al. (2013) examined seed and found *Alternaria* fungi were the most prevalent, and *Alternaria alternata*, *Alternaria raphani*, *Alternaria citri*, and *Alternaria tenuissima* killed the following percentages of seed: 62, 59, 66, and 60% compared to the control of 0%.

PAKISTAN

- B.G. Nayyar et al. (2013) examined 15 samples of seed to detect fungi using 3 methods: agar plate, blotter, and deep freezing and found *Alternaria citri.*
- B.G. Nayyar et al. (2017) analyzed a total of 428 *Alternaria* isolates obtained from 105 seed samples and grouped into 36 distinct taxonomic groups based on growth pattern and morphological characters and identified the following species: *Alternaria citri.*

A3.1.1h *Alternaria tenuissima* (28 Apr 2021)

Family: Pleosporaceae

Definition: Amount of tolerance to *Alternaria tenuissima* (Kunze) Wiltshire 1933.

(Wikipedia, 28 Apr 2021) ***Alternaria tenuissima*** is a saprophytic fungus and opportunistic plant pathogen. It is cosmopolitan in distribution and can colonize a wide range of plant hosts. Colonies of *A. tenuissima* produce chains on agar growth media. The fungus often forms concentric ring patterns on infected plant leaves. This species produces the allergen Alt a 1, one of the most important outdoor seasonal fungal allergens associated with allergy and asthma provocation. In rare circumstances, this species is also known to infect immunosuppressed humans and animals.

References:

MEXICO

- Agrolytics.org (2021) reported sesame hosts *Alternaria tenuissima*.

INDIA

- V. Bharathi et al. (2013) collected sesame seeds from farmers in Andhra Pradesh. They tested the seeds for mycoflora and found: *Alternaria tenuissima.*

IRAQ

- N.A. Saad et al. (2013) examined seed and found *Alternaria* fungi were the most prevalent, and *Alternaria alternata*, *Alternaria raphani*, *Alternaria citri*, and *Alternaria tenuissima* killed the following percentages of seed: 62, 59, 66, and 60% compared to the control of 0%.

PAKISTAN

- B.G. Nayyar et al. (2017) analyzed a total of 428 *Alternaria* isolates obtained from 105 seed samples and grouped into 36 distinct taxonomic groups based on growth pattern and morphological characters and identified the following species: *Alternaria tenuissima.*

A3.1.1i *Alternaria brassicae* (8 May 2021)

Synonym: *Alternaria macrosporum*

Family: Pleosporaceae

Definition: Amount of tolerance to *Alternaria brassicae* (Berkeley) Saccardo 1880.

(Wikipedia, 8 May 2021) ***Alternaria brassicae*** is a plant pathogen able to infect most *Brassica* species including important crops such as broccoli, cabbage and oil seed rape. It causes damping off if infection occurs in younger plants and less severe leaf spot symptoms on infections of older plants

References:

EGYPT

- A. Hashem et al. (2014) collected 18 seed samples of sesame in Egypt (12 samples) and Saudi Arabia (6 samples). They identified the following mycoflora: *Alternaria brassicae.*

INDIA

- M.K. Naik et al. (2017) reported sesame production, particularly in India, has been declining since last decade and 'Leaf blight' caused by *Alternaria* spp. is reported to cause yield loss up to 30-40%. They investigated the fungal toxin produced by Alternaria and its pathogenicity. A total of 164 Alternaria strains (*A. alternata* [39], *A. brassicae* [10], *A. porri* [6], *A. tenuissima* [03], *A. sesami* [1] and *Alternaria* sp. [72]) were isolated on potato dextrose agar media from the infected sesame leaves showing circular concentric rings with dark brown spots symptoms. Among 164 isolates, 23 showed toxigenicity, varied from highly toxigenic (*A. alternata*) to least toxigenic (*A. brassicae*). [For more information see Naik in *Alternata* spp. above]

ISRAEL

- G. Minz and Z. Solel (1959) reported that leaf spot, shot hole, and podspots caused by *Alternaria macrosporum* is present. [Cited by E.A. Weiss, 1971, and G.S. Saharan, 1989]

PAKISTAN

- B.G. Nayyar et al. (2017) – See this reference in *Alternaria alternata*, which reported that isolates identified as *Alternaria brassicae* using morphological characterization were identified as *Alternaria alternata* using molecular analysis.

A3.1.1j *Alternaria solani* (4 Jun 2021)

Family: Pleosporaceae

Definition: Amount of tolerance to *Alternaria solani* Sorauer 1896.

(Wikipedia, 4 Jun 2021) ***Alternaria solani*** is a fungal pathogen that produces a disease in tomato and potato plants called **early blight**. The pathogen produces distinctive "bullseye" patterned leaf spots and can also cause stem lesions and fruit rot on tomato and tuber blight on potato. Despite the name "early," foliar symptoms usually occur on older leaves. If uncontrolled, early blight can cause significant yield reductions. Primary methods of controlling this disease include preventing long periods of wetness on leaf surfaces and applying fungicides. Early blight can also be caused by ***Alternaria tomatophila***, which is more virulent on stems and leaves of tomato plants than ***Alternaria solani***.

References:

COSTA RICA

- R. Mendez (1940) recorded *Alternaria solani* with a secondary infection of *Helminthosporium sesami*. Excessive atmospheric and soil humidity appears to be the chief contributing factor in severe outbreaks of leaf spot and control should be based in the first place on selection of ecologically appropriate sites, supplemented by such cultural measures as use of healthy seed (treated with a standard fungicides) of resistant early maturing varieties of medium stature, sowing in rows and not at random. [Cited by G.S. Saharan, 1989]

EGYPT

- A. Hashem et al. (2014) collected 18 seed samples of sesame in Egypt (12 samples) and Saudi Arabia (6 samples). They identified *Alternaria solani.*

PAKISTAN

- B.G. Nayyar et al. (2017) analyzed a total of 428 *Alternaria* isolates obtained from 105 seed samples and grouped into 36 distinct taxonomic groups based on growth pattern and morphological characters and identified the following species: *Alternaria solani.*

SUDAN

- H.I.H. Idriss (2016) collected farmer saved red and white sesame from 7 locations in Sudan. 14 different fungi representing ten genera were identified. *Alternaria solani* was categorized as a low frequency of occurrence fungi.

UNKNOWN

- Jones and Grout-Mendez reported *Alternaria solani* caused a disease in sesame. [Cited by R.S. Vasudeva, 1961]

A3.1.1k *Alternaria lini* (3 Jul 2021)

Family: Pleosporaceae

Definition: Amount of tolerance to *Alternaria lini* Dey 1933.

References:

INDIA

- A.L. Siddaramaiah et al. (1981c) studied the effects of sulphur and phosphorus compounds on growth and sporulation of *Alternaria sesami* and *Alternaria lini.* Potassium dihydrogen phosphate supported maximum growth followed by disodium hydrogen phosphate and dipotassium hydrogen orthophosphate. Maximum sporulation was supported by dipotassium hydrogen arthophosphate and disodium hydrogen phosphate.

A3.1.1l *Alternaria brassicicola* (20 Aug 2021)

Family: Pleosporaceae

Definition: Amount of tolerance to *Alternaria brassicicola* (Schwein.) Wiltshire.

(Wikipedia, 20 Aug 2021) ***Alternaria brassicicola*** is a fungal necrotrophic plant pathogen that causes black spot disease on a wide range of hosts, particularly in the genus of *Brassica*, including a number of economically important crops such as cabbage, Chinese cabbage, cauliflower, oilseeds, broccoli and canola. Although mainly known as a significant plant pathogen, it also contributes to various respiratory allergic conditions such as asthma and rhinoconjunctivitis. Despite the presence of mating genes, no sexual reproductive stage has been reported for this fungus. In terms of geography, it is most likely to be found in tropical and sub-tropical regions, but also in places with high rain and humidity such as Poland. It has also been found in Taiwan and Israel. Its main mode of propagation is vegetative. The resulting conidia reside in the soil, air and water. These spores are extremely resilient and can overwinter on crop debris and overwintering herbaceous plants.

References:

PAKISTAN

- N. Altaf et al. (2004) tested 400 seeds from each of 10 cultivars for seedborne mycoflora. Eleven phytopathogenic fungi were found to include: *Alternaria brassicola.* [Authors comment: the reference says '*brassicola*', but all references use '*brassicicola*'.
- B.G. Nayyar et al. (2017) analyzed a total of 428 *Alternaria* isolates obtained from 105 seed samples and grouped into 36 distinct taxonomic groups based on growth pattern and morphological characters and identified the following species: *Alternaria brassicicola.*

A3.1.1m *Alternaria radicina* (2 Oct 2021)

Family: Pleosporaceae

Definition: Amount of tolerance to *Alternaria radicina* Meier, Drechsler & E.D. Eddy 1922.

(Wikipedia, 2 Oct 2021): ***Alternaria radicina*** is a fungal plant pathogen infecting carrots.

References:

PAKISTAN

- N. Altaf et al. (2004) tested 400 seeds from each of 10 cultivars for seedborne mycoflora. Eleven phytopathogenic fungi were found to include: *Alternaria redicina.*
- B.G. Nayyar et al. (2013) examined 15 samples of seed to detect fungi using 3 methods: agar plate, blotter, and deep freezing. The following was found: *Alternaria radicina.*
- B.G. Nayyar et al. (2017) analyzed a total of 428 *Alternaria* isolates obtained from 105 seed samples and grouped into 36 distinct taxonomic groups based on growth pattern and morphological characters and identified the following species: *Alternaria radicina.*

A3.1.1n *Alternaria mali* (6 Sep 2021)

Family: Pleosporaceae

Definition: Amount of tolerance to *Alternaria mali* Roberts 1914.

(Wikipedia, 6 Sep 2021) ***Alternaria mali***, also called **alternaria blotch of apple**, is a pathogenic fungus affecting plants. It is prevalent in the southern United States and elsewhere and damages the leaves of infected apple trees.

References:

REPUBLIC OF KOREA

- J.W. Hyun et al. (1999) reported *Bacillus polymyxa* (synonym of *Paenibacillus polymyxa*) was isolated as an antibiotic compound that was an antagonist against *Fusarium oxysporum* f. sp. *sesami.* Under greenhouse conditions *Bacillus polymyxa* was shown its minimum inhibitory concentrations were 12.8 µg/ml for *F. oxysporum* and *Alternaria mali*, 6.4 µg/ml for *Colletotrichum gloeosporioides* and *Rhizoctonia solani*, and 3.2 µg/ml for *Phytophthora capsici.*

A3.1.2 *Helminthosporium* spp. (10 Apr 2021)

Family: Pleosporaceae

Definition: Amount of tolerance to *Helminthosporium* spp. Link 1809.

(www.britannica.com/science, accessed 10 Apr 2021) Helminthosporium, genus of fungi in the order Pleosporales (phylum Ascomycota, kingdom Fungi) that exists as asexual anamorphs and causes leaf blight, especially of grasses (e.g., bluegrass, corn, oats), in humid areas. Symptoms include grayish green, tan, or brown elliptical spots that appear on lower leaves and spread later to upper leaves. Control is possible through spraying of fungicide and use of resistant plants.

References:

CHINA

- O.A. Reinking (1919) recorded *Helminthosporium* sp. on sesame. [Cited by G.S. Saharan, 1989]

INDIA

- N.O. Srikantappa et al. (2009) studied 28 samples of sesame taken from fields, farmers, retail shops and APMC markets from 5 areas. They found 34 four fungi including *Helminthosporium* sp. The fungi significantly reduced germination.
- B. Khamari et al. (2018e) collected 15 sesame seed samples from different localities of Odisha reported the infestation of *Helminthosporium* sp. ranged from 0 to 0.5%.

PHILLIPINES

- O.A. Reinking (1918) recorded *Helminthosporium* sp. on sesame. [Cited by G.S. Saharan, 1989]

SAUDI ARABIA

- A.H. Bahkali and M.A. Moslem (1996) reported the following mycoflora on 5 cultivars: *Helminthosporium* sp.

UNITED STATES

- Anon (1959) reported *Alternaria* sp. and *Cylindrosporium* sp. were the main diseases in Florida nurseries. *Cercospora* sp. and *Helminthosporium* sp. are minor problems.
- C.A. Thomas (1959b) reported leaf spots or blights caused by species of Alternaria, Cercospora, Corynespora, Helminthosporium, and other fungi appear to be the chief diseases limiting production in areas of high rainfall and humidity. Observations over a period of years and in a number of locations will tell us what levels of resistance are sufficient for satisfactory production in an average year in a particular area. Whether or not lines can be found that possess higher resistance than our present ones remains a question. It would appear, however, that the discovery and use of such lines is necessary before commercial production can be profitable in some areas.
- D.R. Langham et al. (2010c) stated *Helmintosporium sp*. has been reported in sesame in the USA in research nurseries but have not been seen in commercial fields since 1978.

A3.1.2a *Helminthosporium sesami* (10 Apr 2021)

Family: Pleosporaceae

Definition: Amount of tolerance to *Helminthosporium sesami* T. Miyake.

(D.D. Poole, 1956a) Most prominent symptoms of *Helminthosporium sesami* were found on the stems, leaves, pedicels and capsules of almost mature plants - lesions on the stem varied from small flecks 1 mm. in diameter to large, sunken, dark-brown spots 10 x 40 mm. In many cases stem lesions coalesced and brought about weakened areas on the stem. Lesions on the capsules and pedicels varied from small dark-brown spots at the base of the pedicel to large brown lesions, which enveloped the capsule and resulted in almost complete loss of the seed in it. Leaf lesions varied from small brown spots about 1 mm to large, elongated lesions 2 x 20 mm. Extensive leaf lesions brought about some premature defoliation.

References:

INTERNATIONAL

- J.R. Morschel (1964) reported the following pathogen in the world: *Helminthosporium sesami* (Leaf blotch), which is seedborne. [Cited by D.F. Beech. 1995a]
- E.A. Weiss (1971) reported *Helminthosporium sesami* can be of local importance and under more intensive agricultural conditions could become more so. High humidity favors spread of the disease, and young plants are more susceptible than mature ones. Soil conditions such as soil fertility appear to exert considerable influence on the severity of infestations.
- C. Wescott (1971) reported the following pathogen: leaf spots (*Helminthosporium sesami*).
- C. Chattopadhyay et al. (2019) described the following symptoms of aerial stem rot caused by *Helminthosporium sesami*: Leaf lesions vary from small brown spots 1 mm in diameter to large, elongated lesions of about 2-20 mm. Lesions of the stem range from small flecks 1 mm in diameter to large, sunken, dark-brown spots 10 x 40 mm in size. High humidity favors spread of the disease, and young plants less than 21 days old are much more susceptible than mature ones. Nitrogen increases the susceptibility. Phosphorus or potash alone or phosphorus and calcium show decrease in the severity of infection.

CHINA

- J. Miyake (1912) reported *Helminthosporium sesami* near Shashi, Hubei.
- L.C. Tu (1985b) reported *Helminthosporium sesami* (Leaf spot) in Henan province with a damage level of 1 out of possible 3.
- L.L. Li (1988) reported *Helminthosporium sesami* (Leaf blight) causes minor or regional damage to sesame. The disease may harm leaves, leaf stalks, stems and capsules. It occurs commonly at the mid and late stages of sesame development. Generally, it is not considered as a serious disease. Its symptom appears on the leaves as brown spots with 4-12 mm in diameter, indistinct ring line, and black mildew on the spots. The severely affected leaves wilt, die, and fall. The spots on the stem and leaf stalk are initially shuttle-shaped and become red-brown and slightly sunken. The pathogen overwinters through hyphae in the crop debris and also through the conidiospores on the plant debris and seed. The use of healthy seed, crops rotation, cleaning the field, and draining the logged water are effective in controlling the disease. Spray of Bordeaux mixture (1:1:150) is also effective at the initial stage of the disease development.

- H.M. Miao and H.Y. Liu (2010) reported the following pathogen: *Helminthosporium sesami*.

COSTA RICA

- R. Mendez (1940) recorded *Helminthosporium sesami* in sesame as a secondary infection to *Alternaria solani*. Excessive atmospheric and soil humidity appears to be the chief contributing factor in severe outbreaks of leaf spot and control should be based in the first place on selection of ecologically appropriate sites, supplemented by such cultural measures as use of healthy seed (treated with a standard fungicides) of resistant early maturing varieties of medium stature, sowing in rows and not at random. [Cited by G.S. Saharan, 1989, and R.S. Vasuveda, 1961]

EGYPT

- M.M. Satour (1981) reported the presence of *Helminthosporium sesami* (Leafspot) on sesame.
- M.M. El-Fawy and M.A.A. El-Said (2018) evaluated the efficiency of some zinc (zinc oxide [ZnO], zinc sulfate [$ZnSO_4$]) and phosphorus (dipotassium phosphate [K_2HPO_4] and disodium phosphate [Na_2HPO_4]) sources against *Helminthosporium sesami* and their effect on some agronomic traits. The following were the results in terms of inhibiting mycelial growth *in vitro*.

Treatment	Inhibition growth (%) at (mM)					
	0.0	25	50	75	100	Mean
ZnO	0.00	13.81	40.00	54.67	70.95	35.89
$ZnSO_4$	0.00	26.19	57.14	68.10	78.57	46.00
K_2HPO_4	0.00	16.67	16.19	23.34	35.24	18.29
Na_2HPO_4	0.00	7.62	13.81	17.14	32.38	14.19
Mean	0.00	16.07	31.79	40.81	54.29	-

The following table shows the effect of foliar treatment under field conditions during 2016 and 2017 growing seasons.

Treatment	Disease severity (%)					
	Season 2016			Season 2017		
	One spray	Two sprays	Mean	One spray	Two sprays	Mean
ZnO	11.23	10.09	10.66	13.10	11.85	12.48
$ZnSO_4$	12.52	11.35	11.94	15.00	14.10	14.55
K_2HPO_4	15.41	12.82	14.12	17.35	17.12	17.24
Na_2HPO_4	18.62	16.91	17.77	18.95	17.47	18.21
Curve 25%	10.05	7.98	9.02	12.03	11.96	12.00
Control	49.84	47.37	48.61	51.09	50.87	50.98
Mean	19.61	17.75	-	21.25	20.56	-

The following table shows the effects on the yields and yield components for 2017. The results for 2016 paralleled these results.

Treatments	Season 2017					
	Plant height (cm)	No. of branches per plant	No. of capsules per plant	Weight of 1000 seeds (g)	Seed oil content (%)	Seed yield (kg/ feddan)
ZnO	161.67	7.33	161.00	3.58	44.00	383.50
$ZnSO_4$	203.33	8.00	171.67	3.91	46.67	416.00
K_2HPO_4	220.00	11.00	193.33	3.99	47.33	483.00
$Na2HPO_4$	211.67	8.00	177.00	3.75	45.67	452.00
Curve 25%	155.00	6.33	155.00	3.73	44.67	387.00
Control	130.00	5.33	115.00	2.90	38.00	310.00
Mean	180.28	7.67	162.17	3.65	44.39	405.25
L.S.D	22.03	2.28	7.53	0.34	4.41	40.48

INDIA

- M.M. Satour (1981) reported the presence of *Helminthosporium sesami* (Leafspot).
- A.R. Wasnikar et al. (1987) reported the influence of fungi varied for seed and soil contamination: *Helminthosporium sesami*: 35 and 38%. [Based on abstract]

- A.R. Wasnikar et al. (1988) reported media were prepared with various C and N contents. In general, growth of *Alternaria sesami*, *Fusarium oxysporum* f. sp. *sesami*, *Helminthosporium sesami* and *Myrothecium roridum*, the most important pathogens of sesame, increased with C and N concentrations. [Based on abstract]

ITALY
- P.A. Saccardo (1917) reported *Helminthosporium sesami* was recorded on sesame. [Cited by G.S. Saharan, 1989]
- R. Parisi (1933) recorded *Helminthosporium sesami* on sesame in Southern Italy. [Cited by R.S. Vasuveda, 1961, and G.S. Saharan, 1989]

JAPAN
- K. Watanabe (1950) reported leaf blotch of sesame caused by *Helminthosporium sesami* affects the leaves, petioles, stems and pods of seedling plants. The conidiophores measure 105 to 337.5 (average 1941 µ long by 5 to 10 (average 7.11) µ wide, with 2 to 9 septa and conidia 27.5 to 267.5 (average 102.9) µ by 5 to 17.5 (average 15.03) µ with 3 to 20 septa (average 8. 77). The fungus grew readily on various media at an optimum temp. of between 21 and 30°C at pH 0.6. In culture, conidia measured on an average 100.2 by 10.66 µ at 23°C and 88.7 by 10.46 µ at 37°C. Pathogenicity to sesame was demonstrated in inoculation experiments. Hot water treatment has proved effective in disinfecting contaminated seed.

KENYA
- H.A. Van Rheenen (1981d) reported the goal of developing resistance to *Helminthosporium sesami*.

PHILIPPINES
- C. Chattopadhyay et al. (2019) described the presence of *Helminthosporium sesami*.

TANZANIA
- Kafiriti, E. and O. Mponda (n.d.) in a grower guide reported the following pathogen: *Helminthosporium sesami.*

UNITED STATES
- M.L. Kinman (1955) reported leaf and stem blight caused by *Helminthosporium sesami*
- D.D. Poole (1956a) reported that aerial stem rot (*Helminthosporium sesami*) attacked Guacara in 1954 near College Station, Texas. This appears to be a seedborne disease. [Based on abstract] [Authors comment: Guacara is a Venezuelan variety and is one of the progenitors of all non-dehiscent sesame developed by Sesaco.]
- W.J. Stone (1959) reported a relatively long (60-72 hours) exposure to 100% relative humidity and a temperature of about 30° C resulted in good infection of sesame by *Helminthosporium sesami*. Age of the plants and of the pathogen in culture at the time of inoculation were found to be of great importance. Plants less than 21 days old were the most susceptible, and inoculum from cultures 7 days old caused the greatest damage to sesame. Soil fertility affected the severity of the disease. Nitrogen showed a high increase and K2O alone had a tendency to reduce infection. Only 14 of 267 sesame lines screened for resistance showed tolerance to *Helminthosporium* blight. [Based on abstract]
- D.T. Smith et al. (2000) reported after sesame seedlings are established, root damage can occur from *Helminthosporium sesami*. This pathogen infects the vascular system and can reduce stands and cause premature death.
- Anon. (2015c) USA PVP descriptor: 7. Diseases – *Helminthosporium* blight (*Helminthosporium sesami).* The following ratings are used:
  - 0 = Not tested
  - 1 = Susceptible
  - 2 = Low resistance
  - 3 = Moderate resistance
  - 4 = High resistance

A3.1.2b *Helminthosporium halodes* (24 May 2021)

Family: Pleosporaceae

Definition: Amount of tolerance to *Helminthosporium halodes*.

References:

NIGERIA

- D. McDonald (1964) reported *Helminthosporium halodes*.
- H.A. Van Rheenen (1972) reported the following pathogen: *Helminthosporium halodes.*

A3.1.2c *Helminthosporium tetramera* (2 Jun 2021)

Family: Pleosporaceae

Definition: Amount of tolerance to *Helminthosporium tetramera*.

References:

INDIA

- R.K.S. Chauhan and B.M. Kulshrestha (1984b) reported the diffusate obtained from the fruit cavities of sesame inoculated with a spore suspension of *Alternaria sesami* was inhibitory to the germination of spores. It inhibited the spore germination of *Helminthosporium tetramera*. No inhibition was caused by the extracts of healthy uninoculated fruits.
- K. Kumar et al. (1984a) reported *Helminthosporium tertramera* was found to be associated with the seeds of varieties T-4 and T-12. The species was pathogenic and reduced germination by causing seed rot under laboratory conditions and produced brown necrotic spots on leaves.

A3.1.2d *Helminthosporium magnisporum* (3 Oct 2021)

*Synonym: *Helminthosporium gigasporum*

Family: Pleosporaceae

Definition: Amount of tolerance to *Helminthosporium magnisporum*.

References:

TANZANIA

- G.B. Wallace (1933) reported the most destructive diseases of sesame were a leaf curl probably caused by a virus and a bacterial disease affecting the stems, branches and leaves. Two leaf fungi attacking this host are an *Oospora* sp. and *Helminthosporium gigasporum* f. sp. *javanicum*. [Cited by R.S. Vasudeva, 1961, and G.S. Saharan, 1989]

A3.1.3 *Drechslera spp.* (27 Apr 2021)

Family: Pleosporaceae

Definition: Amount of tolerance to *Drechslera spp.* S. Ito 1930.

(Wikipedia, 27 Apr 2021) ***Drechslera*** is a genus of fungi. Many of the species in this genus are plant pathogens.

The following species have been associated with sesame but there are no known reports of being a pathogen, producing a toxin, inhibiting germination, affecting seed quality, or being used as a biocontrol or biofertilizer.

- *Drechslera ellisii* [Egypt and Saudi Arabia]
- *Drechslera halodes* [Pakistan]
- *Drechslera hawaiiensis* [Pakistan]
- *Drechslera tetramera* [Pakistan]

References:

BRAZIL

- M.G.R. Faiad et al. (2002) reported:
  - They examined seed from 416 accessions from 7 Brazilian states at 25°C under alternating black lights and darkness in a 12-hour photoperiod for 8 days. They found the following fungus: *Drechslera* sp.

- They examined 31 seed samples that had been stored for 5 and 9 years at 8°C and 25% RH. They found the following fungus: *Drechslera* sp.
- They concluded that sesame seeds are infested by a population of fungi, and the seed acts as a vehicle for pathogen dissemination.

INDIA
- V. Bharathi et al. (2013) collected sesame seeds from farmers in Andhra Pradesh. They tested the seeds for mycoflora, and the following fungus was found: *Drechslera* spp.

SAUDI ARABIA
- A.H. Bahkali and M.A. Moslem (1996) reported the following mycoflora on 5 cultivars: *Drechslera* sp.

SUDAN
- H.I.H. Idriss (2016) collected farmer saved red and white sesame from 7 locations in Sudan. 14 different fungi representing ten genera were identified. One of the low frequency fungi was *Drechslera* sp.

A3.1.3a *Drechslera rostratum* (7 May 2021)

Synonym: *Drechslera rostrata*

Family: Pleosporaceae

Definition: Amount of tolerance to *Drechslera rostratum* (Drechsler) K.J. Leonard & Suggs 1974.

References:

INTERNATIONAL
- P. Neergaard (1979) reported the following pathogen caused a disease in sesame: *Drechslera rostrata*. [Cited by G.S. Saharan, 1989]

SUDAN
- N.M.A. Hamid (2006) identified the following fungus from seed collected from 3 areas of Sudan: D*rechslera rostrata*. [Based on abstract]

A3.1.3b *Drechslera sesami* (7 May 2021)

Family: Pleosporaceae

Definition: Amount of tolerance to *Drechslera sesami* (J. Miyake) M.J. Richardson & E.M. Fraser.

References:

INTERNATIONAL
- P. Neergaard (1979) reported the following pathogen caused a disease in sesame: *Drechslera sesami*. [Cited by G.S. Saharan, 1989]

MEXICO
- Agrolytics.org (2021) reported sesame hosts *Drechslera sesami*.

A3.1.4 *Cochliobolus* spp. (7 May 2021)

Family: Pleosporaceae

Definition: Amount of tolerance to *Cochliobolus* spp. Drechsler.

(Wikipedia, 7 May 2021) The fungal genus ***Cochliobolus*** includes 55 species, including the following plant pathogenic species: *C. carbonum*, *C. heterostrophus*, *C. miyabeanus*, *C. sativus* and *C. lunatus*.

References:

NIGERIA

- C.A. Amienyo et al. (2015) studied the effect of mycoflora collected from 5 markets on the deterioration of lipid content of seed. Visually healthy seeds were inoculated with spores of each of the nine fungi isolated from diseased seeds and incubated at 25+20°C for 7days. The healthy and fungal infected seeds were analyzed for their lipid content. The percentage incidence at the 5 locations is shown below.

Fungi incidence	Location				
	A	B	C	D	E
Alternaria alternate	6.6	3.6	3.2	2.0	0.0
Aspergillus chevalieri	10.3	4.2	5.0	0.0	0.0
Aspergillus niger	0.0	6.1	7.4	2.6	5.2
Aspergillus oryzae	3.3	4.0	0.0	0.0	0.0
Aspergillus flavus	3.9	3.1	2.7	0.0	0.0
Aspergillus terreus	4.8	11.2	2.4	13.0	0.0
Cochliobolus Spp.	9.5	0.0	0.0	0.0	0.0
Geotrichum candidum	0.0	0.0	0.0	0.0	3.5
Phoma Spp.	5.9	2.0	0.0	0.0	0.0

Fungi utilize basic compounds of the seeds for their metabolism and growth and may affect the germination rate of the seed. The uninoculated seed had 49.35% lipid. The following shows the lipid content after 7 days of infection.

Fungi	Lipid content (%)
Aspergillus chevalieri	42.40
Aspergillus oryzae	43.50
Aspergillus niger	45.00
Aspergillus terreus	45.45
Alternaria alternata	47.80
Cochliobolus Spp	48.10
Aspergillus flavus	48.70
Phoma Spp.	49.15
Geotrichum candidum	49.40

A3.1.4a *Cochliobolus sativus* (7 May 2021)

Synonym: *Drechslera sorokiniana*

Family: Pleosporaceae

Definition: Amount of tolerance to *Cochliobolus sativus* (S. Ito & Kurib.) Drechsler ex Dastur 1942.

(Wikipedia, 7 May 2021) The fungus ***Cochliobolus sativus*** is the teleomorph (sexual stage) of ***Bipolaris sorokiniana*** (anamorph) which is the causal agent of a wide variety of cereal diseases. The pathogen can infect and cause disease on roots (where it is known as common root rot), leaf and stem, and head tissue. *C. sativus* is extremely rare in nature and thus it is the asexual or anamorphic stage which causes infections. The two most common diseases caused by *B. sorokiniana* are spot blotch and common root rot, mainly on wheat and barley crops.

References:

INTERNATIONAL

- P. Neergaard (1979) reported the following pathogen caused a disease in sesame: *Drechslera sorokiniana*. [Cited by G.S. Saharan, 1989]

CUBA

- La Habana (2009) in a grower guide reported the following pathogen: *Drechslera sorokiniana*.

A3.1.4b *Cochliobolus spicifer* (3 Oct 2021)

Family: Pleosporaceae

Definition: Amount of tolerance to *Cochliobolus spicifer* R.R. Nelson 1964.

(Wikipedia, 3 Oct 2021) ***Cochliobolus spicifer*** is a fungal plant pathogen.

References:

INDIA

- S.K. Tripathi et al. (1984) reported leaf spot disease of sesamum caused by Drechslera state of *Cochliobolus specifer* Nelson was observed at Jabalpur in Aug-Sep 1982. The disease started with a pale yellow area at the tip of leaf lamina which developed into a blackish brown lesion. The lesion developed in the form of V-shaped chlorotic zone towards the petiole, gradually increased in size and gave blighted appearance. The extent of disease incidence was around 10-20%. The disease is favored by high humidity and temperature. The plants start drying from tip towards the base. [Cited by G.S. Saharan, 1989]

A3.1.5 *Curvularia* spp. (2 Jul 2021)

Family: Pleosporaceae

Definition: Amount of tolerance to *Curvularia* spp. Boedijn 1933.

(Wikipedia, 2 Jul 2021) ***Curvularia*** is a hyphomycete (mold) fungus which is a facultative pathogen, or beneficial partner of many plant species and common in soil. Most *Curvularia* are found in tropical regions, though a few are found in temperate zones.

The following species has been associated with sesame but there are no known reports of being a pathogen, producing a toxin, inhibiting germination, affecting seed quality, or being used as a biocontrol or biofertilizer.

- *Curvularia richardia* [Pakistan]

References:

INDIA

- K. Bhattachary and S. Raha (2002) studied fungal infection, moisture content, germinability and deterioration of sesame in storage under natural conditions for a year. Different species of Aspergillus (*A. candidus*, A. *flavus, A. niger, A. terreus*, and *A. ruber*) were dominant followed by Rhizopus, Penicillium, Curvularia, Fusarium, Alternaria, etc. Seed moisture was maximum in the rainy season followed by a gradual decrease during longer storage. As storage proceeded, there was a gradual decrease in field fungi with simultaneous increase in storage fungi, and a reduction in germinability. A gradual loss of carbohydrate (both soluble and insoluble) content was recorded. A loss of protein content was recorded followed by a small increase. Oil content decreased in prolonged storage with simultaneous increase in fatty acid. [Based on abstract]
- V. Bharathi et al. (2013) collected sesame seeds from farmers in Andhra Pradesh and reported *Curvularia* spp.
- B. Khamari et al. (2018e) collected 15 sesame seed samples from different localities of Odisha reported the infestation of *Curvularia* sp. ranged from 0 to 1.5%.

NIGERIA

- A.D. Ojochenemi et al. (2015) examined 46 samples of sesame for mycotoxicological concerns and reported *Curvularia* spp.

PAKISTAN

- N. Altaf et al. (2004) tested 400 seeds from each of 10 cultivars for seedborne mycoflora and reported *Curvularia* sp.

PARAGUAY

- L.C. Rossi and A.L. Orrego (2007) identified the following fungus on sesame seeds: *Curvularia* sp.

SAUDI ARABIA

- A.H. Bahkali and M.A. Moslem (1996) reported five cultivars of sesame were screened for their seedborne mycoflora and reported *Curvularia* spp.

SUDAN

- N.M.A. Hamid (2006) identified the following fungus from seed collected from 3 areas of Sudan: *Curvularia* sp.

A3.1.5a *Curvularia lunata* (2 Jul 2021)

Synonym: *Cochliobolus lunatus*

Family: Pleosporaceae

Definition: Amount of tolerance to *Curvularia lunata* (Wakker) Boedijn 1933.

(Wikipedia, 2 Jul 2021) *Curvularia* defined by the type species *C. lunata* (Wakker) Boedijn. *Curvularia lunata* appears as shiny velvety-black, fluffy growth on the colony surface. *C. lunata* is distinguished by septate, dematiaceous hyphae producing brown, geniculate conidiophores. The poroconidia are curved slightly to distinctly, transversely septate, with an expanded third cell from the pore end of the conidium. *Curvularia* can be easily distinguished from *Bipolaris* and *Drechslera* spp. since the conidia are non-distoseptate, that is, septate from edge to edge of the conidial wall. The teleomorphic state of the type species *Curvularia lunata* is *Cochliobolus lunatus* (Fam. Pleosporaceae, Ord. Pleosporales, Cla. Loculoascomycetes, Phy. Ascomycota).

References:

BANGLADESH

- M.D. Hosen and S. Shamsi (2017) isolated the following fungus from sesame seeds: *Curvularia lunata.*

CUBA

- La Habana (2009) in a grower guide reported the following pathogen: *Curvularia lunata*.

INDIA

- S.N. Bhargava and D.N. Shukla (1979a) reported seed coat leachates and seed extracts of sesame decreased spore germination of *Fusarium oxysporum*, *Fusarium solani* and *Curvularia lunata* (*Cochliobolus lunatus*). Culture filtrates of the fungi inhibited seed germination of the plants. [Cited by G.S. Saharan, 1989]
- R.K.S. Chauhan and B.M. Kulshrestha (1984b) reported the diffusate obtained from the fruit cavities of sesame inoculated with a spore suspension of *Alternaria sesami* was inhibitory to the germination of spores of *Curvularia lunata.*
- K. Kumar et al. (1984a) reported *Curvularia lunata* was found to be associated with the seeds of varieties T-4 and T-12. The species was pathogenic and reduced germination by causing seed rot under laboratory conditions.
- N.O. Srikantappa et al. (2009) studied 28 samples of sesame taken from fields, farmers, retail shops and APMC markets from 5 areas. They found 34 four fungi including *Curvularia lunata.* The fungi significantly reduced germination.
- R.B. Kakde and A.M. Chavan (2011) examined the effects of fungi on seeds in storage. Ten dominant fungi were isolated from seeds of groundnut, soybean, sesame, safflower, and sunflower. One hundred grams of seeds were inoculated with 10 ml of the fungi. The flasks were left at room temperature for 14 days and then analyzed for sugars, crude fat, and fiber. The results are as follow.

Table 1. Change in reducing sugar (g/100gm) due to seed-borne fungi

Fungi	Sunflower	Sesame	Groundnut	Soybean	Safflower
Alternaria dianthicola	5.2	4.8	1.1	1.1	1.3
Curvularia lunata	4.9	5.0	2.5	1.5	1.8
Curvularia pellescens	5.0	5.4	2.1	1.2	1.6
Fusarium oxysporum	4.7	4.4	1.8	1.7	1.1
Fusarium equiseti	4.6	4.8	1.6	1.2	1.0
Macrophomina phaseolina	5.8	3.5	2.2	2.0	2.2
Rhizopus stolonifer	6.1	5.0	1.1	1.8	2.1
Penicillium digitatum	5.5	4.6	1.9	1.7	1.4
Penicillium chrysogenum	5.2	4.9	2.0	1.6	1.6
Trichoderma viride	6.7	6.1	2.1	1.9	2.6
Control	7.2	6.9	3.1	2.4	2.8
C.D. at 0.05	0.52	0.62	1.21	0.24	0.21

Table 2. Change in crude fat (g/100gm) due to seed-borne fungi

Fungi	Sunflower	Sesame	Groundnut	Soybean	Safflower
Alternaria dianthicola	35.5	10.2	37.1	49.8	22
Curvularia lunata	43.5	14.3	32.5	48.2	26
Curvularia pellescens	45.5	10	41	49	27
Fusarium oxysporum	43	16.1	38	44	20
Fusarium equiseti	47	14.2	35	49.7	19
Macrophomina phaseolina	39	10.5	39.3	46.8	30
Rhizopus stolonifer	50	16.3	40.2	48.6	33
Penicillium digitatum	42	15.3	34.3	39	24
Penicillium chrysogenum	44	12.8	36.2	41	27
Trichoderma viride	46	17.5	40	46	35
Control	49	20	45	50	36
C.D. at 0.05	2.71	2.05	2.04	2.4	3.7

Table 3. Change in crude fiber (g/100) due to seed-borne fungi

Fungi	Sunflower	Sesame	Groundnut	Soybean	Safflower
Alternaria dianthicola	39.1	35.6	33.9	26.1	20.1
Curvularia lunata	52.3	30.6	38.8	34.5	21.8
Curvularia pellescens	46.1	41.1	42.3	31.1	21.6
Fusarium oxysporum	53.1	36.5	34.7	37.0	21.0
Fusarium equiseti	50.7	36.4	37.9	21.0	22.5
Macrophomina phaseolina	47.7	34.8	41.9	36.6	17.9
Rhizopus stolonifer	41.6	31.6	40.1	28.5	19.6
Penicillium digitatum	43.5	40.5	27.6	21.0	14.4
Penicillium chrysogenum	40.5	27.7	31.7	36.9	13.9
Trichoderma viride	47.5	35.1	38.3	37.0	19.8
Control	51.3	47.7	38.0	23.3	19.9
C.D. at 0.05	3.16	6.11	2.39	4.2	1.82

NIGERIA

- H.A. Van Rheenen (1972) reported the following pathogen: *Curvularia lunata.*
- O.A. Enikuomehin (2010) evaluated the effectiveness of seedborne fungi control by plant extracts of leaves (*Azadirachta indica, Vernonia amygdalina, Musa paradisiaca* and *Anacardium occidentales*) and synthetic fungicides (Team [Carbendazin 12% + Mancozeb 63%] and Ridomil [Metalaxyl 60g + 60 g CuO_2]) using two sesame cultivars (530-6-1 and NCRIBEN-03L). All plant extracts significantly ($P \leq 0.05$) reduced the fungal infection of seeds. *A. indica* leaf extract was comparable to the synthetic fungicides in reducing fungal infection of seeds. Leaf extracts of *A. occidentales* and *M. parasitica* enhanced significant ($P \leq 0.05$) seedling emergence. *Alternaria sesamicola, Curvularia lunata* and *Fusarium* spp. were most sensitive to *A. indica* and *M. paradisiaca* leaf extracts. [Based on abstract]
- F.M. Afolagboye (2011) reported the following fungus from 4 sesame varieties (NCRIBEN 03L, NCRIBEN 01M, E8 and 530-6-1) at Abeokuta: *Curvularia lunata.*

PAKISTAN

- K.H. Wagan et al. (2002) reported 4 species of seedborne fungi, that is *Alternaria sesami, A. sesamicola, Curvularia lunata* [*Cochliobolus lunatus*], and *Fusarium oxysporum* were isolated from infected seeds of sesame varieties PR-125, S-17, PR-19-9, and PR-14-2. The frequency of fungi was highest from PR-125 (25.63%) followed by S-17 (24.75%), PR-19-9 (23.13%) and PR-14-2 (22.5%). *A. sesami* was isolated as most predominant fungus according to its infection percentage (22.5-62.5). However, *C. lunata* was most frequently isolated from the variety PR-14-2. Maximum seed germination percentage (82.0) was obtained from the healthy seeds of PR-14-2 on filter paper followed by PR-125 (76.0), S-17 (67.0) and lowest from PR-19-9 (62.0). Vitigran blue [copper oxychloride] significantly (P=0.05) reduced the colony growth of the fungus followed by Liro-Manzeb [mancozeb], Dithane M-45 [mancozeb] and Topsin-M [thiophanate-methyl]. The number of spots on 2-month-old inoculated plants was significantly (P=0.05) reduced by spraying with Vitigran blue compared to Liro-Manzeb, Dithane M-45 and Topsin-M.

SUDAN

- N.M.A. Hamid (2006) identified the following fungus from seed collected from 3 areas of Sudan: *Curvularia lunata*.
- H.I.H. Idriss (2016) collected farmer saved red and white sesame from 7 locations in Sudan. 14 different fungi representing ten genera were identified. One of the low frequency fungi was *Curvularia lunata*.

A3.1.5b *Curvularia macularis* (2 Jul 2021)

Family: Pleosporaceae

Definition: Amount of tolerance to *Curvularia macularis*.

References:

NIGERIA
- D. McDonald (1964) reported *Curvularia macularis* was one of the most virulent pathogens.
- E.A. Weiss (1971) reported *Curvularia macularis* is a minor disease.

A3.1.5c *Curvularia fallax* (5 Jul 2021)

Family: Pleosporaceae

Definition: Amount of tolerance to *Curvularia fallax* Boedijn 1933.

References:

INDIA
- P. Kumar and U.S. Mishra (1992) reported a new leaf spot disease caused by *Curvularia fallax* was recorded for the first time in India. [Based on abstract]

A3.1.5d *Curvularia neergaardii* (3 Oct 2021)

Synonym: *Drechslera neergaardi*

Family: Pleosporaceae

Definition: Amount of tolerance to *Curvularia neergaardii* (Danquah) Y.P. Tan & R.G. Shivas 2014.

References:

INDIA
- A.S. Reddy and S.M. Reddy (1982a) reported *Drechslera neergaardi* and *Phoma nebulosa* were recorded for the first time in *Sesamum* seed. [Cited by G.S. Saharan, 1989]

A3.1.6 *Exserohilum* spp. (28 Sep 2021)

Synonym: *Setosphaeria* spp.

Family: Pleosporaceae

Definition: Amount of tolerance to *Exserohilum* spp. K.J. Leonard & Suggs 1974.

(Wikipedia, 28 Sep 2021) ***Exserohilum*** is a genus of fungi in the family Pleosporaceae. The *Exserohilum* species are known for causing blight and human immune system diseases. The sexual reproductive (or ascigerous) states of Exserohilum species are known as Setosphaeria. The type species is *Exserohilum turcicum*. This genus is among three dematiaceous that are categorized for containing pathogens leading to diseases like phaeohyphomycosis..

References:

EGYPT
- M.M.I. Abdel-Hafez et al. (2012) examined the soils around the roots of sesame and reported *Setosphaeria* spp. in the rhizosphere and rhizoplane.
- M.M.I. Abdel-Hafez et al. (2014) took ten samples of sesame from local markets in Assiut city. They found the following: *Setosphaeria* spp.

SAUDI ARABIA
- A.H. Bahkali and M.A. Moslem (1996) reported the following mycoflora on 5 cultivars: *Setosphaeria sp.*

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A3.2 Family: Corynesporascaceae

(Wikipedia, 10 Apr 2021) The **Corynesporascaceae** are a family of fungi with an uncertain taxonomic placement in the class Dothideomycetes.

The following species have been reported to cause diseases, produce a toxin, inhibit germination, or affect seed quality.

- A3.2.1 *Corynespora* spp.
- A3.2.1a *Corynespora cassiicola*
- A3.2.1b *Corynespora sesameum*

A3.2.1 *Corynespora* spp. (10 Dec 2021)

Family: Corynesporascaceae

Definition: Amount of tolerance to *Corynespora* spp. Güssow 1906.

Summary:

Photo: D.R. Langham {in China}

Photo: K.A. Cochran {USA}

The symptoms for ***Corynespora cassiicola*** are dark, irregularly shaped spots appear on the leaves; they enlarge, become brown with light centers, and coalesce forming a blotchy configuration. A concentric "target" pattern may be seen on lesions. Extensive defoliation occurs, and the affected plants often die. Infection on the stems is characterized by light-brown to reddish brown, elongated lesions which later spread over the entire stems, causing death of the plants. Affected stems are bent irregularly or swollen on the lesion affected area. Cankers of various sizes also appear on the stem and are often seen originating at the node near the pod base, or the crown of the plant. The pathogen has been reported to cause root rot and is likely associated with a crown rot. In immature plants, the infected stem cracks lengthwise and breadthwise, and these cracks continue to expand if the plant manages to survive to maturity. Heavy, black to grey velvet-like sporulation is often observed on the crown area. Seedling infection has not been observed under field conditions, though it is seedborne. Capsules can be infected with symptoms appearing as sunken lesions that may be brown or with pale centers. Seeds may be infested and will appear shriveled and brown in severe cases, which can result in aborted seed or reduced seed quality. Symptoms usually appear and rapidly reach epiphytotic conditions as the plants reach maturity. The pathogen perpetuates through plant debris and is seedborne. *C. sesameum* is also a pathogen of sesame. *Corynespora* spp. have been reported in international lists, Australia, Brazil, China, Colombia, Costa Rica, Cuba, Ecuador, India, Japan, Mexico, Republic of Korea, United States, and Venezuela.

(Wikipedia, 10 Apr 2021) ***Corynespora*** is a fungus genus. It is a member of the mitosporic Ascomycota, a heterogeneous group of ascomycotic fungi whose common characteristic is the absence of a sexual state.

References:

INTERNATIONAL

- Anon (2000a) is an organic grower guide for America. It describes the following disease and its recommended organic method of control: Corynespora Blight – Elimination of plant residues. Clean seeds.

INDIA

- K.N. Gupta et al. (2018) recommended cultural and chemical practices to alleviate or control Corynespora blight; refer to the introduction.

REPUBLIC OF KOREA

- J.I. Lee et al. (1985i) reported A new high-yielding sesame variety ‘Ansanggae’ was developed by mutation breeding of ‘Early Russian’. Ansanggae was moderately resistant to seedling blight including Rhizoctonia blights, and resistant to Corynespora leaf blight, Phytophthora blight, and Fusarium wilt. [Based on abstract]
- S.W Kang and H.K. Kim (1989) reported *Corynespora sp*. is frequently encountered in the soils. [Based on abstract]

UNITED STATES

- C.A. Thomas (1959b) reported leaf spots or blights caused by species of Alternaria, Cercospora, Corynespora, Helminthosporium, and other fungi appear to be the chief diseases limiting production in areas of high rainfall and humidity. Observations over a period of years and in a number of locations will tell us what levels of resistance are sufficient for satisfactory production in an average year in a particular area. Whether or not lines can be found that possess higher resistance than our present ones remains a question. It would appear, however, that the discovery and use of such lines is necessary before commercial production can be profitable in some areas.
- D.R. Langham et al. (2010c) stated *Corynespora* has been reported in sesame in the USA in research nurseries but have not been seen in commercial fields since 1978.

A3.2.1a *Corynespora cassiicola* (10 Dec 2021)

Synonym: *Corynespora sesamum*

Family: Corynesporascaceae

Definition: Amount of tolerance to *Corynespora cassiicola* (Berk. & M.A. Curtis) C.T. Wei 1950.

(Wikipedia, 10 Apr 2021) ***Corynespora cassiicola*** is a species of fungus well known as a plant pathogen. It is a sac fungus in the family Corynesporascaceae. It is the type species of the genus *Corynespora*.

This fungus infects over 530 species of plants in 53 families. It is most common in the tropics and subtropics. It has also been isolated from nematodes and from human skin.

The fungus is known as a pathogen of many agricultural crop plants, especially cowpea, cucumber, papaya, rubber, soybean, and tomato. It has caused crop failures resulting in high economic losses in over 70 countries. On several plants, such as tomatoes, the fungus causes a disease called target spot or target leaf spot. The disease is identified by leaf damage taking the form of target-shaped spots with light centers and dark margins, as well as pits on the fruit. The fungus also causes a disease on the cultivated rubber tree *Hevea brasiliensis* called corynespora leaf fall (CLF).

In regards to detection of *Corynespora cassiicola*, it is useful to inspect the plant's bottom leaves while looking for ring-patterned spots that can be up to 10 mm in diameter. This pathogen is able to show symptoms on a vast host range and on several different structures. That being said, it is beneficial to additionally check the plant's roots, stems, and fruit exterior for symptoms.

There are several cultural control practices that may be useful for managing this pathogen. Before planting begins, measures should be taken for prevention. These measures include avoiding planting crops next to ones known to already have the disease. In order to do so, seedlings should be checked for these leaf spots previously mentioned. If the *Corynespora cassiicola* is discovered on the plant during its development, management of the disease includes removing and burning the plant's lower leaves. Additionally, it's important to ensure that there are no weeds present on the plant plots because these weeds may act as hosts and harbor the fungus. If the pathogen is discovered after harvesting the host, management includes burning the infected crop in the attempt to rid the disease from the environment. Furthermore, practicing plant rotation and waiting three years before replanting the host on the same land can be beneficial for pathogen prevention. Chemical control may also be employed to promote disease prevention.

Although *Corynespora cassiicola* has been reportedly located in a wide distribution throughout the world, the conditions in which this pathogen best spreads and develops are found in the tropics and subtropics. The locations of these reports include plant species in American Samoa, Brazil, Malaysia, and Micronesia. Furthermore, the pathogen was reported in Mexico in 2013 and China in 2014.

Corynespora cassiicola requires high humidity for infection and is additionally favored in locations with substantial periods of high moisture (16–44 hours). In other words, the leaf wetness is likely a major environmental factor driving the disease for this fungal pathogen. The humidity may be used as a surrogate for leaf wetness, as it is an essential component of an environment and has data that can be easily measured. This pathogen is an especially prominent foliar disease of tomato in Florida, which provides the optimal high humidity environment for the disease growth and development.

Additionally, this pathogen may be easily dispersed throughout the environment by wind. Thus, it has been found on diverse substrates of its hosts including the roots, stems, and leaves. The pathogen has even been reported on human skin, seen as causing severe damage and blisters.

References:

INTERNATIONAL

- J.R. Morschel (1964) reported the following pathogen in the world: *Corynespora cassiicola* (Leaf spot). [Cited by D.F. Beech. 1995a]
- C. Wescott (1971) reported the following pathogen: blight (*Corynespora cassiicola*).
- E.A. Weiss (1971) reported *Corynespora cassiicola* symptoms are large irregular-shaped, concentrically zoned light-brown lesions, which later coalesce and cause defoliataion. Infection of stems is characterized by light-brown elongated lesions which later spread over the entire stem, causing death. The disease is seedborne.
- P. Neergaard (1979) reported the following pathogen caused a disease in sesame: *Corynespora cassiicola*. [Cited by G.S. Saharan, 1989]
- C. Chattopadhyay et al. (2019) described the following symptoms for *Corynespora cassiicola*: Dark, irregularly shaped spots appear on the leaves and stems. They enlarge, become brown with light centers, and coalesce forming a blotchy configuration, Extensive defoliation occurs, and the affected plants die. Affected stems are bent irregularly on the lesions. Cankers of various sizes also appear on the stem. In immature plants, the infected stem cracks lengthwise and breadthwise. The pathogen perpetuates through plant debris and infected seeds. It is however, inactivated when infected seeds are stored at 16-28°C with 50% humidity. Seed treatment with Carbendazim at 0.1% and spraying the crop with Mancozeb can be effective in disease management.
- CAB International (accessed 12 Apr 2021) reported sesame was a host of *Corynespora cassiicola* (Target leaf spot of tomato).

AUSTRALIA

- M.R. Bennett (1986-1997). In his sesame development program in the Northern Territories of Australia between 1986 and 1997, he took data on 'Susceptibility to *Corynespora cassiicola*'. His ideotype included tolerance to this pest. In the 1991-92 wet season there were red lesions on the stems, petioles, and capsules of all the lines, but there were some plants of Pachequeno that had no symptoms.
- M.R. Bennett (1995b) reported *Corynespora cassiicola* (Target spot) can severely affect grain yields. Target spot first appears as dark (often purplish) spots on leaves stems and capsules. As spots enlarge, they develop lighter colored centers.
- D.F. Beech (1995a) reported the following pathogen: *Corynespora cassiicola* (Leaf spot).
- B.D. Conde (1995) reported the following pathogen: *Corynespora cassiicola* (Capsule/stem/leaf spot) has a wide host range. At first the disease appears as dark (often purplish in color) spots on leaves, stems, and capsules. As spots enlarge, they develop lighter colored centers. The disease was first seen on sesame in early 1989 on both trial and commercial sowings during prolonged wet weather and has the potential to be a serious disease. Selection of resistance is important.

CHINA

- H.Y Zhang/H.M. Miao (pers. comm. 2016): The *Corynespora cassiicola* descriptor is used in the breeding program by the Henan Sesame Research Center.

Corynespora cassiicola in a determinate mutant field at Henan Sesame Research Center in Zhengzhou, China. Photo: D.R. Langham, 2017.

- D.X. Gao et al. (2018) reported in July 2015, sesame plants (var. Liaozhi No. 8) grown in a commercial field in Liaoyang, Liaoning Province exhibited wilt and root rot symptoms. Disease incidence reached 25%. Typical disease symptoms included stunting, chlorosis of the lower leaves, and defoliation by the flowering stage. Reddish-brown, irregular lesions were observed on roots and feeder root density was reduced. As the disease progressed, roots turned violet-brown and developed rough skin with irregular longitudinal lesions and localized rots. Fruits of severely affected plants failed to mature. Symptomatic roots were collected, disinfested, and grown on potato dextrose agar (PDA). Cultures were obtained from single conidia incubated at 25°C for 10 to 15 days. Colonies were dense, villous, gray to dark brown, and often produced yellow or brown pigment on PDA. Conidiophores were brown, erect, broad at the base, formed singly or in groups, 1 to 20 septa, measuring 32 to 350 × 8 to 12 µm. Conidia varied in morphology. They were brown, cylindrical, curved, broad at the base, borne singly or in chains, 2 to 14 pseudosepta, measuring 30 to 255 × 6 to 15 µm.
- M. Jia et al. (2020) *Corynespora* leaf spot is one of the most important diseases in sesame and is caused by a fungal pathogen, *Corynespora cassiicola.* They investigated the role of cell-wall-degrading enzymes (CWDEs) in the process of pathogen infection. The activities of the CWDEs secreted by *Corynespora cassiicola* were disparate in different sesame varieties.

COLOMBIA

- H.C. Patino (1967) reported *Corynespora cassiicola* on sesame seed.

CUBA

- La Habana (2009) in a grower guide reported the following pathogen: *Corynespora cassiicola.*

ECUADOR

- M. Bustamonte (2001) in a grower guide reported the following pathogens: *Corynespora cassiicola* can reduce yields significantly.

INDIA

- U.N. Mohanty and N.N. Mohanty (1958) reported *Corynespora cassiicola* caused a disease in sesame. [Cited by R.S. Vasudeva, 1961]
- H.K. Saksena and D.V. Singh (1975) reported *Corynespora cassiicola* is externally, as well as internally, seedborne. [Cited by M.L. Verma, 1985, and G.S. Saharan, 1989]
- B.N. Shukla and S.C. Vyas (1977) reported target spot caused by *Corynespora cassiicola* produced purple-brown specks to large spots on leaves and stem. Leaves curl and defoliate. Circular to elongated sunken spots on capsules. Seeds turn dark brown.
- K.K. Kushi and M.N. Khare (1979a) reported among 26 samples, *Macrophomina phaseolina* was associated with 23, *Corynespora cassiicola* with 11 and *Alternaria sesami* with 10. Isolates of all 3 were pathogenic, resulting in seed rot, pre- and post-emergence losses, stem rot and leaf spots.
- S.M. Jani and M.R. Siddiqui (1981) reported *Corynespora cassiicola* is seedborne externally and internally. [Cited by G.S. Saharan, 1989]
- S. Maiti et al. (1985 and 1986) reported the following minor pathogen: Leaf spot blight *Corynespora cassiicola* (Berk. and Curtis) Wei.
- M.L. Verma (1985) reported *Corynespora cassiicola* (Corynespora blight – targe spots) is a major disease with the following symptoms: Purple brown specks to large spots, later leaves curling, premature defoliation. Purple,

brown specks to elongated, scattered irregular, 10-15 cm lesions on stem, stem canker and stem bend. Circular/ elongated sunken black spots on pods. Seeds turn dark brown.

- P. Shukla et al. (1987) reported sesame blight caused by *Corynespora cassiicola* perpetuates through seed, soil and diseased plant debris (for ten months).
- P. Kumar and U.S. Mishra (1992) reported sesame diseases were monitored in Uttar Pradesh. In 1987, 12 diseases were recorded and in 1988 powdery mildew [*Oidium sesami*] was also recorded. Leaf and stem spot caused by *Corynespora cassiicola* was the predominant disease (28%) followed by leaf spots caused by *Cercospora sesami* [*Mycosphaerella sesamicola*], *Xanthomonas* [*campestris* pv.] *sesami* and *Alternaria sesami* (11-18%). The remaining diseases reached disease intensities of 10%. Disease intensity was higher in 1987 than in 1988 due to drought. A new leaf spot disease caused by *Curvularia fallax* was recorded for the first time in India. Most of the common diseases of sesame caused yield losses of 20-40%. [Based on abstract]

MEXICO

- Agrolytics.org (2021) reported sesame hosts *Corynespora cassiicola*.

REPUBLIC OF KOREA

- S.H. Yu (1981) reported the following fungi in sesame seed samples *Alternaria sesami, Alternaria sesamicola, Alternaria tenuis* (*Alternaria alternata*), *Corynespora cassiicola*, *Alternaria longissima*, *Fusarium oxysporum,* and *Macrophomina phaseolina*. All were controlled by pre-treatment with chlorine, except for *Corynespora cassiicola*. *C. cassiicola* caused severe seed rot and seedling mortality. *C. cassiicola* induced severe leaf and stem blight in inoculation experiments resulting in death. [Based on abstract and cited by G.S. Saharan, 1989]
- C.W. Kang et al. (1985h) reported Sesame leaf blight *Corynespora cassiicola*) is a serious problem. The lesions on the leaves are enlarged rapidly after the rainy season in summer, greatly reducing sesame yield. Six chemicals including Benomyl 50% WP were applied one to three times after inoculating artificially cultured sesame leaf blight fungi. Three times spraying system of benomyl 50% WP with 1.2 t/ha of l,5000x at ten-day intervals was the most effective for controlling sesame leaf blight. In the treated plots the leaf spot area was 14% vs. 36% in the control, sprayed only once. The 1000-seed weight was 2.7g vs. 2.4g in the control. The yield of the treated plots was l5% higher.
- J.I. Lee and B.H. Choi (1985h) reported sever infections of leaf blight (*Corynespora cassiicola*) are very destructive. They can be controlled by seed sterilization, crop rotation, and Benomyl WP applications.

UNITED STATES

- W.J. Stone and J.P. Jones (1960) reported
  - The *Corynespora cassiicola* overwintered on sesame and soybean debris in the field.
  - Disease also called "target spot" because of concentric rings.
  - The organism is reported to lose pathogenicity with repeated transfers.
  - Fungus can be carried on and within the seed, but surface sterilization can reduce infections.
- T.W. Culp and C.A. Thomas (1964b) reported the following observations on *Corynespora cassiicola* (Berk & Curt.) Wei:
  - Symptoms were large, irregular-shaped, concentrically-zoned, light-brown lesions which later coalesce and cause defoliation. Infection on the stems is characterized by light-brown, elongated lesions which later spread over the entire stems, causing death of the plants.
  - Does not attack seedling stage under field conditions. It usually appears and rapidly reaches epiphytotic conditions as the plants reach maturity.
  - Ven 51 shows some resistance in that it is not attacked until mature.
  - Crop rotation and disease-free planting seed may be of little value since *C. cassiicola* is found in soybeans and cotton also (there are large crops in Miss.).
  - Usually not possible to separate from *Alternaria sesami* under field conditions. Both diseases can occur on the same plant.
  - This and *Alternaria sesami* were believed to be beneficial because it got rid of the leaves at maturity, but then it attacked earlier producing immature seed (seed transmits the disease) and reducing yield in 5 varieties by an average of 49.5%.
  - Excessive rainfall and high humidity favor the blights, but dry years can hurt just as much since under moisture stress the plants become more susceptible. Additional irrigation may help.
  - The fungus is transferred by the seed. Seed treatments and crop rotation should be used.
- K.A. Cochran comments, 2021: This pathogen has long thin spores at tip of a dark brown to black conidiophore and can be easily confused with spores of *Cercospora* spp. or *Helminthosporium* ssp., especially when only

viewing them with a hand lens. Upon inspection with a slide mount using a compound microscope, the cell morphology is different from Cercospora, as Corynespora spores are typically dark colored (may appear silvery grey *en masse*), are larger than Cercospora spores, and conidiophores have a bulbous terminal cell, and typically occur singly though they may be many single conidiophores *en masse* in contrast to Cercospora conidiophores occurring in clusters. *Cercospora* spores are hyaline (clear), have a thick colorless exospore and a prominent basal scar. Corynespora spores often have considerable variability in size, and do not always sporulate readily in culture, which further complicates identification.

This pathogen often presents symptoms as foliar leaf spots, typically with a target-like pattern, leading to the name target leaf spot. In recent observations in the Uvalde area, extensive and frequent crown and stem malformations and rot have been noted. These entail swelling, discoloration, and often splitting. In severe cases, sporulation on stem and crown tissue may be so heavy, it appears similar to a layer of velvet on the surface. The fungus has been recovered from seeds and capsules, indicating it is seedborne. While I have made observations that there is a reduction in plant size and yield as a result of significant disease symptom progression, the full impact of this disease is not well described in sesame in the US.



Crown rot (left with stem lesion at breakage point) with cracking and sporulation (velvety black material)



Stem lesion side/front view with malformed growth, discoloration, and sporulation.

VENEZUELA

- L.J. Subero (1975) reported severe blight, as causing extensive spots on leaves, capsules and stems at flowering and leading to defoliation in experimental plots in periods with continual rain and high pH. *Corynespora cassiicola* was consistently located from diseased tissues.
- B. Mazzani et al. (1981b and 1999) reported the presence of *Corynespora cassiicola*, which causes extensive spots on the leaves, stems, and capsules frequently leading to defoliation.
- A.M. Colmenares and L. Subero (1989a) reported the following pathogens: *Corynespora cassiicola* (Zonate spot). It is found in the leaves, stems, and capsules. It is characterized by light brown round spots with concentric rings on the leaves.

A3.2.1b *Corynespora sesameum* (5 Jul 2021)

Family: Corynesporascaceae

Definition: Amount of tolerance to *Corynespora sesameum* (Sacc.) Goto

References:

BRAZIL

- A. Castillo et al. (1981) evaluated sesame susceptibility to *Corynespora sesami*. [Authors comment: Could not find any other references to this species and so it was placed under *Corynespora sesameum*.]
- M.G.R. Faiad et al. (2002) examined seed from 416 accessions from 7 Brazilian states at 25°C under alternating black lights and darkness in a 12-hour photoperiod for 8 days. They found *Corynespora sesami* [Authors comment: Could not find any other references to this species and so it was placed under *Corynespora*

sesameum]. They then examined 31 seed samples that had been stored for 5 and 9 years at 8°C and 25% RH. They found *Corynespora sesami*. They concluded the seed acts as a vehicle for pathogen dissemination.

CHINA

- L.C. Tu (1985a and 1985b) reported *Corynespora sesamum* (Plant blight) in Henan province with a damage level of 2 out of possible 3.
- L.L. Li (1988) reported *Corynespora sesamum* (Leaf blight) causes minor or regional damage to sesame. The disease may harm leaves, leaf stalks, stems and capsules. It occurs commonly at the mid and late stages of sesame development. Generally, it is not considered as a serious disease. Its symptom appears on the leaves as brown spots with 4-12 mm in diameter, indistinct ring line, and black mildew on the spots. The severely affected leaves wilt, die, and fall. The spots on the stem and leaf stalk are initially shuttle-shaped and become red-brown and slightly sunken. The pathogen overwinters through hyphae in the crop debris and also through the conidiospores on the plant debris and seed. The use of healthy seed, crops rotation, cleaning the field, and draining the logged water are effective in controlling the disease. Spray of Bordeaux mixture (1:1:150) is also effective at the initial stage of the disease development.

JAPAN

- T. Kuzuyuki (2021) cited the following pathogen *Corynespora sesameum* (Leaf blotch) is listed in the Database of Plant Diseases in Japan.

MEXICO

- Agrolytics.org (2021) reported sesame hosts *Corynespora sesameum*.

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A3.3 Family: **Didymellaceae** Gruyter, Aveskamp & Verkley

(Wikipedia, 14 Apr 2021) The **Didymellaceae** are a family of fungi in the order Pleosporales.

Recent phylogenetic examination of some of the larger genera of the Pleosporales, particularly *Phoma*, has led to considerable reorganization of the order, many of the species being placed in this family.

The following species have been reported to cause diseases, produce a toxin, inhibit germination, or affect seed quality.

- A3.3.1 *Phoma* spp.
- A3.3.1a *Phoma sesami*
- A3.3.1b *Phoma nebulosa*
- A3.3.1c *Phoma sesamina*
- A3.3.1d *Phoma exigua*
- A3.3.1e *Phoma variosporeae*
- A3.3.2 *Ascochyta* spp.
- A3.3.2a *Ascochyta sesami*
- A3.3.2b *Ascochyta sesamicola*
- A3.3.3 *Didymella* spp.
- A3.3.3a *Didymella minuta*
- A3.3.3b *Didymella rabiei* (*Syn: *Mycosphaerella rabiei*)

References:

NIGERIA

- A.O. Esan et al. (2020) purchased 60 sesame samples from markets in Nasarawa states during 2 seasons (wet and dry) in order to determine the safety for human consumption. They identified the following fungi: *Aspergillus* section *candidi*, *Aspergillus* section *flavi* (*A. flavus* and *A. tamarii*), *Aspergillus* section *nigri*, *Cladosporium* sp., *Fusarium fujikuroi*, *Penicillium* spp., and Didymellaceae. [For the toxins found refer to section G1 Toxin producing mycoflora.]

A3.3.1 *Phoma* spp. (14 Apr 2021)

Family: Didymellaceae

Definition: Amount of tolerance to *Phoma* spp. Saccardo 1880.

(Wikipedia, 14 Apr 2021) ***Phoma*** is a genus of common coelomycetous soil fungi. It contains many plant pathogenic species. Spores are colorless and unicellular. The pycnidia are black and depressed in the tissues of the host. *Phoma* is arbitrarily limited to those species in which the spores are less than 15 µm as the larger spored forms have been placed in the genus *Macrophoma*. The most important species include *Phoma beta* which is the cause of the heart rot and blight of beets, *Phoma batata* that produces a dry rot of sweet potato, and *Phoma solani*.

The following species have been associated with sesame but there are no known reports of being a pathogen, producing a toxin, inhibiting germination, affecting seed quality, or being used as a biocontrol or biofertilizer.

- *Phoma herbarum* [Egypt]
- *Phoma sorghina* [Sudan]

References:

BRAZIL

- M.G.R. Faiad et al. (2002) examined seed from 416 accessions from 7 Brazilian states at 25°C under alternating black lights and darkness in a 12-hour photoperiod for 8 days. They found *Phoma* sp. They then examined 31 seed samples that had been stored for 5 and 9 years at 8°C and 25% RH. They found *Phoma* sp. They concluded the seed acts as a vehicle for pathogen dissemination.

CUBA

- La Habana (2009) in a grower guide reported the following pathogen: *Phoma* sp.

EGYPT

- A. Hashem et al. (2014) collected 18 seed samples of sesame in Egypt (12 samples) and Saudi Arabia (6 samples). They identified the following mycoflora: *Phoma sp.*

NIGERIA

- C.A. Amienyo et al. (2015) studied the effect of mycoflora collected from 5 markets on the deterioration of lipid content of seed. Visually healthy seeds were inoculated with spores of each of the nine fungi isolated from diseased seeds and incubated at 25+20°C for 7days. The healthy and fungal infected seeds were analyzed for their lipid content. The percentage incidence at the 5 locations is shown below.

Fungi incidence	Location				
	A	B	C	D	E
Alternaria alternate	6.6	3.6	3.2	2.0	0.0
Aspergillus chevalieri	10.3	4.2	5.0	0.0	0.0
Aspergillus niger	0.0	6.1	7.4	2.6	5.2
Aspergillus oryzae	3.3	4.0	0.0	0.0	0.0
Aspergillus flavus	3.9	3.1	2.7	0.0	0.0
Aspergillus terreus	4.8	11.2	2.4	13.0	0.0
Cochliobolus Spp.	9.5	0.0	0.0	0.0	0.0
Geotrichum candidum	0.0	0.0	0.0	0.0	3.5
Phoma Spp.	5.9	2.0	0.0	0.0	0.0

Fungi utilize basic compounds of the seeds for their metabolism and growth and may affect the germination rate of the seed. The uninoculated seed had 49.35% lipid. The following shows the lipid content after 7 days of infection.

Fungi	Lipid content (%)
Aspergillus chevalieri	42.40
Aspergillus oryzae	43.50
Aspergillus niger	45.00
Aspergillus terreus	45.45
Alternaria alternata	47.80
Cochliobolus Spp	48.10
Aspergillus flavus	48.70
Phoma Spp.	49.15
Geotrichum candidum	49.40

- A.D. Ojochenemi et al. (2015) examined 46 samples of sesame and reported *Phoma* spp.

SUDAN

- H.I.H. Idriss (2016) collected farmer saved red and white sesame from 7 locations in Sudan. 14 different fungi representing ten genera were identified. One of the predominant fungi was *Phoma* sp. The rarely reported

Phoma sp. warrants further etiological, ecological, and epidemiological investigations as well as analysis of pest risk assessment of this pathogen under sesame growing conditions in Sudan.

A3.3.1a *Phoma sesami* (1 May 2021)

Family: Didymellaceae

Definition: Amount of tolerance to *Phoma sesami* Sawada.

References:

CHINA
- L.L. Li (1988) reported *Phoma sesami* (Stem necrosis) causes minor or regional damage to sesame.

JAPAN
- Anon. (2015e) NIAS Genebank Japan descriptor: 3.2 *Phoma* wilt resistance. Secondary essential character. Observation and measurement of a block. The degree of resistance to *Phoma sesami* Sawada in field or in injection tests. The following are the ratings to be used:
  - 1 = Very low
  - 3 = Low
  - 4 = Slightly low
  - 5 = Intermediate
  - 6 = Slightly high
  - 7 = High
  - 9 = Very high

MEXICO
- Agrolytics.org (2021) reported sesame is a host of *Phoma sesami*.

REPUBLIC OF KOREA
- J.I. Lee and B.H. Choi (1985h) reported when there is damping off, 70% of the time it is *Fusarium oxysporum* f. sp. *vasinfectum*, 20% *Rhizoctonia solani*, and 10% *Phoma sesami*. Cultivation of resistant varieties like Ahnsanggae is the best method of control since the fungi survive in the soil and also on or in the seed. Vinyl mulching was also helpful in establishing good stands along with seed sterilization with Benlate-T and Benoran WP spraying at one week intervals during the seedling stage. Other methods of control include crop rotation and use of healthy seed.

VENEZUELA
- G. Malaguti and C.H. Diaz (1957) reported a new pathogen in Portuguesa: *Phoma* sp. (Black stalk). It appears as a blackening of a stalks at or just above soil level and induces premature desiccation and poor capsule production.

A3.3.1b *Phoma nebulosa* (15 May 2021)

Family: Pleosporaceae

Definition: Amount of tolerance to (*Phoma nebulosa* (Pers.) Q. Chen & L. Cai 2015.

(Wikipedia, 15 May 2021) ***Phoma nebulosa*** is a fungal plant pathogen infecting spinach.

References:

INDIA
- A.S. Reddy and S.M. Reddy (1982a) reported *Drechslera neergaardi* and *Phoma nebulosa* were recorded for the first time in *Sesamum* seed. [Cited by G.S. Saharan, 1989]
- A.S. Reddy and S.M. Reddy (1982b) studied the activity of alkaline and acid phosphatase, esterase, peroxidase, and polyphenol oxidase in sesamum seed under the influence of *Macrophomina phaseolina* and *Phoma nebulosa*. [Cited by G.S. Saharan, 1989]

A3.3.1c *Phoma sesamina* (3 Jul 2021)

Family: Pleosporaceae

Definition: Amount of tolerance to *Phoma sesamina* Saccardo.

References:

INDIA
- M.N. Reddy and D.S. Rao (1981) reported a new record of *Phoma sesamina*.

ITALY
- P.A. Saccardo (1914) reported *Phoma sesamina* was recorded on sesame. [Cited by G.S. Saharan, 1989]
- P.A. Saccardo (1931) characterized *Phoma sesamina* Saccardo.

MEXICO
- Agrolytics.org (2021) reported sesame is a host of *Phoma sesamina*.

PHILLIPINES
- B. Padilla (1919) collected *Phoma sesamina* on sesame. [https://mycoportal.org/portal/taxa/index.php?taxon=369638]

A3.3.1d *Phoma exigua* (6 Jul 2021)

Family: Pleosporaceae

Definition: Amount of tolerance to *Phoma exigua* Saccardo 1879.

(Wikipedia, 6 Jul 2021) ***Phoma exigua*** (syn. *Ascochyta gossypii*) is a fungal plant pathogen. It causes wet weather blight in cotton and it can be treated with systemic copper.

References:

INDIA
- K.R. Sharma and K.G. Mukerji (1973) reported *Phoma exigua* Desm. isolated from the leaves of sesamum was found to exist in two physiologically different forms which, when cultured at 24 ± 2°C, produce pycnidia only if the exchange of some chemical factors occurs between them.
- S. Maiti et al. (1985 and 1986) reported the following minor pathogen: Blight *Phoma exigua* Desm.

A3.3.1e *Phoma variosporeae* (6 Jul 2021)

Family: Pleosporaceae

Definition: Amount of tolerance to *Phoma variosporeae*.

References:

INDIA
- J.L. Shreemali (1979) reported *Phoma variosporeae* is described from sesame on which it causes ashy-brown marginal lesions surrounded by a dark-brown border and with small punctiform, dark brown pycnidia on the upper leaf surface. [Cited by G.S. Saharan, 1989]
- S. Maiti et al. (1985 and 1986) reported the following minor pathogen: Blight *Phoma variosporeae*.

A3.3.2 *Ascochyta* spp. (28 Apr 2021)

Family: Didymellaceae

Definition: Amount of tolerance to *Ascochyta* spp. Libert 1830.

(Wikipedia, 28 Apr 2021) ***Ascochyta*** is a genus of ascomycete fungi, containing several species that are pathogenic to plants, particularly cereal crops. The taxonomy of this genus is still incomplete. The genus was

first described in 1830 by Marie-Anne Libert, who regarded the spores as minute asci and the cell contents as spherical spores. Numerous revisions to the members of the genus and its description were made for the next several years. Species that are plant pathogenic on cereals include, *A. hordei*, *A. graminea*, *A. sorghi*, *A. tritici*. Symptoms are usually elliptical spots that are initially chlorotic and later become a necrotic brown. Management includes fungicide applications and sanitation of diseased plant tissue debris.

Some of these pathogens in the genus *Ascochyta* affect grass species, including grains.

The following species have been associated with sesame but there are no known reports of being a pathogen, producing a toxin, inhibiting germination, affecting seed quality, or being used as a biocontrol or biofertilizer.

- *Ascochyta gossypii* [Sudan]

A3.3.2a *Ascochyta sesami* (28 Apr 2021)

Family: Didymellaceae

Definition: Amount of tolerance to *Ascochyta sesami* Miura.

References:

CHINA

- L.L. Li (1988) reported *Ascochyta sesami* (Brown spot) causes minor damage to sesame.
- H.M. Miao and H.Y. Liu (2010) reported the following pathogen: *Ascochyta sesami.*

JAPAN

- T. Kuzuyuki (2021) cited the following pathogen *Ascochyta sesami* is listed in the Database of Plant Diseases in Japan.

A3.3.2b *Ascochyta sesamicola* (28 Apr 2021)

Family: Didymellaceae

Definition: Amount of tolerance to *Ascochyta sesamicola* P.K. Chi.

References:

CHINA

- L.L. Li (1988) reported *Ascochyta sesamicola* (Ring spot) causes minor damage to sesame.
- H.M. Miao and H.Y. Liu (2010) reported the following pathogen: *Ascochyta sesamicola.*

A3.3.3 *Didymella* spp. (20 Jul 2021)

Family: Didymellaceae

Definition: Amount of tolerance to *Didymella* spp. Saccardo 1880.

(Wikipedia, 20 Jul 2021) ***Didymella*** is a genus of fungi belonging to the family Didymellaceae. The genus has cosmopolitan distribution.

A3.3.3a *Didymella minuta* (19 May 2021)

Family: Didymellaceae

Definition: Amount of tolerance to *Didymella minuta* Farr 1961.

References:

CAMBODIA

- M.L. Farr (1961) reported *Didymella minuta* was isolated on sesame leaves.

MEXICO

- Agrolytics.org (2021) reported sesame hosts *Didymella minuta*.

A3.3.3b *Didymella rabiei* (20 Jul 2021)

Synonym: *Mycosphaerella rabiei*

Family: Didymellaceae

Definition: Amount of tolerance to *Didymella rabiei* (Pass.) Labr. 1931.

(Wikipedia, 20 Jul 2021) ***Didymella rabiei***, commonly called chickpea ascochyta blight fungus is a fungal plant pathogen of chickpea. *Didymella rabiei* is the teleomorph of ***Ascochyta rabiei***, which is the anamorph, but both names are the same species.

References:

INDIA

- R.K.S. Chauhan and B.M. Kulshrestha (1984b) reported the diffusate obtained from the fruit cavities of sesame inoculated with a spore suspension of *Alternaria sesami* was inhibitory to the germination of spores. It inhibited the spore germination of *Mycosphaerella rabiei*. No inhibition was caused by the extracts of healthy uninoculated fruits.

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A4 Order: Capnodiales Woron.

(Wikipedia, 9 Apr 2021) **Capnodiales** is a diverse order of Dothideomycetes, initially based on the family Capnodiaceae, also known as **sooty mold fungi**. Sooty molds grow as epiphytes, forming masses of black cells on plant leaves and are often associated with the honeydew secreted by insects feeding on plant sap. This diverse order has been expanded by the addition of several families formerly thought unrelated and now also includes saprobes, endophytes, plant pathogens, lichens and rock-inhabiting fungi. The new additions include the genus *Mycosphaerella* containing the causal agents of several economically important crop and tree diseases. A small number of these fungi are also able to parasitize humans and animals, including species able to colonize human hair shafts (*Piedraia hortae*).

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A4.1 Family: Mycosphaerellaceae Lindau

(Wikipedia, 9 Apr 2021) The **Mycosphaerellaceae** are a family of sac fungi. They affect many common plants, such as eucalyptus, the myrtle family, and the Proteaceae. They have a widespread distribution.

The following species have been reported to cause diseases, produce a toxin, inhibit germination, or affect seed quality.

- A4.1.1 *Cercospora* spp.
- A4.1.1a *Cercospora sesami* (*Syn: *C. sesami* var. *somalensis*, *Mycosphaerella sesami*, and *M. sesamicola*)
- A4.1.1b *Cercospora sesamicola*
- A4.1.2 *Pseudocercospora* spp.
- A4.1.2a *Pseudocercospora sesami*
- A4.1.3 *Cercoseptoria* spp.
- A4.1.3a *Cercoseptoria sesami*
- A4.1.4 *Pseudocercosporella* spp.
- A4.1.4a *Pseudocercosporella sesami*
- A4.1.5 *Phaeoisariopsis* spp.
- A4.1.5a *Phaeoisariopsis griseola*
- A4.1.6 *Cercosporidium* spp.
- A4.1.7 *Passalora* spp.
- A4.1.7a *Passalora fulva* (*Syn: *Cladosporium fulvum*)

There are species in this family associated with sesame, but not reported to cause diseases, produce a toxin, inhibit germination, or affect seed quality. See H4.1.

A4.1.1 *Cercospora* spp. (9 Apr 2021)

Family: Mycosphaerellaceae

Definition: Amount of tolerance to *Cercospora* spp. Fresen. ex Fuckel 1863.

Summary:


Photo: K.A. Cochran {USA}


Photo: O.A. Enikuomehin {Nigeria}

Cercospora leaf spot is a major disease in sesame production globally, largely caused by ***Cercospora sesami*** (Synonyms: *Mycosphaerella sesami*, *Mycosphaerella sesamicola*, and *Cercospora sesami* var. *somalensis*) and *C. sesamicola*. The disease manifests itself just before flowering, and the first symptoms are the appearance of small light brown spots on both surfaces of the leaves. In the beginning, the spots are roundish but later coalesce to form irregular patches varying from 5-15 mm in diameter. With the advance mm in diameter. With the advance in age, the color of the spots darkens due to the formation of conidiophores and conidia. The number of spots vary from 100 to 400 per leaf under humid conditions resulting in premature defoliation. The disease, however, is less severe on the stem and the petiole, forming spots of varying lengths. These are light brown at first but gradually become darker in color. The capsules are also affected producing similar spots and quite often destroyed, resulting in poor yield. The fungus may infect the seed, leading to the potential for reduced seed quality and performance. Primary infection is seedborne and from infected debris. The secondary spread is through wind-borne conidia. It is suspected that other species of Cercospora occurring on other crops, such as soybean are pathogenic to sesame and have been observed in the United States. Even within a single species, spores can have a high degree of phenotypic variability with respect to length, which makes molecular identification of species immensely helpful. Other fungi with similarly shaped spores (long and thin, borne on the end of a dark conidiophore) may be easily confused with *Cercospora* spp. particularly when using a hand lens, including *Corynespora* spp, and *Pseudocercospora* spp. There are also other species in the same family that are pathogens: *Pseudocercospora* spp., *Cercoseptoria* spp., *Pseudocercosporella* spp., *Phaeoisariopsis* spp., *Cercosporidium* spp., and *Passalora* spp. *Cercospora* spp. have been reported in international lists, Australia, Brazil, Burkina Faso, China, Colombia, Dominican Republic, Egypt, Ethiopia, Guatemala, Honduras, India, Israel, Italy, Japan, Kenya, Mexico, Myanmar, Nicaragua, Nigeria, Pakistan, Panama, Paraguay, Philippines, Somalia, Sri Lanka, Sudan, Surinam, Tanzania, Thailand, Turkey, Uganda, United States, and Venezuela.


Alternaria spp. and *Cercospora spp.* often occur on the same plant/leaf. Alternaria leaf spot (irregular tan/light brown lesions, mostly on top half of leaf) and Cercospora leaf spot (reddish-brown margins, small circular lesions; see edges of leaf especially). Photo: K.A. Cochran {USA}

(Wikipedia, 9 Apr 2021) **Cercospora** is a genus of ascomycete fungi. Most species have no known sexual stage, and when the sexual stage is identified, it is in the genus Mycosphaerella. Most species of this genus cause plant diseases, and form leaf spots. It is a relatively well-studied genus of fungus, but there are countless species not yet described, and there is still much to learn about the best-known of the species.

The following species has been associated with sesame but there are no known reports of being a pathogen, producing a toxin, inhibiting germination, affecting seed quality, or being used as a biocontrol or biofertilizer.

- *Cercospora chenopodii* [Pakistan]

References:

BRAZIL

- N.E.M. Beltrao and E.C. Freire (1986) in a grower guide reported *Cercospora* sp. causes a major disease.

COLOMBIA

- V.C. Barcenas (1962) reported *Cercospora* sp. was identified on sesame. [Cited by G.S. Saharan, 1989]

GUATEMALA

- Anon (1982a) A grower guide reported *Cercospora* sp. (Mancha blanca redonda) attacks the foliage.

INDIA

- O.P. Kadian (1972) reported two less common genera to include *Cercospora* sp., which reduced seed germination and had adverse effect on the seedlings. The seeds were internally as well as externally seedborne. [Cited by G.S. Saharan, 1989]
- S. Maiti et al. (1985) reported *Cercospora* sp. is important.
- S.K. Patil et al. (2001) evaluated twenty-four genotypes of a varied geographic and genetic diversity which are cultivated in India against Cercospora leaf spot. The disease intensity ranged from 53.33 to 96.67%. None of the genotypes was found to be resistant or tolerant to Cercospora leaf spot disease.
- N. Ranasingh and T. Samal (2013) reported soil application of neem cake @ 250 kg/ha + Seed Treatment with (Thiram 0.2%) + Carbendazim 0.1%) + spray of mancozeb 0.25% + Profenofos 50 EC @ 2ml/l of water at 30 and 45 Days after sowing recorded least incidence of *Alternaria* sp. and *Cercospora* sp. (leaf spot) and capsule borer attack. Spraying of quintal 0.1% (Carbendazim + Iprodione) or Iprodione (Rovral) 0.2% two times (30 and 45 Days) was also effective against *Alternaria* sp. and *Cercospora* sp.
- B. Khamari et al. (2018c) conducted an intensive survey at flowering to ripening of capsule to record the incidence of sesame diseases in 10 agroclimatic zones of Odisha during rabi 2014-15 with the following results.

Sl. No.	Place	Variety	Mac (%)	Fus (%)	Alt (Grade)	PM (Grade)	Cer (Grade)	Phy (%)
1	Bheden	Bheden local	18.09	9.78	3	0	2	0
2	Balianta	VRI-1	23.8	8.0	4	3	2	2.3
3	Nuagaon	Nuagaon local	12.8	3.0	3	0	2	0.6
4	Papadahandi	Papdahandi local	15.2	4.1	2	0	2	1.0
5	Betanati	Betanati local	18.8	0.5	2	2	1	0
6	Kalimela	Kalimela local	11.3	0.8	3	1	2	0.8
7	Agarpada	Agarpada local	8.0	1.0	3	1	1	0.6
8	Kirei	Sundergarh local	15.8	3.9	2	0	1	1.4
9	Khajuripada	Phulbani local	10.5	2.9	3	3	1	0.0
10	Bhawanipatna	Narla local	19.2	4.8	4	0	2	1.4

Mac=*Macrophomina*, Fus= *Fusarium*, Alt= *Alternaria*, PM= Powdery Mildew, Cer= *Cercospora*, Phy= Phyllody

- K. Divya et al. (2020) screened 133 genotypes for tolerance to phyllody, Alternaria leaf spot, Cercospora leaf spot, and downy mildew. There were no genotypes that were resistant to the leaf spots.

KENYA

- H.A.E W'Opindi (1981) reported the presence of *Cercospora* sp.

MEXICO

- Agrolytics.org (2021) reported sesame hosts *Cercospora* spp.

MYANMAR

- D. Myint et al. (2014) reported Cercospora is a serious disease.
- Y.Y. Min and K. Toyota (2019) surveyed diseases in 10 farmer fields and interviewed 25 farmers. They reported the following pathogen: *Cercospora* sp. The disease was reported in 30% of the fields. The yield losses ranged from 5 to 50%.

NIGERIA

- O.A. Enikuomehin (2005) evaluated the efficacy of aqueous leaf extracts of *Aspilia africana, Chromolaena odorata, Musa paradisiaca* and *Tithonia diversifolia* to control Cercospora leaf spot of two sesame cultivars (530-6-1 and Pbtil No.1). Results show that all extracts significantly ($p<0.05$) reduced the incidence and severity of the disease. Germination percentage of seeds from the sprayed plants was higher (77.0 to 83.5%) than that of control (64.5 to 73.0%) as shown below.

Treatment	Fungal incidence (%)		Seed germination (%)		Grain yield (kg ha^{-1})	
	530-6-1	Pbtil No.1	530-6-1	Pbtil No.1	530-6-1	Pbtil No.1
A. africana	8.8^{c}	7.3^{c}	78.5^{c}	83.0^{a}	110.0^{abc}	139.0^{ab}
C. odorata	8.0^{b}	7.0^{b}	77.0^{d}	81.0^{c}	104.9^{ab}	99.9^{bc}
T. diversifolia	4.5^{a}	7.5^{c}	83.5^{b}	78.5^{d}	155.0^{a}	149.6^{ab}
M. paradisiaca	10.0^{d}	10.5^{d}	74.5^{e}	65.5^{e}	100.0^{bc}	110.0^{abc}
Bentex T	4.5^{a}	6.5^{a}	89.0^{a}	82.0^{b}	146.4^{ab}	112.6^{abc}
Control	10.3^{d}	13.5^{e}	73.0^{f}	64.5^{f}	86.0^{c}	72.0^{c}

Seed was treated with the extracts for 30 and 60 minutes with the following results.

Duration of treatment/plant species	Sesame cultivars			
	530-6-1		Pbtil No.1	
	Fungal incidence (%)	Germination (%)	Fungal incidence (%)	Germination (%)
30 min.				
A. africana	4.5	79.5	5.5	79.0
C. odorata	4.0	79.5	3.5	80.5
T. diversifolia	4.5	78.5	4.5	80.5
M. paradisiaca	2.0	83.0	3.0	81.0
Bentex T	4.5	75.0	2.5	76.0
Control	15.5	72.0	12.0	74.0
LSD ($p\leq 0.05$)	3.63	2.90	2.64	2.15
60 min.				
M. paradisiaca	5.5	80.0	4.5	79.0
A. Africana	2.0	84.5	4.0	84.0
C. odorata	2.5	79.5	4.0	80.5
T. diversifolia	2.5	83.0	3.5	82.0
Bentex T	4.5	77.5	2.0	77.0
Control	25.0	62.0	13.5	76.0
LSD ($p\leq 0.05$)	6.69	6.09	3.10	2.26

- O.A. Enikuomehin et al. (2008) evaluated the effects of different row arrangements on incidence and severity of Cercospora leaf spot (CLS) and Alternaria leaf blight (ALB) diseases and seed health of sesame intercropped with maize. Row arrangements were sesame intercropped with maize in alternate pair of rows (2:2), two rows of sesame intercropped with one row of maize (2:1), sesame intercropped with maize in single alternate rows (1:1) with sole sesame as control. Intercropping maize with sesame reduced the incidence and severity of diseases. Sesame intercropped with maize in a (1:1) ration recorded a significantly lower number of infected leaves by CLS and ALB incidence than other row arrangements. ALB lesion number was between 17 and 20 in the (1:1) arrangement relative to 65–104 and 28–43 in the sole crop and other row arrangements, respectively. ALB lesion size was also reduced in the (1:1) than other row arrangements. Fungal infection of harvested sesame seeds was significantly reduced in the intercrop relative to the sole crop. CLS incidence was significant and negatively correlated with seed weight while defoliation was significant and positively correlated with ALB or CLS incidence. Rainfall was significant and positively correlated with CLS or ALB incidence while intercropping induced microclimatic effects that influenced disease incidence. Grain yield, weight of 1000-seed, number of capsules/plant and weight of seed/plant were significantly higher in the (1:1) row arrangement than the sole crop or other row arrangements. The study demonstrates that intercropping sesame with maize in a single alternate row (1:1) arrangement can be used to reduce foliar diseases of sesame. [Based on abstract]
- O.A. Enikuomehin et al. (2008) evaluated the effect of different population densities of sesame intercropped with maize, in a single alternate row (1:1) arrangement on the incidence and severity of foliar diseases of

sesame during the early and late cropping seasons of 2006 and 2007, respectively. The experiment comprised four treatments, namely sesame planted at 266,666, 177,777 and 133,333 plants/ha intercropped with maize (53,000 plants/ha) and sole sesame at 266,666 plants/ha. Sesame at 133,333 plants/ha + maize showed a lower incidence of Cercospora leaf spot (CLS) and Alternaria leaf blight (ALB) disease and also produced a higher grain yield than the other treatments. The incidence of normal or discolored seeds was not influenced by sesame population density. Significant negative correlations existed between foliar disease incidence and proportion of normal or white/cream colored seeds. Foliar disease incidence was negatively correlated with incidence of abnormal or discolored seeds. Intercropping did not influence maize agronomic characteristics and grain yields. [Based on abstract]

- H. Nahunnaro and B.A. Tunwari (2012b) investigated the effect of plant extracts (*Azadirachta indica, Jatropha curcas* L., *Alium sativum, Ocimum gratissimum* L., and *Chromolaena odorata) and the synthetic fungicide* (Benlate) on Cercospora leaf spot on sesame agronomic traits associated with yield at Ardokola and Gassol in 2011. The two fields were inoculated with spore suspension of 5 x 104 conidial/ml for even distribution of the pathogen at 3WAS. Thereafter, plant extracts (10%) were sprayed as from 4 WAS using ULV sprayer and repeated at two weeks intervals until 10 WAS. The results were as follow.

	*Intensity of CLS (%)		[1]Plant height (cm)		[1]Branches per plant		[1]Capsules per plant		[1] Seed Yield in kgha[-1]	
Treatments	Ardokola	Gassol	Ardokola	Gassol	Ardokola	Gassol	Ardokola	Gassol	Ardokola	Gassol
Neem	49.998b	47.52b	163.92a	140.69a	3.63ab	3.05a	151.47a	213.90b	818.31b	773.95c
Jatropha	50.27b	46.80bc	162.48a	142.06a	3.53b	3.06a	137.52a	209.10b	837.91b	787.24bc
Garlic	50.80b	45.09d	163.66a	140.79a	3.75a	2.96a	159.33a	258.44a	925.38a	843.19abc
Ocimum	48.75b	45.14cd	161.19a	141.27a	3.54b	2.96a	152.88a	214.19b	782.97b	797.38bc
Chromoleana	49.28b	44.30d	164.22a	139.24a	3.61ab	3.11a	145.47a	224.44ab	849.13ab	871.41ab
Benlate	49.998b	44.67d	167.083a	140.94a	3.50b	3.03a	155.52a	209.25b	863.47ab	891.91a
Control	57.94a	55.44a	149.70b	136.94a	2.92c	2.71b	108.45b	162.78c	548.66c	551.04d
Mean	51.0059	46.99	161.75	140.27	3.49	2.98	144.38	213.16	803.69	788.02
S.E.	3.13	2.60	9.88	7.56	0.27	0.32	28.10	49.51	107.39	113.17
p-value	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001

Means in the same column followed by the same letter(s) are not significantly different (0.05) using Duncan's Multiple Range Test.
*Percentage leaf area diseased estimated at 12WAS
[1]parameters determined at harvest

Although the reduction of Cercospora leaf spot was negligible, the yields were significantly increased.

- B.A. Tunwari and H. Nahunnaro (2012) surveyed 120 farms in 30 locations and reported Cercospora leaf spot (CLS - *Cercospora* sp.) caused 22 – 53% losses. CLS was low at 8 weeks after sowing and became more prevalent at 12 weeks after sowing. The disease was seen in all the areas visited.

- C.N. Ezekiel et al. (2014) isolated the following fungi on sesame seeds: *Cercospora* sp.
- A.D. Ojochenemi et al. (2015) examined 46 samples of sesame and reported *Cercospora* spp.
- M. Jimoh et al. (2016) evaluated the effect of foliar spray of aqueous extracts of *Tithonia diversifolia* or *Ocimum gratissimum* on Cercospora leaf spot (CLS) and Alternaria leaf blight (ALB) diseases of sesame intercropped with maize. The spraying regime was at 2 weeks interval from 3 to 12 weeks after planting. Extracts of *T. diversifolia* or *O. gratissimum* reduced the incidence and severity of both diseases. CLS incidence and severity as well as defoliation was significantly ($p < 0.05$) reduced below what obtained in the unsprayed intercrop. ALB lesion size was significantly ($p < 0.05$) reduced by *T. diversifolia* extract at 8.0% (w/v) from 154.7 mm^2 (sole crop) or 13.4 mm^2 (unsprayed intercrop) to 4.9 mm^2 (sprayed intercrop). *T. diversifolia* extract at 8.0% (w/v) enhanced higher values of grain yield/plant and incidence of normal seeds, and lower incidence of fungal infection of seeds than in the unsprayed intercrop. [Based on abstract]

PAKISTAN

- B.G. Nayyar et al. (2013) examined 15 samples of seed to detect fungi using 3 methods: agar plate, blotter, and deep freezing and found *Cercospora sp*.
- B.G. Nayyar et al. (2014) studied the effects of fungal pathogens on the germination of sesame. Seven prevalent fungal species viz. *Alternaria alternata, Aspergillus flavus, Aspergillus niger, Cercospora* sp., *Fusarium oxysporum, Penicillium egyptiacum* and *Rhizopus oryzae* associated with sesame seeds were selected for this study. Fungi associated with seeds affected the seed health and resulted in reduced seed germination, and seedling abnormality as shown in the table below.

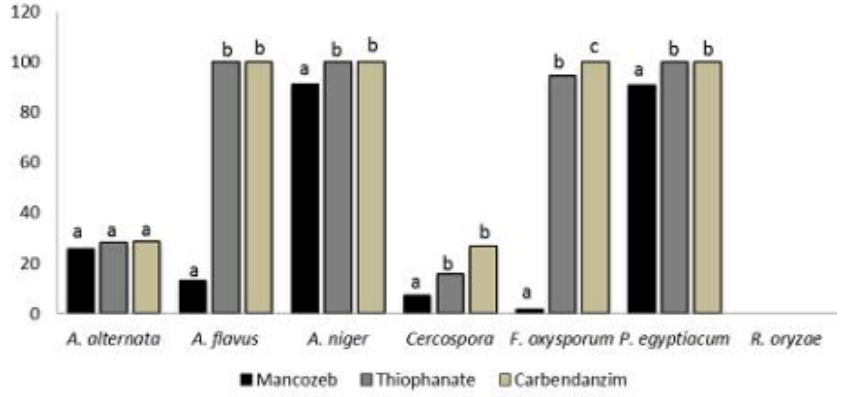
Treatments	Normal seedlings %age	Abnormal seedlings %age	Un germinated seeds %age	Fungi isolated
Surface sterilized seeds	80	14	6	*Aspergillus flavus* *Aspergillus niger* *Fusarium oxysporum*
Naturally infected seeds	64	26	10	*Alternaria alternata* *Aspergillus flavus* *Aspergillus niger* *Fusarium oxysporum* *Penicillium egyptiacum*

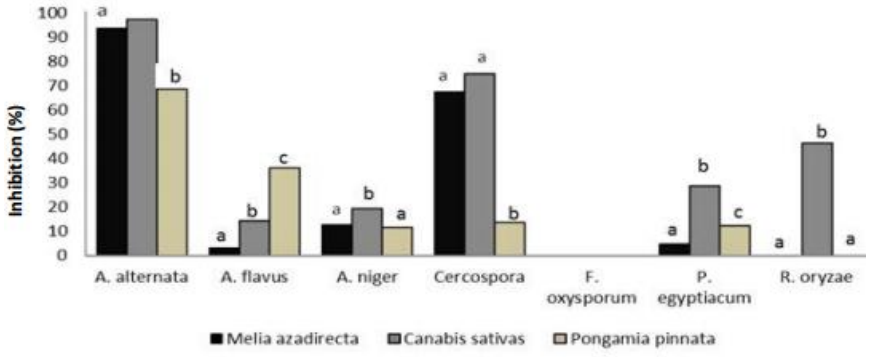
The pathogenicity of the 7 fungi was tested with the following results.

S. No.	Fungi isolated	Pathogenic Effect	Healthy Plants
1	*A. alternata*	Infected root & stem, Weak stem, Reduced growth	55%
2	*A. flavus*	Reduced growth	70%
3	*A. niger*	Reduced growth, Infected roots, Weak stem	13%
4	*Cercospora* sp.	Infected stem, Weak stem, Reduced growth	40%
5	*P. egyptiacum*	Infected root, Weak stem	26%
6	*R. oryzae*	Reduced growth, Infected roots & stem, Weak stem	30%
7	*F. oxysporum*	Reduced growth, Leaves short & infected	32%

Abnormality rate of seedlings depends on the type of pathogens with which they are infected. There is also need for the management programs to control seedborne pathogens and reduce their impact on sesame production in Pakistan.

- B.G. Nayyar et al. (2016) evaluated different treatments to increase the germination and inhibit the fungi on sesame seeds: application of fungicides (Mancozeb, Thiophante Methyl, and Carbendazim) and plant extracts (*Melia azedarach*, *Cannabis sativa* and *Pongamia pinnata*). Seed germination was tested by following the protocol of International Seed Testing Association. Antifungal activity was tested by poisoned food technique. The results revealed that the germination increased effectively, due to thiophanate methyl up to 46%, followed by *Cannabis sativa* (37%). The treatments had the following effects on specific fungi in terms of germination and inhibition: *Alternaria alternata, Aspergillus flavus, Aspergillus niger, Cercospora sp., Fusarium oxysporum, Penicillium egyptiacum*, and *Rhizopus oryzae.*





PANAMA
- R.W. Toler et al. (1959) reported Cercospora leaf Spot is present and is severe and limiting Panama.

PARAGUAY
- N. Lezcano (2006) in a grower guide reported the following pathogen: *Cercospora* sp.

PHILIPPINES
- N.M. Tepora (1989) reported the following disease: Cercospora leaf spot.

UGANDA
- W.O. Anyanga (2019) reported Cercospora is one of the main diseases.

UNITED STATES
- J. A. Martin (1953a) and M.L. Kinman and J.A. Martin (1954) reported *Cercospora* sp. in the U.S. The development is favored by excessive rainfall and high humidity. The organism is seedborne. They felt it could be controlled by producing disease free seed in the desert or by appropriate seed treatment. They found that a Japanese variety, Sirogoma, and the original source of the indehiscent gene were moderately resistant.
- Anon (1959) reported *Alternaria* sp. and *Cylindrosporium* sp. were the main diseases in Florida nurseries. *Cercospora* sp. and *Helminthosporium* sp. are minor problems.
- C.A. Thomas (1959b) reported leaf spots or blights caused by species of Alternaria, Cercospora, Corynespora, Helminthosporium, and other fungi appear to be the chief diseases limiting production in areas of high rainfall and humidity. Observations over a period of years and in a number of locations will tell us what levels of resistance are sufficient for satisfactory production in an average year in a particular area. Whether or not lines can be found that possess higher resistance than our present ones remains a question. It would appear, however, that the discovery and use of such lines is necessary before commercial production can be profitable in some areas.
- D.R. Langham et al. (2010c) stated *Cercospora* sp. has been reported in sesame in the USA in research nurseries but have not been seen in commercial fields since 1978.
- C. Stichler (pers. comm. 2016): *Cercospora* showed up in South Texas in 2016 and prematurely defoliated whole fields, substantially reducing yields. Early planted sesame escaped.

VENEZUELA
- D.G. Langham et al. (1961c) used the following symbology in the Sesamum Foundation: *Resistencia a Cercospora* (C1-C5).
  - C1 = Resistant
  - C2-C4 = Intermediate
  - C5 = Susceptible
- B. Mazzani (1981a) reported *Cercospora* sp. (Leaf spot) is one of the major diseases.

A4.1.1a *Cercospora sesami* (10 Dec 2021)

Synomyms: *Mycosphaerella sesami, Mycosphaerella sesamicola,* and *Cercospora sesami* var. *somalensis*

Family: Mycosphaerellaceae

Definition: Amount of tolerance to *Cercospora sesami* Zimmermann 1904.

(Anon. n.d.k) Leaf spot - *Cercospora sesami*

Symptoms: The disease first appears on the leaves as minute water-soaked lesions, which enlarge to form round to irregular spots of 5-15 mm diameter on both the leaf surface. The spots coalesce to form irregular patches of varying size leading to premature defoliation. The infection is also seen on stem and petiole forming spots of varying lengths. Dark linear spots also occur on pods causing drying shedding.

Pathogen: The hypha of the fungus is irregularly septate, light brown and thick walled. Conidiophores are produced in cluster and are 1-3 septate, hyaline at the tip and light brown colored at base. Conidia are elongated, 7-10 septate, hyaline to light yellow, broad at the base and tapering towards the apex.

Disease Cycle: The fungus is externally and internally seedborne. The fungus also survives in plant debris. Primary infection may be from the seeds and infected debris. The secondary spread is through wind-borne conidia.

Management: Treat the seeds with Carbendazin or Thiram at 2g/kg; spray with Mancozeb at 2kg/ha.

(CAB International, 9 Apr 2021) Cercospora leaf spot, caused by the fungus Cercospora sesami, infects all above ground parts of the plant, resulting in complete defoliation which leads to severe economic losses. The disease, which affects leaves as early as 4 weeks after planting, starts as small pinhead-sized cottony spots on the infected leaves. These spots gradually spread on the lamina and can extend up to 4 mm in diameter. Extensive infection leads to defoliation and damage of capsules before the plant reaches maturity which can result in yield losses of 20 to 50%.

The fungal spores are spread to healthy plants through rain, irrigation water and wind. Germination occurs in humid conditions, usually during late spring and summer, and fungus growth is encouraged when leaves are frequently damp.

Management: Carry out field sanitation and destroy crop residues; treat seeds with thiram or carbendazim @ 2 g per Kg of seed; early planting should be done, i.e., planting immediately after the onset of the monsoon; follow intercropping system of sesame + pearl millet (3:1); use a resistant variety, such as RT-127; apply a foliar spray (2-3 times) of wettable sulphur 80 % wp (0.2%) at 10 day intervals from when the disease appears; apply three sprays of Mancozeb (0.25 %) at 15 day intervals from when disease appears

References:

INTERNATIONAL

- R.S. Vasudeva (1961) reported *Cercospora sesami* is a major disease in the world. It manifests itself just before flowering, and the first symptoms are the appearance of small light brown spots on both surfaces of the leaves. In the beginning, the spots are more of less roundish but later coalesce to form irregular patches varying from 5-15 mm in diameter. With the advance in age, the color of the spots darkens due to the formation of conidiophores and conidia. The number of spots vary from 100 to 400 per leaf under humid conditions resulting in premature defoliation. The disease, however, is less severe on the stem and the petiole, forming spots of varying lengths. These are light brown at first but gradually become darker in color. The capsules are also affected producing similar spots and quite often destroyed resulting in poor yield.
- J.R. Morschel (1964) reported the following pathogen in the world: *Cercospora sesami* (Leaf spot). [Cited by D.F. Beech. 1995a]
- C. Wescott (1971) reported the following pathogen: leaf spots (*Cercospora sesami*).
- P. Neergaard (1979) reported the following pathogen caused a disease in sesame: *Cercospora sesami*. [Cited by G.S. Saharan, 1989]
- M.O. Khidir (1981a) in a review of sesame in East Africa and the Near East reported the following disease was a problem: *Cercospora sesami*.

- Anon (2000a) is an organic grower guide for America. It describes the following pathogen and its recommended organic method of control: *Cercospora sesami* (White Spot) is transmitted through seeds, and plant residues in the soil. Should burn the plant residue. Treat the seed with hot water treatment: 30 minutes at 53°C. Use of resistant varieties.
- Anon. (2004a) IPGRI descriptor: 10.2.2. Biotic stress susceptibility to *Cercospora sesami.* (Leaf spot)
  - In each case it is important to state the origin of the infestation or infection, i.e., natural, field inoculation, or laboratory. Also specify the causal organism and the corresponding symptoms. The susceptibility scale is as follows:
    - 1 = Very low or no visible sign of susceptibility
    - 3 = Low
    - 5 = Intermediate
    - 7 = High
    - 9 = Very high
  - The growth state, coded according to the list below at which each reaction was recorded should be appended to the record of that reaction.
    - 1 = Seed
    - 2 = Seedling
    - 3 = Pre-flowering
    - 4 = Early flowering
    - 5 = Mid-flowering
    - 6 = Late-flowering
    - 7 = Maturity
- C. Chattopadhyay et al. (2019) reported the following symptoms of *Cercospora sesami* Zimmerman (*Mycosphaerella sesamicola*) (White leaf spot or Cercospora leaf spot): Small circular spots are scattered on both leaf surfaces. At first, they are minute, and later they increase in size to become 5 mm in diameter with whitish center (white spot) surrounded by a blackish purple margin. The spots may enlarge rapidly, coalesce into irregular blotches that often become about 4 cm in diameter, and are concentrically zoned. Under humid conditions, the disease becomes severe involving premature defoliation. The disease causes defoliation particularly in early maturing varieties. On petioles, the spots are elongated. Capsules show more or less circular, brown-to-black lesions (1–7 mm).

  Many synthetic fungicides have shown promise in the management of sesame diseases (O. Shokalu et al. 2002 {Nigeria}). However, the high cost of such chemicals forbids their use by ordinary farmers. Seed treatment with systemic fungicides like carbendazim (0.15%) or Bayleton (0.15%) is reported to be effective in the control of the seedborne inoculum. Sesame crop sprayed with carbendazim at 0.1% or Quintal at 0.2 gives best degree of disease management with increase in seed yield by 31.28% (M.Z. Hoque et al. 2009 {Bangladesh}; M.G. Palakshappa et al. 2012 {India}). Two sprays of a mixture of mancozeb at 0.2% plus endosulfan 35 EC at 1 mL/L, first spray being given at flower initiation stage and the second at pod formation stage, result in good control of insect pests and Cercospora leaf spot disease (S. Ali and R.B. Singh 2003 {India}).

  Hot-water treatment of seeds at a temperature of 53°C for 30 min gives good control of the disease. Aqueous leaf extract of plants *Aspilia africana, Chromolaena odorata, A. indica,* and *Allium sativum,* when sprayed once every week, give significant reduction in disease severity (O.A. Enikuomehin 2005 {Nigeria}; H. Nahunnaro and B.A. Tunwari 2012c {Nigeria}). The plant extracts of garlic, Ocimum, and Chromolaena are comparable to synthetic fungicide (Benlate) in reducing the amount of Cercospora leaf spot on sesame (O.A. Enikuomehin and O.T. Peters 2002a {Nigeria}; B.A. Tunwari and H. Nahunnaro 2014b {Nigeria}). Plant debris should be burned after threshing and before plowing. Early-sown crop in the middle of June to first week of July is less affected due to Cercospora leaf spot, and these sowing dates are preferred for sowing sesame in wider row spacing of 20-30 cm in India and Nigeria (S.K. Tripathi et al. 1998a {India}; O.A. Enikuomehin et al. 2002b {Nigeria}; M.L. Verma et al. 2005 {India}). Intercropping-induced microclimatic effects influence foliar disease severity including that of Cercospora leaf spot of sesame. Grain yield, 1000-seed weight, number of capsules/plant, and weight of seed/plant have been observed to be significantly higher in the 1:1 row arrangement than the sole crop or other row arrangements. Intercropping sesame with maize (1:1) can be used to reduce white leaf spot severity of sesame (O.A. Enikuomehin et al. 2008 {Nigeria}).
- CAB International (accessed 12 Apr 2021) reported sesame was a host of *Cercospora sesami* (Leaf spot: sesame).

- N. Ransingh et al. (2021) reported the following symptoms of *Cercospora sesame* Zimmerman and *Cercospora sesamicola* Mohanty (Cercospora leaf spot): Initially, the disease appears as minute water-soaked lesions on the leaves, which enlarge to form round to irregular shaped spots of 5-15 mm diameter with whitish center and blackish-purple margin on both the leaf surfaces. In some cases, the spots are surrounded by a yellow halo. Spots may be light brown, reddish-brown, or dark brown in color with a whitish center. These spots increase in size and are delimited by veinlets of leaves which later become angular. In case of severe infection, excessive development of spots on leaf leads to drying up and shedding of leaves, causing defoliation of the plant. Premature defoliation is severe in humid condition (S.J. Kolte 1985{India}). Defoliation and damage to capsules before maturity results into 20–50% yield loss. Cercospora leaf spot is otherwise known as frogeye leaf spot disease. The pathogen penetrates the plant directly or through stomata and destroys the leaf tissues forming circular or irregularly shaped brownish spots with a light whitish center resembling 'frogeye.'

  The fungus survives in seed as well as in plant debris. It may survive on seed both externally as well as internally. Thus, the seed provides the primary infection, but secondary spread is carried out by wind-borne conidia. When conidia land on the surface of leaves, they germinate in the presence of free moisture. The hyphae emerge from germinated spores and infect the plant by entering through stomatal openings, wounds or by direct penetration. After penetrating the leaf surface, fungal hyphae ramify the parenchymous tissue and grow intercellularly (M.P. Steinkamp et al. 1981 {United States}). Cercosporin toxin produced by hyphae damages the cell membranes primarily through lipid peroxidation and leads to necrosis of cells. Pathogen absorbs nutrients that are leached through the damaged leaf cells.

  During humid conditions, the spore germinates. If leaves are frequently damp, the germination process is encouraged. High humidity (95% and above) conditions are essential for conidial germination. A wide range of temperature (25-30°C) is required for conidia germinate. Warm and humid conditions are conducive for the disease development.

  Alteration of cultural practices is helpful to get rid of this disease to some extent. Maintenance of field sanitation by destroying crop residues is key to disease management strategy. Planting early, i.e., immediately after the onset of the monsoon is helpful to avoid the disease. Intercropping of sesame with pearl millet in the ratio of 3:1 is beneficial for reducing disease incidence.

  Seed may be treated with chemicals like thiram or carbendazim at the rate of 2 g/kg of seed. Spraying of carbendazim @ 0.1% is effective in managing the disease. Three sprays of Mancozeb @ 0.25% at fifteen days interval from the first appearance of disease can also be used for managing the disease.

AUSTRALIA

- D.F. Beech (1981a and 1995a) reported the presence of *Cercospora sesami* (leaf spot) in Australia in 1941 and 1961.
- B.D. Conde (1995) reported the following pathogen: *Cercospora sesami* (imperfect state of *Mycosphaerella sesami*) (small Cercospora leaf spot) is characterized by small circular spots on both leaf surfaces. The spots are light brown with grey centers about 1-5 mm in diameter. This disease has not posed a danger in the Northern Territory.
- R.G. Shivas et al. (1996) reported *Cercospora sesami* [*Mycosphaerella sesamicola*] in a commercial crop of sesame at Beverley Springs Station, Western Australia.
- M.R. Bennett and B. Conde (2003) reported *Cercospora sesami* (small Cercospora leaf spot) [*Mycosphaerella sesami*]. This is characterized by scattered lesions on both leaf surfaces. This disease has not posed a danger in the Northern Territories.

BRAZIL

- A.P. Viegas and G.C. Teixeira (1945) reported *Cercospora sesami* caused a disease in sesame. [Cited by R.S. Vasudeva, 1961, and G.S. Saharan, 1989]
- C. Kurozawa et al. (1985) reported Morada indeiscente and Morada were resistant to *Cercospora sesami* in field trials. Carbendazim and thiophanite methyl eliminated seed infection. Viability of the fungus decreased after 4 years of seed storage. [Cited by G.S. Saharan]
- M.G.R. Faiad et al. (2002) examined seed from 416 accessions from 7 Brazilian states at 25°C under alternating black lights and darkness in a 12-hour photoperiod for 8 days. They found *Cercospora sesami.* They then examined 31 seed samples that had been stored for 5 and 9 years at 8°C and 25% RH. They found *Cercospora sesami.* They concluded the seed acts as a vehicle for pathogen dissemination.
- N.H.C. Arriel et al. (2009) reported *Cercospora sesami*. This disease can develop in plants from infected seeds at an early stage of development. One can find lesions in the cotyledons of the seedlings that have abundant

inoculum of the pathogen, which will give rise to secondary infections throughout the plant, affecting leaves, petioles, stem and fruit. In leaves and capsules, symptoms are characterized by presence of rounded spots, more or less regular, with the center of light gray to whitish coloration and brown edges; on the stems and petioles, the lesions are wide and elliptical, reaching form cancers with necrotic and depressed areas. When the disease strikes severely, plants can become totally leafless. The fungus is transmitted by the seeds, both internally and externally. The pathogen penetrates the inside the capsule and reaches the seeds, making them blackish. To prevent the spread of the pathogen, it is recommended to use of healthy, pathogen-free seeds. The treatment of seeds with systemic fungicides, based on carbendazin and thiophanate methyl can be used for control. Sprays preventives with fungicides that have as active ingredient the copper sulphate, when the plants reach the height of 25 cm to 30 cm, has provided efficient control of this disease. The use of resistant cultivars is the most effective control method. In the 1990s, behavioral studies of different commercial cultivars showed significant differences in the level of resistance to this disease. Currently, commercial cultivars recommended by Embrapa (CNPA G2, CNPA G3, CNPA G4 and BRS Seda) have been tolerant to this disease.

- V.P. Queiroga et al. (2010c and 2019) reported *Cercospora sesami*. For control burn the crop residue or hot water treatment for 30 minutes at 53°C. Use resistant varieties: Maporal, Morada id, Acarigua, Arawaca, and Inamar [Authors comment: These are all Venezuelan varieties.]

- N.E.M. Beltrao et al. (2013) reported *Cercospora sesami*. Rounded spots appear on the leaves and fruits, with a center light gray to off-white with brown edges. On the stems and petioles, the lesions are large and elliptical, even forming cancers with an area necrotic and depressed. According to Lima et al. (1997) in the case of incidence severe disease the plants are completely defoliated. The fungus can also penetrate inside the capsule and reach the seeds, making them dark. Cotyledon injuries can give rise to reflex infections, that is, those in which symptoms are exhibited in organs distant from the site of action of the pathogen. High rainfall and high relative humidity contribute to for the further development of the disease (C.R. Casela and A.S. Ferreira, 2003).
- N.H.C. Arriel et al. (n.d.) Brazil descriptor: CERCOSPORIOSE (*Cercospora sesami*). This disease affects the leaves, petioles, stems and fruits. In the leaves and fruits, the symptoms are characterized by the presence of more or less regular rounded spots, with a light gray to off-white center and brown edges. In the stems and petioles, the lesions are large and elliptical, forming cancers with necrotic and depressed areas. In cases of severe attacks, which are favored by high rainfall, the plants are almost completely defoliated. When the fungus penetrates inside the capsule, it reaches the seeds, making them black. The following are the ratings to be used.
  - 1 : 0 to 5%
  - 2 : 6 to 25%
  - 3 : 26 to 50%
  - 4 : 51 to 75%
  - 5 : 76 to 100%

BURKINA FASO

- M.M. Satour (1981) reported the presence of *Cercospora sesami* (Leafspot).

CHINA

- L.C. Tu (1985b) reported *Cercospora sesami* (Leaf spot) in Henan province with a damage level of 2 out of possible 3.
- L.L. Li (1988) reported *Cercospora sesami* (Leaf spot) causes minor or regional damage to sesame. The disease is not as serious as other diseases. The fungus attacks both the leaves and capsules. It occurs mainly in the flowering phase. Leaf spots are angular or round measuring 1-5 mm in size. The fruiting bodies of the fungus might become visible on the lower surface of the leaves, and the color is olivaceous brown. Capsule spots are round with grey center and dark-brown edge, slightly sunken. Leaf spots break easily and cause the leaves to fall. The pathogen is seedborne. and 16% been reported in China. The stromata in that are spread by wind and rain in the condition. Under rainy and moist conditions, the disease may be severe. Seed treatment with hot

water (53°C) or 0.1% Mercuric chloride for 30 to 60 minutes, crop rotation, clean cultivation, and 1 to 2 sprays of Bordeaux mixture (1:1:100) before and after flowering phase, are considered as the effective measures of control of the disease.

- H.M. Miao and H.Y. Liu (2010) reported the following pathogen: *Cercospora sesami.*

COLOMBIA

- H.C. Patino (1967) reported *Cercospora sesami* on sesame seed.
- Anon. (2013c) in a grower guide reported *Cercospora sesami* causes a major disease.

DOMINICAN REPUBLIC

- R. Ciferri and R. Gonzalez Fragoso (1926) reported *Cercospora sesami* on the leaves.
- R. Ciferri (1930) reported *Cercospora sesami* Zimm. (Leaf spot) was common everywhere but of no economic importance.

EGYPT

- M.M. Satour (1981) reported the presence of *Cercospora sesami* (Leafspot).

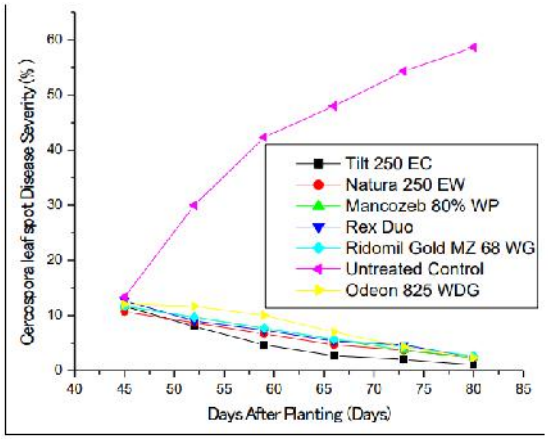
ETHIOPIA

- E. Teshome and D. Kora (2021) evaluated the effectiveness of fungicides (Odeon 825 WDG, Mancozeb 80% WP, Natura 250 EW, Ridomil Gold MZ 68 WG, RexDuo, Tilt 250 EC) on *Cercospora sesami* in 2015/16 and 2016/17 at DeloMana (6.42N 39.83E). They rated the damage with the following scale.

Scale	Disease Severity (%)	Resistance Category	Rating	Cercospora leaf spot characteristics
1	0-14	Immune (I)	No disease	No trace of infection
2	14.1-29	Highly Resistant (HR)	Hypersensitivity	Hypersensitive spot on lower leaves only
3	29.1-43	Resistant (R)	Trace infection	Small lesion on lower leaves only
4	43.1-57	Moderately Resistant (MR)	Slight infection	Small lesions on lower and upper leaves and stems
5	57.1-71	Moderately Susceptible (MS)	Moderate infection	Advanced lesions[1] on upper and lower leaves, with or without new infection stem and petiole
6	71.1-86	Susceptible (S)	Severe infection	Advanced lesionson upper and lower leaves, flower, buds, stems and petiole and slight infection of Capsule
7	86.1-100	Highly Susceptible (HS)	Very severe infection	All features of the above with severe infection of Capsule

[1] Advanced lesion is characterized by a dark to dark-brown spot with a whitish to the straw-colored or perforated center (Einkuomehin, *et al.*, 2002)

The results were as follow.



The effects on yield and yield components were as follow.

Treatment	% Stand	No. Capsule/plant	Capsule length (mm)	Plant height (cm)	TKW (gm)	Grain yield (kg/ha)
Unsprayed Control	75.00	21.33	2.30	114.22	2.80	457.87
Odeon 825 WDG	81.67	57.11	2.41	119.56	3.27	564.40
Ridomil Gold MZ 68 WG	86.67	59.56	2.35	133.89	2.87	555.37
Rex Duo	88.33	62.11	2.77	117.78	3.33	581.57
Mancozeb 80% WP	86.67	54.22	2.54	133.89	2.87	558.43
Natura 250 EW	88.33	66.56	2.79	142.78	3.13	590.51
Tilt 250 EC	90.00	71.67	3.01	144.89	3.27	618.98
CV (%)	6.53	26.35	7.73	12.75	6.84	15.40
$LSD_{(p\leq 0.05)}$	9.74	25.88	0.35	28.94	0.37	151.25

Note: TKW-Thousand Kernel Weight.

HONDURAS

- V.P. Queiroga et al. (2016) reported *Cercospora sesami* (Mancha circular) symptoms are the presence of round spots with a grayish center and purple border.

INDIA

- S. Choudhary (1944) reported the *Cercospora sesami* usually makes its appearance just at or before flowering, but sometimes plants a month hold are attacked. The attack is more severe in the later stages. It manifests itself as small light brown spots less roundish, but later become irregular in outline and occasionally sever coalesce forming irregular spots often as large as 5-15 mm in diameter. The spots are found on both surfaces of the leaf. The color of the spots which is at first light brown changes to a darker color with the formation of the conidiophores and the conidia. The leaf tissue around the spots very often loses the normal green color and takes a yellowish hue. On the petiole, the spots appear along its length; they are elongated and of varying lengths. They are at first light brown as the leaves but gradually become dark. The stem as a rule is much less infected than the leaves. In shape and color, the spots on the stem resemble the petiole. Sometimes the whole stem dries, and the plant droops down. Lesions also appear on the capsules, and they are often numerous. They are more of less circular and measure from 1-7 mm in diameter. In the early stages the spots are brown but in advanced stages, they become black and often the capsule is destroyed.
- S. Choudhary (1945) reported the sesame blight caused by *Cercospora sesami* is a serious disease in Assam where it caused an average yield reduction of 5%. The pathogen is perpetuated by infected seeds and plant residues in the field. Chemical seed treatments were ineffectual against the disease, but half an hour immersion in water heated to 128°F, as recommended by Nusbaum gave excellent results in large scale field plantings in 1943 and 1944. After one year's storage, the seeds were free from superficial contamination, but the fungus still persisted in the interior. [Cited by G.S. Saharan]
- N.N. Mohanty and B.C. Behera (1958b) reported a severe leaf spot of sesame was found to be caused by *Cercospora sesamicola* (Mohanty) with spores indistinctly 2-7 septate, 20-120 x 2-8 µ. It differs from *Cercospora sesami* in the uniformly brown angular spots, short, narrow, closely packed conidiophores and narrow cylindrical conidia.
- G.S. Saharan and J.S. Chohan (1972) reported *Cercospora sesami* (Leaf spot). [Cited by G.S. Saharan, 1989]
- M.M. Satour (1981) reported the presence of *Cercospora sesami* (Leafspot).
- M.L. Verma (1985) reported *Cercospora sesami* (Cercospora leaf – white spot) is a major disease with the following symptoms: Minute, small to large irregular, light brown to black brown spots on leaf, petiole, stem, and capsules; sometimes white round spot on leaf. Several spots cause leaf blight.
- Anon (1992a) in a grower guide reported *Cercospora sesami* (Cercospora leaf spot) appears from the 4-6 leaf stage of the crop and continue until maturity. Small brown and irregular spots are formed on the leaves. Later they increase in size and number and cover the whole leaf which results in immature defoliation.
- P. Kumar and U.S. Mishra (1992) reported sesame diseases were monitored in Uttar Pradesh. In 1987, 12 diseases were recorded and in 1988 powdery mildew [*Oidium sesami*] was also recorded. Leaf and stem spot caused by *Corynespora cassiicola* was the predominant disease (28%) followed by leaf spots caused by *Cercospora sesami* [*Mycosphaerella sesamicola*], *Xanthomonas* [*campestris* pv.] *sesami* and *Alternaria sesami* (11-18%). The remaining diseases reached disease intensities of 10%. Disease intensity was higher in 1987 than in 1988 due to drought. A new leaf spot disease caused by *Curvularia fallax* was recorded for the first time in India. Most of the common diseases of sesame caused yield losses of 20-40%. [Based on abstract]
- N.O. Srikantappa et al. (2009) studied 28 samples of sesame taken from fields, farmers, retail shops and APMC markets from 5 areas. They found 34 four fungi including *Cercospora sesami.* The fungi significantly reduced germination.

- M.G. Palakshappa et al. (2012) reported Cercospora leaf spot caused by *Cercospora sesami* infects all parts of the plant resulting into complete defoliation which leads to severe economic losses. They evaluated in 2009 and 2010 using susceptible variety (DS1) at Dharwad, Karnataka (15.46N 75.01E). The results were as follow.

Sr. No.	Treatments	Per cent disease index				Yield (kg/ha)			
		2009	2010	Mean	Pooled data *Kharif* 2009 and 2010	2009	2010	Mean	Pooled data *Kharif* 2009 and 2010
1.	Carbendazim 50WP@0.1%	48.45	54.00	51.22	50.98	352.60	981.58	667.09	667.08
		(43.79)	(47.30)*	(45.54)	(45.57)				
2.	Chlorothalonil 75% WP@ 0.2%	70.31	71.00	70.65	70.65	240.37	789.60	514.98	514.99
		(56.97)	(57.47)	(57.22)	(57.23)				
3.	Copper oxychloride 50% WP	72.06	76.00	74.03	74.03	210.47	803.45	506.96	506.96
	@0.25% + Streptocycline @ 0.01%	(58.12)	(61.30)	(59.71)	(59.43)				
4.	Mancozeb 75% WP@ 0.2%	69.46	71.00	70.23	70.22	270.80	828.92	549.86	549.86
		(58.48)	(57.42)	(57.95)	(56.95)				
5.	Propiconazole 25% EC@ 0.1%	68.54	71.00	69.77	69.79	251.60	783.20	517.40	517.40
		(55.93)	(57.47)	(56.70)	(56.72)				
6.	Wettable sulphur 80% WP@ 0.2%	71.56	79.00	75.28	75.28	204.60	848.25	526.43	526.44
		(57.10)	(64.34)	(60.72)	(60.33)				
7.	Quintal 50%WP	44.41	49.00	46.70	45.95	470.00	1166.32	818.16	818.19
	(Carbendazim+Iprodion) @0.1%	(39.23)	(44.42)	(41.82)	(42.68)				
8.	Saff (Carbendazim 12	68.55	58.00	63.27	63.27	361.65	879.52	620.59	620.59
	WP+Mancozeb 63 WP) @ 0.2%	(56.00)	(49.70)	(52.85)	(52.74)				
9.	Control	88.22	81.00	84.61	84.61	215.26	654.87	435.07	435.07
		(73.12)	(64.32)	(68.72)	(66.97)				
S.E.±		2.52	2.44	-	1.28	16.27	48.24	-	24.43
C.D. (P=0.05)		7.26	7.11	-	3.73	46.82	140.79	-	71.30
C.V. %		9.04	8.70	-	4.61	11.47	11.21	-	8.53

- B.A. Tunwari and H. Nahunnaro (2014b) conducted an *in vivo* study on Cercospora leaf spot – CLS (*Cercospora sesami*) using 5 plant extracts (Neem - *Azadirachta indica, Jatropha curcas*, Garlic - *Alium sativum, Ocimum gratissimum* L., and *Chromolaena odorata*) and a synthetic fungicide (Benlate) on 4 sesame varieties (Yandev 55, NCRIBEN 01M, E8 and NCRIBEN-03L) in 2011. The results of the severity of CLS (Cersev12), capsules per plant (CPP), seeds per capsule (SPC), 1000-seed weight (OTSW), and seed weight per plant (SYPP) were as follow.

Treatments	Cersev 12	CPP	SPC	OTS W	SYPP
Neem	39.52b	172.25 b	61.82b	2.79c	6.89b
Jatropha	38.74c	169.44 b	61.01b	2.89b	6.95b
Garlic	38.12cd	185.81 a	65.19a	3.11a	7.34a
Ocimum	37.77d	189.94 a	65.36a	3.10a	7.37a
Chromolaena	37.77d	187.56 a	65.40a	3.12a	7.37a
Benlate	38.12cd	189.38 a	65.42a	3.13a	7.40a
Control	44.65a	143.44 c	57.04c	2.57d	6.56c
Mean	39.24	176.83	63.03	2.95	7.13
CV (%)	2.60	7.47	2.85	2.06	1.72
S.E.	1.02	13.21	1.80	0.06	0.12
p-value	0.001	0.001	0.001	0.001	0.001

- B.A. Tunwari and H. Nahunnaro (2014a) conducted an *in vivo* study on Cercospora leaf spot – CLS (*Cercospora sesami*) using 5 plant extracts (Neem - *Azadirachta indica, Jatropha curcas*, Garlic - *Alium sativum*, *Ocimum gratissimum* L., and *Chromolaena odorata*) and a synthetic fungicide (Benlate) on 4 sesame varieties (Yandev 55, NCRIBEN 01M, E8 and NCRIBEN-03L) in 2011 and 2012. The results of the severity of CLS were as follow.

	Sesame varieties				
Plant extracts	Yandev 55	NCRIBEN-01M	E8	NCRIBEN-03L	Mean
Neem	44.11^{b}	38.57^{f}	36.91^{g}	41.41^{d}	40.25
Jatropha	43.39^{b}	38.21^{f}	36.43^{g}	41.06^{d}	39.77
Garlic	42.32^{c}	36.96^{g}	35.36^{h}	39.64^{e}	38.57
Ocimum	42.32^{c}	36.43^{g}	35.00^{hi}	39.64^{e}	38.30
Chromolaena	42.32^{c}	36.43^{g}	34.82^{i}	39.64^{e}	38.35
Benlate	42.32^{c}	36.78^{g}	34.64^{i}	39.82^{e}	38.39
Control	49.29^{a}	43.23^{bc}	41.09^{d}	48.22^{a}	45.46
Mean	43.72	38.09	36.32	41.35	39.87

- K.N. Gupta et al. (2018) reported Cercospora leaf spot (*Cercospora sesami* Zimm) is one of the most economically important diseases of sesame in almost all the production area. The crop is affected by the pathogens at all stages of the growth and causes heavy economic losses. Due to lack of resistant sources the released varieties are highly susceptible to Cercospora leaf spot. It appears as small, angular brown leaf spot 5-15 mm in diameter on both leaf surfaces. Under favorable conditions, the disease spreads to leaf petiole, stem and capsules producing linear dark colored lesions. The damage to plant growth and grain yield depends on the severity of infection on the stem and pods and the stage at which the infection takes place. The fungus is seedborne, both internally and externally, but can also survive in the plant debris. Thus, primary infection in the field may be from seed and infested plant debris and secondary spread may be through wind borne conidia. Extensive infection of foliage and capsule leads to defoliation and damage of sesame capsule and yield losses may range from 22 to 53%. The following help reduce the disease: intercropping of sesame + pearl millet (3:1); Spraying Carbindazim (1%), Topsin-M (0.1%), Mancozeb (0.25%), Difenoconazole (0.1%), or Carbindazim 50wp + Mancozeb 3 times as and when disease appear at 15 days intervals; early planting immediately after the onset of the monsoon also helps; and/or the treatment of *Pseudomonas fluorescens* (0.4%).
- Anon. (n.d.k) reported *Cercospora sesami* (Leaf spot) causes a major disease.

ISRAEL

- M.M. Satour (1981) reported the presence of *Cercospora sesami* (Leafspot).

ITALY

- P.A. Saccardo (1906) reported *Cercospora sesami* was recorded on sesame. [Cited by G.S. Saharan, 1989]

JAPAN

- M.M. Satour (1981) reported the presence of *Cercospora sesami* (Leafspot).
- T. Kuzuyuki (2021) cited the following pathogen *Cercospora sesami* (Cercospora leaf spot) is listed in the Database of Plant Diseases in Japan.

KENYA

- H.A. Van Rheenen (1981d) reported the goal of developing resistance to *Cercospora sesami.*

- J.O. Nyanapah et al. (1993) investigated the pathogenicity of *Cercospora sesami* (White leaf spot) and *Cercospora sesamicola* (Angular leaf spot) on sesame and 3 wild species under glasshouse conditions. Sesame cultivar SIK 134 was used since it is very susceptible to the diseases. Both of these diseases have been observed in all areas of Kenya. Within 12 to 28 days following inoculation, both fungi produced symptoms on *S. indicum, S. calycium,* and *S. angolese;* however, only *C. sesamicola* produced infection on *S. latifolium.*
- J.O. Nyanapah et al. (1995 and 1997) evaluated 16 entries to the resistance to *Cercospora sesami* (White leaf spot) and *Cercospora sesamicola* (Angular leaf spot). The most susceptible accessions to both diseases were SPS 071 and SIK 134. Accession SIK 031 and SPS 045 exhibited the latest susceptibility to white leaf spot and angular leave spot, respectively and are suggested as future standards for comparing reaction of other genotypes.

MEXICO

- M.M. Satour (1981) reported the presence of *Cercospora sesami* (Leafspot).
- E.C. Hernandez (2003) in a grower guide reported the following pathogen: *Cercospora sesami* (Mancha redonda). Appears near (before or after flowering) with spots with ash centers and reddish brown edges. For control, use improved varieties.
- Agrolytics.org (2021) reported sesame hosts *Mycosphaerella sesami.*

NICARAGUA

- S.C. Litzenberger and J.A. Stevenson (1957) reported *Cercospora sesami* caused a disease in sesame. [Cited by R.S. Vasudeva, 1961, and G.S. Saharan, 1989]
- Anon. (1998b and 2009a) in grower guides reported Circular spot (caused by *Cercospora sesami*). Round spots with a broad grayish center and a purple border.
- Anon. (2008a) in a grower guide reported *Cercospora sesami* was one of the major pathogens. It is recognized by a round stain on the leaf. When it appears at the end of the cycle, it results in plant defoliation. In addition to the leaves, it attacks the stem and capsules. It appears as a round stain with the center gray and yellowish edges. The main method of control is to use resistant varieties, crop rotation, and good drainage.

NIGERIA

- H.A. Van Rheenen (1972) reported the leaf pathogen *Cercospora sesami* had the following symptoms: It can attack all above ground parts of the plant, and it commonly produces lesions on leaves, petioles, stems, and capsules. The leaf spots have a brown center with a darker brown margin, are roughly circular in shape and from 2-4 mm in diameter but may coalesce to form lesions of about 8 mm in diameter. The petioles and the steams tend to have more elongated spots than the leaves. The lesions on the capsules are round in shape, slightly sunken in the tissue, and at first of a brown color which later becomes dark brown to black.
- M.M. Satour (1981) reported the presence of *Cercospora sesami* (Leafspot).
- J.E. Onyibe et al. (2005) in a grower guide reported the following pathogen: *Cercospora sesami.* Early planting especially with the onset of the rain gives a healthy crop. A delay in planting usually increases the change of disease attacks on Beniseed.
- F.M. Afolagboye (2011) reported the following fungus from 4 sesame varieties (NCRIBEN 03L, NCRIBEN 01M, E8 and 530-6-1) at Abeokuta: *Cercospora sesami.*
- H. Nahunnaro and B.A. Tunwari (2012a) investigated the reactions of four adaptable sesame cultivars (Yandev 55, NCRIBEN 01M, E8 and NCRIBEN-03L) to Cercospora leaf spot (CLS) caused by *Cercospora sesami* in 2011 at Ardokola (8.75N 11.25E) and Gassol (8.43N 10.53E). E8 and NCRIBEN-01M reduced the amount (15.35% and 16.16%) of Cercospora leaf spot disease compared with Yandev 55. Similarly, E8 and NCRIBEN-01M had better establishments, more branches, and higher seed yield than the other varieties. Their ratings used the following criteria.

Scale	Disease severity (%)	Resistant Category	Rating	Leaf spot characteristics
1.	0 - 14	Immune (I)	No disease	No trace of infection
2.	14.1 - 29	Highly resistant (HR)	Hypersensitivity	Hypersensitive spot on lower leaves only
3.	29.1 - 43	Resistant (R)	Trace infection	Small lesions on lower leaves only
4.	43.1 - 57	Moderately resistant (MR)	Slight infection	Small lesions on lower and upper leaves and stem
5.	57.1 - 71	Moderately susceptible (MS)	Moderate infection	Advanced lesions[1] on upper and lower leaves, with or without new infections on stem and petiole
6.	71.1 - 86	Susceptible (S)	Severe infection	Advanced lesions on upper and lower leaves, flower, buds, stems and petiole and slight infection of pod[1]
7.	86.1 - 100	Highly susceptible (HS)	Very Severe infection	All features of 6 above with severe infection of pod

[1]Advanced lesion is characterized by a dark to dark-brown spots with a whitish to straw-coloured or perforated centre [30].

- J.B. Kabeh (2017b) reported *Cercospora sesami* is a major disease causing severe leaf spots. He tested 5 varieties in 2014 and 2015 in terms of agronomic traits and tolerance to diseases and pests (Leaf curl – Tobacco mosaic virus, Fungal leaf spot = *Cercospora sesami*, galls are from the insect *Asphondylia sesami* - gall fly) on a 1-5 scale with 1 being tolerant.

Varieties	Severity of Leaf Curls	Severity of Fungal Leaf Spot	Number of galled capsules	Number of dead stands due to phyllody
2014				
Yandev 55	1.29±0.33^{ab}	1.93±0.06^{a}	5.79±0.64^{a}	1.96±0.23^{ab}
NCRIBEN-01M	1.87±0.00^{a}	1.31±0.09^{c}	5.70±0.38^{a}	1.83±0.37^{ab}
E-8	0.97±0.15^{b}	1.86±0.11^{ab}	5.73±0.51^{a}	1.65±0.07^{b}
Ex-Sudan	1.85±0.18^{a}	1.80±0.07^{ab}	5.46±0.32^{a}	1.59±0.34^{a}
ICEASE-00018	1.97±0.22^{a}	1.65±0.07^{b}	4.63±0.61^{a}	1.81±0.28^{ab}
2015				
Yandev 55	1.27±0.21^{bc}	1.92±0.16^{a}	5.14±0.99^{a}	1.92±0.13^{ab}
NCRIBEN-01M	1.86±0.11^{a}	1.40±0.10^{b}	5.41±0.41^{a}	1.72±0.32^{b}
E-8	1.18±0.18^{c}	1.63±0.19^{ab}	5.40±0.79^{a}	1.86±0.11^{ab}
Ex-Sudan	1.79±0.13^{ab}	1.72±0.14^{ab}	5.91±0.53^{a}	2.65±0.27^{a}
ICEASE-00018	1.83±0.21^{a}	1.57±0.13^{ab}	4.67±0.39^{a}	2.10±0.35^{ab}

- O.A. Enikuomehin (pers. comm., 2021) reported the causal pathogen of Cercospora leaf spot is *Cercospora sesami* Zimm. Symptoms: lesions first appear as a small pin-head sized dark spot on the lower leaves. These gradually enlarge irregularly to about 0.4-1.0 mm in diameter. At an advanced stage (about 6 weeks after appearance), the lesions appear as dark-brown necrotic area surrounding a straw-colored, whitish or perforated center. Lesion size at advanced stage is about 1.7-3.9 mm in diameter and could coalesce to form extended necrotic areas. At advanced stage, symptoms are found on all foliage, petioles, and capsules. In most instances, both Cercospora leaf spot and Alternaria leaf blight may be found on the same infected plant.


PARAGUAY

- L. Ayala et al. (2010, 2011, and 2013b) in grower guides reported the following pathogen: *Cercospora sesami.*
- Anon. (2015a) Paraguay descriptor: 1.10 Incidence of *Cercospora sesami.* The following ratings are used:
  - 0 = Sin informacion [No information]
  - 1 = Resistente [Resistant]
  - 2 = Medianamente resistente [Moderately resistant]
  - 3 = Medianamente susceptible [Moderately susceptible]

- 4 = Susceptible [Susceptible]

SOMALIA

- M. Curzi (1932) reported *Cercospora sesami* Zimm var. *somalensis* Curzi n.v. on the leaves produced sparse spots 0.5 to 5 mm in diameter. At first that are minute sub-rotund with a whitish center surrounded by a blackish-purple margin later they become large, angular and distinctly zonate with alternately whitish and blackish-purple circles. The amphigenous, chestnut dimorphous conidiophores arise from prominent stromata in small bundles or singly on the upper surface of leaf they usually arise in tufts and are conspicuously thickened at the base and tapering or geniculated at the apex, non-septate or sparsely septate, and measuring 27 to 40 by 3 to 7 µ. On the under surface, they arise singly or in bundles of two or four and are straight, septate and frequently 3 to 4 µ in diameter. The straight or flexuous cylindrical, hyaline conidia are 5 to 6-septate and measure 40 to 70 by 3 to 3.5 µ. [Cited by G.S. Saharan, 1989]

SRI LANKA

- M. Park (1937) reported *Cercospora sesami* caused a disease in sesame. [Cited by R.S. Vasudeva, 1961, and G.S. Saharan, 1989]

SUDAN

- M.M. Satour (1981) reported the presence of *Cercospora sesami* (Leafspot).
- H.I.H. Idriss (2016) collected farmer saved red and white sesame from 7 locations in Sudan. 14 different fungi representing ten genera were identified. One of the less frequent fungi was *Cercospora sesami*.
- A.R.C. Umaima (pers. comm. 2021): *Cercospora sesami* (Cercospora leaf spot) is a current problem. The symptoms are dark linear spots with grey centers occur on leaves and capsules causing drying and shedding.

SURINAM

- H.L.V.V. Delprado reported *Cercospora sesami* was a new record.

TANZANIA

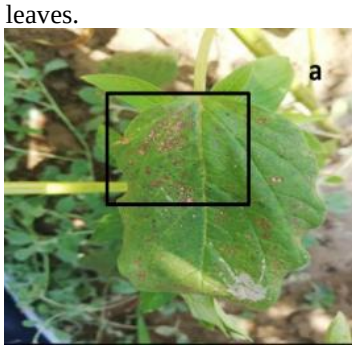
- A.K. Auckland (1981a) reported the goal of developing resistance to *Cercospora sesami.*
- Kafiriti, E. and O. Mponda (n.d.) in a grower guide reported the following pathogen: *Cercospora sesami.*

THAILAND

- V. Benjasil (1985a) reported *Cercospora sesami* (Brown leaf spot) causes losses in yield.

TURKEY

- F. Akdeniz and H. Sert (2019) reported *Cercospora sesami* infects all above ground parts of the plant, resulting in complete defoliation which leads to severe economic losses. The disease starts as small spots on the infected leaves.



- N. Isler et al. (n.d.) reported the following pathogen: *Cercospora sesami.* For control, plant resistant varieties.

UGANDA

- C.G. Hansford (1931, 1938, 1939, 1940, and 1943) reported the following pathogen: *Cercospora sesami.* [Cited by G.S. Saharan, 1989]
- S.B. Mathur and F. Kabeer (1975) reported the following pathogen: *Cercospora sesami* had an infestation of 25-68% in the four genotypes.
- J.P. Egonyu (2005) reported two leaf spot pathogens: *Cercospora sesami* and *Cylindrosporium sesami.* The severity was significantly affected by time of planting. Spores require moisture and particular temperature ranges to germinate and infect leaves. When conditions are too cold, too hot or too dry, spores fail to germinate, and infections do not occur. The late planted crop received less rains compared to its early planted counterpart so had less water for the dispersal of the fungal spores, hence, low level of the disease as shown below.

Time of planting(WAO)	Leaf curl		Leaf spot		Wilt	
	Incidence (%)	Severity	Incidence(%)	Severity	Incidence(%)	Severity
0	16.4	3.05	84.8	2	17.1	3.62
2	29.4	4.05	70.7	1.1	29.9	1.62
4	11.5	3.76	42.1	1.	66.4	3.76
$LSD_{0.05}$	9.50	NS	9.02	0.3	7.29	0.539

WAO-Weeks after onset of rain.

The population did not have as much effect as shown below.

Density('000 plants/ha)	Leaf curl		Leaf spot		Wilt	
	Incidence (%)	Severity	Incidence(%)	Severity	Incidence(%)	Severity
40	25.7	4.4	47	2.5	55.4	4.7
50	15.4	4.7	31.8	3.3	60.6	5
60	14.3	3	50	2	71.4	4
70	23.1	5	49.3	3.3	68.7	4.7
80	22.3	3	34.3	1	56.1	5
90	30.6	5	48.9	2.8	53.8	4.3
140	16.9	4.5	50.1	1.5	56.9	5
150	26.7	5	33.3	3	73.3	5
160	26.7	3	60	2	46.7	4
170	27.7	5	56.9	2.5	55	4.5
200	26.9	4	30.8	2	61.5	5
210	15.4	4	61.2	2	34.6	5
220	36	4	52.2	1.5	31.9	4.5
410	60	5	56	4	40	5
$LSD_{0.05}$	NS	NS	NS	1.5	NS	NS

Intercropping did not have an effect as shown below.

Cropping pattern	Leaf curl		Leaf spot		Wilt	
	Incidence (%)	Severity	Incidence (%)	Severity	Incidence (%)	Severity
Sole sesame	35.4	5	41.2	2.75	52.4	4.75
Sesame + finger millet	23.4	4.33	47.7	2.45	56.4	4.64
$LSD_{0.05}$	11.3	0.63	NS	NS	NS	NS

UNITED STATES

- C. J. Nusbaum (1941b) reported in 1939 the sesame crop in coastal region of South Carolina was severely damaged by blight (*Cercospora sesami*) which was found to be present to a maximum extent of 16 percent internally in seed samples from South Carolina, Georgia, and Florida. Virtually complete control of this source of contamination was affected by 30 minutes immersion of the seed in water heated to 128°F, while surface borne inoculum eliminated by treatment for the same period at 118°F. Over one year storage freed heavily diseased seed from superficial infection, but the fungus still persisted in the interior. [Cited by G.S. Saharan, 1989]
- J.A. Martin (1949b) reported the following:
  - *Cercospora sesami* is most prevalent during prolonged rainy seasons with high temperatures.
  - There are wide differences in susceptibility.
  - All aerial parts of the plants at any stage of growth are affected, and the disease is seedborne. Complete defoliation can occur.
  - At first the lesions appear as tiny flecks and then they develop into round spots from 1 to 2 mm and gradually change to a brown color. On very susceptible plants, one lesion can grow to a large size and many will coalesce covering the entire leaf. On resistant varieties, they rarely coalesce.
  - Lesions do not appear on the capsule, petiole, or stem.
- J.A. Martin (1949c) reported two of the breeding objectives are to develop tolerance to *Cercospora sesami* and *Fusarium* sp.
- M.L. Kinman (1955) reported at least 2 fungi (*Cercospora sesami* and *Alternaria* spp.), and 1 bacterium (*Pseudomonas sesami*) are known to cause leaf spot diseases. The development of these leaf troubles is favored by excessive rainfall and high humidity. The causal organisms can be seedborne. It may be possible to control the leaf spots by the use of disease-free seed or by appropriate seed treatment. The *Alternaria* spp. may not be subject to complete control by these methods, since it appears to spread from other hosts. Disease-free seed can be grown in the desert under irrigation. Hot water seed treatment or treatment with the antibiotic Streptomycin will eliminate seed-born bacterial leaf spot
- R.A. Kilpatrick and H.W. Johnson (1956) reported *Cercospora sesami* produced conidia on carrot leaf decoction agar. In general, sporulation tended to be more profuse in dishes containing 25 to 40 ml agar than in those with only 10 to 15 ml and in daylight than darkness.
- D.T. Smith et al. (2000) reported the following pathogen: *Cercospora sesami.*
- Anon. (2015c) USA PVP descriptor: 7. Diseases – *Cercospora sesami* leaf spot. The following ratings are used:
  - 0 = Not tested
  - 1 = Susceptible
  - 2 = Low resistance
  - 3 = Moderate resistance
  - 4 = High resistance
- D.R. Langham comments, 2021: Most of my experience in sesame in the USA has been in Arizona, Texas, and Oklahoma in the areas where there was little rainfall and low humidity. Leaf spots did show up occasionally, but they were not an economic problem, and so I never bothered to determine if they were from *Alternaria sesami* or *Cercospora sesami*, even though C. Stichler once showed me the difference. When I did find lines with many leaf spots, I eliminated them from the breeding program.
- K.A. Cochran comments, 2021: I have encountered *Cercospora* spp. in many crops in my career, but only a few times in the 6 years I have been working on sesame. When environmental conditions are favorable (humid or moist and moderate to warm temperatures), it can be a significant issue. In my initial observations, when conditions are favorable for other nearby crops (cotton and soybean in particular) to have problems with Cercospora, that is the time to start watching the sesame closely. I think as sesame expands into less arid areas or is irrigated to maximize yields, we will start seeing more of this problem as we do with many other foliar pathogens.

Advanced Cercospora on capsules, stems and leaves. Photo: K.A. Cochran {USA}

VENEZUELA

- A.S. Muller and D.A. Texera. (1941) reported *Cercospora sesami* caused white to grey, sharply delimited spots, 1 to 2 mm in diameter on sesame foliage and capsules number 100 to 400 per leaf. Under humid conditions, the disease may assume a severe character involving premature defoliation and reducing yield. [Cited by G.S. Saharan, 1989]
- B. Mazzani (1953c) reported a new variety 'Morada' was tolerant to *Alternaria* spp. (Irregular stain) and *Cercospora sesami* (Round stain). Although the diseases show up, they are of low intensity and late in the cycle resulting in little effect on the plants.
- M. Barboza et al. (1966) screened 10 varieties for tolerance to *Cercospora sesami* and *Alternaria* spp. All of the varieties were affected with a 15.7 to 55.2% loss in yield. [Cited by G.S. Saharan]
- G. Malaguti (1973) reported the following leaf disease: round white spot (*Cercospora sesami*). [Cited by G.S. Saharan, 1989]
- B. Mazzani et al. (1981b) reported the presence of *Cercospora sesami* (Roundish white leaf spot) is one of the major diseases.
- A.M. Colmenares and L. Subero (1989a) reported the following pathogens: *Cercospora sesami* (White spot) is found in the leaves, stems, and capsules. It is characterized by small white round spots and depending on the cultivar is surrounded by a purple colored ring.
- B. Mazzani (1999) reported the following pathogen: *Cercospora sesami.* He reported minor susceptibility in Maporal, Morada id, Acarigua, and Inamar.

A4.1.1b *Cercospora sesamicola* (9 Apr 2021)

Family: Mycosphaerellaceae

Definition: Amount of tolerance to *Cercospora sesamicola* Mohanty.

References:

INTERNATIONAL

- R.S. Vasuveda (1961) reported *Cercospora sesamicola* is a minor disease. The disease differs slightly from *Cercospora sesami* in forming uniformly brown angular spots instead of roundish or irregular ones. The conidiophores are compact, short and narrow, and bear narrowly cylindrical conidia.
- C. Chattopadhyay et al. (2019) described the following symptoms of *Cercospora sesamicola.* Leaf spots are angularly limited by the leaf veinlets measuring 1-8 mm in size. Initially, the spots are minute and become visible as chlorotic lesions on the upper surface of the leaves; later, when the affected tissues become necrotic, the color of the spots changes to dark brown, whereas on the corresponding lower surface of the leaves, the color of the spots remains olivaceous brown. The fruiting bodies of the fungus might become visible on both surfaces of the leaves but chiefly on the lower surface. *C. sesamicola* perpetuates only through viable sclerotia in crop debris and possibly through infected seeds.
- N. Ransingh et al. (2021) reported the pathogens of Cercospora leaf spot are *Cercospora sesame* Zimmerman and *Cercospora sesamicola* Mohanty. See *Cercospora sesami* for symptoms and other information.

AUSTRALIA

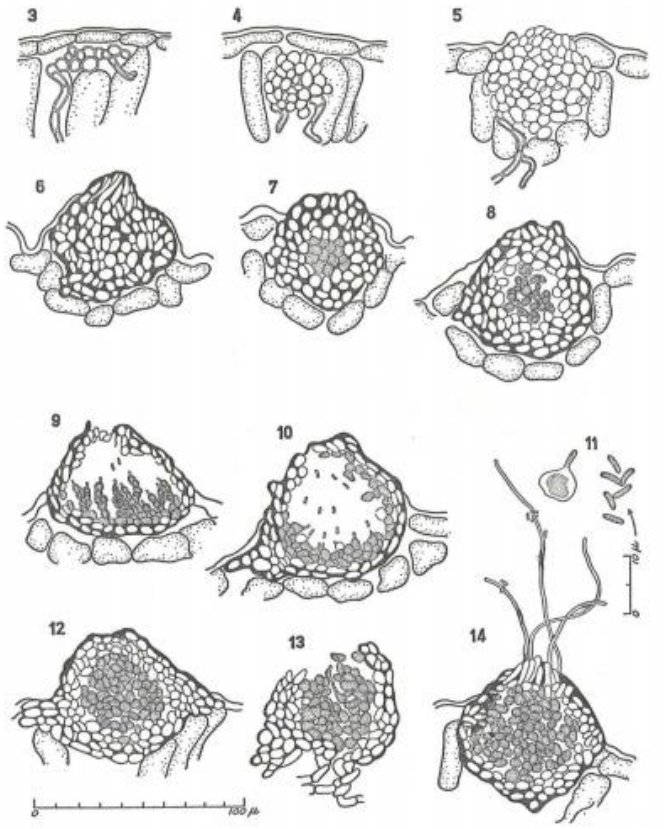
- M.R. Bennett (1986-1997). In his sesame development program in the Northern Territories of Australia between 1986 and 1997, he took data on 'Susceptibility to *Cercospora sesamicola*'. His ideotype included tolerance to this disease.

ETHIOPIA

- T. Geremew et al. (2009) reported the following diseases are a minor problem: *Cercospora sesamicola* (Leaf spot).

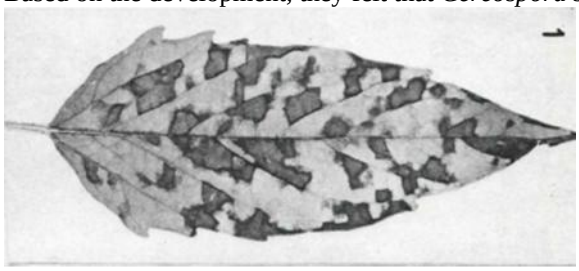
INDIA

- N.N. Mohanty and B.C. Behera (1958b) reported a severe leaf spot of sesame was found to be caused by *Cercospora sesamicola* (Mohanty) with spores indistinctly 2-7 septate, 20-120 x 2-8 µ. It differs from *Cercospora sesami* in the uniformly brown angular spots, short, narrow, closely packed conidiophores and narrow cylindrical conidia.
- Y. Rathaiah and M.S. Pavgi (1973) studied the mode of perpetuation of *Cercospora sesamicola*. No symptoms developed on any of the host plants raised from seeds from the infected as well as healthy plants. Maximum infections were observed towards the maturity of the crop, suggesting susceptibility of the host plants increased at the later stages of growth. Seedlings different age groups (10, 20, 30, 40, 50 and 60 days) were grown in pots, inoculated at a time and incubated under moisture for 48hr. Observations on the disease incidence showed that the seedlings were equally susceptible to the pathogen at all stages of their growth. This indicated that the age of the host was not a conditioning factor in the severity of these diseases. The initial infection symptoms of *C. sesamicola* appear on one and half months old sesame plants near the end of August. The over-summered sclerotia germinate in August, when the temperature is reduced to 28°C and bring about the infection when the plants are about one and half months old. Initial symptoms on the lowermost leaves of mature host plants in the infected fields suggested 2 possible sources of primary inoculum: a) vegetative saprobic mycelium, and b) viable sclerotia in the crop debris. Failure to grow in sterilized soil indicated that *C. sesamicola* does not thrive in the field soil as saprobes. Heat resistance and longevity studies of the sclerotia suggested that survival through the non-crop adverse conditions to bring about the primary infection. Apparently *C. sesamicola* lives between crops as sclerotia in leaf debris in the surface field soil.
- Y. Rathaiah and M.S. Pavgi (1976) reported although heat resistant, conidia of *Cercospora sesamicola* are precluded from serving as primary inoculum by their short life. Tolerance of heat by sclerotia and/or stromata indicated the possibility of their over summering in the field in crop debris and later in the soil.
- Y. Rathaiah and M.S. Pavgi (1978) described the development of sclerotia and spermogonia of *Cercospora sesamicola* in leaves as follows.



- Fig. 3,4 . Multiplication and thickening of cells of the hyphae developing into a subepidermal young sclerotium.
- Fig. 5. Young immature sclerotium.
- Fig. 6. A mature sclerotium with developing ostiole.
- Fig. 7. Developing spermogonium differentiating thin-walled, densely protoplasmic cells in the center.
- Fig. 8. Young spermogonium forming loose cells in the center.
- Fig. 9. Spermogonium with spermatial mother cells at the base, producing spermatia.
- Fig. 10. Mature spermogonium containing spermatia awaiting escape through ostiole.
- Fig. 11. Spermatial mother cell and spermatia.
- Fig. 12. A young perithecium with loose thin-walled cells in the center.
- Fig. 13. Young perithecium with archicarps.
- Fig. 14. Young perithecium showing long filiform, projecting trichogynes with few spermatia attached.

Based on the development, they felt that *Cercospora sesami* is the anamorph of *Mycosphaerella sesami*.



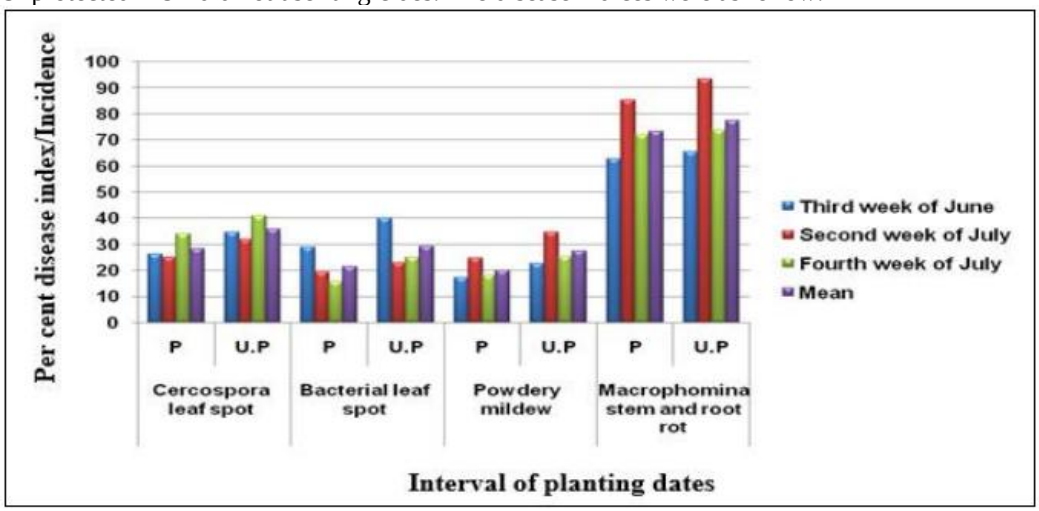
- M.L. Verma (1985) reported *Cercospora sesamicola* (Angular leaf spot) is a major disease with the following symptoms: Uniformly angular, brown leaf spots.
- M.G. Palakshappa et al. (2020a) reported Cercospora leaf spot caused by *Cercospora sesamicola* was destructive disease infecting all parts of the plant from seedling to physiological maturity leading to seedborne and further serves as primary source of inoculum for next season. They evaluated in 2019 and 2020 using susceptible variety (DSS-9) at Dharwad, Karnataka (15.46N 75.01E). The results were as follow.

Modules	Treatments	Per cent disease index	Yield (kg/ha)
Biointensive (M_1)	Seed treatment with *Trichoderma viride* @ 10 g/kg furrow application of enriched *Trichoderma viride* (2.5 kg *Trichoderma viride* + 100 kg Vermicompost) @ 250 kg/ha, Spray of *Pseudomonas fluroscenes* @ 10 g/l at 30-35, Wettable sulphur @ 2g/l at 50-60 days after sowing	72.50 (58.60)*	600
Chemical (M_2)	Seed treatment with Carbendazim 50 % WP @ 2 g/kg, spray of combi product (Tebuconazole 50 % + Trifloxystrobin 25 % WG) @ 0.5 g/l at 30-35 and second spray at 50-60 days after sowing	45.00 (42.15)	800
Adaptive (M_3)	Seed treatment with *Trichoderma viride* @ 10 g/kg furrow application of enriched *Trichoderma viride* (2.5 kg *Trichoderma viride* + 100 kg Vermicompost) @ 250 kg/ha, Spray of Combi product	44.80 (42.00)	872

	(Tebuconazole 50 % + Trifloxystrobin 25 % WG) @ 0.5 g/l at 30-35 and second spray at 50-60 days after sowing		
Untreated Check (M_4)	Untreated check	92.12 (73.32)	481
	S.Em± CD at 5% C.V(%)	1.77 5.45 7.33	13.42 37.33 4.36

*Figures in parenthesis indicate angular transformation values.

- M.G. Palakshappa et al. (2020b) evaluated the date of planting (3rd week of June, 2nd week of July, and 4th week of July) on diseases from 2014 to 2017 at Dharwad, Karnataka (15.46N 75.01E). The main constraint for the low productivity of this crop is due to severe outbreak of various fungal stem and root rot of sesame (*Macrophomina phaseolina*), Alternaria leaf spot (*Alternaria sesami*), Powdery mildew (*Leveillula taurica*), Cercospora leaf spot (*Cercospora sesamicola*), Bacterial leaf spot (*Pseudomonas syringae* pv. *sesam*i), viral and phytoplasma diseases. The control (Protected – P) used fungicides viz., Carbendazim @ 0.1% and combi product (Tebuconazole 50% + Trifloxistrobin 25% WG) @ 0.05% were sprayed at 15 days intervals and the Unprotected – UP did not use fungicides. The disease indices were as follow.

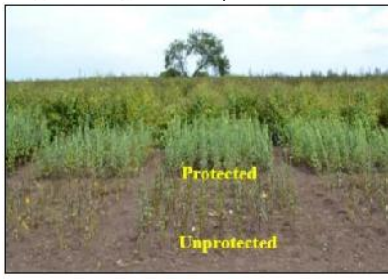


The effects on yield were as follow.

Planting intervals	Yield q/ha								Mean yield q/ha	
	Kharif- 2014		*Kharif*- 2015		*Kharif* -2016		*Kharif*- 2017			
	P	UP	P	UP	P	UP	P	UP	P	UP
Third week of June	11.80	4.30	9.70	5.75	5.45	4.62	5.40	3.04	8.08	4.42
Second week of July	7.00	2.60	7.10	4.00	6.89	3.64	2.69	1.86	5.92	3.02
Fourth week of July	4.10	1.30	4.40	3.35	1.12	0.47	1.92	0.62	2.88	1.44
Mean	7.63	2.73	7.06	5.03	4.48	3.57	3.33	1.84	5.62	3.29

Third week of June sowing

Second week of July sowing



Fourth week of July sowing

KENYA

- J.O. Nyanapah et al. (1993) investigated the pathogenicity of *Cercospora sesami* (White leaf spot) and *Cercospora sesamicola* (Angular leaf spot) on sesame and 3 wild species under glasshouse conditions. Sesame cultivar SIK 134 was used since it is very susceptible to the diseases. Both of these diseases have been observed in all areas of Kenya. Within 12 to 28 days following inoculation, both fungi produced symptoms on *S. indicum, S. calycium,* and *S. angolese;* however, only *C. sesamicola* produced infection on *S. latifolium.*

- J.O. Nyanapah et al. (1995 and 1997) evaluated 16 entries to the resistance to *Cercospora sesami* (White leaf spot) and *Cercospora sesamicola* (Angular leaf spot). The most susceptible accessions to both diseases were SPS 071 and SIK 134. Accession SIK 031 and SPS 045 exhibited the latest susceptibility to white leaf spot and angular leave spot, respectively and are suggested as future standards for comparing reaction of other genotypes.

NICARAGUA
- C. Chattopadhyay et al. (2019) reported the presence of *Cercospora sesamicola.*

NIGERIA
- D. McDonald (1964) reported *Cercospora sesamicola* was one of the most virulent pathogens.

PANAMA
- J.B. Ferrer (1960) reported a disease that is caused in Panama by *Cercospora sesamicola* Mohanty which is different that *C. sesami* as reported by Mohanty. He adds the following:
  - A severe outbreak occurred, burning the leaves and greatly reducing the yields. It seems to be the most serious foliage disease in Panama.
  - Leaf spots were observed as numerous, dull brown, without a distinct border, angular to irregular, vein-limited, small at first then coalescing until the entire leaf dies.
  - The disease is seed transmitted.
  - Some varieties are less susceptible than others.
  - The fungus showed small brown stomata; fascicles compact and dense; very pale in color; slightly curved, 2-3µ x 20-200µ.

TANZANIA
- Kafiriti, E. and O. Mponda (n.d.) in a grower guide reported the following pathogen: *Cercospora sesamicola.*

UNITED STATES
- Anon. (2015c) USA PVP descriptor: 7. Diseases – *Cercospora sesamicola* leaf spot The following ratings are used:
  - 0 = Not tested
  - 1 = Susceptible
  - 2 = Low resistance
  - 3 = Moderate resistance
  - 4 = High resistance

A4.1.2 *Pseudocercospora* spp. (29 Aug 2021)

Family: Mycosphaerellaceae

Definition: Amount of tolerance to *Pseudocercospora* spp. Speg. 1911.

(Wikipedia, 29 Aug 2021) ***Pseudocercospora*** is a genus of ascomycete fungi. An anamorphic version of the genus *Mycosphaerella*, *Pseudocercospora* species are plant pathogens. The widely distributed genus has been estimated to contain over 1100 species, concentrated predominantly in tropical regions. *Pseudocercospora* was circumscribed by Italian-Argentinian botanist Carlos Luigi Spegazzini in 1910.

A4.1.2 *Pseudocercospora sesami* (12 May 2021)

Family: Mycosphaerellaceae

Definition: Amount of tolerance to *Pseudocercospora sesami* Deighton Hansf.

References:

AUSTRALIA
- M.R. Bennett (1995b) reported *Pseudocercospora sesami* (large Cercospora leaf spot) can severely affect grain yields. The disease causes large, irregularly shaped, dull brown spots on the foliage. The spots often coalesce, killing portions or entire leaves on susceptible cultivars during humid conditions.

- B.D. Conde (1995) reported the following pathogen: *Pseudocercospora sesami* (imperfect state of *Mycosphaerella sesamicola*) (Large cercospora leaf spot).
- R.G. Shivas et al. (1996) reported *Pseudocercospora sesami* in a commercial crop of sesame at Beverley Springs Station, Western Australia.
- M.R. Bennett and B. Conde (2003) reported *Pseudocercospora sesami* (large Cercospora leaf spot) [Mycosphaerella sesamicola]. Spots on the foliage are large and irregularly-shaped. These often coalesce, killing portions or entire leaves on susceptible varieties during humid conditions produced by periods of rainy weather or overhead sprinklers. Previous experience in the Northern Territories indicates that it is important to select varieties with some resistance to this disease.

ECUADOR

- M. Bustamonte (2001) in a grower guide reported the following pathogens: *Pseudocercospora sesami* can reduce yields significantly. It causes large, irregularly shaped, brown spots in the foliage. The stain, usually accompanied by necrosis, kills a large part, if not all the leaves of susceptible cultivars if humid conditions persist. The main mode of transmission is through seeds or plant residues in the soil. It is recommended to burn contaminated waste, or you can do a treatment with hot water for the seeds, which consists of leaving them for 30 minutes at a temperature of 43°C. One of the best options where the incidence and severity of the disease are too pronounced is the use of resistant varieties. You can also manipulate the sowing date in order to reduce the time of exposure of the crop to conditions of high humidity and temperature that favor the development of the disease.

MEXICO

- Agrolytics.org (2021) reported sesame hosts *Pseudocercospora sesami.*

VENEZUELA

- A.M. Colmenares and L. Subero (1989a) reported the following pathogen: *Pseudocercospora sesami* (Angular spot). This disease is characterized by the appearance of necrotic spots bounded by the ribs of the plant which are dark brown on the outer side and light brown on the back part.
- B. Mazzani (1999) reported the following pathogen: *Pseudocercospora sesami.* A.M. Colmenares (1989b) reported minor damage in the field in Arawaca, Caripucha, Cápsula larga, and Ajimo Atar. In the laboratory with inoculacion minor damage in *Sesamum radiatum*, Maporal, Arawaca and Adong Acol. There was major damage in the laboratory in Piritu, Caripucha, Venezuela 52, and Aceitera.

A4.1.3 *Cercoseptoria* spp. (12 May 2021)

Family: Mycosphaerellaceae

Definition: Amount of tolerance to *Cercoseptoria* spp.

References:

UNITED STATES

- D.R. Langham et al. (2010c) stated *Cercoseptoria* has been reported in sesame in the USA in research nurseries but have not been seen in commercial fields since 1978.

A4.1.3a *Cercoseptoria sesami* (12 May 2021)

Family: Mycosphaerellaceae

Definition: Amount of tolerance to *Cercoseptoria sesami* (Hansford) Deighton.

References:

INDIA

- S.A. Singh (1984) reported a severe form of leaf spotting on sesame plants intercropped with *Phaseolus calcarotus* at Kukthar was due to *Cercoseptoria sesami* not previously recorded in India.
- S. Maiti et al. (1985 and 1986) reported the following minor pathogen: Leaf spot blight *Cercoseptoria sesami* (Hansf) Deighton.

UNITED STATES
- D.T. Smith et al. (2000) reported the following pathogen: *Cercoseptoria sesami.*

VENEZUELA
- B. Mazzani (1999) reported the following pathogen: *Cercoseptoria sesami.* He reported minor susceptibility in Maporal, Morada id, Acarigua, and Inamar.

A4.1.4 *Pseudocercosporella* spp. (30 Aug 2021)

Family: Mycosphaerellaceae

Definition: Amount of tolerance to *Pseudocercosporella* spp. Deighton 1973.

A4.1.4 *Pseudocercosporella sesami* (19 May 2021)

Family: Mycosphaerellaceae

Definition: Amount of tolerance to *Pseudocercosporella sesami* Purkay. & Mallik.

References:

INDIA
- R.P. Purkayastha and F. Malik (1976) reported *Pseudocercosporella sesami* on sesame.

TURKEY
- F. Akdeniz and H. Sert (2019) reported *Pseudocercosporella sesami-indici* (U. Braun) occurs on sesame throughout the tropics although it appears to be less common and widespread than *Cercospora sesami*.

A4.1.5 *Phaeoisariopsis* spp. (9 Jun 2021)

Family: Mycosphaerellaceae

Definition: Amount of tolerance to *Phaeoisariopsis* spp. Ferraris 1909.

A4.1.5 *Phaeoisariopsis griseola* (9 Jun 2021)

Family: Mycosphaerellaceae

Definition: Amount of tolerance to *Phaeoisariopsis griseola* (Saccardo) Crous & Braun.

References:

MEXICO
- E.C. Hernandez (2003) in a grower guide reported the following pathogen: *Phaeoisariopsis griseola* (Mancha angular). It starts on the lower leaves and spreads rapidly to the rest of the plant.

A4.1.6 *Cercosporidium* spp. (11 Jun 2021)

Family: Mycosphaerellaceae

Definition: Amount of tolerance to *Cercosporidium* s.pp. Earle 1901.

References:

PARAGUAY
- L. Ayala et al. (2010, 2011, and 2013b) in grower guides reported the following pathogen: *Cercosporidium* spp.

A4.1.7 *Passalora* spp. (20 Jul 2021)

Family: Mycosphaerellaceae

Definition: Amount of tolerance to *Passalora* spp. Fr. 1849.

A4.1.7a *Passalora fulva* (20 Jul 2021)

Synonym: *Cladosporium fulvum*

Family: Mycosphaerellaceae

Definition: Amount of tolerance to *Passalora fulva* (Cooke) U. Braun & Crous 2003.

(Wikipedia, 20 Jul 2021) ***Passalora fulva*** is a fungal plant pathogen that causes tomato leaf mold. *P. fulva* only attacks tomato plants, especially the foliage, and it is a common disease in greenhouses, but can also occur in the field. The pathogen is likely to grow in humid and cool conditions. In greenhouses, this disease causes big problems during the fall, in the early winter and spring, due to the high relative humidity of air and the temperature, that are propitious for the leaf mold development. This disease was first described in the North Carolina, by Mordecai Cubitt Cooke (1883), on cultivated tomato (Cooke 1883), although it is originally from South and Central America. The causal fungus of tomato leaf mold may also be referred to as *Cladosporium fulvum* (Cooke 1883), a former name.

References:

INDIA

- N.O. Srikantappa et al. (2009) studied 28 samples of sesame taken from fields, farmers, retail shops and APMC markets from 5 areas. They found 34 four fungi to include: *Cladosporium fulvum.* The fungi significantly reduced germination.

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A4.2 Family: **Davidiellaceae** Chalm. & R.G. Archibald

(Wikipedia, 28 Apr 2021) The **Davidiellaceae** are a family of fungi in the Ascomycota, class Dothideomycetes. The family was defined in 2006 based on the results of molecular phylogenetic analysis of various Dothideomycetes species, and contains the genus *Davidiella* and six other genera.

The following species have been reported to cause diseases, produce a toxin, inhibit germination, or affect seed quality.

- A4.2.1 *Cladosporium* spp.
- A4.2.1a *Cladosporium oxysporum*
- A4.2.1b *Cladosporium cladosporioides*
- A4.2.1c *Cladosporium herbarum*
- A4.2.1d *Cladosporium macrocarpum*
- A4.2.1e *Cladosporium chlorocephalum*
- A4.2.1f *Cladosporium sphaerospermum*
- A4.2.1g *Cladosporium tenuissimum*
- A4.2.1h *Cladosporium variabile*

A4.2.1 *Cladosporium* spp. (28 Apr 2021)

Family: Davidiellaceae

Definition: Amount of tolerance to *Cladosporium* spp. Link 1816.

(Wikipedia, 28 Apr 2021) ***Cladosporium*** is a genus of fungi including some of the most common indoor and outdoor molds. Species produce olive-green to brown or black colonies and have dark-pigmented conidia that are formed in simple or branching chains. Many species of *Cladosporium* are commonly found on living and dead plant material. Some species are plant pathogens, others parasitize other fungi. *Cladosporium* spores are wind-dispersed, and they are often extremely abundant in outdoor air. Indoors *Cladosporium* species may grow on surfaces when

moisture is present. *Cladosporium fulvum* [Authors comment: reclassified as *Passalora fulva*], cause of tomato leaf mould, has been an important genetic model, in that the genetics of host resistance are understood. In the 1960s, it was estimated that the genus *Cladosporium* contained around 500 plant-pathogenic and saprotrophic species, but this number has since been increased to over 772 species. The genus *Cladosporium* is very closely related to black yeasts in the order Dothideales. *Cladosporium* species are often highly osmotolerant, growing easily on media containing 10% glucose or 12–17% NaCl. They are rarely grown on media containing 24% NaCl or 50% glucose and never isolated from medium with 32% NaCl or greater. Most species have very fragile spore chains, making it extremely difficult to prepare a mount for microscopic observation in which the conidial chains are preserved intact.

References:

CUBA

- La Habana (2009) in a grower guide reported the following pathogen: *Cladosporium* sp.

EGYPT

- M.M.I. Abdel-Hafez et al. (2012) examined the soils around the roots of sesame and reported *Cladosporium* spp. in the rhizosphere.
- M.M.I. Abdel-Hafez et al. (2014) took ten samples of sesame from local markets in Assiut city. They found *Cladosporium* sp.
- B.A. Sabry et al. (2016) in Egypt studied 28 sesame samples collected from food stores in different governates. They found the following fungi.

Governorate	NC/ TNS	Fungal load (log_{10} CFU/g)		Percentage occurrence of fungal genera				
		Range	Mean ± SD	*Alternaria*	*Aspergillus*	*Fusarium*	*Penicillium*	*Cladosporium*
Great Cairo	4/4	1.72 –2.32	1.91±0.77[a]	34.21	60.53	2.63	ND	2.63
Kalioubia	3/3	1.72 –2.32	1.97±1.03[a]	4.17	91.66	ND	4.17	ND
Alexandria	6/6	1.72 –2.67	1.99±1.63[a]	4.35	82.61	6.52	ND	6.52
El-Behera	5/5	1.72 –2.87	2.15±1.63[b]	ND	71.82	0.91	17.27	10.00
Kafr El-Sheik	5/5	1.72 –2.80	2.26±2.72[c]	3.96	60.40	1.98	17.82	15.84
Dakahlia	5/5	1.72 –3.02	2.52±0.70[d]	ND	79.68	1.59	6.37	12.35

NC: Number of contaminated samples; TNS: Total number of samples
Mean with different superscript letters are significantly different

INDIA

- J.H. Mitter and R.N. Tandon (1930) reported *Cladosporium* sp. caused a disease in sesame. [Cited by R.S. Vasudeva, 1961]
- S. Maiti et al. (1985 and 1986) reported the following minor pathogen: Blight *Cladosporium* sp.
- M.L. Verma (1985) reported *Cladosporium* sp. is a minor disease causing leaf spot.
- V. Bharathi et al. (2013) collected sesame seeds from farmers in Andhra Pradesh. They tested the seeds for mycoflora, and the following fungus was found: *Cladosporium* spp.

IRAQ

- F. Al-Refaee (2005) collected sesame seeds from 6 regions of Iraq and isolated *Cladosporium* spp.
- .A. Saad et al. (2013) examined seed and found the following fungi: *Cladosporium* spp.

NIGERIA

- A.O. Esan et al. (2020) purchased 60 sesame samples from markets in Nasarawa states during 2 seasons (wet and dry) in order to determine the safety for human consumption. They identified the following fungi: *Aspergillus* section *candidi*, *Aspergillus* section *flavi* (*A. flavus* and *A. tamarii*), *Aspergillus* section *nigri*, *Cladosporium* sp., *Fusarium fujikuroi*, *Penicillium* spp., and Didymellaceae. [For the toxins found refer to section G1 Toxin producing mycoflora.]

PAKISTAN

- A.S. Shakir and M. Ansar (1992) studied 25 samples of seed collected from various areas in Punjab and found the following fungus: *Cladosporium* spp.

SAUDI ARABIA

- A.H. Bahkali and M.A. Moslem (1996) reported the following mycoflora on 5 cultivars: *Cladosporium* sp.

VENEZUELA

- J.B. Pineda and E.R. Glonnella (1988b) isolated 12 different cultures of fungi from soil samples collected in El Playon (7.47N 73.20W) and Turen (9.33N 69.11W) where some locations showed a low incidence of dry stem disease (*Macrophomina phaseolina*). The isolates were 8 *Aspergillus* spp., 2 *Trichoderma* spp., 1 *Cladosporium* sp. and 1 *Pythium* sp.
- B. Mazzani (1999) reported the following pathogen: *Cladosporium* sp.

A4.2.1a *Cladosporium oxysporum* (12 Jun 2021)

Family: Davidiellaceae

Definition: Amount of tolerance to *Cladosporium oxysporum* Berkeley and M.A. Curtis 1869.

(Wikipedia, 12 Jun 2021) ***Cladosporium oxysporum*** is an airborne fungus that is commonly found outdoors and is distributed throughout the tropical and subtropical region, it is mostly located In Asia and Africa. It spreads through airborne spores and is often extremely abundant in outdoor air during the spring and summer seasons. It mainly feeds on decomposing organic matter in warmer climates but can also be parasitic and feed on living plants. The airborne spores can occasionally cause cutaneous infections in humans, and the high prevalence of *C. oxysporum* in outdoor air during warm seasons contributes to its importance as an etiological agent of allergic disease and possibly human cutaneous phaeohyphomycosis in tropical regions.

References:

IRAN

- M. Gooya et al. (2000) reported during 1997/99 one seed samples of each 17 sesame cultivars from 10 locations resulted in 145 isolates, which included 34 species of 15 genera. They identified *Cladosporium oxysporum.*

PAKISTAN

- M. Ajmal et al. (2021) evaluated the incidence of mycobiota and contamination of AFB_1 in sesame seeds from rainfed and irrigated zones of the Punjab, Pakistan. *Aspergillus flavus* was the leading contaminant found in fresh and stored sesame seeds from rainfed and irrigated zone followed by *A. niger*, *Alternaria alternata* and *Fusarium oxysporum*. Least reported fungi were *Aspergillus ochraceus* and *Cladosporium oxysporum*. AFB_1 analysis revealed that 92% fresh and 99% stored samples were contaminated with AFB_1. 20% fresh and 100% stored samples from rainfed zone and 28% fresh and 60% stored samples from irrigated zone were tainted with AFB_1 levels above 20 ppb and not fit for human consumption.

A4.2.1b *Cladosporium cladosporioides* (20 Jul 2021)

Family: Davidiellaceae

Definition: Amount of tolerance to *Cladosporium cladosporioides* (Fresen.) G.A. de Vries 1952.

(Wikipedia, 20 Jul 2021) ***Cladosporium cladosporioides*** is a darkly pigmented mold that occurs world-wide on a wide range of materials both outdoors and indoors. It is one of the most common fungi in outdoor air where its spores are important in seasonal allergic disease. While this species rarely causes invasive disease in animals, it is an important agent of plant disease, attacking both the leaves and fruits of many plants. This species produces asexual spores in delicate, branched chains that break apart readily and drift in the air. It is able to grow under low water conditions and at very low temperatures.

References:

EGYPT

- A. Hashem et al. (2014) collected 18 seed samples of sesame in Egypt (12 samples) and Saudi Arabia (6 samples). They identified the following mycoflora: *Cladosporium cladosporioides*,

INDIA

- R.K.S. Chauhan and B.M. Kulshrestha (1984b) reported the diffusate obtained from the fruit cavities of sesame inoculated with a spore suspension of *Alternaria sesami* was inhibitory to the germination of spores. It inhibited

the spore germination of *Cladosporium cladosporioides*. No inhibition was caused by the extracts of healthy uninoculated fruits.
- N.O. Srikantappa et al. (2009) studied 28 samples of sesame taken from fields, farmers, retail shops and APMC markets from 5 areas. They found 34 four fungi to include: *Cladosporium cladosporioides.* The fungi significantly reduced germination.

IRAN
- M. Gooya et al. (2000) reported during 1997/99 one seed samples of each 17 sesame cultivars from 10 locations resulted in 145 isolates, which included 34 species of 15 genera. They identified *Cladosporium cladosporioides.*

IRAQ
- F. Al-Refaee (2005) collected sesame seeds from 6 regions of Iraq and isolated fungi to determine which produced lipase. The following fungi were isolated: *Cladosporium cladosporioides.*

A4.2.1c *Cladosporium herbarum* (20 Jul 2021)

Family: Davidiellaceae

Definition: Amount of tolerance to *Cladosporium herbarum* (Pers.) Link 1816.

(Wikipedia, 20 Jul 2021) ***Cladosporium herbarum*** is a common fungus found worldwide in organic and inorganic matter. It is efficiently distributed in the air, where it exists as the most frequently occurring fungal species. It can grow over a wide range of temperatures including very cold environments, giving it the ability to grow on refrigerated meat and form "black spots". Its high prevalence in the air and production of allergens makes *C. herbarum* an important exacerbant of asthma and hay fever.

References:

INDIA
- N.O. Srikantappa et al. (2009) studied 28 samples of sesame taken from fields, farmers, retail shops and APMC markets from 5 areas. They found 34 four fungi to include: *Cladosporium herbarum.* The fungi significantly reduced germination.

IRAN
- M. Gooya et al. (2000) reported during 1997/99 one seed samples of each 17 sesame cultivars from 10 locations resulted in 145 isolates, which included 34 species of 15 genera. They identified *Cladosporium herbarum.*

PAKISTAN
- B.G. Nayyar et al. (2013) examined 15 samples of seed to detect fungi using 3 methods: agar plate, blotter, and deep freezing. The following was found: *Cladosporium herbarum.*

A4.2.1d *Cladosporium macrocarpum* (20 Jul 2021)

Family: Davidiellaceae

Definition: Amount of tolerance to *Cladosporium macrocarpum* Preuss 1848.

References:

IRAN
- M. Gooya et al. (2000) reported during 1997/99 one seed samples of each 17 sesame cultivars from 10 locations resulted in 145 isolates, which included 34 species of 15 genera. They identified *Cladosporium macrocarpum.*

A4.2.1e *Cladosporium chlorocephalum* (20 Jul 2021)

Family: Davidiellaceae

Definition: Amount of tolerance to *Cladosporium chlorocephalum* (Fresen.) E.W. Mason & M.B. Ellis.

References:

INDIA

- N.O. Srikantappa et al. (2009) studied 28 samples of sesame taken from fields, farmers, retail shops and APMC markets from 5 areas. They found 34 four fungi to include: *Cladosporium chlorocephalum.* The fungi significantly reduced germination.

A4.2.1f *Cladosporium sphaerospermum* (20 Jul 2021)

Family: Davidiellaceae

Definition: Amount of tolerance to *Cladosporium sphaerospermum* Penzig 1882.

(Wikipedia, 20 Jul 2021) ***Cladosporium sphaerospermum*** is a radiotrophic fungus] belonging to the genus *Cladosporium* and was described in 1886 by Albert Julius Otto Penzig from the decaying leaves and branches of *Citrus*. It is a dematiaceous (darkly-pigmented) fungus characterized by slow growth and largely asexual reproduction. *Cladosporium sphaerospermum* consists of a complex of poorly morphologically differentiated, "cryptic" species that share many physiological and ecological attributes. In older literature, all of these sibling species were classified as *C. sphaerospermum* despite their unique nature. Accordingly, there is confusion in older literature reports on the physiological and habitat regularities of *C. sphaerospermum* in the strict sense. This fungus is most phylogenetically similar to *C. fusiforme*. According to modern phylogenetic analyses, the previously synonymized species, *Cladosporium langeroni*, is a distinct species.

References:

PAKISTAN

- B.G. Nayyar et al. (2013) examined 15 samples of seed to detect fungi using 3 methods: agar plate, blotter, and deep freezing. The following was found: *Cladosporium sphaerospermum.*

A4.2.1g *Cladosporium tenuissimum* (20 Jul 2021)

Family: Davidiellaceae

Definition: Amount of tolerance to *Cladosporium tenuissimum* Cooke 1878.

References:

PAKISTAN

- B.G. Nayyar et al. (2013) examined 15 samples of seed to detect fungi using 3 methods: agar plate, blotter, and deep freezing. The following was found: *Cladosporium tenuissimum.*

A4.2.1h *Cladosporium variabile* (20 Jul 2021)

Family: Davidiellaceae

Definition: Amount of tolerance to *Cladosporium variabile* (Cooke) G.A. de Vries 1952.

References:

PAKISTAN

- B.G. Nayyar et al. (2013) examined 15 samples of seed to detect fungi using 3 methods: agar plate, blotter, and deep freezing. The following was found: *Cladosporium variable.*

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A5 Order: Erysiphales H. Gwynne-Vaughan 1922

(Wikipedia, 9 Apr 2021) **Erysiphales** are an order of ascomycete fungi. The order contains one family, **Erysiphaceae**. Many of them cause plant diseases called powdery mildew. The order contains one family (Erysiphaceae), 28 genera and approximately 100 species. Many imperfect fungi (fungi whose sexual reproduction is unknown) belong here, especially the genus *Oidium*.

Erysiphales have a superficial mycelium which extracts nourishment from the host plant through specialized hyphae that penetrate the epidermal cells of the host by means of absorbing organs called haustoria. The teleomorphs are usually more distinctive and diverse than the anamorphs. Whether the asci are bitunicate or unitunicate (i.e., consisting of one or two layers), is as yet a matter of discussion. The cleistothecia (or *chasmothecia*) have the asci arranged in a hymenial layer, resembling perithecia.

The cleistothecia are minute, usually not much more than 0.1 mm ($\frac{1}{256}$ in) in diameter. From the outer wall of the cleistothecium specialized hyphae (appendages) grow out. The number of asci per ascoma varies and is important in discriminating between genera.

Erysiphales are notable for intricate appendages which follow fractal geometry within Fibonacci numbers and can be useful for species identification. The infection of the host plant begins with the sexual ascospores, or the asexual conidia germinating on the surface of the plants leaf or stem, resulting in septate mycelium of uninucleate cells. In most powdery mildews only the epidermal cells are attacked. The external mycelium gives rise to short, erect conidiophores, each of which bear a single row of barrel-shaped spores, the youngest being at the base (the affected parts become thus covered with a forest of conidiophores assuming a white powdery appearance). The ripe spores become detached and are readily dispersed by the wind, causing fresh infection. In autumn the sexual cleistothecia are produced. The cleistothecia represent the resting (hibernating) stage of the pathogen. The ascospores remain dormant all winter to germinate in spring. When the asci expand, they rupture the cleistothecia wall throwing the ascospores into the air.

Erysiphales are obligate parasites on leaves and fruits of higher plants, causing diseases called powdery mildews. Most attempts to grow them in culture have failed. *Erysiphales* have a nearly cosmopolitan distribution, except Australia, and have developed fungicide resistance just as widely. Total loss of function has resulted in some cases. Resistance management planning, use of multi-mode of action fungicides, and altered frequency and quantity of application are needed to slow the progress of resistance.

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A5.1 Family: Erysiphaceae E. & C. Tulasne 1861

Summary:

Photos: P. Venkata Ramana Rao et al. (2013) {India}

Powdery mildew is caused by many obligate biotrophic fungal species in the Erysiphaceae family (*Erysiphe* spp., *Leveillula* spp., *Podosphaera* spp., *Oidium* spp., and *Pseudoidium* spp.) While some species can infect many host plants, most are host specific. Powdery mildews produce asexual conidia as the main source of inoculum during the season. At the end of the season, sexual spores (ascospores) are produced in tiny black generally spherical structures (chasmothecia, formerly cleistothecia) with clear to whitish-clear appendages. These are some of the most easily recognized features of powdery mildew, though they are not always present on symptomatic sesame. Chattopadhyay et al. (2019) reported symptoms start as small whitish spots on the upper surface of the leaves. The spots coalesce, finally covering the entire leaf surface with a pale grey to white fungal growth. The mildew is sometimes confined to the upper surface of the leaves, though it can be apparent on top and bottom in a highly favorable environment for disease development, which is humid and warm. Free water and hot temperatures are unfavorable for the pathogen. Much of the “powdery” substance on the leaf surface is conidiophores and conidia. In previous work, the disease caused a yield loss of 42%. The earlier onset of symptoms, the greater the likelihood of high incidence and severity of disease, leading to lower yields. The pathogens are seedborne and soilborne. Recently, taxonomy has been greatly revised using DNA analysis, while previous

taxonomy relied primarily on morphology of teleomorph stages (Heffer et al., 2006). The following species have been reported to cause powdery mildew: *Erysiphe betae, E. cichoracearum, E. cruciferarum, E. orontii, Leveillula taurica, Oidium sesami, Podosphaera fuliginea, P. fusca,* and *Pseudoidium pedaliacearum.* Powdery mildew has been reported in international lists, Australia, China, Ethiopia, Greece, India, Iraq, Israel, Japan, Malawi, Mexico, Myanmar, Nigeria, Pakistan, Somalia, Sri Lanka, Sudan, Tanzania, Thailand, Uganda, United States, and Venezuela.

(Wikipedia, 9 Apr 2021) See the explanation in the **Erysiphales** order above. This is the only family in the order**.** The disease caused by these pathogens is known as Powdery mildew.

The following species have been reported to cause diseases, produce a toxin, inhibit germination, or affect seed quality.

- A5.1.1 *Oidium* spp. (*Syn: *Oospora* spp.)
- A5.1.1a *Oidium sesami*
- A5.1.2 *Erysiphe* spp.
- A5.1.2a *Erysiphe cichoracearum* (*Syn: *Oidium acanthospermi*)
- A5.1.2b *Erysiphe orontii*
- A5.1.2c *Erysiphe betae* (*Syn: *Erysiphe polygoni*)
- A5.1.2d *Erysiphe cruciferarum* (*Erysiphe communis*)
- A5.1.3 *Leveillula* spp.
- A5.1.3a *Leveillula taurica* (*Syn: *Oidiopsis taurica*)
- A5.1.4 *Podosphaera* spp.
- A5.1.4a *Podosphaera fuliginea* (*Syn: *Oidium erysiphoides*, *Podosphaera xanthii*, and *Sphaerotheca fuliginea*)
- A5.1.4b *Podosphaera fusca*
- A5.1.5 *Pseudoidium* spp.
- A5.1.5a *Pseudoidium pedaliacearum*

References:

INTERNATIONAL

- M.O. Khidir (1981a) in a review of sesame in East Africa and the Near East reported the following disease was a problem: powdery mildew.
- C. Chattopadhyay et al. (2019) described the following symptoms of powdery mildew caused by *Oidium erysiphoides, Oidium sesami, Sphaerotheca fuliginea, Leveillula taurica,* and *Erysiphe cichoracearum:* Symptoms start as small whitish spots on the upper surface of the leaves. The spots coalesce to form a single spot, finally coveting the entire leaf surface with a dirty white fungal growth. Generally, the mildew is confined to the upper surface of the leaves. The perithecial stage may or may not be observed on sesame leaves. The disease causes a yield loss of 42%. For every 1% increase in disease severity, there is a yield loss of 5.63 kg/ha. There is a significant negative correlation between days to maturity and powdery mildew occurrence and severity. Use of host resistance appears to be the most promising method for the control. Inheritance of resistance/tolerance to powdery mildew reveals that susceptibility is dominant over tolerance and is controlled by two independent recessive genes with complementary epistasis. The crop can be protected by spray application of wettable sulphur (0.2%) fungicides or by dusting sulphur dust at the rate of 20 kg/ha or Karathane spray (1%).
- N. Ransingh et al. (2021) reported the following symptoms of various pathogens (Powdery mildew): It is a foliar disease that affects almost all the above-ground parts of the plant. It initiates with development of grayish-white powdery growth on the upper surface of leaves. It gradually spreads to flowers and young capsules. Severely affected parts like leaves may get twisted and malformed. The affected flowers and young capsules shed prematurely. The whitish mycelia turn to dark or black in color in the advanced stage due to the development of cleistothecia

  The pathogen is an obligate parasite. It perennates in the infected plant debris present in soil in the form of cleistothecia. The ascospores from these cleistothecia initiate the infection and spread through wind-borne conidia. Dry humid weather along with low relative humidity aggravates the disease.

  Clean cultivation is the key for management of this disease as the pathogen survives in infected plant debris. The infected plant debris and stubbles should be removed from the field and destroyed properly. The weed plants and wild host are also removed from in and around the fields. Applications of wettable sulphur @ 0.2%

or dust sulphur at 25 kg/ha is effective to control the disease. Repeat it after 15 days. Other fungicides such as Tridemorph, Dinocap can also be used for effective management of disease.

INDIA

- S. Maiti et al. (1985) reported mildew is not a serious disease. A number of organisms have been reported to cause this disease.
- C. Jeyalakshmi et al. (2013) evaluated integrated disease management practices to combat major diseases (Alternaria leaf blight, *Macrophomina* root rot, and Powdery mildew) and to increase the seed yield of sesame during summer 2009 and 2010 using at Karaikal (10.93N 79.84E). The treatments were as follow.
  - M1: Soil application of neem cake @ 250 kg /ha+ seed treatment with thiram (0.2%) + carbendazim (0.1%) + foliar spray of mancozeb (0.25%) + endosulfan (0.07%) at 30 and 45 DAS.
  - M2: Seed treatment with *Trichoderma viride* (0.4 %) + soil application of *T. viride* @ 2.5 kg/ha + foliar spray of mancozeb (0.25%) + endosulfan (0.07%) at 30 and 45 DAS.
  - M3: Soil application of neem cake @ 250 kg /ha + seed treatment with *T. viride* (0.4 %) + soil application of *T. viride* @ 2.5 kg/ha + foliar spray of azadirachtin (0.03%) @ 3 mL/L on 30 and 45 DAS.
  - M4: Farmer's practices (control)

  The results were as follow.

Module	2009*				2010*			
	Root rot (%)	Powdery mildew (PDI)	Seed yield (kg/ha)	C:B ratio	Root rot (%)	*Alternaria* blight (PDI)	Seed yield (kg/ha)	C:B
M1	8.28[b]	5.10[b]	680[c]	1:1.03	8.80[b]	5.44[b]	708[c]	1:1.18
M2	7.05[b]	4.22[b]	690[b]	1:1.13	6.90[b]	6.16[b]	720[b]	1:1.28
M3	3.04[a]	2.01[a]	760[a]	1:1.20	2.54[a] (9.13)	2.48[a]	766[a]	1:1.32
M4	17.7[c]	11.95[c]	545[d]	1:1.00	18.60[c]	19.40[c]	495[d]	1:0.98

- P. Venkata Ramana Rao et al. (2013) reviewed the inheritance of powdery mildew and provided the following summary. S. Krishnaswami et al. (1983) were one of the first to study genetics of resistance to powdery mildew in F_2 progenies of crosses involving susceptible and resistant parents. They concluded resistance to powdery mildew disease to be controlled by two major genes with complementary gene action. C.D. Reddy and S. Haripriya (1990) reported from their study of a set of 36 F_1 hybrids, ten to show heterosis for tolerance to the disease while, five significant heterobeltiosis. In a series of crosses with RT 54 as resistant parent, all the hybrids were moderately tolerant indicating that it can be a donor parent in breeding for resistance against powdery mildew. C.D. Reddy and S. Haripriya (1993a) studied 36 hybrids evolved from a 9×9 diallel cross and observed five F_1s to show significant heterosis and heterobeltiosis for tolerance to the disease. G. Raja Ravindran and A. Amrithadeva Rathinam (1996b) studied F_2 progenies of 24 cross combinations involving Co-1 as resistant parent and reported resistant and susceptible plants to segregate in the ratio of 9:7 indicating resistance to be governed by two pairs of dominant genes showing complementary gene action. In a line×tester design, D. Kumaresan and N. Nadarajan (2002a) studied 12 lines, 4 testers and 48 F_1s for their per performance, heterosis and nature of gene action involved in the inheritance of powdery mildew. They observed that lines Si 3315/11 and OMT 30 and tester Co-1 recorded superior mean performance and desirable GCA effect for powdery mildew resistance indicating that these three parents could be used as donor parents for transferring powdery mildew resistance.

- M. Kabi et al. (2019) screened 30 genotypes for tolerance to powdery mildew. They were classified into resistant (10), moderately resistant (13) and susceptible (7) categories. VRI-1 showed highly resistant reaction. No genotypes found to be immune in response.

- K. Divya et al. (2020) screened 133 genotypes for tolerance to phyllody, Alternaria leaf spot, Cercospora leaf spot, and downy mildew. They identified the following genotypes as being resistant to powdery mildew: V-72, IISL-4, 10KRE8-2, 30KRDS-1-14, TKG-22, SDSN-15-70, RT-376, SDSN-15-99, 30DRDS-1-13, and 30KRDS-1-7.
- M. Kavi et al. (2021) reported in crossing a susceptible and resistant variety to powdery mildew, the F_2 plants segregated in a ratio of 9 (resistant): 7 (susceptible) indicating a digenic mode of inheritance with complementary epistasis for resistance. The RGA marker was found in the resistant type, but not in the susceptible type.

NIGERIA

- O.A. Enikuomehin (pers. comm. 2021) reported Powdery mildew.

PHILIPPINES

- N.M. Tepora (1989 and 1993) reported the following disease: Powdery mildew. The nature of the damage was white masses of mildew spores cover the leaves of the plants, which later turn yellow and wither. Control measures include any of the following: Benomyl, Thiophanate, or Tetrachlorisophthal nitrile at the rate of 2-3 tbs/18 l of water. Spray as soon as the disease appears.

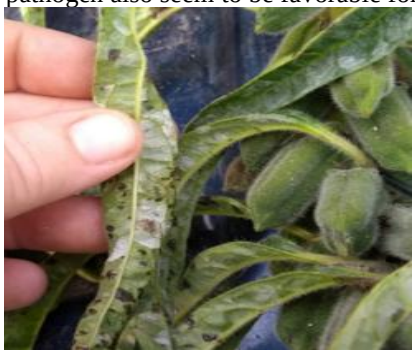
REPUBLIC OF KOREA

- S.U. Kim (pers. comm. 2015): The following is a photo of Powdery mildew on sesame compared to a normal line in a greenhouse.

UNITED STATES

- D.T. Smith et al. (2000) reported powdery mildew has been noted in South Texas but did not affect yields.
- D.R. Langham comments, 2021: In over 100 nurseries in 36 years, I saw powdery mildew only a handful of times, and lines with the disease were not carried forward. However, bear in mind that almost all of my nurseries were in areas with low rainfall and low humidity.
- K.A. Cochran comments, 2021: I don't encounter powdery mildew often in the SW Texas production area, but that may be a different case for areas where conditions are more consistently humid and have more mild

summers (below 38°C), such as what occurred in SW Texas in the summer of 2021, when I found the diseased plants in the photo below. On the occasions I have encountered it, symptoms were severe, and the disease occurred in a high percentage of plants. It was associated with reduced yield quality and quantity. I suspect the inoculum is likely present in nearby weeds or volunteers. Environmental conditions that are favorable for this pathogen also seem to be favorable for bacterial leaf spot and Corynespora.



Powdery mildew (white patches) and bacterial leaf spot (black spots) on the same leaf.

A5.1.1 *Oidium* spp. (9 Apr 2021)

Synonym: *Oospora* spp.

Family: Erysiphaceae

Definition: Amount of tolerance to *Oidium* spp. Link 1824.

(Wikipedia, 9 Apr 2021) ***Oidium*** is a genus of Deuteromycetes, where traditionally most anamorphs of the order Erysiphales are included. Most of them are plant pathogens causing different forms of powdery mildew.

References:

INTERNATIONAL

- J.R. Morschel (1964) reported the following pathogen in the world: *Oidium* spp. (Powdery mildew). [Cited by D.F. Beech. 1995a]
- E.A. Weiss (1971) reported *Oidium* sp. is commonly found on sesame in more humid areas or following prolonged rains. Symptoms are masses of white mildew spores covering the leaves, which turn yellow and wither. High intra-row populations promote the disease.

AUSTRALIA

- D.F. Beech (1981a and 1995a) reported the presence of *Oidium* sp. (Powdery mildew) in 1958.
- B.D. Conde (1995) reported the following pathogen: *Oidium* sp. (Powdery mildew) appears as a white powdery coating on the leaves but has not been serious enough to warrant control.
- M.R. Bennett and B. Conde (2003) reported *Oidium* sp. does not warrant control at present.

CHINA

- L.C. Tu (1985b) reported *Oidium* sp. (Powderry mildew) in Henan province with a damage level of 1 out of possible 3.
- X.R. Zhang/L.H. Wang (pers. comm. 2016): The *Oidium* sp. descriptor is used in the breeding program by the Chinese Academy of Agricultural Sciences-Oil Crops Research Institute, Wuhan.

ETHIOPIA

- T. Geremew et al. (2009) reported the following diseases are a minor problem: *Oidium* sp.(imperfect stage) (Powdery mildew).

GREECE

- M.M. Satour (1981) reported the presence of *Oidium* sp. (Powderry mildew).

INDIA

- P.R. Mehta (1951) reported *Oidium* sp. (Powdery mildew) was a disease that affected sesame. [Cited by G.S. Saharan, 1989]

- E.V. Abraham et al. (1976) studied the effects of 2 foliar sprays of various insecticides were applied 40 and 60 days after sowing. In the kharif season (August-November), combinations of 0.2% Dithane M-45 (a mixture of maneb and zineb containing 16% manganese and 2% zinc) with endosulfan or fenthion at 0.5 kg/ha were effective in controlling powdery mildew (*Oidium sp*.), leaf blight (*Alternaria sesami*), *Aphis gossypii* Glov. and *Asphondylia sesami* Felt. In the rabi season (February-May), when the incidence of powdery mildew was high, combinations of 0.25% Miltox (a mixture of copper oxychloride and zineb) with endosulfan or fenthion at 0.5 kg were the best, followed by those of 0.2% Dithane M-45 with carbaryl at 1 kg/ha, or endosulfan or fenthion at 0.5 kg/ha. [Based on abstract]
- M.M. Satour (1981) reported the presence of *Oidium* sp. (Powderry mildew).
- K. Kabunanithi et al. (1993) evaluated 41 entries against *Oidium* sp. (Powdery mildew), which inflicts considerable damage to sesame in Tamil Nadu. They rated the tolerance in the field and in the greenhouse based on a 0 to 5 rating from immune to highly susceptible. In the greenhouse they increased the disease pressure by spraying a conidial suspension (10^{-5} conidia/ml) at a weekly interval from 30 to 45 DAS plus they increased the humidity by frequent water sprayings. Only 1 entry (OMT 30) was found to be moderately tolerance (10-25% of the leaf area infected) with ratings of 1.6 in the field and 1.7 in the greenhouse, while the existing varieties rated 2.0 to 4.4 in the field and 2.2 to 5.0 in the greenhouse.
- B. Khamari et al. (2018c) conducted an intensive survey at flowering to ripening of capsule to record the incidence of sesame diseases in 10 agroclimatic zones of Odisha during rabi 2014-15 with the following results.

Sl. No.	Place	Variety	Mac (%)	Fus (%)	Alt (Grade)	PM (Grade)	Cer (Grade)	Phy (%)
1	Bheden	Bheden local	18.09	9.78	3	0	2	0
2	Balianta	VRI-1	23.8	8.0	4	3	2	2.3
3	Nuagaon	Nuagaon local	12.8	3.0	3	0	2	0.6
4	Papadahandi	Papdahandi local	15.2	4.1	2	0	2	1.0
5	Betanati	Betanati local	18.8	0.5	2	2	1	0
6	Kalimela	Kalimela local	11.3	0.8	3	1	2	0.8
7	Agarpada	Agarpada local	8.0	1.0	3	1	1	0.6
8	Kirei	Sundergarh local	15.8	3.9	2	0	1	1.4
9	Khajuripada	Phulbani local	10.5	2.9	3	3	1	0.0
10	Bhawanipatna	Narla local	19.2	4.8	4	0	2	1.4

Mac=*Macrophomina*, Fus= *Fusarium*, Alt= *Alternaria*, PM= Powdery Mildew, Cer= *Cercospora*, Phy= Phyllody

ISRAEL

- M.M. Satour (1981) reported the presence of *Oidium* sp. (Powderry mildew).

JAPAN

- K. Hirata (1966) provided the distribution of *Oidium* sp. [Cited by G.S. Saharan, 1989]
- T. Kuzuyuki (2021) reported the following pathogen: *Oidium* sp. (Powdery mildew).

MEXICO

- Agrolytics.org (2021) reported sesame hosts *Oidium* spp.

MYANMAR

- Y.Y. Min and K. Toyota (2019) surveyed diseases in 10 farmer fields and interviewed 25 farmers. They reported the following pathogen: *Oidium* sp. with a low incidence.

NIGERIA

- H.A. Van Rheenen (1972) reported the following pathogen: *Oidium* sp.
- M.M. Satour (1981) reported the presence of *Oidium* sp. (Powderry mildew).

SRI LANKA

- J. Kailayapillai et al. (1989) studied the morphology of *Oidium* sp. The fungus is an obligate parasite which cannot be cultivated *in vitro*. Under natural conditions the infection first appeared as small, tiny white superficial patches on the upper surface of mature leaf at the age of 40 days or more. Symptoms included surface leaf necrosis, premature leaf fall, stunted growth of the plant at an early stage, yellowing and chlorosis of leaf at the mature stage, and browning of flower buds. The life cycle is initiated by airborne conidia. At 25

±1°C and 100% relative humidity, conidia started to germinate in about 4 hours and germination was maximum at about 24 hours after incubation. The penetration of the host was completed within 28 hours. The second germtube was observed after about 30 hours and the third after about 36 hours of incubation. Secondary elongating hyphae, conidiophore initials, and abstriction of conidiophore were observed at 60, 144, and 156 hours after incubation, respectively. The colony produced maximum amount of conidia on the 9th day after incubation. The colony remained productive even up to 12 days from the time of incubation.

SUDAN
- M.M. Satour (1981) reported the presence of *Oidium* sp. (Powderry mildew).

TANZANIA
- G.B. Wallace (1933) reported the most destructive diseases of sesame were a leaf curl probably caused by a virus and a bacterial disease affecting the stems, branches and leaves. Two leaf fungi attacking this host are an *Oospora* sp. and *Helminthosporium gigasporum* f. sp. *javanicum*. [Cited by R.S. Vasudeva, 1961, and G.S. Saharan, 1989]

UGANDA
- J.D. Snowden (1927) reported a mildew (*Oidium* sp.) on sesame in same plot where the sclerotia and pycnidia of *Macrophomina corchon* (*Macrophomina phaseoli*) were found is thought to have made the leaves more susceptible to attack by the latter. [Cited by G.S. Saharan, 1989]

UNITED STATES
- Anon. (2015c) USA PVP descriptor: *7. Diseases* – Powdery mildew (*Oidium* spp. – Mandatory. The following ratings are used:
  - 0 = Not tested
  - 1 = Susceptible
  - 2 = Low resistance
  - 3 = Moderate resistance
  - 4 = High resistance

VENEZUELA
- M.M. Satour (1981) reported the presence of *Oidium* sp. (Powdery mildew).

A5.1.1a *Oidium sesami* (26 May 2021)

Family: Erysiphaceae

Definition: Amount of tolerance to *Oidium sesami* U. Srinivas, Bagyan. & M. Raju.

References:

INTERNATIONAL
- CAB International (accessed 12 Apr 2021) reported sesame was a host of *Oidium sesami*.

INDIA
- P. Kumar and U.S. Mishra (1992) reported sesame diseases were monitored in Uttar Pradesh. In 1987, 12 diseases were recorded and in 1988 powdery mildew [*Oidium sesami*] was also recorded. Leaf and stem spot caused by *Corynespora cassiicola* was the predominant disease (28%) followed by leaf spots caused by *Cercospora sesami* [*Mycosphaerella sesamicola*], *Xanthomonas* [*campestris* pv.] *sesami* and *Alternaria sesami* (11-18%). The remaining diseases reached disease intensities of 10%. Disease intensity was higher in 1987 than in 1988 due to drought. A new leaf spot disease caused by *Curvularia fallax* was recorded for the first time in India. Most of the common diseases of sesame caused yield losses of 20-40%. [Based on abstract]
- U. Srinivasulu et al. (2003) reported *Oidium sesami*. [Based on abstract]
- K.C. Puzari et al. (2006) reported *Oidium sesami* in the North-eastern region of India. [Cited by M. Kabi et al., 2021]

A5.1.2 *Erysiphe* spp. (9 Apr 2021)

Family: Erysiphaceae

Definition: Amount of tolerance to *Erysiphe* spp. R. Hedw. ex DC. 1805.

(Wikipedia, 9 Apr 2021) ***Erysiphe*** is a genus of fungi in the family Erysiphaceae. Many of the species in this genus are plant pathogens which cause powdery mildew.

References:

ETHIOPIA

- T. Geremew et al. (1992 and 2009) reported the following diseases are a minor problem: *Erysiphe* sp. (perfect stage) (Powdery mildew).

INDIA

- C.D. Kaushik et al. (1986) reported phyllody (MLO), root rot (*Macrophomina phaseoli*), leaf curl (virus), Bacterial leaf blight (*Xanthomonas* sp.), powdery mildew (*Erysiphe* sp.), and Phytophthora blight.

A5.1.2a *Erysiphe cichoracearum* (9 Apr 2021)

Synonym: *Oidium acanthospermi*

Family: Erysiphaceae

Definition: Amount of tolerance to *Erysiphe cichoracearum* (DC) 1805.

(Wikipedia, 9 Apr 2021) ***Erysiphe cichoracearum*** is a fungal plant pathogen that causes powdery mildew disease of cucurbits. The primary symptoms are white, powder-like spots on the leaves and stems.

(Anon. n.d.k) Powdery mildew - *Erysiphe cichoracearum* (Syn: *Oidium acanthospermi*)

Symptoms: Initially greyish-white powdery growth appears on the upper surface of leaves. When several spots coalesce, the entire leaf surface may be covered with powdery coating. In severe cases, the infection may be seen on the flowers and young capsules, leading to premature shedding. The severally affected leaves may be twisted and malformed. In the advanced stages of infection, the mycelial growth changes to dark or black because of development of cleistothecia.


Pathogen: The Pathogen produces hyaline, septate mycelium which is extophytic and sends haustoria into the host epidermis. Conidiophores arise from the primary mycelium and are short and non-septate bearing conidia in long chains. The conidia are ellipsoid or barrel-shaped, single celled and hyaline. The cleistothecia are dark, globose with the hyaline or pale brown myceloid appendages. The asci are ovate, and each ascus produces 2-3 ascospores, which are thin walled, elliptical and pale brown in color.

Favorable Conditions: Dry humid weather and low relative humidity.

Disease Cycle: The pathogen is an obligate parasite and disease perennates through cleistothecia in the infected plant debris in soil. The ascospores from the cleistothecia cause primary infection. The secondary spread is through wind-borne conidia.

Management: Remove the infected plant debris and destroy; spray wettable sulphur at 2.5 kg/ha or karathane 1L/ha repeat after 15 days.

References:

INTERNATIONAL

- Anon (2000a) is an organic grower guide for America. It describes the following pathogen and its recommended organic method of control: *Erysiphe cichoracearum* (Powdery mildew) – Use resistant varieties; late varieties are less susceptible. Wettable sulfur (0.2%) or application of powdered sulfur 20 kg/ha the 45th and 65th day after sowing.

CHINA

- E.A. Weiss (1971) reported *Erysiphe cichoracearum* is a damaging pathogen and is common in the Suchow area.
- L.L. Li (1988) reported *Erysiphe cichoracearum* (Mildew) causes minor or regional damage to sesame. The pathogen attacks leaves, petioles, stems and capsules. The diseased portions of plants are covered with white powder. Thus, photosynthesis of the diseased leaves is weakened; the plants grow poorly and die earlier than expected. The disease occurs more under late or Autumn sowing.
- H.M. Miao and H.Y. Liu (2010) reported the following pathogen: *Erysiphe cichoracearum.*

INDIA

- S. Krishnaswami et al. (1983) reported results of investigations involving 164 genotypes indicated that resistance to *Erysiphe cichoracearum* in sesamum may be controlled by two major complementary genes. [Cited by G.S. Saharan, 1989 and P. Venkata Ramana Rao, 2013a]
- M.L. Verma (1985) reported *Erysiphe cichoracearum* (*Oidium erysiphoides*) (Powdery mildew) is a major disease with the following symptoms: Small patches of white powder on upper and occasionally lower surface of leaves.
- D. Kumaresan and N. Nadarajan (2002a) reported Si 3315/11 and OMT 30 and the tester Co 1 are good parents in breeding for tolerance to *Oidium acanthospermi*, which showed considerable economic damage throughout the sesame growing areas in post rainy/severe winter season.
- K. Satyagopal et al. (2014) in an IPM manual reported *Erysiphe cichoracearum* (Powdery mildew) was a regional problem in Rajasthan. For cultural control, the Bower system (maintain gapping) of cropping reduces the disease incidence.
- Anon. (n.d.k) reported *Erysiphe cichoracearum* (Syn: *Oidium acanthospermi*) (Powdery mildew) causes a major disease.

JAPAN

- K. Hirata (1966) provided the distribution of *Erysiphe cichoracearum.* [Cited by G.S. Saharan, 1989]

MEXICO

- Agrolytics.org (2021) reported sesame hosts *Erysiphe cichoracearum.*

SUDAN

- A.R.C. Umaima (pers. comm. 2021): *Erysiphe cichoracearum* (Powdery mildew) is a current problem. The symptoms are grayish-white powdery growth on the upper surface of leaves. In severe infections leaves, flowers and young capsules covered with powdery coating leading to premature shedding, twisting and malformation.

THAILAND

- D. B. Reddy (1971) reported *Erysiphe cichoracearum* on sesame. [Cited by G.S. Saharan, 1989]

UGANDA

- J.P. Egonyu (2005) reported the following pathogen: *Erysiphe cichoracearum.*

A5.1.2b *Erysiphe orontii* (9 Apr 2021)

Family: Erysiphaceae

Definition: Amount of tolerance to *Erysiphe orontii* Castagne.

References:

INTERNATIONAL

- Anon. (2004a) IPGRI descriptor: 10.2.7. Biotic stress susceptibility to *Erysiphe orontii* (Powdery mildew)
  - In each case it is important to state the origin of the infestation or infection, i.e., natural, field inoculation, or laboratory. Also specify the causal organism and the corresponding symptoms. The susceptibility scale is as follows:
    - 1 = Very low or no visible sign of susceptibility
    - 3 = Low
    - 5 = Intermediate
    - 7 = High
    - 9 = Very high
  - The growth state, coded according to the list below at which each reaction was recorded should be appended to the record of that reaction.
    - 1 = Seed
    - 2 = Seedling
    - 3 = Pre-flowering
    - 4 = Early flowering
    - 5 = Mid-flowering
    - 6 = Late-flowering
    - 7 = Maturity

INDIA

- K.N. Gupta et al. (2018) reported Powdery mildew caused by *Erysiphe orontii*. It is the most important disease of sesame, occurring widely throughout India and causes substantial qualitative and quantitative loss to the crop. It occurs in epidemic scale under heavy rainfall condition followed by low night temperature and high humidity. It appears at flowering to capsule formation stage as small patches of white powder on upper side and occasionally on lower surface of leaves. Defoliation of severely infected plant occurs before maturity. Powdery mildew causes yield losses ranging from 25 to 50% depending upon the level of incidence an average yield loss of 45% has been reported to be caused by Powdery mildew. The problem can be alleviated by foliar spray of neem oil 3% (might be due to the presence of sulphur containing compounds viz., nimbidin and azadirachtin); spraying Sulfex (0.2%) or Karathane (0.2%).

A5.1.2c *Erysiphe betae* (4 Jun 2021)

Synonym: *Erysiphe polygoni*

Family: Erysiphaceae

Definition: Amount of tolerance to *Erysiphe betae* (Vanha) Weltzien 1963.

(Wikipedia, 4 Jun 2021) **Erysiphe betae** is a plant pathogen. It is a form of powdery mildew that can affect crops of sugar beet, when it can cause up to a 30% yield loss. The fungus occurs worldwide in all regions where sugar beet is grown and it also infects other edible crops, e.g. beetroot.

References:

ETHIOPIA

- A. Ciccarone (1940) reported *Erysiphe polygoni* caused a disease in sesame. [Cited by R.S. Vasudeva, 1961]

A5.1.2d *Erysiphe cruciferarum* (20 Jul 2021)

Synonym: *Erysiphe communis*

Family: Erysiphaceae

Definition: Amount of tolerance to *Erysiphe cruciferarum* Opiz ex L. Junell 1967.

(Wikipedia, 20 Jul 2021) ***Erysiphe cruciferarum*** is a plant pathogen of the family Erysiphaceae, which causes the main powdery mildew of crucifers, including on *Brassica* crops, such as cauliflower, cabbage, broccoli, and Brussels sprouts. *E. cruciferarum* is distributed worldwide, and is of particular concentration in continental Europe and the Indian subcontinent. *E. cruciferarum* is an ascomycete fungus that has both sexual and asexual stages. It is also an obligate parasite that appears to have host specificity; for example, isolates from turnip will not infect Brussels sprout, and vice versa. While being a part of the family Erysiphaceae, it belongs to those members in which the conidia are formed singly and whose haustoria are multilobed.

This species is also being evaluated as a potential biological control for the invasive plant garlic mustard.

References:

JAPAN
- K. Hirata (1966) provided the distribution of *Erysiphe communis.* [Cited by G.S. Saharan, 1989]

A5.1.3 *Leveillula* spp. (27 Apr 2021)

Family: Erysiphaceae

Definition: Amount of tolerance to *Leveillula* spp. G. Arnaud 1921.

(Wikipedia, 27 Apr 2021) ***Leveillula*** is a genus of fungi in the family Erysiphaceae.

References:

TURKEY
- N. Isler et al. (n.d.) reported the following pathogen: *Leveillula* sp. For control, plant resistant varieties and remove crop residue.

UNITED STATES
- D.R. Langham et al. (2010c) stated *Leveillula* sp. has been reported in sesame in the USA in research nurseries but have not been seen in commercial fields since 1978.

A5.1.3a *Leveillula taurica* (27 Apr 2021)

Synonym: *Oidiopsis taurica*

Family: Erysiphaceae

Definition: Amount of tolerance to *Leveillula taurica* (Lev.) G. Arnaud 1921.

(Wikipedia, 27 Apr 2021) ***Leveillula taurica*** is an obligate fungal pathogen, from the phylum *Ascomycota*, which causes powdery mildew on onion. This disease prefers warm, dry environments. It is rare in the United States and is currently restricted to western states. Globally, it is also a minor problem with limited occurrences in the Middle East, Europe, and South America. *L. taurica* causes powdery mildew of onions, but is also known to infect other allium, solanaceous, and cucurbit species. The disease has appeared in parts of the Middle East, the Mediterranean, and South and North America. Currently, it is not a cause for major concern in the U.S. and throughout the world, as its geographic extent is sparse. In addition, it is relatively easy to control through basic sanitation and reducing water stress.

L. taurica is the pathogen responsible for powdery mildew on onions, but it can also infect peppers, tomatoes, eggplant, cotton, and garlic. While *L. taurica* can infect many different plants, it is actually very host specific. Different races of *L. taurica* can only infect certain crops, and even specific cultivars within the same crop. An accurate way to describe its host specificity is that this disease is, “a composite species consisting of many host-specific races." Symptoms of Onion Powdery Mildew (OPM) are usually seen as circular or oblong lesions that are 5 to 20 mm and have a chlorotic or necrotic appearance. The lesions appear on older leaves before the bulb of the onion begins to form, but also can occur on the younger leaves towards the end of the season. As the disease

progresses signs of OPM can also be seen. On the lesions white mycelium can be found with conidiophores bearing either lanceolate or rounded conidia.

The polycyclic disease cycle of *L. taurica* is similar to that of other powdery mildew species. It overwinters (as chasmothecia) in crop residues above the soil surface. Under favorable climatic conditions, the chasmothecia open and release ascospores, which are wind-dispersed. The ascospores enter the host through its stomata, germinate, and colonize the host's tissues with its mycelia. The pathogen then begins to produce its asexual conidia, either singly or on branched conidiophores. The conidia exit through the host's stomata and serve as a secondary inoculum to spread disease after initial infection. In the fall, the pathogen undergoes sexual reproduction and again produces chasmothecia, its dormant, overwintering structure.

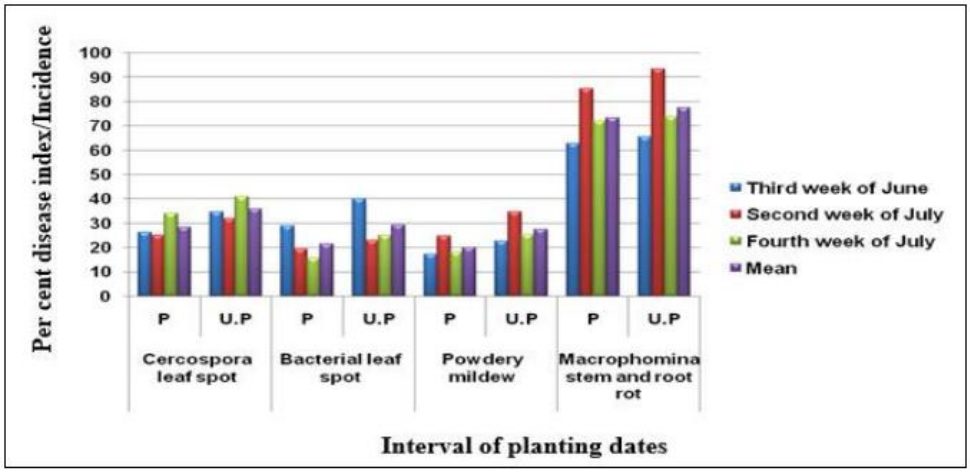
References:

INTERNATIONAL

- Anon (2000a) is an organic grower guide for America. It describes the following pathogen and its recommended organic method of control: *Leveillula taurica* (Powdery mildew) – Use resistant varieties; late varieties are less susceptible. Wettable sulfur (0.2%) or application of powdered sulfur 20 kg/ha the 45th and 65th day after sowing.
- CAB International (accessed 12 Apr 2021) reported sesame was a minor host of *Leveillula taurica* (powdery mildew of cotton).

INDIA

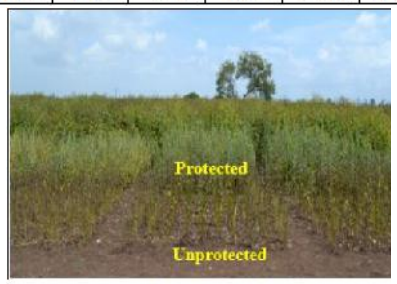
- M.K. Patel et al. (1949) reported *Leveillula taurica* caused powdery mildew in sesame. [Cited by R.S. Vasudeva, 1961]
- G.S. Saharan and J.S. Chohan (1972) reported *Leveillula taurica* (Powdery mildew). [Cited by G.S. Saharan, 1989]
- Anon (1992a) in a grower guide reported *Leveillula taurica* (Powdery mildew) appears when the crop is 45 to 90 days old. Whitish patches appear on the leaves. The severely infected leaves drop off. The plant is defoliated before maturity.
- G. Raja Ravindran and A. Amrithadeva Rathinam (1996b) crossed a variety CO1 resistant to powdery mildew (*Leveillula taurica*) with susceptible genotypes TSS 6, DPI 1526, TMV 4, THAU 28, TMV 5, and DPI 1525. They analyzed the data of 24 F_2 lines and concluded the inheritance of powdery mildew resistance in sesame was found to be due to two pairs of dominant genes sowing complementary gene action.
- T.G.N. Rao and N. Padmavathi (1999) screened 40 sesame genotypes were screened for their reaction to powdery mildew (*Leveillula taurica* Lev) during Rabi 1996 under natural disease pressure at Hyderabad (77.92E and 18.99N). Powdery mildew is one the serious diseases reported in India both in Kharif and Rabi seasons. The disease was found to cause an average yield loss up to 45%. Two lines viz., 22AN-8 and Phule Til-1 were found to be highly resistant, while seven lines viz., TKG-21, DS-1, GT-2, TMV-4, Pb Til N0.1, Krishna and B-181 were moderately resistant to powdery mildew.
- K. Satyagopal et al. (2014) in an IPM manual reported *Leveillula taurica* (Powdery mildew) was a regional problem in Rajasthan. For cultural control, the Bower system (maintain gapping) of cropping reduces the disease incidence.
- M.G. Palakshappa et al. (2020b) evaluated the date of planting (3rd week of June, 2nd week of July, and 4th week of July) on diseases from 2014 to 2017 at Dharwad, Karnataka (15.46N 75.01E). The main constraint for the low productivity of this crop is due to severe outbreak of various fungal stem and root rot of sesame (*Macrophomina phaseolina*), Alternaria leaf spot (*Alternaria sesami*), Powdery mildew (*Leveillula taurica*), Cercospora leaf spot (*Cercospora sesamicola*), Bacterial leaf spot (*Pseudomonas syringae* pv. *sesam*i), viral and phytoplasma diseases. The control (Protected – P) used fungicides viz., Carbendazim @ 0.1% and combi product (Tebuconazole 50% + Trifloxistrobin 25% WG) @ 0.05% were sprayed at 15 days intervals and the Unprotected – UP did not use fungicides. The disease indices were as follow.



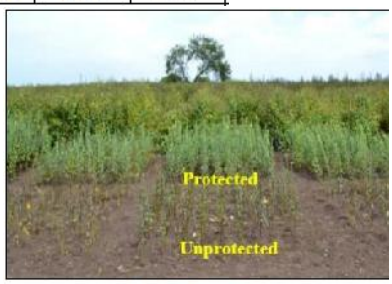
The effects on yield were as follow.

Planting intervals	Yield q/ha								Mean yield q/ha	
	Kharif- 2014		*Kharif*- 2015		*Kharif* -2016		*Kharif*- 2017			
	P	UP	P	UP	P	UP	P	UP	P	UP
Third week of June	11.80	4.30	9.70	5.75	5.45	4.62	5.40	3.04	8.08	4.42
Second week of July	7.00	2.60	7.10	4.00	6.89	3.64	2.69	1.86	5.92	3.02
Fourth week of July	4.10	1.30	4.40	3.35	1.12	0.47	1.92	0.62	2.88	1.44
Mean	7.63	2.73	7.06	5.03	4.48	3.57	3.33	1.84	5.62	3.29

Third week of June sowing



Second week of July sowing



Fourth week of July sowing

ITALY

- A. Graniti (1958) reported in 1954 sesame was attacked for the first time in Sicily by powdery mildew (*Leveillula taurica*). Biometrical data and inoculation tests on other common hosts appeared to confirm the existence of specialized strains of the fungus. [Cited by G.S. Saharan]

JAPAN

- K. Hirata (1966) provided the distribution of *Leveillula taurica.* [Cited by G.S. Saharan, 1989]

MEXICO

- E.C. Hernandez (2003) in a grower guide reported the following pathogen: *Leveillula taurica* (Moho polvoriento). It mainly affects the basal part of the leaves, due to the presence of a fungus that softens tissues in the form of rot. It is usually due to excesses of humidity. Eliminate the affected plants and apply a fungicide to the whole plant.
- Agrolytics.org (2021) reported sesame hosts *Leveillula taurica.*

PAKISTAN

- D.A. Shambharkar et al. (1997) evaluated 30 genotypes from 9 countries for tolerance to *Alternaria sesami*, *Leveillula taurica*, *Macrophomina phaseolina*, and phyllody. The *Leveillula taurica* incidence ranged from 6.5 to 45.0%. The genotypes SIK-113 and SIK-104 from Kenya exhibited better tolerance under high as well as low input conditions. Other good genotypes were Krishna, Padma, and Tapi. These genotypes should be used for breeding programs.

VENEZUELA

- E.J. Parra R. et al. (1976) reported a Powdery mildew was recorded on the variety Aceitera and it was identified as *Leveillula taurica*. The following photo shows a normal leaf and an infected leaf.

- A.M. Colmenares and L. Subero (1989a) reported the following less relevant pathogens: *Leveillula taurica* (Powdery mildew).

A5.1.4 *Podosphaera* spp. (27 Apr 2021)

Synonym: *Sphaerotheca* spp.

Family: Erysiphaceae

Definition: Amount of tolerance to *Podosphaera* spp. Kunze 1823.

(Wikipedia, 27 Apr 2021) ***Podosphaera*** is a genus of fungi in the family Erysiphaceae. Species in this genus are plant pathogens, causing powdery mildew.

References:

JAPAN

- K. Hirata (1966) provided the distribution of *Sphaerotheca* sp. [Cited by G.S. Saharan, 1989]

A5.1.4a *Podosphaera fuliginea* (27 Apr 2021)

Synomyms: *Oidium erysiphoides*, *Podosphaera xanthii*, and *Sphaerotheca fuliginea*

Family: Erysiphaceae

Definition: Amount of tolerance to *Podosphaera fuliginea* (Schltdl.) U. Braun & S. Takam 2000.

(Wikipedia, 27 Apr 2021) ***Podosphaera fuliginea*** (also known as *Podosphaera xanthii*) is a plant pathogen that causes powdery mildew on cucurbits. *Podosphaera fuliginea* and *Erysiphe cichoracearum* are the two most commonly recorded fungi causing cucurbit powdery mildew. In the past, *Erysiphe cichoracearum* was considered to be the primary causal organism throughout most of the world. Today, *Podosphaera fuliginea* is more commonly reported.

Powdery mildew is manifest on the plant by white powdery fungal growth on the surface of the leaf, usually both sides of the leaf show fungal growth. The host tissue is frequently stunted, distorted, discolored, and scarred. The fruit of infected plants are usually smaller and the flavor is affected negatively, as fewer sugars and solids are stored in the fruit.

Podosphaera fuliginea uses haustoria to gain access to the leaf epidermal cells. The fungus is usually spread during the spring through mycelium from infected plant, or through ascocarps. Signs appear after 3–7 days of infection if conditions are favorable. The mycelium grows rapidly during the warm summer months with an optimum temperature of about 10-32°C (50-90°F). The leaves are most susceptible 16–23 days after unfolding. High humidity favors the development of disease, but infection can occur at relative humidity as low a 50%. The conidia of the fungus are spread through the air and thus can travel over great distances. The mycelium can also overwinter in the buds of infected plants.

References:

INTERNATIONAL

- J.R. Morschel (1964) reported the following pathogen in the world: *Sphaerotheca fuliginea* (Sesame mildew). [Cited by D.F. Beech. 1995a]
- Anon (2000a) is an organic grower guide for America. It describes the following pathogen and its recommended organic method of control: *Oidium erysiphoides*/*Sphaerotheca fuliginea* (Powdery mildew) – Use resistant varieties; late varieties are less susceptible. Wettable sulfur (0.2%) or application of powdered sulfur 20 kg/ha the 45th and 65th day after sowing.

AUSTRALIA
- C. Chattopadhyay et al. (2019) reported *Oidium erysiphoides.*

CHINA
- L.L. Li (1988) reported *Oidium erysiphoides* (Mildew) causes minor or regional damage to sesame. The pathogen attacks leaves, petioles, stems and capsules. The diseased portions of plants are covered with white powder. Thus, photosynthesis of the diseased leaves is weakened; the plants grow poorly and die earlier than expected. The disease occurs more under late or Autumn sowing.

ETHIOPIA
- B.K Yirga and B. Fiseha (2017a) reported the following pathogen: *Sphaerotheca fuliginea* (Powdery mildew).
- B.K Yirga et al. (2018a) surveyed 10 locations representative low land areas of western zone of Tigray for 3 years (2015, 2016, and 2017). *Xanthomonas campestris* pv. *sesami* - bacterial blight (83.24%) recorded the highest disease incidence followed by *Sphaerotheca fuliginea* - powdery mildew (78.13%), *Fusarium oxysporum* f. sp. *sesami* - fusarium wilt (78%), phyllody (72.01%) and *Alternaria* spp. - blight leaf spot (72%). Whereas blight leaf spot recorded highest severity (31.33%), followed by fusarium wilt (27.2%), phyllody (25.24%), bacterial blight (22.76%) and powdery mildew (22.6%). The phyllody is vectored by *Orosius albicinctus.*

INDIA
- P.D. Gemawat and O.P. Verma (1972) provided the symptoms and morphology of *Sphaerotheca fuliginea.* [Cited by G.S. Saharan, 1989]
- M.L. Verma (1985) reported *Sphaerotheca fuliginea* (Powdery mildew) is a major disease with the following symptoms: Small patches of white powder on upper and occasionally lower surface of leaves.
- K. Satyagopal et al. (2014) in an IPM manual reported *Sphaerotheca fuliginea* (Powdery mildew) was a regional problem in Rajasthan. For cultural control, the Bower system (maintain gapping) of cropping reduces the disease incidence.

IRAQ
- C. Chattopadhyay et al. (2019) reported *Oidium erysiphoides.*

JAPAN
- C. Chattopadhyay et al. (2019) reported *Oidium erysiphoides.*

MALAWI
- E. Lawrence (1951) reported *Sphaerotheca fuliginea* (Mildew) causes one of the more important diseases. [Cited by R.S. Vasudeva, 1961, and G.S. Saharan, 1989]

MEXICO
- Anon. (2010a) in a grower guide reported the following main pathogen: *Podosphaera xanthii.* It is an obligate parasite in cucurbits. In greenhouse the release of conidia is triggered by irrigation or air movement, which is then dispersed from plant to plant. Conidia may overwinter in crops of cucurbits in the greenhouse, dispersing by the wind towards for field crops during spring and summer. Other non-cucurbit hosts are considered not serve as sources of inoculum, since *P. xanthii* shows a high degree of pathological specialization within its host range.

SOMALIA
- E. Castellani and A.N. Jama (1984) reported the presence of *Oidium erysiphoides.*

SUDAN
- S.A.J. Tarr (1954) reported Powdery mildew (*Sphaerotheca fuliginea*) occurs on sesame in most areas. [Cited by G.S. Saharan, 1989]

TANZANIA

- G.B. Wallace (1933) reported *Sphaerotheca fuliginea* caused a disease in sesame. [Cited by R.S. Vasudeva, 1961]

TURKEY

- N. Isler et al. (n.d.) reported the following pathogen: *Sphaerotheca fuliginea.* For control, plant resistant varieties and remove crop residue.

UGANDA

- J.P. Egonyu (2005) reported the following pathogen: *Sphaerotheca fuliginea.*

A5.1.4b *Podosphaera fusca* (19 May 2021)

Family: Erysiphaceae

Definition: Amount of tolerance to *Podosphaera fusca* (Fr.) U. Braun & Shishkoff 2000.

(Wikipedia, 19 May 2021) ***Podosphaera fusca*** is a fungus that parasitically infects plants (a phytopathogen). It is one cause of powdery mildew in melons and gourds.

Some sources suggest that *P. fusca* should be considered synonymous with *P. xanthii*, while others maintain they are separate species in the subsection *Magnicellulata* of the section *Sphaerotheca* of the genus *Podosphaera*, as of 2011, based on the size of chasmothecia, and on the thin-walled portion of the asci (oculus).

References:

TURKEY

- F. Akdeniz and H. Sert (2019) reported *Podosphaera fusca* in sesame. Scattered mycelia appear as pale yellow spots on both sides of the stem, petioles and leaves or in groups. These spots enlarge as white powdery fungal growth comprising primarily of asexual spores (conidia) develops on upper and under leaf surfaces, petioles, and stems of infected plants, shaded lower leaves, and leaf undersurfaces.

A5.1.5 *Pseudoidium* spp. (26 May 2021)

Family: Erysiphaceae

Definition: Amount of tolerance to *Pseudoidium* spp. Y.S. Paul & J.N. Kapoor 1986.

A5.1.5a *Pseudoidium pedaliacearum* (26 May 2021)

Family: Erysiphaceae

Definition: Amount of tolerance to *Pseudoidium pedaliacearum* (H.D. Shin) H.D. Shin 2012.

References:

JAPAN

- T. Kuzuyuki (2021) reported the following pathogen: *Pseudoidium pedaliacearum* (Powdery mildew).

REPUBLIC OF KOREA

- H.D. Shin et al. (2018) reported collections of *Pseudoidium pedaliacearum* on *Sesamum indicum* from Japan, Korea, and Nepal have been morphologically examined and subjected to molecular sequence analyses in order to clarify the taxonomic status and phylogenetic affinity of this powdery mildew. *Pseudoidium pedaliacearum* pertains to the *Erysiphe aquilegiae* clade.

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A6 Order: Cantharellales Gaum 1926

(Wikipedia, 9 Apr 2021) The **Cantharellales** are an order of fungi in the class Agaricomycetes. The order includes not only the chanterelles (Cantharellaceae), but also some of the tooth fungi (Hydnaceae), clavarioid fungi (Aphelariaceae and Clavulinaceae), and corticioid fungi (Botryobasidiaceae). Species within the order are variously ectomycorrhizal, saprotrophic, associated with orchids, or facultative plant pathogens. Those of economic importance include edible and commercially collected Cantharellus, Craterellus, and Hydnum species as well as crop pathogens in the genera Ceratobasidium and Thanatephorus (Rhizoctonia).

Most fungi within the order are ectomycorrhizal, forming mutually beneficial associations with certain trees, shrubs, and other vascular plants. Species in the Botryobasidiaceae are believed to be saprotrophs of fallen wood and leaf litter. Species in the Ceratobasidiaceae are also saprotrophs, but some are capable of becoming facultative plant pathogens. Species in the Tulasnellaceae are saprotrophic but are also associated with orchid mycorrhiza, as are some species in the Ceratobasidiaceae. Distribution is cosmopolitan.

Sporocarps (fruit bodies) of chanterelles and some Hydnum species, particularly *Hydnum repandum*, are edible and widely collected on a commercial scale. They are marketed fresh or processed and traded internationally. Several species in the Ceratobasidiaceae, notably *Rhizoctonia solani*, cause significant diseases of cereals and other commercial crops, as well as turf grass.

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A6.1 Family: Ceratobasidiaceae G.W. Martin 1848

(Wikipedia, 9 Apr 2021) The **Ceratobasidiaceae** are a family of fungi in the order Cantharellales. All species within the family have basidiocarps (fruit bodies) that are thin and effused. They have sometimes been included within the corticioid fungi or alternatively within the "heterobasidiomycetes". Species are saprotrophic, but some are also facultative plant pathogens or are associated with orchid mycorrhiza. Genera of economic importance include Ceratobasidium and Thanatephorus (anamorph *Rhizoctonia*), both of which contain plant pathogenic species causing diseases of commercial crops and turf grass.

Species are mainly saprotrophic, occurring in the soil and producing fruit bodies on dead stems and plant detritus. Some occur on attached leaves and stems.

Several species of *Ceratobasidium* and *Thanatephorus* (including its anamorph *Rhizoctonia*) are opportunistic parasites of plants, causing a variety of economically important diseases of crops.

The following species have been reported to cause diseases, produce a toxin, inhibit germination, or affect seed quality.

- A6.1.1 *Rhizoctonia* spp.
- A6.1.1a *Rhizoctonia solani* (*Syn: *Pellicularia filamentosa, R. grisea,* and *Thanatephorus cucumeris*)

A6.1.1 *Rhizoctonia* spp. (11 Dec 2021)

Family: Ceratobasidiaceae

Definition: Amount of tolerance to *Rhizoctonia* spp. DC 1805.

Summary:

Seedlings killed by Rhizoctonia. Photo: B. Lyssy {USA}

Rhizoctonia solani crown and stem necrosis on sesame. Photo: K.A. Cochran {USA}

Rhizoctonia solani (Synonyms: *Pellicularia filamentosa* and *Rhizoctonia grisea*, teleomorph: *Thanatephorus cucumeris*) is a plant pathogenic fungus with a wide host range and worldwide distribution, which was discovered more than 100 years ago. Although it has a wide range of hosts, its main targets are herbaceous plants. The pathogen thrives in warm and moist conditions, though infection and symptoms can occur in a wide variety of environments. Symptoms can manifest in sesame as seedling disease/damping off, root rot, crown rot, and stem necrosis. Lesions are brown to dark-brown in color, often sunken and may circle the stem, girdling it. Diagnostic features are observed microscopically and include hyphae that are relatively large and have right angle branching with constrictions at the base of the branching. The fungus is easily cultured and sclerotia typically form readily in culture. Molecular identification (PCR) can be useful to confirm identity. This pathogen typically occurs as hyphae or sclerotia in the soil and in/on host plant material. Sclerotia are durable nugget-like pieces of modified hyphae (usually measuring from one to a few mm in diameter) that can live in the soil or plant debris for many years. This fungus doesn't typically sporulate sexually, but basidiospores may occur on infected plant tissues. Asexual spores are not produced, though sclerotia serve in a similar capacity in the life cycle. *R. solani* isolates are categorized into anastomosis groups (AGs), which is important to note in diagnostic efforts. AGs are determined by the ability of a given isolate to undergo hyphal fusion with a known AG isolate. Currently, only AG4 has been reported to be pathogenic to sesame in the US. Additional information is needed regarding what AGs are pathogenic to sesame globally. While it often infects its hosts when they are in early stages of development, such as seeds and seedlings, infection can occur later in the season. If infection occurs early in the season, and often results in stunting, root rot, and plant decline. Many infections are most apparent late in the season, when stunted and poorly developed plants are more vulnerable to lodging. Co-infection with *Macrophomina phaseolina* has been observed, and resulted in severe stunting, poor capsule set, and late season lodging. This pathogen is very difficult to manage, as it is very long lived in the soil, no resistant lines have been identified, and while chemical management regulations vary by country, labelled fungicides are generally not available. *Rhizoctonia* spp. have been reported in International lists, Australia, Bolivia, Brazil, China, Colombia, Costa Rica, Dominican Republic, Egypt, India, Iraq, Japan, Myanmar, Nicaragua, Pakistan, Panama, Republic of Korea, Uganda, United States, and Venezuela.

(Wikipedia, 9 Apr 2021) ***Rhizoctonia*** is a genus of anamorphic fungi in the order Cantharellales. Species do not produce spores, but are composed of hyphae and sclerotia (hyphal propagules) and are asexual states of fungi in the genus Thanatephorus. *Rhizoctonia* species are saprotrophic, but are also facultative plant pathogens, causing commercially important crop diseases. They are also endomycorrhizal associates of orchids. The genus name was formerly used to accommodate many superficially similar, but unrelated fungi.

In its current sense, the genus is effectively restricted to the type species *R. solani* and its synonyms. The genus name is still, however, widely used in its old, artificial sense. Molecular research, based on cladistic analysis of DNA sequences, places *Rhizoctonia* within the family Ceratobasidiaceae.

The following species have been associated with sesame but there are no known reports of being a pathogen, producing a toxin, inhibiting germination, affecting seed quality, or being used as a biocontrol or biofertilizer.

- *Rhizoctonia leguminicola* [India]
- *Rhizoctonia stolonifer* [Iraq]

References:

AUSTRALIA

- D.F. Beech (1981a) reported the presence of *Rhizoctonia* sp. (crown rot) in 1971.

COLOMBIA
- V.C. Barcenas (1962) reported *Rhizoctonia* sp. was identified on sesame. [Cited by G.S. Saharan, 1989]

DOMINICAN REPUBLIC
- R. Ciferri (1930) reported *Rhizoctonia* sp. occurs rarely in clay soils in rainy seasons.

INDIA
- E.J. Butler (1918) reported *Rhizoctonia* sp. occurs on sesame. [Cited by G.S. Saharan. 1989]

NICARAGUA
- R.A. Marenco M. et al. (1988) reported the most important diseases are those that rot the base of the stem, and this is most severe in soils with insufficient drainage. The principal causes of this fungal disease have been identified as being *Macrophomina* sp., *Fusarium* sp. and *Rhizoctonia* sp. The only methods of control are to rotate crops and at the same time to avoid planting in soils with poor drainage.

REPUBLIC OF KOREA
- J.I. Lee et al. (1985i) reported A new high-yielding sesame variety 'Ansanggae' was developed by mutation breeding of 'Early Russian'. Ansanggae was moderately resistant to seedling blight including Rhizoctonia blights, and resistant to Corynespora leaf blight, Phytophthora blight, and Fusarium wilt. [Based on abstract]

UGANDA
- E.A. Weiss (1971) reported mixed infections of *Fusarium oxysporum* and *Rhizoctonia* spp**.**

UNITED STATES
- D.T. Smith et al. (2000) reported *Rhizoctonia* spp. was observed on sesame in North Carolina. This pathogen can attack seedlings, cause damping off, reduce crop stands in cool, wet soils, and may attack the crop later in the growing season. Sesame seedlings may emerge, but seedling diseases may reduce stands 70% to 90%.
- D.R. Langham et al. (2010c) stated *Rhizoctonia* sp. has been reported in sesame in the USA in research nurseries but have not been seen in commercial fields since 1978.
- C. Stichler (pers. comm. 2015): *Rhizoctonia* showed up the Uvalde area in 2015 for the first time. It reduced yields in late planted crops.

Sesame seedlings killed by *Rhizoctonia* spp. Photo: B. Lyssy.

VENEZUELA
- B. Mazzani et al. (1973) introduced a new variety 'Maporal' which is especially adapted to conditions in which soilborne pathogens (*Phytophthora*, *Fusarium*, *Macrophomina*, and *Rhizoctonia*) are prevalent.
- C. Zambrano and O. Tortolero (1985) conducted studies on 540 sesame cultivars, and isolations from seedling rot and soil and reported the following pathogen: *Rhizoctonia* sp.

A6.1.1a *Rhizoctonia solani* (10 Dec 2021)

Synonyms: *Pellicularia filamentosa, Rhizoctonia grisea,* and *Thanatephorus cucumeris*

Family: Ceratobasidiaceae

Definition: Amount of tolerance to *Rhizoctonia solani* J.G. Kühn 1858.

(Wikipedia, 9 Apr 2021) ***Rhizoctonia solani*** (teleomorph: ***Thanatephorus cucumeris***) is a plant pathogenic fungus with a wide host range and worldwide distribution. It was discovered more than 100 years ago. *R. solani* frequently exists as thread-like growth on plants or in culture and is considered a soilborne pathogen. *R. solani* is best known to cause various plant diseases such as collar rot, root rot, damping off, and wire stem. *R. solani* attacks its hosts when they are in their early stages of development, such as seeds and seedlings, which are typically found in the soil. The pathogen is known to cause serious plant losses by attacking primarily the roots and lower stems of plants. Although it has a wide range of hosts, its main targets are herbaceous plants. Occasionally,

sexual spores (basidiospores) are produced on infected plants. The disease cycle of *R. solani* is important in management and control of the pathogen. The pathogen is not currently known to produce any asexual spores (conidia), though it is considered to have an asexual lifecycle perpetuated through sclerotia.

R. solani causes a wide range of commercially significant plant diseases. The fungus has a wide host range and strains of *R. solani* may differ in the hosts they are able to infect, the virulence of infection, selectivity for a given host (which may range from nonpathogenic to highly virulent), the temperature at which infection occurs, the ability to develop in lower soil levels, the ability to form sclerotia, the growth rate, and survival in a certain area. These factors may not always be distinctive in every host that *Rhizoctonia* attacks or in every strain thereof.

R. solani primarily attacks seeds of plants below the soil surface, but can also infect pods, roots, leaves, and stems. The most common symptom of *Rhizoctonia* is "damping off", or the failure of infected seeds to germinate. *R. solani* may invade the seed before it has germinated to cause this pre-emergent damping off, or it can kill very young seedlings soon after they emerge from the soil. Seeds that do germinate before being killed by the fungus have reddish-brown lesions and cankers on stems and roots.

Various environmental conditions put the plant at higher risk of infection due to *Rhizoctonia*, the pathogen prefers warmer, wet climates for infection and growth. Postemergent damping off is a further delay in attack of *R. solani*. The seedling is most susceptible to disease in its early stages.

R. solani can survive in the soil for many years in the form of sclerotia. Sclerotia of *Rhizoctonia* have thick outer layers to allow for survival, and they function as the overwintering structure for the pathogen. In some rare cases (such as the teleomorph) the pathogen may also take on the form of mycelia that reside in the soil, as well. The fungus is attracted to the plant by chemical stimuli released by a growing plant and/or decomposing plant residue. The process of penetration of a host can be accomplished in a number of ways. Entry can occur through direct penetration of the plant cuticle/epidermis or by means of natural openings in the plant. Hyphae come in contact with the plant and attach to the plant by which through growth they begin to produce an appressorium which penetrates the plant cell and allows for the pathogen to obtain nutrients from the plant cell. The pathogen can also release enzymes that break down plant cell walls and continues to colonize and grow inside dead tissue. This breakdown of the cell walls and colonization of the pathogen within the host forms the sclerotia. New inoculum is produced on or within the host tissue, and a new cycle is repeated when new plants become available. The disease cycle begins as such:

1. Sclerotia/mycelium overwinter in plant debris, soil, or host plants.
2. The young hyphae and fruiting basidia (rare) emerge and produce mycelia and rarely basidiospores.
3. The very rare production of the germinating basidiospores penetrate the stoma, whereas the mycelia land on the plant surface and secrete the necessary enzymes onto the plant surface to initiate invasion of the host plant.
4. After the mycelia successfully invade the host, necrosis and sclerotia form in and around the infected tissue which then leads to the various symptoms associated with the disease, such as soil rot, stem rot, damping off, etc. and the process begins all over again.

The pathogen is known to prefer warm, wet weather, and outbreaks typically occur in the early summer months. Most symptoms of the pathogen do not occur until late summer thus most farmers do not become aware of the diseased crop until harvest. A combination of environmental factors has been linked to the prevalence of the pathogen, such as presence of host plant, frequent rainfall/irrigation, and increased temperatures in spring and summer. In addition, a reduction of drainage of the soil due to various techniques such as soil compaction are also known to create favorable environments for the pathogen. The pathogen is dispersed as sclerotia, and these sclerotia can travel by means of wind, water, or soil movement between host plants.

References:

INTERNATIONAL

- R.S. Vasudeva (1961) reported sesame stalks were successfully infected with *Rhizoctonia grisea.*
- J.R. Morschel (1964) reported the following pathogen in the world: *Rhizoctonia solani* (Crown rot). [Cited by D.F. Beech. 1995a]

AUSTRALIA

- M.M. Satour (1981) reported the presence of *Rhizoctonia solani* (Root rot).

BOLIVIA

- B. Carreno L. et al. (n.d.) in a grower guide reported *Rhizoctonia solani*. It primarily attacks the stems starting at the soil level and then rising on the stem. When the attack is severe, the leaves will turn yellow, and the plants may dry down and die.

BRAZIL

- M.G.R. Faiad et al. (2002) examined seed from 416 accessions from 7 Brazilian states at 25°C under alternating black lights and darkness in a 12-hour photoperiod for 8 days. They found *Rhizoctonia solani.* They concluded the seed acts as a vehicle for pathogen dissemination.

CHINA

- L.L. Li (1988) reported *Rhizoctonia solani* (Rhizoctonia rot) causes minor or regional damage to sesame. The pathogen mainly infects the basal portions of the stems of seedlings. Affected plants show all the symptoms of wilt together with black discoloration of the base of stem which frequently breaks off at ground level. The symptom development is discolored spots on one side of the base of stem gradually spread around the stem, and the diseased part then sinks, shrinks and rots. In winter, the pathogen survives through mycelium and sclerotia in soil. The fungus is known to live in the soil for many years. The pathogen spreads through running water, wind, rain, and farming operation. Throughout the seedling stage, low temperature, high moisture, and poor growth are advantageous to the great occurrence at the disease. The disease can be controlled by planting in proper time, protecting the accumulation of rainwater, frequently intertilling to increase soil temperature and the application of potash and phosphate fertilizer so as to improve the resistance of plants.
  He also reported *Thanatephorus cucumeris* causes minor or regional damage to sesame. Koppert.com stated *Thanatephorus cucumeris* was long known as Rhizoctonia solani, the vegetative stage. It was long believed to be a sterile fungus, but recently it was discovered that the fungus produces basidiospores. These spores do not play a role in the epidemics or dispersal of the fungus, only the mycelium is important in this context. *Thanatephorus cucumeris* is a soil-inhabiting fungus, that is very persistent in the soil. It overwinters as mycelium or sclerotia in the soil and on crop residues. It is also seedborne. *Thanatephorus cucumeris* causes diseases such as phytophthora root rot and black leg.
- H.M. Miao and H.Y. Liu (2010) reported the following pathogen: *Rhizoctonia solani.*

COSTA RICA

- Anon (1991a) in a grower guide reported the following pathogen: *Rhizoctonia solani.*

EGYPT

- A.K.A. El-Ghany et al. (1970) reported *Fusarium oxysporum, Rhizoctonia solani* and *Sclerotium bataticola* were isolated from diseased plants. Infection tests showed that vars. Introduction 51, Sharkya 57, 62 and 203 and especially Sharkya 79 were least susceptible. High soil moisture levels due to frequent irrigation increased infection. The best yields were obtained with irrigation every two weeks.
- M.S. Serry et al. (1976) reported mature plant reaction to *Rhizoctonia solani* was governed by two pairs of genes, the double recessive conferring tolerance in crosses between 3 local and 4 introduced sesame cultivars. In another cross the reaction was governed by a single gene pair, susceptibility being recessive. [Cited by G.S. Saharan, 1989]
- M.S. Serry (1981a and 1981b) reported the presence of *Rhizoctonia solani* is a major hazard.
- M.B. Seoud et al. (1982) reported the most destructive diseases al sesame in Egypt are caused by *Fusarium oxysporum, Rhizoctonia solani* and *Sclerotium bataticola* (*Macrophomina phaseolina*). Seed treatment with Vitavax (carboxin) + Captan @ 4 g/ka seed and soil treatment with Daconil 2787 (chlorothalonil) at 3.75 kg/feddan gave the best control and highest yields.

- M.M. Satour (1984) reported one of the prevalent disease causal organisms was *Rhizoctonia solani.* [Cited by G.S. Saharan, 1989]
- A.A. El-Deeb et al. (1985) reported cvs. Giza-25, Giza-24, Local-78 and Local 96 were susceptible to *Macrophomina phaseolina., Rhizoctonia solani, Fusarium* ox*ysporum* f. sp. *sesami* and *Verticilium albo-atrum*. [Cited by G.S. Saharan, 1989]
- S. Shafshak et al. (1985) reported out of three crosses, N.A. 372-6 x Giza 25 (tolerant x tolerant) N.A. 342-6 x Margo and Giza-25 x Margo (tolerant x susceptible) reaction to *Rhizoctonia solani* showed complete dominance of tolerance (9T:7S) in first cross and dominance of susceptibility (3T:l3S) in the other two crosses. Two gene pairs control the difference between the parents in their reaction to *R. solani.*
- E. Abdou et al. (2001) collected seed from several locations in Egypt. *Fusarium* was the most dominant fungi associated with the diseased sesame plants. Of 3 *Fusarium* species *Fusarium oxysporum* f. sp. *sesami* was the highest frequency, followed by *Macrophomina phaseolina, Mucor haemalis, Thielaviopsis basicola* (Wetn), and *Rhizoctonia solani*. Application of ascorbic acid or salicylic acid to seeds and/or plants reduced the number of the diseased sesame seedling plants. Treated seeds plus twice irrigation with either ascorbic acid or salicylic acid caused the best control against *F. oxysporum* f. sp. *sesami* infection as compared to the fungicide Benlate. Meantime, ascorbic and salicylic acids had less effect to control sesame damping-off and root rot wilt diseases caused by infection with *M. phaseolina, Mucor haemalis* or *Thielaviopsis basicola* as compared to Benlate. [Based on abstract]
- O.A.R.A. Wahid et al. (2007) evaluated the infestation of *Rhizoctonia solani* in 2004 and 2005 at Ismailia. All screened sesame genotypes showed varied significant degrees of infestation with the root rot pathogen. It is worth to mention that some of sesame genotypes kept their resistance characteristic classes as moderately resistant (MR) or resistant (R) during the two successive seasons. Such genotypes might be useful for breeding programs due to stability of their resistant character as well as their seed yield.
- A. Hashem et al. (2014) collected 18 seed samples of sesame in Egypt (12 samples) and Saudi Arabia (6 samples). They identified the following mycoflora: *Rhizoctonia solani.*

INDIA

- M.M. Satour (1981) reported the presence of *Rhizoctonia solani* (Root rot).
- A. Bose and B. Nandi (1982) reported *Aspergillus ochraceus* and *Rhizoctonia solani* caused maximum reduction in oil content of sesame seeds. Deteriorated oil samples showed change in color, iodine value and saponification with prolonged incubation depending on the fungus and substrate. [Cited by G.S. Saharan, 1989]
- A.S. Reddy and S.M. Reddy (1983a) reported fungal succession on sesame seeds with different moisture levels was analyzed monthly. Incidence varied with moisture content. *Alternaria alternata* was abundant only in the initial stages. *Aspergillus flavus* predominated while *Macrophomina phaseolina* and *Rhizoctonia solani* were associated only with seeds of high moisture content. The seed mycoflora at first increased with storage time but subsequently decreased. Seed germination increased with storage time. [Cited by G.S. Saharan, 1989]
- A. Bose and B. Nandi (1985) reported cellulase was produced in culture best by *Aspergillus fumigatus, A. candidus* and *Rhizoctonia solani*; endopolygalacturonase and lipase by *A. flavus*. Reduction in germinability and oil content and increase in fat acidity were most pronounced in seeds inoculated with *A. flavus, A. fumigatus,* and *R. solani*. [Cited by G.S. Saharan, 1989]
- S. Maiti et al. (1985 and 1986) reported the following minor pathogen: Stem rot *Pellicularia filamentosa* (Pat) Rogers.
- M.L. Verma (1985) reported *Rhizoctonia solani - Pellicularia filamentosa* (Root and stem rot) is a major disease with the following symptoms: Wilting of seedlings. Blackening of basal/upper portion of stem.
- V. Bharathi et al. (2013) collected sesame seeds from farmers in Andhra Pradesh. They tested the seeds for mycoflora, and the following fungus was found: *Rhizoctonia solani.*
- K.N. Gupta et al. (2018) reported seed treatment with *Trichoderma viride* helped control *Rhizoctonia solani*. For other recommendations on cultural and chemical practices to alleviate or control the disease refer to the introduction.

IRAQ

- K.M. Tamini and H.A. Hadwan (1985) reported the differences in the amount of inhibition of growth of a range of sesamum wilt causing fungi by gaseous metabolites from *Neurospora sitophila* and *Trichoderma harzianum* could be accounted for by differences in their ages. The highest level of growth inhibition from test fungi ever recorded was as follows: 3-day-old *N. sitophila* was 55% on virulent *Rhizoctonia solani,* 51% on a virulent *Rhizoctonia solani,* 48% on *Fusarium oxysporum* and 40% on *Macrophomina phaseoli*. *Other* soilborne fungi were less effective than *N. sitophila*. [Cited by G.S. Saharan, 1989]

- F. Al-Refaee (2005) collected sesame seeds from 6 regions of Iraq and isolated *Rhizoctonia solani*.
- N.A. Saad et al. (2013) examined seed and found the following fungus: *Rhizoctonia solani.*

JAPAN

- T. Kuzuyuki (2021) reported the following pathogen: *Rhizoctonia solani* (Foliage rot).

MYANMAR

- D. Rhind (1924) reported a serious root disease of sesamum caused by *Rhizoctonia solani* occurred in the Allanmyo district and elsewhere. About a tenth of crop was killed, which developed a fortnight before the harvest. Affected plants show all the symptoms of wilt together with a black discoloration of the base of stem which frequently breaks off at ground level. Diseased plants develop no seed. [Cited by G.S. Saharan., 1989]
- D. Rhind (1926) reported the root disease of sesame reported in 1924 was again destructive in the East and West Central circles. The losses over the whole area probably averaging 10%. *Rhizoctonia solani* was almost invariably found on the dead plants.

NICARAGUA

- Anon. (2008a) in a grower guide reported *Rhizoctonia solani* was one of the major pathogens. It is very common in sesame and is known as root rot. It occurs in areas with frequent rains. The fungus needs high ambient humidity and high temperatures for its development. The damaged seed will rot; in the seedling there is a strangulation at the soil level impeding nutrient flow and then the seedling will wilt and die. The main method of control is resistant varieties.

PAKISTAN

- A. Shaw et al. (2014) reported *Rhizoctonia solani* was isolated as predominant fungus from the roots of infected sesame plants collected from a sesame field in Tandojam. Pathogenicity test of *R. solani* was conducted by inoculating 10 sesame varieties (S-167, Kotri-3, S-70-62, Kotri-1, K-509, Sehwan-2, Kotri-2, S-122, S-147 and S-20-18) with fresh culture of the fungus. Plant growth parameters (root and shoot length) were significantly reduced in S-122 and S-70-62 inoculated with *R. solani* as compared to K-509, Shewan-2, Kotri-2 and other sesame varieties. Mycelial growth of *R. solani* was significantly inhibited with high dose of calatropis extract followed by its medium and lower doses as compared to datura and garlic extracts. Root length was significantly increased with datura extract in sesame varieties, Kotri-3, S-122 followed by Kotri-1, S-20-18 and Shewan-2. Maximum shoot length was also recorded in S-122, Shewan-2, Kotri-3 and Kotri-1 treated with datura as compared to calatropis and garlic extracts.

PANAMA

- R.W. Toler et al. (1959) reported *Rhizoctonia solani* is present and is severe in localized areas.

REPUBLIC OF KOREA

- J.I. Lee and B.H. Choi (1985h) reported when there is damping off, 70% of the time it is *Fusarium oxysporum* f. sp. *vasinfectum*, 20% *Rhizoctonia solani*, and 10% *Phoma sesami*. Cultivation of resistant varieties like Ahnsanggae is the best method of control since the fungi survive in the soil and also on or in the seed. Vinyl mulching was also helpful in establishing good stands along with seed sterilization with Benlate-T and Benoran WP spraying at one week intervals during the seedling stage. Other methods of control include crop rotation and use of healthy seed.
- J.I. Lee and B.H. Choi (1985l) reported that *Rhizoctonia solani* was reduced by planting under vinyl film. [Based on abstract]
- J.W. Hyun et al. (1999) reported *Bacillus polymyxa* (synonym of *Paenibacillus polymyxa*) was isolated as an antibiotic compound that was an antagonist against *Fusarium oxysporum* f. sp. *sesami*. Under greenhouse conditions *Bacillus polymyxa* was shown its minimum inhibitory concentrations were 12.8 µg/ml for *F. oxysporum* and *Alternaria mali*, 6.4 µg/ml for *Colletotrichum gloeosporioides* and *Rhizoctonia solani*, and 3.2 µg/ml for *Phytophthora capsici*.
- S.W Kang and H.K. Kim (1989) reported *Rhizoctonia solani* is frequently encountered in the soils. [Based on abstract]

UNITED STATES

- C.R. Maier (1959) reported residues of sesame cut down on the severity of *Rhizoctonia solani* on bean root rot.
- K.A. Cochran et al. (2018) reported root rot and stalk rot symptoms were noted on sesame in an irrigated commercial production field in Uvalde County, TX (29.40N 99.62W). Stems had dark brown lesions just above the soil line, and plants with advanced symptoms exhibited necrosis progressing up the stem. Stunting, late

season lodging, and reduced yield were associated with areas of disease in approximately 5% of the ≈45-ha field. They isolated *Rhizoctonia solani* and were able to duplicate the symptoms in pot experiments. Sesame is a common specialty oilseed crop in Texas and internationally, with growing interest owing to its ability to be grown in dryland conditions. Although production in Texas often entails dryland practices, producers irrigate the crop regularly to maximize yields. This increase in moisture could increase disease pressure of *R. solani* and result in greater economic losses.

- D.R. Langham comments, 2021: In my 28 years of sesame in Uvalde I had not seen Rhizoctonia. After I retired, I was looking at a field with a Sesaco breeder and saw that the root collar of the plants was circled in brown and yet the plants were not dying, which was unusual for other root rots (Macrophomina, Fusarium, and Phytophthora) in the area. The breeder later confirmed that it was Rhizoctonia.
- K.A. Cochran comments, 2021: I have worked with *Rhizoctonia solani* since I began in plant pathology. In 2015, when I was looking at my first sesame samples, I noted lesions on the lower stems that looked suspiciously similar to those caused by *R. solani* on previous crops I had worked with. Subtle characteristics of the lesions that raised red flags included a reddish tone to the brown discoloration (think brown with a touch of deep red), sunken tissues in the lesion, and partial to complete stem girdling at or just below the soil line. Rhizoctonia solani is very difficult to manage due to its longevity in the soil, very broad host range, and lack of fungicides for crops like sesame.

VENEZUELA

- M.M. Satour (1981) reported the presence of *Rhizoctonia solani* (Root rot).

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A7 Order: Glomerellales Chadef. Ex Reblova, W. Garns & Seifert 2011

(Wikipedia, 10 Apr 2021) **Glomerellales** is an order of fungi within the subclass Hypocreomycetidae. Unlike other orders within Hypocreomycetidae, members of the Glomerellales exhibit a darkly pigmented perithecia. The order was first recognized by Chadefaud (1960), although it was not validly published at this time. It has since been cited by Lanier et al. (1978) and invalidly published by Locquin (1984). However the Glomerellales was still not valid until M. Réblová et al. study in 2011.

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A7.1 Family: Plectosphaerellaceae Zare

(Giraldo, A. and P.W. Crous, 2019) The family Plectosphaerellaceae (Glomerellales, *Sordariomycetes*) includes numerous plant pathogenic genera and soilborne fungal species. Ten genera are currently accepted, including several taxa that occupy an unresolved position within the family.

The following species have been reported to cause diseases, produce a toxin, inhibit germination, or affect seed quality.

- A7.1.1 *Verticillium* spp.
- A7.1.1a *Verticillium albo-atrum*
- A7.1.1b *Verticillium dahlia*

There are species in this family associated with sesame, but not reported to cause diseases, produce a toxin, inhibit germination, or affect seed quality. See H8.1.

A7.1.1 *Verticillium* spp. (10 Apr 2021)

Family: Plectosphaerellaceae

Definition: Amount of tolerance to *Verticillium* spp. Nees 1816.

(Wikipedia, 10 Apr 2021) ***Verticillium*** is a genus of fungi in the division Ascomycota, and are an anamorphic form of the family Plectosphaerellaceae. The genus used to include diverse groups comprising saprobes and parasites of higher plants, insects, nematodes, mollusk eggs, and other fungi, thus the genus used to have a wide-ranging group of taxa characterized by simple but ill-defined characters. The genus, currently thought to contain 51 species, may be broadly divided into three ecologically based groups - mycopathogens, entomopathogens, and plant pathogens and related saprotrophs. However, the genus has undergone recent revision into which most entomopathogenic and mycopathogenic isolates fall into a new group called *Lecanicillium*.

At least five species are known to cause a wilt disease in plants called verticillium wilt: *V. dahliae*, *V. longisporum*, *V. albo-atrum*, *V. nubilum*, and *V. tricorpus*. A sixth species, *V. theobromae*, causes fruit or crown rot, a non-wilting disease.

Verticillium wilt is a disease that can affect over 400 different eudicot plants, many of which are economically important worldwide. Several characteristics of *Verticillium* make it difficult to manage: prolonged survival in soils without the presence of a host, inaccessibility during infection, a wide host range, and limited resistance in host germplasm. However, all monocots, gymnosperms and ferns are immune.

The fungus survives in the soil principally in the form of microsclerotia, invades the plant through the root system, colonizes the vasculature, and eventually leads to plant death. The main mechanisms of its pathogenesis are xylem vessel blockage and toxin production. When the fungus propagates within a host plant, the mycelium blocks the xylem vessels, impairing the transport of water and nutrients in the host. The forces of transpiration and respiration in leaves combined with blocked xylem transport cause water imbalances in leaves that result in leaf yellowing and wilting, contributing to plant death. In addition, *Verticillium* produces mycotoxins within the plant that can cause necrosis in leaves and impair metabolism in the plant body. In some systems, toxin production has been shown to be the main cause of plant wilting.

First identified from potatoes in Germany in 1870, this disease affects a variety of cultivated plants and can persist as a saprotrophic soil organism for more than 15 years. Identification can be made by looking for one-celled conidia, hyaline round to ellipsoid which are formed at the tips of whorled branches. They are easily separated from the tips.

When infecting ornamental trees such as maples, elms, aspen, ash, beech, catalpa, oak, and others, the first symptoms are midsummer wilting on one side of a tree or branch. The sapwood has greenish or brownish streaks, and the infection can take a few years to progress to the rest of the tree or move rapidly. The fungi universally move up the xylem vessels. In fruit trees, the infection is known as black heart, and is common in apricots and sometimes affects almond, peach, plum, and avocado trees. This fungus affects herbaceous ornamentals such as chrysanthemums, mints, *Lychnis* spp. It infects many agriculturally important crops like vegetables such as tomatoes, eggplants, okra, broccoli, cauliflower and rhubarb; food related crops like rapeseed and hops; and fiber crops like cotton.

References:

ETHIOPIA
- T. Geremew et al. (2009) reported the following diseases are a minor problem: *Verticillium* sp. (Wilt).

UNITED STATES
- C.A. Thomas (1959b) reported Verticillium wilt is a problem for present and future investigations.
- D.T. Smith et al. (2000) reported Verticillium wilt is a major plant pest and has occurred on sesame in New Mexico and at higher elevations in Texas. This pathogen is commonly present in slightly acid to alkaline cotton fields. In some years Verticillium wilt resulted in plant losses in sesame variety trials at Lubbock but did not appreciably affect yields. In western or semi-arid areas, verticillium wilt could be a severe disease in future years. Crop rotations and sanitation are important control strategies.
- D.R. Langham et al. (2010c) stated *Verticillium* sp. has been reported in sesame in the USA in research nurseries but have not been seen in commercial fields since 1978.

A7.1.1a *Verticillium albo-atrum* (10 Apr 2021)

Family: Plectosphaerellaceae

Definition: Amount of tolerance to *Verticillium albo-atrum* Reinke & Berthold 1879.

(Wikipedia, 10 Apr 2021) ***Verticillium albo-atrum*** is a plant pathogen with many hosts.

References:

INTERNATIONAL
- C. Wescott (1971) reported the following pathogen: wilt (*Verticillium albo-atrum*).

BULGARIA
- E.A. Weiss (1971) cited P. Popov and J. Dimitrov (1964 and 1967) that there are two Bulgarian varieties (Sadovo 1 and 2) that have greater resistance to *Verticilium albo-atrum*.

CHINA
- L.L. Li (1988) reported *Verticilium albo-atrum* (Yellow wilt) causes minor or regional damage to sesame.

EGYPT
- A.A. El-Deeb et al. (1985) reported cvs. Giza-25, Giza-24, Local-78 and Local 96 were susceptible to *Macrophomina phaseolina*., *Rhizoctonia solani, Fusarium* ox*ysporum* f. sp. *sesami* and *Verticilium albo-atrum*. [Cited by G.S. Saharan, 1989]

PAKISTAN
- B.G. Nayyar et al. (2013) examined 15 samples of seed to detect fungi using 3 methods: agar plate, blotter, and deep freezing and found *Verticillium albo-atrum*.

UNITED STATES
- J.E. Chilton (1957) reported that the symptoms of *Verticillium albo-atrum* are yellow mottling and epinasty of leaves with considerable necroses in the mottled areas. Defoliation was severe with stunting and even death occurring. Internally brown steaks in xylem tissue of petioles, stems and roots were prunned. The plants studied were purposefully grown on the infested areas. The average number of days for the first symptom to appear was 44 days.
- A.W. Engelhard (1957) reported *Verticillium albo-atrum* has been recorded on sesame. [Cited by G.S. Saharan, 1989]

- R.D. Brigham (1985b) *Verticillium albo-atrum* caused loss of some plants each year.
- Anon. (2015c) USA PVP descriptor: *7. Diseases –Verticilium* wilt (*Verticilium albo-atrum).* The following ratings are used:
  - 0 = Not tested
  - 1 = Susceptible
  - 2 = Low resistance
  - 3 = Moderate resistance
  - 4 = High resistance

A7.1.1b *Verticillium dahliae* (10 Apr 2021)

Family: Plectosphaerellaceae

Definition: Amount of tolerance to *Verticillium dahliae* Klebahn 1913.

(Wikipedia, 10 Apr 2021) ***Verticillium dahliae*** is a fungal plant pathogen. It causes verticillium wilt in many plant species, causing leaves to curl and discolor. It may cause death in some plants. Over 400 plant species are affected by *Verticillium* complex.

References:

INTERNATIONAL

- J.R. Morschel (1964) reported the following pathogen in the world: *Verticilium dahliae* (Wilt). [Cited by D.F. Beech. 1995a]

AUSTRALIA

- D.F. Beech (1981a and 1995a) reported the presence of *Verticilium dahliae* (wilt) in sesame in 1958.

INDIA

- N.O. Srikantappa et al. (2009) studied 28 samples of sesame taken from fields, farmers, retail shops and APMC markets from 5 areas. They found 34 four fungi including *Verticillium dahliae.* The fungi significantly reduced germination.

IRAN

- R. Kamram (1985) reported *Verticillium dahliae* was isolated from stems of wilted sesame.

TURKEY

- M. Esentepe et al. (1972) reported *Verticillium dahliae* was isolated from sesame. [Cited by G.S. Saharan, 1989]

UGANDA

- C.G. Hansford (1931, 1938, 1939, 1940, and 1943) reported the following pathogen: *Verticillium dahliae.* [Cited by G.S. Saharan, 1989]
- S.B. Mathur and F. Kabeer (1975) reported the following pathogen: *Verticillium dahliae* in trace or moderate amounts in 4 genotypes.
- J.P. Egonyu (2005) reported two wilting pathogens: *Verticillium dahliae* and *Fusarium oxysporum.* The severity was significantly affected by time of planting with more wilting in later plantings as shown below.

Time of planting(WAO)	Leaf curl		Leaf spot		Wilt	
	Incidence (%)	Severity	Incidence(%)	Severity	Incidence(%)	Severity
0	16.4	3.05	84.8	2	17.1	3.62
2	29.4	4.05	70.7	1.1	29.9	1.62
4	11.5	3.76	42.1	1.	66.4	3.76
$LSD_{0.05}$	9.50	NS	9.02	0.3	7.29	0.539

WAO-Weeks after onset of rain.

The population did not have as much effect as shown below.

Density('000 plants/ha)	Leaf curl		Leaf spot		Wilt	
	Incidence (%)	Severity	Incidence(%)	Severity	Incidence(%)	Severity
40	25.7	4.4	47	2.5	55.4	4.7
50	15.4	4.7	31.8	3.3	60.6	5
60	14.3	3	50	2	71.4	4
70	23.1	5	49.3	3.3	68.7	4.7
80	22.3	3	34.3	1	56.1	5
90	30.6	5	48.9	2.8	53.8	4.3
140	16.9	4.5	50.1	1.5	56.9	5
150	26.7	5	33.3	3	73.3	5
160	26.7	3	60	2	46.7	4
170	27.7	5	56.9	2.5	55	4.5
200	26.9	4	30.8	2	61.5	5
210	15.4	4	61.2	2	34.6	5
220	36	4	52.2	1.5	31.9	4.5
410	60	5	56	4	40	5
$LSD_{0.05}$	NS	NS	NS	1.5	NS	NS

Intercropping did not have an effect as shown below.

Cropping pattern	Leaf curl		Leaf spot		Wilt	
	Incidence (%)	Severity	Incidence (%)	Severity	Incidence (%)	Severity
Sole sesame	35.4	5	41.2	2.75	52.4	4.75
Sesame + finger millet	23.4	4.33	47.7	2.45	56.4	4.64
$LSD_{0.05}$	11.3	0.63	NS	NS	NS	NS

UZBEKISTAN

- A.A. Vasilieff (1933) reported the results of experiments in 1932 in the neighborhood of Namangan (Turkestan) to determine the host range of *Verticillium dahliae* showed that when sown in plots which previously had the disease, the sesame was severely infected to the extent of 85 to 93.5%. [Cited by G.S. Saharan, 1989]

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A7.2 Family: Glomerellaceae (Locquin) ex Seifert & W. Gams. 2007

(Wikipedia, 11 Apr 2021) ***Glomerellaceae*** is a family of fungi in the class *Sordariomycetes*.

The following species have been reported to cause diseases, produce a toxin, inhibit germination, or affect seed quality.

- A7.2.1 *Colletotrichum* spp.
- A7.2.1a *Colletotrichum gloeosporioides* (*Syn: *Glomerella cingulata*)
- A7.2.1b *Colletotrichum truncatum* (*Syn: *Colletotrichum capsici*)
- A7.2.1c *Colletotrichum sesamina* (*Syn: *Vermicularia sesamina*)

A7.2.1 *Colletotrichum* spp. (11 Apr 2021)

Family: Glomerellaceae

Definition: Amount of tolerance to *Colletotrichum* spp. Corda 1831.

Summary:

Acervuli sporulating on the stem.

Progressing lesion

Photos: K.A. Cochran {USA}

***Colletotrichum* spp.** has been reported to cause anthracnose on many crops, including sesame. Foliar symptoms can occur and may result in defoliation in serious cases. Medium to dark brown water soaked lesions may occur on leaves or stems. This pathogen has also been observed to cause stem lesions on lower portions of the stem progressing upward. Heavy sporulation can occur when conditions are favorable. Acervuli with conidial ooze are typically about the size of a pinhead or slightly smaller and can be observed with a good quality loupe. Acervuli may or may not have setae, depending on the species of Colletotrichum present. As this fungus is readily spread in humid conditions with splashing water, areas at risk for significant disease development include irrigated fields, fields planted in areas with higher or more frequent rainfall, or areas late season rains are likely to occur prior to harvest. The pathogen is seedborne. Most publications classify Colletotrichum at the genus level, but there are some publications that have identified *C. gloeosporioides, C. sesamina*, and *C. truncatum. Colletotrichum* spp. have been reported in international lists, China, India, Italy, Japan, Mexico, Myanmar, Nigeria, Paraguay, Republic of Korea, Thailand, Uganda, and United States.

(Wikipedia, 11 Apr 2021) ***Colletotrichum*** (sexual stage: *Glomerella*) is a genus of fungi that are symbionts to plants as endophytes (living within the plant) or phytopathogens. Many of the species in this genus are plant pathogens, but some species may have a mutualistic relationship with hosts.

(Anon. n.d.k) Anthracnose - *Colletotrichum* sp. – a minor disease

Symptoms: Dark brown lesions on leaf stem and capsules with black acervuli in the central portion.

References:

INTERNATIONAL

- R.S. Vasudeva (1961) *Colletotrichum* spp. is a minor disease. In India it appears sometime in August. In the beginning it manifests itself only on one side of the plant, which becomes dirty or dull green due to loss of color. The new leaves appearing on the same side of the plant turn pale and are invariably destroyed. The affected portions of the plant become dark in color, the disorganized cortex gives way, and the inner woody portion is exposed. The black brownish appearance on one side of the plant may or may not be continuous but at times it extends from foot to top. The disease affects the setting of capsules, and in most cases, the affected plants are destroyed before the capsules are mature. The fungus enters the plant either through the injured portion or healthy surface.
- J.R. Morschel (1964) reported the following pathogen in the world: *Colletotrichum* spp. (anthracnose). [Cited by D.F. Beech. 1995a]
- E.A. Weiss (1971) reported *Colletotrichum* spp. symptoms are the stem becomes discored on the affected side, initially a dull-gree turning later to brown or black. Leaves are not attacked, but those on the infected side of the plant become light-colored and fall. The cortical tissue of the infected stem and branches cracks and exposes the inner tissues. Brown streaks or black spots may be continuous along the length of the stem, or may be interruped by areas of healthy tissue. Infected plants produce few capsules.
- Anon. (2004a) IPGRI descriptor: 10.2.3. Biotic stress susceptibility to *Colletotrichum* spp.
  - In each case it is important to state the origin of the infestation or infection, i.e., natural, field inoculation, or laboratory. Also specify the causal organism and the corresponding symptoms. The susceptibility scale is as follows:
    - 1 = Very low or no visible sign of susceptibility
    - 3 = Low
    - 5 = Intermediate
    - 7 = High
    - 9 = Very high
  - The growth state, coded according to the list below at which each reaction was recorded should be appended to the record of that reaction.

- 1 = Seed
- 2 = Seedling
- 3 = Pre-flowering
- 4 = Early flowering
- 5 = Mid-flowering
- 6 = Late-flowering
- 7 = Maturity

CHINA
- L.C. Tu (1985b) reported to *Colletotrichum* sp. (Anthracnose) in Henan province with a damage level of 1 out of possible 3.
- L.L. Li (1988) reported *Colletotrichum* sp. (Anthracnose) causes minor or regional damage to sesame.

INDIA
- P.R. Mehta (1951) reported *Colletotrichum* sp. affected 10 to 12% of the early sown plants, whereas on the late sown crop disease was negligible. Oval or elliptical, water-soaked lesions on stem or leaf axis are characteristic of this disease. As the spots do not encircle the stem completely longitudinal streaks of dead tissue are fanned, sometimes running the whole length of the stem and involving the fruiting branches. [Cited by G.S. Saharan, 1989]
- B. Singh (1953) reported *Colletotrichum* sp. caused a disease in sesame but had been noted as early as 1943. [Cited by R.S. Vasudeva, 1961]
- K.R. Sharma and K.G. Mukerji (1974) reported a pathogenic *Colletotrichum* spp. on aging, senescing, and decaying leaves. [Cited by G.S. Saharan, 1989]
- M.M. Satour (1981) reported the presence of *Colletotrichum* sp. (Anthracnose).
- S. Maiti et al. (1985 and 1986) reported the following minor pathogen: Anthracnose *Colletotrichum* sp.
- P.L. Radha (2013) collected 18 cultivars from 7 districts in Karnataka and identified the following fungus: *Colletotrichum* sp.
- Anon. (n.d.k) reported *Colletotrichum* sp. (Syn: *Oidium acanthospermi*) (Anthracnose) causes a minor disease.

JAPAN
- M.M. Satour (1981) reported the presence of *Colletotrichum* sp. (Anthracnose).

MEXICO
- M.M. Satour (1981) reported the presence of *Colletotrichum* sp. (Anthracnose).

MYANMAR
- D. Myint et al. (2014) reported Anthracnose is a serious disease.

NIGERIA
- M.M. Satour (1981) reported the presence of *Colletotrichum* sp. (Anthracnose).

PARAGUAY
- L.C. Rossi and A.L. Orrego (2007) identified the following fungus on sesame seeds: *Colletotrichum* sp.

THAILAND
- V. Benjasil (1985a) reported *Colletotrichum* sp. (Anthracnose).causes losses in yield.

UGANDA
- J.D. Snowden (1927) reported *Colletotrichum* sp. caused a disease in sesame. [Cited by R.S. Vasudeva, 1961, and G.S. Saharan, 1989]
- W.O. Anyanga (2019) reported Anthracnose is increasing.

UNITED STATES
- K.A. Cochran comments, 2021: I have encountered this disease most of the 6 years I have been in Texas, but not often are symptoms as dramatic as those shown in the photos below. I found these highly symptomatic plants just outside Hondo, Texas late in the season, but prior to dry down. I have yet to confirm the species of Colletotrichum involved, but many species do have a wide plant host range and are known to be seedborne. The full extent of the impact of this pathogen in sesame production in the United States is not well understood, especially as modern sesame production is expanding into new areas and including more irrigated fields to maximize yields. This disease can be highly problematic in other crops, and has a history of readily developing fungicide resistance, so I believe this disease should be monitored and assessed carefully in the coming seasons

given the host range and ability to spread prolifically under the right conditions in the field. This pathogen thrives (and spores spread) with rainfall/sprinkler irrigation, even very small amounts of moisture. For USA production (and anywhere with a similar climate situation), I think a particularly concerning time for rapid disease development is later in the season when late season rains are likely, especially 3-8 weeks before harvest.

The margin of the progressing lesion is black with chocolate brown changing to grey necrotic tissue with heavy sporulation.

A7.2.1a *Colletotrichum gloeosporioides* (2 Jul 2021)

Synonym: *Glomerella cingulata*

Family: Glomerellaceae

Definition: Amount of tolerance to *Colletotrichum gloeosporioides* (Penz.) Penz. & Sacc. 1884.

(Wikipedia, 2 Jul 2021) ***Glomerella cingulata*** is a fungal plant pathogen, being the name of the sexual stage (teleomorph) while the more commonly referred to asexual stage (anamorph) is called ***Colletotrichum gloeosporioides***. This pathogen is a significant problem worldwide, causing anthracnose and fruit rotting diseases on hundreds of economically important hosts. ***Colletotrichum gloeosporioides*** has an extremely broad host range, causing anthracnose disease on a variety of crops such as cereals and grasses, legumes, fruits, vegetables, perennial crops, and trees. It has been observed as infecting harvested durian of the species *Durio graveolens*. Although the species is so broad in susceptible hosts, some studies are suggesting *C. gloeosporioides* has sub-populations specific to each host. The symptoms can vary from host to host, but tend to manifest as water soaked, sunken spots on fruit that turn necrotic as the disease progresses, and small dark lesions on leaves.

References:

NIGERIA

- D. McDonald (1964) reported *Colletotrichum gloeosporioides (Glomerella cingulata)*.

REPUBLIC OF KOREA

- J.W. Hyun et al. (1999) reported *Bacillus polymyxa* (synonym of *Paenibacillus polymyxa*) was isolated as an antibiotic compound that was an antagonist against *Fusarium oxysporum* f. sp. *sesami.* Under greenhouse conditions *Bacillus polymyxa* was shown its minimum inhibitory concentrations were 12.8 µg/ml for *F. oxysporum* and *Alternaria mali*, 6.4 µg/ml for *Colletotrichum gloeosporioides* and *Rhizoctonia solani*, and 3.2 µg/ml for *Phytophthora capsici.*

A7.2.1b *Colletotrichum truncatum* (20 Jul 2021)

Synonym: *Colletotrichum capsici*

Family: Glomerellaceae

Definition: Amount of tolerance to *Colletotrichum truncatum* (Schwein.) Andrus & W.D. Moore, 1935.

(Wikipedia, 3 Oct 2021) ***Colletotrichum truncatum*** is a plant pathogen.

References:

INDIA

- R.K.S. Chauhan and B.M. Kulshrestha (1984b) reported the diffusate obtained from the fruit cavities of sesame inoculated with a spore suspension of *Alternaria sesami* was inhibitory to the germination of spores. It inhibited the spore germination of *Colletotrichum capsici*. No inhibition was caused by the extracts of healthy uninoculated fruits.

A7.2.1c *Colletotrichum sesamina* (3 Jul 2021)

Synonym: *Vermicularia sesamina*

Family: Glomerellaceae

Definition: Amount of tolerance to *Colletotrichum sesamina* Saccardo.

References:

ITALY

- P.A. Saccardo (1931) characterized *Vermicularia sesamina* Saccardo.

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A8 Order: Helotiales Nannf. ex Korf & Lizon 2000

(Wikipedia, 10 Apr 2021) **Helotiales** is an order of the class Leotiomycetes within the division Ascomycota. According to a 2008 estimate, the order contains 10 families, 501 genera, and 3881 species.

Helotiales is the largest order of inoperculate discomycetes. It contains the famous blue-green cup fungi that makes its home on oaks is known by the genus name *Chlorociboria*.

Helotiales is distinguished by its disc or cup-shaped apothecia. Its asci are only slightly thickened in contrast to other Leotiomycetes. Most *Helotiales* live as saprobes on soil humus, dead logs, manure and other organic matter. The order includes most fungi that engage in ericoid mycorrhiza. Including *Rhizoscyphus ericae*, *Meliniomyces* species and *Cairneyella variabilis*.

The order contains some of the worst plant pathogens

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A8.1 Family: Dermateaceae Fries 1849

(Wikipedia, 10 Apr 2021) The **Dermateaceae** is a family of cup fungi in the order Helotiales. Most species in this family are plant pathogens but some are saprobes.

The following species have been reported to cause diseases, produce a toxin, inhibit germination, or affect seed quality.

- A8.1.1 *Cylindrosporium* spp.
- A8.1.1a *Cylindrosporium sesami*
- A8.1.2 *Gloeosporium* spp.
- A8.1.2a *Gloeosporium macrophomoides*

A8.1.1 *Cylindrosporium* spp. (10 Apr 2021)

Family: Dermateaceae

Definition: Amount of tolerance to *Cylindrosporium* spp. Grev. 1822

(Wikipedia, 10 Apr 2021) ***Cylindrosporium*** is a genus of parasitic fungi. The genus includes several plant pathogens that cause leaf spot.

References:

BRAZIL

- N.E.M. Beltrao and E.C. Freire (1986) in a grower guide reported *Cylindrosporium* sp. causes a major disease.

COSTA RICA

- Anon (1991a) in a grower guide reported the following pathogen: *Cylindrosporium* spp.

UGANDA

- W.O. Anyanga (2019) reported Cylindrosporium is one of the main diseases.

UNITED STATES

- Anon (1959) reported *Cylindrosporium* sp. in Florida. In order to study the development of angular leaf spot and the relative susceptibility of sesame, a lot of 12 varieties was planted in the same site where the disease appeared last season. The disease appeared early and spread to all the material in a short time. It did not spread, however, to plantings further away in the station.

VENEZUELA

- B. Mazzani (1981a) reported *Cylindrosporium* sp. (Leaf spot) is one of the major diseases.

A8.1.1a *Cylindrosporium sesami* (10 Apr 2021)

Family: Dermateaceae

Definition: Amount of tolerance to *Cylindrosporium sesami* Hansford.

References:

INTERNATIONAL

- E.A. Weiss (1971) reported *Cylindrosporium sesami* symptoms are long, irregular, angular interveinal leaf-spots which coalesce and form larger necrotic areas. Certain cultivars are tolerant, and these strains also have tolerance to Alternaria leaf-spot. It has been suggested there is a relationship between *Xanthomonas sesami* and *Cylindrosporium sesami.*
- C. Chattopadhyay et al. (2019) described the following symptoms of *Cylindrosporium sesami.* Spots on the leaves are water soaked, brown, and limited to veinal areas and assume an angular shape. They are 2-20 mm in diameter and may enlarge rapidly to coalesce into extensive necrotic areas. In the case of severe infection, defoliation occurs. The upper surface of the spot on the leaves shows the presence of dark subepidermal fungal acervuli. The affected leaves frequently show the association of spots caused by *Alternaria sesami* and/or *Cercospora sesami*. Seed treatment with commonly used fungicides (1-3 g/kg seed) can be effective for the control of the disease.
- CAB International (accessed 12 Apr 2021) reported sesame was a major host of *Cylindrosporium sesami* (Angular leaf spot of sesame).

AUSTRALIA

- M.R. Bennett (1986-1997). In his sesame development program in the Northern Territories of Australia between 1986 and 1997, he took data on 'Susceptibility to *Cylindrosporium sesami*'. His ideotype included tolerance to this disease.

BRAZIL

- G.S. Silva and G.S. Melo (1976) reported *Cylindrosporium sesami* causing leaf spot of sesame was reported.
- N.H.C. Arriel et al. (2007a) studied 108 accessions from Brazil and the world. They used *Angular leaf spot – Cylindrosporium sesami* as one of the descriptors. They showed the following correlations with other plant traits.

CP	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
1	1.00	-0.15	-0.09	-0.04	-0.10	0.00	-0.13	-0.10	0.27	-0.01	-0.04	-0.10	0.00	-0.04	0.01	-0.24	-0.02	-0.02	0.01	-0.02	-0.06	-0.10	-0.10	0.08	0.07	-0.15	-0.02	-0.19	-0.09	0.16
2		1.00	0.39	0.15	-0.14	0.60	0.36	-0.02	-0.44	-0.03	-0.19	0.56	0.43	-0.21	0.03	0.22	0.11	0.04	-0.10	0.05	0.04	0.05	0.10	-0.09	-0.06	0.32	0.32	-0.10	0.48	-0.19
3			1.00	0.05	-0.23	0.52	0.21	-0.09	-0.36	0.04	0.10	0.35	0.77	-0.23	-0.05	0.24	0.00	-0.20	0.02	0.00	-0.05	-0.08	0.07	-0.33	-0.20	0.24	0.25	0.19	0.31	0.06
4				1.00	0.23	0.27	0.24	0.53	-0.38	0.20	0.29	0.35	-0.03	0.17	0.05	-0.01	-0.07	-0.16	-0.13	-0.03	-0.06	-0.11	-0.02	0.23	0.08	0.06	-0.08	0.11	0.33	0.12
5					1.00	-0.26	0.10	0.42	-0.01	-0.02	0.21	-0.03	-0.14	0.15	-0.08	0.15	-0.06	-0.03	-0.10	-0.04	-0.14	-0.06	-0.10	0.42	0.25	-0.11	-0.40	-0.27	-0.01	-0.18
6						1.00	0.20	-0.17	-0.32	0.01	-0.11	0.42	0.49	-0.31	-0.14	0.06	0.11	-0.14	-0.04	0.12	0.19	-0.09	0.10	-0.07	0.00	0.31	0.17	-0.07	0.36	-0.02
7							1.00	0.17	-0.52	0.04	0.13	0.58	0.17	0.16	0.19	0.13	0.05	-0.14	-0.13	0.00	-0.04	-0.05	-0.03	0.23	-0.01	0.33	0.17	0.06	0.50	-0.03
8								1.00	-0.23	0.09	0.34	0.16	-0.25	0.30	-0.07	0.07	0.02	0.03	-0.18	0.01	-0.22	0.05	0.00	0.05	0.10	-0.17	-0.14	0.17	0.14	-0.05
9									1.00	-0.05	-0.10	-0.87	-0.31	-0.18	-0.04	-0.29	-0.05	0.00	0.27	-0.04	0.10	-0.10	0.06	-0.19	0.00	-0.50	-0.06	0.03	-0.75	-0.11
10										1.00	0.14	0.00	0.01	0.19	-0.14	-0.24	-0.01	-0.37	0.07	-0.03	0.07	-0.08	0.08	0.04	0.01	-0.08	-0.02	0.10	0.01	0.07
11											1.00	0.05	-0.09	0.24	-0.02	-0.05	-0.04	0.11	-0.09	-0.02	-0.16	0.04	0.05	0.13	-0.08	-0.14	-0.22	0.20	0.05	0.10
12												1.00	0.31	0.11	0.01	0.22	0.02	0.03	-0.30	0.01	-0.09	0.05	-0.08	0.18	-0.01	0.58	0.14	-0.13	0.86	0.13
13													1.00	-0.24	0.02	0.33	0.03	-0.18	-0.07	0.02	0.01	-0.11	-0.02	-0.13	-0.13	0.21	0.11	-0.08	0.27	0.00
14														1.00	0.16	-0.05	-0.08	-0.03	-0.04	-0.05	-0.22	0.33	-0.42	0.24	0.01	0.02	-0.08	0.10	0.10	-0.04
15															1.00	0.00	-0.01	-0.01	0.02	0.00	-0.20	-0.02	-0.12	0.10	0.00	0.02	0.13	0.06	0.01	-0.03
16																1.00	-0.15	0.17	-0.12	-0.10	0.00	0.13	0.02	-0.09	0.09	0.13	-0.02	0.05	0.19	-0.12
17																	1.00	-0.02	-0.13	0.70	0.06	-0.03	-0.05	0.00	0.00	0.03	0.04	-0.05	0.02	-0.04
18																		1.00	-0.30	-0.01	-0.14	0.45	-0.18	-0.06	0.09	0.00	-0.10	-0.13	0.03	-0.13
19																			1.00	-0.21	0.00	-0.10	0.39	-0.20	-0.07	-0.22	0.10	0.21	-0.33	-0.08
20																				1.00	0.04	-0.02	-0.12	0.10	0.00	0.02	-0.07	-0.14	0.01	-0.03
21																					1.00	-0.06	0.21	-0.14	0.02	0.26	0.03	0.08	-0.07	0.09
22																						1.00	-0.21	-0.05	0.07	0.07	0.10	0.02	0.04	-0.31
23																							1.00	-0.31	0.06	-0.22	0.12	0.20	-0.07	0.07
24																								1.00	0.14	0.13	-0.46	-0.57	0.15	0.03
25																									1.00	0.05	0.04	-0.01	-0.01	0.06
26																										1.00	0.13	-0.18	0.50	0.13
27																											1.00	0.24	0.12	-0.03
28																												1.00	-0.11	0.14
29																													1.00	0.13
30																														1.00

*1-Flowering; 2- plant height; 3- insertion height of the 1st capsule; 4- no. of capsules/plant ; 5- capsule length; 6-no. of branches; 7-stand; 8-grain yield; 9-cycle; 10-weight of 1000 seeds; 11- no. of capsules/axil; 12-plant growth; 13- capsule insertion; 14- angular leaf spot; 15- black rot; 16-pests; 17-stem shape; 18-stem pilosity; 19-branch color; 20-branch; 21-leaf color; 22-leaf pilosity; 23- leaf position; 24- leaf shape; 25-leaf size; 26- basal leaf shape; 27- V- pigmentation of the flower; 28- flower color; 29- capsule dehiscence; 30-seed color.

- N.H.C. Arriel et al. (2009) reported *Cylindrosporium sesami*. Angular spot is considered one of the main diseases of the sesame. The incidence is always very high, reaching many sometimes 100% of the plants and, depending on the degree of severity, can compromise large areas of the leaf blade This disease occurs in adult plants, usually affecting the leaves, with symptoms that are characterized by the presence of angular, polygonal and irregular spots, almost always limited on one or more sides by the ribs. These injuries present brown or dark brown color and are uniform, with tint lighter on the underside of the leaf. Pathogen structures can be found on

both sides of the leaf, being more abundant on the adaxial face. Angular spot affects, with greater intensity, lower and older leaves, located in the lower third of the plants, inducing defoliation in this region. The pathogen is transferred by seeds. For the control of this disease, it is recommended to disinfect the seeds; however, the most efficient and economical control is the use of resistant cultivars. In cultivation in low-lying areas, relative humidity (< 60 %) and high temperatures (> 28°C), damaged leaves are minimal.

- V.P. Queiroga et al. (2010c and 2019) reported *Cylindrosporium sesami.* For control use resistant varieties.


- N.E.M. Beltrao et al. (2013) reported *Cylindrosporium sesami*. Angular stain can cause serious damage to culture. The incidence is always very high, often reaching 100% of the plants (E.F. Lima et al., 2001). It usually affects the leaves, producing angular, polygonal spots and irregular, ranging in color from brown to dark brown, limited on one or more sides by the ribs. If it is found that at the bottom of the leaf the lesion is clearer. It is found with greater intensity in the lower third of the plant. The fungus is transmitted by seeds (R.G. Orellana, 1961; G. Malaguti, 1973). The spread of the disease occurs through the wind that transports spores from infected plants to healthy plants (G. Malaguti, 1973). The use of resistant cultivars is the most efficient and economical way control of this disease. Seed treatment by disinfecting them, is also recommending as well as crop rotation (E.F. Lima et al., 2001).
- N.H.C. Arriel et al. (n.d.) Brazil descriptor: MANCHA ANGULAR (*Cylindrosporium sesami*): A disease that usually affects the leaves, producing angular, quadratic, rectangular and irregular lesions, almost always limited on one or more sides by the ribs. These lesions have uniform brown or dark brown color with a lighter shade on the underside of the leaf. This disease most severely affects older, falling leaves, leaving the leafless plant in the lower half. The following are the ratings to be used.
  - 1 : 0 to 5%
  - 2 : 6 to 25%
  - 3 : 26 to 50%
  - 4 : 51 to 75%
  - 5 : 76 to 100%

ETHIOPIA

- T. Geremew et al. (2009) reported the following diseases are a minor problem: *Cylindrosporium sesami* (Leaf spot).

GUATEMALA

- Anon (1982a) A grower guide reported *Cylindrosporium sesami* Hans (Mancha irregular) attacks the foliage.

INDIA

- M.U. Vishnav et al. (1985) reported a severe leaf spot disease of sesamum caused by *Cylindrosporium sesami* Hansford was observed in Gujarat Kharif 1983-84. The disease appears as small irregular slight yellowish spots at first, later on becoming necrotic dark brown and measured 5 to 15 nm. As the disease advanced, the spots coalesced to form irregular dark brown necrotic lesions resulting in leaf blight symptoms. Bud necrosis appears under humid conditions. Acervuli can be observed on both surfaces of leaves.

KENYA

- H.A. Van Rheenen (1981d) reported the goal of developing resistance to *Cylindrosporium sesami.*

MYANMAR

- M.L. Farr (1961) reported *Cylindrosporium sesami* on sesame. [Cited by G.S. Saharan, 1989]

NIGERIA

- H.A. Van Rheenen (1972) reported the leaf pathogen *Cylindrosporium sesami* had the following symptoms: The lesions on the leaves are angular in shape, 4-10 mm across and of a greyish brown color in the center with lighter gray margin. The leaf spots may coalesce, covering sections of the lamina. Later during the development many minute dark spots can be seen scattered over the lesions, indicating the sites of acervuli.

SAUDI ARABIA

- Anon. 1967a reported *Cylindrosporium sesami* on sesame was common.

SUDAN

- H. Schmutterer and J. Kranz (1965) reported *Cylindrosporium sesami* was shown to be the agent of a disease in Sudan previously described in connection with *Xanthomonas sesami* and thought to be physiogenic. Symptoms of disease to be called brown leaf spot are compared with those caused by other sesame pathogens. Spots are confined to the leaves, irregular, angular, sharply defined. Often adjacent to veins uniformly dirty brown, somewhat lighter on undersides, 2-10 mm diameter numerous and sometimes merging. [Cited by G.S. Saharan, 1989]

UGANDA

- C.G. Hansford (1931, 1938, 1939, 1940, and 1943) reported the following pathogen: *Cylindrosporium sesami.* [Cited by G.S. Saharan, 1989 and R.S. Vasuveda, 1961]
- J.P. Egonyu (2005) reported two leaf spot pathogens: *Cercospora sesami* and *Cylindrosporium sesami.* The severity was significantly affected by time of planting. Spores require moisture and particular temperature ranges to germinate and infect leaves. When conditions are too cold, too hot or too dry, spores fail to germinate, and infections do not occur. The late planted crop received less rains compared to its early planted counterpart so had less water for the dispersal of the fungal spores, hence, low level of the disease as shown below.

Time of planting(WAO)	Leaf curl		Leaf spot		Wilt	
	Incidence (%)	Severity	Incidence(%)	Severity	Incidence(%)	Severity
0	16.4	3.05	84.8	2	17.1	3.62
2	29.4	4.05	70.7	1.1	29.9	1.62
4	11.5	3.76	42.1	1.	66.4	3.76
$LSD_{0.05}$	9.50	NS	9.02	0.3	7.29	0.539

WAO-Weeks after onset of rain.

The population did not have as much effect as shown below.

Density('000 plants/ha)	Leaf curl		Leaf spot		Wilt	
	Incidence (%)	Severity	Incidence(%)	Severity	Incidence(%)	Severity
40	25.7	4.4	47	2.5	55.4	4.7
50	15.4	4.7	31.8	3.3	60.6	5
60	14.3	3	50	2	71.4	4
70	23.1	5	49.3	3.3	68.7	4.7
80	22.3	3	34.3	1	56.1	5
90	30.6	5	48.9	2.8	53.8	4.3
140	16.9	4.5	50.1	1.5	56.9	5
150	26.7	5	33.3	3	73.3	5
160	26.7	3	60	2	46.7	4
170	27.7	5	56.9	2.5	55	4.5
200	26.9	4	30.8	2	61.5	5
210	15.4	4	61.2	2	34.6	5
220	36	4	52.2	1.5	31.9	4.5
410	60	5	56	4	40	5
$LSD_{0.05}$	NS	NS	NS	1.5	NS	NS

Intercropping did not have an effect as shown below.

Cropping pattern	Leaf curl		Leaf spot		Wilt	
	Incidence (%)	Severity	Incidence (%)	Severity	Incidence (%)	Severity
Sole sesame	35.4	5	41.2	2.75	52.4	4.75
Sesame + finger millet	23.4	4.33	47.7	2.45	56.4	4.64
$LSD_{0.05}$	11.3	0.63	NS	NS	NS	NS

UNITED STATES

- R.G. Orellana (1961) reported *Cylindrosporium sesami* is severe in Florida and South Carolina and is a new record for the U.S.A. Seedborne sclerotia apparently initiated the 1958 outbreak at Fla. Exp. Sta., Gainesville, the disease being disseminated during the growing season by air-borne conidia. Optimum temperature for growth of the fungus was 27±°C, min. 16°, max. 33°; it was pathogenic to sesame and soybean but not to tobacco or castor bean (*Ricinus communis*). About 20 lines of sesame from the world collection were moderately resistant.

VENEZUELA

- G. Malaguti and A. Ciccarone (1966) reported *Cylindrosporium sesami* is a severe leaf spot of sesamum characterized by brown spots 2-20 mm diameter in the veinal areas, sometimes coalescing into large necrotic areas but only rarely on stems or capsules. It is a limiting factor during rainy season. Vars. Aceitera, Acarigua and Venezuela 52 were affected in all sesame-growing regions. Infection by *C. sesami* is sometimes also associated with white round spot (*Cercospora sesami*). [Cited by G.S. Saharan]
- G. Malaguti (1973) reported the following leaf disease: angular brown spot (*Cylindrosporium sesami*). [Cited by G.S. Saharan, 1989]
- B. Mazzani et al. (1981b) reported the presence of *Cylindrosporium sesami* (Angular brown leaf spot) is one of the major diseases.
- B. Mazzani (1999) reported the following pathogen: *Cylindrosporium sesami.* A.M. Colmenares (1989b) reported minor damage in the field in Arawaca, Caripucha, Cápsula larga, and Ajimo Atar. In the laboratory with inoculacion minor damage in *Sesamum radiatum*, Maporal, Arawaca and Adong Acol. There was major damage in the laboratory in Piritu, Caripucha, Venezuela 52, and Aceitera.

A8.1.2 *Gloeosporium* spp. (3 Jul 2021)

Family: Dematеaceae

Definition: Amount of tolerance to *Gloeosporium* spp. Desm. & Mont. 1849.

(Wikipedia, 3 Jul 2021) ***Gloeosporium*** is a genus of fungi belonging to the family Dermateaceae. The genus has cosmopolitan distribution

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A8.1.2a *Gloeosporium macrophomoides* (3 Jul 2021)

Family: Dematеaceae

Definition: Amount of tolerance to *Gloeosporium macrophomoides* Saccardo.

References:

ITALY

- P.A. Saccardo (1931) characterized *Gloeosporium macrophomoides* (Saccardo).

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A8.2 Family: Sclerotiniaceae Whetzel 1945

(Wikipedia, 7 Jun 2021) The **Sclerotiniaceae** are a family of fungi in the order Helotiales. Many species in this family are plant pathogens.

The following species have been reported to cause diseases, produce a toxin, inhibit germination, or affect seed quality.

- A8.2.1 *Sclerotinia* spp.
- A8.2.1a *Sclerotinia sclerotiorum*

There are species in this family associated with sesame, but not reported to cause diseases, produce a toxin, inhibit germination, or affect seed quality. See H3.1.

A8.2.1 *Sclerotinia* spp. (7Jun 2021)

Family: Sclerotiniaceae

Definition: Amount of tolerance to *Sclerotinia* spp. Fuckel 1870.

(Wikipedia, 7 Jun 2021) ***Sclerotinia*** is a genus of fungi in the family Sclerotiniaceae. The widely distributed genus contains 14 species.

References:

MEXICO

- Agrolytics.org (2021) reported sesame hosts *Sclerotinia* spp.

A8.2.1a *Sclerotinia sclerotiorum* (7Jun 2021)

Family: Sclerotiniaceae

Definition: Amount of tolerance to *Sclerotinia scelrotiorum* (Libert) de Bary 1884.

(Wikipedia, 7 Jun 2021) ***Sclerotinia sclerotiorum*** is a plant pathogenic fungus and can cause a disease called white mold if conditions are conducive. *S. sclerotiorum* can also be known as cottony rot, watery soft rot, stem rot, drop, crown rot and blossom blight. A key characteristic of this pathogen is its ability to produce black resting structures known as sclerotia and white fuzzy growths of mycelium on the plant it infects. These sclerotia give rise to a fruiting body in the spring that produces spores in a sac which is why fungi in this class are called sac fungi (Ascomycetes). This pathogen can occur on many continents and has a wide host range of plants. When *S. sclerotiorum* is onset in the field by favorable environmental conditions, losses can be great and control measures should be considered.

References:

INTERNATIONAL

- CAB International lists sesame as a major host of *Sclerotinia sclerotiorum* (Cottony soft rot)

INDIA

- N.O. Srikantappa et al. (2009) studied 28 samples of sesame taken from fields, farmers, retail shops and APMC markets from 5 areas. They found 34 four fungi to include *Sclerotinia sclerotiorum.* The fungi significantly reduced germination.

MEXICO

- Anon. (2010a) in a grower guide reported the following main pathogen: *Sclerotinia sclerotiorum.* This pathogen survives the winter in the soil. Depending on the harvest and environmental conditions, the sclerotia germinate to produce mycelium that infect the roots and basal stems causing wilting or dropping of plant leaves to produce ascospores that infect tissues above ground. The spread of the fungus is produced by the growth of the mycelium, the sclerotia formed on infected plants can survive in the field or as contaminants in crop seeds, roots or tubers; thus, sclerotia can be distributed with infected seed.

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A9 Order: Atheliales Julich 1981

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A9.1 Family: Atheliaceae Julich 1981

(Wikipedia, 10 Apr 2021) **Atheliaceae** is a family of corticioid fungi placed under the monotypic order **Atheliales**. Both the order and the family were described by Walter Jülich in 1981. According to a 2008 estimate, the family contains 20 genera and approximately 100 species. However, many genera formerly considered to belong in the Atheliaceae have since been moved to other families, including Amylocorticiaceae, Albatrellaceae, and Hygrophoraceae. Despite being a relatively small group with inconspicuous forms, Atheliaceae members show great diversity in life strategies and are widespread in distribution. Additionally, being a group strictly composed of corticioid fungi, they may also provide insights on the evolution of fruiting body forms in basidiomycetes.

The following species have been reported to cause diseases, produce a toxin, inhibit germination, or affect seed quality.

- A9.1.1 *Athelia* spp.
- A9.1.1a *Athelia rolfsii* (*Syn: *Botryobasidium rolfsii, Corticium rolfsii, Pellicularia rolfsii,* and *Sclerotium rolfsii*)
- A9.1.1b *Athelia arachnoidea* (**Syn: Corticium centrifugum*)

A9.1.1 *Athelia* spp. (10 Apr 2021)

Family: Atheliaceae

Definition: Amount of tolerance to *Athelia* spp. Persoon 1818.

(Wikipedia, 10 Apr 2021) ***Athelia*** is a genus of corticioid fungi in the family Atheliaceae. Some species are facultative parasites of plants (including crops) and of lichens. The widespread genus contains 28 species. However, *Athelia rolfsii* was found to belong in the Amylocorticiales in a molecular phylogenetics study, but has yet not been renamed.

A9.1.1a *Athelia rolfsii* (11 Apr 2021)

Synonyms: *Pellicularia rolfsii*, *Sclerotium rolfsii*, *Botryobasidium rolfsii*, and *Corticium rolfsii.*

Family: Atheliaceae

Definition: Amount of tolerance to *Athelia rolfsii* (Curzi) C.C. Tu & Kimbr. 1978.

(Wikipedia, 10 Apr 2021) ***Athelia rolfsii*** is a corticioid fungus in the family Atheliaceae. It is a facultative plant pathogen and is the causal agent of "southern blight" disease in crops.

The fungus produces effused basidiocarps (fruit bodies) that are smooth and white. Microscopically, they consist of ribbon-like hyphae with clamp connections. Basidia are club-shaped, bearing four smooth, ellipsoid basidiospores, measuring 4–7 by 3–5 µm. Small, brownish sclerotia (hyphal propagules) are also formed, arising from the hyphae.

Athelia rolfsii occurs in soil as a saprotroph, but can also attack living plants. It has an almost indiscriminate host range, but its capacity to form sclerotia (propagules that remain in the soil) means that it particularly attacks seasonal crops. It mostly occurs in warm soils (above 15 °C) and can be a serious pest of vegetables in tropical and subtropical regions (including Florida, where it was first recognized), causing "southern blight".

The soilborne fungal pathogen *Athelia rolfsii* is a basidiomycete that typically exists only as mycelium and sclerotia (anamorph: *Sclerotium rolfsii*, or asexual state). It causes the disease Southern Blight and typically overwinters as sclerotia. The sclerotia is a survival structure composed of a hard rind and cortex containing hyphae and is typically considered the primary inoculum. The pathogen has a very large host range, affecting over 500 plant species (including tomato, onion, snapbean and pea) in the United States of America. The fungus attacks the host crown and stem tissues at the soil line by producing a number of compounds such as oxalic acid, in addition to enzymes that are pectinolytic and cellulytic. These compounds effectively kill plant tissue and allow the fungus to enter other areas of the plant. After gaining entry, the pathogen uses the plant tissues to produce mycelium (often forming mycelial mats), as well as additional sclerotia. Sclerotia formation occurs when conditions are especially warm and humid,

primarily in the summer months in the United States of America. Susceptible plants exhibit stem lesions near the soil line, and thus often wilt and eventually die. Infection caused by Southern Blight is not considered systemic.

Athelia rolfsii typically prefers warm, humid climates (whence the name of the disease, Southern Blight) which is required for optimal growth (i.e., to produce mycelium and sclerotia). This makes the disease an important issue in regions such as the Southern United States, especially for solanaceous crops. In addition, oxygen rich and acidic soils have also been found to favor growth of the pathogen. Southern Blight can be spread (by way of sclerotia and mycelium) by contaminated farm tools and implements, irrigation systems and infected soil and plant material.

Management of the disease is critical, especially in agricultural regions. Although historically management has been difficult, there are several practical ways to reduce disease pressure. Simply avoiding infected fields is perhaps the most straightforward management technique given the large host range and durability of survival structures (i.e., sclerotia). However, when this is not possible, practicing proper sanitation and implementing effective crop rotations can help. Deep tillage has also been shown to reduce Southern Blight occurrence by burying infected plant tissues and creating an anaerobic environment that hinders pathogen growth. Soil solarization and certain organic amendments (e.g. composted chicken manure and rye-vetch green manure), as well as introducing certain *Trichoderma spp.* have also been shown to reduce plant death and number of sclerotia produced in the field in tomatoes. In addition to these cultural methods, chemical methods (e.g., fungicides) can also be employed. These methods all disrupt the production of mycelium and sclerotia, thus reducing the spread of disease.

References:

INTERNATIONAL

- E.A. Weiss (1971) reported *Sclerotium rolfsii* is a minor disease.
- CAB International (accessed 12 Apr 2021) lists sesame as a minor host of *Athelia rolfsii* (Sclerotium rot).

CHINA

- H.M. Miao and H.Y. Liu (2010) reported the following pathogen: *Sclerotium rolfsii.*

COSTA RICA

- Anon (1991a) in a grower guide reported the following pathogen: *Sclerotium rolfsii*.

GREECE

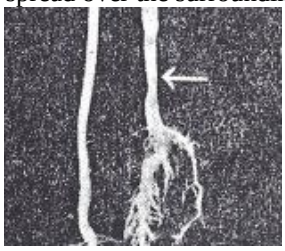
- S.G. Georfopoulos and C.C. Thanasoulopoulos (1960) reported *Sclerotium rolfsii* was isolated from young plants. [Cited by G.S. Saharan, 1989]

HONDURAS

- V.P. Queiroga et al. (2016) reported *Sclerotium rolfsii* affects the root and base of the stem. You can see the fan-shaped mycelium and on this some creamy, brown or black balls. The plants wither and die.

INDIA

- R.P. Misra and M.N. Khare (1970) sclerotial leaf and stem rot was observed due to *Sclerotium rolfsii*.
- P.N. Chaudhary and A.K. Singh (1974) reported *Corticium rolfsii* caused a severe case of foot rot. White ropy mycelium ran several inches over the stem above the soil level causing them to rot. Diseased plants showed maximum damage at the lower portion of the shoot and affected portion was considerably constricted, as shown below. Most of the necrotic tissues at later stages of infection were covered with profuse white mycelial growth. White to mustard brown globular sclerotia were produced in large number of the infected parts of the plant. Some of the leaves and branches were also discolored and softened, which hastened withering of the plant. Defoliation occurred in affected plants, and if infection occurred after initiation of capsules, such plants bore few capsules. Disease could be detected in early stages by the dull appearance of affected plants in the field. Growth was checked and plants wilted and died prematurely. The disease was widespread in dense crop stand and after heavy rains when the weather was humid and warm. Under such circumstances, mycelium spread over the surrounding soil infecting other plants.



- N.B. Kulkarni (1965) reported *Pellicularia rolfsii* is a minor pathogen. [Cited by E.A. Weiss, 1971]
- S. Maiti et al. (1985 and 1986) reported the following minor pathogen: Stem rot *Sclerotium rolfsii* Sacc.
- M.L. Verma (1985) reported *Sclerotium rolfsii – Corticium rolfsii* (Collar rot) is a major disease with the following symptoms: Brown to black necrotic rings on base of stem, upward and downward shriveling of stem with white mycelium, plant dies. Water soaked leaf spots with white mycelium underside.
- S.J. Gaikwad and D.J. Kapgate (1990) examined the possible biological control of the fungus *Sclerotium rolfsii*, the causal agent of the root-rot disease of sesame. Laboratory studies showed that 2 fungi were capable of limiting the growth of the pathogen of the root-rot disease. Pot trials showed that in the presence of the fungi *Trichoderma harzianum* and *Penicillium pinophilum*, only 10 and 15%, respectively, of sesame plants were infected with *S. rolfsii*; infection in the absence of the 2 fungi (control plants) was 100%. [Based on abstract]
- N.O. Srikantappa et al. (2009) studied 28 samples of sesame taken from fields, farmers, retail shops and APMC markets from 5 areas. They found 34 four fungi including *Sclerotinia rolfsii.* The fungi significantly reduced germination.
- K.N. Gupta et al. (2018) recommended cultural, chemical, and biocontrol practices to alleviate or control *Sclerotium rolfsii*; refer to the introduction.

ITALY

- P.A. Saccardo (1931) characterized *Botryobasidium rolfsii* (Saccardo).

JAPAN

- T. Kuzuyuki (2021) cited the following pathogen *Sclerotium rolfsii* (Stem rot) is listed in the Database of Plant Diseases in Japan.

MEXICO

- J.R. Penaloza and D.R. Moctezuma (~1992) in a grower guide reported: *Sclerotium rolfsii.*
- Anon. (2010a) in a grower guide reported the following main pathogen: *Sclerotium rolfsii.* Its saprophytic ability allows it to survive in the soil between cultivation cycles in infected plant residues. The fungus can survive as mycelium or as any of its three different types of spores. Soil infested with chlamydospores and attached to plant parts may be soil sterilized, which is too expensive for most farmers. Some fungicides provide a certain degree of control of the pathogen; however, the use of cultivars resistant to the fungus is recommended. The seed can be treated with mixtures of benomyl, carboxin, carboxin/captan or carboxim/ thiram. In addition, garlic extracts have been used to inhibit the germination of spores and mycelium growth.
- Agrolytics.org (2021) reported sesame hosts *Sclerotium rolfsii.*

NICARAGUA

- Anon. (1998b and 2009a) in grower guides reported *Sclerotium rolfsii*. Affects the root and base of the stem. The plants wither and die.

NIGERIA

- Enikuomehin (pers. comm., 2021) reported the causal pathogen of Stem Blight/Foot Rot is *Sclerotium rolfsii* Sacc. Symptoms: Whitish mycelial mass and light to dark-brown sclerotia of the fungal pathogen appear at the foot of the infected plant, usually at the soil surface surrounding the stem. The infected tissue turns brown and loses its form leading to drooping of all above ground parts and collapse of the infected plant. Infected plants get killed within 14 days of infection.

PHILIPPINES

- N.M. Tepora (1993a) reported the following disease: *Sclerotium rolfsii*. The nature of the damage is rotting and wilting of the infected plants. Control measures include seed treatment with Captan or Thiram before sowing.

SUDAN

- E.A. Weiss (1971) reported *Sclerotium rolfsii* is a minor pathogen.

UNITED STATES

- J. A. Martin (1953a) and M.L. Kinman and J.A. Martin (1954) reported *Pellicularia rolfsii* has been known to attack sesame in the US.
- M.L. Kinman (1955) reported Southern blight (*Pellicularia rolfsii*) is known to attack sesame.
- C.A. Thomas (1959b) reported Southern blight is a problem for present and future investigations.
- Anon. (2015c) USA PVP descriptor: *7.* Diseases – Southern blight (*Pellicularia rolfsii*). The following ratings are used:

- 0 = Not tested
- 1 = Susceptible
- 2 = Low resistance
- 3 = Moderate resistance
- 4 = High resistance

VENEZUELA

- A.M. Colmenares and L. Subero (1989a) reported the following less relevant pathogens: *Sclerotium rolfsii* (Soft rot of the stem).

A9.1.1b *Athelia arachnoidea* (1 May 2021)

Synonym: *Corticium centrifugum* and *Hypochnus centrifuges*

Family: Atheliaceae

Definition: Amount of tolerance to *Athelia arachnoidea* (Berkely) Julich 1972.

(Wikipedia, 1 May 2021) ***Athelia arachnoidea*** is a corticioid fungus in the family Atheliaceae. The species forms thin, white, cobwebby basidiocarps (fruit bodies) and typically occurs saprotrophically on leaf litter and fallen wood. It can, however, also be a facultative parasite of lichens and can additionally be a plant pathogen (typically found in its asexual ***Fibularhizoctonia carotae*** state), causing "crater rot" of stored carrots.

References:

CHINA

- L.L. Li (1988) reported *Corticium centrifugum* causes minor or regional damage to sesame.

JAPAN

- K. Yokogi (1927) reported cultural studies on *Hypochnus centrifuges* (*Corticium centrifugum*), casual organism of white-silk disease of sesame showed that minimum temperature for growth is below 10°, optimum 28° to 32° and maximum 41°C. Sclerotial formation is scanty in darkness while the mycelium makes profuse growth under similar conditions. The organism is also pathogenic to rice and soybeans. [Cited by G.S. Saharan, 1989]

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A10 Order: Pezizales J. Schrot. 1894

(Wikipedia, 12 Apr 2021) The **Pezizales** are an order of the subphylum Pezizomycotina within the phylum Ascomycota. The order contains 16 families, 199 genera, and 1683 species. It contains a number of species of economic importance, such as morels, the black and white truffles, and the desert truffles. The Pezizales can be saprobic, mycorrhizal, or parasitic on plants. Species grow on soil, wood, leaves and dung. Soil-inhabiting species often fruit in habitats with a high pH and low content of organic matter, including disturbed ground. Most species occur in temperate regions or at high elevation. Several members of the Sarcoscyphaceae and Sarcosomataceae are common in tropical regions.

Members of this order are characterized by asci that typically open by rupturing to form a terminal or eccentric lid or operculum. The ascomata are apothecia or are closed structures of various forms derived from apothecia. Apothecia range in size from less than a millimeter to approximately 15 cm and may be stalked or sessile. The order includes epigeous, semihypogeous to hypogeous (truffles) taxa. The ascospores are single-celled, bipolar symmetrical, and usually bilaterally symmetrical, ranging from roughly spherical to ellipsoidal to occasionally fusoid. The ascospores of some species develop surface ornamentations such as warts, ridges, or spines. The tissues of the ascomata are fleshy and often fragile. Although the majority of species are known only in the teleomorphic state, the anamorphs of some species are known.

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A10.1 Family: Rhizinaceae Bonorden 1851

(Wikipedia, 12 Apr 2021) The **Rhizinaceae** are a family of ascomycete fungi in the order Pezizales. The family was circumscribed by German mycologist Hermann Friedrich Bonorden in 1851.

The following species have been reported to cause diseases, produce a toxin, inhibit germination, or affect seed quality.

- A10.1.1 *Phymatotrichopsis* spp.
- A10.1.1a *Phymatotrichopsis omnivora* (*Syn: *Phymatotrichum omnivorum*)

A10.1.1 *Phymatotrichopsis* spp. (10 Apr 2021)

Family: Rhizinaceae

Definition: Amount of tolerance to *Phymatotrichopsis* spp. Hennebert 1973.

A10.1.1 *Phymatotrichopsis omnivora* (10 Apr 2021)

Synonym: *Phymatotrichum omnivorum*

Family: Rhizinaceae

Definition: Amount of tolerance to *Phymatotrichopsis omnivora* (Duggar) Hennebert 1973.

(Wikipedia, 10 Apr 2021) **Texas root rot** (also known as Phymatotrichopsis root rot, Phymatotrichum root rot, cotton root rot, or, in the older literature, Ozonium root rot) is a pathogen fairly common in Mexico and the southwestern United States that causes sudden wilt and death of affected plants, usually during the warmer months. It is a soilborne fungus of the species *Phymatotrichopsis omnivora* that attacks the roots of susceptible plants. It was first discovered in 1888 by Pammel, and was named by Duggar in 1916.

References:

UNITED STATES

- M.L. Kinman (1955) reported sesame is moderately resistant to Cotton root rot (*Phymatotrichum omnivora*, and any damage usually occurs too late in the season to cause much loss in yield.
- E.A. Weiss (1971) reported *Phymatotrichum omnivorum* usually occurs late in the season and causes little loss of yield.
- D.T. Smith et al. (2000) reported Cotton root rot is one of the most pervasive plant pathogens in agriculture and infests the roots and vascular systems of over 2,000 plant species. However, cotton root rot has not been

observed on sesame and Texas studies from the 1930's indicate that sesame is resistant to this broad-spectrum disease.

- D. Ray Langham comments, 2021: Cotton root rot is a serious problem in Texas cotton requiring several years between crops. Recently, there has been a soil treatment that has reduced the problem significantly. For 10 years, I planted a nursery with a cotton farmer in San Angelo, Texas. There were areas in his cotton where all of the cotton would die off, and yet in the next year, there was no kill in those areas when sesame was planted. At times, sesame and cotton would be planted in the same field. In those cases, there was dying off in cotton adjacent to the sesame rows with no kill in the sesame.

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A11 Order: Trichosphaeriales M.E. Barr 1983

(Wikipedia, 12Apr 2021) The **Trichosphaeriales** are an order of sac fungi. It is monotypic, and consists of the single family, the **Trichosphaeriaceae**.

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A11.1 Family: Trichosphaeriaceae G. Winter 1885.

The following species have been reported to cause diseases, produce a toxin, inhibit germination, or affect seed quality.

- A11.1.1 *Nigrospora* spp.
- A11.1.1a *Nigrospora sphaerica*
- A11.1.1b *Nigrospora oryzae*

A11.1.1 *Nigrospora* spp. (12 Apr 2021)

Family: Trichosphaeriaceae

Definition: Amount of tolerance to *Nigrospora* spp. Zimmerman 1902.

(drfungus.org, 12 Apr 2021) *Nigrospora* is a filamentous dematiaceous fungus widely distributed in soil, decaying plants, and seeds. It is a common laboratory contaminant. Although it has been isolated from a few clinical samples, its pathogenicity in man remains uncertain.

Nigrospora grows rapidly and produces woolly colonies on potato dextrose agar at 25°C. The colonies mature within 4 days. Color of the colony is white initially and then becomes gray with black areas and turns to black eventually from both front and reverse. Sporulation may take more than 3 weeks for some isolates.

Septate hyaline hyphae, hyaline or slightly pigmented conidiophores, and conidia are visualized. The conidiogenous cells on the conidiophores are inflated, swollen, and ampulliform in shape. They bear a single conidium (14-20 µm in diameter) at their apex. Conidia are black, solitary, unicellular, slightly flattened horizontally, and have a thin equatorial germ slit.

A11.1.1a *Nigrospora sphaerica* (12 Apr 2021)

Family: Trichosphaeriaceae

Definition: Amount of tolerance to *Nigrospora sphaerica* Mason 1927.

(Wikipedia, 12 Apr 2021) ***Nigrospora sphaerica*** is an airborne filamentous fungus in the phylum Ascomycota. It is found in soil, air, and plants as a leaf pathogen. It can occur as an endophyte where it produces antiviral and antifungal secondary metabolites. Sporulation of *N. sphaerica* causes its initial white colored colonies to rapidly turn black. *N. sphaerica* is often confused with the closely related species *N. oryzae* due to their morphological similarities.

N. sphaerica colonies grow rapidly and appear hairy or woolly. The conidiophores are short and clustered surfacing from mycelium. They appear translucent in color and have an average range of 8-11µm in diameter. The conidiophores are often straight stalks or slightly curved. Conidia grow from the tips of the translucent conidiophores. The conidia are brownish black, oblate spheroid, and single celled. On average they range from 16-18µm in diameter. The initial white translucent looking colony of *N. sphaerica* turns brown/black due to mass sporulation of conidia from the conidiophores. In laboratories, *N. sphaerica* is grown on potato dextrose agar (PDA) at room temperature.

N. sphaerica is commonly found in air, soil, various plants, and some cereal grains. It is rarely found in indoor environments. *N. sphaerica* has been identified in many areas around the world, however it is most prevalent in tropical and subtropical countries.

During asexual reproduction *N. sphaerica* releases spores known as conidia. The conidia are ejected out forcefully at maximum horizontal distances of 6.7 cm, and 2 cm vertically. Discharge of spores occurs in all directions. The mechanism for projection relies on the conidiophore consisting of a flask-shaped support cell that bears the

conidium. Liquid from the support cell squirts through the supporting cell projecting the spore outwards. This characteristic of forcible spore discharge is rarely seen in hyphomycetes. *N. sphaerica* requires moisture to release spores into the air, therefore accumulation begins around 2:00 a.m. with peak time of abundance occurring around 10:00 a.m. Spore count rapidly decreases after 10:00 a.m. and remains low throughout the day.

Decaying plants is one of the most common places where *N. sphaerica* is found. Many studies around the world found *N. sphaerica* as a leaf pathogen. *N. sphaerica* was isolated from various plants displaying leaf spots. These reported cases reveal newly identified plant hosts for the pathogen *N. sphaerica* that have been validated through Koch's postulates. The disease affected plants of all ages, being especially pronounced in younger plants. Fungal colonies displayed an initial white color that eventually turned gray/brown. Based on these morphological characteristics, *N. sphaerica* was identified as the fungal pathogen. Inoculation of the pathogen using conidial suspension spray, and re-isolation of *N. sphaerica* satisfied Koch's postulates.

References:

CHINA

- H. Zhao et al. (2014) reported a new leaf blight (*Nigrospora sphaerica*) has increasingly been observed in sesame fields in Anhui, Hubei, and Henan provinces since 2010. Approximately 30-40% of the plants were symptomatic in the affected fields. Initial symptoms were yellow to brown, irregularly shaped lesions. Lesions later expanded, and the affected leaves turned grayish to dark brown and wilted, with a layer of whitish mycelial growth on the underside. Severe blighting caused the center of lesions to fall out, leaving holes in the leaves. [Based on abstract]

PAKISTAN

- A. Rehman et al. (n.d.) reported a 10-13% incidence of *Nigrospora sphaerica* around Faisalabad. The symptoms were characterized by yellow-brown and irregular lesions. At later stages, the lesions expanded, and the affected leaves turned grayish to dark-brown and finally became wilted.

A11.1.1b *Nigrospora oryzae* (19 Jul 2021)

Family: Trichosphaeriaceae

Definition: Amount of tolerance to *Nigrospora oryzae* (Berk. & Br.) Petch.

(Wikipedia, 12Apr 2021) ***Nigrospora oryzae*** is often confused with the closely related species *N. sphaerica* due to their morphological similarities.

References:

EGYPT

- N.A. Darwood (1980) reported sesamum was one of the hosts infected with *Nigrospora oryzae* causing seed rot. It was fast growing, with optimum temperature of 25-30°C. It was tolerant of antibiotics produced by soil microorganisms. [Based on abstract]

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A12 Order: Saccharomycetales Kudryatsev 1960

(Wikipedia, 19 Apr 2021) **Saccharomycetales** belongs to the kingdom of Fungi and the division Ascomycota. It is the only order in the class Saccharomycetes. There are currently 13 families recognized as belonging to Saccharomycetales.

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A12.1 Family: Saccharomycetaceae G. Winter 1881.

(Wikipedia, 19 Apr 2021) The **Saccharomycetaceae** are a family of yeasts in the order Saccharomycetales that reproduce by budding. Species in the family have a cosmopolitan distribution, and are present in a wide variety of habitats, especially those with a plentiful supply of carbohydrate sources. The family contains the species *Saccharomyces cerevisiae*, perhaps the most economically important fungus.

The following species have been reported to cause diseases, produce a toxin, inhibit germination, or affect seed quality.

- A12.1.1 *Candida* spp.

A12.1.1 *Candida* spp. (20 Jul 2021)

Family: Saccharomycetaceae

Definition: Amount of tolerance to *Candida* spp. Berkhout.

(Wikipedia, 20 Jul 2021) ***Candida*** is a genus of yeasts and is the most common cause of fungal infections worldwide. Many species are harmless commensals or endosymbionts of hosts including humans; however, when mucosal barriers are disrupted or the immune system is compromised they can invade and cause disease, known as an opportunistic infection. Candida is located on most of mucosal surfaces and mainly the gastrointestinal tract, along with the skin. *Candida albicans* is the most commonly isolated species and can cause infections (candidiasis or thrush) in humans and other animals. In winemaking, some species of *Candida* can potentially spoil wines.

Many species are found in gut flora, including *C. albicans* in mammalian hosts, whereas others live as endosymbionts in insect hosts. Systemic infections of the bloodstream and major organs (candidemia or invasive candidiasis), particularly in patients with an impaired immune system (immunocompromised), affect over 90,000 people a year in the US.

The genome of several *Candida* species has been sequenced.

Antibiotics promote yeast (fungal) infections, including gastrointestinal (GI) *Candida* overgrowth and penetration of the GI mucosa. While women are more susceptible to genital yeast infections, men can also be infected. Certain factors, such as prolonged antibiotic use, increase the risk for both men and women. People with diabetes or the immunocompromised, such as those infected with HIV, are more susceptible to yeast infections.

Candida antarctica and *Candida rugosa* are a source of industrially important lipases, while *Candida krusei* is prominently used to ferment cacao during chocolate production. *Candida rugosa* is also used as an enzyme supplement to support fat digestion with its broad specificity for lipid hydrolysis.

References:

INDIA

- K.R. Sharma and K.G. Mukerji (1974) reported a pathogenic *Candida* spp. on aging, senescing, and decaying leaves. [Cited by G.S. Saharan, 1989]

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A12.2 Family: Dipodascaceae Engl. & E. Gilg 1924

(Wikipedia, 24 Aug 2021) The **Dipodascaceae** are a family of yeasts in the order Saccharomycetales. According to the 2007 Outline of Ascomycota, the family contains four genera; however, the placement of *Sporopachydermia*

and *Yarrowia* is uncertain. Species in the family have a widespread distribution, and are found in decaying plant tissue, or as spoilage organisms in the food industry.

The following species have been reported to cause diseases, produce a toxin, inhibit germination, or affect seed quality.

- A12.2.1 *Geotrichum* spp.
- A12.2.1a *Geotrichum candidum*

A12.2.1 *Geotrichum* spp. (30 Aug 2021)

Family: Dipodascaceae

Definition: Amount of tolerance to *Geotrichum* spp. Link 1809.

(Wikipedia, 30 Aug 2021) Geotrichum is a genus of fungi found worldwide in soil, water, air, and sewage, as well as in plants, cereals, and dairy products; it is also commonly found in normal human flora and is isolated from sputum and feces. It was first described in 1809 by Johann Heinrich Friedrich Link. The genus *Geotrichum* includes over 100 species. Some are welcome and even considered desirable. For example, skilled cheesemakers create conditions favorable for the formation of a *Geotrichum candidum* rind on certain goat's milk and cow's milk cheeses, proudly declaring the rind to be the most flavorful part of such cheeses.

The most clinically relevant species is *Saprochaeta capitata*, formerly known as *Geotrichum capitatum*, with most cases occurring in Europe. *Saprochaete clavata*, formerly known as *Geotrichum clavatum*, is an uncommon infection that has been associated with sporadic outbreaks. *Geotrichum candidum* is closely related to *Saprochaeta* sp., rarely isolated but may cause invasive and disseminated disease with high mortality Yeast-like and mold-like strains have been identified.

The most important risk factor for invasive fungal infection related to *Geotrichum* is severe immunosuppression, especially in hematological malignancies as acute leukemia, associated with profound and prolonged neutropenia. Fungemia is very common, often with deep organ involvement (lung, liver, spleen, and central nervous system) and also skin and mucous membranes lesions. There is no optimal treatment for *Geotrichum* infections but based on existing data guidelines recommend amphotericin B with or without co-administered flucytosine or with voriconazole showing good in vitro susceptibility.

Mortality associated with Geotrichum-related infections is high, ranging from 57% to 80%. Increasing the knowledge on *Geotrichum* related invasive fungal infections may improve early diagnosis and adequate treatment of these severe infections.

A12.2.1 *Geotrichum candidum* (24 Aug 2021)

Family: Dipodascaceae

Definition: Amount of tolerance to *Geotrichum candidum* Link 1809.

(Wikipedia, 24 Aug 2021) ***Geotrichum candidum*** is a fungus which is a member of the human microbiome, notably associated with skin, sputum and feces where it occurs in 25–30% of specimens. It is common in soil and has been isolated from soil collected around the world, in all continents. *G. candidum* is the causative agent of the human disease geotrichosis, the plant disease **sour rot** which infects citrus fruits, tomatoes, carrots, and other vegetables. It can affect harvested fruit of durians such as *Durio graveolens*.

G. candidum is used widely in the production of certain dairy products including rind cheeses such as Camembert, Saint-Nectaire, Reblochon and others. The fungus can also be found in a Nordic yogurt-like product known as viili where it is responsible for the product's velvety texture. In a 2001 study, *G. candidum* was found to consume the polycarbonate found in CDs. However, this effect has not been reproduced.

References:

NIGERIA

- C.A. Amienyo et al. (2015) studied the effect of mycoflora collected from 5 markets on the deterioration of lipid content of seed. Visually healthy seeds were inoculated with spores of each of the nine fungi isolated from diseased seeds and incubated at 25+20°C for 7days. The healthy and fungal infected seeds were analyzed for their lipid content. The percentage incidence at the 5 locations is shown below.

Fungi incidence	Location				
	A	B	C	D	E
Alternaria alternate	6.6	3.6	3.2	2.0	0.0
Aspergillus chevalieri	10.3	4.2	5.0	0.0	0.0
Aspergillus niger	0.0	6.1	7.4	2.6	5.2
Aspergillus oryzae	3.3	4.0	0.0	0.0	0.0
Aspergillus flavus	3.9	3.1	2.7	0.0	0.0
Aspergillus terreus	4.8	11.2	2.4	13.0	0.0
Cochliobolus Spp.	9.5	0.0	0.0	0.0	0.0
Geotrichum candidum	0.0	0.0	0.0	0.0	3.5
Phoma Spp.	5.9	2.0	0.0	0.0	0.0

Fungi utilize basic compounds of the seeds for their metabolism and growth and may affect the germination rate of the seed. The uninoculated seed had 49.35% lipid. The following shows the lipid content after 7 days of infection.

Fungi	Lipid content (%)
Aspergillus chevalieri	42.40
Aspergillus oryzae	43.50
Aspergillus niger	45.00
Aspergillus terreus	45.45
Alternaria alternata	47.80
Cochliobolus Spp	48.10
Aspergillus flavus	48.70
Phoma Spp.	49.15
Geotrichum candidum	49.40

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A13 Order: Eurotiales G.W. Martin ex Benny& Kimbr 1980

(Wikipedia, 17 Apr 2021) The **Eurotiales** are an order of sac fungi, also known as the green and blue molds. The order contains three families, 49 genera, and 928 species. It was circumscribed in 1980.

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A13.1 Family: Trichocomaceae E. Fisch 1897.

(Wikipedia, 17 Apr 2021) The **Trichocomaceae** are a family of fungi in the order Eurotiales. Taxa are saprobes with aggressive colonization strategies, adaptable to extreme environmental conditions. Family members are cosmopolitan in distribution, ubiquitous in soil, and common associates of decaying plant and food material. The family contains some of the most familiar fungi, such as *Penicillium* and *Aspergillus*. It has been proposed that the family should be split into the three families Aspergillaceae, Thermoascaceae and Trichocomaceae.

The following species have been reported to cause diseases, produce a toxin, inhibit germination, or affect seed quality.

- A13.1.1 *Aspergillus* spp.
- A13.1.1a *Aspergillus flavus*
- A13.1.1b *Aspergillus niger*
- A13.1.1c *Aspergillus parasiticus*
- A13.1.1d *Aspergillus nomius*
- A13.1.1e *Aspergillus ochraceus*
- A13.1.1f *Aspergillus tamarii*
- A13.1.1g *Aspergillus parvisclerotigenus*
- A13.1.1h *Aspergillus fumigatus*
- A13.1.1i *Aspergillus candidus*
- A13.1.1j *Aspergillus sacchari*
- A13.1.1k *Aspergillus clavatus*
- A13.1.1l *Aspergillus carbonarius*
- A13.1.1m *Aspergillus flavipes*
- A13.1.1n *Aspergillus alba*
- A13.1.1o *Aspergillus viridus*
- A13.1.1p *Aspergillus chevalleri*
- A13.1.1q *Aspergillus oryzae*
- A13.1.1r *Aspergillus terreus*
- A13.1.1s *Aspergillus ruber*
- A13.1.2 *Penicillium* spp.
- A13.1.2a *Penicillium egyptiacum*
- A13.1.2b *Penicillium citrinum*
- A13.1.2c *Penicillium rubrum*
- A13.1.2d *Penicillium verrucosum*
- A13.1.2e *Penicillium viridicatum*
- A13.1.2f *Penicillium nordicum*
- A13.1.2g *Penicillium crustosum*
- A13.1.2h *Penicillium brevicompactum*
- A13.1.2i *Penicillium chrysogenum*

There are species in this family that are used for biocontrols. See E2.1.

There are species in this family associated with sesame, but not reported to cause diseases, produce a toxin, inhibit germination, or affect seed quality. See H11.1.

A13.1.1 *Aspergillus* spp. (22 Apr 2021)

Family: Trichocomaceae

There are *Aspergillus* spp. that affect seed quality (A13.1.1) while other species have been proposed as biocontrols (E2.1.2).

Definition: Amount of tolerance to *Aspergillus* spp. P. Micheli ex Haller 1768.

(Wikipedia, 22 Apr 2021) ***Aspergillus*** is a genus consisting of a few hundred mould species found in various climates worldwide. *Aspergillus* was first catalogued in 1729 by the Italian priest and biologist Pier Antonio Micheli. Viewing the fungi under a microscope, Micheli was reminded of the shape of an *aspergillum* (holy water sprinkler), from Latin *spargere* (to sprinkle), and named the genus accordingly. Aspergillum is an asexual spore-forming structure common to all *Aspergillus* species; around one-third of species are also known to have a sexual stage. While some species of *Aspergillus* are known to cause fungal infections, others are of commercial importance.

The following species have been associated with sesame but there are no known reports of being a pathogen, producing a toxin, inhibiting germination, affecting seed quality, or being used as a biocontrol or biofertilizer.

- *Aspergillus amstelodami* [Egypt]
- *Aspergillus caespitosus* [Egypt and Saudi Arabia]
- *Aspergillus funiculosus* [International lists]
- *Aspergillus glaucus* [Nigeria and Venezuela]
- *Aspergillus montevidensis* [Egypt]
- *Aspergillus quadrilineatus* [Egypt and Saudi Arabia] (*Syn: *Emericella quadrilineata*)
- *Aspergillus repens* [Egypt]
- *Aspergillus tetrazonus* [Egypt and Saudi Arabia]
- *Aspergillus versicolor* [India]

References:

EGYPT

- M.M.I. Abdel-Hafez et al. (2012) examined the soils around the roots of sesame and reported *Aspergillus* spp.in the rhizosphere and rhizoplane.

INDIA

- O.P. Kadian (1972) reported two less common genera to include *Aspergillus* sp., which reduced seed germination and had adverse effect on the seedlings. The seeds were internally as well as externally seedborne. [Cited by G.S. Saharan, 1989]
- A.S. Reddy and S.M. Reddy (1983b) reported 36 fungal species were obtained from 105 seed samples of sesame. Several species of *Aspergillus, Fusarium* as well as *Penicillium citrinum* can produce a very wide range of mycotoxins. [Cited by G.S. Saharan, 1989]

NIGERIA

- A.D. Ojochenemi et al. (2015) examined 46 samples of sesame and reported *Aspergillus* spp.
- A.O. Esan et al. (2020) purchased 60 sesame samples from markets in Nasarawa states during 2 seasons (wet and dry) in order to determine the safety for human consumption. They identified the following fungi: *Aspergillus* section *candidi*, *Aspergillus* section *flavi* (*A. flavus* and *A. tamarii*), *Aspergillus* section *nigri*, *Cladosporium* sp., *Fusarium fujikuroi, Penicillium* spp., and Didymellaceae. [For the toxins found refer to section G1 Toxin producing mycoflora.]

PAKISTAN

- A.S. Shakir and M. Ansar (1992) studied 25 samples of seed collected from various areas in Punjab and found the following fungus: *Aspergillus* spp.

PARAGUAY

- L.C. Rossi and A.L. Orrego (2007) identified the following fungus on sesame seeds: *Aspergillus* sp.

SAUDI ARABIA

- A.H. Bahkali and M.A. Moslem (1996) reported the following mycoflora on 5 cultivars: *Aspergillus* sp.

VENEZUELA

- J.B. Pineda and E.R. Glonnella (1988b) isolated 12 different cultures of fungi from soil samples collected in El Playon (7.47N 73.20W) and Turen (9.33N 69.11W) where some locations showed a low incidence of dry stem disease (*Macrophomina phaseolina*). The isolates were 8 *Aspergillus* spp., 2 *Trichoderma* spp., 1 *Cladosporium* sp. and 1 *Pythium* sp. These organisms were tested against one isolate of *Macrophomina phaseolina* (Tassi)

Gold, pathogenic in sesame. They determined 2 *Aspergillus* spp. and 2 *Trichoderma* spp. could inhibit the growing and sclerotia production of this pathogen. Under natural field conditions, *Trichoderma* I and *Aspergillus* 1 were highly effective in reducing sesame dead plant percentage by *M. phaseolina* until 72 days after planting, indicating a good control.

- B. Mazzani (1999) reported the following pathogen: *Aspergillus* sp.

A13.1.1a *Aspergillus flavus* (22 Apr 2021)

Aspergillus flavus affects seed quality (A13.1.1a) and has been used as a biocontrol (E2.1.2g). *Aspergillus flavus* has been reported to occur from the field.

Family: Trichocomaceae

Definition: Amount of tolerance to *Aspergillus flavus* Link 1809.

(Wikipedia, 22 Apr 2021) ***Aspergillus flavus*** is a saprotrophic and pathogenic fungus with a cosmopolitan distribution. It is best known for its colonization of cereal grains, legumes, and tree nuts. Postharvest rot typically develops during harvest, storage, and/or transit. Its specific name flavus derives from the Latin meaning yellow, a reference to the frequently observed color of the spores. *A. flavus* infections can occur while hosts are still in the field (preharvest), but often show no symptoms (dormancy) until postharvest storage and/or transport. In addition to causing preharvest and postharvest infections, many strains produce significant quantities of toxic compounds known as mycotoxins, which, when consumed, are toxic to mammals. *A. flavus* is also an opportunistic human and animal pathogen, causing aspergillosis in immunocompromised individuals.

Aspergillus flavus is found globally as a saprophyte in soils and causes disease on many important agriculture crops. Common hosts of the pathogen are cereal grains, legumes, and tree nuts. Specifically, *A. flavus* infection causes ear rot in corn and yellow mold in peanuts either before or after harvest. Infection can be present in the field, preharvest, postharvest, during storage, and during transit. It is common for the pathogen to originate while host crops are still in the field; however, symptoms and signs of the pathogen are often unseen. *A. flavus* has the potential to infect seedlings by sporulation on injured seeds. In grains, the pathogen can invade seed embryos and cause infection, which decreases germination and can lead to infected seeds planted in the field. The pathogen can also discolor embryos, damage seedlings, and kill seedlings, which reduces grade and price of the grains. The incidence of *A. flavus* infection increases in the presence of insects and any type of stress on the host in the field as a result of damage. Stresses include stalk rot, drought, severe leaf damage, and/or less than ideal storage conditions. Generally, excessive moisture conditions and high temperatures of storage grains and legumes increase the occurrence of *A. flavus* aflatoxin production. In mammals, the pathogen can cause liver cancer through consumption of contaminated feed or aspergillosis through invasive growth.

Aspergillus flavus infections will not always reduce crop yields alone; however, postharvest disease can reduce the total crop yield by 10 to 30%, and in developing countries that produce perishable crops, total loss can be greater than 30%. In grains and legumes, postharvest disease results in the production of mycotoxins. The largest economic loss caused by this pathogen is a result of aflatoxin production. In the United States, annual economic loss estimations of peanuts, corn, cottonseed, walnuts, and almonds are less severe when compared to Asia and Africa.

References:

INTERNATIONAL

- CAB International (accessed 12 Apr 2021) reported sesame was a minor host of *Aspergillus flavus* (Aspergillus ear rot).

ALGERIA

- N.A. Mimoune et al. (2016) examined 12 samples from the market and found a percentage of 30.3% of *Aspergillus flavus* isolates produced AFB1, with levels ranging from 0.69 to 44.28 µg/g.

BANGLADESH

- M.D. Hosen and S. Shamsi (2017) isolated the following fungus from sesame seeds: *Aspergillus flavus.*

CUBA

- La Habana (2009) in a grower guide reported the following fungus: *Aspergillus flavus.*

EGYPT

- R.S. Farag et al. (1985a) reported *Aspergillus flavus* on the seed had an effect on seed composition as follows.

Seed component	Healthy seed	Infected seed
Proteins	22.1%	23.6%
Lipids	58.3%	49.0%
Carbohydrates	14.2%	21.7%
Crude fiber	2.1%	2.6%

- H.A.H. Hasan (2002) reported *Aspergillus flavus* was a pathogen in the rhizosphere and rhizoplane. [Cited by S.I.I. Abdel-Hafez, 2012]
- M.M.I. Abdel-Hafez et al. (2014) took ten samples of sesame from local markets in Assiut city. They found *Aspergillus flavus* Link.
- A. Hashem et al. (2014) collected 18 seed samples of sesame in Egypt (12 samples) and Saudi Arabia (6 samples). They identified the following mycoflora: *Aspergillus flavus.*
- B.A. Sabry et al. (2016) in Egypt studied 28 sesame samples collected from food stores in different governates. They found the following fungi.

Governorate	NC/ TNS	Fungal load (log_{10} CFU/g)		Percentage occurrence of fungal genera				
		Range	Mean ± SD	*Alternaria*	*Aspergillus*	*Fusarium*	*Penicillium*	*Cladosporium*
Great Cairo	4/4	1.72 –2.32	1.91±0.77[a]	34.21	60.53	2.63	ND	2.63
Kalioubia	3/3	1.72 –2.32	1.97±1.03[a]	4.17	91.66	ND	4.17	ND
Alexandria	6/6	1.72 –2.67	1.99±1.63[a]	4.35	82.61	6.52	ND	6.52
El-Behera	5/5	1.72 –2.87	2.15±1.63[b]	ND	71.82	0.91	17.27	10.00
Kafr El-Sheik	5/5	1.72 –2.80	2.26±2.72[c]	3.96	60.40	1.98	17.82	15.84
Dakahlia	5/5	1.72 –3.02	2.52±0.70[d]	ND	79.68	1.59	6.37	12.35

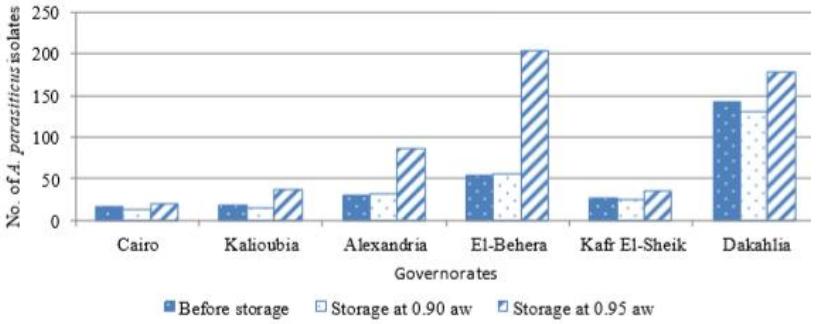
NC: Number of contaminated samples; TNS: Total number of samples
Mean with different superscript letters are significantly different

They found the following *Aspergillus* sp.

Governorate	NC/ TNS	*Aspergillus* load (log_{10}CFU/g)		Percentage occurrence of *Aspergillus* species		
		Range	Mean ± SD	*Aspergillus parasiticus*	*Aspergillus flavus*	*Aspergillus niger*
Great Cairo	1/4	1.72 –2.32	1.96±0.86[a]	69.56	8.69	21.75
Kalioubia	1/3	1.72 –2.32	2.02±1.09[a]	77.27	4.54	18.18
Alexandria	1/6	1.72 –2.67	2.02±1.77[a]	78.95	ND	21.05
El-Behera	3/5	1.72 –2.87	2.23±3.09[b]	67.08	ND	32.91
Kafr El-Sheik	3/5	1.72 –2.80	2.37±3.41[b]	42.62	ND	57.38
Dakahlia	3/5	2.20 –3.02	2.69±0.75[c]	71.00	ND	29.00

NC: Number of contaminated samples; TNS: Total number of samples

Stored sesame samples at the higher water activity (a_w 0.95) showed an increase of total fungal count compared with samples stored at a lower water activity (a_w 0.90).



They found the following percentages and levels of aflatoxins.

Governorates	TNS	Aflatoxin B_1		Aflatoxin B_2		Aflatoxin G_1		Aflatoxin G_2	
		µg/kg	%	µg/kg	%	µg/kg	%	µg/kg	%
Great Cairo	4	18.63 ± 0.79	100	ND	ND	18.27 ± 1.31	100	ND	ND
Kalioubia	3	23.25 ± 0.93	100	ND	ND	21.33 ±1.22	66.66	ND	ND
Alexandria	6	21.04 ± 2.32	66.66	0.28 ± 0.10	33.33	51.47 ± 2.18	33.33	1.55 ± 0.59	16.66
El-Behera	5	66.74 ± 1.71	60.00	0.42 ± 0.07	40.00	43.81 ± 2.10	80.00	ND	ND
Kafr El-Sheik	5	29.94 ± 1.02	100	ND	ND	14.88 ± 1.55	80.00	ND	ND
Dakahlia	5	42.37 ± 1.34	100	0.19 ± 0.10	20.00	27.51 ±1.07	100	0.12 ± 0.13	20.00

Results are mean ± SD (n=3); TNS: Total number of samples

Roasting or microwaving can reduce the amount of aflatoxins but will not eliminate them. The following table shows the percentage reduction under several trials.

Treatment Time	Roasting		Microwave (20 kgy)
	100ºC	150ºC	
5	-	-	18.14±0.024
20	5.33±0.026	11.50±0.079	-
30	7.21±0.011	14.14±0.090	-

Results are mean ±SD (n=3)

GREECE

- E. Kollia et al. (2016) in Greece examined 30 samples of sesame products for the presence of AFB_1. Aflatoxins are a group of secondary metabolites produced by the species: *Aspergillus flavus, Aspergillus parasiticus* and the rare *Aspergillus nomius*. Among these, aflatoxin B_1 (AFB_1) is the most naturally occurring compound of toxigenic isolates of *Aspergillus* species and the most dangerous contaminant of foods and feeds due to carcinogenic and mutagenic activity. Sesame seeds are sensitive to AF-producing fungal invasion, because of their oil content, and may therefore be contaminated with Afs and particularly AFB_1. [For more information refer to G1 Toxin producing mycoflora]

INDIA

- B.K. Singh and T. Prasad (1979) reported *Aspergillus flavus* and *Aspergillus niger* inoculations decreased the cholesterol level of the seed. [Cited by G.S. Saharan, 1989]
- A.S. Reddy and S.M. Reddy (1983a) reported fungal succession on sesame seeds with different moisture levels was analyzed monthly. Incidence varied with moisture content. *Alternaria alternata* was abundant only in the initial stages. *Aspergillus flavus* predominated while *Macrophomina phaseolina* and *Rhizoctonia solani* were associated only with seeds of high moisture content. The seed mycoflora at first increased with storage time but subsequently decreased. Seed germination increased with storage time. [Cited by G.S. Saharan, 1989]
- K. Kumar et al. (1984a) reported *Aspergillus flavus* was found to be associated with the seeds of varieties T-4 and T-12. The species was pathogenic and reduced germination by causing seed rot under laboratory conditions.
- A. Bose and B. Nandi (1985) reported cellulase was produced in culture best by *Aspergillus fumigatus, A. candidus* and *Rhizoctonia solani*; endopolygalacturonase and lipase by *A. flavus*. Reduction in germinability and oil content and increase in fat acidity were most pronounced in seeds inoculated with *A. flavus, A. fumigatus,* and *R. solani*. [Cited by G.S. Saharan, 1989]
- B.K. Vaidehi et al. (1985) reported culture filtrates of *Aspergillus flavus* reduced germination percentage and root and shoot elongation of sesame with the maximum on the 30th day. [Cited by G.S. Saharan, 1989]
- B.K. Singh (1987) reported *Aspergillus flavus* was found frequently on sesame seeds. [Cited by G.S. Saharan, 1989]
- N. Saxena and D. Karan (1991) reported seeds of sesame cv. T-85 collected in Andhra Pradesh had *Aspergillus flavus.* Seed protein and carbohydrate contents were analyzed before and 10, 20 and 30 days after inoculation. The fungi decreased protein and carbohydrate contents. It is suggested that the fungi contain a protein hydrolyzing enzyme, and the carbohydrate is consumed and converted into carbon dioxide and water. [Based on abstract]
- K. Bhattachary and S. Raha (2002) studied fungal infection, moisture content, germinability and deterioration of sesame in storage under natural conditions for a year. Different species of Aspergillus (*A. candidus*, A. *flavus, A. niger, A. terreus*, and *A. ruber*) were dominant followed by Rhizopus, Penicillium, Curvularia, Fusarium, Alternaria, etc. Seed moisture was maximum in the rainy season followed by a gradual decrease during longer storage. As storage proceeded, there was a gradual decrease in field fungi with simultaneous increase in storage fungi, and a reduction in germinability. A gradual loss of carbohydrate (both soluble and

insoluble) content was recorded. A loss of protein content was recorded followed by a small increase. Oil content decreased in prolonged storage with simultaneous increase in fatty acid. [Based on abstract]

- N.O. Srikantappa et al. (2009) studied 28 samples of sesame taken from fields, farmers, retail shops and APMC markets from 5 areas. They found 34 four fungi including *Aspergillus flavus.* The fungi significantly reduced germination.
- V. Bharathi et al. (2013) collected sesame seeds from farmers in Andhra Pradesh. They tested the seeds for mycoflora, and the following fungus was found: *Aspergillus flavus.*
- P.L. Radha (2013) collected 18 cultivars from 7 districts in Karnataka and identified the following fungus: *Aspergillus flavus*.
- H.R. Aglave (2016) screened two varieties (CV.N-85 and CV. Phule-1) for seed mycoflora. Twenty-seven fungi were isolated from these varieties. Varietal variation was found during the investigation. The following fungus was present *Aspergillus flavus.*
- B. Khamari et al. (2018e) collected 15 sesame seed samples from different localities of Odisha reported the infestation of *Aspergillus flavus* ranged from 1 to 5.5%.

IRAN

- M. Gooya et al. (2000) took one seed samples of each 17 sesame cultivars from 10 locations leading to 145 isolates during 1997/99 They identified *Aspergillus flavus.*
- A. Habibi and Z. Banihashemi (2008) studied the genetic diversity of a population of *Aspergillus flavus* isolated from sesame seeds collected in 2004 and 2005 from various parts of Iran through vegetative compatibility, and their mycotoxin production. Sixteen vegetative compatibility groups (VCGs) were identified among the *nit* mutants. VCGs were not evenly distributed through Iran. With few exceptions, there was a relationship between a VCG and the amount of mycotoxins produced by its isolates.

IRAQ

- F. Al-Refaee (2005) collected sesame seeds from 6 regions of Iraq and isolated *Aspergillus flavus.*
- N.A. Saad et al. (2013) examined seed and found the following fungus: *Aspergillus flavus.*

NIGERIA

- M.C. Mbach and C.D. Akueshi (2009b) conducted an experiment with two species of seeds of sesame (*Sesamum indicum* and *Sesamum radiatum*) inoculated with a storage fungus (*Aspergillus flavus*) previously isolated from seeds of sesame. The inoculated seeds were incubated for 10, 15 and 20 day intervals at 30°C. Results showed that *S. indicum* inoculated with the test fungus *A. flavus* and incubated for a period of 20 days showed the presence of aflatoxin B_1 estimated to be 25 ppb. While seeds of *S. radiatum* inoculated with the same test fungus and inoculated for the same length of time did not show any presence of aflatoxin. All the seeds of the two species of sesamum inoculated with the test fungus and incubated for 10 and 15 day intervals showed no presence of aflatoxin. The results portray the danger of consuming infested seeds of sesame which usually appear uninfested to a casual observer when *A. flavus* grows on them and the inherent danger of using such seeds for livestock feed.
- F.M. Afolagboye (2011) studied the effects of hot and cold water leaf extracts (*Lantana camara, Bryophyllum pinnatum, Eichornia crassipes, Lawsonia innermis* and *Zingiber officinale*) on 2 fungi (*Aspergillus niger* and *Aspergillus flavus*) using 4 sesame varieties (NCRIBEN 03L, NCRIBEN 01M, E8 and 530-6-1). Hot water extract of all test plants exhibited strong fungitoxicity (84.0-92.1% mycelial growth inhibition) against *Aspergillus niger* while *Aspergillus flavus* was most sensitive to hot water extract of *Z. officinale*. Mycelial growth inhibition of *Aspergillus flavus* by cold water extracts of the tested plants ranged between 18.3 and 73.2%. The plant extracts have potential for management of seedborne fungi of sesame. [Based on abstract]
- M.N. Suleiman et al. (2013) studied the effect of barks (*Anacadium occidentale* [cashew] and *Mangifera indica* [mango]) on mycoflora (*Aspergillus niger*, *Aspergillus flavus* and *Penicillium* sp) using 10 cultivars. The following figures show the fungal incidence on the cultivars and the distribution on the fungi.

Table 1: Fungal Incidence on Seeds of ten sesame cultivars

Cultivars	Normal seeds*	Infected seeds*	Fungal incidence (%)
01 – M	10	190	95.00
02 – M	25	175	87.50
03 – M	53	147	73.50
E8	05	195	97.50
Ex sudan	41	159	79.50
Oke	24	176	88.00
Any	12	188	94.00
1Lo	61	139	69.50
Off – 1	67	133	66.50
Off – 2	44	156	78.00

***Out of 200 seeds of each cultivar**

Table 2: % of fungal infections on seeds of ten cultivars of sesame (%)

Fungus	01-M	02-M	03-M	E8	Ex sudan	Oke	Any	ILO	Off-1	Off-2
Aspergillus niger	15.50	0.00	0.00	8.50	7.50	5.00	8.40	9.25	0.00	6.30
Aspergillus flavus	10.30	0.00	0.00	7.20	6.50	6.50	8.00	8.40	0.00	6.10
Penicillium sp	5.00	7.50	5.20	6.00	0.00	0.00	5.30	0.00	0.00	0.00

The following figures show the effectiveness of the bark extracts. They concluded that with the ready availability of these trees and the ease of extraction, this would be a farmer methodology to reduce the fungi on the seed.

Table 3: Inhibitory effect of cashew bark extract (*A. occidentale*) on mycelial growth of the fungi.

Concentration (%)	Mean percentage *Aspergillus*	Inhibition ± SE (%) *Penicillium*
Control (0)	$0.00.0\pm0.0^{a}$	$0.00.0\pm0.0^{a}$
40	$98.87.0\pm0.4^{b}$	$50.92.0\pm6.9^{b}$
60	100.0 ± 0.0^{c}	64.76 ± 7.8^{bc}
80	100.0 ± 0.0^{c}	76.64 ± 5.4^{cd}
100	100.0 ± 0.0^{c}	92.80 ± 2.8^{d}

In each fungus, means followed by the same letter are not significantly different ($P \leq 0.05$).

Table 4: Inhibitory effects of Mango bark extract (*Mangifera indica*) on mycelial growth of the fungi.

Concentration (%)	Mean percentage *Aspergillus*	Inhibition ± SE (%) *Penicillium*
Control (0)	$0.00.0\pm0.0^{a}$	$0.00.0\pm0.0^{a}$
40	$98.3.0\pm0.6^{b}$	$46.22.0\pm7.9^{b}$
60	99.2 ± 0.3^{bc}	50.82 ± 7.5^{bc}
80	100.0 ± 0.0^{c}	68.25 ± 6.1^{cd}
100	100.0 ± 0.0^{c}	81.15 ± 5.4^{d}

- B. Doka (2014) reported aflatoxins (B_1 B_2 and G_1 G_2) produced by *Aspergillus flavus* can be poisonous to people and livestock and cannot be exported. Aflatoxin contamination can occur in the field, before harvest, during harvesting and post-harvest handling processes, e.g. field sun-drying, storage, and transportation of product. The soil in the field is known to be an excellent storage medium for *Aspergillus* spp. Pre-harvest contamination is influenced by soil moisture and temperature and is likely to be most serious under drought conditions. Postharvest aflatoxin contamination occurs if the seeds become moist and/or damaged and can occur at harvest or later.
- C.N. Ezekiel et al. (2014) isolated the following fungi on sesame seeds: *Aspergillus flavus*. The following were the ranges of aflatoxins found on the sesame.

Concentration (µg/kg) of aflatoxins from toxigenic species

		A. flavus		*A. parvisclerotigenus*			
		B	G	B	G	Total B	Total G
Sesame	Range	75.8–326.1	–	215.6–1011.2	363.2–1980.7	75.8–1011.2	363.2–1980.7
	Mean[1]	190.1b	–	601.3	863.9	597.1a	863.9

- C.A. Amienyo et al. (2015) studied the effect of mycoflora collected from 5 markets on the deterioration of lipid content of seed. Visually healthy seeds were inoculated with spores of each of the nine fungi isolated

from diseased seeds and incubated at 25+20°C for 7days. The healthy and fungal infected seeds were analyzed for their lipid content. The percentage incidence at the 5 locations is shown below.

Fungi incidence	Location				
	A	B	C	D	E
Alternaria alternate	6.6	3.6	3.2	2.0	0.0
Aspergillus chevalieri	10.3	4.2	5.0	0.0	0.0
Aspergillus niger	0.0	6.1	7.4	2.6	5.2
Aspergillus oryzae	3.3	4.0	0.0	0.0	0.0
Aspergillus flavus	3.9	3.1	2.7	0.0	0.0
Aspergillus terreus	4.8	11.2	2.4	13.0	0.0
Cochliobolus Spp.	9.5	0.0	0.0	0.0	0.0
Geotrichum candidum	0.0	0.0	0.0	0.0	3.5
Phoma Spp.	5.9	2.0	0.0	0.0	0.0

Fungi utilize basic compounds of the seeds for their metabolism and growth and may affect the germination rate of the seed. The uninoculated seed had 49.35% lipid. The following shows the lipid content after 7 days of infection.

Fungi	Lipid content (%)
Aspergillus chevalieri	42.40
Aspergillus oryzae	43.50
Aspergillus niger	45.00
Aspergillus terreus	45.45
Alternaria alternata	47.80
Cochliobolus Spp	48.10
Aspergillus flavus	48.70
Phoma Spp.	49.15
Geotrichum candidum	49.40

- A.D. Ojochenemi et al. (2015) examined 46 samples of sesame and reported *Aspergillus flavus*.
- S.T. Anjorin et al. (2016) studied the effects of 6 botanicals (baobab [*Adansonia digitate*] leaf powder, hot pepper [*Capsicum annum*] fruits, and ordeal tree [*Erythrophleum suaveolens*] bark and leaves, garlic bulbs and ginger rhizomes) against fungi isolated from sesame seeds (*Aspergillus niger, Aspergillus flavus, Mucor* spp., *Fusarium* spp., *Alternaria* spp. And *Penicillium* spp.). The ginger, garlic, and ordeal bark were not effective. The results of the effective treatments were as follows.

Sesame seeds treated with plant extracts	*Aspergillusniger*	*Fusarium*spp.	*Aspergillusflavus* (cfug/ml)	*Penicillium* spp.	*MucorAlternaria* spp. spp.
Baobab leaf extract (100%)	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{b}	0.00^{b} 0.00^{b}
Baobab leaf extract (10%)	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{b}	0.00^{b} 0.00^{b}
Ordeal leaf extract(100%)	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{b}	0.00^{b} 0.00^{b}
Ordeal leaf extract(10%)	0.00^{c}	1.00^{bc}	0.00^{c}	1.00^{b}	0.00^{b} 0.00^{b}
Hot pepper fruit extract(100%)	4.00^{b}	2.00^{b}	0.00^{c}	4.00^{a}	1.00^{ab} 0.00^{b}
Hot pepper fruit extract(10%)	5.00^{b}	2.00^{b}	0.00^{c}	0.00^{b}	1.00^{ab} 0.00^{b}
Untreated sesame seed before storage	7.00^{a}	5.00^{a}	4.00^{a}	5.00^{a}	1.00^{ab} 2.00^{a}
Untreated sesame seed after storage	5.00^{b}	5.00^{a}	2.00^{b}	4.00^{a}	2.00^{a} 1.00^{b}

- A.O. Esan et al. (2020) purchased 60 sesame samples from markets in Nasarawa states during 2 seasons (wet and dry) in order to determine the safety for human consumption. They identified the following fungi: *Aspergillus* section *candidi*, *Aspergillus* section *flavi* (*A. flavus* and *A. tamarii*), *Aspergillus* section *nigri, Cladosporium* sp., *Fusarium fujikuroi, Penicillium* spp., and Didymellaceae. [For the toxins found refer to section G1 Toxin producing mycoflora.]

PAKISTAN

- B.G. Nayyar et al. (2013) examined 15 samples of seed to detect fungi using 3 methods: agar plate, blotter, and deep freezing and found *Aspergillus flavus.*
- B.G. Nayyar et al. (2014) studied the effects of fungal pathogens on the germination of sesame. Seven prevalent fungal species viz. *Alternaria alternata, Aspergillus flavus, Aspergillus niger, Cercospora* sp., *Fusarium oxysporum, Penicillium egyptiacum* and *Rhizopus oryzae* associated with sesame seeds were selected for this study. Fungi associated with seeds affected the seed health and resulted in reduced seed germination, and seedling abnormality as shown in the table below.

Treatments	Normal seedlings %age	Abnormal seedlings %age	Un germinated seeds %age	Fungi isolated
Surface sterilized seeds	80	14	6	*Aspergillus flavus* *Aspergillus niger* *Fusarium oxysporum*
Naturally infected seeds	64	26	10	*Alternaria alternata* *Aspergillus flavus* *Aspergillus niger* *Fusarium oxysporum* *Penicillium egyptiacum*

The pathogenicity of the 7 fungi was tested with the following results.

S. No.	Fungi isolated	Pathogenic Effect	Healthy Plants
1	*A. alternata*	Infected root & stem, Weak stem, Reduced growth	55%
2	*A. flavus*	Reduced growth	70%
3	*A. niger*	Reduced growth, Infected roots, Weak stem	13%
4	*Cercospora* sp.	Infected stem, Weak stem, Reduced growth	40%
5	*P. egyptiacum*	Infected root, Weak stem	26%
6	*R. oryzae*	Reduced growth, Infected roots & stem, Weak stem	30%
7	*F. oxysporum*	Reduced growth, Leaves short & infected	32%

Abnormality rate of seedlings depends on the type of pathogens with which they are infected. There is also need for the management programs to control seedborne pathogens and reduce their impact on sesame production.

- M. Ajmal et al. (2021) evaluated the incidence of mycobiota and contamination of AFB_1 in sesame seeds from rainfed and irrigated zones of the Punjab, Pakistan. *Aspergillus flavus* was the leading contaminant found in fresh and stored sesame seeds from rainfed and irrigated zone followed by *A. niger*, *Alternaria alternata* and *Fusarium oxysporum*. Least reported fungi were *Aspergillus ochraceus* and *Cladosporium oxysporum*. AFB_1 analysis revealed that 92% fresh and 99% stored samples were contaminated with AFB_1. 20% fresh and 100% stored samples from rainfed zone and 28% fresh and 60% stored samples from irrigated zone were tainted with AFB_1 levels above 20 ppb and not fit for human consumption.

SENEGAL

- P.M. Diedhiou et al. (2011) studied *Aspergillus flavus* and aflatoxin colonization from 5 districts. They looked at 500 isolates (20 from each sample from 5 villages in the 5 districts). The colony color, spore morphology and aflatoxin profile of various species and strains of Aspergillus section Flavi were as follow.

Aspergillus species	Strain	Colony colour	Spore morphology	Sclerotia diameter (μm)	Aflatoxin B_1	Aflatoxin B_2	Aflatoxin G_1	Aflatoxin G_2
A. flavus	L	Greenish yellow	Smooth	>400	±	±	–	–
A. flavus	S	Greenish yellow	Smooth	<400	+	+	–	–
Unnamed taxon	S_{BG}	Greenish yellow	Smooth	<400	+	+	+	+
A. parasiticus	na	Dark green	Echinulate	na	+	+	+	+
A. tamarii	na	Brown	Echinulate	na	–	–	–	–

na, not applicable; +, produces aflatoxin; –, does not produce aflatoxin; ±, some strains are aflatoxigenic and others not.

- The aflatoxin content of sesame and the cfu load were very low for the two conservation methods (living room and storage) used by farmers. The results were as follow.

AEZ	District	Number isolated	Toxigenic (%)	*A. flavus* (%)	Strain S_{BG} (%)	*A. tamarii* (%)
SG	Kolda	100	51	87	13	0
	Sedhiou	100	32	75	25	0
	Mean	–	41.5	81	19	0
SS	Kaffrine	100	70	97	3	0
	Tambacounda	100	33	93	7	0
	Nioro	100	41	79	21	0
	Mean	–	48	89.6	10.3	0
	LSD[a]	–	24.6	19.5	19.5	0

		B-aflatoxin (ng/g)[a]		CFU/g[b]	
AEZ	District	Mean	Range	Mean	Range

SG	Kolda	0.3	0–1.0	483	13–2000
	Sedhiou	0.1	0–0.2	200	17–800
SS	Kaffrine	0.2	0–0.3	230	100–350
	Nioro	0.3	0–1.2	9400	200–42 800
	Tambacounda	0.1	0–0.2	120	100–200
	LSD[c]	0.4	–	11 042	–

[a]Only aflatoxin B_1 was detected in both maize and sesame samples.
[b]CFU = colony-forming units per gram of sample; mean of five locations (one field per location).

SIERRA LEONE

- F.E. Jonsyn (1988) sampled the fungi in 4 different geographical areas and found three toxigenic Aspergillus species: *A. flavus* Link ex Fries, *A. ochraceus* Wilhelm, and *A. tamarii* Kita were common to all samples. *Penicillium citrinum* Thom and two Fusarium sp. were found in samples from two localities. The mycotoxins aflatoxin B_1 and G_1, ochratoxin A and B, and citrinin were positively identified. [Based on abstract]
- F.E. Jonsyn (1990) examined 49 samples of seed. *Aspergillus* spp were the dominant group irrespective of the locality. Toxigenic Aspergillus included *Aspergillus flavus* Link ex Fries, *Aspergillus tamarii* Kita and *Aspergillus ochraceus* Wilhelm. *Penicillium citrinum* Thom was the only toxigenic Penicillium isolated. [Based on abstract]

SUDAN

- M.A.F. Khamees and E. Schlosser (1990) reported *Aspergillus flavus* was present in 77% of samples of 165 Sudanese sesame seed samples. [Based on abstract]
- N.M.A. Hamid (2006) identified the following fungus from seed collected from 3 areas of Sudan: *Aspergillus flavus.*
- H.I.H. Idriss (2016) collected farmer saved red and white sesame from 7 locations in Sudan. 14 different fungi representing ten genera were identified. One of the predominant fungi was *Aspergillus flavus*.

THAILAND

- A. Chinaputi (2005) sampled 375 samples of black sesame and 285 samples of white sesame collected from local markets in Bangkok over 8 months. For black seeds, the amount of aflatoxin contamination was an average of 91.7% and the amount was 0.4-179.4 microgram/kg (ppb). Among the contaminated samples, 25% were over the maximum level limit (20 ppb). Low amount and low percentage of contaminated samples were found in the white seeds. *Aspergillus flavus* was found in all the samples with aflatoxin.

UNITED STATES

- P.K. Chang et al. (2020) reported a collection of 500 *Aspergillus flavus* isolates from four sesame varieties (S-34, S-35, S-38, and S-39) that were planted in field plots in the Mississippi Delta and in the Florida Panhandle were investigated because of low-level aflatoxin contamination detected in sesame seeds. A rapid molecular fingerprinting method was developed to assess the influence of prior applications of the atoxigenic Afla-Guard® biocontrol product whose active strain is NRRL21882 on the *A. flavus* populations within each field plot. Depending on sesame seed sampled, 66.7% to 95.9% of *A. flavus* isolates from Mississippi belonged to the NRRL21882 genotype, which lacks the aflatoxin and cyclopiazonic acid biosynthesis gene clusters. In contrast, only 5.0% to 32.5% of the isolates from Florida had lost both gene clusters. The high incidence of NRRL21882-like *A. flavus* in Mississippi sesame samples can be attributed to prior applications of Afla-Guard® in that local area. The results suggest the adaptability of this particular type of atoxigenic *A. flavus* biocontrol strain in the field.

VENEZUELA

- Y. Martinez et al. (1991) in studying aflatoxin reported the following fungi on sesame: *Aspergillus flavus.*

A13.1.1b *Aspergillus niger* (22 Apr 2021)

Aspergillus niger affects seed quality (A13.1.1b) and has been used as a biocontrol (E2.1.2a).

Family: Trichocomaceae

Definition: Amount of tolerance to *Aspergillus niger* van Tieghem 1867.

(Wikipedia, 22 Apr 2021) ***Aspergillus niger*** is a fungus and one of the most common species of the genus *Aspergillus*. It causes a disease called "black mold" on certain fruits and vegetables such as grapes, apricots, onions, and peanuts, and is a common contaminant of food. It is ubiquitous in soil and is commonly reported from indoor environments, where its black colonies can be confused with those of *Stachybotrys* (species of which have also been called "black mold").

Some strains of *A. niger* have been reported to produce potent mycotoxins called ochratoxins; other sources disagree, claiming this report is based upon misidentification of the fungal species. Recent evidence suggests some true *A. niger* strains do produce ochratoxin A. It also produces the isoflavone orobol.

References:

INTERNATIONAL

- CAB International (accessed 12 Apr 2021) reported sesame was a minor host of *Aspergillus niger* (Black mold of onion).

ALGERIA

- N.A. Mimoune et al. (2016) examined 12 samples from the market and isolated *Aspergillus niger*, which did not produce ochratoxin A.

BANGLADESH

- M.D. Hosen and S. Shamsi (2017) isolated the following fungus from sesame seeds: *Aspergillus niger*. They evaluated the effects of fungicides (Bavistin DF, Capvit 50 WP, Dithane M-45, Ridomil Gold MZ 68 WG and Tilt 250 EC at 100, 200, 300, 400 and 500 ppm) and plant extracts (*Allium sativum* L. (bulb), *Azadirachta indica* A. Juss. (leaf), *Citrus limon* (L.) Burm. F. (leaf), *Mangifera indica* L. (leaf) and *Psidium guajava* L. (leaf) at 5, 10, 15 and 20%) against both *Aspergillus niger* and *Fusarium merismoides*. The results of the fungicides were as follow.

Name of fungicides	% inhibition of radial growth at different concentrations (ppm)				
	100	200	300	400	500
Bavistin DF	100[a]	100[a]	100[a]	100[a]	100[a]
Capvit 50 WP	0.0[NS]	0.0[NS]	0.0[NS]	0.0[NS]	0.0[NS]
Dithane M-45	43.82[a]	52.62[a]	56.18[a]	57.30[a]	60.67[a]
Ridomil MZ Gold	47.75[a]	53.37[a]	70.00[a]	100[a]	100[a]
Tilt 250 EC	87.08[a]	88.76[a]	92.70[a]	97.75[a]	98.88[a]

The results of the plant extracts were as follow.

Name of plant	% inhibition of radial growth of the pathogen at different conc. (%)			
	5	10	15	20
Allium sativum	100[a]	100[a]	100[a]	100[a]
Azadirachta indica	64.04[a]	66.29[a]	67.42[a]	82.02[a]
Citrus limon	74.16[a]	78.65[a]	79.78[a]	80.90[a]
Mangifera indica	0.0[NS]	67.98[a]	70.79[a]	74.16[a]
Psidium guajava	0.0[NS]	0.0[NS]	0.0[NS]	75.84[a]

EGYPT

- I.A. El-Kady et al. (1986) reported isolating *Aspergillus niger* from market samples.
- H.A.H. Hasan (2002) reported *Aspergillus niger* was a pathogen in the rhizosphere and rhizoplane. [Cited by S.I.I. Abdel-Hafez, 2012]
- M.M.I. Abdel-Hafez et al. (2014) took ten samples of sesame from local markets in Assiut city. They found *Aspergillus niger* van Tieghem.
- A. Hashem et al. (2014) collected 18 seed samples of sesame in Egypt (12 samples) and Saudi Arabia (6 samples). They identified the following mycoflora: *Aspergillus niger.*
- B.A. Sabry et al. (2016) in Egypt studied 28 sesame samples collected from food stores in different governates. They found the following fungi.

Governorate	NC/ TNS	Fungal load (log_{10} CFU/g)		Percentage occurrence of fungal genera				
		Range	Mean ± SD	*Alternaria*	*Aspergillus*	*Fusarium*	*Penicillium*	*Cladosporium*
Great Cairo	4/4	1.72 –2.32	1.91±0.77[a]	34.21	60.53	2.63	ND	2.63
Kalioubia	3/3	1.72 –2.32	1.97±1.03[a]	4.17	91.66	ND	4.17	ND
Alexandria	6/6	1.72 –2.67	1.99±1.63[a]	4.35	82.61	6.52	ND	6.52
El-Behera	5/5	1.72 –2.87	2.15±1.63[b]	ND	71.82	0.91	17.27	10.00
Kafr El-Sheik	5/5	1.72 –2.80	2.26±2.72[c]	3.96	60.40	1.98	17.82	15.84
Dakahlia	5/5	1.72 –3.02	2.52±0.70[d]	ND	79.68	1.59	6.37	12.35

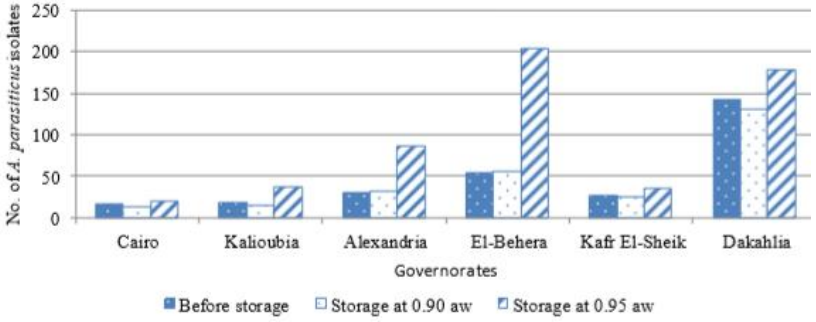
NC: Number of contaminated samples; TNS: Total number of samples
Mean with different superscript letters are significantly different

They found the following *Aspergillus* sp.

Governorate	NC/ TNS	*Aspergillus* load (log_{10}CFU/g)		Percentage occurrence of *Aspergillus* species		
		Range	Mean ± SD	*Aspergillus parasiticus*	*Aspergillus flavus*	*Aspergillus niger*
Great Cairo	1/4	1.72 –2.32	1.96±0.86[a]	69.56	8.69	21.75
Kalioubia	1/3	1.72 –2.32	2.02±1.09[a]	77.27	4.54	18.18
Alexandria	1/6	1.72 –2.67	2.02±1.77[a]	78.95	ND	21.05
El-Behera	3/5	1.72 –2.87	2.23±3.09[b]	67.08	ND	32.91
Kafr El-Sheik	3/5	1.72 –2.80	2.37±3.41[b]	42.62	ND	57.38
Dakahlia	3/5	2.20 –3.02	2.69±0.75[c]	71.00	ND	29.00

NC: Number of contaminated samples; TNS: Total number of samples

Stored sesame samples at the higher water activity (a_w 0.95) showed an increase of total fungal count compared with samples stored at a lower water activity (a_w 0.90).



They found the following percentages and levels of aflatoxins.

Governorates	TNS	Aflatoxin B_1		Aflatoxin B_2		Aflatoxin G_1		Aflatoxin G_2	
		µg/kg	%	µg/kg	%	µg/kg	%	µg/kg	%
Great Cairo	4	18.63 ± 0.79	100	ND	ND	18.27 ± 1.31	100	ND	ND
Kalioubia	3	23.25 ± 0.93	100	ND	ND	21.33 ±1.22	66.66	ND	ND
Alexandria	6	21.04 ± 2.32	66.66	0.28 ± 0.10	33.33	51.47 ± 2.18	33.33	1.55 ± 0.59	16.66
El-Behera	5	66.74 ± 1.71	60.00	0.42 ± 0.07	40.00	43.81 ± 2.10	80.00	ND	ND
Kafr El-Sheik	5	29.94 ± 1.02	100	ND	ND	14.88 ± 1.55	80.00	ND	ND
Dakahlia	5	42.37 ± 1.34	100	0.19 ± 0.10	20.00	27.51 ±1.07	100	0.12 ± 0.13	20.00

Results are mean ± SD (n=3); TNS: Total number of samples

Roasting or microwaving can reduce the amount of aflatoxins but will not eliminate them. The following table shows the percentage reduction under several trials.

Treatment Time	Roasting		Microwave (20 kgy)
	100°C	150°C	
5	-	-	18.14±0.024
20	5.33±0.026	11.50±0.079	-
30	7.21±0.011	14.14±0.090	-

Results are mean ±SD (n=3)

INDIA

- B.K. Singh and T. Prasad (1979) reported *Aspergillus flavus* and *Aspergillus niger* inoculations decreased the cholesterol level of the seed. [Cited by G.S. Saharan, 1989]
- B. Nandi et al. (1981) reported *Aspergillus niger* and *A. fumigatus* caused deterioration of sesame seeds in storage.
- R.K.S. Chauhan and B.M. Kulshrestha (1984b) reported the diffusate obtained from the fruit cavities of sesame inoculated with a spore suspension of *Alternaria sesami* was inhibitory to the germination of spores of *Aspergillus niger*.
- K. Kumar et al. (1984a) reported *Aspergillus niger* was found to be associated with the seeds of varieties T-4 and T-12. The species was pathogenic and reduced germination by causing seed rot under laboratory conditions.
- N. Saxena and D. Karan (1991) reported seeds of sesame cv. T-85 collected in Andhra Pradesh had *Aspergillus niger*. Seed protein and carbohydrate contents were analyzed before and 10, 20 and 30 days after inoculation. The fungi decreased protein and carbohydrate contents. It is suggested that the fungi contain a protein hydrolyzing enzyme, and the carbohydrate is consumed and converted into carbon dioxide and water. [Based on abstract]
- K. Bhattachary and S. Raha (2002) studied fungal infection, moisture content, germinability and deterioration of sesame in storage under natural conditions for a year. Different species of Aspergillus (*A. candidus*, A. *flavus, A. niger, A. terreus*, and *A. ruber*) were dominant followed by Rhizopus, Penicillium, Curvularia, Fusarium, Alternaria, etc. Seed moisture was maximum in the rainy season followed by a gradual decrease during longer storage. As storage proceeded, there was a gradual decrease in field fungi with simultaneous increase in storage fungi, and a reduction in germinability. A gradual loss of carbohydrate (both soluble and insoluble) content was recorded. A loss of protein content was recorded followed by a small increase. Oil content decreased in prolonged storage with simultaneous increase in fatty acid. [Based on abstract]
- G.C. Mondal and B. Nandi (2006) studied the deteriorative efficacy of storage fungi through change in the quality of different edible oils. Maximum loss of oil was recorded with *Aspergillus niger*. Refractive indices of oil decreased in most of the cases with concomitant increase in free fatty acids. The deteriorated oil samples showed change in color, saponification value and iodine value with longer incubation which depended partly on the fungus involved and partly on the type of substrate. Both *A. niger* and *A. fumigatus* produced higher amount of lipase than others. Production of lipase enzyme and mycelia were always higher on emulsified oil than on seed meal media. [Based on abstract]
- N.O. Srikantappa et al. (2009) studied 28 samples of sesame taken from fields, farmers, retail shops and APMC markets from 5 areas. They found 34 four fungi including *Aspergillus niger*. The fungi significantly reduced germination.
- V. Bharathi et al. (2013) collected sesame seeds from farmers in Andhra Pradesh. They tested the seeds for mycoflora, and the following fungus was found: *Aspergillus niger*.
- P.L. Radha (2013) collected 18 cultivars from 7 districts in Karnataka and identified the following fungus: *Aspergillus niger*.
- H.R. Aglave (2016) screened two varieties (CV.N-85 and CV. Phule-1) for seed mycoflora. Twenty-seven fungi were isolated from these varieties. Varietal variation was found during the investigation. The following fungus was present *Aspergillus niger*.
- B. Khamari et al. (2018e) collected 15 sesame seed samples from different localities of Odisha reported the infestation of *Aspergillus niger* ranged from 1 to 6.5%.

IRAN

- M. Gooya et al. (2000) took one seed samples of each 17 sesame cultivars from 10 locations leading to 145 isolates during 1997/99 They identified *Aspergillus niger*.

IRAQ

- F. Al-Refaee (2005) collected sesame seeds from 6 regions of Iraq and isolated *Aspergillus niger*.
- N.A. Saad et al. (2013) examined seed and found the following fungus: *Aspergillus niger*.

NIGERIA

- F.M. Afolagboye (2011) studied the effects of hot and cold water leaf extracts (*Lantana camara, Bryophyllum pinnatum, Eichornia crassipes, Lawsonia innermis* and *Zingiber officinale*) on 2 fungi (*Aspergillus niger* and *Aspergillus flavus*) using 4 sesame varieties (NCRIBEN 03L, NCRIBEN 01M, E8 and 530-6-1). Hot water extract of all test plants exhibited strong fungitoxicity (84.0-92.1% mycelial growth inhibition) against *Aspergillus niger* while *Aspergillus flavus* was most sensitive to hot water extract of *Z. officinale*. Mycelial growth inhibition of *Aspergillus flavus* by cold water extracts of the tested plants ranged between 18.3 and 73.2%. The plant extracts have potential for management of seedborne fungi of sesame. [Based on abstract]
- M.N. Suleiman et al. (2013) studied the effect of barks (*Anacadium occidentale* [cashew] and *Mangifera indica* [mango]) on mycoflora (*Aspergillus niger, Aspergillus flavus* and *Penicillium* sp) using 10 cultivars. The following figures show the fungal incidence on the cultivars and the distribution on the fungi.

Table 1: Fungal Incidence on Seeds of ten sesame cultivars

Cultivars	Normal seeds*	Infected seeds*	Fungal incidence (%)
01 – M	10	190	95.00
02 – M	25	175	87.50
03 – M	53	147	73.50
E8	05	195	97.50
Ex sudan	41	159	79.50
Oke	24	176	88.00
Any	12	188	94.00
1Lo	61	139	69.50
Off – 1	67	133	66.50
Off – 2	44	156	78.00

***Out of 200 seeds of each cultivar**

Table 2: % of fungal infections on seeds of ten cultivars of sesame (%)

Fungus	01-M	02-M	03-M	E8	Ex sudan	Oke	Any	ILO	Off-1	Off-2
Aspergillus niger	15.50	0.00	0.00	8.50	7.50	5.00	8.40	9.25	0.00	6.30
Aspergillus flavus	10.30	0.00	0.00	7.20	6.50	6.50	8.00	8.40	0.00	6.10
Penicillium sp	5.00	7.50	5.20	6.00	0.00	0.00	5.30	0.00	0.00	0.00

The following figures show the effectiveness of the bark extracts. They concluded that with the ready availability of these trees and the ease of extraction, this would be a farmer methodology to reduce the fungi on the seed.

Table 3: Inhibitory effect of cashew bark extract (*A. occidentale*) on mycelial growth of the fungi.

Concentration (%)	Mean percentage *Aspergillus*	Inhibition ± SE (%) *Penicillium*
Control (0)	$0.00.0\pm0.0^{a}$	$0.00.0\pm0.0^{a}$
40	$98.87.0\pm0.4^{b}$	$50.92.0\pm6.9^{b}$
60	100.0 ± 0.0^{c}	64.76 ± 7.8^{bc}
80	100.0 ± 0.0^{c}	76.64 ± 5.4^{cd}
100	100.0 ± 0.0^{c}	92.80 ± 2.8^{d}

In each fungus, means followed by the same letter are not significantly different ($P \leq 0.05$).

Table 4: Inhibitory effects of Mango bark extract (*Mangifera indica*) on mycelial growth of the fungi.

Concentration (%)	Mean percentage *Aspergillus*	Inhibition ± SE (%) *Penicillium*
Control (0)	$0.00.0\pm0.0^{a}$	$0.00.0\pm0.0^{a}$
40	$98.3.0\pm0.6^{b}$	$46.22.0\pm7.9^{b}$
60	99.2 ± 0.3^{bc}	50.82 ± 7.5^{bc}
80	100.0 ± 0.0^{c}	68.25 ± 6.1^{cd}
100	100.0 ± 0.0^{c}	81.15 ± 5.4^{d}

- C.A. Amienyo et al. (2015) studied the effect of mycoflora collected from 5 markets on the deterioration of lipid content of seed. Visually healthy seeds were inoculated with spores of each of the nine fungi isolated

from diseased seeds and incubated at 25+20°C for 7days. The healthy and fungal infected seeds were analyzed for their lipid content. The percentage incidence at the 5 locations is shown below.

Fungi incidence	Location				
	A	B	C	D	E
Alternaria alternate	6.6	3.6	3.2	2.0	0.0
Aspergillus chevalieri	10.3	4.2	5.0	0.0	0.0
Aspergillus niger	0.0	6.1	7.4	2.6	5.2
Aspergillus oryzae	3.3	4.0	0.0	0.0	0.0
Aspergillus flavus	3.9	3.1	2.7	0.0	0.0
Aspergillus terreus	4.8	11.2	2.4	13.0	0.0
Cochliobolus Spp.	9.5	0.0	0.0	0.0	0.0
Geotrichum candidum	0.0	0.0	0.0	0.0	3.5
Phoma Spp.	5.9	2.0	0.0	0.0	0.0

Fungi utilize basic compounds of the seeds for their metabolism and growth and may affect the germination rate of the seed. The uninoculated seed had 49.35% lipid. The following shows the lipid content after 7 days of infection.

Fungi	Lipid content (%)
Aspergillus chevalieri	42.40
Aspergillus oryzae	43.50
Aspergillus niger	45.00
Aspergillus terreus	45.45
Alternaria alternata	47.80
Cochliobolus Spp	48.10
Aspergillus flavus	48.70
Phoma Spp.	49.15
Geotrichum candidum	49.40

- A.D. Ojochenemi et al. (2015) examined 46 samples of sesame and reported *Aspergillus niger*.
- S.T. Anjorin et al. (2016) studied the effects of 6 botanicals (baobab [*Adansonia digitate*] leaf powder, hot pepper [*Capsicum annum*] fruits, and ordeal tree [*Erythrophleum suaveolens*] bark and leaves, garlic bulbs and ginger rhizomes) against fungi isolated from sesame seeds (*Aspergillus niger, Aspergillus flavus, Mucor* spp., *Fusarium* spp., *Alternaria* spp. And *Penicillium* spp.). The ginger, garlic, and ordeal bark were not effective. The results of the effective treatments were as follows.

Sesame seeds treated with plant extracts	*Aspergillusniger*	*Fusarium*spp.	*Aspergillusflavus* (cfug/ml)	*Penicillium* spp.	*MucorAlternaria* spp. spp.
Baobab leaf extract (100%)	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{b}	0.00^{b} 0.00^{b}
Baobab leaf extract (10%)	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{b}	0.00^{b} 0.00^{b}
Ordeal leaf extract(100%)	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{b}	0.00^{b} 0.00^{b}
Ordeal leaf extract(10%)	0.00^{c}	1.00^{bc}	0.00^{c}	1.00^{b}	0.00^{b} 0.00^{b}
Hot pepper fruit extract(100%)	4.00^{b}	2.00^{b}	0.00^{c}	4.00^{a}	1.00^{ab} 0.00^{b}
Hot pepper fruit extract(10%)	5.00^{b}	2.00^{b}	0.00^{c}	0.00^{b}	1.00^{ab} 0.00^{b}
Untreated sesame seed before storage	7.00^{a}	5.00^{a}	4.00^{a}	5.00^{a}	1.00^{ab} 2.00^{a}
Untreated sesame seed after storage	5.00^{b}	5.00^{a}	2.00^{b}	4.00^{a}	2.00^{a} 1.00^{b}

PAKISTAN

- B.G. Nayyar et al. (2013) examined 15 samples of seed to detect fungi using 3 methods: agar plate, blotter, and deep freezing and found *Aspergillus niger*.
- B.G. Nayyar et al. (2014) studied the effects of fungal pathogens on the germination of sesame. Seven prevalent fungal species viz. *Alternaria alternata, Aspergillus flavus, Aspergillus niger, Cercospora* sp., *Fusarium oxysporum, Penicillium egyptiacum* and *Rhizopus oryzae* associated with sesame seeds were selected for this study. Fungi associated with seeds affected the seed health and resulted in reduced seed germination, and seedling abnormality as shown in the table below.

Treatments	Normal seedlings %age	Abnormal seedlings %age	Un germinated seeds %age	Fungi isolated
Surface sterilized seeds	80	14	6	*Aspergillus flavus* *Aspergillus niger* *Fusarium oxysporum*
Naturally infected seeds	64	26	10	*Alternaria alternata* *Aspergillus flavus* *Aspergillus niger* *Fusarium oxysporum* *Penicillium egyptiacum*

The pathogenicity of the 7 fungi was tested with the following results.

S. No.	Fungi isolated	Pathogenic Effect	Healthy Plants
1	*A. alternata*	Infected root & stem, Weak stem, Reduced growth	55%
2	*A. flavus*	Reduced growth	70%
3	*A. niger*	Reduced growth, Infected roots, Weak stem	13%
4	*Cercospora* sp.	Infected stem, Weak stem, Reduced growth	40%
5	*P. egyptiacum*	Infected root, Weak stem	26%
6	*R. oryzae*	Reduced growth, Infected roots & stem, Weak stem	30%
7	*F. oxysporum*	Reduced growth, Leaves short & infected	32%

Abnormality rate of seedlings depends on the type of pathogens with which they are infected. There is also need for the management programs to control seedborne pathogens and reduce their impact on sesame production.

- M. Ajmal et al. (2021) evaluated the incidence of mycobiota and contamination of AFB_1 in sesame seeds from rainfed and irrigated zones of the Punjab, Pakistan. *Aspergillus flavus* was the leading contaminant found in fresh and stored sesame seeds from rainfed and irrigated zone followed by *A. niger*, *Alternaria alternata* and *Fusarium oxysporum*. Least reported fungi were *Aspergillus ochraceus* and *Cladosporium oxysporum*. AFB_1 analysis revealed that 92% fresh and 99% stored samples were contaminated with AFB_1. 20% fresh and 100% stored samples from rainfed zone and 28% fresh and 60% stored samples from irrigated zone were tainted with AFB_1 levels above 20 ppb and not fit for human consumption.

SUDAN

- N.M.A. Hamid (2006) identified the following fungus from seed collected from 3 areas of Sudan: *Aspergillus niger*.
- H.I.H. Idriss (2016) collected farmer saved red and white sesame from 7 locations in Sudan. 14 different fungi representing ten genera were identified. One of the predominant fungi was *Aspergillus niger*.

VENEZUELA

- Y. Martinez et al. (1991) in studying aflatoxin reported the following fungi on sesame: *Aspergillus niger*.

A13.1.1c *Aspergillus parasiticus* (7 May 2021)

Family: Trichocomaceae

Definition: Amount of tolerance to *Aspergillus parasiticus* Speare 1912.

(Wikipedia, 7 May 2021) ***Aspergillus parasiticus*** is a fungus belonging to the genus *Aspergillus*. This species is an unspecialized saprophytic mold, mostly found outdoors in areas of rich soil with decaying plant material as well as in dry grain storage facilities. Often confused with the closely related species, *A. flavus*, *A. parasiticus* has defined morphological and molecular differences. *Aspergillus parasiticus* is one of three fungi able to produce the mycotoxin, aflatoxin, one of the most carcinogenic naturally occurring substances. Environmental stress can upregulate aflatoxin production by the fungus, which can occur when the fungus is growing on plants that become damaged due to exposure to poor weather conditions, during drought, by insects, or by birds0. In humans, exposure to *A. parasiticus* toxins can cause delayed development in children and produce serious liver diseases and/or hepatic carcinoma in adults. The fungus can also cause the infection known as aspergillosis in humans and other animals. *A. parasiticus* is of agricultural importance due to its ability to cause disease in corn, peanut, and cottonseed.

References:

ALGERIA

- N.A. Mimoune et al. (2016) examined 12 samples from the market and isolated Aspergillus parasiticus, which produced AFB and AFG.

EGYPT

- A. Hashem et al. (2014) collected 18 seed samples of sesame in Egypt (12 samples) and Saudi Arabia (6 samples). They identified the following mycoflora: *Aspergillus parasiticus.*
- B.A. Sabry et al. (2016) in Egypt studied 28 sesame samples collected from food stores in different governates. They found the following fungi.

Governorate	NC/ TNS	Fungal load (log_{10} CFU/g)		Percentage occurrence of fungal genera				
		Range	Mean ± SD	*Alternaria*	*Aspergillus*	*Fusarium*	*Penicillium*	*Cladosporium*
Great Cairo	4/4	1.72 –2.32	1.91±0.77[a]	34.21	60.53	2.63	ND	2.63
Kalioubia	3/3	1.72 –2.32	1.97±1.03[a]	4.17	91.66	ND	4.17	ND
Alexandria	6/6	1.72 –2.67	1.99±1.63[a]	4.35	82.61	6.52	ND	6.52
El-Behera	5/5	1.72 –2.87	2.15±1.63[b]	ND	71.82	0.91	17.27	10.00
Kafr El-Sheik	5/5	1.72 –2.80	2.26±2.72[c]	3.96	60.40	1.98	17.82	15.84
Dakahlia	5/5	1.72 –3.02	2.52±0.70[d]	ND	79.68	1.59	6.37	12.35

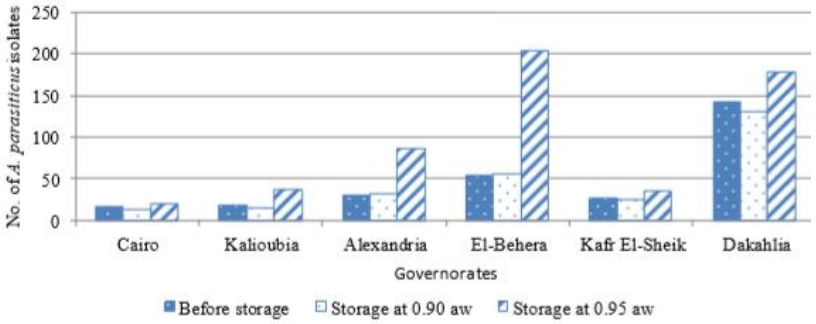
NC: Number of contaminated samples; TNS: Total number of samples
Mean with different superscript letters are significantly different

They found the following *Aspergillus* sp.

Governorate	NC/ TNS	*Aspergillus* load (log_{10}CFU/g)		Percentage occurrence of *Aspergillus* species		
		Range	Mean ± SD	*Aspergillus parasiticus*	*Aspergillus flavus*	*Aspergillus niger*
Great Cairo	1/4	1.72 –2.32	1.96±0.86[a]	69.56	8.69	21.75
Kalioubia	1/3	1.72 –2.32	2.02±1.09[a]	77.27	4.54	18.18
Alexandria	1/6	1.72 –2.67	2.02±1.77[a]	78.95	ND	21.05
El-Behera	3/5	1.72 –2.87	2.23±3.09[b]	67.08	ND	32.91
Kafr El-Sheik	3/5	1.72 –2.80	2.37±3.41[b]	42.62	ND	57.38
Dakahlia	3/5	2.20 –3.02	2.69±0.75[c]	71.00	ND	29.00

NC: Number of contaminated samples; TNS: Total number of samples

Stored sesame samples at the higher water activity (a_w 0.95) showed an increase of total fungal count compared with samples stored at a lower water activity (a_w 0.90).



They found the following percentages and levels of aflatoxins.

Governorates	TNS	Aflatoxin B_1		Aflatoxin B_2		Aflatoxin G_1		Aflatoxin G_2	
		µg/kg	%	µg/kg	%	µg/kg	%	µg/kg	%
Great Cairo	4	18.63 ± 0.79	100	ND	ND	18.27 ± 1.31	100	ND	ND
Kalioubia	3	23.25 ± 0.93	100	ND	ND	21.33 ±1.22	66.66	ND	ND
Alexandria	6	21.04 ± 2.32	66.66	0.28 ± 0.10	33.33	51.47 ± 2.18	33.33	1.55 ± 0.59	16.66
El-Behera	5	66.74 ± 1.71	60.00	0.42 ± 0.07	40.00	43.81 ± 2.10	80.00	ND	ND
Kafr El-Sheik	5	29.94 ± 1.02	100	ND	ND	14.88 ± 1.55	80.00	ND	ND
Dakahlia	5	42.37 ± 1.34	100	0.19 ± 0.10	20.00	27.51 ±1.07	100	0.12 ± 0.13	20.00

Results are mean ± SD (n=3); TNS: Total number of samples

Roasting or microwaving can reduce the amount of aflatoxins but will not eliminate them. The following table shows the percentage reduction under several trials.

Treatment Time	Roasting		Microwave (20 kgy)
	100°C	150°C	
5	-	-	18.14±0.024
20	5.33±0.026	11.50±0.079	-
30	7.21±0.011	14.14±0.090	-

Results are mean ±SD (n=3)

GREECE

- E. Kollia et al. (2014 and 2017) reported aflatoxin B_1 has been considered as the most potent liver carcinogen for humans. Sesame seeds are sensitive to AF-producing fungal invasion, because of their oil content, and may therefore be contaminated with Afs and particularly AFB_1. They studied the possibility of controlling *Aspergillus* with extracts from *Cynara cardunculus* L. (Asteraceae), commonly named "cardoon" or "wild artichoke." They found AFB_1 production in sesame seeds inoculated with *Aspergillus parasiticus* and addition of *C. cardunculus* head extract, was significantly lower (99.6%) compared to AFB_1 production by *A. parasiticus* in sesame seeds (control). Due to its antifungal and anti-aflatoxigenic effectiveness, *C. cardunculus* L. can be used for pre- and post-harvest AF control strategies or during storage. [Based on poster]
- E. Kollia et al. (2016) in Greece examined 30 samples of sesame products for the presence of AFB_1. Aflatoxins are a group of secondary metabolites produced by the species: *Aspergillus flavus, Aspergillus parasiticus* and the rare *Aspergillus nomius*. Among these, aflatoxin B_1 (AFB_1) is the most naturally occurring compound of toxigenic isolates of *Aspergillus* species and the most dangerous contaminant of foods and feeds due to carcinogenic and mutagenic activity. Sesame seeds are sensitive to AF-producing fungal invasion, because of their oil content, and may therefore be contaminated with Afs and particularly AFB_1. [For more information refer to G1 Toxin producing mycoflora]

NIGERIA

- A.D. Ojochenemi et al. (2015) examined 46 samples of sesame and reported *Aspergillus parasiticus*.

SENEGAL

- P.M. Diedhiou et al. (2011) studied *Aspergillus parasiticus* and aflatoxin colonization from 5 districts. They looked at 500 isolates (20 from each sample from 5 villages in the 5 districts). The colony color, spore morphology and aflatoxin profile of various species and strains of Aspergillus section Flavi were as follow.

Aspergillus species	Strain	Colony colour	Spore morphology	Sclerotia diameter (μm)	Aflatoxin B_1	Aflatoxin B_2	Aflatoxin G_1	Aflatoxin G_2
A. flavus	L	Greenish yellow	Smooth	>400	±	±	–	–
A. flavus	S	Greenish yellow	Smooth	<400	+	+	–	–
Unnamed taxon	S_{BG}	Greenish yellow	Smooth	<400	+	+	+	+
A. parasiticus	na	Dark green	Echinulate	na	+	+	+	+
A. tamarii	na	Brown	Echinulate	na	–	–	–	–

na, not applicable; +, produces aflatoxin; –, does not produce aflatoxin; ±, some strains are aflatoxigenic and others not.

A13.1.1d *Aspergillus nomius* (7 May 2021)

Family: Trichocomaceae

Definition: Amount of tolerance to *Aspergillus nomius* Kurtzman, B.W. Horn & Hesseltine 1987.

(Wikipedia, 7 May 2021) ***Aspergillus nomius*** is a species of fungus in the genus *Aspergillus*. It is from the *Flavi* section. The species was first described in 1987. It has been reported to produce aflatoxin B1, aflatoxin B2, aflatoxin G1, aflatoxin G2, aspergillic acid, kojic acid, nominine, paspaline, pseurotin, and tenuazonic acid. *A. nomius* has been identified as the cause of human infections.

References:

GREECE

- E. Kollia et al. (2016) in Greece examined 30 samples of sesame products for the presence of AFB_1. Aflatoxins are a group of secondary metabolites produced by the species: *Aspergillus flavus, Aspergillus parasiticus* and the rare *Aspergillus nomius*. Among these, aflatoxin B_1 (AFB_1) is the most naturally occurring compound of toxigenic isolates of *Aspergillus* species and the most dangerous contaminant of foods and feeds due to

carcinogenic and mutagenic activity. Sesame seeds are sensitive to AF-producing fungal invasion, because of their oil content, and may therefore be contaminated with Afs and particularly AFB_1. [For more information refer to G1 Toxin producing mycoflora]

A13.1.1e *Aspergillus ochraceus* (8 May 2021)

Family: Trichocomaceae

Definition: Amount of tolerance to *Aspergillus ochraceus* K. Wilhelm 1877.

(Wikipedia, 8 May 2021) ***Aspergillus ochraceus*** is a mold species in the genus *Aspergillus* known to produce the toxin ochratoxin A, one of the most abundant food-contaminating mycotoxins, and citrinin. It also produces the dihydroisocoumarin mellein. It is a filamentous fungus in nature and has characteristic biseriate conidiophores. Traditionally a soil fungus, has now began to adapt to varied ecological niches, like agricultural commodities, farmed animal and marine species. In humans and animals, the consumption of this fungus produces chronic neurotoxic, immunosuppressive, genotoxic, carcinogenic and teratogenic effects. Its airborne spores are one of the potential causes of asthma in children and lung diseases in humans. The pig and chicken populations in the farms are the most affected by this fungus and its mycotoxins. Certain fungicides like mancozeb, copper oxychloride, and sulfur have inhibitory effects on the growth of this fungus and its mycotoxin producing capacities.

References:

ALGERIA
- N.A. Mimoune et al. (2016) examined 12 samples from the market and isolated *Aspergillus ochraceus*.

EGYPT
- M.M.I. Abdel-Hafez et al. (2014) took ten samples of sesame from local markets in Assiut city. They found *Aspergillus ochraceus*.
- A. Hashem et al. (2014) collected 18 seed samples of sesame in Egypt (12 samples) and Saudi Arabia (6 samples). They identified the following mycoflora: *Aspergillus ochraceus.*

INDIA
- A. Bose and B. Nandi (1982) reported *Aspergillus ochraceus* and *Rhizoctonia solani* caused maximum reduction in oil content of sesame seeds. Deteriorated oil samples showed change in color, iodine value and saponification with prolonged incubation depending on the fungus and substrate. [Cited by G.S. Saharan, 1989]
- N.O. Srikantappa et al. (2009) studied 28 samples of sesame taken from fields, farmers, retail shops and APMC markets from 5 areas. They found 34 four fungi including *Aspergillus ochraceus.* The fungi significantly reduced germination.

IRAN
- M. Gooya et al. (2000) took one seed samples of each 17 sesame cultivars from 10 locations leading to 145 isolates during 1997/99 They identified *Aspergillus ochraceus.*

PAKISTAN
- M. Ajmal et al. (2021) evaluated the incidence of mycobiota and contamination of AFB_1 in sesame seeds from rainfed and irrigated zones of the Punjab, Pakistan. *Aspergillus flavus* was the leading contaminant found in fresh and stored sesame seeds from rainfed and irrigated zone followed by *A. niger*, *Alternaria alternata* and *Fusarium oxysporum*. Least reported fungi were *Aspergillus ochraceus* and *Cladosporium oxysporum*. AFB_1 analysis revealed that 92% fresh and 99% stored samples were contaminated with AFB_1. 20% fresh and 100% stored samples from rainfed zone and 28% fresh and 60% stored samples from irrigated zone were tainted with AFB_1 levels above 20 ppb and not fit for human consumption.

SIERRA LEONE
- F.E. Jonsyn (1988) sampled the fungi in 4 different geographical areas and found three toxigenic Aspergillus species: *A. flavus* Link ex Fries, *A. ochraceus* Wilhelm, and *A. tamarii* Kita were common to all samples. *Penicillium citrinum* Thom and two Fusarium sp. were found in samples from two localities. The mycotoxins aflatoxin B_1 and G_1, ochratoxin A and B, and citrinin were positively identified. [Based on abstract]
- F.E. Jonsyn (1990) examined 49 samples of seed. *Aspergillus* spp were the dominant group irrespective of the locality. Toxigenic Aspergillus included *Aspergillus flavus* Link ex Fries, *Aspergillus tamarii* Kita

and *Aspergillus ochraceus* Wilhelm. *Penicillium citrinum* Thom was the only toxigenic Penicillium isolated. [Based on abstract]

VENEZUELA

- Y. Martinez et al. (1991) in studying aflatoxin reported the following fungi on sesame: *Aspergillus ochraceus.*

A13.1.1f *Aspergillus tamarii* (8 May 2021)

Family: Trichocomaceae

Definition: Amount of tolerance to *Aspergillus tamarii* Kita 1913.

(Wikipedia, 8 May 2021) ***Aspergillus tamarii*** is a species of fungus in the genus *Aspergillus*. It is from the *Flavi* section. The species was first described in 1913. *A. tamarii* has been used in the production of soy sauce. It has been isolated from soil in the United States

References:

NIGERIA

- C.N. Ezekiel et al. (2014) isolated the following fungi on sesame seeds: *Aspergillus tamarii*.
- A.D. Ojochenemi et al. (2015) examined 46 samples of sesame and reported *Aspergillus tamarii*.
- A.O. Esan et al. (2020) purchased 60 sesame samples from markets in Nasarawa states during 2 seasons (wet and dry) in order to determine the safety for human consumption. They identified the following fungi: *Aspergillus* section *candidi*, *Aspergillus* section *flavi* (*A. flavus* and *A. tamarii*), *Aspergillus* section *nigri*, *Cladosporium* sp., *Fusarium fujikuroi*, *Penicillium* spp., and Didymellaceae. [For the toxins found refer to section G1 Toxin producing mycoflora.]

SENEGAL

- P.M. Diedhiou et al. (2011) studied *Aspergillus tamarii* and aflatoxin colonization from 5 districts. They looked at 500 isolates (20 from each sample from 5 villages in the 5 districts). The colony color, spore morphology and aflatoxin profile of various species and strains of Aspergillus section Flavi were as follow.

Aspergillus species	Strain	Colony colour	Spore morphology	Sclerotia diameter (μm)	Aflatoxin B_1	Aflatoxin B_2	Aflatoxin G_1	Aflatoxin G_2
A. flavus	L	Greenish yellow	Smooth	>400	±	±	–	–
A. flavus	S	Greenish yellow	Smooth	<400	+	+	–	–
Unnamed taxon	S_{BG}	Greenish yellow	Smooth	<400	+	+	+	+
A. parasiticus	na	Dark green	Echinulate	na	+	+	+	+
A. tamarii	na	Brown	Echinulate	na	–	–	–	–

na, not applicable; +, produces aflatoxin; –, does not produce aflatoxin; ±, some strains are aflatoxigenic and others not.

The aflatoxin content of sesame and the cfu load were very low for the two conservation methods (living room and storage) used by farmers. The results were as follow.

AEZ	District	Number isolated	Toxigenic (%)	*A. flavus* (%)	Strain S_{BG} (%)	*A. tamarii* (%)
SG	Kolda	100	51	87	13	0
	Sedhiou	100	32	75	25	0
	Mean	–	41.5	81	19	0
SS	Kaffrine	100	70	97	3	0
	Tambacounda	100	33	93	7	0
	Nioro	100	41	79	21	0
	Mean	–	48	89.6	10.3	0
	LSD[a]	–	24.6	19.5	19.5	0

		B-aflatoxin (ng/g)[a]		CFU/g[b]	
AEZ	District	Mean	Range	Mean	Range
SG	Kolda	0.3	0–1.0	483	13–2000
	Sedhiou	0.1	0–0.2	200	17–800
SS	Kaffrine	0.2	0–0.3	230	100–350
	Nioro	0.3	0–1.2	9400	200–42 800
	Tambacounda	0.1	0–0.2	120	100–200
	LSD[c]	0.4	–	11 042	–

[a]Only aflatoxin B_1 was detected in both maize and sesame samples.
[b]CFU = colony-forming units per gram of sample; mean of five locations (one field per location).

SIERRA LEONE

- F.E. Jonsyn (1988) sampled the fungi in 4 different geographical areas and found three toxigenic Aspergillus species: *A. flavus* Link ex Fries, *A. ochraceus* Wilhelm, and *A. tamarii* Kita were common to all samples. *Penicillium citrinum* Thom and two Fusarium sp. were found in samples from two localities. The mycotoxins aflatoxin B_1 and G_1, ochratoxin A and B, and citrinin were positively identified. [Based on abstract]
- F.E. Jonsyn (1990) examined 49 samples of seed. *Aspergillus* spp were the dominant group irrespective of the locality. Toxigenic Aspergillus included *Aspergillus flavus* Link ex Fries, *Aspergillus tamarii* Kita and *Aspergillus ochraceus* Wilhelm. *Penicillium citrinum* Thom was the only toxigenic Penicillium isolated. [Based on abstract]

VENEZUELA

- Y. Martinez et al. (1991) in studying aflatoxin reported the following fungi on sesame: *Aspergillus tamarii*.

A13.1.1g *Aspergillus parvisclerotigenus* (11 May 2021)

Family: Trichocomaceae

Definition: Amount of tolerance to *Aspergillus parvisclerotigenus* (Mich. Saito & Tsuruta) Frisvad & Samson 2005.

(Wikipedia, 11 May 2021) ***Aspergillus parvisclerotigenus*** is a species of fungus in the genus *Aspergillus*. It is from the *Flavi* section. The species was first described in 2005. *A. parvisclerotigenus* has been isolated in Nigeria and has been found to produce aflatoxin B1, aflatoxin B2, aflatoxin G1, aflatoxin G2, aflatrem, aflavarin, aspirochlorin, cyclopiazonic acid, kojic acid, and paspaline.

References:

NIGERIA

- C.N. Ezekiel et al. (2014) isolated the following fungi on sesame seeds: *Aspergillus parvisclerotigenus*. The following were the ranges of aflatoxins found on the sesame.

Concentration (µg/kg) of aflatoxins from toxigenic species

		A. flavus		*A. parvisclerotigenus*			
		B	G	B	G	Total B	Total G
Sesame	Range	75.8–326.1	–	215.6–1011.2	363.2–1980.7	75.8–1011.2	363.2–1980.7
	Mean[1]	190.1b	–	601.3	863.9	597.1a	863.9

A13.1.1h *Aspergillus fumigatus* (12 May 2021)

Aspergillus fumigatus affects seed quality (A13.1.1h) and has been used as a biocontrol (E2.1.2b).

Family: Trichocomaceae

Definition: Amount of tolerance to *Aspergillus fumigatus* Fresenius 1863.

(Wikipedia, 12 May 2021) ***Aspergillus fumigatus*** is a species of fungus in the genus *Aspergillus*, and is one of the most common *Aspergillus* species to cause disease in individuals with an immunodeficiency.

Aspergillus fumigatus, a saprotroph widespread in nature, is typically found in soil and decaying organic matter, such as compost heaps, where it plays an essential role in carbon and nitrogen recycling. Colonies of the fungus produce from conidiophores; thousands of minute grey-green conidia (2–3 µm) which readily become airborne. For many years, *A. fumigatus* was thought to only reproduce asexually, as neither mating nor meiosis had ever been observed. In 2008, *A. fumigatus* was shown to possess a fully functional sexual reproductive cycle, 145 years after its original description by Fresenius. Although *A. fumigatus* occurs in areas with widely different climates and environments, it displays low genetic variation and a lack of population genetic differentiation on a global scale. Thus, the capability for sex is maintained, though little genetic variation is produced.

References:

BANGLADESH

- M.D. Hosen and S. Shamsi (2017) isolated the following fungus from sesame seeds: *Aspergillus fumigatus.*

INDIA

- B. Nandi et al. (1981) reported *Aspergillus niger* and *A. fumigatus* caused deterioration of sesame seeds in storage. [Cited by G.S. Saharan, 1989]
- K. Kumar et al. (1984a) reported *Aspergillus fumigatus* was found to be associated with the seeds of varieties T-4 and T-12. The species was pathogenic and reduced germination by causing seed rot under laboratory conditions.
- A. Bose and B. Nandi (1985) reported cellulase was produced in culture best by *Aspergillus fumigatus, A. candidus* and *Rhizoctonia solani*; endopolygalacturonase and lipase by *A. flavus*. Reduction in germinability and oil content and increase in fat acidity were most pronounced in seeds inoculated with *A. flavus, A. fumigatus,* and *R. solani*. [Cited by G.S. Saharan, 1989]
- V. Bharathi et al. (2013) collected sesame seeds from farmers in Andhra Pradesh. They tested the seeds for mycoflora, and the following fungus was found: *Aspergillus fumigatus.*

NIGERIA

- F.M. Afolagboye (2011) reported the following fungus from 4 sesame varieties (NCRIBEN 03L, NCRIBEN 01M, E8 and 530-6-1) at Abeokuta: *Aspergillus fumigatus.*

A13.1.1i *Aspergillus candidus* (15 May 2021)

Family: Trichocomaceae

Definition: Amount of tolerance to *Aspergillus candidus* Link 1809.

(Wikipedia, 15 May 2021) ***Aspergillus candidus*** (also called *A. triticus*, *A. albus*, and *A. okazakii*) is a white-spored species of fungus in the genus *Aspergillus*. Despite its lack of pigmentation, it is closely related to the most darkly-pigmented aspergilli in the *Aspergillus niger* group. It is a common soil fungus worldwide and is known as a contaminant of a wide array of materials from the indoor environment to foods and products. It is an uncommon agent of onychomycosis and aspergillosis. The species epithet *candidus* (L.) refers to the white pigmentation of colonies of this fungus. It is from the *Candidi* section. The fungi in the *Candidi* section are known for their white spores. It has been isolated from wheat flour, djambee, and wheat grain.

References:

INDIA

- K. Kumar et al. (1984a) reported *Aspergillus candidus* was found to be associated with the seeds of varieties T-4 and T-12. The species was pathogenic and reduced germination by causing seed rot under laboratory conditions.
- A. Bose and B. Nandi (1985) reported cellulase was produced in culture best by *Aspergillus fumigatus, A. candidus* and *Rhizoctonia solani*; endopolygalacturonase and lipase by *A. flavus*. Reduction in germinability and oil content and increase in fat acidity were most pronounced in seeds inoculated with *A. flavus, A. fumigatus,* and *R. solani*. [Cited by G.S. Saharan, 1989]
- K. Bhattachary and S. Raha (2002) studied fungal infection, moisture content, germinability and deterioration of sesame in storage under natural conditions for a year. Different species of Aspergillus (*A. candidus*, A. *flavus, A. niger, A. terreus*, and *A. ruber*) were dominant followed by Rhizopus, Penicillium, Curvularia, Fusarium, Alternaria, etc. Seed moisture was maximum in the rainy season followed by a gradual decrease during longer storage. As storage proceeded, there was a gradual decrease in field fungi with simultaneous increase in storage fungi, and a reduction in germinability. A gradual loss of carbohydrate (both soluble and insoluble) content was recorded. A loss of protein content was recorded followed by a small increase. Oil content decreased in prolonged storage with simultaneous increase in fatty acid. [Based on abstract]
- N.O. Srikantappa et al. (2009) studied 28 samples of sesame taken from fields, farmers, retail shops and APMC markets from 5 areas. They found *Aspergillus candidus.* The fungi significantly reduced germination.

A13.1.1j *Aspergillus sacchari* (2 Jun 2021)

Family: Trichocomaceae

Definition: Amount of tolerance to *Aspergillus sacchari*.

References:

INDIA

- K. Kumar et al. (1984a) reported *Aspergillus sacchari* was found to be associated with the seeds of varieties T-4 and T-12. The species was pathogenic and reduced germination by causing seed rot under laboratory conditions.

A13.1.1k *Aspergillus clavatus* (2 Jun 2021)

Aspergillus clavatus affects seed quality (A13.1.1k) and has been used as a biocontrol (E2.1.2c).

Family: Trichocomaceae

Definition: Amount of tolerance to *Aspergillus clavatus* Desmazieres 1834.

(Wikipedia, 2 Jun 2021) ***Aspergillus clavatus*** is a species of fungus in the genus *Aspergillus* with conidia dimensions 3–4.5 x 2.5–4.5 µm. It is found in soil and animal manure. The fungus was first described scientifically in 1834 by the French mycologist John Baptiste Henri Joseph Desmazières.

The fungus can produce the toxin patulin, which may be associated with disease in humans and animals. This species is only occasionally pathogenic. *A. clavatus* is allergenic, causing the occupational hypersensitivity pneumonitis known as malt-worker's lung.

References:

INDIA

- K. Kumar et al. (1984a) reported *Aspergillus clavatus* was found to be associated with the seeds of varieties T-4 and T-12. The species was pathogenic and reduced germination by causing seed rot under laboratory conditions.

A13.1.1l *Aspergillus carbonarius* (24 Jul 2021)

Family: Trichocomaceae

Definition: Amount of tolerance to *Aspergillus carbonarius* (Bainier) Thom 1916.

References:

ALGERIA

- N.A. Mimoune et al. (2016) examined 12 samples from the market and isolated *Aspergillus carbonarius*, which produced ochratoxin A.

EGYPT

- A. Hashem et al. (2014) collected 18 seed samples of sesame in Egypt (12 samples) and Saudi Arabia (6 samples). They identified *Aspergillus carbonarius.*

A13.1.1m *Aspergillus flavipes* (24 Jul 2021)

Family: Trichocomaceae

Definition: Amount of tolerance to *Aspergillus flavipes* (Bainier & Sartory) Thom & Church 1926.

(Wikipedia, 24 Jul 2021) ***Aspergillus flavipes*** is a species of fungus in the genus *Aspergillus*. It is from the *Flavipedes* section. The species was first described in 1926. It has been reported to produce sterigmatocystin, citrinin, and lovastatin.

References:

EGYPT

- H.A.H. Hasan (2002) reported *Aspergillus flavipes* was a pathogen in the rhizoplane. [Cited by S.I.I. Abdel-Hafez, 2012]

A13.1.1n *Aspergillus alba* (20 Aug 2021)

Family: Trichocomaceae

Definition: Amount of tolerance to *Aspergillus alba*.

References:

PAKISTAN

- N. Altaf et al. (2004) tested 400 seeds from each of 10 cultivars for seedborne mycoflora. Eleven phytopathogenic fungi were found to include: *Aspergillus alba*.

A13.1.1o *Aspergillus viridus* (20 Aug 2021)

Family: Trichocomaceae

Definition: Amount of tolerance to *Aspergillus viridus*.

References:

PAKISTAN

- N. Altaf et al. (2004) tested 400 seeds from each of 10 cultivars for seedborne mycoflora. Eleven phytopathogenic fungi were found to include: *Aspergillus viridus.*

A13.1.1p *Aspergillus chevalieri* (24 Aug 2021)

Family: Trichocomaceae

Definition: Amount of tolerance to *Aspergillus chevalieri* Thom & Church 1926.

(Wikipedia, 24 Aug 2021) ***Aspergillus chevalieri*** is a species of fungus in the genus *Aspergillus*. It is from the *Aspergillus* section. The fungi in the *Aspergillus* section are known for their ability to grow at extremely low water activities. The species was first described in 1926. It has since been reported as an opportunistic pathogen causing skin infections.

The genome of *A. chevalieri* was sequenced as a part of the *Aspergillus* whole-genome sequencing project - a project dedicated to performing whole-genome sequencing of all members of the genus *Aspergillus*. The genome assembly size was 26.41 Mbp.

References:

NIGERIA

- C.A. Amienyo et al. (2015) studied the effect of mycoflora collected from 5 markets on the deterioration of lipid content of seed. Visually healthy seeds were inoculated with spores of each of the nine fungi isolated from diseased seeds and incubated at 25+20°C for 7days. The healthy and fungal infected seeds were analyzed for their lipid content. The percentage incidence at the 5 locations is shown below.

Fungi incidence	Location				
	A	B	C	D	E
Alternaria alternate	6.6	3.6	3.2	2.0	0.0
Aspergillus chevalieri	10.3	4.2	5.0	0.0	0.0
Aspergillus niger	0.0	6.1	7.4	2.6	5.2
Aspergillus oryzae	3.3	4.0	0.0	0.0	0.0
Aspergillus flavus	3.9	3.1	2.7	0.0	0.0
Aspergillus terreus	4.8	11.2	2.4	13.0	0.0
Cochliobolus Spp.	9.5	0.0	0.0	0.0	0.0
Geotrichum candidum	0.0	0.0	0.0	0.0	3.5
Phoma Spp.	5.9	2.0	0.0	0.0	0.0

Fungi utilize basic compounds of the seeds for their metabolism and growth and may affect the germination rate of the seed. The uninoculated seed had 49.35% lipid. The following shows the lipid content after 7 days of infection.

Fungi	Lipid content (%)
Aspergillus chevalieri	42.40
Aspergillus oryzae	43.50
Aspergillus niger	45.00
Aspergillus terreus	45.45
Alternaria alternata	47.80
Cochliobolus Spp	48.10
Aspergillus flavus	48.70
Phoma Spp.	49.15
Geotrichum candidum	49.40

A13.1.1q *Aspergillus oryzae* (24 Aug 2021)

Family: Trichocomaceae

Definition: Amount of tolerance to *Aspergillus oryzae* (Ahlburg) E. Cohn.

(Wikipedia, 24 Aug 2021) ***Aspergillus oryzae***, also known as **kōji mold**, is a filamentous fungus (a mold) used in East Asia to saccharify rice, sweet potato, and barley in the making of alcoholic beverages such as *sake* and *shōchū*, and also to ferment soybeans for making soy sauce and *miso*. However, in the production of fermented foods of soybeans such as soy sauce and *miso*, *Aspergillus sojae* is mainly used instead of *A. oryzae*. *A. oryzae* is also used for the production of rice vinegars. Barley *kōji* or rice *koji* are made by fermenting the grains with *A. oryzae* hyphae.

References:

EGYPT

- Hashem et al. (2014) collected 18 seed samples of sesame in Egypt (12 samples) and Saudi Arabia (6 samples). They identified the following fungus: *Aspergillus oryzae.*

NIGERIA

- C.A. Amienyo et al. (2015) studied the effect of mycoflora collected from 5 markets on the deterioration of lipid content of seed. Visually healthy seeds were inoculated with spores of each of the nine fungi isolated from diseased seeds and incubated at 25+20°C for 7days. The healthy and fungal infected seeds were analyzed for their lipid content. The percentage incidence at the 5 locations is shown below.

Fungi incidence	Location				
	A	B	C	D	E
Alternaria alternate	6.6	3.6	3.2	2.0	0.0
Aspergillus chevalieri	10.3	4.2	5.0	0.0	0.0
Aspergillus niger	0.0	6.1	7.4	2.6	5.2
Aspergillus oryzae	3.3	4.0	0.0	0.0	0.0
Aspergillus flavus	3.9	3.1	2.7	0.0	0.0
Aspergillus terreus	4.8	11.2	2.4	13.0	0.0
Cochliobolus Spp.	9.5	0.0	0.0	0.0	0.0
Geotrichum candidum	0.0	0.0	0.0	0.0	3.5
Phoma Spp.	5.9	2.0	0.0	0.0	0.0

Fungi utilize basic compounds of the seeds for their metabolism and growth and may affect the germination rate of the seed. The uninoculated seed had 49.35% lipid. The following shows the lipid content after 7 days of infection.

Fungi	Lipid content (%)
Aspergillus chevalieri	42.40
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Aspergillus terreus	45.45
Alternaria alternata	47.80
Cochliobolus Spp	48.10
Aspergillus flavus	48.70
Phoma Spp.	49.15
Geotrichum candidum	49.40

A13.1.1r *Aspergillus terreus* (24 Aug 2021)

Aspergillus terreus is a pathogen (A13.1.1r) and has been used as a biocontrol (E2.1.2d)

Family: Trichocomaceae

Definition: Amount of biocontrol provided by *Aspergillus terreus* Thom 1918.

(Wikipedia, 17 Jul 2021) ***Aspergillus terreus***, also known as *Aspergillus terrestris*, is a fungus (mold) found worldwide in soil. Although thought to be strictly asexual until recently, *A. terreus* is now known to be capable of sexual reproduction. This saprotrophic fungus is prevalent in warmer climates such as tropical and subtropical regions. Aside from being located in soil, *A. terreus* has also been found in habitats such as decomposing vegetation and dust. *A. terreus* is commonly used in industry to produce important organic acids, such as itaconic acid and *cis*-aconitic acid, as well as enzymes, like xylanase. It was also the initial source for the drug mevinolin (lovastatin), a drug for lowering serum cholesterol.

Aspergillus terreus can cause opportunistic infection in people with deficient immune systems. It is relatively resistant to amphotericin B, a common antifungal drug. *Aspergillus terreus* also produces aspterric acid and 6-hydroxymellein, inhibitors of pollen development in *Arabidopsis thaliana*.

References:

EGYPT

- M.M.I. Abdel-Hafez et al. (2014) took ten samples of sesame from local markets in Assiut city. They found the following: *Aspergillus terreus* Thom.
- A. Hashem et al. (2014) collected 18 seed samples of sesame in Egypt (12 samples) and Saudi Arabia (6 samples). They identified *Aspergillus terreus.*

INDIA

- K. Kumar et al. (1984a) reported 17 fungal species were found to be associated with the seeds of *Sesamum* varieties T-4 and T-12: *Aspergillus terreus.*
- K. Bhattachary and S. Raha (2002) studied fungal infection, moisture content, germinability and deterioration of sesame in storage under natural conditions for a year. Different species of Aspergillus (*A. candidus*, A. *flavus*, *A. niger*, *A. terreus*, and *A. ruber*) were dominant followed by Rhizopus, Penicillium, Curvularia, Fusarium, Alternaria, etc. Seed moisture was maximum in the rainy season followed by a gradual decrease during longer storage. As storage proceeded, there was a gradual decrease in field fungi with simultaneous increase in storage fungi, and a reduction in germinability. A gradual loss of carbohydrate (both soluble and insoluble) content was recorded. A loss of protein content was recorded followed by a small increase. Oil content decreased in prolonged storage with simultaneous increase in fatty acid. [Based on abstract]
- N.O. Srikantappa et al. (2009) studied 28 samples of sesame taken from fields, farmers, retail shops and APMC markets from 5 areas. They found *Aspergillus terreus.* The fungi significantly reduced germination.
- V. Bharathi et al. (2013) collected sesame seeds from farmers in Andhra Pradesh. They tested the seeds for mycoflora and found *Alternaria terreus.*

- H.R. Aglave (2016) screened two varieties (CV.N-85 and CV. Phule-1) for seed mycoflora. Twenty-seven fungi were isolated from these varieties. Varietal variation was found during the investigation. The following fungi was present: *Aspergillus terreus.*

IRAN

- M. Gooya et al. (2000) reported during 1997/99 one seed samples of each 17 sesame cultivars from 10 locations resulted in 145 isolates, which included 34 species of 15 genera. The identified *Aspergillus terreus*.

IRAQ

- N.A. Saad et al. (2013) examined seed and found the following fungi: *Aspergillus niger, Aspergillus terreus*

NIGERIA

- C.A. Amienyo et al. (2015) studied the effect of mycoflora collected from 5 markets on the deterioration of lipid content of seed. Visually healthy seeds were inoculated with spores of each of the nine fungi isolated from diseased seeds and incubated at 25+20°C for 7days. The healthy and fungal infected seeds were analyzed for their lipid content. The percentage incidence at the 5 locations is shown below.

Fungi incidence	Location				
	A	B	C	D	E
Alternaria alternate	6.6	3.6	3.2	2.0	0.0
Aspergillus chevalieri	10.3	4.2	5.0	0.0	0.0
Aspergillus niger	0.0	6.1	7.4	2.6	5.2
Aspergillus oryzae	3.3	4.0	0.0	0.0	0.0
Aspergillus flavus	3.9	3.1	2.7	0.0	0.0
Aspergillus terreus	4.8	11.2	2.4	13.0	0.0
Cochliobolus Spp.	9.5	0.0	0.0	0.0	0.0
Geotrichum candidum	0.0	0.0	0.0	0.0	3.5
Phoma Spp.	5.9	2.0	0.0	0.0	0.0

Fungi utilize basic compounds of the seeds for their metabolism and growth and may affect the germination rate of the seed. The uninoculated seed had 49.35% lipid. The following shows the lipid content after 7 days of infection.

Fungi	Lipid content (%)
Aspergillus chevalieri	42.40
Aspergillus oryzae	43.50
Aspergillus niger	45.00
Aspergillus terreus	45.45
Alternaria alternata	47.80
Cochliobolus Spp	48.10
Aspergillus flavus	48.70
Phoma Spp.	49.15
Geotrichum candidum	49.40

A13.1.1s *Aspergillus ruber* (25 Aug 2021)

Family: Trichocomaceae

Definition: Amount of tolerance to *Aspergillus ruber* Thom and Church 1926.

(Wikipedia, 25 Aug 2021) ***Aspergillus ruber*** is a species of fungus in the genus *Aspergillus*. It is from the *Aspergillus* section. The species was first described in 1929. It has been isolated from coffee beans in the UK, tea and soil in China, and malt dust in the Czech Republic. It has been reported to produce auroglaucin, bisanthrons, catenarin, dihydroauroglaucin, echinulins, epiheveadrides, erythroglaucin, flavoglaucin, isoechinulins, neoechinulins, physcion, questin, questinol, tetracyclic, and tetrahydroauroglaucin

References:

INDIA

- K. Bhattachary and S. Raha (2002) studied fungal infection, moisture content, germinability and deterioration of sesame in storage under natural conditions for a year. Different species of Aspergillus (*A. candidus*, A. *flavus*, *A. niger*, *A. terreus*, and *A. ruber*) were dominant followed by Rhizopus, Penicillium, Curvularia, Fusarium, Alternaria, etc. Seed moisture was maximum in the rainy season followed by a gradual decrease

during longer storage. As storage proceeded, there was a gradual decrease in field fungi with simultaneous increase in storage fungi, and a reduction in germinability. A gradual loss of carbohydrate (both soluble and insoluble) content was recorded. A loss of protein content was recorded followed by a small increase. Oil content decreased in prolonged storage with simultaneous increase in fatty acid. [Based on abstract]

A13.1.2 *Penicillium* spp. (22 Apr 2021)

Family: Trichocomaceae

There are *Penicillium* spp. that affect seed quality (A13.1.2) while other species have been proposed as biocontrols (E2.1.1).

Definition: Amount of tolerance to *Penicillium* spp. Link 1809.

(Wikipedia, 22 Apr 2021) ***Penicillium*** is a genus of ascomycetous fungi that is part of the mycobiome of many species and is of major importance in the natural environment, in food spoilage, and in food and drug production.

Some members of the genus produce penicillin, a molecule that is used as an antibiotic, which kills or stops the growth of certain kinds of bacteria. Other species are used in cheesemaking. According to the *Dictionary of the Fungi* (10th edition, 2008), the widespread genus contains over 300 species.

The following species have been associated with sesame but there are no known reports of being a pathogen, producing a toxin, inhibiting germination, affecting seed quality, or being used as a biocontrol or biofertilizer.

- *Penicillium citratum* [India]
- *Penicillium expansum* [Pakistan]
- *Penicillium herqui* [Pakistan]
- *Penicillium italicum* [Pakistan]
- *Penicillium janthinellum* [Pakistan]
- *Penicillium jensemi* [Pakistan]
- *Penicillium lanso-coerellum* [Pakistan]
- *Penicillium lilacinum* [Pakistan]
- *Penicillium oxalicum* [Egypt and Saudi Arabia]
- *Penicillium paxilli* [Pakistan]
- *Penicillium purpurogenum* [Egypt and Saudi Arabia]
- *Penicillium waksmani* [Pakistan]

References:

BANGLADESH

- M.D. Hosen and S. Shamsi (2017) isolated the following fungus from sesame seeds: *Penicillium* sp.

CUBA

- La Habana (2009) in a grower guide reported the following pathogen: *Penicillium* sp.

EGYPT

- M.M.I. Abdel-Hafez et al. (2012) examined the soils around the roots of sesame and reported *Penicillium* spp. in the rhizosphere and rhizoplane.
- M.M.I. Abdel-Hafez et al. (2014) took ten samples of sesame from local markets in Assiut city. They found *Penicillium* spp.
- B.A. Sabry et al. (2016) in Egypt studied 28 sesame samples collected from food stores in different governates. They found the following fungi.

Governorate	NC/TNS	Fungal load (log_{10} CFU/g)		Percentage occurrence of fungal genera				
		Range	Mean ± SD	*Alternaria*	*Aspergillus*	*Fusarium*	*Penicillium*	*Cladosporium*
Great Cairo	4/4	1.72 –2.32	1.91±0.77[a]	34.21	60.53	2.63	ND	2.63
Kalioubia	3/3	1.72 –2.32	1.97±1.03[a]	4.17	91.66	ND	4.17	ND
Alexandria	6/6	1.72 –2.67	1.99±1.63[a]	4.35	82.61	6.52	ND	6.52
El-Behera	5/5	1.72 –2.87	2.15±1.63[b]	ND	71.82	0.91	17.27	10.00
Kafr El-Sheik	5/5	1.72 –2.80	2.26±2.72[c]	3.96	60.40	1.98	17.82	15.84
Dakahlia	5/5	1.72 –3.02	2.52±0.70[d]	ND	79.68	1.59	6.37	12.35

NC: Number of contaminated samples; TNS: Total number of samples
Mean with different superscript letters are significantly different

INDIA

- K. Bhattachary and S. Raha (2002) studied fungal infection, moisture content, germinability and deterioration of sesame in storage under natural conditions for a year. Different species of Aspergillus (*A. candidus*, A. *flavus*, *A. niger*, *A. terreus*, and *A. ruber*) were dominant followed by Rhizopus, Penicillium, Curvularia, Fusarium, Alternaria, etc. Seed moisture was maximum in the rainy season followed by a gradual decrease during longer storage. As storage proceeded, there was a gradual decrease in field fungi with simultaneous increase in storage fungi, and a reduction in germinability. A gradual loss of carbohydrate (both soluble and insoluble) content was recorded. A loss of protein content was recorded followed by a small increase. Oil content decreased in prolonged storage with simultaneous increase in fatty acid. [Based on abstract]
- V. Bharathi et al. (2013) collected sesame seeds from farmers in Andhra Pradesh. They tested the seeds for mycoflora, and the following fungus was found: *Penicillium* spp.
- P.L. Radha (2013) collected 18 cultivars from 7 districts in Karnataka and identified the following fungus: *Penicillium* sp.
- B. Khamari et al. (2018e) collected 15 sesame seed samples from different localities of Odisha reported the infestation of *Penicillium* sp. ranged from 0 to 2.5%.

IRAQ

- F. Al-Refaee (2005) collected sesame seeds from 6 regions of Iraq and isolated *Penicillium* spp.
- N.A. Saad et al. (2013) examined seed and found the following fungi: *Penicillium* sp.

NIGERIA

- F.M. Afolagboye (2011) reported the following fungus from 4 sesame varieties (NCRIBEN 03L, NCRIBEN 01M, E8 and 530-6-1) at Abeokuta: *Penicillium* spp.
- M.N. Suleiman et al. (2013) studied the effect of barks (*Anacadium occidentale* [cashew] and *Mangifera indica* [mango]) on mycoflora (*Aspergillus niger*, *Aspergillus flavus* and *Penicillium* sp.) using 10 cultivars. The following figures show the fungal incidence on the cultivars and the distribution on the fungi.

Table 1: Fungal Incidence on Seeds of ten sesame cultivars

Cultivars	Normal seeds*	Infected seeds*	Fungal incidence (%)
01 – M	10	190	95.00
02 – M	25	175	87.50
03 – M	53	147	73.50
E8	05	195	97.50
Ex sudan	41	159	79.50
Oke	24	176	88.00
Any	12	188	94.00
1Lo	61	139	69.50
Off – 1	67	133	66.50
Off – 2	44	156	78.00

***Out of 200 seeds of each cultivar**

Table 2: % of fungal infections on seeds of ten cultivars of sesame (%)

Fungus	01-M	02-M	03-M	E8	Ex sudan	Oke	Any	ILO	Off-1	Off-2
Aspergillus niger	15.50	0.00	0.00	8.50	7.50	5.00	8.40	9.25	0.00	6.30
Aspergillus flavus	10.30	0.00	0.00	7.20	6.50	6.50	8.00	8.40	0.00	6.10
Penicillium sp	5.00	7.50	5.20	6.00	0.00	0.00	5.30	0.00	0.00	0.00

The following figures show the effectiveness of the bark extracts. They concluded that with the ready availability of these trees and the ease of extraction, this would be a farmer methodology to reduce the fungi on the seed.

Table 3: Inhibitory effect of cashew bark extract (*A. occidentale*) on mycelial growth of the fungi.

Concentration (%)	Mean percentage *Aspergillus*	Inhibition ± SE (%) *Penicillium*
Control (0)	$0.00.0\pm0.0^{a}$	$0.00.0\pm0.0^{a}$
40	$98.87.0\pm0.4^{b}$	$50.92.0\pm6.9^{b}$
60	100.0 ± 0.0^{c}	64.76 ± 7.8^{bc}
80	100.0 ± 0.0^{c}	76.64 ± 5.4^{cd}
100	100.0 ± 0.0^{c}	92.80 ± 2.8^{d}

In each fungus, means followed by the same letter are not significantly different ($P \leq 0.05$).

Table 4: Inhibitory effects of Mango bark extract (*Mangifera indica*) on mycelial growth of the fungi.

Concentration (%)	Mean percentage *Aspergillus*	Inhibition ± SE (%) *Penicillium*
Control (0)	$0.00.0\pm0.0^{a}$	$0.00.0\pm0.0^{a}$
40	$98.3.0\pm0.6^{b}$	$46.22.0\pm7.9^{b}$
60	99.2 ± 0.3^{bc}	50.82 ± 7.5^{bc}
80	100.0 ± 0.0^{c}	68.25 ± 6.1^{cd}
100	100.0 ± 0.0^{c}	81.15 ± 5.4^{d}

- C.N. Ezekiel et al. (2014) isolated the following fungi on sesame seeds: *Penicillium* sp.
- A.D. Ojochenemi et al. (2015) examined 46 samples of sesame and reported *Penicillium* spp.
- S.T. Anjorin et al. (2016) studied the effects of 6 botanicals (baobab [*Adansonia digitate*] leaf powder, hot pepper [*Capsicum annum*] fruits, and ordeal tree [*Erythrophleum suaveolens*] bark and leaves, garlic bulbs and ginger rhizomes) against fungi isolated from sesame seeds (*Aspergillus niger, Aspergillus flavus, Mucor* spp., *Fusarium* spp., *Alternaria* spp., and *Penicillium* spp.). The ginger, garlic, and ordeal bark were not effective. The results of the effective treatments were as follow.

Sesame seeds treated with plant extracts	*Aspergillusniger*	*Fusarium*spp.	*Aspergillusflavus* (cfug/ml)	*Penicillium* spp.	*MucorAlternaria* spp. spp.
Baobab leaf extract (100%)	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{b}	0.00^{b} 0.00^{b}
Baobab leaf extract (10%)	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{b}	0.00^{b} 0.00^{b}
Ordeal leaf extract(100%)	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{b}	0.00^{b} 0.00^{b}
Ordeal leaf extract(10%)	0.00^{c}	1.00^{bc}	0.00^{c}	1.00^{b}	0.00^{b} 0.00^{b}
Hot pepper fruit extract(100%)	4.00^{b}	2.00^{b}	0.00^{c}	4.00^{a}	1.00^{ab} 0.00^{b}
Hot pepper fruit extract(10%)	5.00^{b}	2.00^{b}	0.00^{c}	0.00^{b}	1.00^{ab} 0.00^{b}
Untreated sesame seed before storage	7.00^{a}	5.00^{a}	4.00^{a}	5.00^{a}	1.00^{ab} 2.00^{a}
Untreated sesame seed after storage	5.00^{b}	5.00^{a}	2.00^{b}	4.00^{a}	2.00^{a} 1.00^{b}

- A.O. Esan et al. (2020) purchased 60 sesame samples from markets in Nasarawa states during 2 seasons (wet and dry) in order to determine the safety for human consumption. They identified the following fungi: *Aspergillus* section *candidi*, *Aspergillus* section *flavi* (*A. flavus* and *A. tamarii*), *Aspergillus* section *nigri, Cladosporium* sp., *Fusarium fujikuroi, Penicillium* spp., and Didymellaceae.]For the toxins found refer to section G1 Toxin producing mycoflora.]

PARAGUAY

- L.C. Rossi and A.L. Orrego (2007) identified the following fungus on sesame seeds: *Penicillium* sp.

SAUDI ARABIA

- A.H. Bahkali and M.A. Moslem (1996) reported the following mycoflora on 5 cultivars: *Penicillium* sp.

VENEZUELA

- Y. Martinez et al. (1991) in studying aflatoxin reported the following fungi on sesame: *Penicillium* sp.
- B. Mazzani (1999) reported the following pathogen: *Penicillium* sp.

A13.1.2a *Penicillium egyptiacum* (22 Apr 2021)

Family: Trichocomaceae

Definition: Amount of tolerance to *Penicillium egyptiacum* J.F.H. Beyma 1933.

(Wikipedia, 22 Apr 2021) *Penicillium egyptiacum* isolated from soil in Egypt, differs from most species of the genus in producing perithecia with readiness on most common media. Tests of its behavior at various temperatures, on media of different *p*H, in conditions of different humidity and at reduced atmospheric pressure, show that special conditions of the environment have no particular effect on the formation of the perithecia. Of the conditions tested, humidity seems to exert most effect. The archicarp is not coiled, but has the form of a short, stout septate hypha.

Asci develop rapidly, and not after a period of inactivity. The species is homothallic. [Based on abstract]

References:

PAKISTAN

- B.G. Nayyar et al. (2013) examined 15 samples of seed to detect fungi using 3 methods: agar plate, blotter, and deep freezing and found *Penicillium egyptiacum*.
- B.G. Nayyar et al. (2014) studied the effects of fungal pathogens on the germination of sesame. Seven prevalent fungal species viz. *Alternaria alternata, Aspergillus flavus, Aspergillus niger, Cercospora* sp., *Fusarium oxysporum, Penicillium egyptiacum* and *Rhizopus oryzae* associated with sesame seeds were selected for this study. Fungi associated with seeds affected the seed health and resulted in reduced seed germination, and seedling abnormality as shown in the table below.

Treatments	Normal seedlings %age	Abnormal seedlings %age	Un germinated seeds %age	Fungi isolated
Surface sterilized seeds	80	14	6	*Aspergillus flavus* *Aspergillus niger* *Fusarium oxysporum*
Naturally infected seeds	64	26	10	*Alternaria alternata* *Aspergillus flavus* *Aspergillus niger* *Fusarium oxysporum* *Penicillium egyptiacum*

The pathogenicity of the 7 fungi was tested with the following results.

S. No.	Fungi isolated	Pathogenic Effect	Healthy Plants
1	*A. alternata*	Infected root & stem, Weak stem, Reduced growth	55%
2	*A. flavus*	Reduced growth	70%
3	*A. niger*	Reduced growth, Infected roots, Weak stem	13%
4	*Cercospora* sp.	Infected stem, Weak stem, Reduced growth	40%
5	*P. egyptiacum*	Infected root, Weak stem	26%
6	*R. oryzae*	Reduced growth, Infected roots & stem, Weak stem	30%
7	*F. oxysporum*	Reduced growth, Leaves short & infected	32%

Abnormality rate of seedlings depends on the type of pathogens with which they are infected. There is also need for the management programs to control seedborne pathogens and reduce their impact on sesame production.

A13.1.2b *Penicillium citrinum* (8 May 2021)

Family: Trichocomaceae

Definition: Amount of tolerance to *Penicillium citrinum* Thom 1910.

(Wikipedia, 8 May 2021) ***Penicillium citrinum*** is an anamorph, mesophilic fungus species of the genus of *Penicillium* which produces tanzawaic acid A-D, ACC, Mevastatin, Quinocitrinine A, Quinocitrinine B,

and nephrotoxic citrinin. *Penicillium citrinum* is often found on moldy citrus fruits and occasionally it occurs in tropical spices and cereals. This Penicillium species also causes mortality for the mosquito Culex quinquefasciatus. Because of its mesophilic character, *Penicillium citrinum* occurs worldwide. The first statin (*Mevastatin*) was 1970 isolated from this species.

References:

EGYPT

- A. Hashem et al. (2014) collected 18 seed samples of sesame in Egypt (12 samples) and Saudi Arabia (6 samples). They identified the following mycoflora: *Penicillium citrinum.*

INDIA

- A.S. Reddy and S.M. Reddy (1983b) reported 36 fungal species were obtained from 105 seed samples of sesame. Several species of *Aspergillus, Fusarium* as well as *Penicillium citrinum* can produce a very wide range of mycotoxins. [Cited by G.S. Saharan, 1989]
- B.K. Vaidehi et al. (1985) reported culture filtrates of *Penicillium citrinum* reduced germination percentage and root and shoot elongation of sesame with the maximum on the 30th day. [Cited by G.S. Saharan, 1989]

IRAN

- M. Gooya et al. (2000) took one seed samples of each 17 sesame cultivars from 10 locations leading to 145 isolates during 1997/99 They identified *Penicillium citrinum.*

SIERRA LEONE

- F.E. Jonsyn (1988) sampled the fungi in 4 different geographical areas and found three toxigenic Aspergillus species: *A. flavus* Link ex Fries, *A. ochraceus* Wilhelm, and *A. tamarii* Kita were common to all samples. *Penicillium citrinum* Thom and two Fusarium sp. were found in samples from two localities. The mycotoxins aflatoxin B_1 and G_1, ochratoxin A and B, and citrinin were positively identified. [Based on abstract]
- F.E. Jonsyn (1990) examined 49 samples of seed. *Aspergillus* spp were the dominant group irrespective of the locality. Toxigenic Aspergillus included *Aspergillus flavus* Link ex Fries, *Aspergillus tamarii* Kita and *Aspergillus ochraceus* Wilhelm. *Penicillium citrinum* Thom was the only toxigenic Penicillium isolated. [Based on abstract]

A13.1.2c *Penicillium rubrum* (27 Jun 2021)

Family: Trichocomaceae

Definition: Amount of tolerance to *Penicillium rubrum* Stoll O 1904.

(Wikipedia, 27 Jun 2021) ***Penicillium rubrum*** is a species of fungus in the genus *Penicillium* which produces kojic acid, mitorubrin, mitorubrinol, rubratoxin A, rubratoxin B rubralactone, rubramin and occurs in grain corn and soybeans. *Penicillium rubrum* is similar to the species *Penicillium chrysogenum*.

References:

INDIA

- K. Kumar et al. (1984a) reported 17 fungal species were found to be associated with the seeds of *Sesamum* varieties T-4 and T-12 to include *Penicillium rubrum.*
- B.K. Vaidehi et al. (1985) reported culture filtrates of *Penicillium rubrum* reduced germination percentage and root and shoot elongation of sesame with the maximum on the 30th day. [Cited by G.S. Saharan, 1989]

A13.1.2d *Penicillium verrucosum* (27 Jul 2021)

Family: Trichocomaceae

Definition: Amount of tolerance to *Penicillium verrucosum* Dierckx 1901.

(Wikipedia, 27 Jul 2021) ***Penicillium verrucosum*** is a psychrophilic fungus which was discovered in Belgium and introduced by Dierckx in 1901. Six varieties of this species have been recognized based primarily on differences in colony color: *P. verrucosum var. album*, *P. verrucosum var. corymbiferum*, *P. verrucosum var. cyclopium*, *P.*

verrucosum var. ochraceum, *P. verrucosum var. melanochlorum* and *P. verrucosum var. verrucosum*. This fungus has important implications in food, specifically for grains and other cereal crops on which it grows. Its growth is carefully regulated in order to reduce food spoilage by this fungi and its toxic products. The genome of *P. verrucosum* has been sequenced and the gene clusters for the biosynthesis of its mycotoxins have been identified.

References:

EGYPT

- A. Hashem et al. (2014) collected 18 seed samples of sesame in Egypt (12 samples) and Saudi Arabia (6 samples). They identified *Penicillium verrucosum.* Ochratoxin A (OTA) is a secondary metabolite (mycotoxin) produced by some seedborne fungi belonging to *Aspergillus* and *Penicillium* genera. The total OTA contamination percent of the Egyptian samples were significantly less (16.7%) than those of the Saudi samples (83.3%).

Isolate code	Orginal location	Seedborne fungal isolates	Ochratoxin A production (µg/100 ml culture medium)
1	Bani Swief	*A. ochraceus*	122.4
2	Bani Swief	*A. ochraceus*	118.6
3	Bani Swief	*A. ochraceus*	120.7
4	Jizan	*P. viridicatum*	24.8
5	Bani Swief	*P. nordicum*	112.4
6	Holy Makkah	*P. verrucosum*	27.3
7	Ismailia	*A. niger*	14.5
8	Ismailia	*A. niger*	13.4
9	Jizan	*P. crustosum*	12.3
10	Sohag	*P. brevicompactum*	17.6
11	Sohag	*P. brevicompactum*	17.5
12	Sohag	*A. carbonarius*	147.5
13	Holy Makkah	*A. niger*	7.2
14	Jizan	*A. niger*	32.6
15	Holy Makkah	*A. ochraceus*	37.5
16	Jizan	*A. ochraceus*	36.4
17	Ismailia	*A. ochraceus*	10.4

A13.1.2e *Penicillium viridicatum* (27 Jul 2021)

Family: Trichocomaceae

Definition: Amount of tolerance to *Penicillium viridicatum* Westling 1911.

(Wikipedia, 27 Jul 2021) ***Penicillium viridicatum*** is a psychrophilic species of fungus in the genus , penicillic acid and citrinin. *Penicillium viridicatum* can spoil grapes and melons.

References:

EGYPT

- A. Hashem et al. (2014) collected 18 seed samples of sesame in Egypt (12 samples) and Saudi Arabia (6 samples). They identified *Penicillium viridicatum.* Ochratoxin A (OTA) is a secondary metabolite (mycotoxin) produced by some seedborne fungi belonging to *Aspergillus* and *Penicillium* genera. The total OTA contamination percent of the Egyptian samples were significantly less (16.7%) than those of the Saudi samples (83.3%).

Isolate code	Orginal location	Seedborne fungal isolates	Ochratoxin A production (µg/100 ml culture medium)
1	Bani Swief	*A. ochraceus*	122.4
2	Bani Swief	*A. ochraceus*	118.6
3	Bani Swief	*A. ochraceus*	120.7
4	Jizan	*P. viridicatum*	24.8
5	Bani Swief	*P. nordicum*	112.4
6	Holy Makkah	*P. verrucosum*	27.3
7	Ismailia	*A. niger*	14.5
8	Ismailia	*A. niger*	13.4
9	Jizan	*P. crustosum*	12.3
10	Sohag	*P. brevicompactum*	17.6
11	Sohag	*P. brevicompactum*	17.5
12	Sohag	*A. carbonarius*	147.5
13	Holy Makkah	*A. niger*	7.2
14	Jizan	*A. niger*	32.6
15	Holy Makkah	*A. ochraceus*	37.5
16	Jizan	*A. ochraceus*	36.4
17	Ismailia	*A. ochraceus*	10.4

A13.1.2f *Penicillium nordicum* (27 Jul 2021)

Family: Trichocomaceae

Definition: Amount of tolerance to *Penicillium nordicum* Dragoni & Cantoni ex C. Ramírez 1985.

(Wikipedia, 27 Jul 2021) ***Penicillium nordicum*** is an anamorph species of fungus in the genus *Penicillium* which produces ochratoxin A. *Penicillium nordicum* contaminates protein rich foods and foods with high NaCl-konzentration. It is mostly found on dry-cured meat products and cheese products.

References:

EGYPT

- A. Hashem et al. (2014) collected 18 seed samples of sesame in Egypt (12 samples) and Saudi Arabia (6 samples). They identified *Penicillium nordicum.* Ochratoxin A (OTA) is a secondary metabolite (mycotoxin) produced by some seedborne fungi belonging to *Aspergillus* and *Penicillium* genera. The total OTA contamination percent of the Egyptian samples were significantly less (16.7%) than those of the Saudi samples (83.3%).

Isolate code	Orginal location	Seedborne fungal isolates	Ochratoxin A production (µg/100 ml culture medium)
1	Bani Swief	*A. ochraceus*	122.4
2	Bani Swief	*A. ochraceus*	118.6
3	Bani Swief	*A. ochraceus*	120.7
4	Jizan	*P. viridicatum*	24.8
5	Bani Swief	*P. nordicum*	112.4
6	Holy Makkah	*P. verrucosum*	27.3
7	Ismailia	*A. niger*	14.5
8	Ismailia	*A. niger*	13.4
9	Jizan	*P. crustosum*	12.3
10	Sohag	*P. brevicompactum*	17.6
11	Sohag	*P. brevicompactum*	17.5
12	Sohag	*A. carbonarius*	147.5
13	Holy Makkah	*A. niger*	7.2
14	Jizan	*A. niger*	32.6
15	Holy Makkah	*A. ochraceus*	37.5
16	Jizan	*A. ochraceus*	36.4
17	Ismailia	*A. ochraceus*	10.4

A13.1.2g *Penicillium crustosum* (27 Jul 2021)

Penicillium crustosum affects seed quality (A13.1.2g) and has been proposed as a biocontrol (E2.1.1d).

Family: Trichocomaceae

Definition: Amount of tolerance to *Penicillium crustosum* Thom 1930.

(Wikipedia, 27 Jul 2021) ***Penicillium crustosum*** is a blue-green or blue-grey mold that can cause food spoilage, particularly of protein-rich foods such as meats and cheeses. It is identified by its complex biseriate conidiophores on which phialides produce asexual spores. It can grow at fairly low temperatures (it is a psychrophile), and in low water activity environments.

Penicillium crustosum produces mycotoxins, most notoriously the neurotoxic penitrems, including the best known penitrem toxin, penitrem A, and including penitrems A through G. Penitrem G has been shown to have insecticidal activity. In addition, *P. crustosum* can produce thomitrems A and E, and roquefortine C. Consumption of foods spoiled by this mold can cause transient neurological symptoms such as tremors. In dogs, symptoms can include vomiting, convulsion, tremors, ataxia, and tachycardia

References:

EGYPT

- A. Hashem et al. (2014) collected 18 seed samples of sesame in Egypt (12 samples) and Saudi Arabia (6 samples). They identified *Penicillium crustosum.* Ochratoxin A (OTA) is a secondary metabolite (mycotoxin) produced by some seedborne fungi belonging to *Aspergillus* and *Penicillium* genera. The total OTA contamination percent of the Egyptian samples were significantly less (16.7%) than those of the Saudi samples (83.3%).

Isolate code	Orginal location	Seedborne fungal isolates	Ochratoxin A production (µg/100 ml culture medium)
1	Bani Swief	*A. ochraceus*	122.4
2	Bani Swief	*A. ochraceus*	118.6
3	Bani Swief	*A. ochraceus*	120.7
4	Jizan	*P. viridicatum*	24.8
5	Bani Swief	*P. nordicum*	112.4
6	Holy Makkah	*P. verrucosum*	27.3
7	Ismailia	*A. niger*	14.5
8	Ismailia	*A. niger*	13.4
9	Jizan	*P. crustosum*	12.3
10	Sohag	*P. brevicompactum*	17.6
11	Sohag	*P. brevicompactum*	17.5
12	Sohag	*A. carbonarius*	147.5
13	Holy Makkah	*A. niger*	7.2
14	Jizan	*A. niger*	32.6
15	Holy Makkah	*A. ochraceus*	37.5
16	Jizan	*A. ochraceus*	36.4
17	Ismailia	*A. ochraceus*	10.4

A13.1.2h *Penicillium brevicompactum* (27 Jul 2021)

Family: Trichocomaceae

Definition: Amount of tolerance to *Penicillium brevicompactum* Dierckx 1901.

(Wikipedia, 27 Jul 2021) ***Penicillium brevicompactum*** is a species of mold in the genus Penicillium which is known to produce mycophenolic acid (MPA) mycotoxins. This type of mold can be identified genetically in an index called ERMI (Enviromental Relative Moldinee Index) using qualitative and quantitative PCR analysis (QPCR) for fungi.

References:

EGYPT

- A. Hashem et al. (2014) collected 18 seed samples of sesame in Egypt (12 samples) and Saudi Arabia (6 samples). They identified *Penicillium brevicompactum.* Ochratoxin A (OTA) is a secondary metabolite (mycotoxin) produced by some seedborne fungi belonging to *Aspergillus* and *Penicillium* genera. The total OTA contamination percent of the Egyptian samples were significantly less (16.7%) than those of the Saudi samples (83.3%).

Isolate code	Orginal location	Seedborne fungal isolates	Ochratoxin A production (µg/100 ml culture medium)
1	Bani Swief	*A. ochraceus*	122.4
2	Bani Swief	*A. ochraceus*	118.6
3	Bani Swief	*A. ochraceus*	120.7
4	Jizan	*P. viridicatum*	24.8
5	Bani Swief	*P. nordicum*	112.4
6	Holy Makkah	*P. verrucosum*	27.3
7	Ismailia	*A. niger*	14.5
8	Ismailia	*A. niger*	13.4
9	Jizan	*P. crustosum*	12.3
10	Sohag	*P. brevicompactum*	17.6
11	Sohag	*P. brevicompactum*	17.5
12	Sohag	*A. carbonarius*	147.5
13	Holy Makkah	*A. niger*	7.2
14	Jizan	*A. niger*	32.6
15	Holy Makkah	*A. ochraceus*	37.5
16	Jizan	*A. ochraceus*	36.4
17	Ismailia	*A. ochraceus*	10.4

IRAN

- M. Gooya et al. (2000) reported during 1997/99 one seed samples of each 17 sesame cultivars from 10 locations resulted in 145 isolates, which included 34 species of 15 genera. The identified *Penicillium brevicompactum.*

A13.1.2i *Penicillium chrysogenum* (17 Jul 2021)

Penicillium chrysogenum affects seed quality (A13.1.2i) and has been proposed as a biocontrol (E2.1.1c).

Family: Trichocomaceae

Definition: Amount of biocontrol provided by *Penicillium chrysogenum* Thom 1910.

(Wikipedia, 17 Jul 2021) ***Penicillium chrysogenum*** is a species of fungus in the genus *Penicillium*. It is common in temperate and subtropical regions and can be found on salted food products, but it is mostly found in indoor environments, especially in damp or water-damaged buildings. It has been recognized as a species complex that includes *P. notatum*, *P. meleagrinum*, and *P. cyaneofulvum*, but molecular phylogeny established that it is a distinct species and that *P. notatum* (its popular synonym) is *P. rubens.* It has rarely been reported as a cause of human disease. It is the source of several β-lactam antibiotics, most significantly penicillin. Other secondary metabolites of *P. chrysogenum* include roquefortine C, meleagrin, chrysogine, 6-MSA YWA1/melanin, andrastatin A, fungisporin, secalonic acids, sorbicillin, and PR-toxin.

Like the many other species of the genus *Penicillium*, *P. chrysogenum* usually reproduces by forming dry chains of spores (or conidia) from brush-shaped conidiophores. The conidia are typically carried by air currents to new colonization sites. In *P. chrysogenum*, the conidia are blue to blue-green, and the mold sometimes exudes a yellow pigment. However, *P. chrysogenum* cannot be identified based on color alone. Observations of morphology and microscopic features are needed to confirm its identity and DNA sequencing is essential to distinguish it from closely related species such as *P. rubens*. The sexual stage of *P. chrysogenum* was discovered in 2013 by mating cultures in the dark on oatmeal agar supplemented with biotin, after the mating types (MAT1-1 or MAT1-2) of the strains had been determined using PCR amplification.

The airborne asexual spores of *P. chrysogenum* are important human allergens. Vacuolar and alkaline serine proteases have been implicated as the major allergenic proteins.

P. chrysogenum has been used industrially to produce penicillin and xanthocillin X, to treat pulp mill waste, and to produce the enzymes polyamine oxidase, phosphogluconate dehydrogenase, and glucose oxidase.

References:

EGYPT

- I.A. El-Kady et al. (1986) reported isolating *Penicillium chrysogenum.*
- A. Hashem et al. (2014) collected 18 seed samples of sesame in Egypt (12 samples) and Saudi Arabia (6 samples). They identified *Penicillium chrysogenum.*
- M.G.A. Hegazy et al. (2019) evaluated the effects of biocontrols (*Alternaria alternate, Aspergillus* spp. and *Penicillium* spp.) on *Fusarium oxysporum* f. sp. *sesami* with the following results.

Isolate No.	Endophytic fungi isolate	Average of inhibition zone diameter (mm)
1	*Alternaria alternate*	1.5 ^{ef}
2	*Aspergillus clavatus*	9.2 ^{b}
3	*Aspergillus fumigatus*	0.8 ^{ef}
4	*Aspergillus niger*	11.6 ^{a}
5	*Aspergillus sydowii*	1.3 ^{ef}
6	*Aspergillus terreus* (1)	2.3 ^{e}
7	*Aspergillus terreus* (2)	5.9 ^{cd}
8	*Penicillium chrysogenum* (1)	9.2 ^{b}
9	*Penicillium chrysogenum* (2)	2.3 ^{e}
10	*Penicillium crustosum* (1)	7.1 ^{bc}
11	*Penicillium crustosum* (2)	8.2 ^{b}
12	*Penicillium crustosum* (3)	2.8 ^{e}
13	Control	0.0 ^{f}

Means followed by the same letters (s) in a column are not significantly different at ($p \leq 0.05$) according to Duncan's multiple-range test.

The species with the highest levels of inhibition were further tested using different concentrations.

Endophytic fungi	Concentration (%)	Average of colony diameter (mm)	Inhibition (%)
Aspergillus niger	1	73.30	18.55 ^{i}
	2	69.30	23.00 ^{ghi}
	5	63.30	29.66 ^{fgh}
	10	57.00	36.66 ^{ef}
	20	45.00	50.00 ^{d}
Aspergillus terreus (1)	1	68.30	24.11 ^{ghi}
	2	55.00	38.88 ^{e}
	5	45.00	50.00 ^{d}
	10	36.60	59.33 ^{bc}
	20	26.60	70.44 ^{a}
Aspergillus terreus (2)	1	73.30	18.55 ^{i}
	2	65.30	27.44 ^{gh}
	5	56.60	37.11 ^{ef}
	10	43.30	51.88 ^{cd}
	20	33.30	63.00 ^{ab}
Penicillium chrysogenum (1)	1	75.00	16.66 ^{i}
	2	70.00	22.22 ^{hi}
	5	62.00	31.11 ^{efg}
	10	55.00	38.88 ^{e}
	20	44.00	51.11 ^{cd}
Control		90.00	00.00 ^{j}

Means followed by the same letters (s) in a column are not significantly different at ($p \leq 0.05$) according to Duncan's multiple-range test.

The species were then used in the greenhouse with the following results.

Treatments	Disease Severity (%)	Plant growth parameters					
		Shoot			Root		Number of bods
		Plant height (cm)	Fresh weight (g)	Dry weight (g)	Fresh weight (g)	Dry weight (g)	
Aspergillus niger	36 ^{c}	73 ^{ab}	11.8 ^{b}	3.66 ^{b}	3.33 ^{c}	1.3 ^{c}	10 ^{c}
Aspergillus terreus (1)	41 ^{bc}	83 ^{b}	19 ^{a}	4.66 ^{a}	7.83 ^{a}	3.43 ^{a}	16 ^{a}
Aspergillus terreus (2)	52 ^{b}	96 ^{a}	10.3 ^{bc}	3 ^{c}	7.6 ^{a}	2.66 ^{b}	11 ^{b}
Penicillium chrysogenum (1)	38.6 ^{bc}	85 ^{b}	10.6 ^{bc}	2.2 ^{d}	6.66 ^{ab}	1.46 ^{c}	10 ^{c}
Control (untreated)	94.3 ^{a}	56 ^{c}	9.6 ^{c}	2 ^{c}	4 ^{b}	1.16 ^{c}	9 ^{d}

Means followed by the same letters (s) in a column are not significantly different at ($p \leq 0.05$) according to Duncan's multiple-range test.

The species were then compared to using *Trichoderma* spp. alone or in combination with the following results.

Treatments	Disease Severity (%)	Growth parameters					
		Shoot			Root		
		Shoot height (cm)	Fresh weight (g)	Dry weight (g)	Fresh weight (g)	Dry weight (g)	Number of bods
A. niger + *Trichoderma* sp.	16 ^{c}	91.3 ^{b}	24.6 ^{c}	9.6 ^{b}	14.6 ^{b}	7.1 ^{b}	8 ^{c}
A. terreus $_{(1)}$ + *Trichoderma* sp.	25.3 ^{bc}	84 ^{c}	27 ^{b}	8.5 ^{c}	15.3 ^{b}	5.6 ^{c}	12 ^{b}
A. terreus $_{(2)}$ + *Trichoderma* sp.	46.6 ^{a}	84 ^{c}	27.5 ^{b}	7.6 ^{d}	13 c	5.4 ^{c}	6 ^{d}
P. chrysogenum $_{(1)}$ + *Trichoderma* sp.	36 ^{ab}	80 ^{d}	17.5 ^{d}	6 ^{e}	9.3 ^{d}	3.5 ^{d}	13 ^{a}
Control (*Trichoderma* sp. only)	13.3 ^{c}	98 ^{a}	42.3 ^{a}	12.6 ^{a}	25.6 ^{a}	14.3 ^{a}	12 ^{b}

INDIA

- R.B. Kakde and A.M. Chavan (2011) examined the effects of fungi on seeds in storage. Ten dominant fungi were isolated from seeds of groundnut, soybean, sesame, safflower, and sunflower. One hundred grams of seeds were inoculated with 10 ml of the fungi. The flasks were left at room temperature for 14 days and then analyzed for sugars, crude fat, and fiber. The results are as follow.

Table 1. Change in reducing sugar (g/100gm) due to seed-borne fungi

Fungi	Sunflower	Sesame	Groundnut	Soybean	Safflower
Alternaria dianthicola	5.2	4.8	1.1	1.1	1.3
Curvularia lunata	4.9	5.0	2.5	1.5	1.8
Curvularia pellescens	5.0	5.4	2.1	1.2	1.6
Fusarium oxysporum	4.7	4.4	1.8	1.7	1.1
Fusarium equiseti	4.6	4.8	1.6	1.2	1.0
Macrophomina phaseolina	5.8	3.5	2.2	2.0	2.2
Rhizopus stolonifer	6.1	5.0	1.1	1.8	2.1
Penicillium digitatum	5.5	4.6	1.9	1.7	1.4
Penicillium chrysogenum	5.2	4.9	2.0	1.6	1.6
Trichoderma viride	6.7	6.1	2.1	1.9	2.6
Control	7.2	6.9	3.1	2.4	2.8
C.D. at 0.05	0.52	0.62	1.21	0.24	0.21

Table 2. Change in crude fat (g/100gm) due to seed-borne fungi

Fungi	Sunflower	Sesame	Groundnut	Soybean	Safflower
Alternaria dianthicola	35.5	10.2	37.1	49.8	22
Curvularia lunata	43.5	14.3	32.5	48.2	26
Curvularia pellescens	45.5	10	41	49	27
Fusarium oxysporum	43	16.1	38	44	20
Fusarium equiseti	47	14.2	35	49.7	19
Macrophomina phaseolina	39	10.5	39.3	46.8	30
Rhizopus stolonifer	50	16.3	40.2	48.6	33
Penicillium digitatum	42	15.3	34.8	39	24
Penicillium chrysogenum	44	12.8	36.2	41	27
Trichoderma viride	46	17.5	40	46	35
Control	49	20	45	50	36
C.D. at 0.05	2.71	2.05	2.04	2.4	3.7

Table 3. Change in crude fiber (g/100) due to seed-borne fungi

Fungi	Sunflower	Sesame	Groundnut	Soybean	Safflower
Alternaria dianthicola	39.1	35.6	33.9	26.1	20.1
Curvularia lunata	52.3	30.6	38.8	34.5	21.8
Curvularia pellescens	46.1	41.1	42.3	31.1	21.6
Fusarium oxysporum	53.1	36.5	34.7	37.0	21.0
Fusarium equiseti	50.7	36.4	37.9	21.0	22.5
Macrophomina phaseolina	47.7	34.8	41.9	36.6	17.9
Rhizopus stolonifer	41.6	31.6	40.1	28.5	19.6
Penicillium digitatum	43.5	40.5	27.6	21.0	14.4
Penicillium chrysogenum	40.5	27.7	31.7	36.9	13.9
Trichoderma viride	47.5	35.1	38.3	37.0	19.8
Control	51.3	47.7	38.0	23.3	19.9
C.D. at 0.05	3.16	6.11	2.39	4.2	1.82

IRAN

- M. Gooya et al. (2000) reported during 1997/99 one seed samples of each 17 sesame cultivars from 10 locations resulted in 145 isolates, which included 34 species of 15 genera. They identified *Penicillium chrysogenum*.

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A14 Order: Mucorales Dumort. 1829

(Wikipedia, 19 Apr 2021) The **Mucorales** is the largest and best studied order of zygomycete fungi. Members of this order are sometimes called **pin molds**. The term mucormycosis is now preferred for infections caused by molds belonging to the order Mucorales.

There are species in this order associated with sesame, but not reported to cause diseases, produce a toxin, inhibit germination, or affect seed quality. See H1.

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A14.1 Family: Mucoraceae Fresen. 1821

(Wikipedia, 19 Apr 2021) The **Mucoraceae** are a family of fungi of the order Mucorales, characterized by having the thallus not segmented or ramified. Pathogenic genera include *Absidia*, *Apophysomyces*, *Mucor*, *Rhizomucor*, and *Rhizopus*. According to a 2008 estimate, the family contains 25 genera and 129 species.

The following species have been reported to cause diseases, produce a toxin, inhibit germination, or affect seed quality.

- A14.1.1 *Rhizopus* spp.
- A14.1.1a *Rhizopus oryzae*
- A14.1.1b *Rhizopus stolonifer* (*Syn: *Rhizopus nigricans*)
- A14.1.2 *Mucor* spp.
- A14.1.2a *Mucor hiemalis*

A14.1.1 *Rhizopus* spp. (19 Apr 2021)

Family: Mucoraceae

Definition: Amount of tolerance to *Rhizopus* spp**.** Ehrenb. 1820.

(Wikipedia, 19 Apr 2021) ***Rhizopus*** is a genus of common saprophytic fungi on plants and specialized parasites on animals. They are found in a wide variety of organic substances , including “mature fruits and vegetables”, jellies, syrups, leather, bread, peanuts, and tobacco. They are multicellular. Some *Rhizopus* species are opportunistic agents of human zygomycosis (fungal infection) and can be fatal. *Rhizopus* infections may also be a complication of diabetic ketoacidosis. This widespread genus includes at least eight species.

Rhizopus species grow as filamentous, branching hyphae that generally lack cross-walls (i.e., they are coenocytic). They reproduce by forming asexual and sexual spores. In asexual reproduction, sporangiospores are produced inside a spherical structure, the sporangium. Sporangia are supported by a large apophysate columella atop a long stalk, the sporangiophore. Sporangiophores arise among distinctive, root-like rhizoids. In sexual reproduction, a dark zygospore is produced at the point where two compatible mycelia fuse. Upon germination, a zygospore produces colonies that are genetically different from either parent.

References:

EGYPT

- M.M.I. Abdel-Hafez et al. (2014) took ten samples of sesame from local markets in Assiut city. They found *Rhizopus* sp.

INDIA

- K. Bhattachary and S. Raha (2002) studied fungal infection, moisture content, germinability and deterioration of sesame in storage under natural conditions for a year. Different species of Aspergillus (*A. candidus*, A. *flavus*, *A. niger*, *A. terreus*, and *A. ruber*) were dominant followed by Rhizopus, Penicillium, Curvularia, Fusarium, Alternaria, etc. Seed moisture was maximum in the rainy season followed by a gradual decrease during longer storage. As storage proceeded, there was a gradual decrease in field fungi with simultaneous increase in storage fungi, and a reduction in germinability. A gradual loss of carbohydrate (both soluble and insoluble) content was recorded. A loss of protein content was recorded followed by a small increase. Oil content decreased in prolonged storage with simultaneous increase in fatty acid. [Based on abstract]

- V. Bharathi et al. (2013) collected sesame seeds from farmers in Andhra Pradesh. They tested the seeds for mycoflora, and the following fungus was found: *Rhizopus* spp.

NIGERIA

- C.N. Ezekiel et al. (2014) isolated the following fungi on sesame seeds: *Rhizopus* sp.
- A.D. Ojochenemi et al. (2015) examined 46 samples of sesame and reported *Rhizopus* spp.

SAUDI ARABIA

- A.H. Bahkali and M.A. Moslem (1996) reported the following mycoflora on 5 cultivars: *Rhizopus* sp.

SUDAN

- N.M.A. Hamid (2006) identified the following fungus from seed collected from 3 areas of Sudan: *Rhizopus* sp.
- H.I.H. Idriss (2016) collected farmer saved red and white sesame from 7 locations in Sudan. 14 different fungi representing ten genera were identified. One of the low frequency fungi was *Rhizopus* sp.

A14.1.1a *Rhizopus oryzae* (19 Apr 2021)

Family: Mucoraceae

Definition: Amount of tolerance to *Rhizopus oryzae* Went & H.C. Prinsen Geerligs 1895.

(Wikipedia, 19 Apr 2021) ***Rhizopus oryzae*** is a filamentous heterothallic microfungus that occurs as a saprotroph in soil, dung, and rotting vegetation. This species is very similar to *Rhizopus stolonifer*, but it can be distinguished by its smaller sporangia and air-dispersed sporangiospores. It differs from *R. oligosporus* and *R. microsporus* by its larger columellae and sporangiospores. *R. oryzae* is used economically in the production of the enzymes, glucoamylase and lipase, in the synthesis of organic acids, and in various fermented foods. The many strains of *R. oryzae* produce a wide range of enzymes such as carbohydrate digesting enzymes and polymers along with a number of organic acids, ethanol and esters giving it useful properties within the food industries, bio-diesel production, and pharmaceutical industries. It is also an opportunistic pathogen of humans causing mucormycosis.

R. oryzae is used in the production of alcoholic beverages in parts of Asia and Africa.

References:

IRAN

- M. Gooya et al. (2000) took one seed samples of each 17 sesame cultivars from 10 locations leading to 145 isolates during 1997/99 They identified *Rhizopus oryzae*.

PAKISTAN

- B.G. Nayyar et al. (2013) examined 15 samples of seed to detect fungi using 3 methods: agar plate, blotter, and deep freezing and found *Rhizopus oryzae*.
- B.G. Nayyar et al. (2014) studied the effects of fungal pathogens on the germination of sesame. Seven prevalent fungal species viz. *Alternaria alternata, Aspergillus flavus, Aspergillus niger, Cercospora* sp., *Fusarium oxysporum, Penicillium egyptiacum* and *Rhizopus oryzae* associated with sesame seeds were selected for this study. Fungi associated with seeds affected the seed health and resulted in reduced seed germination, and seedling abnormality as shown in the table below.

Treatments	Normal seedlings %age	Abnormal seedlings %age	Un germinated seeds %age	Fungi isolated
Surface sterilized seeds	80	14	6	*Aspergillus flavus* *Aspergillus niger* *Fusarium oxysporum*
Naturally infected seeds	64	26	10	*Alternaria alternata* *Aspergillus flavus* *Aspergillus niger* *Fusarium oxysporum* *Penicillium egyptiacum*

The pathogenicity of the 7 fungi was tested with the following results.

S. No.	Fungi isolated	Pathogenic Effect	Healthy Plants
1	*A. alternata*	Infected root & stem, Weak stem, Reduced growth	55%
2	*A. flavus*	Reduced growth	70%
3	*A. niger*	Reduced growth, Infected roots, Weak stem	13%
4	*Cercospora* sp.	Infected stem, Weak stem, Reduced growth	40%
5	*P. egyptiacum*	Infected root, Weak stem	26%
6	*R. oryzae*	Reduced growth, Infected roots & stem, Weak stem	30%
7	*F. oxysporum*	Reduced growth, Leaves short & infected	32%

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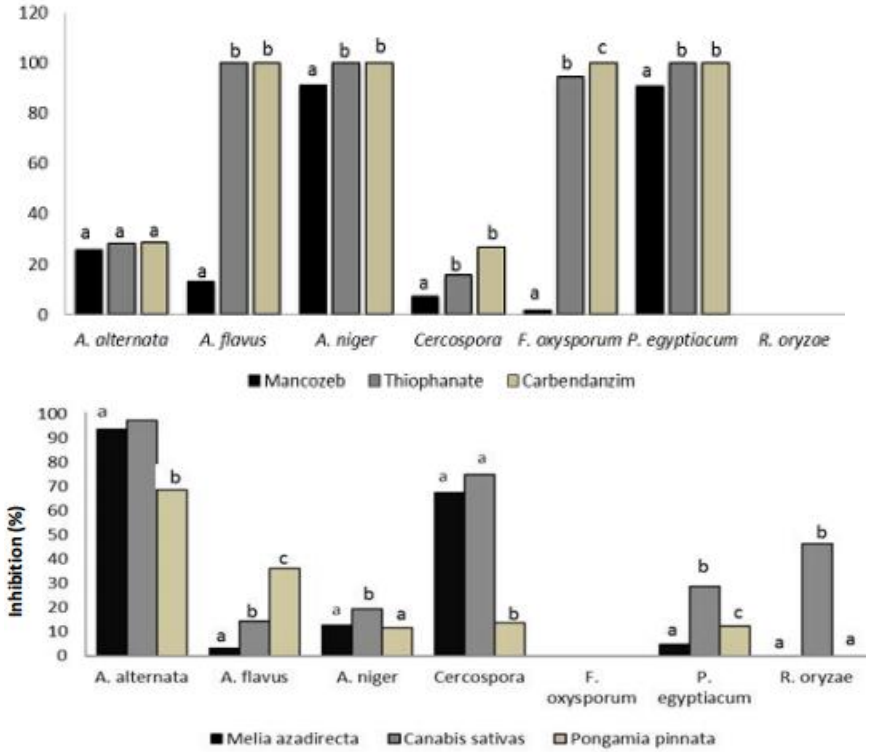
Abnormality rate of seedlings depends on the type of pathogens with which they are infected. There is also need for the management programs to control seedborne pathogens and reduce their impact on sesame production in Pakistan.

- B.G. Nayyar et al. (2016) evaluated different treatments to increase the germination and inhibit the fungi on sesame seeds: application of fungicides (Mancozeb, Thiophante Methyl, and Carbendazim) and plant extracts (*Melia azedarach*, *Cannabis sativa* and *Pongamia pinnata*). Seed germination was tested by following the protocol of International Seed Testing Association. Antifungal activity was tested by poisoned food technique. The results revealed that the germination increased effectively, due to thiophanate methyl up to 46%, followed by *Cannabis sativa* (37%). Out of 7 fungi tested against fungicides and plant extracts, 4 fungi, namely *Aspergillus flavus, Aspergillus niger*, *Fusarium oxysporum* and *Penicillium egyptiacum*, were inhibited up to 100% by Carbendazim and Thiophanate Methyl, while Mancozeb inhibited *Penicillium egyptiacum* (100%), only. *Cannabis sativa* inhibited *Alternaria alternata* (100%) and *Rhizopus oryzae* (55.6%). Overall treatment with fungicides gave best results but they were not eco-friendly. So, this study recommends the use of plant extracts and bioagents, which may increase seed germination and inhibit seedborne fungi without any harmful effect. The treatments had the following effects on specific fungi in terms of germination and inhibition: *Alternaria alternata, Aspergillus flavus, Aspergillus niger, Cercospora sp., Fusarium oxysporum, Penicillium egyptiacum* and *Rhizopus oryzae.*



A14.1.1b *Rhizopus stolonifer* (20 Jul 2021)

Synonym: *Rhizopus nigricans*

Family: Mucoraceae

Definition: Amount of tolerance to *Rhizopus stolonifer* Vuillemin.

(Wikipedia, 20 Jul 2021) ***Rhizopus stolonifer*** is commonly known as black bread mold. It is a member of *Zygomycota* and considered the most important species in the genus *Rhizopus*. It is one of the most common fungi in the world and has a global distribution although it is most commonly found in tropical and subtropical regions. It is a common agent of decomposition of stored foods. Like other members of the genus *Rhizopus*, *R. stolonifer* grows rapidly, mostly in indoor environments.

References:

BANGLADESH

- M.D. Hosen and S. Shamsi (2017) isolated the following fungi from sesame seeds: *Aspergillus flavus, A. fumigatus, A. niger, Curvularia lunata, Fusarium merismoides, Mucor* sp., *Penicillium* sp., and *Rhizopus stolonifer*.

EGYPT

- H.A.H. Hasan (2002) reported *Rhizopus stolonifer* was a pathogen in the rhizosphere and rhizoplane. [Cited by S.I.I. Abdel-Hafez, 2012]

INDIA

- R.K.S. Chauhan and B.M. Kulshrestha (1984b) reported the diffusate obtained from the fruit cavities of sesame inoculated with a spore suspension of *Alternaria sesami* was inhibitory to the germination of spores. It inhibited the spore germination of *Rhizopus stolonifer*. No inhibition was caused by the extracts of healthy uninoculated fruits.
- K. Kumar et al. (1984a) reported *Rhizopus nigricans* was found to be associated with the seeds of varieties T-4 and T-12. The species was pathogenic and reduced germination by causing seed rot under laboratory conditions.
- N.O. Srikantappa et al. (2009) studied 28 samples of sesame taken from fields, farmers, retail shops and APMC markets from 5 areas. They found *Rhizopus stolonifer*. The fungi significantly reduced germination.
- F.M. Afolagboye (2011) reported the following fungus from 4 sesame varieties (NCRIBEN 03L, NCRIBEN 01M, E8 and 530-6-1) at Abeokuta: *Rhizopus nigricans.* [Based on abstract]
- R.B. Kakde and A.M. Chavan (2011) examined the effects of fungi on seeds in storage. Ten dominant fungi were isolated from seeds of groundnut, soybean, sesame, safflower, and sunflower. One hundred grams of seeds were inoculated with 10 ml of the fungi. The flasks were left at room temperature for 14 days and then analyzed for sugars, crude fat, and fiber. The results are as follow.

Table 1. Change in reducing sugar (g/100gm) due to seed-borne fungi

Fungi	Sunflower	Sesame	Groundnut	Soybean	Safflower
Alternaria dianthicola	5.2	4.8	1.1	1.1	1.3
Curvularia lunata	4.9	5.0	2.5	1.5	1.8
Curvularia pellescens	5.0	5.4	2.1	1.2	1.6
Fusarium oxysporum	4.7	4.4	1.8	1.7	1.1
Fusarium equiseti	4.6	4.8	1.6	1.2	1.0
Macrophomina phaseolina	5.8	3.5	2.2	2.0	2.2
Rhizopus stolonifer	6.1	5.0	1.1	1.8	2.1
Penicillium digitatum	5.5	4.6	1.9	1.7	1.4
Penicillium chrysogenum	5.2	4.9	2.0	1.6	1.6
Trichoderma viride	6.7	6.1	2.1	1.9	2.6
Control	7.2	6.9	3.1	2.4	2.8
C.D. at 0.05	0.52	0.62	1.21	0.24	0.21

Table 2. Change in crude fat (g/100gm) due to seed-borne fungi

Fungi	Sunflower	Sesame	Groundnut	Soybean	Safflower
Alternaria dianthicola	35.5	10.2	37.1	49.8	22
Curvularia lunata	43.5	14.3	32.5	48.2	26
Curvularia pellescens	45.5	10	41	49	27
Fusarium oxysporum	43	16.1	38	44	20
Fusarium equiseti	47	14.2	35	49.7	19
Macrophomina phaseolina	39	10.5	39.3	46.8	30
Rhizopus stolonifer	50	16.3	40.2	48.6	33
Penicillium digitatum	42	15.3	34.3	39	24
Penicillium chrysogenum	44	12.8	36.2	41	27
Trichoderma viride	46	17.5	40	46	35
Control	49	20	45	50	36
C.D. at 0.05	2.71	2.05	2.04	2.4	3.7

Table 3. Change in crude fiber (g/100) due to seed-borne fungi

Fungi	Sunflower	Sesame	Groundnut	Soybean	Safflower
Alternaria dianthicola	39.1	35.6	33.9	26.1	20.1
Curvularia lunata	52.3	30.6	38.8	34.5	21.8
Curvularia pellescens	46.1	41.1	42.3	31.1	21.6
Fusarium oxysporum	53.1	36.5	34.7	37.0	21.0
Fusarium equiseti	50.7	36.4	37.9	21.0	22.5
Macrophomina phaseolina	47.7	34.8	41.9	36.6	17.9
Rhizopus stolonifer	41.6	31.6	40.1	28.5	19.6
Penicillium digitatum	43.5	40.5	27.6	21.0	14.4
Penicillium chrysogenum	40.5	27.7	31.7	36.9	13.9
Trichoderma viride	47.5	35.1	38.3	37.0	19.8
Control	51.3	47.7	38.0	23.3	19.9
C.D. at 0.05	3.16	6.11	2.39	4.2	1.82

- V. Bharathi et al. (2013) collected sesame seeds from farmers in Andhra Pradesh. They tested the seeds for mycoflora and found *Rhizopus stolonifer*.
- H.R. Aglave (2016) screened two varieties (CV.N-85 and CV. Phule-1) for seed mycoflora. Twenty-seven fungi were isolated from these varieties. Varietal variation was found during the investigation. The following fungus was present *Rhizopus stolonifer*.

A14.1.2 *Mucor* spp. (19 Apr 2021)

Family: Mucoraceae

Definition: Amount of tolerance to *Mucor* spp. Fresen.

(Wikipedia, 19 Apr 2021) ***Mucor*** is a microbial genus of approximately 40 species of molds commonly found in soil, digestive systems, plant surfaces, some cheeses like Tomme de savoie, rotten vegetable matter and iron oxide residue in the biosorption process.

Colonies of this fungal genus are typically white to beige or grey and fast-growing. Colonies on culture medium may grow to several cm in height. Older colonies become grey to brown in color due to the development of spores.

Mucor spores or sporangiospores can be simple or branched and form apical, globular sporangia that are supported and elevated by a column-shaped columella. *Mucor* species can be differentiated from molds of the genera *Absidia*, *Rhizomucor*, and *Rhizopus* by the shape and insertion of the columella, and the lack of stolons and rhizoids. Some *Mucor* species produce chlamydospores. They form mold with irregular non-septate hyphae branching at wide angles (>90°).

The following species has been associated with sesame but there are no known reports of being a pathogen, producing a toxin, inhibiting germination, affecting seed quality, or being used as a biocontrol or biofertilizer.

- *Mucor mucedo* [India]

References:

BANGLADESH

- M.D. Hosen and S. Shamsi (2017) isolated the following fungus from sesame seeds: *Mucor* sp.

INDIA

- P.L. Radha (2013) collected 18 cultivars from 7 districts in Karnataka and identified the following fungus: *Mucor* sp.

NIGERIA

- C.N. Ezekiel et al. (2014) isolated the following fungi on sesame seeds: *Mucor* sp.
- S.T. Anjorin et al. (2016) studied the effects of 6 botanicals (baobab [*Adansonia digitate*] leaf powder, hot pepper [*Capsicum annum*] fruits, and ordeal tree [*Erythrophleum suaveolens*] bark and leaves, garlic bulbs and ginger rhizomes) against fungi isolated from sesame seeds (*Aspergillus niger*, *Aspergillus flavus*, *Mucor* spp., *Fusarium* spp., *Alternaria* spp., and *Penicillium* spp.). The ginger, garlic, and ordeal bark were not effective. The results of the effective treatments were as follow.

Sesame seeds treated with plant extracts	*Aspergillusniger*	*Fusarium*spp.	*Aspergillusflavus* (cfug/ml)	*Penicillium* spp.	*MucorAlternaria* spp. spp.
Baobab leaf extract (100%)	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{b}	0.00^{b} 0.00^{b}
Baobab leaf extract (10%)	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{b}	0.00^{b} 0.00^{b}
Ordeal leaf extract(100%)	0.00^{c}	0.00^{c}	0.00^{c}	0.00^{b}	0.00^{b} 0.00^{b}
Ordeal leaf extract(10%)	0.00^{c}	1.00^{bc}	0.00^{c}	1.00^{b}	0.00^{b} 0.00^{b}
Hot pepper fruit extract(100%)	4.00^{b}	2.00^{b}	0.00^{c}	4.00^{a}	1.00^{ab} 0.00^{b}
Hot pepper fruit extract(10%)	5.00^{b}	2.00^{b}	0.00^{c}	0.00^{b}	1.00^{ab} 0.00^{b}
Untreated sesame seed before storage	7.00^{a}	5.00^{a}	4.00^{a}	5.00^{a}	1.00^{ab} 2.00^{a}
Untreated sesame seed after storage	5.00^{b}	5.00^{a}	2.00^{b}	4.00^{a}	2.00^{a} 1.00^{b}

SAUDI ARABIA

- A.H. Bahkali and M.A. Moslem (1996) reported the following mycoflora on 5 cultivars: *Mucor* sp.

VENEZUELA

- Y. Martinez et al. (1991) in studying aflatoxin reported the following fungi on sesame: *Mucor* sp.

A14.1.2a *Mucor hiemalis* (19 Apr 2021)

Family: Mucoraceae

Definition: Amount of tolerance to *Mucor hiemalis* Wehmer 1903.

(Wikipedia, 19 Apr 2021) ***Mucor hiemalis*** Mucor hiemalis is among the zygosporic fungi found in unspoiled foods. It has different industrial importance as biotransforming agents of pharmacological and chemical compounds. *M. hiemalis* grows in expanding gray colonies. It grows branched sporangiophores that yielding yellow to dark brown sporangia which can mate to form black-brown, spiny zygospores.

References:

EGYPT

- E. Abdou et al. (2001) collected seed from several locations in Egypt. *Fusarium* was the most dominant fungi associated with the diseased sesame plants. Of 3 *Fusarium* species *Fusarium oxysporum* f. sp. *sesami* was the highest frequency, followed by *Macrophomina phaseolina, Mucor haemalis, Thielaviopsis basicola* (Wetn), and *Rhizoctonia solani*. Application of ascorbic acid or salicylic acid to seeds and/or plants reduced the number of the diseased sesame seedling plants. Treated seeds plus twice irrigation with either ascorbic acid or salicylic acid caused the best control against *F. oxysporum* f. sp. *sesami* infection as compared to the fungicide Benlate. Meantime, ascorbic and salicylic acids had less effect to control sesame damping-off and root rot wilt diseases caused by infection with *M. phaseolina, Mucor haemalis* or *Thielaviopsis basicola* as compared to Benlate. [Based on abstract]
- E. Abdou et al. (2004) reported both salicylic acid (SA) and yeast (*Saccharomyces cerevisiae*) seed treatments affected incidence of wilt and root rot of sesame incited by *Fusarium oxysporum* f. sp *sesami*, *Macrophomina phaseolina*, *Thielaviopsis basicola*, and *Mucor haemalis*. Also, yeast derivatives variously affected root rot/wilt severity. Combining SA with yeast or with its derivatives showed, in most cases, inhibition effects against the tested pathogenic fungi. [Based on abstract]

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A14.2 Family: Choanephoraceae J. Schrot 1897

(Wikipedia, 28 Apr 2021) The **Choanephoraceae** are a family of fungi in the order Mucorales. Members of this family are found mostly in the tropics or subtropics, and only rarely in temperate zones. The family currently includes species formerly classified in the family *Gilbertellaceae*.

The following species have been reported to cause diseases, produce a toxin, inhibit germination, or affect seed quality.

- A14.2.1 *Choanephora* spp.
- A14.2.1a *Choanephora cucurbitarum*

A14.2.1 *Choanephora* spp. (28 Apr 2021)

Family: Choanephoraceae

Definition: Amount of tolerance to *Choanephora* spp.

(Wikipedia, 28 Apr 2021) ***Choanephora*** is a genus of Zygomycota fungi. *Choanephora* species are known as plant pathogens.

A14.2.1a *Choanephora cucurbitarum* (28 Apr 2021)

Family: Choanephoraceae

Definition: Amount of tolerance to *Choanephora cucurbitarum* (Berk. & Ravenel) Thaxt. 1903.

(Wikipedia, 28 Apr 2021) ***Choanephora cucurbitarum*** is a fungal plant pathogen that causes fruit and blossom rot of various cucurbits. It can also affect okra, snap bean, and southern pea, and may cause a stem and leaf rot of *Withania somnifera*. Recently Das et al. 2017 added few more patho-index on aubergine (*Solanum melongena* L.), teasle gourd (*Momordica subangulata* Blume subsp. *Renigera* (G. Don) de Wilde, hyacinth bean (*Lablab purpureus* (L.) Sweet), green pea (*Pisum sativum*) from India. Wet weather, high temperature and high humidity favor disease development from inoculum that is typically soilborne. Signs of infection on fruits or leaves include water-soaked, necrotic lesions, which progress rapidly under ideal conditions. As the fungus begins to produce spores, affected tissues become dark grey-brown and hairy as a result of the superficial sporangia.

References:

INTERNATIONAL

- CAB International (accessed 12 Apr 2021) reported sesame as a minor host of *Choanephora cucurbitarum* (Choanephora fruit rot)

INDIA

- Karma and S. Singh (1976) reported *Choanephora cucurbitarum* causing severe losses in Sesamum seedlings in July 1974. [Cited by G.S. Saharan, 1989]
- S. Maiti et al. (1985 and 1986) reported the following minor pathogen: Wet rot *Choanephora cucurbitarum* (Berk and Rev.) Thaxt.
- M.L. Verma (1985) reported *Choanephora cucurbitarum* (Wet rot) is a minor disease with the following symptoms: Wet rot of seedlings. Pod blight.

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A15 Order: Microascales Luttr. ex Benny & R.K. Benj. 1980

(Wikipedia, 19 Apr 2021) The **Microascales** are an order of fungi in the class Sordariomycetes, subclass Hypocreomycetidae. This is a relatively small order of mostly saprobic fungi that live in soil, rotting vegetation and dung. Some species are plant pathogens, such as *Ceratocystis fimbriata*, transmitted by beetles to living trees and causing cacao wilt and many other economically important diseases. Species in the genus *Pseudallescheria* (family Microascaceae) are pathogenic to humans, for example, *Pseudallescheria boydii* can cause allergic bronchopulmonary disease. The order was circumscribed in 1980.

The Microascales are characterized by a lack of stroma, black perithecial ascomata with long necks or rarely with cleistothecial ascomata that lack paraphyses. They have roughly spherical and short-lived asci that develop singly or in chains. Nonseptate, colorless ascospores often have ornamenting ridges or wings. The anamorphs of the family Microascaceae produce percurrently proliferating conidiogenous cells (annellides) and sometimes chlamydospore-like or aleurioconidial synanamorphs; these are classified mostly in the genera *Scopulariopsis*, *Graphium* and *Scedosporium*.

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A15.1 Family: Ceratocystidaceae Locq. Ex Reblova, W. Gams & Seifert 2011

(Wikipedia, 19 Apr 2021) The **Ceratocystidaceae** are a family of fungi in the class Sordariomycetes, subclass Hypocreomycetidae.

The following species have been reported to cause diseases, produce a toxin, inhibit germination, or affect seed quality.

- A15.1.1 *Thielaviopsis* spp.
- A15.1.1a *Thielaviopsis basicola*

There are species in this family associated with sesame, but not reported to cause diseases, produce a toxin, inhibit germination, or affect seed quality. See H2.1.

A15.1.1 *Thielaviopsis* spp. (19 Apr 2021)

Family: Ceratocystidaceae

Definition: Amount of tolerance to *Thielaviopsis* spp. Went 1893.

(Wikipedia, 19 Apr 2021) ***Thielaviopsis*** is a small genus of fungi in the order Microascales. The genus includes several important agricultural pathogens. The most widespread is *T. basicola*, the causal agent in several root rot diseases of economically important crop species including cotton and a variety of vegetables. In cotton, *Thielaviopsis* root rot, also known as black root rot causes necrosis of the roots and stunting of the crop plants.

References:

UNITED STATES

- D.R. Langham et al. (2010c) stated *Thielaviopsis* sp. has been reported in sesame in the USA in research nurseries but have not been seen in commercial fields since 1978.

A15.1.1a *Thielaviopsis basicola* (19 Apr 2021)

Family: Ceratocystidaceae

Definition: Amount of tolerance to *Thielaviopsis basicola* Berk. & Broome) Ferraris 1912.

(Wikipedia, 19 Apr 2021) ***Thielaviopsis basicola*** is the plant-pathogen fungi responsible for black root rot disease. This particular disease has a large host range, affecting woody ornamentals, herbaceous ornamentals, agronomic crops, and even vegetable crops. Examples of susceptible hosts include petunia, pansy, poinsettia, tobacco, cotton, carrot, lettuce, tomato, and others. Symptoms of this disease resemble nutrient deficiency but are truly a result of the decaying root systems of plants. Common symptoms include chlorotic lower foliage, yellowing of plant, stunting or

wilting, and black lesions along the roots. The lesions along the roots may appear red at first, getting darker and turning black as the disease progresses. Black root lesions that begin in the middle of a root can also spread further along the roots in either direction. Due to the nature of the pathogen, the disease can easily be identified by the black lesions along the roots, especially when compared to healthy roots. The black lesions that appear along the roots are a result of the formation of chlamydospores, resting spores of the fungi that contribute to its pathogenicity. The chlamydospores are a dark brown-black color and cause the "discoloration" of the roots when they are produced in large amounts.

References:

INTERNATIONAL

- E.A. Weiss (1971) reported *Thielaviopsis basicola* often kills young plants and stunts those more mature. Symptoms are blackening and decay of the root system, which is progressively attacked until destroyed. Discoloration of the stem extends 5 to 10 cm above soil level. The disease is soilborne and is most destructive in heavy, cold, slightly acid or alkaline soils well supplied with humus. Long wet periods after emergence increase the severity of attacks. Soils with pH of 5.6 of lower, or sandy soils low in organic matter are less affected.

EGYPT

- E. Abdou et al. (2001) collected seed from several locations in Egypt. *Fusarium* was the most dominant fungi associated with the diseased sesame plants. Of 3 *Fusarium* species *Fusarium oxysporum* f. sp. *sesami* was the highest frequency, followed by *Macrophomina phaseolina, Mucor haemalis, Thielaviopsis basicola,* and *Rhizoctonia solani*. Application of ascorbic acid or salicylic acid to seeds and/or plants reduced the number of the diseased sesame seedling plants. Treated seeds plus twice irrigation with either ascorbic acid or salicylic acid caused the best control against *F. oxysporum* f. sp. *sesami* infection as compared to the fungicide Benlate. Meantime, ascorbic and salicylic acids had less effect to control sesame damping-off and root rot wilt diseases caused by infection with *M. phaseolina, Mucor haemalis* or *Thielaviopsis basicola* as compared to Benlate. [Based on abstract]
- E. Abdou et al. (2004) reported both salicylic acid (SA) and yeast (*Saccharomyces cerevisiae*) seed treatments affected incidence of wilt and root rot of sesame incited by *Fusarium oxysporum* f. sp *sesami*, *Macrophomina phaseolina*, *Thielaviopsis basicola,* and *Mucor haemalis*. Also, yeast derivatives variously affected root rot/wilt severity. Combining SA with yeast or with its derivatives showed, in most cases, inhibition effects against the tested pathogenic fungi. [Based on abstract]

UNITED STATES

- C.A. Thomas and G.C. Papasizas (1965a) reported a severe red rot of roots and lower stems of the sesame varieties Oro and Margo in experimental plots was caused by *Thielaviopsis basicola*. Later the disease was observed in the field in Texas. [Cited by G.S. Saharan, 1989]
- P.B. Adams (1971) reported soil amended with alfalfa hay, corn stover, and cabbage tissue substantially reduced red root of sesame caused by *Thielaviopsis basicola* in greenhouse experiments. In the field, alfalfa hay and corn stover provided no significant control. In a crop rotation study, no significant control was obtained when sesame followed oat, corn, or cabbage. In the greenhouse at a temp at 15°C, alfalfa hay provided no control, whereas at 20 and 25°C, alfalfa hay provided substantial control. At 30 and 35°C, red root was controlled by temperature alone. When the soil temperature was cycled 10 hours at 25°C and 14 hours at 30°C, disease severity was significantly less than that at constant 25°C, and similar to that at constant 30 C. Maximum germination of chlamydospores of *T. basicola* in soil was obtained at 25°C, with percentage of germination declining rapidly to zero at 35°C. Use of clear plastic mulch in the field to raise the soil temperature provided significant control of red root 7 weeks after planting, but not 12 weeks after planting. [Based on abstract]
- D.T. Smith et al. (2000) reported after sesame seedlings are established, root damage can occur from *Thielaviopsis basicola*. This pathogen infects the vascular system and can reduce stands and cause premature death.

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A16 Order: Helicobasidiales R. Bauer, Begerow, J.P. Samp., M. Weiss & Oberw. 2006

(Wikipedia, 1 May 2021) The **Helicobasidiales** are an order of rust fungi in the class Pucciniomycetes. It contains the single family **Helicobasidiaceae**, which itself comprises three genera: *Helicobasidium*, *Stypinella*, and *Tuberculina*. Helicobasidiales was circumscribed in 2006.

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A16.1 Family: Helicobasidiaceae P.M. Kirk 2008

The following species have been reported to cause diseases, produce a toxin, inhibit germination, or affect seed quality.

- A16.1.1 *Helicobasidium* spp.
- A16.1.1 *Helicobasidium mompa*

A16.1.1 *Helicobasidium* spp. (1 May 2021)

Family: Helicobasidiaceae

Definition: Amount of tolerance to *Helicobasidium* spp. Patouillard 1885.

(Wikipedia, 1 May 2021) ***Helicobasidium*** is a genus of fungus in the family Helicobasidiaceae.

A16.1.1 *Helicobasidium mompa* (1 May 2021)

Family: Helicobasidiaceae

Definition: Amount of tolerance to *Helicobasidium mompa* Tanaka 1891.

References:

CHINA

- L.L. Li (1988) reported *Helicobasidium mompa* (Purple root rot) causes minor or regional damage to sesame.

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A17 Order: **Xylariales** Nannfeldt 1932

(Wikipedia, 24 May 2021) The **Xylariales** are an order of fungi within the class Sordariomycetes (also known as Pyrenomycetes), subdivision Pezizomycotina, division Ascomycota. It is the only order of the subclass **Xylariomycetidae**. Xylariales was circumscribed in 1932 by Swedish mycologist John Axel Nannfeldt, and Xylariomycetidae by Ove Erik Eriksson and Katarina Winka in 1997.

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A17.1 Family: **Amphisphaeriaceae** G. Winter 1885

(Wikipedia, 24 May 2021) The ***Amphisphaeriaceae*** are a family of fungi that is mainly found in parts of New Zealand, South America, Asia and parts of Europe. According to the 2007 Outline of Ascomycota, there are 41 genera placed within the family, although the position of 13 of those genera is uncertain.

The following species have been reported to cause diseases, produce a toxin, inhibit germination, or affect seed quality.

- A17.1 *Pestalotia macrotricha*
- A17.1.1 *Pestalotiopsis* spp.
- A17.1.1.1a *Pestalotiopsis mayumbensis*

A17.1.1 ***Pestalotiopsis* spp.** (9 Aug 2021)

Family: Amphisphaeriaceae

Definition: Amount of tolerance to *Pestalotiopsis* spp. Steyaert 1949.

(Wikipedia, 9 Aug 2021) ***Pestalotiopsis*** is a genus of ascomycete fungi. *Pestalotiopsis* species are known as plant pathogens. Some members of the genus are able to grow on the synthetic polymer *polyurethane* as its sole carbon source under both aerobic and anaerobic conditions, hence show promise as a form of bioremediation for waste reduction. Some members of the genus are able to produce taxol.

A17.1.1a ***Pestalotiopsis mayumbensis*** (24 May 2021)

Family: Amphisphaeriaceae

Definition: Amount of tolerance to *Pestalotiopsis mayumbensis* (Steyaert) Steyaert 1949.

(Wikipedia, 24 May 2021) ***Pestalotiopsis mayumbensis*** is a fungal species that was first described by Steyaert, and got its current name from Steyaert in 1949. *Pestalotiopsis mayumbensis* is part of the genus *Pestalotiopsis* and the family Amphisphaeriaceae. No subspecies are listed in the Catalog of Life.

References:

NIGERIA

- D. McDonald (1964) reported *Pestalotiopsis mayumbensis*.
- H.A. Van Rheenen (1972) reported the following pathogen: *Pestalotiopsis mayumbensis.*

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A18 Order: Chytridiales Cohn 1879

(Wikipedia, 26 May 2021) Fungi of the order **Chytridiales**, like other members of its division, may either have a monocentric thallus or a polycentric rhizomycelium. When the ribosomal genes of members classified in this order were first examined using molecular techniques, it was discovered that the order contained some species that were not related. With the culture and characterization of *Chytridium olla*, the type species of this order, the limits of the Chytridiales were established. The Chytridiales is now monophyletic and species such as *Polychytrium aggregatum*, *Chytriomyces angularis* and *Cladochytrium replicatum* have been transferred to other orders.

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A18.1 Family: Synchytriaceae J. Schroter 1897

(Wikipedia, 26 May 2021) ***Synchytriaceae*** is a chytrid fungus family in the division Chytridiomycota. The family was described by German mycologist Joseph Schröter in 1892. The type genus, *Synchytrium*, contains about 200 species of fungi that are parasitic on flowering plants, ferns, mosses, and algae. *Synchytrium endobioticum* causes potato wart disease, an economically important disease of cultivated potato.

The following species have been reported to cause diseases, produce a toxin, inhibit germination, or affect seed quality.

- A18.1.1 *Synchytrium* spp.
- A18.1.1a *Synchytrium sesami*
- A18.1.1b *Synchytrium sesamicola*

A18.1.1 *Synchytrium* spp. (26 May 2021)

Family: Synchytriaceae

Definition: Amount of tolerance to *Synchytrium* spp. de Bary & Woronin 1865.

(Wikipedia, 26 May 2021) ***Synchytrium*** is a large genus of plant pathogens within the phylum Chytridiomycota. Species are commonly known as false rust or wart disease. Approximately 200 species are described, and all are obligate parasites of angiosperms, ferns, or mosses. Early species were mistakenly classified among the higher fungi (Ascomycota or Basidiomycota) because of their superficial similarity to the rust fungi. Anton de Bary and Mikhail S. Woronin recognized the true nature of these fungi and established the genus to accommodate *Synchytrium taraxaci*, which grows on dandelions, and *S. succisae*, which grows on *Succisa pratensis*. *Synchytrium taraxaci* is the type of the genus. The genus has been divided into 6 subgenera based on differences in life cycles.

A18.1.1a *Synchytrium sesami* (26 May 2021)

Family: Synchytriaceae

Definition: Amount of tolerance to *Synchytrium sesami* S. Sinha & J.C.S. Gupta.

References:

INDIA

- S.G. Gupta and S. Sinha (1951) reported *Synchytrium sesami* on sesame. [Cited by G.S. Saharan, 1989]
- S. Maiti et al. (1985 and 1986) reported the following minor pathogen: Leaf gall *Synchytrium sesami* Sinha and Gupta.

MEXICO

- Agrolytics.org (2021) reported sesame hosts *Synchytrium sesami*.

A18.1.1b *Synchytrium sesamicola* (26 May 2021)

Family: Synchytriaceae

Definition: Amount of tolerance to *Synchytrium sesamicola* Lacy.

References:

INTERNATIONAL

- J.R. Morschel (1964) reported the following pathogen in the world: *Synchytrium sesamicola*. [Cited by D.F. Beech. 1995a]

INDIA

- R.C. Lacy (1951) reported *Synchytrium sesamicola* on sesame was parasitic on young shoots. Infection was confined to young axillary shoots which became considerably malformed. Instead of showing normal, robust growth, they appeared like curled, spindly growth with deformity. Due to imperfect leaf expansion, the young leaflets were puckered and curled into curious shapes. Severely infected shoots did not bear any flowers or capsules but withered away prematurely.
- S.N. Bhargava et al. (1979b) observed a nematode (*Rhabitoid* sp.) associated with resting sporangia of (*Synchytrium sesamicola*) causing a serious gall disease of sesame. Application of neem cake to the soil checked the disease and the nematodes. [Cited by G.S. Saharan, 1989]
- M. Variar and M.S. Pagvi (1979) reported a rise in temperature under dry conditions gradually reduced the percentage germination of sporangia of *Synchytrium sesamicola* in lab tests. Viability steeply declined at 36°C or higher. [Cited by G.S. Saharan, 1989]
- M. Variar and M.S. Pagvi (1981a) reported the germination of evanescent prosori from the sporangial galls of *Synchytrium sesamicola* on sesame was observed and studied in sequence. Anomalies in the sporangioqenesis and zoosporogenesis were discussed. Sexuality between the planoqametes represented by their pairing and fusion was similar in the 4 spp and is described for *Synchytrium sesamicola*. [Cited by G.S. Saharan, 1989]
- M. Variar and M.S. Pagvi (1981b) reported none of the varieties tested against Synchytrium sesamicola (Lacy) was found immune or highly resistance. Two were resistant, JT66-276 and SP70-23 and the rest showed infection ranging between resistant and highly susceptible at the seedling and adolescent (young leaf) stages. [Cited by G.S. Saharan, 1989]
- S. Maiti et al. (1985 and 1986) reported the following minor pathogen: Leaf gall *Synchytrium sesamicola* Lacy.

MEXICO

- Agrolytics.org (2021) reported sesame hosts *Synchytrium sesamicola.*

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A19 Order: Sordariales Chadef. ex D. Hawksw. & O.E. Erikss. 1986

(Wikipedia, 19 Apr 2021) The **Sordariales** are an order of fungi within the class Sordariomycetes (also known as Pyrenomycetes), subdivision Pezizomycotina, division Ascomycota.

Most Sordariales are saprobic, producing solitary perithecial ascomata. They are commonly found on dung or decaying plant matter.

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A19.1 Family: Chaetomiaceae G. Winter 1885

(Wikipedia, 19 Apr 2021) The **Chaetomiaceae** are a family of fungi in the Ascomycota, class Sordariomycetes.

The following species have been reported to cause diseases, produce a toxin, inhibit germination, or affect seed quality.

- A19.1.1 *Pseudothielavia* spp.
- A19.1.1a *Pseudothielavia terricola* (*Syn: *Thielavia terricola*)

A19.1.1 *Pseudothielavia* spp. (6 Jul 2021)

Family: Chaetomiaceae

Definition: Amount of tolerance to *Pseudothielavia* spp. X. Wei Wang & Houbraken 2019

A19.1.1a *Pseudothielavia terricola* (27 May 2021)

Synonym: *Thielavia terricola*

Family: Chaetomiaceae

Definition: Amount of tolerance to *Pseudothielavia terricola* (J.C. Gilman & E.V. Abbott) X. Wei Wang & Houbraken 2019.

(Wikipedia, 27 May 2021) ***Pseudothielavia terricola*** is a fungal species of the phylum Ascomycota, order Chaetomiaceae, and genus *Pseudothielavia*. *Pseudothielavia terricola* is widely distributed, especially in the tropical region of the world – with documented appearances in Africa, Southern Europe, and Asia. The species is mainly found in soil but can also be found on other materials such as animal dung. The species was first assigned to the genus Coniothyrium in 1927 but was soon re-assigned to the genus Thielavia which endured for almost 90 years. Recently, through intensive phylogenetic research and reassessment, the species was designated to a brand new genus, *Pseudothielavia*; The etymology of *Pseudothielavia* means similar to the genus *Thielavia* – the high resemblance was what contributed to the species assignment to the genus *Thielavia* 9 decades ago. The fungus is mesophilic, grows abundantly in a pH level between 3.9-6, and is able to utilize multiple carbohydrates to support its growth. Mature *Pseudothielavia terricola* colonies in culture is dark brown in color and spread out. *Pseudothielavia terricola* synthesizes a variety of compounds, two of which are Thielavin A & B. Thielavin A & B were determined to be strong inhibitors of prostaglandin synthesis which subsequently boasts the species' clinical research value in prostaglandin dysregulation.

References:

INDIA

- B.P. Chakravarti et al. (1971) reported *Thielavia terricola* var. *minor* caused damping off and root rot of sesamum. [Cited by G.S. Saharan, 1989]
- B.P. Chakravarti et al. (1973) evaluated 14 fungicides and 2 antibiotics against *Thielavia terricola* var. *minor*. Ziram and Brassicol were effective as seed treatment and soil drench. Cupramar, copper sandoz., Fytolan, Dithane Z-78, Ziram, Aureofungin, and Brassicol were effective as soil drench while Actidione was phytotoxic.
- S. Maiti et al. (1985 and 1986) reported the following minor pathogen: Damping off *Thielavia terricola* (Gilman and Abboutt) Emmons and *Thielavia terricola* var. *minor* Rayas and Borutt.

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A20 Order: Sphaeropsidales C.E. Bessey 1907

(Wikipedia, 7 Jul 2021) **Sphaeropsidales** is an order of Coelomycetes fungi. These are conidial fungi where the conidia form in a growing cavity in the host's tissue. The fruiting structures are spherical with an opening at the apex (pycnidia).

Four form-families can be distinguished. Sphaeropsidaceae are fungi with pycnidia dark colored, leathery to carbonous, stromatic or non-stromatic generally provided with a circular opening. Zythiaceae are fungi with pycnidia as in the Sphaeropsidaceae but light colored instead of dark, and soft or waxy instead of leathery. Leptostromataceae are fungi with pycnidia shield-shaped or elongated and flattened. Excipulaceae are fungi where mature pycnidia are somewhat deeply cup-shaped. In the family Sphaeropsidaceae, species of the genus *Darluca* are hyperparasitic on rusts while species of *Cicinnobolus* are hyperparasites of powdery mildew. Their mycelium is grown longitudinally in the mycelium of their hosts.

Members of this order can produce bisnaphthyl pigments, such as Sphaerolone and dihydrosphaerolone, or 2-hydroxyjuglone.

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A20.1 Family: Sphaeropsidaceae

The following species have been reported to cause diseases, produce a toxin, inhibit germination, or affect seed quality.

- A20.1.1 *Sphaeronema* spp.
- A20.1.1a *Sphaeronema sesami*

A20.1.1 *Sphaeronema* spp. (7 Jul 2021)

Family: Sphaeropsidaceae

Definition: Amount of tolerance to *Sphaeronema* spp.

A20.1.1a *Sphaeronema sesami* (7 Jul 2021)

Family: Sphaeropsidaceae

Definition: Amount of tolerance to *Sphaeronema sesami* Sehgal and Daftari.

References:

INDIA

- S.P. Sehgal and L.N. Daftari (1966c) reported a new leaf spot of sesame caused by *Sphaeronema sesami.* [Cited by E.A. Weiss, 1971 and G.S. Saharan, 1989]
- Anon. (1970a) reported *Sphaeronema sesami* caused a leaf spot.
- S. Maiti et al. (1985 and 1986) reported the following minor pathogen: Blight *Sphaeronema sesami* Sehgal and Daftari.

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B Pest: Oomycetes (Oomycota) Arx 1967

(Wikipedia, 8 Apr 2021) **Oomycetes** or **Oomycota** form a distinct phylogenetic lineage of fungus-like eukaryotic microorganisms. They are filamentous and heterotrophic, and can reproduce both sexually and asexually. Sexual reproduction of an oospore is the result of contact between hyphae of male antheridia and female oogonia; these spores can overwinter and are known as resting spores. Asexual reproduction involves the formation of chlamydospores and sporangia, producing motile zoospores. Oomycetes occupy both saprophytic and pathogenic lifestyles, and include some of the most notorious pathogens of plants, causing devastating diseases such as late blight of potato and sudden oak death. One oomycete, the mycoparasite *Pythium oligandrum*, is used for biocontrol, attacking plant pathogenic fungi. The oomycetes are also often referred to as **water molds** (or **water moulds**), although the water-preferring nature which led to that name is not true of most species, which are terrestrial pathogens.

Oomycetes were originally grouped with fungi due to similarities in morphology and lifestyle. However, molecular and phylogenetic studies revealed significant differences between fungi and oomycetes which means the latter are now grouped with the stramenopiles (which include some types of algae). The Oomycetes have a very sparse fossil record; a possible oomycete has been described from Cretaceous amber.

B1 Order: Peronosporales Fisch 1892

(Wikipedia, 8 Apr 2021) The **Peronosporales** are an order of water molds (class Oomycetes) which can be pathogenic.

Many diseases of plants are sometimes classified under this order but are sometimes considered members of order Pythiales. Some of these pathogenic protists include the organisms responsible for potato blight, eucalyptus dieback, sudden oak death, and blue mold. Further genetic studies may place these organisms more definitively in one order or another.

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B1.1 Family: Peronosporaceae de Bary 1863

(Wikipedia, 8 Apr 2021) **Peronosporaceae** are a family of water molds that contains 21 genera, comprising more than 600 species. Most of them are called downy mildews.

Peronosporaceae are obligate biotrophic plant pathogens. They parasitize their host plants as an intercellular mycelium using haustoria to penetrate the host cells. The downy mildews reproduce asexually by forming sporangia on distinctive white sporangiophores usually formed on the lower surface of infected leaves. These constitute the “downy mildew”. The sporangia are wind-dispersed to the surface of other leaves. According to the genus concerned, the sporangia may then germinate by forming zoospores, thus resembling *Phytophthora*, or by germ-tube. In the latter case, the sporangia behave as conidia and are often referred to as such. Sexual reproduction is via oospores.

The parasitized plants are angiosperms or gymnosperms, and most Peronosporaceae are pathogens of herbaceous dicots.

The following species have been reported to cause diseases, produce a toxin, inhibit germination, or affect seed quality.

- B1.1.1 *Phytophthora* spp.
- B1.1.1a *Phytophthora nicotianae* (*Syn: *P. nicotianae* var. *parasitica*, *P. parasitica*, and *P. parasitica* var. *sesami*)
- B1.1.1b *Phytophthora cactorum*
- B1.1.1c *Phytophthora hibernalis*
- B1.1.1d *Phytophthora drechsleri*
- B1.1.1e *Phytophthora palmivora*
- B1.1.1f *Phytophthora capsici*
- B1.1.1g *Phytophthora tropicalis*

B1.1.1 *Phytophthora* spp. (11 Dec 2021)

Family: Peronosporaceae

Definition: Amount of tolerance to *Phytophthora* spp. de Bary 1876.

Summary:

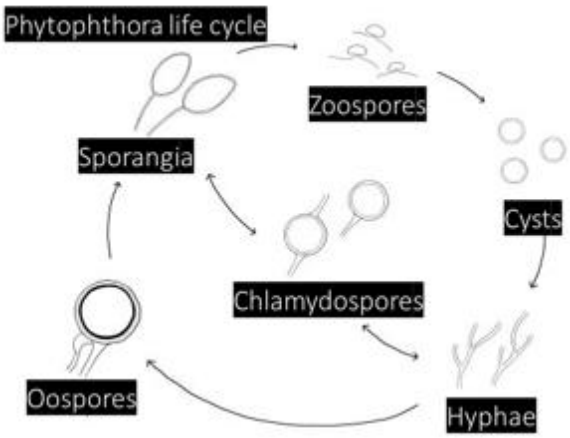

Photo: H.M. Miao {China}

Phytophthora nicotianae (Synonyms: *Phytophthora nicotianae* var. *parasitica*, *Phytophthora nicotianae* var. *sesami*, *Phytophthora parasitica.*, and *Phytophthora parasitica* var. *sesami.*) is a locally damaging disease. These microbes thrive in moist moderate to warm conditions, where disease epidemics can progress rapidly. Symptoms include water soaked spots on leaves and stems. Lesions on the leaves may coalesce and cause defoliation. Stem and branch lesions are initially brown and darken to black with age. The blackening of the stem is often most apparent near soil level. Affected branches produce poorly formed capsules with shriveled seeds, and affected plants show progressive wilting ending in death. Wet soils, rain, and warm temperatures favor the spread of the disease, and its incidence is higher on more clay heavy soils with poor drainage. Low areas in fields may be particularly affected. *Phytophthora* spp. typically overwinter as oospores or chlamydospores, which can germinate sporangia. Motile zoospores are generated within sporangia, are released upon maturity, and can swim through water and subsequently infect new plant tissues. Inoculum can carry over in either soil or plant material. The pathogen may spread by being seedborne and soilborne. Other *Phytophthora* species reported to be pathogenic on sesame, include *P. cactorum, P. capsici, P. drechsleri, P. hibernalis, P. palmivora,* and *P. tropicalis. Phytophthora* spp. have been reported in international lists, Argentina, China, Dominican Republic, Egypt, Guatemala, Honduras, India, Iran, Japan, Kenya, Malawi, Mexico, Nicaragua, Nigeria, Paraguay, Peru, Republic of Korea, Sri Lanka, Tanzania, Thailand, Turkey, United States, and Venezuela.

It should be noted that *Phytophthora* is actually an oomycete, not a true fungus, so it's always a good idea to double check fungicide labels for efficacy against it specifically prior to applying. Oomycetes are also known as water molds, which is quite telling regarding how much they thrive in water logged or moist conditions. *Phytophthora* spp. and other oomycetes have fairly interesting life cycles that include motile spores (zoospores) that can actually swim through even a thin film of water seeking out plant tissues to colonize utilizing chemotaxis. This unique characteristic is one part of why these pathogens spread so prolifically in moist conditions. Without moving water, zoospores could probably swim only a few cm at most, and soil particles may limit that distance.

(Wikipedia, 8 Apr 2021) ***Phytophthora*** is a genus of plant-damaging oomycetes (water molds), whose member species are capable of causing enormous economic losses on crops worldwide, as well as environmental damage in natural ecosystems. The cell wall of *Phytophthora* is made up of cellulose. The genus was first described by Heinrich Anton de Bary in 1875. Approximately 170 species have been described, although 100–500 undiscovered *Phytophthora* species are estimated to exist. *Phytophthora* spp. are mostly pathogens of dicotyledons, and many are relatively host-specific parasites.

(http://forestphytophthoras.org/phytophthora-basics, accessed 11 Oct 2021)



Phytophthora species resemble true fungi because they grow by means of fine filaments, called hyphae, and produce spores. But unlike true fungi, their cell walls contain cellulose instead of chitin, their hyphae lack cross-walls, and the diploid phase, rather than the haploid phase, dominates their life cycle. It also produces swimming spores, called zoospores. There are currently more than 80 described species worldwide. Phytophthora species are among the most destructive pathogens of agricultural crops and forests in the world. Phytophthora species are well adapted to diverse plant hosts and environments, and they produce several types of structures that are specialized for survival, dispersal, or infection.

- Oospores are sexual reproductive spores that result from fertilization of the oogonium (female organ) by an antheridium (male organ).
- Some Phytophthora species are self-fertile (homothallic), whereas others require cross fertilization (hererothallic). Oospores are thick-walled, generally globose structures that enable long-term survival in plant tissue or soil. In heterothallic species, oospores are produced only after hyphae from two different mating types. In homothallic species, oospores form a single mating type.
- Chlamydospores are another type of thick-walled, long-term survival spore, but they are produced asexually. In the presence of water, such as during wet weather, Phytophthora chlamydospores or oospores germinate to form sporangiophores bearing sporangia.
- In some Phytophthora species, sporangia can detach and be blown or splashed with water to nearby plants. Sporangia release short-lived, on-celled, flagellated zoospores that can swim through thin films of water on leaf surfaces or in water-filled soil pores and can accumulate in puddles and ponds. Sporangia can also germinate directly to form additional sporangiophores. When zoospores land on a suitable infection site, they stop swimming, drop their flagella, and develop a cell wall (they encyst).
- A cyst is a short-lived resting structure. Cysts germinate to form the microscopic, filamentous structures called hyphae. Hyphae allow the pathogen to infect and grows within plant cells to obtain food.
- Once Phytophthora infects, the plant, it produces more chlamydospores, oospores, and/or sporangia, thus completing the cycle.

Phytophthora species damage plants by killing tissues. Infection and resulting necrosis may be in leaves, stems, or roots. The symptom of foliar infection is called “blight.” Infection on stems creates a “canker”, which may be localized or expand around the stem. If branches are girdled by expanding cankers “dieback” results. Phytophthora may also invade the water conducting wood (xylem) beneath the inner bark and cause symptoms in all or part of the canopy associated with water stress, such as “wilt.”

Many Phytophthora infect the roots, causing “root rot.” Some kill fine roots only, and in others necrosis may progress up the root and into the root crown. Fine root necrosis may lead to upper canopy “wilt” in times of water stress or “decline” over a longer time span. Root rot that progresses into major roots or the main stem amy result in gradual “decline” or sudden “death” of the canopy. Infection that starts near the ground line or progresses to the main stem from the roots may be visible as a “canker” or “collar root.”

References:

INTERNATIONAL

- Anon (2000a) is an organic grower guide for America. It describes the following disease and its recommended organic method of control: Phytophthora Blight – Rotation of crops, resistant varieties, clean seeds. It mentions a treatment with a copper product, but this product was banned in Europe in 2002.

CHINA

- Anon. (2006a) China descriptor: 8.3 (131) Resistance to *Phytophthora* blight (CCCC). They provide a methodology for artificial inoculations and observing in natural fields. The following are the ratings to be used.
  - 0 = Immune

- 1 = High resistance (HR)
- 3 = Resistance (R)
- 5 = Susceptible (S)
- 7 = High susceptibility (HS)
- X.R. Zhang/L.H. Wang (pers. comm. 2016): This descriptor is used to describe new germplasm that is acquired by the Chinese Academy of Agricultural Sciences-Oil Crops Research Institute, Wuhan.

- H.M. Miao, pers. comm., 2021: In July there was a massive storm in the Zhengzhou area of Henan Province with areas receiving as much as 718 mm of rain over 3 days. Sesame fields without drainage were devastated. The tops of the plants bent over; then, over time the stem changed to black and along with the leaves and tip. When the rain was long, lots of white fungus hypha could be easily seen on the infected tissues. In some fields all of the plants were affected. In other fields, a few plants escaped.


GUATEMALA

- Anon (1982a) A grower guide reported *Phytophthora* sp. causes black rot at the juncture of the stem and root. When the attack is late, it debilitates the plant, accelerates maturity, and reduces yield. When the attack is early, it kills the plants.

HONDURAS

- V.P. Queiroga et al. (2016) reported *Phytophthora* sp. is found in any stratum and part of the plant. Causes a black coloration in the infected place. In some cases, it causes an acceleration of the maturity of the crop, achieving the fall of the grain and in other cases the wilting and death of the plant.

INDIA

- S.P. Sehgal and N. Prasad (1966b) reported the Phytophthora survives in the soil in the form of mycelium or chlamydospores as it does not from oospores. The mycelium of the fungus lives in the embryo in dormant condition; therefore, seeds play some role in the initiation and spread of disease in new localities. [Cited by G.S. Saharan, 1989]
- O.P. Kadian (1972) reported five common genera to include *Phytophthora* spp., which reduced seed germination and had adverse effect on the seedlings. The seeds were internally as well as externally seedborne. The seed infestations (%) with *Phytophthora* were comparatively higher than with other five genera. [Cited by G.S. Saharan, 1989]
- N.D. Desai and S.N. Goyal (1981c) reported that M-3-1 and M-3-2 (Bihar), No 2-39 and No. 66-193 (M.P.) are resistant to *Phytophthora*.
- C.D. Kaushik et al. (1986) reported phyllody (MLO), root rot (*Macrophomina phaseoli*), leaf curl (virus), Bacterial leaf blight (*Xanthomonas* sp.), powdery mildew (*Erysiphe* sp.), and Phytophthora blight.

KENYA

- B. Mazzani (1987) visited sesame growing regions and reported the following major pathogen: *Phytophthora* spp.

MEXICO

- E.C. Hernandez (2003) in a grower guide reported the following pathogen: *Phytophthora* sp. (Pie negro o pata seca [black foot or dry foot]). It is appears at any plant age manifested by a stain more or less blackish wet that starts in the neck region and extends up the stem. For control, use resistant or tolerant varieties or resistant, good seed, good drainage of the land, an appropriate row spacing.
- L.A. Moraila (2015) in a grower guide reported with *Phytophthora* sp. The leaves wilt, and a brown or blackish colored stain appears on the stem extending from the root collar to the upper parts of the plant. The stain may not cover the entire stem circumference. The plant dies quickly, but it can be prevented by avoiding rainwater puddles.

NICARAGUA

- Anon. (1998b and 2009a) in grower guides reported Black foot (*Phytophthora* sp.). The base of the stem rots and turns black. It is found in all parts of the plant. In some cases, there is an acceleration to maturity resulting in seed loss, while in other cases there is wilting and the death of the plants.

PARAGUAY

- N. Lezcano (2006) in a grower guide reported the following pathogen: *Phytophthora* sp.

REPUBLIC OF KOREA

- J.I. Lee et al. (1985i) reported A new high-yielding sesame variety 'Ansanggae' was developed by mutation breeding of 'Early Russian'. Ansanggae was moderately resistant to seedling blight including Rhizoctonia blights, and resistant to Corynespora leaf blight, Phytophthora blight, and Fusarium wilt. [Based on abstract]
- S.U. Kim (pers. comm. 2015): The following is a photo of the kill from *Phytophthora* sp. on sesame in a greenhouse.

THAILAND

- V. Benjasil (1985a) reported *Phytophthora* sp. (Leaf and stem rot) causes losses in yield.

UNITED STATES

- D.C. Erwin reported species of *Pseudomonas*, *Bacillus*, and *Streptomyces*, which are most active at 25-27°C at field capacity moisture level, can be suppressive to Phytophthora species in soil (Cited by C. Chattopadhyay et al., 2019).
- D.R. Langham (1998e) reported that Sesaco took notes in most years on "37b. *Phytophthora*. Important in South Texas."
- D.T. Smith et al. (2000) reported Phytophthora root and crown rot can be a serious disease problem in sesame. Infestations start in the root, spread to the crown area, and move into the lower stem. The fungus is soilborne and moves with surface water. Phytophthora root rot is common in pepper and tomato fields and could become a significant problem when sesame is grown in rotation. Phytophthora root rot was studied in sesame over several years at the Texas Agricultural Experiment Station research farm near College Station. Several hundred lines from the sesame germplasm collection were screened in field and greenhouse studies in a search for some source of genetic resistance. Over 90% of the varieties and lines died. Only scattered plants escaped damage and there was no optimism for finding genetic resistance in sesame for root and crown rot tolerance. Phytophthora root rot was far more severe when sesame was planted two or more years in the same field but was lower when plots were continually rotated to new land each year. Trials with numerous fungicides and fumigants did not suppress Phytophthora root rot in sesame, which can result in a 10% yield loss with susceptible varieties. Some lines, such as S-23, S-24, and S-25 show some resistance to this soil pathogen.
- K.A. Cochran comments, 2021: I have primarily observed *Phytophthora* spp. in over-irrigated fields or those suffering from an abundance of rain. While it can be expensive and/or time consuming, efforts to alter the growing environment, such as improving drainage topography, are highly beneficial as part of a disease management program in areas prone to flooding or standing water. It should be noted that this pathogen can spread relatively long distances despite being primarily soilborne. If flood irrigation or even heavy rains cause water to run from an infested area to another (e.g., down a row), that water can carry inoculum as far as it flows, in some cases all the way through a field.

VENEZUELA

- D. Montilla and C. Nava (1966b) screened the percentage of infected plants by *Phytophthora* sp. using 3 varieties (Guacara, Aceitera, and Renner) over time (34, 39, and 44 DAS) with the following results.

Tipo	34	39	44
Guacara	12,02	20,94	39,57
Aceitera	12,62	21,11	26,06
Renner	1,07	3,67	9,46

- B. Mazzani et al. (1973) introduced a new variety 'Maporal' which is especially adapted to conditions in which soilborne pathogens (*Phytophthora, Fusarium, Macrophomina*, and *Rhizoctonia*) are prevalent.
- B. Mazzani (1981a and 1981b) reported *Phytophthora* sp.(Crown and stem rot) is one of the major diseases and a permanent threat in the main sesame producing areas. In humid soil or extemporal rain conditions, sesame fields suffer heavy loss from stem rot. The trouble starts with rotting of basal stems and ends with the plant's death. Sesame cultivars commonly grown in Venezuela are very susceptible. Resistance was incorporated through a backcross of Aceitera and Arapatol 6.
- B. Mazzani (1999) reported the following pathogen: *Phytophthora* sp. Resistant varieties were *Sesamum radiatum*, Arapatol 6, and Adong Acol, and very susceptible were Venezuela 52, Venezuela 51, Caripucha, and Venezuela 44.

B1.1.1a *Phytophthora nicotianae* (8 Apr 2021)

Synonyms: *Phytophthora nicotianae* var. *parasitica, Phytophthora nicotianae* var. *sesami, Phytophthora parasitica.,* and *Phytophthora parasitica* var. *sesami* [Some references place this under *Phytophthora palmivora*] Some prefer to call this species *Phytophthora parasitica.*

Family: Peronosporaceae

Definition: Amount of tolerance to *Phytophthora nicotianae* Breda de Hahn 1896.

(Wikipedia, 8 Apr 2021) ***Phytophthora nicotianae*** or **black shank** is an oomycete belonging to the order Peronosprales and family Peronosporaceae.

Phytophthora nicotianae has a broad host range comprising 255 genera from 90 families. This pathogen can cause root rot, crown rot, fruit rot, leaf infection, and stem infection. Damping off symptoms can be observed in young seedlings. The first above ground symptom that will be observed is the wilting of plants, which leads to stunting. Roots will be blackened and decayed. In final stages of the disease the stem begins to turn black, hence the name Black Shank. Another symptom is disk-like appearance of the pith, although this is not a definitive symptom as it may also be the result of lightning strikes. Initially, tips of newly infected plants start to yellow and dry followed by softening of the "neck" of the plants that eventually fall over. Infected leaves may show grey lesions. Roots may become necrotic in late disease.

Black Shank is a polycyclic soilborne disease, with the possibility of multiple disease cycles per growing season occurring from May to October. There are important structures this pathogen uses in its disease cycle. Chlamydospores are produced asexually and serve as long lived resting structures, surviving from four to six years. Chlamydospores are the primary survival structure, the primary inoculum, and are usually produced in abundance. These spores germinate in warm and moist soil to produce a germ tube that infects plants or produces a sporangium. Another asexual structure and secondary inoculum, appearing ovoid, pear, or spherical in shape are called sporangium. These spores are produced and can either germinate directly or release motile zoospores within 24 hours of inoculation with the right conditions. Zoospores are kidney shaped with an anterior tinsel flagellum and a posterior whip like flagellum that helps to navigate toward root tips were infection occurs. Black Shank needs water for germination and movement because zoospores swim through soil pores and standing water. Splashing water from rain or irrigation can infect healthy plant leaves leading to more repeating secondary cycles. Zoospores move toward nutrient gradients around root tips and host wounds. Once the root surface is contacted, zoospores encyst, and a germ tube will emerge penetrating the epidermis. Infection leads to systemic rotting of the root system

and wilting and chlorosis in the leaves. Another structure called hyphae is colorless, transparent, and coenocytic, but colonies may yellow with age. Also, there is much morphological variation in colony type with different isolates of *P. nicotianae* and the growth may differ when grown on different media. The hyphae are heterothallic and require two mating types to produce oospores, the sexual survival structure. Many fields only contain one mating type, so the zoospores rarely germinate and rarely cause epidemics.

This pathogen thrives in temperatures ranging from 84-90°F (29-32°C). Disease is prominent in many agricultural productive regions and therefore is a major host to many warm environment crops. Black Shank needs water for germination and movement. Saturated soil optimizes disease spread because water is used for dissemination of motile zoospores and sporangia. Low-lying areas of the soil that remain wet for prolonged periods of time will have more disease. Splashing water from rain or irrigation can infect healthy plant leaves leading to more repeating secondary cycles. Soils that are not saturated will lead to little to no disease development, so water management is important. Optimum soil pH for development is between 6 and 7. Levels of calcium and magnesium in the soils can affect disease progress.

(Anon. n.d.k) Stem blight – *Phytophthora parasitica* var. *sesami*

Symptoms: Black colored lesions appear on the stem near the soil level. The disease spreads further and affects branches and may girdle the stem, resulting in the death of the plant. Leaves may also show water-soaked patches and spread till the leaves wither. Infection may be seen on flowers and capsules. Infected capsules are poorly developed with shriveled seeds.

Pathogen: The fungus produces non-septate, hyaline mycelium. The sporangiophores are hyaline and branched sympodially and bear sporangia. The sporangia are hyaline and spherical with a prominent apical papilla. The oospores are smooth, spherical and thick walled.

Favorable Conditions: Prolonged rainfall; low temperature (25˚C); high relative humidity (above 90%).

Disease Cycle: The fungus can survive in the soil through dormant mycelium and oospores. The seeds also carry the fungus as dormant mycelium, which causes the primary infection. Secondary spread of the disease is through wind-borne sporangia.

Management: Treat the seeds with Captan or thiram at 2g/kg or metalaxyl @ 4g/kg; avoid continuous cropping of sesamum in the same field; remove and destroy infected plant debris.

References:

INTERNATIONAL

- R.S. Vasuveda (1961) reported *Phytophthora parasitica* is a major disease in the world. The disease makes its first appearance by producing damp blackish lesions on the collar of the stem at the soil level. It spreads gradually upward and within a few days blackish streaks are observed on the stem. These are the first visible symptoms of the disease. In severly infected plants the disease spreads to the stem and branches and might girdle the stem resulting in the death of the plant. The disease may attack the plant at any stage of growth but does so mostly at the time of flowering. The affected plants show water-soaked patches on the leaves and these gradually spread till the leaves wither away. Similar symptoms appear on the inflorescence. Infected plants which may escape complete wilting bear very few poorly developed capsules with shrivelled seeds.
- E.A. Weiss (1971) reported *Phytophthora parasitica* is a locally damaging disease. Symptoms are the formation of characteristic water soaked spots on leaves and stems. Those of the leaves may coalesce and cause leaf-fall. Those of the stem and branches are brown initially but become black when mature. The blackening of the stem is often most marked near soil level. Affected branches produce poorly formed capsules with shriveled seeds, and affected plants show progressive wilting ending in death. Wet soils, rain, and high temperatures favor the spread of the disease, and its incidence is higher on more clayey soils.
- P. Neergaard (1979) reported the following pathogen caused a disease in sesame: *Phytophthora nicotianae* var. *sesami*. [Cited by G.S. Saharan, 1989]
- Anon. (2004a) IPGRI descriptor: 10.2.6. Biotic stress susceptibility to *Phytophthora parasitica*. (*Phytophora* stem rot/blight)
  - In each case it is important to state the origin of the infestation or infection, i.e., natural, field inoculation, or laboratory. Also specify the causal organism and the corresponding symptoms. The susceptibility scale is as follows:
    - 1 = Very low or no visible sign of susceptibility

- 3 = Low
- 5 = Intermediate
- 7 = High
- 9 = Very high

o The growth state, coded according to the list below at which each reaction was recorded should be appended to the record of that reaction.

- 1 = Seed
- 2 = Seedling
- 3 = Pre-flowering
- 4 = Early flowering
- 5 = Mid-flowering
- 6 = Late-flowering
- 7 = Maturity

- C. Chattopadhyay et al. (2019) described the following symptoms of *Phytophthora parasitica* var. *sesami* and var. *parasitica*: The disease can attack plants of all ages after they attain 10 days of age. Symptoms appear on all aerial parts of the affected plants. The first symptom is the appearance of water-soaked brown spots on leaves and stems. The spots gradually extend in size. Under favorable weather conditions, the brownish discolored spots spread rapidly both upward and downward and also around the stem. The brownish area later turns deep brown and becomes black with the spread of the infection. The capsules are also affected. In humid weather, the white woolly growth of the fungus can be seen on the surface of affected capsules. Capsules on affected branches are poorly formed. The seeds remain shriveled in the case of severe attack.

  The pathogen can survive in mycelial form up to 50°C temperature, and culture having chlamydospores may survive up to 52°C. Viability of the culture can be kept in a refrigerator for 1 year at 5°C. These studies suggest that the fungus can survive in soil during the summer and winter where temperature never rises beyond 50°C or drops below 5°C. The fungus survives in soil during the unfavorable period in the form of dormant mycelium and/or in the form of chlamydospores. In addition to soil, seed also appears to play an important role in the recurrence and spread of the disease. In seed, the mycelium has been located in the embryo.

  Seedborne infection can be controlled by treating the seed with thiram (0.3%). Secondary infection and further spread of the disease can be brought under control by three sprayings of Bordeaux mixture (3:3:50), each at an interval of 1 week after the appearance of the disease (M.L. Verma et al. 2005 {India}). Spray application of dithiocarbamate fungicides such as mancozeb (0.3%) or zineb (0.3%) and Fytolan (copper oxychloride) (0.3%) is reported to be effective in the control of the disease (M.K. Kalita et al. 2000, 2002 {India}).

  Sanitation and clean cultivation should be followed as additional measures to control the disease. Use of sowing date depending upon the prevailing local conditions. Fields with light soil with proper drainage should be preferred to avoid heavy losses due to disease. The intercropping of sesame with soybean, castor, maize, sorghum, or pearl millet in the ratio of 1:3 or 3:1 shows a low incidence of the disease with higher yield. Application of farm yard manure (FYM) or neem cake with inorganic fertilizers N60, P40, and K_20 reduces the disease incidence (M.L. Verma et al. 2005 {India}).
- CAB International (accessed 12 Apr 2021) reported sesame was a minor host of *Phytophthora nicotianae* (Black shank).
- N. Ransingh et al. (2021) reported the following symptoms of *Phytophthora parasitica* var. *sesame* (Phytophthora blight): The disease symptoms initiate with water-soaked spots of chestnut brown color on leaves and stems, which later turns to black. Severity of disease is greater in humid weather. The main root of the plant gets affected, and hence it can be easily pulled out. The affected plants shed leaves prematurely. The seeds produced from those plants are shriveled.

  It is a soilborne pathogen that survives in the soil in the form of dormant mycelium and oospores. Dormant mycelium present on the surface of the seed also causes the primary infection. The secondary spread occurs by wind-borne sporangia. Prolonged rainfall, low temperature (25°C) and high relative humidity (above 90%) favors the disease. Severity of disease is greater in heavy soil with high soil moisture.

  Proper field sanitation by removal and destruction of infected plant parts is an important step towards the management of disease. Continuous cropping of sesame in the field should be avoided. Follow crop rotations with non-host crop. Intercropping with blackgram in a proportion of 1:3 reduces incidence of Phytophthora blight. Treat the seed with metalaxyl @4 g/Kg of seed. Foliar spraying of metalaxyl or mancozeb @0.2% is very effective.

ARGENTINA

- M.J. Frezzi (1950) reported *Phytophthora parasitica* on sesamum was isolated for the first time along with other hosts. [Cited by R.S. Vasudeva, 1961 and G.S. Saharan, 1989]

CHINA

- L.C. Tu (1985a and 1985b) reported *Phytophthora nicotianae* (Wilt) in Henan province with a damage level of 2 out of possible 3.
- L.L. Li (1988) reported *Phytophthora nicotianae* var. *sesami* (Blight), *Phytophthora*. *Parasitica* var. *sesami* (Blight) cause severe damage to sesame. Over 30% of the incidence of the disease has been reported to cause the death of the plants. The seeds remain shriveled in the case of severe attack, and the yield and oil content of the seeds drop by a big margin. Symptoms of the disease mainly appear on the basal portion of the stem as shrunken and ulcer spots, primarily water-soaked, and deep-green spots, and then as dark-brown sunken spots. The cortices of the diseased plants become soft and form a vertical and shrunken crack. The disease mainly destroys phloem and cambium. The fungus from the upper portion of the diseased stem may infect the capsules, thus forming water-soaked, dark-green spots on them. The spots gradually become shrunken, sunken and small. In the case of moisture, the white woolly growth of the fungus can be seen on the surface of the affected capsules resulting in the dryness and death of the upper stems and leaves of the infected part. The symptom of the affected leaves is the appearance of larger tawny spots with some ring line. When there is moisture, the tawny spots spread rapidly around the spot and the edge of the spot forms a ring-like white growth of fungus (sporocarp of the fungus). If the weather is dry the spots also become dry, thin and open, and the diseased leaves become malformed at last. The fungus grows well at an optimum temperature of 28°C. The fungus survives in soil, during the unfavorable periods, in the form of dormant mycelium and/or in the form of chlamydospores (or oospores) The pathogen attacks the basal portion of the stem, thus forming a source of primary inoculum. The incubation period is about 10 days after inoculation. The sporangia spreads from the already infected portions of plants through wind, rain and running water. The disease begins at the squaring period of sesame in July and prevails at the beginning of August. Of the disease.
- H.M. Miao and H.Y. Liu (2010) reported the following pathogen: *Phytophthora nicotianae*.

DOMINICAN REPUBLIC

- R. Ciferri (1930) reported a destructive disease occurred in 1928 on sesame; the symptoms were very similar to those of tobacco blank shank (*Phytophthora nicotianae*). It is attributed to an undetermined species of *Phytophthora* which rapidly developed in a moist chamber on infected material and which was frequently associated with a species of *Fusarium*. In 1928 it completely destroyed the plots but has not found in other parts of the country.

EGYPT

- M.S. Serry (1981a and 1981b) reported the presence of *Phytophthora parasitica* is a major hazard.
- M.M. Satour (1984) reported one of the prevalent disease causal organisms was *Phytophthora parasitica*. [Cited by G.S. Saharan, 1989]

INDIA

- J.F. Dastur (1913) reported sesame seedlings grown between castor seedlings in Pusa, Bihar, were attacked by *Phytophthora parasitica*, which was also parasitic on young castor plants.
- E.J. Butler (1918) reported *Phytophthora parasitica* caused a disease in sesame. [Cited by R.S. Vasudeva, 1961]
- M. Mitra (1929) reported *Phytophthora parasitica* caused a disease in sesame. [Cited by R.S. Vasudeva, 1961]
- M.K. Patel et al. (1949) reported *Phytophthora parasitica* caused a disease in sesame. [Cited by R.S. Vasudeva, 1961]
- G.B. Kale and N. Prasad (1957) reported *Phytophthora parasitica* is characterized by the appearance of water-soaked spots on the leaves, which extend in size and result in destruction of the leaves. Similar water-soaked spots can also be observed on the shoot. The lesions so formed are brown in the beginning but later turn black. At this stage, affected plants can easily be distinguished from healthy ones even from a distance. The capsules on the affected branches are poorly formed. With humid weather a wooly growth of the fungus can be seen on the capsules bearing caenocytic mycelium with papillate zoosporangia. In a survey they determined losses in yield ranged from 13 to 64%.
- C.D. Krantikumar et al. (1963) reported *Phytophthora parasitica* causes severe losses locally especially in regions with heavy soil and heavy rainfall (30-40”). Pure lines obtained from such areas showed more resistance. [Cited by G.S. Saharan, 1989]

- P.D. Gemawat and N. Prasad (1965a) reported the existence of variation in the pathogenicity of different isolates of *Phytophthora parasitica* f. sp. *sesami*. The pathogen can survive under the conditions in the Anand area (22.56N 72.93E) despite its restricted host range. The progress of the disease is rapid at 28-30°C but decreases with a raise in temperature. The growth of the sesame plants remains unaffected at these temperatures. The disease is not seedborne. However, the viability of the seeds is reduced to a great extent due to infection. The disease can be controlled with Bordeaux (3-3-50) mixture. Three sprayings of the fungicide are necessary to control the disease effectively.
- P.D. Gemawat and N. Prasad (1965b) screened 41 cultivars in a greenhouse and 33 in the field against *Phytophthora parasitica* f. sp. *sesami*. In the greenhouse 1 strain was resistant (75A/1-1/2-1) and two others (58/1-1/2-2/1 and 23A/1-1-1-2) showed some tolerance. But in subsequent years plants raised from selfed seed from these particular plants were found to be susceptible. In the field, all the 33 different varieties were susceptible.
- P.D. Gemawat and N. Prasad (1965c) reported when soil containing sesame seeds was inoculated with *Phytophthora parasitica* f. sp. *sesami*, the seed germinated but seedlings became blighted within 7 days. When the collar region of plants 2-8 weeks old was inoculated or the soil was inoculated, symptoms appeared in plants of all ages 3 and 7 days after inoculation.
- S.P. Sehgal and N. Prasad (1966a) studied the variation in the pathogenicity of single zoospore isolates of *Phytophthora parasitica* var. *sesami* (*F. nicotianae* var. *parasitica*) and found no variability in morphology or physiology. They opined the pathogen was seedborne. The pathogen survives in soil for 1 year as mycelium or chlamydospores because oospores are not formed. [Cited by M.L. Verma, 1985 and G.S. Saharan, 1989]
- Anon. (1970a) reported *Phytophthora parasitica* caused sesame blight.
- N. Prasad et al. (1970) reported heavy rains for at least 2 weeks and high humidity (above 90%) for 3 weeks or more favor the development of *Phytophthora parasitica* var. *sesami*. When such favorable conditions persist for a longer time, the infection appears quite fast. It is observed that the initial development of the disease is much earlier when the soil temperature is 28°C, while the initial appearance of the disease is delayed with an increase in the soil temperature up to 37°C. The pathogen is favored by 30°C, can tolerate 35°C, but fails to grow at 37°C. Hence, soil temperature of 28-30°C is necessary for disease development. [Cited by C. Chattopadhay et al., 2019]
- P.D. Gemawat and O.P. Verma (197lb) reported 70 different varieties and collection of sesame were tested for resistance to blight (*Phytophthora parasitica* var. *sesami*) under natural and artificial infection conditions. None of the varieties were found to be comparatively resistant to the disease. Sesamum lines No. 2-39, F-8 and 19/1/46-2 were found less susceptible to the disease.
- S.P. Sehgal and N. Prasad (1971a) reported the loss of pathogenicity of *Phytophthora parasitica* f. sp. *sesami* in culture but found it revived with increased virulence after host passage. [Cited by M.L. Verma, 1985]
- S.P. Sehgal and N. Prasad (1972) screened 370 collections. No variety or species of sesame was found to be immune to *Phytophthora. Parasitica* f. sp. *sesami*, but 14 were resistant at the seedling stage and 17 at the adult stage. [Cited by M.L. Verma, 1985]
- G.S. Saharan and J.S. Chohan (1972) reported *Phytophthora parasitica* (Blight). [Cited by G.S. Saharan, 1989]
- B.P. Singh et al. (1977) reported *Phytophthora parasitica* f. sp. *sesami* was seedborne. [Cited by M.L. Verma, 1985]
- M.M. Satour (1981) reported the presence of *Phytophthora parasitica* (Root rot, stem rot, wilt).
- T. Singh and D. Singh (1983) isolated 24 fungi. They detected *Phytophthora parasitica* f. sp. *sesami* in the microtome sections of seeds.
- S. Maiti et al. (1985) reported *Phytophthora nicotianae* pv. *parasitica* is important.
- Y. Rathaiah (1985) reported *Phytophthora parasitica* f. sp. *sesami* is most severe in May and June. Plants sown in early August showed considerable disease escape.
- M.L. Verma (1985) reported *Phytophthora parasitica* (*Phytophthora nicotianae* var. *parasitica*) (Damping off/Phytophthora blight) is a major disease with the following symptoms: Preemergence and postemergence death of seedlings. Girdling of collar region and collapse. Black water soaked spots leading to blight on leaf, stem canker and pod blight. Seeds shriveled, brown.
- Anon (1992a) in a grower guide reported *Phytophthora sesami* (Seedling blight) appears post emergence at the seeding to flowering stages. Initially, water soaked areas appear on the cotyledonary leaves of the newly emerged seedling and soon the tip is infected. Die-back rotting develops very fast and causes blight within few hours. In older plants, the die-back symptoms are seen. In few cases while large spots are more common.

- A.K. Dubey and T. Singh (1999) reported *Phytophthora parasitica* var. *sesame* causing blight of sesame is predominantly soilborne pathogen which over-winters through chlamydospores of the pathogen as seed contaminants. [Cited by A.K. Dubey et al., 2011]
- M.L. Verma et al. (2002) reported antagonistic *Trichoderma viride*, *Trichoderma harzianum*, and *Pseudomonas fluorescence*, when used as seed treatment, not only reduce *Phytophthora parasitica* var. *sesami* significantly but substantially increase the sesame yield. [Cited by C. Chattopadhyay et al., 2019]
- A.K. Dubey et al. (2011) reported *b*esides causing blight, *Phytophthora parasitica* var. *sesami* is found to be associated with vivipary in immature seeds of sesame contained in green capsules of plants raised from naturally infected seeds. The green capsules split lengthwise due to emergence of few seedlings from the capsules. The pathogen induced emergence of the radicle, hypocotyls and cotyledons through the seed coat within the capsule. Such viviparous condition occurred in 25-48.8% of the capsules and 27.08-36.12% of the seeds. The viviparous pods were characterized by internal browning of pedicel, septum and placenta. The seeds carried white cottony growth of *P. parasitica* var. *sesami*. Such viviparous condition was not visible in capsules with normal looking seeds. Vivipary in our case might be due to fungal stimulation. Presence of pathogen in different parts of the capsules and seedlings were established by incubation and cleared preparation. In immature developing capsules, hyphae were observed in tissues of pericarp, placenta, locules and ovules. It is an unusual phenomenon that besides increasing the seed infection also renders poor-quality seeds. The host-pathogen interaction results in abnormal seedling emergence, which lacks vigor and further survival.

- K. Satyagopal et al. (2014) in an IPM manual reported *Phytophthora parasitica* var. *sesami* symptoms were as follows:
  - Disease can occur at all stages of the plant.
  - Initial symptom is water soaked spots on leaves and stems.
  - The spots are chestnut brown in the beginning later turn to black.
  - Premature leaf fall occurs.

  In humid weather, severity of disease increases; main root is affected; diseased plants are easily pulled out; plants produce shriveled seeds and gives blighted appearance. The pathogen survives in soil. High soil moisture favors the development of the pathogen. The disease is severe in the area of heavy soil with high rainfall. Cultural control: Avoid planting overlapping crops in adjacent area. Crop rotations, viz., sesame-maize, cabbage, okra-sesame-maize, maize-sesame-maize and sesame- finger millet-egg plant are reported effective in reducing disease incidence. Crop rotation with non-host crops, particularly with paddy. • Provide good drainage Seed treatment: Treatment with *Trichoderma* sp. @ 4 g/Kg of seed, *Pseudomonas fluorescens* @ 2 g/Kg seed, or *Bacillus subtilis* @ 2 g/Kg seed or NSKE 4%.
- H.J. Kapadiya et al. (2015) screened germplasm for resistance to *Phytophthora parasitica.* Initial symptom of Phytophthora blight is water soaked spots on leaves and stems. The spots are chestnut brown in the beginning, later turn to black. In humid weather, severity of disease increases, main root is affected, diseased plants are easily pulled out and produce shriveled seeds and gives blighted appearance. High soil moisture favors the development of the pathogen. The mortality of the plants due to the disease may be as high as 72-80% (Reeti Singh et al., 2005). It may cause 100% loss under most favorable conditions when infection occurs severely at seedling stage. Out of several entries screened, released varieties Gujarat Til 10 (GT 10) was superior against Phytophthora blight disease in both the years. This was only the variety who recorded less than 10% disease intensity ranging from 3.74 and 5.92% under high disease presser condition of 2013. In low disease presser condition of 2014, many entries appeared in resistance category, but the least infection (1.51 to 2.67%) was observed in GT 10. The following photo shows a Phytophthora infected seedling.

- K.N. Gupta et al. (2018) reported Phytophthora blight (*Phytophthora parasitica* var. *sesami*) produces initial symptoms of water soaked spots on leaves and stem. The spots are brown in the beginning which later turns to black. Disease can attack at all the stages of the crop. Phytophthora tolerant varieties are MT-75, TKG-22, and TKG055. Phytophthora may be alleviated by good drainage; soil solarization; crop rotation; late planting (about 3 weeks after onset of monsoon); intercropping of sesame + pearl millet (3:1 or 4:1); and/or soil treatment of Ridomil Mz (0.25%). *Pseudomonas* sp., *Bacillus* sp., *and Streptomyces* sp., which are most active at 25-27°C at field capacity moisture level could be suppressive of Phytophthora species in soil. *Trichoderma harzianum*, which are common soil fungi, are also antagonistic to Phytophthora species.
- A.K. Dubey et al. (2021) studied the survival of oospores and chlamydospores of *Phytophthora parasitica* var. *sesami* in plant debris.
  - Debris kept in ambient laboratory condition: The viability of oospores and chlamydospores initially varied from 77-86% and 77-80% respectively in leaf, stem and leaf + stem mixed debris. Not much effect on their viability was seen after two months of storage, but later after seven months of storage, it decreased to 53-58% (oospores) and 50-51% (chlamydospores).
  - Debris kept in unsterilized soil in laboratory: The different categories of debris buried in unsterilized soil showed 69-72% viable oospores and 64-60% viable chlamydospores. Their viability decreased gradually and became 49-52% and 42- 46% respectively after seven months. The type of debris (leaf or stem) did not show significant difference in percent viability of oospores and chlamydospores.
  - Debris kept in field condition: Viability of both chlamydospores and oospores decreased sharply in the debris buried in soil under natural field condition. Initially, it ranged from 65-67% and 60-65% respectively for chlamydospores and oospores. After three months it decreased to 10-21% and 6-18%. Their viability decreased to 0-5% and 0-2% after five months. No viable oospores and chlamydospores were observed after seven months of overwintering.
- Anon. (n.d.k) reported *Phytophthora parasitica* var. *sesami* (Stem blight) causes a minor disease.

IRAN

- Anon. (1967b) reported sesame is a host of *Phytophthora nicotianae.* [Cited by G.S. Saharan, 1989]

JAPAN

- T. Kuzuyuki (2021) reported the following pathogen: *Phytophthora nicotianae* (Blight).

MEXICO

- M.M. Satour (1981) reported the presence of *Phytophthora parasitica* (Root rot, stem rot, wilt).
- Anon. (2010a) in a grower guide reported the following main pathogen: *Phytophthora nicotianae.* For its control, fumigation of the soil with methyl bromide, but this can allow rapid accumulation of a pathogen, if introduced later, due to the absence of competitors. The use of thiram in seed and metalaxyl spraying reduces the disease.

NIGERIA

- M.M. Satour (1981) reported the presence of *Phytophthora parasitica* (Root rot, stem rot, wilt).

REPUBLIC OF KOREA

- E.K. Cho et al. (1981) reported Phytophthora blight (*Phytophthora nicotianae* var. *parasitica*) in 4 areas. The rate of disease incidence ranged from 0 to 61% depending on the field observed. Diseased plants of sesame generally showed dark discoloration on the stem leading to plant death.
- S.H. Choi et al. (1984) reported cultivation in 0.2 m wide ridges in plots mulched with black vinyl reduced the spread of the disease (*Phytophthora nicotianae* var. *parasitica*) by at least 30% and increased yield by 22% compared with mulching alone. [Cited by G.S. Saharan, 1989 and C. Chattopadhyay, 2019]

- C.W. Kang et al. (1985g) reported Sesame Phytophthora blight (*Phytophthora nicotiana* var. *parasitica*) is a serious problem. The lesions on the stem and leaf are enlarged rapidly in the middle of the rainy season during the summer and causes great yield reduction. Five chemicals were applied one to three times from the middle of July to the middle of August after inoculating with artificially cultured sesame Phytophthora blight fungi. Metasyl 25% WP (sprayed three times at ten day intervals 1,000x solution of 1.2 t/ha) was the most effective for controlling Phytophthora blight. The incidence rate in the treated material was 18% vs. 6l% for the control, and the number of capsules per plant was 75 in the treated vs. 65 in the untreated. The yields were 9% higher in the treated plots. [Based on abstract]
- J.I. Lee and B.H. Choi (1985h) reported that *Phytophthora parasitica* is first manifested by damp blackish lesions on the collar of the stem at the soil surface and/or on the 10 cm of stem above the soil surface, particularly during the rainy season from July to August. The disease is controlled by removing the affected plants, by spraying Metasil WP 2 or 3 times, and by proper irrigation and drainage of the field so as to avoid water logging.
- B.K. Chung and K.S. Hong (1991) and B.K. Chung and S.O. Ser (1992) isolated *Streptomyces bikiniensis* and reported it is antagonistic to *Phytophthora nicotianae* var. *parasitica* and *Fusarium oxysporum* f. sp. *vasinfectum.*

SRI LANKA

- R. Pathirana (1992a) initiated a mutation breeding program to develop tolerance to *Phytophthora nicotianae* var. *parasitica*, which is a serious disease. Gamma ray treatments of 450 Gy and 600 Gy produced more lines tolerant to the disease than the other doses used.
- R. Pathirana (2000) in continuing the mutation breeding program listed in 1992a above developed a mutant variety (ANK S2), which may be used to increase the declining sesame area due to low yield of existing varieties and their susceptibility to disease.

TANZANIA

- M.M. Satour (1981) reported the presence of *Phytophthora parasitica* (Root rot, stem rot, wilt).
- Kafiriti, E. and O. Mponda (n.d.) in a grower guide reported the following pathogen: *Phytophthora nicotianae* var. *sesami.*

TURKEY

- N. Isler et al. (n.d.) reported the following pathogen: *Phytophthora parasitica* var. *sesami.* For control, use fields with good drainage, plant resistant varieties, and use a 2 year rotation.

UNITED STATES

- D.R. Langham et al. (2010c) reported sesame root rots (combination of *Fusarium oxysporum, Phytophthora parasitica*, and *Macrophomina phaseolina*) have been encountered mostly on fields where sesame is planted after sesame. The current varieties are tolerant but not resistant to the root rots. The best way to avoid sesame root rot is to rotate different crops every summer.
- Anon. (2015c) USA PVP descriptor: 7. Diseases – *Phytophthora* blight or rot (*Phytophthora parasitica* var. *sesami*). The following ratings are used:
  - 0 = Not tested
  - 1 = Susceptible
  - 2 = Low resistance
  - 3 = Moderate resistance
  - 4 = High resistance
- D.R. Langham (2015b) USA patent descriptor: 36. Tolerance to *Phytophthora* stem rot (*P. parasitica*)
  - Definition: Amount of tolerance to *Phytophthora* stem rot.
  - Values: Average of a minimum of three plots of a subjective rating based on the following values: 0 to 8 scale of the % of infected plants (Intermediate values are used).
    - 8 = Zero disease
    - 7 = <10% infected
    - 4 = 50% infected
    - 1 = >90% infected
    - 0 = all infected
    - Intermediate values may be used
    - NT = not tested
    - NEC = no economic damage - not enough insects to do ratings

- Ratings can be done in several ways:
  - Take ratings after the disease is no longer increasing.
  - Take ratings on consecutive weeks until the disease is no longer increasing and average ratings.
  - Take periodic ratings and average ratings.
- Comments:
  - *Phytophthora* has been a problem in Arizona and Texas, particularly on fields that have been over-irrigated. Normally, only the *Composite Kill Tolerance* rating is taken.
  - There are three root diseases that affect sesame in Texas: *Fusarium oxysporum*, *Macrophomina phaseoli,* and *Phytophthora parasitica*. Between 1988 and the present, spores of these three have been accumulated in one small area (1 square km) north of Uvalde, and thus it is an excellent screening area for the diseases. Although each root rot disease attacks sesame in a different way and may result in different symptoms, no effort is made to definitively determine which disease is the etiological agent for the affected plants. Pathological screenings in the past have found all 3 pathogens present in dead plants.
  - The amount of kill is usually increased with any type of stress to the plants. Drought can increase the amount of *Macrophomina*; too much water can increase the amount of *Phytophthora*; high temperatures and humidity can increase the amount of *Fusarium* and *Phytophthora*. High population can increase all three diseases

- D.R. Langham comments, 2021: My first encounter with *Phytophthora nicotianae* was in 1981 in Yuma, Arizona. The 3-5 ha fields were laser leveled and irrigated with flood irrigation. The water had to be cut off before the water reached the end of the field, or there would be too much water, which would kill the plants with *P. nicotianae.* The University of Arizona identified the pathogen. There was also almost every time some kill at the water source where the plants had the most exposure to water. One year I decided to plant a disease nursery with over 300 lines to identify tolerant lines. I over-irrigated the field right at dawn so the plants would have maximum heat. When I cut off the water, the water level was about 50 cm up on the stem and it took over 20 hours to absorb all the moisture into the soil. Not a single plant died. So much for the design of a perfect experiment. In retrospect, the air temperature as over 40°C with no cloud cover making the water even hotter. Perhaps, the pathogen was killed at those high temperatures.

  When moving the nurseries to Texas in 1988, J.R. Mulkey of Texas A&M reported that in his nurseries, he isolated *Macrophomina phaseolina*, *Phytophthora nicotianae*, and *Fusarium oxysporum* in dead plants. He felt that probably only one of the pathogens had penetrated the plant defenses, but once that defensive line was broken, the others were able to enter the plant. He felt that *M. phaseolina* was the culprit when after starting with good moisture, a crop faced a drought. The symptoms appeared over several days. He felt that *P. nicotianae* appeared after an overirrigation or a heavy rain that resulted in puddling. The initial symptoms appeared overnight with a characteristic drooping of the top of the plant. The plant may or may partly recover. He did not have much experience with *F. oxysporum.*

  In my first nursery in Uvalde the irrigation was furrow irrigation. I made the mistake of having a berm at the end of the field resulting in standing water at the end. The day before the irrigation, I had a beautiful crop, along with a commercial field next to it. The next morning the heads of the plants for the 30 meters from the end of the fields were bent over and died a few days later. The suffocation from too much moisture with no oxygen to the roots compromised the sesame plant defenses enabling *Phytophtora nicotianae* to enter the plants. From then on, I never trapped the water. The pattern persisted for many years in commercial fields – particularly in fields that were contoured with low spots to minimize erosion.

  Our advice to farmers was to rotate crops with at least 2 years between sesame crops, and this generally worked. The exceptions were actually on the unexpected side. For a time, there was a government program called 'set-aside'. A cotton farmer would not plant cotton on a certain proportion of his field and still be paid for the 'unharvested crop.' Sesame could be planted and harvested on the 'set-aside' ground. In West Texas, some farmers planted sesame on the same ground for 4 successive years with no disease. In other parts of Texas, there was disease in the second year of planting on the same ground.

  I maintained nurseries in Uvalde within 100 meters of each other for 26 years. I would rotate the field each 3 years in order to create tremendous populations of *Macrophomina phaseolina, Phytophthora nicotianae,* and *Fusarium oxysporum.* I would plant 'canary lines' that were very susceptible to the diseases to make sure there was pathogen pressure each year. I would discard any lines that were susceptible with the exception of crosses between tolerant and susceptible lines to move desirable traits from the susceptible line to the tolerant line. In those cases, the disease would appear in the F_1, but would often segregate in the F_2 and later generations. By the time that a variety was ready to be released, it was considered tolerant to the 3 diseases. Although this

proved true for *P. nicotianae*, and *F. oxysporum*, it was not true for *M. phaseolina*. Although there were many spores of *M. phaseolina*, the nurseries did not have drought conditions to induce the disease.

There was still some kill from *P. parasitica* on extreme puddling. For example, in West Texas there are 'playas' where a lake could form after extensive rains and would remain from several weeks to as much as months depending on the soil and amount of rain. Sesame in these lakes would die.

VENEZUELA

- G. Malaguti and B. Mazzani (1953) isolated *Phytophthora parasitica* in Aragua in heavy soils with poor drainage or if faulty irrigation caused prolonged waterlogging. The disease is characterized by a dark stain that starts below the soil and progresses up the stem and branches. The first symptom is a damp, blackish lesion on the collar or below soil level. It spreads rapidly to the stem and branches either girdling the stem and strangling the basal part or extending in irregular vertical streaks. The main root is also affected, and the plants are easily removed from the soil leaving the rootlets and rotten cortex behind. The leaves, flowers and branch tips wither and hang downwards. The plant may be attacked at any stage but mostly at the time of flowering. A peculiarity of the disease in Venezuela is that it attacks the tip of the stem and leaves of the newly germinated seedlings causing a type of blight. It can attack at any stage, but is more common during flowering. If it attacks at an early stage, it will affect the leaves.

- B. Mazzani et al. (1975) reported a new Aceitera variety resistant to *Phytophthora nicotianae* var. *parasitica*, *Macrophomina phaseoli*, and *Fusarium oxysporum* f. sp. *sesami* was obtained by backcrossing with the African var. Ajioo Atar 55 resistant to *Phytophthora* and *Macrophomina*. The yield and vegetative characteristics of the new variety resemble those of the original Aceitera which is resistant to *Fusarium*.
- M.M. Satour (1981) reported the presence of *Phytophthora parasitica* (Root rot, stem rot, wilt).
- A.M. Colmenares and L. Subero (1989a) reported the following pathogen: *Phytophthora parasitica* (Black leg). This disease is characterized by a necrosis which usually starts at the root and then goes up to the collar region of the plant. The root and collar rot are dark brown with a wet and somewhat compressed appearance. Dieback may also be observed either when the pathogen attacks the apex and leaves under abundant rain conditions and when the crop is in the initial development stage.

B1.1.1b *Phytophthora cactorum* (5 Jun 2021)

Family: Peronosporaceae

Definition: Amount of tolerance to *Phytophthora cactorum* (Lebert & Cohn) J. Schröter 1886.

(Wikipedia, 5 Jun 2021) ***Phytophthora cactorum*** is a plant pathogen that causes root rot on rhododendron and many other species.

References:

INTERNATIONAL

- J.R. Morschel (1964) reported the following pathogen in the world: *Phytophtora cactorum* (Stem canker). [Cited by D.F. Beech. 1995a]

PERU

- B.S. Crandall and J. Dieguez (1948) reported wilted plants in the lower, poorly drained sections of the plots and closer inspection revealed extensive stem cankers between the collar and tip of the growing point. Girdling infections at the collar led to complete wilting of the plant. Infection apparently originated in the leaves or

young lateral branches and spread much more rapidly in a vertical than in a horizontal direction. Dissection of the cankers indicated that the pathogen was primarily an invader of cambium and phloem tissue. Some infection of the capsules was also noted. The fungus isolated in pure culture from the advancing margins of cankers was a species of *Phytophthora* with sporangia measuring 37.4 to 51 µ by 23.8 to 27.2 µ (mean 39.7 by 25.5 µ) produced on branching sporangiphores and oogonia averaging 25.5 µ with paragynous antheridia. It is apparently identical with *Phytophthora cactorum* and forms first record.

B1.1.1c *Phytophthora hibernalis* (18 Jun 2021)

Family: Peronosporaceae

Definition: Amount of tolerance to *Phytophthora hibernalis* Carne 1925.

(Wikipedia, 18 Jun 2021) ***Phytophthora hibernalis*** is a plant pathogen infecting citruses.

References:

VENEZUELA

- C. Zambrano and O. Tortolero (1985) conducted studies on 540 sesame cultivars and isolations from seedling rot and soil and reported the following pathogen: *Phytophtora hibernalis. Macrophomina phaseoli* caused heavier infection than *Phytophthora hibernalis* during dry conditions.

B1.1.1d *Phytophthora drechsleri* (21 Jul 2021)

Family: Peronosporaceae

Definition: Amount of tolerance to *Phytophthora drechsleri* Tucker 1931.

(Wikipedia, 21 Jul 2021) ***Phytophthora drechsleri*** is a plant pathogen with many hosts.

References:

MALAWI

- G.R. Bates (1961) reported *Phytophthora drechsleri.*

B1.1.1e *Phytophthora palmivora* (21 Jul 2021)

Family: Peronosporaceae

Definition: Amount of tolerance to *Phytophthora palmivora* E.J. Butler.

(Wikipedia, 21 Jul 2021) ***Phytophthora palmivora*** is an oomycete that causes bud-rot of palms, fruit-rot or kole-roga of coconut and areca nut. These are among the most serious diseases caused by fungi and moulds in South India. It occurs almost every year in Malnad, Mysore, North & South Kanara, Malabar and other areas. Similar diseases of palms are also known to occur in Sri Lanka, Mauritius, and Sumatra. The causative organism was first identified as *Phytophthora palmivora* by Edwin John Butler in 1917.

References:

Some place *Phytophthora parasitica* var. *sesami* as a synonym of *Phytophthora palmivora.* Until this is settled, all of the references to *Phytophthora parasitica* var. *sesami* have been placed under *Phytophthora nicotianae.*

VENEZUELA

- G. Malaguti (1953) skirts the issue by just calling it the *Phytophthora parasitica – Phytophthora palmivora* group.

B1.1.1f *Phytophthora capsici* (6 Sep 2021)

Family: Peronosporaceae

Definition: Amount of tolerance to *Phytophthora capsici* Leonian 1922.

(Wikipedia, 6 Sep 2021) ***Phytophthora capsici*** is an oomycete plant pathogen that causes blight and fruit rot of peppers and other important commercial crops. It was first described by L. Leonian at the New Mexico State University Agricultural Experiment Station in Las Cruces in 1922 on a crop of chili peppers. In 1967, a study by M.M. Satour and E.E. Butler found 45 species of cultivated plants and weeds susceptible to *P. capsici.* In Greek, *Phytophthora capsici* means "plant destroyer of capsicums". *P. capsici* has a wide range of hosts including members of the families Solanaceae and Cucurbitaceae as well as Fabaceae.

References:

REPUBLIC OF KOREA

- J.W. Hyun et al. (1999) reported *Bacillus polymyxa* (synonym of *Paenibacillus polymyxa*) was isolated as an antibiotic compound that was an antagonist against *Fusarium oxysporum* f. sp. *sesami.* Under greenhouse conditions *Bacillus polymyxa* was shown its minimum inhibitory concentrations were 12.8 µg/ml for *F. oxysporum* and *Alternaria mali,* 6.4 µg/ml for *Colletotrichum gloeosporioides* and *Rhizoctonia solani*, and 3.2 µg/ml for *Phytophthora capsici.*

B1.1.1g *Phytophthora tropicalis* (22 Sep 2021)

Family: Peronosporaceae

Definition: Amount of tolerance to *Phytophthora tropicalis* Aragaki & J. Y. Uchida 2001.

References:

INTERNATIONAL

- CAB International (accessed 12 Apr 2021) reported sesame was a minor host of *Phytophthora tropicalis.*

MEXICO

- S.A. Ortega-Acosta et al. (2016) reported during December 2011, the presence of rot was detected in sesame plants in different commercial plots located in Guerrero State. Symptoms were stem and root rot, yellowing and wilting of leaves. A sterile toothpick containing a small portion of mycelium was inserted into the stem base of 12 healthy plants. In six plants that served as controls, only a sterile toothpick was inserted. Within 14 days after inoculation, all plants inoculated with mycelium showed symptoms similar to what was observed on the diseased plants in field plantations, whereas control plants showed no symptoms. The presence of the disease might cause significant losses in sesame plantations

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B1.2 Family: Pythiaceae Schroter 1897

(Wikipedia, 8 Apr 2021) **Pythiaceae** is a family of water molds. The family includes serious plant and animal pathogens in the genus *Pythium*. The family was circumscribed by German mycologist Joseph Schröter in 1893.

Live on land (terrestrial), and in water (aquatic), and a combination of the two, (amphibious). Live as deadly parasites, causing some serious plant and animal diseases when terrestrial. The diploid (2N) life stage predominates, with a short haplophase initiated during sexual reproduction as well as asexual reproduction (homothallism predominates in the Family) to fuse gametes.

The sporangia may germinate via a germ tube or by release of motile zoospores, depending on the species and the environmental conditions.

Some *Pythium* species cause “damping off” diseases in young plants (seedlings).

The following species have been reported to cause diseases, produce a toxin, inhibit germination, or affect seed quality.

- B1.2.1 *Pythium* spp.
- B1.2.1a *Pythium ultimum*
- B1.2.1b *Pythium debaryanum*
- B1.2.1c *Pythium aphanidermatum*
- B1.2.1d *Pythium oligandrum*

B1.2.1 *Pythium* spp. (8 Apr 2021)

Family: Pythiaceae

Definition: Amount of tolerance to *Pythium* spp. Pringsheim 1858.

(Wikipedia, 8 Apr 2021) ***Pythium*** is a genus of parasitic oomycetes. They were formerly classified as fungi. Most species are plant parasites, but *Pythium insidiosum* is an important pathogen of animals, causing pythiosis. The feet of the fungus gnat are frequently a vector for their transmission.

Pythium species, like others in the family Pythiaceae, are usually characterized by their production of coenocytic hyphae without septations. Generally contain a single oospore. Contain an elongated and club-shaped antheridium.

Pythium-induced root rot is a common crop disease. When the organism kills newly emerged or emerging seedlings, it is known as damping off, and is a very common problem in fields and greenhouses. Thus there is tremendous interest in genetic host resistance, but no crop has ever developed adequate resistance to *Pythium*. This disease complex usually involves other pathogens such as *Phytophthora* and *Rhizoctonia*. Pythium wilt is caused by zoospore infection of older plants, leading to biotrophic infections that become necrotrophic in response to colonization/reinfection pressures or environmental stress, leading to minor or severe wilting caused by impeded root functioning.

Many *Pythium* species, along with their close relatives *Phytophthora*, are plant pathogens of economic importance in agriculture. *Pythium* spp. tend to be very generalistic and unspecific in their large range of hosts, while *Phytophthora* spp. are generally more host-specific. For this reason, *Pythium* spp. are more devastating in the root rot they cause in crops, because crop rotation alone often does not eradicate the pathogen as *Pythium* spp. are also good saprotrophs, and survive for a long time on decaying plant matter.

In field crops, damage by *Pythium* spp. is often limited to the area affected, as the motile zoospores require ample surface water to travel long distances. Additionally, the capillaries formed by soil particles act as a natural filter and effectively trap many zoospores. However, in hydroponic systems inside greenhouses, where extensive monocultures of plants are maintained in plant nutrient solution (containing nitrogen, potassium, phosphate, and micronutrients) that is continuously recirculated to the crop, *Pythium* spp. cause extensive and devastating root rot and is often difficult to prevent or control. The root rot affects entire operations (tens of thousands of plants, in many instances) within two to four days due to the inherent nature of hydroponic systems where roots are nakedly exposed to the water medium, in which the zoospores can move freely. Various *Pythium* populations have been known to have resistance to mefenoxam since the 1980s and metalaxyl since 1984.

Several *Pythium* species, including *P. oligandrum*, *P. nunn*, *P. periplocum*, and *P. acanthicum*, are mycoparasites of plant pathogenic fungi and oomycetes, and have received interest as potential biocontrol agents.

References:

COSTA RICA

- Anon (1991a) in a grower guide reported the following pathogen: *Pythium* spp.

KENYA

- B. Mazzani (1987) visited sesame growing regions and reported the following major pathogen: *Pythium* spp.

PAKISTAN

- H.N. Farhan et al. (2011) investigated the biological activity of *Pseudomonas* bacteria as biocides to protect sesame crop from some fungi and to evaluate its efficiency as plant growth promoting. The first experiment investigated the effects of *Pseudomonas putida* (Pp) and *Pseudomonas fluorescens* (Pf) on germination and

seedlings growth of sesame crop against Pythium, Alternaria, and Fusarium under plastic house conditions. The following are the results.

Treatments	Sterilized soil		Non sterilized soil	
	Germination (%)	Seedlings (cm)	Germination (%)	Seedlings (cm)
Pythium + Pp	80	4.0	70	3.2
Fusarium + Pp	84	3.5	85	2.5
Alternaria + Pp	86.7	4.5	82	3.3
Pythium + Pf	65	3.2	65.3	2.2
Fusarium + Pf	61.6	4.0	71	3.0
Alternaria + Pf	75.7	3.0	77	1.0
Pythium	0.0	0.0	21	2.0
Fusarium	2.0	0.0	10	0.5
Alternaria	0.0	0.0	19	2.0
Control (no addition)	38.3	1.9	49.3	2.4

The second experiment grew the plants to harvest.

Treatments	Germination percentage	Leaf no. per plant (cm^2/plant)	Leaf area/plant	Chlorophyll content (mg/gm)
Pp + Fusarium	89.7	27	22	3.27
Pp + Pythium,	84.0	28	20	2.29
Pp + Alternaria	86.7	25	18	1.28
Pf + Fusarium	70.7	22	19	3.23
Pf + Pythium	71.0	19	17	1.96
Pf + Alternaria	80.0	19	18	2.25
Fusarium	3.0	6	4	0.21
Pythium	2.3	4	4	0.32
Alternaria	0.0	0	0	0.00
Control (no addition)	52.0	11	9	0.76
LSD 5 %	10.9	3.98	5.12	0.167

Treatments	Height of plant (cm)	Branch no. per plant	Total dry weight of shoot gm/plant
Pp + Fusarium	76.7	5.3	6.9
Pp + Pythium	88.3	8.3	7.7
Pp + Alternaria	67.7	6.3	6.7
Pf + Fusarium	73.3	4.7	4.8
Pf + Pythium	69.7	4.3	5.7
Pf + Alternaria	62.3	5.7	5.6
Fusarium	37.3	1.3	0.23
Pythium	36.3	2.7	0.3
Alternaria	0.0	0.0	0.0
Control (no addition)	55.0	3.3	3.3
LSD 5%	11.4	1.78	1.26

Treatments	Seeds no. per pod per plant	Weight of 1,000 seeds per plant (gm)	Pods no. per plant
Pp + Fusarium	50.7	2.2	33.7
Pp + Pythium	64.0	2.5	37.3
Pp + Alternaria	53.7	2.1	35.9
Pf + Fusarium	53.3	1.9	35.0
Pf + Pythium	54.7	1.6	26.7
Pf + Alternaria	43.7	1.8	32.3
Fusarium	8.3	0.4	1.3
Pythium	13.0	0.7	1.0
Alternaria	0.0	0.0	0.0
Control (no addition)	35.3	1.2	19.0
LSD 5%	4.58	0.22	3.3

Treatments	N% in shoot	P% in shoot	K% in shoot	Oil% in seeds
Pp + Fusarium	0.55	0.67	4.73	43.3
Pp + Pythium,	0.72	0.85	5.53	48.0
Pp + Alternaria	0.63	0.73	4.30	45.0
Pf + Fusarium	0.40	0.61	4.43	42.7
Pf + Pythium	0.32	0.71	4.43	44.0
Pf + Alternaria	0.41	0.66	4.52	43.7
Fusarium	0.07	0.03	2.2	5.3
Pythium	0.06	0.04	1.43	4.7
Alternaria	0.0	0.0	0.0	0.0
Control (no addition)	0.21	0.42	3.05	27.7
LSD 5 %	0.033	0.042	0.576	3.11

REPUBLIC OF KOREA

- S.W. Kang and H.K Kim (1989) reported sesame seeds coated with conidia of *Gliocladium virens*, were sown in the field where sesame had been cultivated for five to six straight years. The antagonistic fungus was evaluated for biocontrol potentials over Benomyl fungicide against Damping-off and Fusarium wilt of sesame for two years with randomized block design with three replicates throughout the growing period of 1987 and

1988. Pathogenic fungi associated with sesame seedling disease in the field plot was predominantly *Fusarium* sp. and *Pythium* sp. at 32.9% and 27%, respectively. Disease incidence of Damping-off and Fusarium wilt at earlier growth stages was 20.1% in 1987 and 15.2% in 1988 for plots of seed-dusted with conidia of G. virens, which was far effective compared to the infection rate at average of 35.2% of the untreated plot. It was especially remarkable that *G. virens* seed-dusting was superior to fungicide seed treatment by Benomyl wp. [Based on abstract]

THAILAND

- V. Benjasil (1985a) reported *Pythium* sp. (Root and stem rot) causes losses in yield.

UNITED STATES

- Cochran comments (2021): *Pythium* spp. can be difficult to differentiate within the genus and from other genera such as *Phytophthora*. A genus specific taxonomic key is helpful, though molecular identification with genus specific primers is likely necessary.

VENEZUELA

- J.B. Pineda and E.R. Glonnella (1988b) isolated 12 different cultures of fungi from soil samples collected in El Playon (7.47N 73.20W) and Turen (9.33N 69.11W) where some locations showed a low incidence of dry stem disease (*Macrophomina phaseolina*). The isolates were 8 *Aspergillus* spp., 2 *Trichoderma* spp., 1 *Cladosporium* sp. and 1 *Pythium* sp.

B1.2.1a *Pythium ultimum* (8 Apr 2021)

Family: Pythiaceae

Definition: Amount of tolerance to *Pythium ultimum* Trow 1901.

(Wikipedia, 8 Apr 2021) ***Pythium ultimum*** is a plant pathogen. It causes the damping off and root rot diseases of hundreds of diverse plant hosts including corn, soybean, potato, wheat, fir, and many ornamental species. *P. ultimum* belongs to the peronosporalean lineage of oomycetes, along with other important plant pathogens such as *Phytophthora* spp. and many genera of downy mildews. *P. ultimum* is a frequent inhabitant of fields, freshwater ponds, and decomposing vegetation in most areas of the world. Contributing to the widespread distribution and persistence of *P. ultimum* is its ability to grow saprotrophically in soil and plant residue. This trait is also exhibited by most *Pythium* spp. but not by the related *Phytophthora* spp., which can only colonize living plant hosts.

Infections of seeds and roots are initiated by both the mycelia and spores of *P. ultimum*. Two spore types are made, depending on the strain. *P. ultimum* is a species complex that includes *P. u.* var. *ultimum* and *P. u.* var. *sporangiiferum*. The major distinguishing feature is that sporangia and zoospores (swimming spores) are produced only rarely by *P. u.* var. *ultimum*. Both species make oospores, which are thick-walled structures produced by sexual recombination. Both varieties are self-fertile (homothallic), which means that a single strain can mate with itself. In addition to oospores, *P. u.* var. *ultimum* also makes hyphal swellings which germinate in a manner resembling sporangia to form plant-infecting hyphae. One important ecological difference between the different types of spores is that sporangia and zoospores are short-lived, while the thick-walled oospores can persist for years within soil, surviving even winter freezes. Mycelia and oospores in soil can infect seeds or roots. This leads to wilting, reduced yield, and ultimately plant death. Common signs of a *Pythium* infection include stunting of the plants, brown coloration of root-tips, and wilting of the plant during the warm part of the day. Management of disease is challenging but focuses on sanitation, fungicides, and biological control. Fungicides include mefenoxam, thiadiazole, etridiazole, propamocarb, dimethomorph, and phosphonates. Biological control agents include the bacteria *Bacillus subtilis*, *Streptomyces griseoviridis*, and the fungi *Candida oleophila*, *Gliocladium catenulatum*, *Trichoderma harzianum*, and *Trichoderma virens*.

Effective resistance in the plant host is generally not available. Sanitation is very important since the pathogen can be easily introduced into pasteurized soil or even soil-free potting mixes on dirty tools or pots. Especially in greenhouses, fungus gnats may also help move the pathogen from place to place. A recent study of greenhouses in Michigan revealed that the same pathogen populations were responsible for the root rot of all greenhouse ornamental plants over a two-year period. These results stress the importance of sanitation and encourage greenhouse growers to improve their scouting of all incoming plant material to prevent additional root rot.

References:

EGYPT

- A. Hashem et al. (2014) collected 18 seed samples of sesame in Egypt (12 samples) and Saudi Arabia (6 samples). They identified the following mycoflora: *Pythium ultimum.*

UNITED STATES

- C.A. Thomas (1959a) reported that *Pythium ultimum* was isolated and found to be the most virulent damper off. The damping off was greatest at 20° C. Orthocide treatments of the seeds were found to be a good control. In a typical field trial the mean percentage stand was increased fran 4.8 in the untreated to 34.8. [Cited by G.S.Saharan. 1989]

B1.2.1b *Pythium debaryanum* (13 Apr 2021)

Family: Pythiaceae

Definition: Amount of tolerance to *Pythium debaryanum* (R. Hesse) Uzuhashi, Tojo & Kakish. 2010.

(Wikipedia, 13 Apr 2021) ***Pythium debaryanum*** is a species of water mould in the family Pythiaceae. It is known as a plant pathogen on many kinds of wild and cultivated plants, including peanut, beet, eucalyptus, tobacco, and pine trees. The plants develop damping off, a disease state.

References:

INTERNATIONAL

- J.R. Morschel (1964) reported the following pathogen in the world: *Pythium debaryanum* (Damping off). [Cited by D.F. Beech. 1995a]

AUSTRALIA

- D.F. Beech (1981a and 1995a) reported the presence *Pythium debaryanum* (Damping off) in sesame in 1966.

EGYPT

- M.M. Satour (1981) reported the presence of *Pythium debaryanum* (Seedling damping off).

MEXICO

- M.M. Satour (1981) reported the presence of *Pythium debaryanum* (Seedling damping off).

UNITED STATES

- M.M. Satour (1981) reported the presence of *Pythium debaryanum* (Seedling damping off).

B1.2.1c *Pythium aphanidermatum* (28 Apr 2021)

Family: Pythiaceae

Definition: Amount of tolerance to *Pythium aphanidermatum* (Edson) Fitzp. 1923.

(Wikipedia, 28 Apr 2021) ***Pythium aphanidermatum*** is a soilborne plant pathogen. *Pythium* is a genus in the class Oomycetes, which are also known as water molds. Oomycetes are not true fungi, as their cell walls are made of cellulose instead of chitin, they are diploid in their vegetative state, and they contain coenocytic hyphae (lacking crosswalls), called a protist. Also, they reproduce asexually with motile biflagellate zoospores that require water to move towards and infect a host. Sexually, they reproduce with structures called antheridia, oogonia, and oospores.

References:

INDIA

- P.D. Gemawat and N. Prasad (1965c) reported when soil containing sesame seeds was inoculated with *Pythium aphanidermatum*, the seeds failed to germinate. When the collar region of plants 2-8 weeks old was inoculated or the soil was inoculated, no infection was observed.
- N.B. Kulkarni (1965) reported *Pythium aphanidermatum* is a minor pathogen. [Cited by E.A. Weiss, 1971]
- S. Maiti et al. (1985 and 1986) reported the following minor pathogen: Damping off *Pythium aphanidermatum* (Eds) Filz.

- M.L. Verma (1985) reported *Pythium aphanidermatum* (Damping off) is a major disease with the following symptoms: Preemergence and postemergence death of seedlings. Girdling of collar region and collapse.

IRAQ

- N.A. Ramadan (2009) reported The effect of the concentrations 0, 1, 2, 3, and 4 mg/ml of alcoholic extracts of cress seeds (*Lipidium sativum*) on the growth and dry weight of root–rot fungi of sesame plants, *Pythium aphanidermatum*, *Fusarium solani* and *Macrophomina phaseolina* indicated high significant inhibitory affect as compared to the control. *M. phaseolina* was mostly inhibited than other fungi when 4mg/ml w, 86.66 and 78.26% respectively. Antagonistic test of the bacterial biocontrol agent *Bacillus cereus* showed high inhibiting effect on all tested pathogens with the maximum inhibition 80.8% on *M. phaseolina*. Culture filtrate of *B. cereus* also showed a highly inhibiting efficiency to the growth and dry weight of the biomass of all pathogenic fungi with the increase of concentrations 10%, 20%, 30% and 40% (v l v) with the 40% was mostly effective on *M. phaseolina* by the ratio of 72.22% and 83.90%, respectively. The best inhibition was achieved with the use of combination of 4 mg/ml of alcoholic extract of Cress seeds and 40% of culture filtrate of *Bacillus cereus*. It showed synergistic inhibitory effect on all pathogenic fungi used, that exceeded the effect of each of the plant extract or culture filtrate of the bacteria separately. [Based on abstract]

B1.2.1d *Pythium oligandrum* (18 Jun 2021)

Family: Pythiaceae

Definition: Amount of tolerance to *Pythium oligandrum* Dreschler.

(Wikipedia, 18 Jun 2021) ***Pythium oligandrum*** is an oomycete. It is a parasite of many fungi and other oomycetes including *Botrytis*, *Fusarium* and *Phytophthora*. It has been licensed as a biocontrol agent in the form of an oospore soil treatment, which reduces pathogen load and concomitant plant disease. *P. oligandrum* can grow within the roots of certain plants, including tomato and sugar beet. Production of auxin-like substances stimulate plant growth. Defense responses can be induced in the plant, which primes the plant from further infection by pathogenic fungi, oomycetes or bacteria.

References:

VENEZUELA

- C. Zambrano and O. Tortolero (1985) conducted studies on 540 sesame cultivars, and isolations from seedling rot and soil and reported the following: *Pythium oligandrum.* [isolated for the first time from sesame seedlings].

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C Pest: Bacteria

(Wikipedia, 21 Feb 2021) **Bacteria:** common noun **bacteria**, singular **bacterium**) are a type of biological cell. They constitute a large domain of prokaryotic microorganisms. Typically a few micrometers in length, bacteria have a number of shapes, ranging from spheres to rods and spirals. Bacteria were among the first life forms to appear on Earth, and are present in most of its habitats. Bacteria inhabit soil, water, acidic hot springs, radioactive waste, and the deep biosphere of the earth's crust. Bacteria also live in symbiotic and parasitic relationships with plants and animals. Most bacteria have not been characterized, and only about 27 percent of the bacterial phyla have species that can be grown in the laboratory. The study of bacteria is known as bacteriology, a branch of microbiology.

Nearly all animal life is dependent on bacteria for survival as only bacteria and some archaea possess the genes and enzymes necessary to synthesize vitamin B_{12}, also known as cobalamin, and provide it through the food chain. Vitamin B_{12} is a water-soluble vitamin that is involved in the metabolism of every cell of the human body. It is a cofactor in DNA synthesis, and in both fatty acid and amino acid metabolism. It is particularly important in the normal functioning of the nervous system via its role in the synthesis of myelin. There are typically 40 million bacterial cells in a gram of soil and a million bacterial cells in a milliliter of fresh water. There are approximately 5×10^{30} bacteria on Earth, forming a biomass which is only exceeded by plants. Bacteria are vital in many stages of the nutrient cycle by recycling nutrients such as the fixation of nitrogen from the atmosphere. The nutrient cycle includes the decomposition of dead bodies; bacteria are responsible for the putrefaction stage in this process. In the biological communities surrounding hydrothermal vents and cold seeps, extremophile bacteria provide the nutrients needed to sustain life by converting dissolved compounds, such as hydrogen sulfide and methane, to energy.

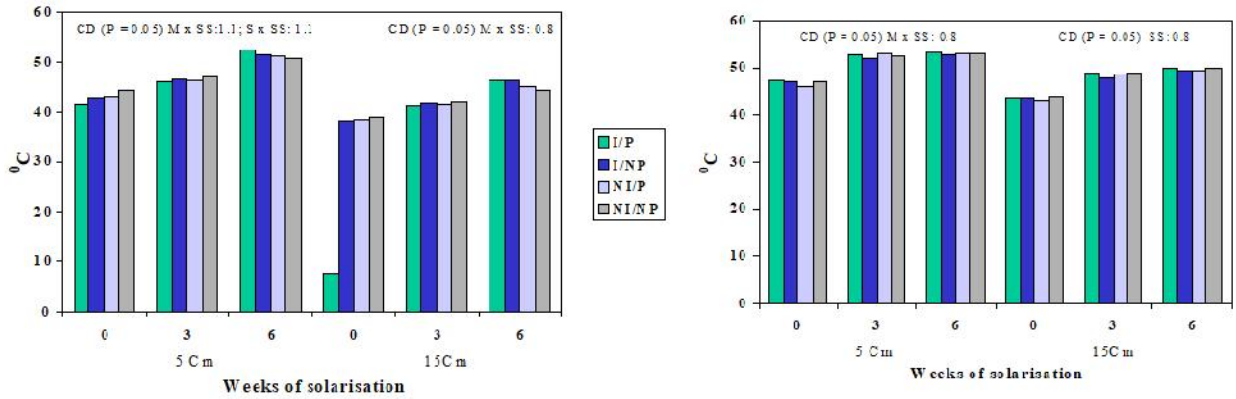
In humans and most animals, the largest number of bacteria exist in the gut, and a large number on the skin. The vast majority of the bacteria in the body are rendered harmless by the protective effects of the immune system, though many are beneficial, particularly in the gut flora. However, several species of bacteria are pathogenic and cause infectious diseases, including cholera, syphilis, anthrax, leprosy, and bubonic plague. The most common fatal bacterial diseases are respiratory infections. Tuberculosis alone kills about 2 million people per year, mostly in sub-Saharan Africa. Antibiotics are used to treat bacterial infections and are also used in farming, making antibiotic resistance a growing problem. In industry, bacteria are important in sewage treatment and the breakdown of oil spills, the production of cheese and yogurt through fermentation, the recovery of gold, palladium, copper and other metals in the mining sector, as well as in biotechnology, and the manufacture of antibiotics and other chemicals.

Once regarded as plants constituting the class *Schizomycetes* ("fission fungi"), bacteria are now classified as prokaryotes. Unlike cells of animals and other eukaryotes, bacterial cells do not contain a nucleus and rarely harbor membrane-bound organelles. Although the term *bacteria* traditionally included all prokaryotes, the scientific classification changed after the discovery in the 1990s that prokaryotes consist of two very different groups of organisms that evolved from an ancient common ancestor. These evolutionary domains are called *Bacteria* and *Archaea*.

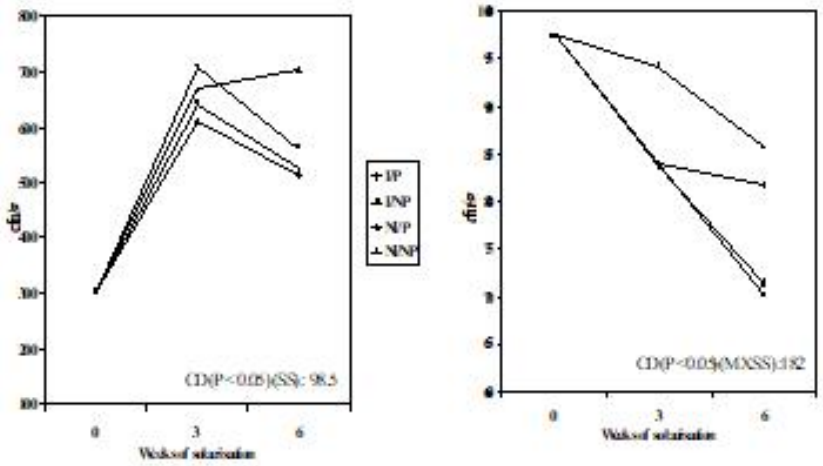
References:

INDIA

- C. Chattopadhyay and R. Kalpana Sastry (1999) studied the effect of soil solarization on the bacteria population in 1995 and 1996 in Hyderabad (77.92E and 18.99N). Plots were irrigated to field capacity according to the design before they were covered with transparent polyethylene mulch of 50 µm thickness for 0, 3, or 6 weeks. The temperatures at 5 and 15 cm depth were as follow in the two years.



The effects on the total bacteria population (cfu/g soil) were as follow.



C1 Order: **Pseudomonadales** Orla-Jensen 1921

(Wikipedia, 9 Apr 2021) The **Pseudomonadales** are an order of Proteobacteria. A few members are opportunistic pathogens, such as species of *Pseudomonas*, *Moraxella*, and *Acinetobacter*, which may cause pneumonia.

There are species in this order associated with sesame, but not reported to cause diseases, produce a toxin, inhibit germination, or affect seed quality. See I1.

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C1.1 Family: **Pseudomonadaceae** Winslow et al. 1917.

(Wikipedia, 9 Apr 2021) The **Pseudomonadaceae** are a family of bacteria which includes the genera Azomonas, Azorhizophilus, Azotobacter, Mesophilobacter, Pseudomonas (the type genus), and Rugamonas. The family Azotobacteraceae was recently reclassified into this family.

Distinguishing characteristics: Oxidase positive – due to the presence of the enzyme cytochrome c oxidase; nonfermentative; many metabolize glucose by the Entner Doudoroff pathway mediated by 6-phosphoglyceraldehyde dehydrogenase and aldolase; polar flagella, enabling motility; and many members produce derivatives of the fluorescent pigment pyoverdin.

The presence of oxidase and polar flagella and inability to carry out fermentation differentiate pseudomonads from the Enterobacteriaceae.

The following species have been reported to cause diseases, produce a toxin, inhibit germination, or affect seed quality.

- C1.1.1 *Pseudomonas* spp.
- C1.1.1a *Pseudomonas syringae*

- C1.1.1b *Pseudomonas syringae* pv. *sesami* (*Syn: *Bacterium sesami, B. sesamicola, Phytomonas sesami, Phytomonas sesamicola,* and *Pseudomonas sesami*)

References:

UNITED STATES

- M. Fay et al. (2021) reported metagenomic analysis of food is becoming more routine and can provide important information pertaining to the shelf life potential and the safety of these products. They examined 10 sesame samples and identified Pseudomonadaceae.

C1.1.1 *Pseudomonas* spp. (9 Apr 2021)

There are *Pseudomonas* species that damage sesame (C1.1.1) and species that are help sesame (F1.1.1).

Family: Pseudomonadaceae

Definition: Amount of tolerance to *Pseudomonas* spp. Migula 1894 emend. Yang et al. 2013.

Summary:

Effect on leaves

Effect on stems and capsules

Photos: S.S. Firdous et al. (2014) {Pakistan}

Pseudomonas syringae* pv. *sesami (Synonyms: *Pseudomonas sesami, Bacterium sesami, Bacterium sesamicola, Phytomonas sesami,* and *Phytomonas sesamicola*) is a major disease with worldwide distribution and probably is the major cause of yield loss whenever it occurs in sesame plantings. It is most damaging under conditions of high rainfall or where high humidity persists for long periods, which are favorable for pathogen spread. Symptoms are light-brown, angular spots, with a darker, more purple margin. Spots may be water soaked initially and become drier as the infection progresses, though water-soaking may not be apparent if conditions become less humid. Spots are generally located between leaf veins, but may advance along the veins and petioles, when they become dark-brown to purple lesions with a shiny appearance. The spots themselves small, but often coalesce to form large necrotic areas on leaves. These later desiccate and disintegrate, giving the leaf a tattered appearance. Spots of the capsules are usually slightly sunken, shiny and purplish-brown in color. The bacteria are internally and externally seedborne and can persist in debris in the field. Wind and rain spread the pathogen. Collection and burning of infected plant debris after harvest and before ploughing will help control the spread in future years. However, the preferred method is to develop tolerant varieties. It has been suggested there is a relationship between *Pseudomonas sesami* and *Xanthomonas sesami*. Additional molecular analysis in the future may provide more insight to the relationship of pathogenic and epiphytic Pseudomonads of sesame and other hosts, as well as relationships with *Xanthomonas* pathogenic to sesame. The pathogen has been reported in international lists, Australia, Brazil, Bulgaria, Burkina Faso, China, Cuba, Ethiopia, Greece, Guatemala, India, Japan, Kenya, Macedonia, Malawi, Mexico, Myanmar, Nigeria, Pakistan, Paraguay, Republic of Korea, Somalia, Sudan, Tanzania, Thailand, Turkey, United States, and Venezuela.

(Wikipedia, 9 Apr 2021) ***Pseudomonas*** is a genus of Gram-negative[1], Gammaproteobacteria, belonging to the family Pseudomonadaceae and containing 191 validly described species. The members of the genus demonstrate a great deal of metabolic diversity and consequently are able to colonize a wide range of niches. Their ease of culture *in vitro* and availability of an increasing number of *Pseudomonas* strain genome sequences has made the genus an excellent focus for scientific research.

Because of their widespread occurrence in water and plant seeds such as dicots, the pseudomonads were observed early in the history of microbiology. The generic name *Pseudomonas* created for these organisms was defined in

[1] **Gram-negative:** Gram-negative bacteria do not retain the crystal violet stain used in the Gram staining method of bacterial differentiation into two broad categories according to their type of cell wall.

rather vague terms by Walter Migula in 1894 and 1900 as a genus of Gram-negative, rod-shaped, and polar-flagellated bacteria with some sporulating species, the latter statement was later proved incorrect and was due to refractive granules of reserve materials.

Members of the genus display these defining characteristics: Rod-shaped; gram-negative; flagellum one or more, providing motility; aerobic; non-spore forming; catalase-positive; and oxidase-positive.

Other characteristics that tend to be associated with *Pseudomonas* species (with some exceptions) include secretion of pyoverdine, a fluorescent yellow-green siderophore under iron-limiting conditions. Certain *Pseudomonas* species may also produce additional types of siderophore, such as pyocyanin by *Pseudomonas aeruginosa* and thioquinolobactin by *Pseudomonas fluorescens*, *Pseudomonas* species also typically give a positive result to the oxidase test, the absence of gas formation from glucose, glucose is oxidized in oxidation/fermentation test using Hugh and Leifson O/F test, beta hemolytic (on blood agar), indole negative, methyl red negative, Voges–Proskauer test negative, and citrate positive.

Pseudomonas may be the most common nucleator of ice crystals in clouds, thereby being of utmost importance to the formation of snow and rain around the world.

All species and strains of *Pseudomonas* have historically been classified as strict aerobes. Exceptions to this classification have recently been discovered in *Pseudomonas* biofilms. A significant number of cells can produce exopolysaccharides associated with biofilm formation. Secretion of exopolysaccharides such as alginate makes it difficult for pseudomonads to be phagocytosed by mammalian white blood cells. Exopolysaccharide production also contributes to surface-colonizing biofilms that are difficult to remove from food preparation surfaces. Growth of pseudomonads on spoiling foods can generate a “fruity” odor.

The following species have been associated with sesame but there are no known reports of being a pathogen, producing a toxin, inhibiting germination, affecting seed quality, or being used as a biocontrol or biofertilizer.

- *Pseudomonas amygdali* [Mexico]
- *Pseudomonas aptata* [International lists]

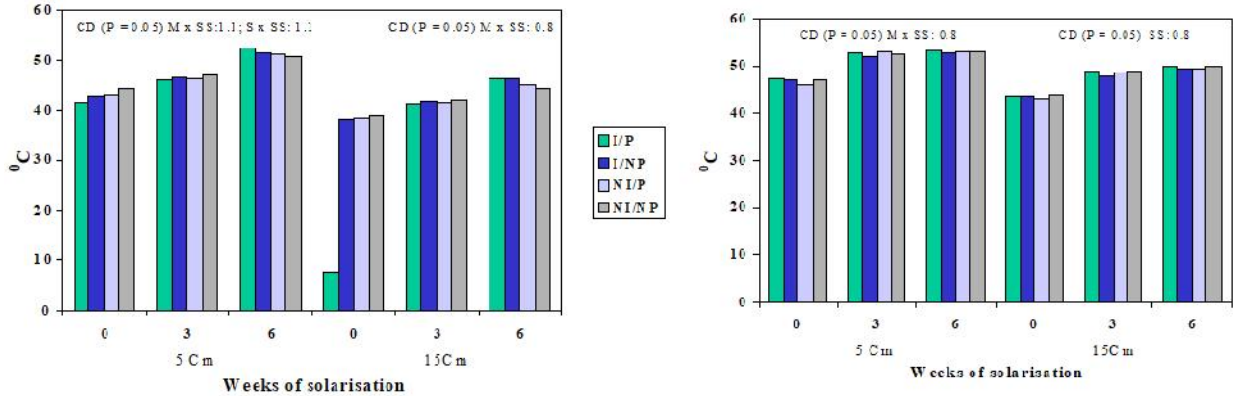
References:

ETHIOPIA

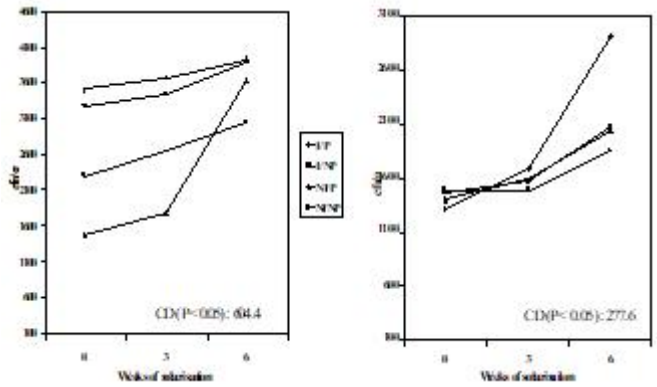
- E. Wondimagegne et al. (1986) screened 70 varieties against inoculation with *Pseudomonas* sp. Two varieties (Morada and Oro short) were tolerant, 20 were moderately affected, and 58 were strongly affected by the pathogen.

INDIA

- O.P. Kadian (1972) reported five common genera to include *Pseudomonas* sp., which reduced seed germination and had adverse effect on the seedlings. The seeds were internally as well as externally seedborne. [Cited by G.S. Saharan, 1989]
- C. Chattopadhyay and R. Kalpana Sastry (1999) studied the effect of soil solarization on the *Pseudomonas* sp. population in 1995 and 1996 in Hyderabad (77.92E and 18.99N). Plots were irrigated to field capacity according to the design before they were covered with transparent polyethylene mulch of 50 µm thickness for 0, 3, or 6 weeks. The temperatures at 5 and 15 cm depth were as follow in the two years.



The effects on the total *Pseudomonas* sp. population (cfu/g soil) were as follow.



JAPAN

- K. Kato et al. (2021) purchased seed in local markets and identified the following bacterium: *Pseudomonas* spp.

MYANMAR

- U.T. Myint (1981) reported that *Pseudomonas* sp. appears in poorly drained, wet soils.

PAKISTAN

- N. Ali and A. Beg (1985) reported *Pseudomonas* sp. (Bacterial blight) is a common and destructive disease. They recommend planting disease resistant varieties, field sanitation (crop rotation and removal of all crop residues after the harvest) and early planting.

PARAGUAY

- N. Lezcano (2006) in a grower guide reported the following pathogen: *Pseudomonas* sp.

REPUBLIC OF KOREA

- S.U. Kim (pers. comm. 2015): The following is a photo of *Pseudomonas* sp. on sesame in a greenhouse.

UNITED STATES

- J. A. Martin (1953a) and M.L. Kinman and J.A. Martin (1954) reported *Pseudomonas* sp. in the U.S. The development is favored by excessive rainfall and high humidity. They felt that the causal organisms are seedborne and may be controlled by the use of disease free seed or by seed treatments. They found that Early Russian was highly resistant. Widespread disease in 1952 allowed evaluation of resistance and several lines were selected in this respect.
- C.A. Thomas (1956) reported that seed of Palmetto sesame soaked for 30 minutes in solutions of 250, 500, 750, and 1000 ppm streptomycin were free from *Pseudomonas* sp. in comparison to untreated ones. Concentrations higher that 500 ppm reduced the rate of seedling growth under certain conditions.
- D.R. Langham (1998e) reported that Sesaco took notes in most years on *"37e. Leaf diseases*. A problem in cool years, but generally does not affect yield." [The leaf disease was considered to be *Pseudomonas* sp.; however, samples were never submitted to a lab for confirmation.]
- D.T. Smith et al. (2000) reported the following pathogen: *Pseudomonas* sp. did not cause yield loss but could be a problem in periods of high rainfall. Leafspot organisms cause spotting on leaves and progresses to destroy leaf tissue.
- D.R. Langham et al. (2010c) reported an unidentified leaf disease (probably Pseudomonas) has appeared in several years when there are cloudy damp cool days, but the plants have grown out of the problem when sunny days return. Normally, there has been little to no economic damage encountered.

- K.A. Cochran comments, 2021: The disease symptoms caused by this pathogen can be difficult to differentiate from other pathogens, such as *Xanthomonas* spp. Thus, many prefer to just call these 'Bacterial leaf spot.' Bacterial diseases of sesame are poorly documented. Molecular analysis, which is currently much more affordable than even 5-10 years ago, is needed to better reveal true identity of many pathogenic isolates isolated from sesame. I would not be surprised if new pathovars or species are implicated in causing disease in the coming years. These bacteria gain entry primarily via wounds or natural openings (i.e., stomata). Reducing the load of sap feeding insects will help reduce the total number of injuries to the plant tissues by reducing the number of openings.


These photos illustrate the difficulty in identifying the pathogen. In the field, the pathogen appeared to be Pseudomonas, but after culturing the bacteria, I determined they were Xanthomonas.

- M. Fay et al. (2021) reported metagenomic analysis of food is becoming more routine and can provide important information pertaining to the shelf life potential and the safety of these products. They examined 10 sesame samples and identified *Pseudomonas* sp.

VENEZUELA

- B. Mazzani (1981a) reported *Pseudomonas* sp. (Leaf spot) is one of the major diseases.

C1.1.1a *Pseudomonas syringae* (9 Apr 2021)

Family: Pseudomonadaceae

Definition: Amount of tolerance to *Pseudomonas syringae* Van Hall 1902.

(Wikipedia, 9 Apr 2021) ***Pseudomonas syringae*** is a rod-shaped, Gram-negative bacterium with polar flagella. As a plant pathogen, it can infect a wide range of species, and exists as over 50 different pathovars, all of which are available to researchers from international culture collections such as the NCPPB, ICMP, and others.

Pseudomonas syringae is a member of the genus *Pseudomonas*, and based on 16S rRNA analysis, it has been placed in the *P. syringae* group. It is named after the lilac tree (*Syringa vulgaris*), from which it was first isolated.

A phylogenomic analysis of 494 complete genomes from the entire *Pseudomonas* genus showed that *P. syringae* does not form a monophyletic species in the strict sense, but a wider evolutionary group that also included other species as well, such as *Pseudomonas avellanae, Pseudomonas savastanoi, Pseudomonas amygdali*, and *Pseudomonas cerasi*.

Pseudomonas syringae tests negative for arginine dihydrolase and oxidase activity, and forms the polymer levan on sucrose nutrient agar. Many, but not all, strains secrete the lipodepsinonapeptide plant toxin syringomycin, and it owes its yellow fluorescent appearance when cultured *in vitro* on King's B medium to production of the siderophore pyoverdin.

Pseudomonas syringae also produces ice nucleation active (INA) proteins which cause water (in plants) to freeze at fairly high temperatures (−1.8 to −3.8°C (28.8 to 25.2°F)), resulting in injury. Since the 1970s, *P. syringae* has been implicated as an atmospheric "biological ice nucleator", with airborne bacteria serving as cloud condensation nuclei. Recent evidence has suggested the species plays a larger role than previously thought in producing rain and snow. They have also been found in the cores of hailstones, aiding in bioprecipitation. These INA proteins are also used in making artificial snow.

Pseudomonas syringae pathogenesis is dependent on effector proteins secreted into the plant cell by the bacterial type III secretion system. Nearly 60 different type III effector families encoded by *hop* genes have been identified in *P. syringae*. Type III effectors contribute to pathogenesis chiefly through their role in suppressing plant defense.

Owing to early availability of the genome sequence for three *P. syringae* strains and the ability of selected strains to cause disease on well-characterized host plants, including *Arabidopsis thaliana*, *Nicotiana benthamiana*, and the tomato, *P. syringae* has come to represent an important model system for experimental characterization of the molecular dynamics of plant-pathogen interactions.

Pseudomonas syringae overwinters on infected plant tissues such as regions of necrosis or gummosis (sap oozing from wounds on the tree) but can also overwinter in healthy looking plant tissues. In the spring, water from rain or other sources will wash the bacteria onto leaves/blossoms where it will grow and survive throughout the summer. This is the epiphyte phase of *P. syringae's* life cycle where it will multiply and spread but will not cause a disease. Once it enters the plant through a leaf's stomata or necrotic spots on either leaves or woody tissue then the disease will start. The pathogen will then exploit and grow in intercellular space causing the leaf spots and cankers. *P. syringae* can also survive in temperatures slightly below freezing. These below freezing temperatures increase the severity of infection within trees like sour cherry, apricot, and peach.

Diseases caused by *P. syringae* tend to be favored by wet, cool conditions – optimum temperatures for disease tend to be around 12–25 °C (54–77 °F), although this can vary according to the pathovar involved. The bacteria tend to be seedborne and are dispersed between plants by rain splash.

Although it is a plant pathogen, it can also live as a saprotroph in the phyllosphere when conditions are not favorable for disease. Some saprotrophic strains of *P. syringae* have been used as biocontrol agents against postharvest rots.

Planktonic *P. syringae* is able to enter plants using its flagella and pili to swim towards a target host. It enters the plant via wounds of natural opening sites, as it is not able to breach the plant cell wall. An example of this is the partnership with the leaf-mining fly *Scaptomyza flava*, which creates holes in leaves during oviposition that the pathogen can take advantage of. The role of taxis in *P. syringae* has not been well-studied, but the bacteria are thought to use chemical signals released by the plant to find their host and cause infection.

Pseudomonas syringae isolates carry a range of virulence factors called type III secretion system (T3SS) effector proteins. These proteins primarily function to cause disease symptoms and manipulate the host's immune response to facilitate infection. The major family of T3SS effectors in *P. syringae* is the *hrp* gene cluster, coding for the Hrp secretion apparatus.

The pathogens also produce phytotoxins which injure the plant and can suppress the host immune system. One such phytotoxin is coronatine, found in pathovars *Pto* and *Pgl*.

Pseudomonas syringae produces polysaccharides which allow it to adhere to the surface of plant cells. It also releases quorum sensing molecules, which allows it to sense the presence of other bacterial cells nearby. If these molecules pass a threshold level, the bacteria change their pattern of gene expression to form a biofilm and begin expression of virulence-related genes. The bacteria secrete highly viscous compounds such as polysaccharides and DNA to create a protective environment in which to grow.

Pseudomonas syringae (more than any mineral or other organism) is responsible for the surface frost damage in plants exposed to the environment. For plants without antifreeze proteins, frost damage usually occurs between -4 and -12 °C as the water in plant tissue can remain in a supercooled liquid state. *P. syringae* can cause water to freeze at temperatures as high as −1.8 °C (28.8 °F), but strains causing ice nucleation at lower temperatures (down to −8 °C) are more common. The freezing causes injuries in the epithelia and makes the nutrients in the underlying plant tissues available to the bacteria.

Pseudomonas syringae has *ina* (ice nucleation-active) genes that make INA proteins which translocate to the outer bacterial membrane on the surface of the bacteria, where the proteins act as nuclei for ice formation. Artificial strains of *P. syringae* known as ice-minus bacteria have been created to reduce frost damage.

Pseudomonas syringae has been found in the center of hailstones, suggesting the bacterium may play a role in Earth's hydrological cycle.

References:

MEXICO

- Agrolytics.org (2021) reported sesame hosts *Pseudomonas syringae.*

PARAGUAY

- L. Ayala et al. (2010, 2011, and 2013b) in grower guides reported the following pathogen: *Pseudomonas syringae*.


C1.1.1b *Pseudomonas syringae* pv. *sesami* (9 Apr 2021)

Synonyms: *Pseudomonas sesami, Bacterium sesami, Bacterium sesamicola, Phytomonas sesami,* and *Phytomonas sesamicola.*

Family: Pseudomonadaceae

Definition: Amount of tolerance to *Pseudomonas syringae* pv. *sesami* (Malkoff) Young, Dye & Wilkie.

(Anon. n.d.k) Bacterial leaf spot – *Pseudomonas sesami*

Symptoms: The disease appears as water-soaked yellow specks on the upper surface of the leaves. They enlarge and become angular as restricted by veins and veinlets. The color of spot may be dark brown with shiny oozes of bacterial masses.

Pathogen: The bacterium is gram negative aerobic rod with one or more polar flagella.

Disease cycle: The bacterium remains viable in the infected plant tissues. It is internally seedborne and secondary spread through rain splash and storms.

Management: Keep the field free of infected plant debris; spray with Streptomycin sulphate or oxytetracycline hydrochloride or streptocyclin at 100g/ha.

References:

INTERNATIONAL

- Anon. (1911) reported sesame has few diseases, but two have been identified as *Pseudomonas sesami* and *Bacillus sesami*. The occurrence of disease is made evident by the wilting of the plants, followed by their destruction. Moist soil favors the development of the disease.
- J.R. Morschel (1964) reported the following pathogen in the world: *Pseudomonas sesami* (Wilt), which is seedborne. [Cited by D.F. Beech. 1995a]
- R.S. Vasudeva (1961) reported *Pseudomonas sesami* might appear at any stage of growth. The first symptoms may appear when the plant is 1-1.5 cm. The infection spreads from the petiole to the leaf blade where angular, vein-limited brown spots, with dark margins and covered with exudate on the undersurface, make their appearance. The severely infected leaves gradually fall off. In the advanced stages of growth, the girdling of the stem leads to the collapse of the whole plant. The cortical tissue is completely disorganized and in cases of severe infection even the vascular bundles are disrupted.
- E.A. Weiss (1971) reported *Pseudomonas sesami* is a major disease with worldwide distribution, and probably is the major cause of yield loss whenever it occurs in sesame plantings. It is most damaging under conditions of

high rainfall or where high humidity persists for long periods. Symptoms are light-brown, dryish, angular spots, with a darker, more purple margin. They are generally located between leaf veins, but may advance along the veins and petioles, when they become dark-brown to purple lesions with a shiny appearance. The spots themselves small, but often coalesce to form large necrotic areas on leaves. These later desiccate and disintegrate, giving the leaf a tattered appearance. Spots of the capsules are usually slightly sunken, shiny and purplish in color. The bacteria are seedborne. Collection and burning of infected plant debris after harvest and before ploughing will help control the spread in future years. However, the preferred method is to develop tolerant varieties as has been done in the United States, Sudan, and Tanzania. It has been suggested there is a relationship between *Pseudomonas sesami* and *Xanthomonas sesami*.

- C. Wescott (1971) reported the following pathogen: bacterial leaf spot (*Pseudomonas sesami*).
- P. Neergaard (1979) reported the following pathogen caused a disease in sesame: *Pseudomonas sesami*. [Cited by G.S. Saharan, 1989]
- M.O. Khidir (1981a) in a review of sesame in East Africa and the Near East reported the following disease was a problem: *Pseudomonas sesami*.
- Anon. (2004a) IPGRI descriptor: 10.3.1. Biotic stress susceptibility to *Pseudomonas sesami.*
  - In each case it is important to state the origin of the infestation or infection, i.e., natural, field inoculation, or laboratory. Also specify the causal organism and the corresponding symptoms. The susceptibility scale is as follows:
    - 1 = Very low or no visible sign of susceptibility
    - 3 = Low
    - 5 = Intermediate
    - 7 = High
    - 9 = Very high
  - The growth state, coded according to the list below at which each reaction was recorded should be appended to the record of that reaction.
    - 1 = Seed
    - 2 = Seedling
    - 3 = Pre-flowering
    - 4 = Early flowering
    - 5 = Mid-flowering
    - 6 = Late-flowering
    - 7 = Maturity
- CAB International (accessed 12 Apr 2021) reported sesame was a major host of *Pseudomonas syringae pv. sesami* (Bacterial: sesame leaf spot)
- N. Ransingh et al. (2021) reported the following symptoms of *Pseudomonas syringae* pv. *sesami* (Bacterial leaf spot): A water-soaked spot develops on the undersurface of the leaf initially which gradually spreads to the upper surface. These spots increase in size to become angular due to restrictions by the veins. These dark brown spots coalesce together to form irregular brown patches causing dry leaves. The reddish-brown lesions may also appear on petioles and stem.

  The bacterium survives in infected plant tissues. The pathogen is internally seedborne. The disease spreads through rain splash. As the pathogen survives in soil, keeping the field free from infected plant debris is the first step towards disease management. Planting seeds should be collected from a healthy source. Use of resistant variety can be a better option

  Due to internal seedborne nature pathogen, seed may be treated with hot water at 52°C for 10 minutes. Seed can also be treated with various chemicals before sowing. Seed should be dipped in Agrimycin 100 (250 ppm) or streptocycline suspension (250 ppm) for 30 minutes before sowing. Spraying of Streptomycin sulfate or Oxytetracycline hydrochloride at the rate of 100 g/ha twice at 15 days interval effectively manage the disease.

AUSTRALIA

- D.F. Beech (1981c) reported the presence *Pseudomonas sesami* (Bacterial leaf spot). Considerable progress has been made in developing resistance through Early Russian.

BRAZIL

- A.L.G. Pereira (1967) reported *Pseudomonas sesami* attacks many varieties, where it was first noted in 1942.

BULGARIA

- K. Malkoff (1903 and 1906) was the first to describe *Pseudomonas* (Bacterium) *sesami.* [Cited by G.S. Saharan, 1989]
- B. Ivanoff (1926) reported *Bacillus sesami* Malk. Was found in two localities attacking the leaves and stems of sesame. A thick, gummy, rapidly drying substance exuded from the surface of the black spots formed by the organism of the stems, usually breaking down at the point attacked. [Cited by G.S. Saharan, 1989] [Authors comment: see I.C. Kovacevski (1930) below.]
- I.C. Kovacevski (1930) studied of the bacterial disease of sesame which was first recorded and described from Bulgaria under the name 'black rot' by Malkoff in 1903 and was attributed by him to *Pseudomonas* (*Bacterium*) *sesami* and *Bacillus sesami*, either singly or in combination. Inoculation experiments in 1929 showed, however, *Bacillus sesami* is not pathogenic to sesame seedlings. Malkoff 's results being explained by the fact that as indicated by his own description, he worked with isolations the purity of which was questionable. *Bacterium sesami* on the other hand reproduced all the symptoms observed in nature, which are also described this proving it to be the real cause of the disease. [Cited by G.S. Saharan, 1989]
- S.G. Delikostadinov (1985) reported Sadovo 1 to 6 are resistant to bacteriosis (*Pseudomonas sesami* Malk.) and this resistance has been incorporated into all breeding materials.

BURKINA FASO

- M.M. Satour (1981) reported the presence of *Pseudomonas sesami* (Leafspot).

CHINA

- L.C. Tu (1985b) reported *Pseudomonas sesami* (Leaf spot) in Henan with a damage level of 1 out of a possible 3.
- L.L. Li (1988) reported *Pseudomonas sesami* (Angular leaf spot) cause major damage to sesame. Bacterial angular leaf spot of sesame first appears after the rain in July and largely in the second or last ten days of August. The disease is serious in the rainy year, thus getting a large number of fallen leaves. The bacteria mainly infect not only leaves, but also petiole and stems. Symptoms primarily appear on leaves as water-soaked spots, and then as black-brown polyangular spots of 2-8 mm, and the spots can be easily perforated. The very high moisture, bacterial ooze from the black-brown spots spreads along a black-brown streak. In dry weather, the diseased leaves are malformed, and they easily fall off. The bacteria over winter on the affected leaves refuse and seeds. The optimum temperature for the bacterial growth is 30°C. The disease is spread by wind and rain. Rainfall is favorable for the occurrence of the severe disease. Seed treatment with 0.1% Mercuric chloride or 0.5% Copper sulphate or hot water (48-53°C) is effective for the control of the disease. Spray application of Bordeaux mixture or Copper sulphate (0.1%) is reported to give 80 to 90% degree of control of the disease at beginning of July. Crop rotation is also an effective method of control.
- H.M. Miao and H.Y. Liu (2010) reported the following pathogen: *Pseudomonas syringae* pv. *sesami.*

CUBA

- La Habana (2009) in a grower guide reported the following pathogen: *Pseudomonas sesami*.

ETHIOPIA

- A.O. Omran et al. (1985) reported variety E is moderately resistant to *Pseudomonas sesami.* On a scale of 9, it scored 1.5 to 2 in all locations.
- A.P. Korobko and E. Wondimagegne (1987) reported severe infections of *Xanthomonas campestris* pv. *sesami* and *Pseudomonas syringae* pv. *sesami*. *Erwinia herbicola* was often associated with the above pathogens. Stem rotting was caused by *Erwinia* sp. [Cited by G.S. Saharan, 1989]
- T. Geremew et al. (1992, 2009, and 2012) reported the following diseases are a major problem: *Pseudomonas sesami* (Blight). It is reported to be damaging under conditions of high rainfall and where high humidity persists for long periods, and less damaging when sesame is grown in more arid areas under furrow irrigation (but when flood-irrigated standing water can encourage the spread of the disease). *Xanthomonas sesami* and *Pseudomonas sesami*) may occur together or separately and can cause considerable yield reduction or complete crop failure in years of favorable conditions for disease development. Sesame blight incidence was reported to vary from 25 to 99% with severity (1-9 score) ranging from 4 to 9.
- B.K Yirga and B. Fiseha (2017a) reported the following pathogen: *Pseudomonas syringae* pv. *sesami* (Bacterial leaf spot).

GREECE

- S.D. Demetriades et al. (1959) reported the first record of *Pseudomonas sesami* on sesame in Greece. [Cited by G.S. Saharan]
- D.G. Zachos and C.G. Panagopoulus (1960) reported Bacterial leaf spot (*Pseudomonas sesami*) of sesame for first time in Greece was found in several districts in summer of 1959.

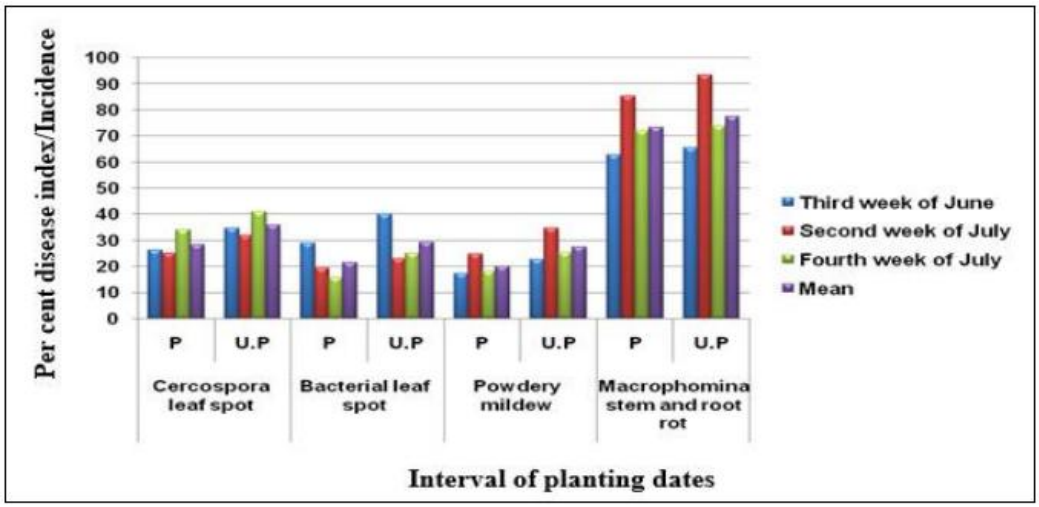
GUATEMALA

- Anon (1982a) A grower guide reported *Pseudomonas sesami* Malk. (Mancha bacterial de la hoja) attacks the foliage.

INDIA

- J.C. Durgapal and Y.P. Rao (1967) reported *Pseudomonas sesami*. The disease was observed when the plants were 5-6 weeks old. Affected leaves showed dark brown to black, vein-limited, angular spots with 1 cm diameter. Some spots merged together covering larger areas or even the entire leaf. Badly diseased leaves soon dried up and were shed. The disease spread to the stem and with severe stem infection, the plants died.
- J.C. Durgapal et al. (1969a) screened 119 genotypes (70 indigenous and 49 exotic) for tolerance to *Pseudomonas sesami*. In the field, when the seedlings were 35 days old, a few lines showed dark brown to black angular spots on leaves due to inoculum from infected seeds. After the appearance, the disease spread very rapidly, and towards the end of the season it was distributed throughout the field. Lines that showed resistance in the field were inoculated in the greenhouse. Of 9 moderately resistant in the field, 6 were moderately resistant in the greenhouse. At the end, only 1 line was considered resistant (Almora local white) while 11 were classified as moderately resistant.
- J.C. Durgapal et al. (1969b) evaluated 3 methods (I: seeds were treated with hot water at 51-52°C for 10 minutes; II: soaked in a missed solution of Agrimycin-100 (0.025%) and Wettable Ceresan (0.05%) for 6 hours; III: surface sterilization for 2 minutes with mercuric chloride (0.1%) followed by washing with sterile distilled water) to control *Pseudomonas sesami*. Methods I and II controlled the disease.
- R.N. Singh (1970) reported both the bacterial leaf spot (*Pseudomonas sesami*) and leaf blight (*Xanthomonas sesami*) pathogens of sesamum failed to survive in debris for more than 45 days in sterilized soil and 7 days in unsterilized soil. The pathogens in the seed were eradicated by treating seed in hot water at 52°C for 10 minutes or by soaking the seeds in a mixed solution of Acrimycin-100 (0.025%) and wet Ceresan (0.05%) at room temperature for 9 hr. Secondary infections in the field were prevented by spraying Streptocycline (0.3 gm in 2.5 gallons of water) as a prophylactic measure on 25 days old seedling followed by 3 more applications at an interval of 15 days.
- S. Maiti et al. (1985) reported bacterial leaf spot, *Pseudomonas syringae* pv. *sesami* causes considerable yield reduction whenever it infects the sesamum crop.
- M.L. Verma (1985) reported *Pseudomonas sesami* (Bacterial leaf spot – Black rot) is a major disease with the following symptoms: Initiates from petiole and spreads to leaf blade as small angular, black to brown spots with dark margin along the veins, spots covered with bacterial exudate on upper side. Defoliation, girdling of stem.
- O.P. Verma and L.N. Daftari (1976a) reported that seed soaking with agrimycin completely checked the infection of *Pseudomonas sesami* and enhanced germination by 94% in comparison with no germination in untreated seeds. In *in vitro* studies streptomycin sulphate was the most effective followed by streptocycline, agrimycin-100, tetracycline hydrochloride and oxytetracyline hydrochloride. [Cited by M.L. Verma, 1985, and G.S. Saharan, 1989]
- R.M. Vajavat and B.P. Chakravarti (1977) reported field experiments indicated that *Pseudomonas sesami* caused 21.1% loss in yield in a local susceptible sesame cv. During 1972 and 27.1% loss in 1973.
- Anon (1992a) in a grower guide reported *Pseudomonas syringae* pv. *sesami* (Bacterial leaf blight) appears from the seedling stage to maturity. Brown spots appear on the leaf which are angular in shape. The margins of such spots are black in color. Under favorable conditions these spots coalesce and ultimately defoliation occurs.
- K.N. Gupta et al. (2018) reported *Pseudomonas syringe* pv. *sesami* (Bacterial leaf spot) causes light brown angular spots with dark purple margin in the leaf veins. It may be alleviated by spraying Agrimycin 100 (250 ppm), Cupervit 50 (0.5%), or Difolatan 80 (0.16%) 3 times as and when disease appear at 15 days intervals.
- M.G. Palakshappa et al. (2020b) evaluated the date of planting (3rd week of June, 2nd week of July, and 4th week of July) on diseases from 2014 to 2017 at Dharwad, Karnataka (15.46N 75.01E). The main constraint for the low productivity of this crop is due to severe outbreak of various fungal stem and root rot of sesame (*Macrophomina phaseolina*), Alternaria leaf spot (*Alternaria sesami*), Powdery mildew (*Leveillula taurica*), Cercospora leaf spot (*Cercospora sesamicola*), Bacterial leaf spot (*Pseudomonas syringae* pv. *sesam*i), viral and phytoplasma diseases. The control (Protected – P) used fungicides viz., Carbendazim @ 0.1% and combi

product (Tebuconazole 50% + Trifloxistrobin 25% WG) @ 0.05% were sprayed at 15 days intervals and the Unprotected – UP did not use fungicides. The disease indices were as follow.



The effects on yield were as follow.

Planting intervals	Yield q/ha								Mean yield q/ha	
	Kharif- 2014		*Kharif*- 2015		*Kharif* -2016		*Kharif*- 2017			
	P	UP	P	UP	P	UP	P	UP	P	UP
Third week of June	11.80	4.30	9.70	5.75	5.45	4.62	5.40	3.04	8.08	4.42
Second week of July	7.00	2.60	7.10	4.00	6.89	3.64	2.69	1.86	5.92	3.02
Fourth week of July	4.10	1.30	4.40	3.35	1.12	0.47	1.92	0.62	2.88	1.44
Mean	7.63	2.73	7.06	5.03	4.48	3.57	3.33	1.84	5.62	3.29

Third week of June sowing Second week of July sowing Fourth week of July sowing

- Anon. (n.d.k) reported *Pseudomonas sesami* (Bacterial leaf spot) causes a major disease.

JAPAN

- K. Nakata (1930) investigated the relationships between three bacteria recorded as the causal organisms of sesame diseases viz, *Bacterium sesami*, *Bacterium solanacearum* and *Bacterium sesamicola*. The results of comparative studies of the morphology, cultural characters and physiological feature of three bacteria indicated that *Bacterium sesami* and *Bacterium sesamicola* are identical but are distinct from *Bacterium solanacearum*. The correct name of former is considered to be Bacterium sesami. Malkoff; synonyms *Pseudomonas sesami* Malk; *Bacterium sesamicola* Takimoto. *Bacterium sesami* causes formation of dark brown spots on sesame leaves and stem in Bulgaria, India, Japan, and Korea. [Cited by G.S. Saharan, 1989]
- T. Kuzuyuki (2021) cited the following pathogen *Pseudomonas syringae* pv. *sesami* and *Bacterium sesamicola* are listed in the Database of Plant Diseases in Japan.

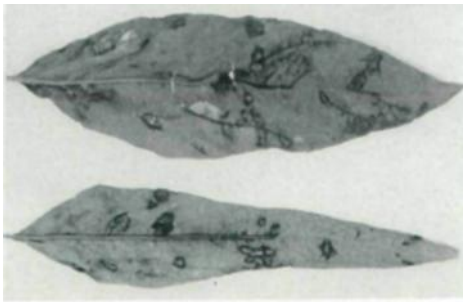
KENYA

- H.A. Van Rheenen (1981d) reported the goal of developing resistance to *Pseudomonas sesami.*

MACEDONIA

- D. Sutic and W.J. Dowson (1962) reported *Pseudomonas sesami* in Gevgelija in 1959. The disease manifested itself on all parts of the plant above ground, in the form of larger or smaller blackish spots. The spots may

appear over the whole length of the stem; frequently they coalesce into large areas, which can be several cm long. The spots may develop over the whole area of the leaves; they are bordered by the veins, giving them a distinct angular form. The disease may also develop on the capsules, which turn black when infected early. The diseased plants may die if seriously infected, causing a total loss of yield.



MALAWI

- W. Van Den Bos and C.J. Zee (2016) in a grower guide reported the following: *Xanthomonas sesami* and *Pseudomonas sesami.* Both pathogens may occur together or separately and can cause complete crop failure in years of favorable conditions for disease development. Bacterial blight incidence and severity varies depending on topography, altitude, and weather conditions. Water logging encourages the spread of the disease. For control, use of clean seed, residue removal, burning, deep ploughing, and crop rotation may control blight incidence. So far, no Bacterial blight tolerant varieties are available in Malawi.

MEXICO

- M.M. Satour (1981) reported the presence of *Pseudomonas sesami* (Leafspot).
- I. Torres (1985) reported that *Pseudomonas sesami* affected the Mexican crop and reduces yields.
- J.R. Penaloza and D.R. Moctezuma (~1992) in a grower guide reported: *Pseudomonas sesami.*
- E.C. Hernandez (2003) in a grower guide reported the following pathogen: *Pseudomonas sesami* (Bacteriosis). Symptoms are dark brown, almost black, spots. Use resistant tolerant varieties. Top seed, and appropriate row spacing.

NIGERIA

- H.A. Van Rheenen (1972) reported the leaf pathogen *Pseudomonas sesami* had the following symptoms: Angular, dark brown to black spots develop on the leaves and marginal necrosis occurs. The individual lesions coalesce, and the necrotic area rapidly spreads down the leaf blade to the petiole form which discolored streaks may be seen passing down the stem and causing rotting and lodging.

PAKISTAN

- M.A. Akhtar (1985) reported a record of *Pseudomonas syringae* pv. *sesami* (Bacterial blight).
- S. Bashir et al. (2007) studied the role of *Pseudomonas syringae* pv. *sesami* (P) and *Xanthomonas campestris* pv. *sesami* (X), alone and combination, in symptoms development of bacterial blight in sesame. Highest leaf infection of 80.6 % occurred in plants inoculated with both the pathogens together as compared to individual inoculations (P = 75.6% and X = 50%). The control plants remained asymptomatic and continued to grow healthier. Significant variability among the two pathogens was noted on defoliation (5%) and stem infection (47.16%) respectively, in case of combined inoculation as against 38 % and 36.66 % in individual inoculations. Responses in stem infection were similar, although in some cases stem tended to be more susceptible. Highest stem infection (47.16%) was observed for P+X, followed by X and P inoculations showing 43.16 and 26.66% infections, respectively. Disease progress was initially slow, and the plants treated with P and X developed small chlorotic and necrotic areas, but it was severe after two weeks when mixture of P+X was used as inoculum. Initially necrotic spots produced by P were small in size (1-3 mm in length) as compared to by X (2-4mm in length) but after 4 weeks of inoculation, the necrotic spots coalesced and caused defoliation in both cases. [Authors comment: the text data and figures conflict. Took the data from the abstract.]
- S.S. Firdous et al. (2009b) conducted a histological study to elucidate the mode of infection of the causal bacterium *Pseudomonas syringae* pv. *sesami* by incubating leaves or discs in bacterial suspension and by infiltration methods. Infected leaves were cleared in lactophenol: ethanol solution. Periodic histology of cleared inoculated discs from infected leaves showed that bacterial cells resided and multiplied in depressions and around trichome bases for 24 h before penetration through stomata and trichome basal cells. When pinpoint-sized spots first appeared at 3 days after inoculation, chloroplast membrane was damaged at this stage. With the

early appearance of small necrotic spot symptoms at 4 days after inoculation, the bacterium was detected in parenchymatous tissues and apparently moved from parenchymatous tissues to transverse vascular systems. This systematic infection process in sesame indicated the involvement of any secondary metabolites. With the appearance of typical leaf spot symptoms comprised of brown lesions 5 to 6 days after inoculation, no further histopathological changes were observed using infected cleared disc technique. Bacterial infection was confirmed in tolerant and susceptible genotypes by both methods, and it was shown that mode of infection in two genotypes was same, but infection was delayed in tolerant genotype.

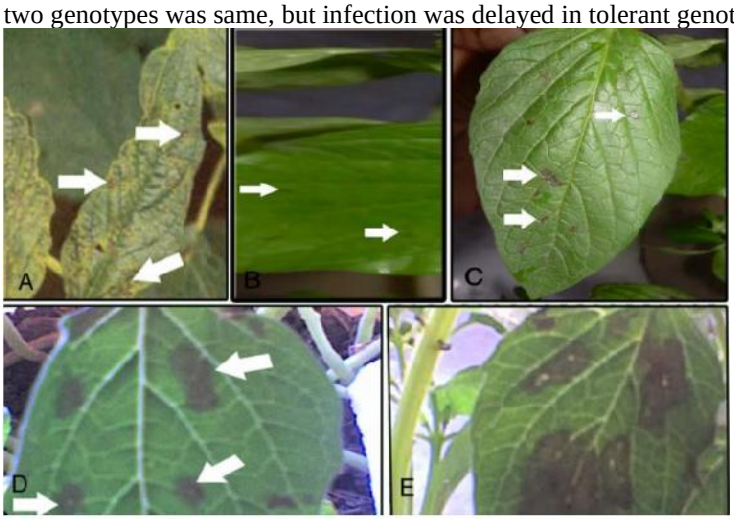
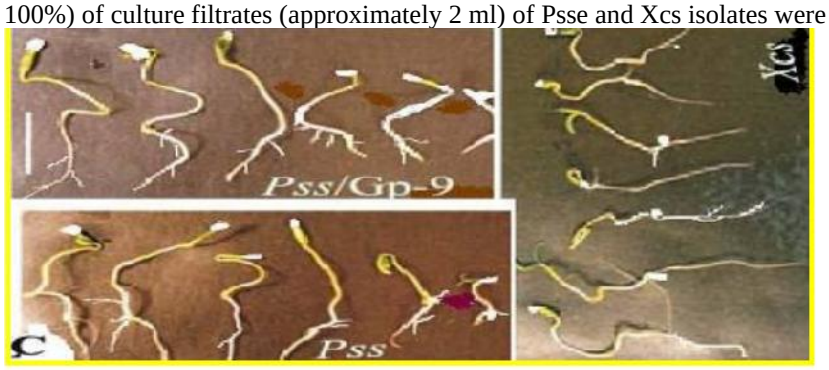


Fig. 3. Symptoms of leaf spot of sesame. A. Typical symptoms of leaf spot composed of light brown angular spots with dark purple margin B. Early symptoms of leaf spot, Pin-point-sized dots on sesame leave (arrows). Dots expand and become small brown and purple spots as the disease progresses. C Lesion enlarged with spots surrounded by purple margins. D&E. In the late stage of infection, the lesions elongated very rapidly toward the leaf tips turned blackish and purplish symptoms developed.

- S.S. Firdous et al. (2013) used different bioassays to detect secondary metabolites produced by *Pseudomonas syringae* pv. *sesami* (Psse) and *Xanthomonas campestris* pv. *sesami* (Xcs) virulent isolates. The bioassays were antibacterial activity, phytotoxic activity, potato tuber outgrowth and seedling assay that included qualitative, semi quantitative and quantitative. In qualitative assay, phytotoxic activity of cell free culture filtrates of Psse-1, Psse-2and IBD-1 of Xcs isolates were applied on non-host plant brinjal and host sesame leaves, and symptoms were observed. Psse-2 isolate elicited water soaking and chlorosis symptoms on both tested plants as produced by pathogen, while Psse-1 showed only water soaking and necrosis symptoms. Psse-2 isolate only induced hypertrophy outgrowth in potato tuber discs, neither Psse-1 nor IBD-1 isolate induces this outgrowth on potato tuber discs. Antibacterial activity was also checked against three pathogenic bacteria such as *Salmonella* sp., *Pseudomonas* sp., and an unknown bacterial pathogen. Results showed that Psse-1 and Xcs isolate showed inhibition zones against only unknown bacterial pathogen, but Psse-2 isolate did not exhibit any such zones against the tested bacterial pathogens. Moreover, biological effects of different concentrations of culture filtrates of Psse and Xcs isolates on sesame susceptible and resistant seedlings showed that all tested culture filtrates illustrated sesame root and shoot inhibition, while the inhibition recorded was more against Psse-2 isolate culture filtrate than others. Xcs and Psse-1 showed less inhibition and effective at 70 and 100% concentrations. Over all inhibition was less in tolerant than susceptible genotypes. Present results showed that Psse isolates produced two different classes of toxins, chlorosis as well as necrosis. Chlorosis inducing toxins did not show antibacterial activity but could be detected in potato tuber discs bioassay. On the other hand, necrosis inducing toxin showed antibacterial activity against unknown bacterial pathogen. Seedling bioassay also shown that chlorosis inducing toxin was more effective in inhibition of seedlings then necrosis production toxin. Photo below is Xcs isolate induced blight like necrosis on sesame.

They also showed the effects on sesame seed germination. Isolates at different concentrations (0, 30, 50, 70 and 100%) of culture filtrates (approximately 2 ml) of Psse and Xcs isolates were applied 2 times within 4 days.



- S.S. Firdous et al. (2014) studied the causal agent of bacterial leaf spot (*Pseudomonas syringae* pv. *sesami)* of sesame. The mode of infection of causal bacterium was conducted in susceptible genotype to elucidate the process of infection within host tissues. Bacterium was identified as dark blue masses in infected tissues using toluidine blue O. Results showed that pathogen colonized substomatal and intercellular spaces of the spongy parenchyma cells when initial water soaking symptoms developed at 2-3 days after inoculation. Upon water soaking progressed, disruption of mesophyll cells occurred, mesophyll tissues were surrounded by bacterium followed by thinning and disruption of the cell walls. Later, when bacterial cells increased in space previously occupied by mesophyll cells, there were empty spaces without any differentiation of tissues. Bacterium did not occur in vascular bundles (tracheary elements) of leaf and stem, but some phloem tissues of stem sections were found infected. It was concluded that damage chloroplast might be due to chlorosis or necrosis inducing toxins, and toxins played a crucial role in pathogenesis of *Pseudomonas syringae* pv. *sesami* in sesame plant.

Effect on leaves

Effect on stems and capsules

PARAGUAY

- Anon. (2015a) Paraguay descriptor: 1.10 Incidence of *Pseudomonas sesami.* The following ratings are used:
  - 0 = Sin informacion [No information]
  - 1 = Resistente [Resistant]
  - 2 = Medianamente resistente [Moderately resistant]
  - 3 = Medianamente susceptible [Moderately susceptible]
  - 4 = Susceptible [Susceptible]

REPUBLIC OF KOREA

- J.W. Kim and. S.C. Na (1990) reported Baeg po go jong-4 and 8 other cultivars had moderate resistance to *Pseudomonas syringae* pv. *sesami.* In the field the disease appeared 20 June, peaked on 10 July, and decreased by mid-August.

SOMALIA

- M. Curzi (1934) reported the sesame bacteriosis caused by *Bacterium sesami* is both vascular and parenchymatous and has many points in common with the disease produced on various hosts by *Bacterium solanacearum*. It is perhaps identical with the sesame disease attributed to latter organism by Kornauth and Smith in 1903 and by Honing in 1913. Smith considered both diseases to be identical and due to *Bacterium solanacearum* which however Nakata and Kovacevski have shown to be distinct from *Bacterium sesami*. [Cited by G.S. Saharan]

SUDAN

- S.A.J. Tarr (1954) reported sesame is commonly attacked by a bacterial blight (blood disease). The symptoms resemble those caused by *Pseudomonas sesami* in India and elsewhere. It can cause severe losses and would probably become very destructive wider conditions of intensive cultivation. [Cited by G.S. Saharan, 1989]
- M.M. Satour (1981) reported the presence of *Pseudomonas sesami* (Leafspot).

TANZANIA

- E.J. Welsford (1932) reported *Pseudomonas sesami.* [Cited by R.S. Vasudeva, 1961]
- G.B. Wallace (1933) reported *Pseudomonas sesami.* [Cited by R.S. Vasudeva, 1961]
- A.K. Auckland (1981a) reported the goal of developing resistance to *Pseudomonas sesami.*
- Kafiriti, E. and O. Mponda (n.d.) in a grower guide reported the following pathogen: *Pseudomonas sesami.*

THAILAND

- C. Leksomboon det al. (1991) reported *Pseudomonas syringae* pv. *sesami.* Infected leaves showed typical necrotic spot with yellow halo but on stem or pod the halo was absent. Preliminary test for bacterial leafspot resistance of sesame by spraying and leaf clipping inoculation methods showed a different resistant reaction in 3 cultivars tested at 7 days after inoculation by either the same or different method, but all cultivars were finally revealed a susceptible reaction at 21 days after inoculation by both methods. [Based on abstract]
- P. Yowabut (1994) confirmed that the causal bacterium of sesame leaf spot in Thailand was *Pseudomonas syringae* pv. *sesami*. He tested 14 varieties and found Col 55 was resistant; Dam Dang-Phitsanulok, Col 30/nw-3, Nakornsawan, Buriram and Roi-et 1 were susceptible and the rests were intermediate. Seeds from the 14 varieties harvested from diseased plants were found to be seed-born with 62.13% infected in the seed coat. Disease control through hot water (55°C) and chemical (75 ppm streptomycin) seed treatment at 30 min each, gave the best results of 47.25 and 100 percent disease reduction with 84.4 and 88.6% seed germination, respectively. [Based on abstract]
- S. Prathuangwong and P. Yowabutra (1996) reported a preliminary seed treatment with both physical and chemical methods for efficient control of sesame bacterial leaf spot (caused by *Pseudomonas syringae* pv. *sesami*) in the laboratory indicated that either 35 min duration in 50°C hot water or 30 min soaking in aqueous solution of 75 ml/I streptomycin fitted to our test criteria of 25 or 100% disease reduction with 79.4 or 88.6% seed germination, respectively. [Based on abstract]

TURKEY

- H. Bremer et al. (1947) reported *Pseudomonas sesami* is believed to be the causal organisms of a wilt of sesame apparently new to Turkey but possibly identical with the bacteriosis described by Malkoff from Bulgaria. Primary infections on the leaves of ten appear as angular, vein delimited, brown spots with blackish brown margins, attaining a diameter up to 2 cm and coalescing to produce a dark network on a brown ground. Primary infections on the stems commonly occur at the site of insertion of petioles while girdling may lead to the collapse of whole plant. Sections through the stems reveal the penetration of the cortex by large irregular lacunae in which the tissue is totally disorganized and filled with bacteria. In severe cases the vascular bundle ring is disrupted in places and infection advances into medulla while the vessels may also contain bacteria. These were isolated in pure culture on potato agar on which they formed circular slimy to liquid lustrous, whitish grey colonies.

UNITED STATES

- M.L. Kinman (1955) reported at least two fungi (*Cercospora sesami* and *Alternaria* spp.), and one bacterium (*Pseudomonas sesami*) are known to cause leaf spot diseases. The development of these leaf troubles is favored

by excessive rainfall and high humidity. The causal organisms can be seedborne. It may be possible to control the leaf spots by the use of disease-free seed or by appropriate seed treatment. The *Alternaria* spp. may not be subject to complete control by these methods, since it appears to spread from other hosts. Disease-free seed can be grown in the desert under irrigation. Hot water seed treatment or treatment with the antibiotic Streptomycin will eliminate seed-born bacterial leaf spot.

- C.A. Thomas (1959a) reported plants grown for seed became infected with *Pseudomonas sesami* (Bacterial leaf spot) and *Alternaria* before harvest. When these seeds were planted, *Alternaria* spots developed on the cotyledons and was usually severe by flowering time. Orthocide gave good protection against both diseases. Seed treatment is of much value under these conditions, but it may not be sufficient under more severe conditions. Control of *Alternaria* and bacterial leaf spot can be done by using clean seed and rotating crops.
- C.A. Thomas and R.G. Orellana (1962b) reported analyses of leaves of sesame varieties grown in the field indicated that soluble nitrogen and glucose are related to level of resistance. In the greenhouse level of resistance could be altered by light intensity and nitrogen fertilization. Since *Pseudomonas sesami* utilizes inorganic nitrogen poorly and polysaccharides not at all, the relation of amino compounds and reducing sugar to resistance of sesame varieties and to the pathogenicity of races of *P. sesami* was studied.
- C.A. Thomas and R.G. Orellana (1962c) reported that a new strain of *Pseudomonas sesami* attacked the high resistant variety Margo in commercial fields in Texas. In greenhouse and field tests, Early Russian was resistant to both the old and new strains. Varietal reaction depended on differences in the concentration of certain amino acids and in the ratio of reducing sugars to these acids. The higher the amount of amino acids, the higher the susceptibility. Venezuela 51, Margo, and Delco are very susceptible. The strains were morphologically distinct, e.g., their glucose and aspargine requirements.
- C.A. Thomas et al. (1962d) provided more detail on the new race of *Pseudomonas sesami* in the USA.
- T.W. Culp (1964a) reported that the Race 2 of *Pseudomonas sesami* that was reported in Texas has attacked sesame in Mississippi. It was either introduced on seed from Texas or it developed independently in the nurseries.
- G.W. Rivers et al. (1964) reported resistance to both races of *Pseudomonas sesami*. Early Russian and B-1-8 contribute the major resistant genes.
- C.A. Thomas (1965b) reported that a short photoperiod of 12 hrs. light day with supplemental N was the most favorable for the development of *Pseudomonas sesami*. Varieties Venezuela 51 and Early Russian (field susceptible and field resistant respectively) both proving susceptible without supplemental N. The former was susceptible for long (16 hrs) photoperiod. [Cited by G.S. Saharan]
- Anon. (2015c) USA PVP descriptor: *7. Diseases – Bacterial leaf spot (Pseudomonas sesami)* – Mandatory. The following ratings are used:
  - 0 = Not tested
  - 1 = Susceptible
  - 2 = Low resistance
  - 3 = Moderate resistance
  - 4 = High resistance
- D.R. Langham (2015b) USA patent descriptor: 38. Tolerance to *bacterial black rot* (*Pseudomonas sesami*)
  - Definition: Amount of tolerance to bacterial black rot.
  - Values: Average of a minimum of three plots of a subjective rating based on the following values: 0 to 8 scale of the % of infected plants (Intermediate values are used).
    - 8 = Zero disease
    - 7 = <10% infected
    - 4 = 50% infected
    - 1 = >90% infected
    - 0 = all infected
    - Intermediate values may be used
    - NT = not tested
    - NEC = no economic damage - not enough insects to do ratings
  - Ratings can be done in several ways:
    - Take ratings after the disease is no longer increasing.
    - Take ratings on consecutive weeks until the disease is no longer increasing and average ratings.
    - Take periodic ratings and average ratings.
  - Distribution: Based on lines in Uvalde nursery in 2004 (Total number of samples tested = 593). Low = 4.00; high = 8.00; avg. = 7.13, std = 1.00.

- <2.4; 0.0%
- <3.8; 0.0%
- <5.2; 8.6%
- <6.6; 16.0%
- >6.5; 75.4%

  - Comments: This disease occurs occasionally when there is continual rainy weather with few clouds. In most years, the disease abates once the weather changes. No economic damage has been noticed.

- D.R. Langham comments, 2021: On the Caprock of Texas when there was a week of cool cloudy weather, leaf spots would appear. They were identified by R.D. Brigham of Texas A&M as *Pseudomonas sesami.* When the weather warmed up and the sun returned, the spots no longer spread, and there was no perceptible effect on yield.

  The Caprock was the major area of sesame production in the 1950s and 1960s. M.L. Kinman and C.A. Thomas developed varieties that were tolerant. It was interesting that new Sesaco varieties (S23, S24, and S25) that had those tolerant varieties in the genealogy were tolerant to *P. sesami*.

VENEZUELA

- G. Malaguti (1973) reported the following leaf disease: bacterial leaf spot (*Pseudomonas sesami*). [Cited by G.S. Saharan, 1989]
- R. Urdaneta and B. Mazzani (1976a) evaluated susceptibility to *Pseudomonas sesami* (Bacterial leaf spot) in 14 sesame varieties. The disease's incidence was lower in a group of varieties originally introduced from Africa, namely Maporal, Morada, Ajimo atar S-5, and Local sesame A-15-13, which showed lesser damages and higher seed production than the more susceptible ones. Where rains were more abundant, bacterial damage was more severe.
- R. Urdaneta and B. Mazzani (1976b) evaluated 5 products (Agrimicin 17-21,3%, Benlate 50,0%; Captan 50,0%; Cupravit 50,0%; Difolatan 80,0%) to control *Pseudomonas sesami* (Bacterial leaf spot). The chemicals were sprayed weekly on sesame plants, starting 44 days after seed germination. Cupravit and Difolatan at highest doses lowered bacterial incidence by 19.2 and 16.8% compared with the control, whereas seeds yields were improved by 117.0 and 67.4% compared with the same control. The other products were ineffective and didn't show any advantage compared to the unsprayed control plot.
- B. Mazzani et al. (1981b) reported the presence of *Pseudomonas sesami* (Bacterial leaf spot) is one of the major diseases.

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C2 Order: Burkholderiales Garrity et al. 2006

(Wikipedia, 9 Apr 2021) The **Burkholderiales** are an order of Proteobacteria. Like all Proteobacteria, they are Gram-negative. They include several pathogenic bacteria, including species of Burkholderia, Bordetella, and Ralstonia. They also include Oxalobacter and related genera, which are unusual in using oxalic acid as their source of carbon. Other well-studied genera include Alcaligenes, Cupriavidus, Achromobacter, Comamonas, Delftia, Massilia, Duganella, Janthinobacterium, Polynucleobacter (important freshwater bacterioplankton), non-pathogenic Paraburkholderia, Caballeronia, Polaromonas, Thiomonas, Collimonas, Hydrogenophaga, Sphaerotilus, Variovorax, Acidovorax, Rubrivivax and Rhodoferax (both members of the photosynthetic purple non-sulfur bacteria), and Herbaspirillum (capable of nitrogen-fixation).

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C2.1 Family: Burkholderiaceae Garrity et al. 2006

(Wikipedia, 9 Apr 2021) The **Burkholderiaceae** are a family of bacteria included in the order Burkholderiales. It includes some pathogenic species.

The following species have been reported to cause diseases, produce a toxin, inhibit germination, or affect seed quality.

- C2.1.1 *Ralstonia* spp.
- C2.1.1a *Ralstonia solanacearum* (*Syn: *Bacillus solanacearum, Bacterium solanacearum*, and *Pseudomonas solanacearum*)

C2.1.1 *Ralstonia* spp. (25 Apr 2021)

Family: Burkholderiaceae

Definition: Amount of tolerance to *Ralstonia* spp. Yabuuchi et al. 1996

(Wikipedia, 25 Apr 2021) ***Ralstonia*** is a genus of Proteobacteria, previously included in the genus *Pseudomonas*. It is named after the American bacteriologist Ericka Ralston. Ericka Ralston was born Ericka Barrett in 1944 in Saratoga, California, and died in 2015 in Sebastopol, California. While in graduate school at the University of California at Berkeley, she identified 20 strains of *Pseudomonas* which formed a phenotypical homologous group, and named them *Pseudomonas pickettii*, after M.J. Pickett in the Department of Bacteriology at the University of California at Los Angeles, from whom she had received the strains. Later, *P. pickettii* was transferred to the new genus *Ralstonia*, along with several other species. She continued her research into bacterial pathogenesis under the name of Ericka Barrett while a professor of microbiology at the University of California at Davis from 1977 until her retirement in 1996.

References:

UNITED STATES

- M. Fay et al. (2021) reported metagenomic analysis of food is becoming more routine and can provide important information pertaining to the shelf life potential and the safety of these products. They examined 10 sesame samples and identified *Ralstonia* sp. Ralstonia is a genus of bacteria which has been identified in soil, water, and plants and are also commensals of humans. Certain species of Ralstonia are members of the human oral cavity and the upper respiratory tract of healthy individuals. Ralstonia can revert from a commensal organism to a pathogen in people who are immune compromised. Species of Ralstonia are also devastating plant pathogens and cause lethal wilting disease in over 200 plant species. Although Ralstonia was identified in all 10 sesame seeds brands, this taxon was at abundances >1% in only four brands. Brand E sesame seeds had the highest proportional abundance of Ralstonia (8.3%) and was also the only brand where the sesame seeds were cultivated in Mexico.

C2.1.1a *Ralstonia solanacearum* (9 Apr 2021)

Synonyms: *Pseudomonas solanacearum, Bacterium solanacearum,* and *Bacillus solanacearum*

Family: Burkholderiaceae

Definition: Amount of tolerance to *Ralstonia solanacearum* (Smith 1896) Yabuuchi et al. 1996 emend. Safni et al. 2014.

(Wikipedia, 9 Apr 2021) ***Ralstonia solanacearum*** is an aerobic non-spore-forming, Gram-negative, plant pathogenic bacterium. *R. solanacearum* is soilborne and motile with a polar flagellar tuft. It colonizes the xylem, causing bacterial wilt in a very wide range of potential host plants. It is known as Granville wilt when it occurs in tobacco. Bacterial wilts of tomato, pepper, eggplant, and Irish potato caused by *R. solanacearum* were among the first diseases that Erwin Frink Smith proved to be caused by a bacterial pathogen. Because of its devastating lethality, *R. solanacearum* is now one of the more intensively studied phytopathogenic bacteria, and bacterial wilt of tomato is a model system for investigating mechanisms of pathogenesis. *Ralstonia* was until recently classified as *Pseudomonas*, with similarity in most aspects, except that it does not produce fluorescent pigment like *Pseudomonas*. The genomes from different strains vary from 5.5 Mb up to 6 Mb, roughly being 3.5 Mb of a chromosome and 2 Mb of a megaplasmid. While the strain GMI1000 was one of the first phytopathogenic bacteria to have its genome completed, the strain UY031 was the first *R. solanacearum* to have its methylome reported. Within the *R. solanacearum* species complex, the four major monophyletic clusters of strains are termed phylotypes, that are geographically distinct: phylotypes I-IV are found in Asia, the Americas, Africa, and Oceania, respectively.

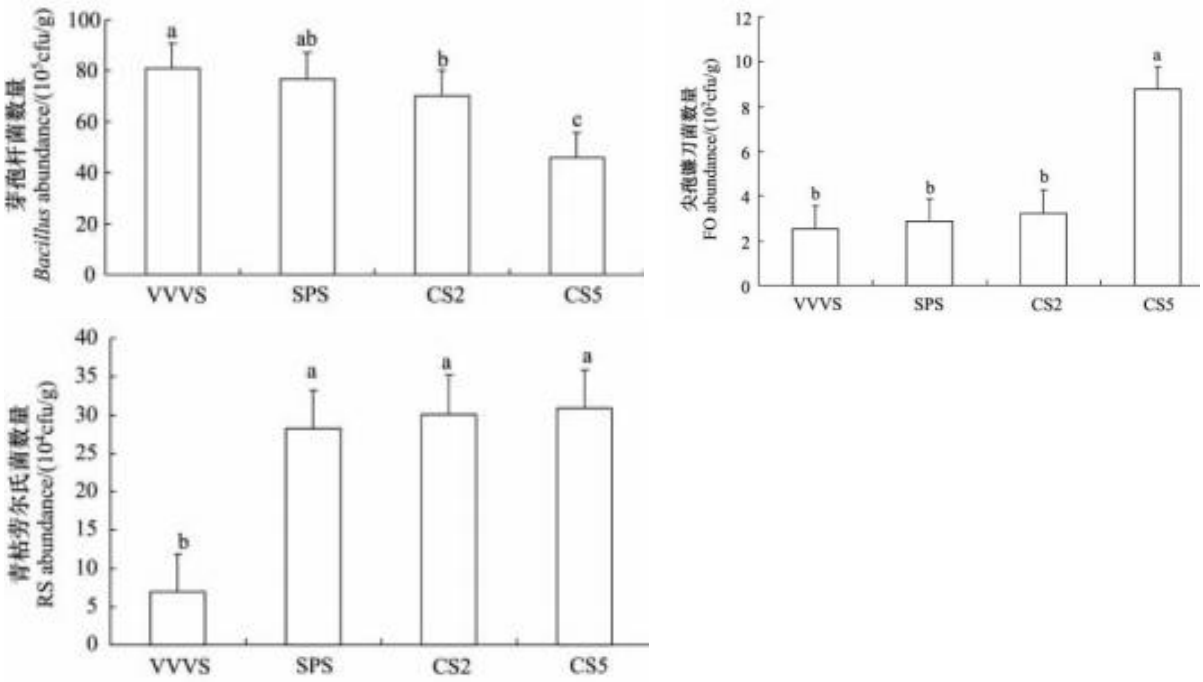
References:

INTERNATIONAL

- C. Wescott (1971) reported the following pathogen: bacterial wilt (*Pseudomonas solanacearum*).
- C. Chattopadhyay et al. (2019) reported soil treatment with combinations of bleaching powder, streptocycline, and mustard cake significantly controls *Ralstonia solanacearum*.

CHINA

- L.C. Tu (1985a and 1985b) reported *Pseudomonas solanacearum* (Leaf spot) in Henan province with a damage level of 1 out of a possible 3.
- L.L. Li (1988) reported *Pseudomonas solanacearum* (Bacterial wilt) occurs quite severely in sesame growing areas of southern China. Up to 40% incidence which causes the death of plants and results in considerable loss in the yield of sesame. After the sesame is attacked by the bacteria, symptoms first appear on the stem as dark-green spots and then brown to black streaks. The terminal portion of the stem often shows 2 to 3 ulcer shuttle crevices and then begins to wilt. The lower leaves soon begin to gradually wilt and hang down. The diseased plants appear to be short of water. Thus, they primarily wilt in the day and become normal at night, but gradually lose their ability to recover after several days. The vascular bundle of the root and stem of the diseased plants turns into brown color at last. The pith of the plants also can be infected and can become hollow. Bacterial ooze can be seen on the surface of the diseased stem, under humidity, which gradually turns into pitch-dark crystal granule. After the leaves are infected by the pathogen, a crisscross network of the blackish-green streaks of the vein appears on the leaf. When the diseased leaf is seen against sunlight, the center of the vein seems to be oil-soaked and transparent. The yellow vein of the under-surface of the diseased leaves protrudes up and down like a ripple. The diseased leaves become savoy, brown in color and finally die. Symptoms first appear on capsules as water-soaked spots and then as dark-brown streaks. Such capsules are thin and small, exposing the shriveled and discolored seed which cannot sprout. The pathogen mainly perpetuates through plant residues in soil and may persist for 3 to 5 years in soil. The bacteria enter the host through the root and/or the wound of the stem and/or stomata. Infection occurs when the soil temperature is 12.8°C. When the soil temperature is between 21 and 43°C, the higher the temperature is, the more severe the disease will be. The pathogen spreads through running water, subterranean pest and farm tools in the field. Since the crop residues in the soil are the most important reservoir of inoculum, the use of over 2 to 3 years rotation with the grass family crops (cotton, sweet potato etc.) may offer a more effective method of control of the disease. Accumulated water should be drained away at once after a rainfall so as to avoid the spread of the pathogen through running water. Applying enough base manure and increasing to apply barnyard manure and plant ash may improve the resistance of plants and reduce the incidence of the disease.
- H.M. Miao and H.Y. Liu (2010) reported the following pathogen: *Pseudomonas solanacearum.*
- J.L. Hua et al. (2012) evaluated the effects of 4 normal crop rotations (vegetable crop (vegetable-vegetable-vegetable-sesame, VVVS), alternation of sesame with peanut (sesame-peanut-sesame, SPS), 2 year continuous sesame, CS2, and 5 year continuous sesame, CS5) on populations of *Bacillus* spp., *Fusarium oxysporum* (FO), and *Ralstonia solanacearum* (RS). The results were as follow.



It was clear that continuous cropping of sesame led to direct changes in the microbial composition of the rhizosphere. Bacteria and actinomycetes decreased in abundance, while fungi increased. When rhizospheric soil changes from "bacterial" to "fungal", its biological activity and fertility decline, and it is slower to recover from ecological fluctuations caused by external factors such as pathogens and waterlogging. Fusarium oxysporum and Ralstonia solanacearum continue to increase in abundance, causing worsening diseases. These factors eventually lead to continuous cultivation problems in sesame.

INDIA

- E.J. Butler (1918) reported *Bacillus solanacearum* occurs on sesame. [Cited by G.S. Saharan, 1989]
- Y. Rathaiah (1984) recorded *Pseudomonas solanacearum* on sesame.
- S. Maiti et al. (1985 and 1986) reported the following minor pathogen: Wilt *Pseudomonas solanacearum* Smith.
- D.K. Hazarika and K.K. Das (1999) studied during 1996 and 1997, the effect of 6 sowing dates from July 2 to August 21 on the incidence of bacterial wilt (*Ralstonia solanacearum*) in relation to weather factors was studied on 4 sesame varieties in Assam. The highest and lowest wilt incidence occurred on variety Madhavi (40.5%) and variety Pb Til No. 1 (15.1%) in the August 21-sown crop and the July 2-sown crop, respectively. Wilt incidence had a direct relationship with sesame yield.

IRAN

- J. Aitman et al. (1972) reported *Pseudomonas solanacearum* caused bacterial wilt in sesame.

JAPAN

- K. Nakata (1930) investigated the relationships between three bacteria recorded as the causal organisms of sesame diseases viz, *Bacterium sesami*, *Bacterium solanacearum* and *Bacterium sesamicola*. The results of comparative studies of the morphology, cultural characters and physiological feature of three bacteria indicated that *Bacterium sesami* and *Bacterium sesamicola* are identical but are distinct from *Bacterium solanacearum*. The correct name of former is considered to be Bacterium sesami. Malkoff; synonyms *Pseudomonas sesami* Malk; *Bacterium sesamicola* Takimoto. *Bacterium sesami* causes formation of dark brown spots on sesame leaves and stem in Bulgaria, India, Japan, and Korea. [Cited by G.S. Saharan, 1989]
- T. Kuzuyuki (2021) cited the following pathogen *Ralstonia solanacearum* (Bacterial wilt) is listed in the Database of Plant Diseases in Japan.

MEXICO

- Agrolytics.org (2021) reported sesame hosts *Ralstonia solanacearum.*

REPUBLIC OF KOREA

- J.I. Lee and B.H. Choi (1985h) reported bacterial wilt (*Pseudomonas solanacearum*) can appear at any stage of growth, particularly during high temperature season from July to August. The disease is serious and causes considerable losses. The most effective control method is tolerant varieties, crop rotation, and applying 2-4 t/ha of lime.

THAILAND

- S. Maneekao et al. (1999b) screened 120 new and 33 existing cultivars against *Macrophomina phaseolina* and *Pseudomonas solanacearum*. They identified MR 13 (red seed) and MR 36 (Black seed) were more tolerant to the pathogens than the existing major cultivars (UB 1 and MK 60).
- N. Worasatit et al. (2001a) evaluated the effect of nitrogen and potassium on the incidence of bacterial stem rot caused by *Ralstonia* (*Pseudomonas*) *solanaceaum* during in the greenhouse in 1997-1999 at Ubon. They concluded application of 50-200 kg N/ha incorporated with 100-200 kg K_2O/ha, and 100 kg P_2O_5/ha of phosphorus can partially reduce the incidence of bacterial stem rot to a certain level and enhance growth and yield of sesame.
- N. Worasatit et al. (2007) studied the effect of crop rotation (roselle, sugarcane, and sword bean) for 2 or 3 years on the population of *Ralstonia* (*Pseudomonas*) *solanaceaum* and the infection and yield of sesame. The experiment was conducted in pots, in the field in the early rainy season, and in the field in the late rainy season. Results showed that a 2 year rotation significantly reduced the population, decreased the infection, and increased the yield per sesame plant.

UNITED STATES

- J. Martin (1953a) reported a bacterial wilt (*Pseudomonas solanacearum*) in sesame in irrigated areas but felt that probably only occurred with improper water management.

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C2.2 Family: Comamonadaceae Willems et al. 1991

(Wikipedia, 26 May 2021) The **Comamonadaceae** are a family of the Betaproteobacteria. Like all Proteobacteria, they are Gram-negative. They are aerobic and most of the species are motile via flagella. The cells are curved rod-shaped.

The following species have been reported to cause diseases, produce a toxin, inhibit germination, or affect seed quality.

- C2.2.1 *Acidovorax* spp.
- C2.2.1a *Acidovorax valerianellae*

C2.2.1 *Acidovorax* spp. (13 Jul 2021)

Family: Comamonadaceae

Definition: Amount of tolerance to *Acidovorax* spp. Willems et al. 1990 emend. Willems et al. 1992

(Wikipedia, 13 Jul 2021) ***Acidovorax*** is a genus of Proteobacteria. All species are facultative. *A. avenae* causes bacterial fruit blotch on cucurbit crops.

C2.2.1a *Acidovorax valerianellae* (26 May 2021)

Family: Comamonadaceae

Definition: Amount of tolerance to *Acidovorax valerianellae* Gardan et al. 2003.

(Wikipedia, 26 May 2021) ***Acidovorax valerianellae*** is a Gram-negative bacterium.

References:

JAPAN

- T. Kuzuyuki (2021) cited the following pathogen *Acidovorax valerianellae* (Bacterial leaf spot) is listed in the Database of Plant Diseases in Japan.

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C3 Order: **Xanthomonadales** Saddler and Bradbury 2005

(Wikipedia, 10 Apr 2021) The **Xanthomonadales** are a bacterial order within the Gammaproteobacteria. They are one of the largest groups of bacterial phytopathogens, harboring species such as *Xanthomonas citri*, *Xanthomonas euvesicatoria*, *Xanthomonas oryzae* and *Xylella fastidiosa*. These bacteria affect agriculturally important plants including tomatoes, bananas, citrus plants, rice, and coffee. Many species within the order are also human pathogens. Species within the genus *Stenotrophomonas* are multidrug resistant opportunistic pathogens that are responsible for nosocomial infections in immunodeficient patients.

The Xanthomonadales are gram-negative, catalase positive, non-spore forming obligate aerobes. Members belonging to the order are straight rods lacking prosthecae. While some members are non-motile, other species within the order are motile by means of flagella. *Stenotrophomonas* is the only genus capable of nitrate reduction within the Xanthomonadales.

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C3.1 Family: **Xanthomonadaceae** Saddler and Bradbury 2005

(Wikipedia, 10 Apr 2021) The **Xanthomonadaceae** are a family of Proteobacteria, within the Xanthomonadales order.

The following species have been reported to cause diseases, produce a toxin, inhibit germination, or affect seed quality.

- C3.1.1 *Xanthomonas* spp.
- C3.1.1a *Xanthomonas euvesicatoria* pv. *sesami* (*Syn: *Xanthomonas campestris* pv. *sesami* and *Xanthomonas sesami*)
- C3.1.1b *Xanthomonas axonopodis* pv. *ricini*

C3.1.1 *Xanthomonas* spp. (11 Dec 2021)

Family: Xanthomonadaceae

Definition: Amount of tolerance to *Xanthomonas* spp. Dowson 1939.

Summary:

Photo: R. Felix-G et al. (2019) {Mexico}

Photos : H. Tadesse (1985) {Ethiopia}

Xanthomonas euvesicatoria* pv. *sesami (Synonyms: *X. campestris* pv. *sesami*, *X. campestris*, and *X. sesami*) has been reported to cause bacterial blight of sesame and can be difficult to distinguish from *Pseudomonas syringae* symptoms. Initial inoculum may be from seed or weed hosts near by. The bacteria gains entry via stomata and other openings, and secondary spread is by water splash from rain or irrigation. High temperature, high humidity, and rainy weather favor the disease. Peak conditions for seedling infection are soil temperatures of 20°C, while infection does not occur with hot conditions, with soil temperature of 40°C. Ideal soil moisture seem to be is 30-40% and relative humidity is 75-87%. Bacterial blight has been described as small, water-soaked, light-brown lesions with yellow (chlorotic) halos around the margin that will coalesce as the infection progresses. Lesions on the capsule and stem are also often present. Chattopadhyay et al. 2019) documented *X. euvesicatoria* pv. *sesami* first occuring on the margin of the cotyledon approximately 10-12 days after sowing. If environmental conditions are favorable lesions will spread, rapidly covering the entire cotyledons, then subsequently become dry. About 4% mortality due to the disease in 4-6 week-old seedlings has been reported. If the seedling survives, dark brown, water-soaked spotsalso appear on the true leaves. In a severe infection, the lesions extend to the stem through the

petiole, leading to the formation of brown discoloration, resulting in systemic invasion and death of the plant. Seed can be infested with viable pathogen up to 16 months. The pathogen may also be found in weeds, such as *Acntospermum hispidum*, which may serve as a green bridge or weed host resevoir. In the case of *A. hispidum*, the pathogen may cause symptoms and harbor the bacterium in its dried leaves from year to year. The disease is known in Sudan as *Marad et Dum*, meaning the blood disease, due to the red color of infected plant tissue. There is another Xanthomonas species that is a pathogen in sesame: *X. axonopodis* pv. *ricini* (Syn. *X. ricinicola*). The pathogen has been reported in international lists, Brazil, Burkina Faso, China, Ecuador, Ethiopia, Honduras, India, Japan, Malawi, Mexico, Myanmar, Nicaragua, Nigeria, Pakistan, Paraguay, Republic of Korea, Sudan, Turkey, United States, and Venezuela.

(Wikipedia, 10 Apr 2021) ***Xanthomonas*** is a genus of Proteobacteria, many of which cause plant diseases. There are at least 27 plant associated *Xanthomonas spp.*, that all together infect at least 400 plant species. Different species typically have specific host and/or tissue range and colonization strategies.

Individual cell characteristics include: Cell type – straight rods; size: 0.4–1.0 µm wide by 1.2–3.0 µm long; motility – motile by a single polar flagellum.

Colony growth characteristics include: Mucoid, convex, and yellow colonies on YDC medium; yellow pigment from xanthomonadin, which contains bromine; most produce large amounts of extracellular polysaccharide; temperature range – 4 to 37 °C, optimal growth 25-30 °C.

Biochemical and physiological test results are: Gram stain – negative; obligate aerobes; catalase positive; oxidase negative.

Xanthomonas species can cause bacterial spots and blights of leaves, stems, and fruits on a wide variety of plant species. Pathogenic species show high degrees of specificity and some are split into multiple pathovars, a species designation based on host specificity. Bacterial leaf spot has caused significant crop losses over the years. In some areas where infection begins soon after transplanting, the total crop can be lost as a result of this disease.

Contaminated seeds, weeds, infected plant debris are the main route of transmission. Infection starts with epiphytic stage, i.e., bacteria grow on the aerial tissues of plant host (leaf, fruit, etc.) followed by endophytic stage when bacteria enter and colonize host tissues through wounds or natural openings. When population of bacteria increases it re-emerges to the surface and is transmitted mainly by wind, rain or through seeds or agricultural machinery, while animal and insect vectors seems to play minor role.

Xanthomonas uses surface polysaccharides, adhesion proteins and type IV pili to attach to the surface and can form biofilms to sustain abiotic stresses (UV, drought, etc.). *Xanthomonas* produce xanthomonadins – yellow pigments that protect from radiation caused from natural light. Resistance to UV is mostly conferred by genes related to oxidative stress and DNA repair. Response to light is important in pathogenicity of these bacteria and regulates surface attachment and production of biofilm.

Xanthomonas possess almost all known secretion systems (types I to VI) that play different roles in the life and disease cycle, with type III secretion system (T3SS) being the key factor of pathogenicity. Typically, *Xanthomonas* T3SS injects a cocktail of 20-30 effector proteins that interfere with plant immune system and various host cellular processes. Many of the effectors are presumably redundant as individual deletions of effector genes does not impair virulence, however mutations in T3SS apparatus have strong effects. Secretion of the effectors is coordinated with expression of other virulence factors via shared regulatory networks. The effector repertoire has been proposed to be a determinant of host specificity. *Xanthomonas* actively kill other bacterial using type IV secretion system and defend itself from amoeba using type VI secretion system.

To prevent infections, limiting the introduction of the bacteria is key. Some resistant cultivars of certain plant species are available as this may be the most economical means for controlling this disease. For chemical control, preventative applications are best to reduce the potential for bacterial development. Copper-containing products offer some protection along with field-grade antibiotics such as oxytetracycline, which is labeled for use on some food crops in the United States. Curative applications of chemical pesticides may slow or reduce the spread of the bacterium but will not cure already diseased plants. It is important to consult chemical pesticide labels when attempting to control bacterial diseases, as different *Xanthomonas* species can have different responses to these applications. Over-reliance on chemical control methods can also result in the selection of resistant isolates, so these applications should be considered a last resort.

Potential use of bacteriophages is also considered, however major limiting factors are their sensitivity to environmental conditions and in particular to UV radiation. Plant beneficial microorganisms or attenuated strains of *Xanthomonas* are being tested as a biocontrol reasoning that they could compete by occupying the same niche and even eradicate pathogenic strain. Generation of plant species resistant to *Xanthomonas* is another potential strategy.

References:

ETHIOPIA

- H. Tadesse (1985) in a presentation reported *Xanthomonas* sp. (Bacterial blight) is a problem.



INDIA

- O.P. Kadian (1972) reported five common genera to include *Xanthomonas* sp., which reduced seed germination and had adverse effect on the seedlings. The seeds were internally as well as externally seedborne. [Cited by G.S. Saharan, 1989]
- C.D. Kaushik et al. (1986) reported phyllody (MLO), root rot (*Macrophomina phaseoli*), leaf curl (virus), Bacterial leaf blight (*Xanthomonas* sp.), powdery mildew (*Erysiphe* sp.), and Phytophthora blight.

JAPAN

- K. Kato et al. (2021) purchased seed in local markets and identified the following bacterium: *Xanthomonas* spp.
- T. Kuzuyuki (2021) cited the following pathogen *Xanthomonas* sp. is listed in the Database of Plant Diseases in Japan.

MEXICO

- Agrolytics.org (2021) reported sesame hosts *Xanthomonas* spp.

MYANMAR

- Y.Y. Min and K. Toyota (2019) surveyed diseases in 10 farmer fields and interviewed 25 farmers. They reported the following pathogen: *Xanthomonas* sp. with a 5% yield loss.

PAKISTAN

- N. Ali and A. Beg (1985) reported *Xanthomonas* sp. (Bacterial blight) is a common and destructive disease. They recommend planting disease resistant varieties, field sanitation (crop rotation and removal of all crop residues after the harvest) and early planting.

UNITED STATES

- K.A. Cochran comments, 2021: The disease symptoms caused by this pathogen can be difficult to differentiate from other pathogens, such as *Pseudomonas* spp. Thus, many prefer to just call these 'Bacterial leaf spot.' Bacterial diseases of sesame are poorly documented. Molecular analysis, which is currently much more affordable than even 5-10 years ago, is needed to better reveal true identity of many pathogenic isolates isolated from sesame. I would not be surprised if new pathovars or species are implicated in causing disease in the coming years. These bacteria gain entry primarily via wounds or natural openings (i.e., stomata). Reducing the load of sap feeding insects will help reduce the total number of injuries to the plant tissues by reducing the number of openings.


These photos illustrate the difficulty in identifying the pathogen. In the field, the pathogen appeared to be Pseudomonas, but after culturing the bacteria, I determined they were Xanthomonas.

VENEZUELA

- B. Mazzani (1981a) reported *Xanthomonas* sp. (Leaf spot) is one of the major diseases.

C3.1.1a *Xanthomonas euvesicatoria* pv. *sesami* (10 Apr 2021)

Synonym: *Xanthomonas campestris, Xanthomonas campestris* pv. *Sesami*, and *Xanthomonas sesami*

Family: Xanthomonadaceae

Definition: Amount of tolerance to *Xanthomonas euvesicatoria* pv. *sesami* (Sabet and Dowson 1960) Constantin et al. 2016

(Anon. n.d.k) Bacterial leaf spot – *Xanthomonas campestris* pv. *sesami*

Symptoms: Initially water-soaked spots appear on the undersurface of the leaf and then on the upper surface. They increase in size, become angular and restricted by veins and dark brown in color. Several spots coalesce together forming irregular brown patches and cause drying of leaves. The reddish brown lesions may also occur on petioles and stem.

Pathogen: The bacterium is a gram negative rod with a monotrichous flagellum.

Disease cycle: The bacterium survives in the infected plant debris and in seeds. The secondary spread is by rain water.

Management: Remove and burn infected plant debris; spray Streptomycin sulphate or oxytetracycline hydrochloride or strephocyclin at 100g/ha.

References:

INTERNATIONAL

- R.S. Vasudeva (1961) reported *Xanthomonas sesami* affects the leaves and the stem, being more severe in the latter. The first symptoms on the leaves consist of small, water-soaked, translucent, more of less circular spots. These are light brown first turning dark brown later. As the size increases, the spots become irregular in shape. Several spots may coalesce to form bigger irregular patches. A bacterial ooze in the form of an exudate can be seen on the diseased spots. The affected leaf ultimately wilts due to severe blighting and finally dries up.

- E.A. Weiss (1971) reported *Xanthomonas sesami* is a major disease. There are two different types of symptoms. One found on the upper leaves and capsules and is dark red-brown to black somewhat translucent spot with sharply defined margins some 2-4 mm in diameter. The other found mainly on lower leaves has grey to light-brown, usually opaque spots approximately 4-14 mm in diameter. It has been suggested there is a relationship between *Xanthomonas sesami* and *Pseudomonas sesami* and with *Cylindrosporium sesami.*
- P. Neergaard (1979) reported the following pathogen caused a disease in sesame: *Xanthomonas sesami.* [Cited by G.S. Saharan, 1989]
- M.O. Khidir (1981a) in a review of sesame in East Africa and the Near East reported the following disease was a problem: *Xanthomonas sesami.*
- Anon. (2004a) IPGRI descriptor: 10.3.2. Biotic stress susceptibility to *Xanthomonas campestris* pv. *sesami.* (Bacterial blight)
  - In each case it is important to state the origin of the infestation or infection, i.e., natural, field inoculation, or laboratory. Also specify the causal organism and the corresponding symptoms. The susceptibility scale is as follows:
    - 1 = Very low or no visible sign of susceptibility
    - 3 = Low
    - 5 = Intermediate
    - 7 = High
    - 9 = Very high
  - The growth state, coded according to the list below at which each reaction was recorded should be appended to the record of that reaction.
    - 1 = Seed
    - 2 = Seedling
    - 3 = Pre-flowering
    - 4 = Early flowering
    - 5 = Mid-flowering
    - 6 = Late-flowering
    - 7 = Maturity
- CAB International (accessed 12 Apr 2021) reported sesame was a major host of *Xanthomonas campestris* pv. *sesami* (Bacterial: sesame blight).
- C. Chattopadhyay et al. (2019) provided the following symptoms of *Xanthomonas campestris* pv. *sesami* (Bacterial blight): Small, water-soaked, light-brown lesions develop on the margin of the cotyledon about 10-12 days after sowing. The lesions may spread, rapidly covering the entire cotyledons, which consequently become dry. About 4% mortality due to the disease in 4-6 week-old seedlings has been reported. If the seedling survives, dark brown, water-soaked spots also appear on the true leaves. In a severe infection, the lesions extend to the stem through the petiole, leading to the formation of brown discoloration, resulting in systemic invasion and death of the plant. The disease is known in Sudan as *Marad et Dum*, meaning the blood disease, due to the red color of infected plant tissue. Seed can carry the pathogen up to a period of 16 monts. A weed plant, *Acntospermum hispidum* is reported to be susceptible. This host acts as a source of suvival of the bacterium in its dried leaves from year to year. The bacterium enters the host primarily through stomata and quickly becomes vascular. The secondary spread is by spattering rains. High temperature and humidity favor the disease. Seedling infection of sesame is most severe at soil temperature of 20°C. Infection does not take place when soil temperature is 40°C. The disease also becomes severe when the soil moisture is 30-40% and relative humidity is 75-87%. Seedling infection can be used as a valid test for determining the resitance of sesame to this disease. Cheminal or antibiotic seed treatment or hot-water treatement of seed and antibiotic spray to check secondary spread are the same as described for bacterial leaf spot (*Pseudomonas syringae* pv. *sesami*). Streptocycline seed treatment for 2 h followed by three sprays at 10-day intervals of streptocycline plus copper oxychloride effectively controls the disease.

BRAZIL

- N.H.C. Arriel et al. (2009) reported *Xanthomonas campestris* pv. *sesami.* The symptoms are characterized by the presence in leaves, stems and capsules of initially dark spots, usually rounded or angular, 2 mm to 3 mm in diameter, which acquire a reddish-brown or black color. These injuries can coalesce, forming large areas of tissue necrotic, which later dry out. This bacteria is spread by rainwater accompanied by wind and is transmitted through the seed. It can survive in crop residues of infected plants and persists in the soil during 4 to 6 months. In soils with high nitrogen content, it has been verified greater severity of the disease. The elimination of

infected plant residues and crop rotation are measures that can reduce the incidence of the disease, as well as the use of seeds for planting from fields free of the pathogen.

- N.E.M. Beltrao et al. (2013) reported *Xanthomonas campestris* pv. *sesami.* The plant can be attacked at any age. In the initial phase of the attack, dark rounded spots may appear or watery angular in the leaves, stems and capsules which, followed posteriorly of a reddish-brown or black coloration that may depress forming a necrotic area (B. Canechio Filho and R. Tella, 1957). The bacterial stain is spread by rainwater along with the wind and transmitted by the seed. Can survive in cultural remains. High temperature and humidity favor the disease. Infection of seedlings of sesame is more severe in soils with temperatures of 20°C. The infection does not occurs when the soil temperature is 40°C. The disease also becomes severe when soil moisture is 30 to 40% and relative humidity is 75 to 87%. (N.A. Wulff and S.F. Pascholati, 2005; A.E. Araujo et al., 2001)

BURKINA FASO

- M.M. Satour (1981) reported the presence of *Xanthomonas sesami* (Leafspot).

CHINA

- L.C. Tu (1985b) reported *Xanthomonas sesami* (Leaf spot).in Henan province with a damage level of 1 out of possible 3.

ETHIOPIA

- A.O. Omran et al. (1985) reported variety E is moderately resistant to *Xanthomonas sesami.* On a scale of 9, it scored 1.5 to 2 in all locations.
- E. Wondimagegne et al. (1986) screened 70 varieties against inoculation with *Xanthomonas sesami.* They divided the results in 4 groups as follow.

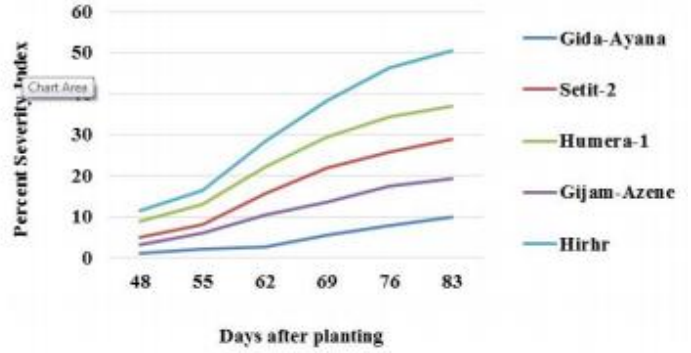
Group number	Number of varieties	Size of spots in mm
1	29	2-5
2	19	5-10
3	15	10-15
4	7	15 and more, stems damaged

- A.P. Korobko and E. Wondimagegne (1987) reported severe infections of *Xanthomonas campestris* pv. *sesami* and *Pseudomonas syringae* pv. *sesami*. *Erwinia herbicola* was often associated with the above pathogens. Stem rotting was caused by *Erwinia* sp. [Cited by G.S. Saharan, 1989]
- T. Geremew et al. (1992, 2009, and 2012) reported the following diseases are a major problem: *Xanthomonas sesami* (Blight). It is reported to be damaging under conditions of high rainfall and where high humidity persists for long periods, and less damaging when sesame is grown in more arid areas under furrow irrigation (but when flood-irrigated standing water can encourage the spread of the disease). *Xanthomonas sesami* and *Pseudomonas sesami*) may occur together or separately and can cause considerable yield reduction or complete crop failure in years of favorable conditions for disease development. Sesame blight incidence was reported to vary from 25 to 99% with severity (1-9 score) ranging from 4 to 9.
- A. Azanaw (2015) studied methods (30 minutes soaking of all except hot water which was 10 minutes of the following: gentamicine sulphate 500 ppm, 1% sodium hypochlorite, 5% sodium chloride, 70% ethyl alcohol, hot water at 52°C, distilled water, and untreated) to control *Xanthomonas campestris* pv. *sesami* using 3 cultivars (Abasena, Humera-1 and Gojam Azene). Seeds were put in the dark at 27°C to germinate for 7 days and then the seedlings were measured. The vigor index = germination % x length of the seedling. The bacteria viability (cfu/ml) was determined using a standard methodology.

Soaking agent	Germination (%)	Seed infection (%)	Vigor index	Viability (cfu/ml)
GS	0.29^{ab} (96)	1.89^{a} (77)	0.45^{a} (1.72)	3.41^{a} (2566)
SH	0.30^{a} (98)	1.11^{c}(24)	0.45^{a}(1.83)	2.24^{b} (176)
SC	0.28^{b} (92)	1.90^{a} (76)	0.41^{ab} (1.85)	3.40^{a} (2533)
EA	0.00^{d} (0)	1.13$_{c}$ (27)	0.00^{c} (0)	1.28^{c} (36)
HW	0.25^{c} (79)	1.50^{b} (16)	0.37^{b} (1.64)	0.00^{d} (0)
DW	0.29^{ab} (96)	1.97^{a} (94)	0.39^{ab} (1.64)	3.42^{a} (2614)
UT	0.29^{ab} (97)	1.99^{a} (97)	0.45^{a} (1.83)	3.46^{a} (2869)
CV (%)	3.74	15.54	16.12	12.24
LSD (5%)	0.0087	0.241	0.0552	0.1787

GS = Gentamicine sulphate, SH = Sodium hypochlorite, SC = Sodium chloride, EA = Ethyl alcohol, HW = Hot water, DW = Distilled water and UT = Untreated, LSD = least significance difference and CV = coefficient variation. ( ) are untransformed means.
Means in columns followed by same letter(s) are not significantly different at 5% level of significance

- B.K Yirga and B. Fiseha (2017a) reported the following pathogen: *Xanthomonas campestris* pv. *sesami* (Bacterial blight).
- B.K Yirga et al. (2018a) surveyed 10 locations representative low land areas of western zone of Tigray for 3 years (2015, 2016, and 2017). *Xanthomonas campestris* pv. *sesami* – bacterial blight (83.24%) recorded the highest disease incidence followed by *Sphaerotheca fuliginea* – powdery mildew (78.13%), *Fusarium oxysporum* f. sp. *sesami* – fusarium wilt (78%), phyllody (72.01%) and *Alternaria* spp. – blight leaf spot (72%). Whereas blight leaf spot recorded highest severity (31.33%), followed by fusarium wilt (27.2%), phyllody (25.24%), bacterial blight (22.76%) and powdery mildew (22.6%). The phyllody is vectored by *Orosius albicinctus.*
- B.K. Yirga et al. (2018b) evaluated 17 sesame genotypes in northern Ethiopia during 2014-2015 main seasons against *Xanthomonas campestris* pv. *sesami* – bacterial blight. Sesame bacterial blight severity was recorded among genotypes ranging from 0-100%. HuRc-4, HuAC-3 and the standard check (Setit -1) were among the highest resistant (HR) sesame genotypes. HuRC-4 and HuRC3 genotypes were found resistant to bacterial blight, fusarium wilt and phyllody. Those genotypes could be used for diseases resistant breeding program across different locations.
- W.N. Golla et al. (2019) evaluated the tolerance to *Xanthomonas campestris* pv. *sesami* using 3 improved and 2 local varieties sesame in a farmer field in 2018 at Dansha (16.63N 36.87E, elev. 747). The land had sesame infested with the fungus the previous year. They calculated the Percent severity index (PSI) and the Area under the Disease Progress Curve (AUDPC). They took ratings from 48 to 83 days after planting with the following results.



The local varieties were Gijam-Azene and Hirhr. The other 3 were the improved varieties.

They took data yield and yield components as follow.

Variety	DF	DM	PH	BPP	TSW	SPC	CPP	Yield (kg/ha)	Oil content (%)
Gida-Ayana	55.3^{a}	111.0^{a}	121.6^{a}	4.0^{a}	2.3^{a}	72.9^{a}	53.6^{a}	651.7^{a}	52.8^{a}
Sertit-2	43.0^{b}	92.0^{d}	109.5^{ab}	3.8^{a}	2.1^{ab}	61.3^{ab}	47.0^{ab}	568.5^{b}	47.2^{c}
Humera-1	40.3^{b}	93.0^{cd}	87.8^{bc}	2.67^{b}	1.9^{b}	54.9^{b}	31.0^{cd}	535.6^{c}	50.2^{b}
Gojam-Azene	53.3^{a}	107.0^{b}	93.3^{bc}	2.9^{b}	2.0^{ab}	49.6^{b}	40.3^{bc}	559.6^{bc}	53.0^{a}
Hirhr	43.3^{b}	94.0^{c}	78.53^{c}	2.0^{c}	1.8^{b}	47.3^{b}	23.3^{d}	428.3^{d}	46.8^{c}
LSD (<5%)	4.9	1.6	23.7	0.6	0.3	15.2	9.9	28.7	2.2
CV%	5.6	0.9	12.8	10.3	8.9	14.1	13.5	2.8	2.3

DF=Days to 50% Flowering; DM=Days to 50% Maturity; PH= Plant Height (Cm); BPP=Branches Per Plant; TSW=1000-Seed Weight; SPC=Seed Per Capsule; CPP=Capsule Per Plant; LSD=Least Significance Difference; CV (%)=Coefficient of Variation; Means of the same letters are not significantly different at 5% level of significance.

The correlations were as follow.

Parameters	PH	BPP	CPP	SPC	TSW	Yield (kg/ha)	AUDPC
PH	-						
BPP	0.86**	-					
CPP	0.89**	0.91	-				
SPC	0.56*	0.65**	0.54*	-			
TSW	0.48^{ns}	0.67**	0.72**	0.54*	-		
Yield	0.82**	0.88**	0.9**	0.65**	0.69**	-	
AUDPC	-0.74**	-0.79**	-0.87**	-0.54*	-0.76**	-0.92**	-
PSI	-0.70**	-0.77**	-0.86**	-0.52*	-0.73**	-0.92**	0.98**

PH= Plant Height; BPP= Branch Per Plant; CPP= Capsule Per Plant; SPC= Seed Per Capsule; TSW= Thousand Seed Weight; AUDPC= Area Under Disease Progress Curve; PSI=Percentage Severity Index in the final assessment date; * and ** refers to mean square values significant and highly significant at p<0.05 and p<0.01 repectively; ns=Refers to mean square values not significant at p<0.05.

The data suggests that the disease reduced yields.

- W.N. Golla et al. (2020) evaluated the tolerance to *Xanthomonas campestris* pv. *sesami* at Dansha (16.63N 36.87E, elev. 747). In 2016/17, they screened 70 genotypes and selected 17 (4 existing varieties and 13 advanced genotypes) to fully evaluate in 2017/18 and 2018/19. The criteria for selection of 17 genotypes out of 70 genotypes were based on the reaction to the disease and seed yield. The data for capsules per plant (CPP), seeds per capsule (SPC) and 1000-weight of seeds (TSW), and yield were as follow.

S/no	Genotype	CPP	SPC	TSW (g)	Yield (kg/ha)
1	WARK-059	46.5^{bc}	57.7^{ab}	2.7^{ab}	491.5^{bcde}
2	WARK-068	49.9^{bc}	51.5^{bc}	2.7^{ab}	471.3^{bcde}
3	WARC-063	69.0^{a}	59.7^{ab}	3.0^{a}	716.2^{a}
4	WARK-070	51.5^{abc}	55.7^{ab}	2.7^{ab}	561.7^{abcd}
5	WARK-074	53.1^{abc}	61.3^{ab}	2.4^{b}	604.5^{ab}
6	WARK-082	44.9^{bc}	62.7^{ab}	2.4^{b}	475.3^{bcde}
7	WARK-081	38.7^{bc}	54.6^{bc}	2.4^{b}	354.0^{e}
8	WARK-084	44.1^{bc}	61.5^{ab}	2.7^{ab}	550.3^{bcd}
9	WARK-092	48.1^{bc}	56.5^{ab}	2.8^{ab}	491.3^{bcde}
10	WARK-093	44.7^{bc}	55.1^{abc}	2.4^{b}	488.7^{bcde}
11	WARK-100	46.1^{bc}	43.6 ^{c}	2.8^{ab}	435.3 ^{cde}
12	WARK-103	43.0^{bc}	54.8^{bc}	2.8ab	465.8^{bcde}
13	ACC-202-374	43.3^{bc}	56.8^{ab}	2.8^{ab}	521.7^{bcd}
14	Gida-Ayana	58.1^{ab}	67.2^{a}	2.4^{b}	577.2^{abc}
15	Gonder-1	53.8^{ab}	58.1^{ab}	2.7^{ab}	588.0^{abc}
16	Humera-1 (standard check)	38.5^{bc}	57.7^{ab}	3.0^{a}	542.0^{bcd}
17	Hirhr (local check)	33.8 ^{m}	52.7^{bc}	2.7^{ab}	402.7^{de}
	Mean	47.5	56.9	2.67	514.0
	LSD (5%)	16.7	10.4	0.4	139.9
	CV (%)	21.2	11.0	9.3	16.4

The data for and percentage severity index (PSI)

S/no	Genotype	PSI value	Disease reaction
1	WARK-059	17.2^{d}	MR
2	WARK-068	34.4^{a}	MS
3	WARC-063	9.3e	R
4	WARK-070	17.7^{d}	MR
5	WARK-074	17.7^{d}	MR
6	WARK-082	32.0^{ab}	MS
7	WARK-081	24.3^{cd}	MS
8	WARK-084	17.5^{d}	MR
9	WARK-092	33.1^{ab}	MS
10	WARK-093	32.5^{ab}	MS
11	WARK-100	25.9^{bc}	MS
12	WARK-103	35.7^{a}	MS
13	ACC-202-374	9.8^{e}	R
14	Gida-Ayana	9.3^{e}	R
15	Gonder-1	9.8^{e}	R
16	Humera-1 (standard check)	34.9^{a}	MS
17	Hirhr (local check)	39.15^{a}	MS
	LSD (5%)	6.632	
	CV (%)	16.9	

PSI: percentage severity index; R: resistant; MR: moderately resistant; MS: moderately susceptible; LSD: least significant difference; CV (%): Coefficient of variation. Means followed with the same letters are not significantly different at 5% level of significance.

The correlations were as follow.

Parameter	CPP	SPC	TSW	Yield (kg/ha)	PSI
CPP	-				
SPC	0.29*	-			
TSW	−0.13^{ns}	−0.25^{ns}	-		
Yield	0.51**	0.48**	0.19^{ns}	-	
PSI	−0.45**	−0.38**	−0.17^{ns}	−0.29*	-

**and *; refers to mean square values highly significant at p < 0.01 and significant at p < 0.05, respectively; ns: means not significant at p < 0.05.

They concluded that genotype WARC-063, WARK-074, Gonder-1 and Gida-Ayana were high yielding and resistant to bacterial blight disease and could be cultivated for seed yield in areas with bacterial blight disease problems.

ECUADOR

- M. Bustamonte (2001) in a grower guide reported the following pathogens: *Xanthomonas campestris.* These pathogens thrive best in hot climates with a temperature of 28°C and high relative humidity. The bacterium survives in the seed and is the main form of transmission; it can survive also in plant residues. The inoculum can be spread by splashing infected water. Host crops include Phaseolus, rice and other forage legumes. The most common symptoms are brown spots with colored margins bright yellow at the edges of the affected leaves. If the temperature and high relative humidity persist; the bacteria can also colonize the center of the leaves and lesions expand until they reach the rib. Bacteria-free seed can be used in combination with crop rotation of with non-hosts of this bacterium. Stubble must be removed to reduce inoculum. The use of varieties resistant is still at the experimental level and promises to be a convenient tactic in the future.

HONDURAS

- V.P. Queiroga et al. (2016) reported *Xanthomonas campestris* pv. *sesami* (Manchas angulares) symptoms are angular spots on the leaves that can turn into a blight of light brown color. On the stem and capsules, the spots are oval and brown in color reddish.

INDIA

- Y.P. Rao (1962) reported a *Xanthomonas* sp. isolated from sesamum plants in 1957-58 with severe stem blight appears to be a distinct strain of *Xanthomonas sesami* in causing light brown spots on leaves and stems but not affecting the capsule. This is the first record of the bacterial disease on this host in India. [Cited by G.S. Saharan, 1989]
- Y.P. Rao and J.C. Durgapal (1966) reported that *Xanthomonas sesami* was effectively eradicated when infected seeds were treated with hot water at 52°C for 10 minutes or soaked in a missed solution of Agrimycin-100 (0.025%) and Wettable Ceresan (0.05%) for 6 hours. [Cited by J.C. Durgapal et al., 1969b]
- A.C. Jain and S.N. Kulkarni (1967) reported there was considerable variation in the reaction of sesame vars. To *Xanthomonas sesami.* T-58 proved resistant, M3-2 was highly susceptible, and the rest were either susceptible or semi-resistant. [Cited by G.S. Saharan, 1989]
- R.N. Singh (1969) reported a first report of *Xanthomonas sesami* from Uttar Pradesh. Two strains, namely Kanpur strain and Fyzabad strain, of the pathogen with similar morphological, cultural and biochemical but differing pathological characters are reported. It is further observed that the Fyzabad strain of the bacterium was found to cause higher disease-incidence and more frequently proved fatal. [Based on abstract]
- J.N. Chand et al. (1970a) reported *Xanthomonas sesami* symptoms were more severe on young than an old leaves and late sowing (July) resulted in plants remaining stunted due to the disease whereas growth was good after June sowing. Bacteria multiplied rapidly in the leaves until the 3rd day when their number was maximum, but they were x10 more numerous in young than in old leaves. *X. sesami* is reduced by seed treatment with Ceresan wet and Streptocycline, but 24 days after sowing all parts of the plant were infected, which indicated rapid secondary spread of the disease. [Cited by M.L. Verma, 1985, and G.S. Saharan, 1989]
- J.N. Chand et al. (1970b) reported *Xanthomonas sesami* causes considerable losses in Madhya Pradesh. Seed soaked for 30 min. in a mixture of Ceresan wet (0.1%) and Streptocycline (1000 ppm) and Ceresan wet alone gave least seedling infection.
- R.N. Singh (1970) reported both the bacterial leaf spot (*Pseudomonas sesami*) and leaf blight (*Xanthomonas sesami*) pathogens of sesamum failed to survive in debris for more than 45 days in sterilized soil and 7 days in unsterilized soil. The pathogens in the seed were eradicated by treating seed in hot water at 52°C for 10 minutes or by soaking the seeds in a mixed solution of Acrimycin-100 (0.025%) and wet Ceresan (0.05%) at room temperature for 9 hr. Secondary infections in the field were prevented by spraying Streptocycline (0.3 gm in

2.5 gallons of water) as a prophylactic measure on 25 days old seedling followed by 3 more applications at an interval of 15 days.

- B.N. Shukla et al. (1972) reported in diseased leaves with *Xanthomonas sesami* all the sugars were markedly reduced. Maximum reduction was in glucose indicating that the organism utilizes all types of sugars and prefers glucose.
- B.N. Shukla et al. (1976) reported younger leaves of sesame, which are more susceptible to *Xanthomonas sesami*, had more stomata and a higher N and moisture content than did older ones.
- J.C. Durgapal (1977) reported an albino isolate of *Xanthomonas sesami*. Typically, it is yellow. On young and healthy host plants, the white and yellow forms produced symptoms of the disease on inoculation. Both forms were similar when compared for their morphological, cultural, biochemical characteristics, and bacteriophage susceptibility.
- M.L. Nayak and R.K. Sharma (1980) reported *Xanthomonas campestris* pv. *sesami* infected both sesame and *Acanthospermum hispidum* growing nearby at Jabalpur. Cross inoculations were positive. The bacterium could survive on dry, hanging leaves on the weed plants until the next season, thus providing a source of infection for the sesame crop.
- R.T. Sapkal (1980) found seed treatment with Streptomycin sulphate, Pausamycin, and Plantormycin checked the growth of *Xanthomonas sesami* and infection of seedlings. [Cited by M.L. Verma, 1985]
- M.M. Satour (1981) reported the presence of *Xanthomonas sesami* (Leafspot).
- S. Maiti et al. (1985) reported bacterial blight, *Xanthomonas campestris* pv. *sesami* is serious during the monsoon and to young plants.
- M.L. Verma (1985) reported *Xanthomonas campestris* pv. *sesami* (Bacterial blight) is a major disease with the following symptoms: Small, water soaked translucent light brown to dark brown, circular spots on cotyledonary or full grown leaves, later becoming angular or irregular, exudate on lesions. Defoliation and stem infection.
- Anon (1992a) in a grower guide reported *Xanthomonas campestris* pv. *sesami* (Bacterial blight) spots appear from 4-5 leaf stage of the crop and continue until maturity. Water soaked, small and irregular spots are formed on the leaves which later increase in number and turn brown under favorable conditions; blighting occurs. Severely infected leaves defoliate. Later, the spots are formed on the twigs which bears poor capsules.
- P. Kumar and U.S. Mishra (1992) reported sesame diseases were monitored in Uttar Pradesh. In 1987, 12 diseases were recorded and in 1988 powdery mildew [*Oidium sesami*] was also recorded. Leaf and stem spot caused by *Corynespora cassiicola* was the predominant disease (28%) followed by leaf spots caused by *Cercospora sesami* [*Mycosphaerella sesamicola*], *Xanthomonas* [*campestris* pv.] *sesami* and *Alternaria sesami* (11-18%). The remaining diseases reached disease intensities of 10%. Disease intensity was higher in 1987 than in 1988 due to drought. A new leaf spot disease caused by *Curvularia fallax* was recorded for the first time in India. Most of the common diseases of sesame caused yield losses of 20-40%. [Based on abstract]
- K. Satyagopal et al. (2014) in an IPM manual reported *Xanthomonas campestris* pv. *sesami* was a regional problem in Assam, Uttar Pradesh, Madhya Pradesh, and Delhi.
- K.N. Gupta et al. (2018) reported *Xanthomonas campestris* pv. *sesami* (Bacterial blight) causes purple brown specks on leaves, which develop in to large spots and defoliate the plants. Bacterial leaf spot of sesame affects the plant at all stages of growth. It infects the seed , which is one of the major methods for dispersing the disease. The disease may be alleviated by using Nitrogen @45 kg/ha or destruction of collateral hosts.
- Anon. (n.d.k) reported *Xanthomonas campestris* pv. *sesami* (Bacterial leaf spot) causes a major disease.

MALAWI

- W. Van Den Bos and C.J. Zee (2016) in a grower guide reported the following: *Xanthomonas sesami* and *Pseudomonas sesami.* Both pathogens may occur together or separately and can cause complete crop failure in years of favorable conditions for disease development. Bacterial blight incidence and severity varies depending on topography, altitude, and weather conditions. Water logging encourages the spread of the disease. For control, use of clean seed, residue removal, burning, deep ploughing, and crop rotation may control blight incidence. So far, no Bacterial blight tolerant varieties are available in Malawi.

MEXICO

- M.M. Satour (1981) reported the presence of *Xanthomonas sesami* (Leafspot).
- R. Felix-G. et al. (2019) reported *Xanthomonas campestris* pv. S*esami* during the rainy season (August–September) when temperatures ranged between 27–40°C. The symptoms were lesions on leaves, petioles, stems and capsules. Up to 100% incidence was observed, and up to 50% of the foliage exhibited symptoms under field conditions. On the left the disease in the field on Pachequeno and on the right induced from an isolate in the greenhouse on Cola de Borrego.

NICARAGUA

- Anon. (1998b and 2009a) in grower guides reported Angular spots (caused by *Xanthomonas campestris* pv. *Sesami*). Angular spots that can be turn to a clear brown blotch. In the stem and capsules the spots are oval and colored reddish brown.

NIGERIA

- A.D. Apka et al. (1988) evaluated severity of bacterial blight (*Xanthomonas campestris* pv. *sesami*) using 10 varieties in pot and field trials conducted during the 1983 and 1984 wet seasons (June–September) at Samaru, Zaria (11.16N 7.64E). Late (August) sowing reduced plant growth and yield without a significant effect on either the incidence or severity of the disease. The number of leaves shed was, however, significantly increased with late sowing while the interaction between sowing dates and varieties was also highly significant. Symptoms appeared earlier and secondary spread in the field was faster with early (June) sown crops. [Based on abstract]
- J.E. Onyibe et al. (2005) in a grower guide reported the following pathogen: *Xanthomonas campestris* pv. *sesami.* The initial symptoms are spots on the leaves resulting in the drying of the growing trips. The spot remains small, and the surrounding tissue dies. On heavy infestation, leafspots merge resulting in larger areas of leaves heavily infected. The pathogen also infects the terminal buds from where the pathogen enters the seeds This disease is however not very serious hence routine cultural practices are sufficient to control it.
- J.B. Kabeh (2017b) reported *Xanthomonas campestris* pv. *sesami* is a minor disease that attacks the leaves and branches and prevents germination and growth.

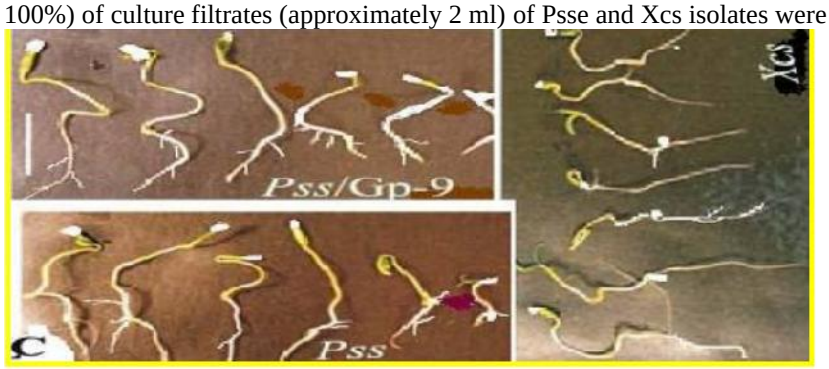
PAKISTAN

- M.A. Akhter (1986) reported a first record of *Xanthomonas campestris* pv. *sesami.*
- S. Bashir et al. (2007) studied the role of *Pseudomonas syringae* pv. *sesami* (P) and *Xanthomonas campestris* pv. *sesami* (X), alone and combination, in symptoms development of bacterial blight in sesame. Highest leaf infection of 80.6 % occurred in plants inoculated with both the pathogens together as compared to individual inoculations (P = 75.6% and X = 50%). The control plants remained asymptomatic and continued to grow healthier. Significant variability among the two pathogens was noted on defoliation (5%) and stem infection (47.16%) respectively, in case of combined inoculation as against 38 % and 36.66 % in individual inoculations. Responses in stem infection were similar, although in some cases stem tended to be more susceptible. Highest stem infection (47.16%) was observed for P+X, followed by X and P inoculations showing 43.16 and 26.66% infections, respectively. Disease progress was initially slow, and the plants treated with P and X developed small chlorotic and necrotic areas, but it was severe after two weeks when mixture of P+X was used as inoculum. Initially necrotic spots produced by P were small in size (1-3 mm in length) as compared to by X (2-

4mm in length) but after 4 weeks of inoculation, the necrotic spots coalesced and caused defoliation in both cases. [Authors comment: the text data and figures conflict. Took the data from the abstract.]

- S.F. Naqvi et al. (2012) evaluated 149 genotypes for resistance against the sesame bacterial blight (*Xanthomonas campestris* pv. *sesami*) which is posing great threat to sesame in Pakistan. None was immune to the bacterial blight, whereas 3 lines were highly resistant, 2 lines were marked as resistant, 10 lines were found to be moderately resistant, 49 lines were categorized as moderately susceptible, 40 were susceptible and the highly susceptible group comprised of 15 lines.
- S.S. Firdous et al. (2013) used different bioassays to detect secondary metabolites produced by *Pseudomonas syringae* pv. *sesami* (Psse) and *Xanthomonas campestris* pv. *sesami* (Xcs) virulent isolates. The bioassays were antibacterial activity, phytotoxic activity, potato tuber outgrowth and seedling assay that included qualitative, semi quantitative and quantitative. In qualitative assay, phytotoxic activity of cell free culture filtrates of Psse-1, Psse-2and IBD-1 of Xcs isolates were applied on non-host plant brinjal and host sesame leaves, and symptoms were observed. Psse-2 isolate elicited water soaking and chlorosis symptoms on both tested plants as produced by pathogen, while Psse-1 showed only water soaking and necrosis symptoms. Psse-2 isolate only induced hypertrophy outgrowth in potato tuber discs, neither Psse-1 nor IBD-1 isolate induces this outgrowth on potato tuber discs. Antibacterial activity was also checked against three pathogenic bacteria such as *Salmonella* sp., *Pseudomonas* sp., and an unknown bacterial pathogen. Results showed that Psse-1 and Xcs isolate showed inhibition zones against only unknown bacterial pathogen but Psse-2 isolate did not exhibit any such zones against the tested bacterial pathogens. Moreover, biological effects of different concentrations of culture filtrates of Psse and Xcs isolates on sesame susceptible and resistant seedlings showed that all tested culture filtrates illustrated sesame root and shoot inhibition, while the inhibition recorded was more against Psse-2 isolate culture filtrate than others. Xcs and Psse-1 showed less inhibition and effective at 70 and 100% concentrations. Over all inhibition was less in tolerant than susceptible genotypes. Present results showed that Psse isolates produced two different classes of toxins, chlorosis as well as necrosis. Chlorosis inducing toxins did not show antibacterial activity but could be detected in potato tuber discs bioassay. On the other hand, necrosis inducing toxin showed antibacterial activity against unknown bacterial pathogen. Seedling bioassay also shown that chlorosis inducing toxin was more effective in inhibition of seedlings then necrosis production toxin. Photo below is Xcs isolate induced blight like necrosis on sesame.

They also showed the effects on sesame seed germination. Isolates at different concentrations (0, 30, 50, 70 and 100%) of culture filtrates (approximately 2 ml) of Psse and Xcs isolates were applied 2 times within 4 days.



- S.F. Naqvi et al. (2013) evaluated biocontrol efficiency using 4 sesame lines (95001, 96007, 96019, and 20003) that were found to be moderately resistant to *Xanthomonas campestris* pv. *sesami* in previous studies. The results were as follow (isolates FD-9, FD-17, ID-3, TTS-7 and GJ-1 were *Pseudomonas fluorescens* and isolates

FD-21, ID-12 and GJ-4 were *Bacillus subtilis* and TTS5 as *Paenibacillus polymyxa*).

Isolates/Lines	95001		96007		96019		20003	
	DI (%)	BE (%)	DI (%)	BE (%)	DI (%)	BE (%)	DI (%)	BE (%)
FD-9	9 a	51 bc	10 def	48 bcd	8 de	49 d	6 defg	55 abc
FD-17	11 cd	40 cd	11 cde	43 cd	9 cd	35 cde	7 cdef	43 bcd
FD-21	12 c	34 d	13 c	33 de	10 c	32 de	8 bcd	33 bcde
ID-3	4 f	77 a	5 g	77 a	3 g	81 a	3 g	78 a
ID-12	6 ef	64 ab	8 f	60 ab	5 f	63 ab	4 fg	62 ab
TTS-5	12 c	32 d	11 cde	41 cd	11 bc	22 e	8 bcd	28 cdef
TTS-7	8 e	55 bc	9 ef	53 bc	7 ef	55 bc	5 efg	62 ab
GJ-1	16 b	14 e	16 b	17 e	12 b	16 ef	10 ab	11 ef
GJ-4	11 cd	43 cd	12 cd	37 cd	11 bc	24 e	9 abc	23 def
Control	18 a	0 e	19 a	0 f	15 a	0 f	12 a	0 f

DI= Disease Incidence, BE= Biocontrol efficiency
Figures with different alphabets are significantly different from each other

- I. Rehman et al. (2013) studied the effects of different filtrates (0, 1, 2, 3, and 4%) of *Xanthomonas campestris* on seed germination (height and root length) of sesame seeds. Smallest root and seedling height was obtained with 4% culture filtrate while there was normal growth in control sesame seedlings as shown below.

Effect of different concentrations of culture filtrate on length of root and whole seedling (A) control (B) 1% filtrate (C) 2% filtrate (D) 3% filtrate I 4% filtrate.

- M. Inam-ul-Haq et al. (2016) reported sesame is an important crop in Pakistan but bacterial blight incited by *Xanthomonas campestris* pv. *sesami* (Xcs) is most a serious and devastating disease of sesame responsible for colossal losses. For decision of effective management strategy, proper identification of pathogen is pre-requisite. The present study was designed to evaluate ELISA with polyclonal antibodies (Pabs) for detection of Xcs with a fact that ELISA is cost effective and can be used for screening of large samples. Pabs were prepared in rabbits against pure isolate of Xcs. Direct antigen coated (DAC)- ELISA was used for the analysis of pathogen in sesame germplasm obtained from NARC (Islamabad). Pathogens from 29 sesame varieties, categorized from resistant to susceptible, were isolated and used as an antigen. After incubation, OD was calculated at 405 nm and results revealed that lowest reaction (0.068) was observed in highly resistant sesame genotypes i.e., SG-22 and SG-55. While varieties SG-34, SG-33 and SG-72 were categorized as resistant based on reactivity (0.073). Thus, it is concluded that ELISA with Pabs should be preferred for detection of Xcs because of the fact that they are more stable, target multiple epitopes on single antigen and are easy to produce. [Based on abstract]

PARAGUAY

- L. Ayala et al. (2010, 2011, and 2013b) in grower guides reported the following pathogen: *Xanthomonas campestris.*
- F. Alvarez and C. Grabowski (2013) evaluated the potential inductor effect of the Ka´a he´e extract, a commercial product with a mixture of trace elements and plant extracts, Acibenzolar-s-methyl (ASM) and Fosetyl-Al, against the bacterial spot caused by *Xanthomonas campestris* pv. *sesami* (Xcs) using in *in vitro* bacteria growth and the intensity of disease in sesame plants. The Ka´a he´e extract and ASM are considered resistance inducers because they not exert direct antimicrobial action on Xcs and reduce the intensity of bacterial spot in sesame plants. The Fosetyl-Al and the product with a mix of trace elements and plant extracts are not considered resistance inducers because they have antimicrobial activity *in vitro* and do not significantly reduce the severity of bacterial spot.

REPUBLIC OF KOREA

- S. Lee et al. (2005) observed *Xanthomonas campestris* pv. *sesami* leaf symptoms initially appeared as water-soaked spots that gradually enlarged, became necrotic, and were often bordered by a small zone of lemon yellow tissue. In the case of severe infection, dead leaves defoliated. Isolations from diseased leaves yielded nearly pure cultures of a yellow-pigmented bacterium typical of a xanthomonad. This is the first report in Korea. Symptoms of bacterial blight of sesame are difficult to differentiate with the bacterial leaf spot caused by *Pseudomonas syringae* pv. *sesami.*

SUDAN

- K.A. Sabet and W.J. Dowson (1960) reported bacteria isolated from small, sharply defined, dark brown spots were identical with those from light brown spots and the latter caused dark brown spots in inoculations. It was concluded that both types of lesions are produced by *Xanthomonas sesami* and probably the differences are attributable to variations in the environment. [Cited by G.S. Saharan, 1989]
- K.A. Sabet (1967) reported sesame grown under rain-cultivation is severely affected by two types of leaf spotting from *Xanthomonas sesami*. In one the spots are usually small, 2–4 mm in diameter, dark red-brown to black in color, somewhat translucent, often angular with sharply defined margins, and may coalesce to form irregular lesions. The dead tissue of the spot later dries up and becomes brittle. In the other type the spots are large, 4–14 mm in diameter or more, greyish or light brown, usually opaque with somewhat diffuse margins, often irregular and frequently coalescing. Affected tissues become wrinkled before they dry. The first type is more often found towards the top of the plant while the second type is more frequently encountered towards the base. [Based on abstract]
- H.A. Habish and A.H. Hammad (1969) reported seed or soil inoculations with *Xanthomonas sesami* produced small, water soaked, dark green, marginal spots on the lower surface of cotyledons. In severe infections the lesions spread over the whole cotyledon, which became dry. Mild attacks resulted in scattered dry brown spots. Infection of growing point caused seedling death, especially in more susceptible varieties. Comparison with leaf inoculation and natural field infection showed that seedling infection could be used as a valid test for grading resistance of a large number of varieties within a short period under uniform conditions. [Cited by G.S. Saharan, 1989]
- H.A. Habish and A.H. Hammad (1970) reported seedling infection of sesame from *Xanthomonas sesami* was most severe at soil temperatures of 20-26°C and also occurred at 39°C but not at 40°C. The incidence of leaf spot was slightly affected by variation in soil moisture between 20 and 40% and in relative humidity between 70 and 85%, but the disease was most severe at 30-40% and 75-80% respectively. Seedling resistance was increased by the applications of N at 45 kg/ha, but at 90-135 kg, germination and growth were retarded. [Cited by G.S. Saharan, 1989]
- H.A. Habish and A.H. Hammad (1971) reported *Xanthomonas sesami* (Leaf spot of sesame) survived in soil for 4-6 months (longer than other closely related spp.) and on seeds for up to 16 months, giving infected seedlings. Of 15 chemicals tested for seed treatment Abavit B and Formalin were the most effective followed by Fertix 6704. [Cited by G.S. Saharan, 1989]
- M.M. Satour (1981) reported the presence of *Xanthomonas sesami* (Leafspot).
- H.E. Osman (1985c) stated *Xanthomonas sesami* is a serious disease that may limit sesame production in Sudan.
- A.M Abdul Rahim and F. S. Adam (1990) reported isolates of *Xanthomonas campestris* pv. *sesami* were inoculated into several cultivars. Seven cultivars proved resistant, and three (*cvs.* Tozi 3, S-76-22 and K112) were highly resistant.
- A.R.C. Umaima (pers. comm. 2021): *Xanthomonas campestris* pv. *sesami* (Bacterial leaf spot) is a current problem. The symptoms are water-soaked spots on the under-surface of leaves; then on the upper surface, dark

brown in color and increase in size, coalesce together forming irregular brown patches and cause drying of leaves, petioles and stems.

TURKEY

- N. Isler et al. (n.d.) reported the following pathogen: *Xanthomonas campestris* pv. *sesami.* For control, plant early, use resistant varieties, and remove crop residues.

UNITED STATES

- C.A, Thomas (1965b) reported that Venezuela 51 susceptibility to *Xanthomonas sesami* increased under short (12 hrs.) photoperiod whereas that of Early Russian was increased by N under short but little affected under long (16 hrs.) photoperiod.
- M.M. Satour (1981) reported the presence of *Xanthomonas sesami* (Leafspot).
- T. Isakeit et al. (2012) reported extensive leaf spots (10 to 30% leaf area affected) occurred on a commercial planting of sesame in Hidalgo County and to a lesser extent (1 to 5% leaf area) on leaves of several varieties in experimental trials in Colorado and Victoria Counties in 2010. The leaf spots were light to dark brown, somewhat circular, and 1 to 3 mm in diameter. *Xanthomonas campestris* pv. *sesami* was isolated from the leaf spots. Currently, acreage of shatter-free varieties of sesame is increasing in arid areas of Texas, Oklahoma, and Kansas. In such areas, the yield impact of this disease is likely to be minimal, except in years with above-average rainfall.

VENEZUELA

- G. Malaguti (1971 and 1973) reported a leaf spot caused by *Xanthomonas* sp. [probably *Xanthomonas sesami*] attacks plants of all ages ,particularly in the rainy season or during periods of high relative humidity, mostly at night. Extensive damage may be caused to leaves, petioles, flowers and stems resulting in defoliation and sterility. [Cited by G.S. Saharan, 1989]
- B. Mazzani et al. (1981b) reported the presence of *Xanthomonas sesami* (Bacterial leaf spot) is one of the major diseases.

C3.1.1b *Xanthomonas axonopodis* pv. *ricini* (1 May 2021)

Synonym: *Xanthomonas ricinicola*

Family: Xanthomonadaceae

Definition: Amount of tolerance to *Xanthomonas axonopodis* pv. *ricini* (Yoshii & Takimoto) Vauterin, Hoste, Kersters & Swings.

(Wikipedia, 1 May 2021) **Citrus canker** is a disease affecting *Citrus* species caused by the bacterium *Xanthomonas axonopodis*. Infection causes lesions on the leaves, stems, and fruit of citrus trees, including lime, oranges, and grapefruit. While not harmful to humans, canker significantly affects the vitality of citrus trees, causing leaves and fruit to drop prematurely; a fruit infected with canker is safe to eat, but too unsightly to be sold.

The disease, which is believed to have originated in Southeast Asia, is extremely persistent when it becomes established in an area. Citrus groves have been destroyed in attempts to eradicate the disease. Brazil and the United States are currently suffering from canker outbreaks.

References:

CHINA

- L.L. Li (1988) reported *Xanthomonas ricinicola* (Bacterial wilt) causes minor or regional damage to sesame.

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C4 Order: Entomoplasmatales Tully et al. 1993

(Wikipedia, 16 Apr 2021) **Entomoplasmatales** is a small order of mollicute bacteria.

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C4.1 Family: Spiroplasmataceae (ex Skripal' 1974) Skripal' 1983

(Wikipedia, 16 Apr 2021) ***Spiroplasma*** is a genus of Mollicutes, a group of small bacteria without cell walls. *Spiroplasma* shares the simple metabolism, parasitic lifestyle, fried-egg colony morphology and small genome of other *Mollicutes*, but has a distinctive helical morphology, unlike *Mycoplasma*. It has a spiral shape and moves in a corkscrew motion. Many *Spiroplasma* are found either in the gut or haemolymph of insects where they can act to manipulate host reproduction or defend the host as endosymbionts. *Spiroplasma* are also disease-causing agents in the phloem of plants. Spiroplasmas are fastidious organisms, which require a rich culture medium. Typically they grow well at 30°C, but not at 37°C. A few species, notably *Spiroplasma mirum*, grow well at 37°C (human body temperature), and cause cataracts and neurological damage in suckling mice. The best studied species of spiroplasmas are *Spiroplasma poulsonii*, a reproductive manipulator and defensive insect symbiont, *Spiroplasma citri*, the causative agent of citrus stubborn disease, and *Spiroplasma kunkelii*, the causative agent of corn stunt disease.

The following species have been reported to cause diseases, produce a toxin, inhibit germination, or affect seed quality.

- C4.1.1 *Spiroplasma* spp.
- C4.1.1a *Spiroplasma citri*

C4.1.1 *Spiroplasma* spp. (25 Apr 2021)

Family: Spiroplasmataceae

Definition: Amount of tolerance to *Spiroplasma* spp. Saglio et al. 1973

(Wikipedia, 25 Apr 2021) ***Spiroplasma*** is a genus of Mollicutes, a group of small bacteria without cell walls. *Spiroplasma* shares the simple metabolism, parasitic lifestyle, fried-egg colony morphology and small genome of other *Mollicutes*, but has a distinctive helical morphology, unlike *Mycoplasma*. It has a spiral shape and moves in a corkscrew motion. Many *Spiroplasma* are found either in the gut or haemolymph of insects where they can act to manipulate host reproduction or defend the host as endosymbionts. *Spiroplasma* are also disease-causing agents in the phloem of plants. Spiroplasmas are fastidious organisms, which require a rich culture medium. Typically they grow well at 30 °C, but not at 37 °C. A few species, notably *Spiroplasma mirum*, grow well at 37 °C (human body temperature), and cause cataracts and neurological damage in suckling mice. The best studied species of spiroplasmas are *Spiroplasma poulsonii*, a reproductive manipulator and defensive insect symbiont, *Spiroplasma citri*, the causative agent of citrus stubborn disease, and *Spiroplasma kunkelii*, the causative agent of corn stunt disease.

Many *Spiroplasma* strains are vertically-transmitted endosymbionts of *Drosophila* species, with a variety of host-altering mechanisms similar to *Wolbachia*. These strains are from the *Spiroplasma poulsonii* clade and can have important effects on host fitness. The *S. poulsonii* strain of *Drosophila neotestacea* protects its host against parasitic nematodes. This interaction is an example of defensive symbiosis, where the fitness of the symbiont is intricately tied to the fitness of the host. The *D. neotestacea S. poulsonii* also defends its fly host from infestation by parasitic wasps. The mechanism through which *S. poulsonii* attacks nematodes and parasitic wasps relies on the presence of toxins called ribosome-inactivating proteins (RIPs), similar to Sarcin or Ricin.

C4.1.1a *Spiroplasma citri* (16 Apr 2021)

Family: Spiroplasmataceae

Definition: Amount of tolerance to *Spiroplasma citri* Saglio et al. 2013.

(Wikipedia, 16 Apr 2021) ***Spiroplasma citri*** is a bacterium species and the causative agent of Citrus stubborn disease

References:

INTERNATIONAL

- CAB International (accessed 12 Apr 2021) reported sesame was associated with *Spiroplasma citri* (Stubborn disease of citrus).

IRAN

- M. Salehi and K. Izadpanah (2002) reported the disease results in stunting, narrow leaves, interveinal and total leaf chlorosis, rapid decline in flower size and number, bud proliferation and wilting. They identified the disease was caused by *Spiroplasma citri*. They attempted to transmit the disease by 3 species of aphid *Myzus persicae, Aphis fabae, and Acrythosiphon pisi,* but were unsuccessful, but the disease was transmitted by the leafhopper *Circulifer haematoceps*.
- N. Nejat et al. (2007) reported *Spiroplasma citri* was transmitted from infected sesame to healthy carrot, love in a mist, bindweed, bushy wallflower, charlock, garden rocket, Mitre cress, and shepherd's purse by the leafhopper vector *Circulifer* (*Neoaliturus*) *haematoceps.* However, *S. citri* was not transmitted to 28 other crops and weeds.

TURKEY

- H. Baspinar et al. (1993) reported two different insects, *Circulifer haematoceps* (Mulsant and Rey) and *Orosius orientalis* (Matsumura) were identified and reported as vectors of *Spiroplasma citri* and phyllody disease in Turkey. The populations and the disease incidence changed in the spring and late summer as shown in the following graphs.

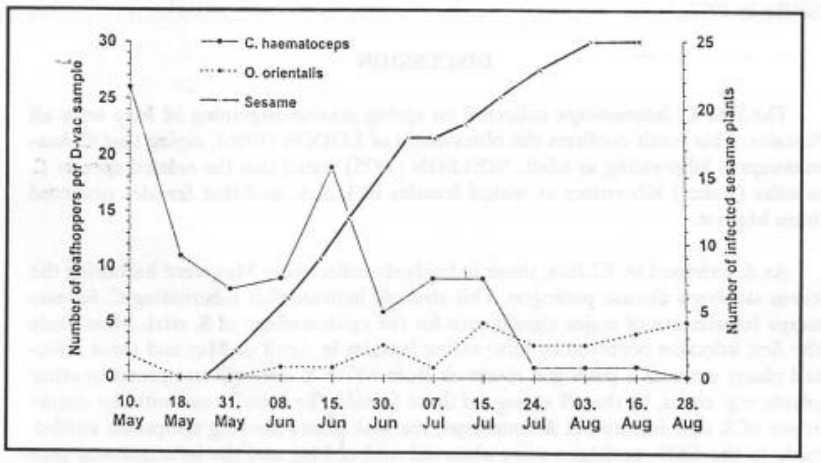

Figure 1 : Population changes of **Circulifer haematoceps** and **Orosius orientalis** as well as number of **Spirolasma citri** and sesame phyllody infected sesame plants in spring sesame in Adana in 1991.

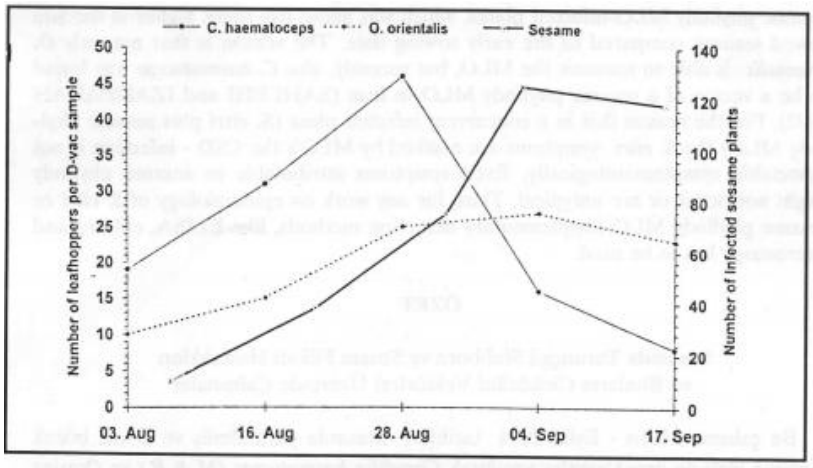

Figure 2 : Population changes of **Circuliferr opacipennis** and **Orosius orientalis** as well as number of **Spirolasma citri** and sesame phyllody infected sesame plants in summer sesame in Adana in 1991.

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C5 PHYLLODY (11 Dec 2021)

Summary:

Photo: K.P. Akhtar et al. (2009a) {Pakistan}

Photo: G.P. Rao et al. (2015) {India}

Arrow points to normal plant.
Photos: E.J.G. Junior et al. (2019) {Paraguay}

Phyllody is a significant disease of sesame globally. It is caused by phytoplasmas, which are bacteria lacking cell walls and are obligate intracellular parasites. Phyllody is a term typically used to describe symptoms including witches' brooming, shoot tip fasciation, floral virescence, reduced leaf size, malformed and discolored growth of tissues (leaves, capsules, flowers). Symptoms are dependent on the stage of crop growth at the time of infection. A plant infected in its early growth remains stunted to about two-thirds of normal plant size, and the entire plant may be symptomatic. The entire inflorescence is replaced by witches' broom symptoms (short, twisted leaves closely arranged on a stem with very short internodes). When infection occurs at later stages, normal capsules are formed on the lower portion of the plants, while phylloid flowers are present on the tops of the main branches and on the new shoots that are produced from the lower portions. The most characteristic symptom of the disease is virescence, which is when flower parts develop into green leaflike structures, followed by abundant vein clearing in different flower parts. A detailed description is as follows: the calyx becomes polysepalous and shows multicostate venation compared to its gamosepalous nature in healthy flowers. The sepals become leaf like but remain smaller in size. The phylloid flowers become actinomorphic in symmetry, and the corolla becomes polypetalous. The corolla may become deep green, depending upon the stage of infection. The veins of the flowers become thick and quite conspicuous. The stamens retain their normal shape, but they may become green in color. Sometimes, the filaments may, however, become flattened, showing its tendency to become leaf like. The anthers become green and contain abnormal pollen grains. In a normal flower, there are only four stamens, but a phylloid flower bears five stamens. The carpels are transformed into a leaf outgrowth, which forms a pseudosyncarpous ovary by their fusion at the margins. This false ovary becomes very enlarged. Inside the ovary, instead of ovules, there are small petiole-like outgrowths, which later grow and burst through the wall of the false ovary producing small shoots. These shoots continue to grow and produce more leaves and phylloid flowers. The stalk of the phylloid flowers is generally elongated, whereas the normal flowers have very short pedicels. Increased IAA content appears to be responsible for proliferation of ovules and shoots. Sometimes, these symptoms are found to be accompanied with yellowing, cracking of seed capsule, germination of seeds in capsules, and formation of dark exudates on the foliage. Normal-shaped flowers may be produced on the symptomless areas of the plants, but such flowers are usually dropped before capsule formation, or the capsules are dropped later leaving the stalk completely bared.

The pathogen is now investigated to be phytoplasma (formerly referred to as mycoplasma-like organism—wall-less bacteria belonging to the class Mollicutes). In Sudan, red varieties of sesame have been found to be affected to the extent of 100%. Incidence and severity appear to vary by variety, with some varieties showing promising tolerance. Sesame phyllody is not transmitted mechanically or by seeds. The disease is transmitted from one plant to another by phloem-feeding leafhoppers. Nymphs of insect are incapable of transmitting the phytoplasma. The pathogen is transmitted by the following leafhopper vectors: *Circulifer haematoceps*, *Deltocephalus* spp., *Empoasca* spp., *Empoasca lybica, Empoasca motti, Hishimonus phycitis, Orosius albicinctus, Orosius argentatus, Orosius cellulosus,* and *Orosius orientalis.* The following phytoplasmas have been identified in sesame: *Candidatus*

phytoplasma asteris (16SrI), *Peanut witches'-broom phytoplasma* (16SrII), *Candidatus* phytoplasma trifolii (16SrVI), and *Pigeon pea witches'-broom phytoplasma* (16SrIX).

(Wikipedia, 3 May 2021) **Phyllody** is the abnormal development of floral parts into leafy structures. It is generally caused by phytoplasma, though it may also be because of environmental factors that result in an imbalance in plant hormones. Phyllody causes the affected plant to become partially or entirely sterile, as it is unable to normally produce flowers.

The condition is also known as **phyllomorphy** or **frondescence**; though the latter may sometimes refer more generically to foliage, leafiness, or the process of leaf growth. Phyllody is usually differentiated from floral virescence, wherein the flowers merely turn green in color but otherwise retain their normal structure. However, floral virescence and phyllody (along with witch's broom and other growth abnormalities), commonly occur together as symptoms of the same diseases. The term **chloranthy** is also often used for phyllody (particularly flowers exhibiting complete phyllody, such that it resembles leaf buds more than flowers), though in some cases it may refer to floral virescence.

(Anon. n.d.k) Phyllody – Phytoplasma

Symptoms: The symptoms start with vein clearing of leaves. The disease manifests itself mostly during flowering stage, when the floral parts are transformed into green leafy structures, which symptoms grow profusely. The flower is rendered sterile. The veins of phylloid structure are thick and prominent. The plant is stunted with reduced internodes and abnormal branching.


Pathogen: It is caused by pleomorphic mycoplasma like bodies present in sieve tube of affected plants, now designated as a phytoplasmal disease.

Disease cycle: The pathogen has a wide host range and survives on alternate hosts like *Brassica campestris* var. *toria, B. rapa*, *Cicer arietinum*, *Crotalaria* sp., *Trifolium* sp., *Arachis hypogaea* which serve as source of inoculum. The disease is transmitted by jassid, *Orosius albicinctus*. Optimum acquisition period of vector is 3-4 days and inoculation feeding period is 30 minutes. The incubation period of the pathogen in leaf hoppers may be 15-63 days and 13-61 days in sesame. Nymphs are incapable of transmitting the phytoplasma. Vector population is more during summer and less during winter months.

Management: Remove all the reservoir and weed hosts; avoid growing sesamum near cotton, groundnut and grain legumes; rogue out the infected plants periodically; spray Monocrotophos or Dimethoate at 500ml/ha to control the jassids

References:

INTERNATIONAL

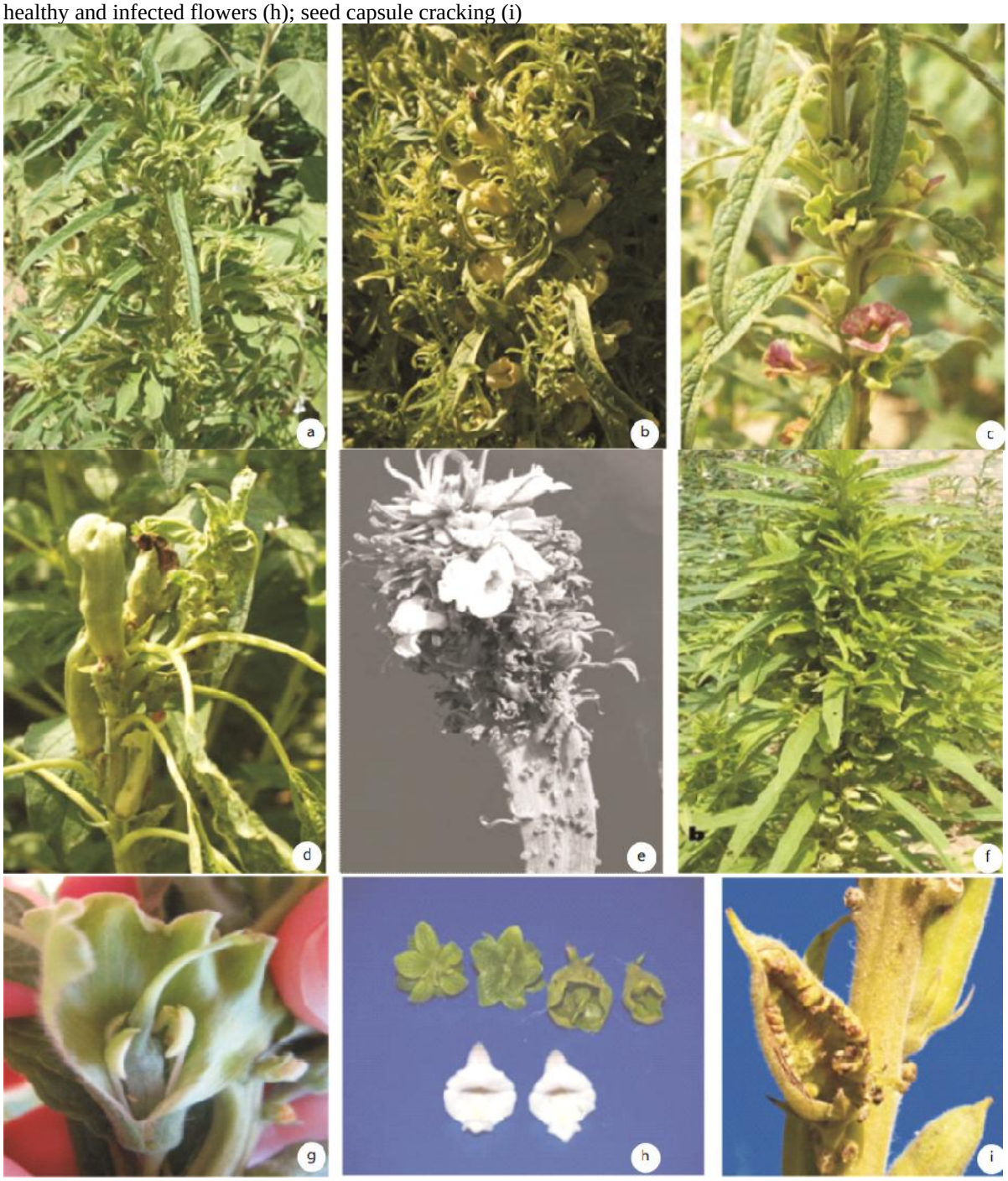
- R.S. Vasuveda (1961) stated that although T.D. McGibbon (1924) seems to be the first to report phyllody, the disease obviously existed before. A diseased specimen of sesame collected from Mirpurkhas (Sind-Pakistan) on 15 October 1908 by C.A. Gammie is preserved in the *Herb. Crypto. Ind. Orient.*, New Delhi. The disease manifests itself in the flowering stage when one or more floral parts are transformed into green leafy structures followed by abundant vegetative growth; the sepals become leaf-like but are smaller in size. The corolla may be partially or completely green depending upon the state of development of the disease. The veins of the sepals and petals in phylloid flowers are usually thick and prominent. The size of the corolla in the case of

phylloid flowers on the main shoots generally get very enlarged. Whereas the corolla in normal flower is zygomorphic, phylloid flowers generally acquire actinomorphic symmetry and the gamopetalous character may become polypetalous. The stamens also turn green in color and in some cases the filaments may be flattened, showing a tendency to become leaf-like. The green anthers are indehiscent and do not contain any functional pollen. The carpels are transformed int two leafy outgrowths which form a pseudosyncarpous ovary by their fusion at the margins. This false ovary becomes very much elongated and flattened. In some cases, it may be replaced by two foliaceous structures, fully separated from each other. Inside the ovary, instead of ovules, a few small petiole-like outgrowths are produced. These later grow, burst though the wall of the ovary and develop into tiny shoots which continue further growth and bear more leaves and phylloid flowers; thus, it appears as if the stalk of the flower has grown through the ovary and has unlimited growth. The affected plants bear small-sized leaves showing marked vein-clearing. The internodes are shortened and there is abundant abnormal branching due to the stimulation of the axillary buds. All these abnormalities result in heavy bundles which make the plants bend down. The plant may be partially or completely phylloid depending on the stage of infection. In partially affected plants the disease expresses itself only at the ends of all or some branches as also on new shoots which are produced on the stem due to stimulation of the axillary buds. The lower portions of the branches bear capsules just like a normal plant. All these capsules, however, contain shriveled up seeds which are not viable. The capsule just below the first-formed phylloid flowers burst by irregular slits thus exposing the green immature ovules fused together in rows. They identified over 35 species of plants that host phyllody in the off-season.

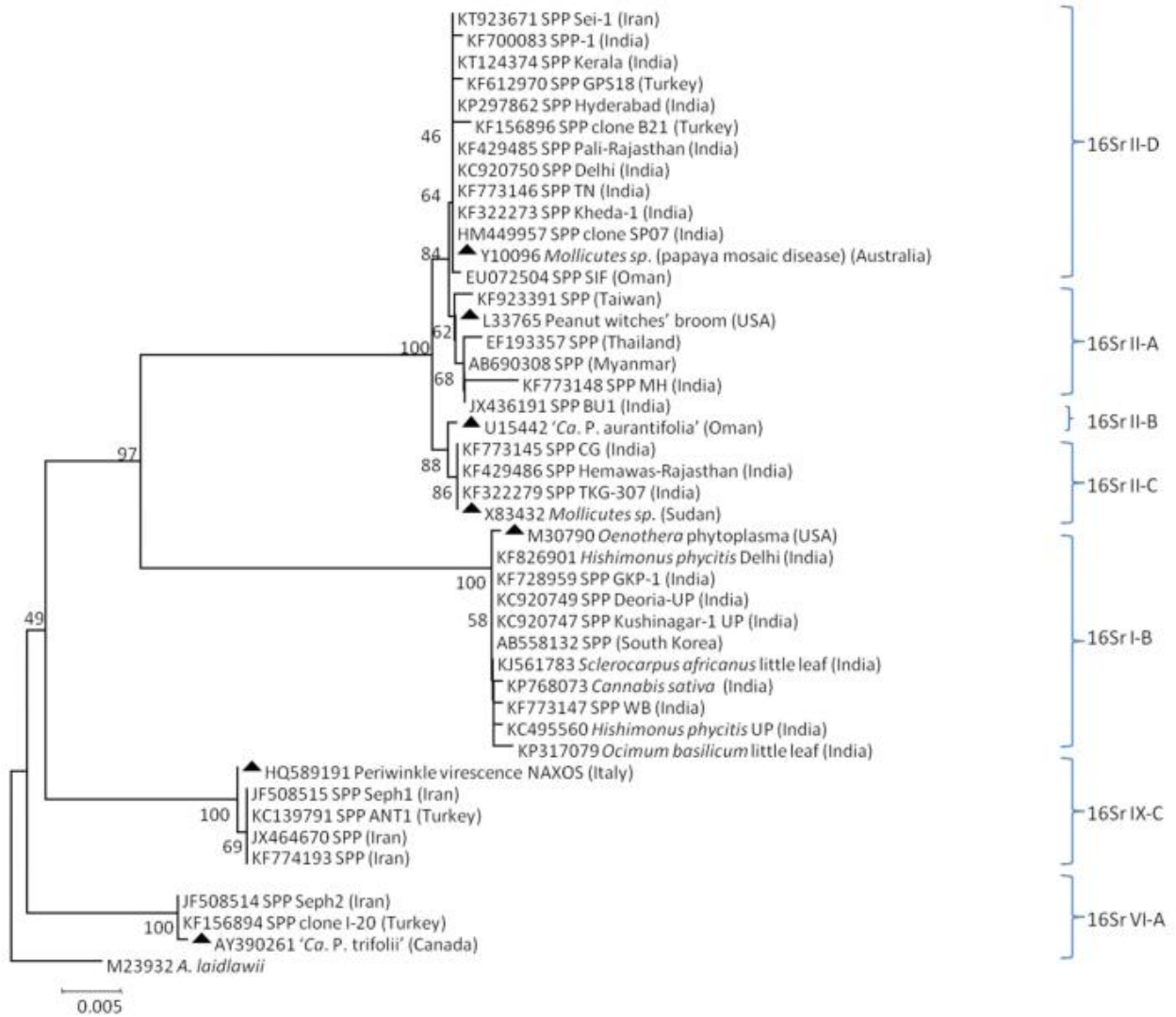
- E.A. Weiss (1971) reported jassids are damaging pests when numbers become large, but one species, *Deltocephalus* spp., is more important as a vector known as phyllody. This is a serious disease in India, Africa, and Asia Minor, and can also be transmitted to other *Sesamum* spp. Thus, control measures to be effective, must also include destruction of alternative hosts of this jassid. The insect become infective for life after a latent period varying with the season, the minimum period being 11 days. Attempts to control this insect in India have not been successful (R.S. Vasuveda, 1954).
- M.O. Khidir (1981a) in a review of sesame in East Africa and the Near East reported the following disease was a problem: phyllody.
- Anon. (2004a) IPGRI descriptor: 10.5.2 MLO transmitted by *Orosius albicinctus* (Phyllody)
  - In each case it is important to state the origin of the infestation or infection, i.e., natural, field inoculation, or laboratory. Also specify the causal organism and the corresponding symptoms. The susceptibility scale is as follows:
    - 1 = Very low or no visible sign of susceptibility
    - 3 = Low
    - 5 = Intermediate
    - 7 = High
    - 9 = Very high
  - The growth state, coded according to the list below at which each reaction was recorded should be appended to the record of that reaction.
    - 1 = Seed
    - 2 = Seedling
    - 3 = Pre-flowering
    - 4 = Early flowering
    - 5 = Mid-flowering
    - 6 = Late-flowering
    - 7 = Maturity
- G.P. Rao et al. (2015) reported an overview on a century progress in research on sesame phyllody disease. Among various biotic stresses, phyllody is a highly destructive disease of sesame. The affected plants become stunted, and the floral parts are transformed into green leaf-like structures followed by abundant vegetative growth resulting in a yield loss up to 34% or even 100% in the cases of severe incidence.

The photos below show sesame plants with different symptoms: little leaf (a), phyllody and witches' broom (b), discoloration of flowers (c), flower virescence (d), shoot tip fasciation I, witches' broom (f), vivipary (g),

healthy and infected flowers (h); seed capsule cracking (i)



The following diagram shows a phylogenetic tree, based on 16S rDNA, showing the relationships among sesame phyllody phytoplasma strains constructed by neighbor joining method using Mega 5.0 software. GenBank accession numbers are specified in the tree; SPP, sesame phyllody phytoplasma. With Mark are the strains classified in the subgroup reported on the left. *Acholeplasma laidlawii* (M23932) was used as an out group. Numbers on branches are bootstrap values obtained for 1,000 replicates (▲ reference strain).



Phylogenetic tree, based on 16S rDNA, showing the relationships among sesame phyllody phytoplasma strains constructed by neighbor joining method using Mega 5.0 software. GenBank accession numbers are specified in the tree; SPP, sesame phyllody phytoplasma. With Mark are the strains classified in the subgroup reported on the left. *Acholeplasma laidlawii* (M23932) was used as an out group. Numbers on branches are bootstrap values obtained for 1,000 replicates (▲ reference strain).

Symptoms, taxonomy and country of phytoplasmas associated with sesame phyllody disease in the world are as follow.

Symptoms	Phytoplasma, group/ subgroup	Detection method	GenBank Accession number	Country	Reference(s)
Flower virescence, phyllody and proliferation	-	Dienes' staining	-	Iran	Salehi and Izadpanah, 1992
Phyllody	Aster yellows, 16SrI-B	PCR/RFLP	KF728952-59	India	Nabi *et al.*, 2015b
Phyllody	Peanut witches' broom, 16SrII-C	PCR/RFLP	KF728953		Nabi *et al.*, 2015a
Witches' broom, phyllody	Aster yellows, 16Sr I-M	PCR	-		Khan *et al.*, 2007; Manjunatha, 2012
Phyllody	Aster yellows, 16SrI-B Peanut witches' broom, 16SrII-C and -D	PCR/RFLP	KF322273-79 KF429485-86 KF437984-87		Madhupriya *et al.*, 2015
Witches' broom	Peanut witches' broom, 16SrII	PCR/RFLP	EU072505	Oman	Al Sakeiti, 2005
Phyllody	Unclassified	PCR/RFLP	Not available	South Korea	Han *et al.*, 1997
Yellowing and dwarfing	Aster yellows	Electron microscopy	Not available	South Korea	Lee *et al.*, 2004
Not described	-	PCR/Hybridization	Not available	Thailand	Nakashima *et al.*, 1995
Yellowing	Aster yellows, 16SrI	PCR	Not available	India	Kumar *et al.*, 2011
Phyllody	Clover proliferation, 16SrVI	PCR/RFLP	Not available	Turkey	Sertkaya *et al.*, 2007
	Clover proliferation, 16SrVI-A	PCR	Not available	Iran	Omidi *et al.*, 2010
Phyllody	Peanut witches' broom, 16SrII	PCR/RFLP	Not available	Iran	Esmailzadeh-Hosseini *et al.*, 2007
Phyllody, abnormal stem curling	Peanut witches' broom, 16SrII-A		KF923391-93	Taiwan	Tseng and Deng, 2014
Stunting, phyllody, no capsule and seeds	Peanut witches' broom, 16SrII-D Pigeon pea witches' broom, 16SrIX-C	PCR/RFLP	KC139791 KC756845-48	Turkey	Catal *et al.*, 2013 Ikten *et al.*, 2014
Phyllody	Peanut witches' broom, 16SrII-D	PCR	KF700083	India	Venkataravanappa *et al.*, 2015, Genbank submission
Virescence, phyllody, yellowing, flower sterility and stem proliferation	Peanut witches' broom, 16SrII-D	PCR/RFLP/Electron microscopy	Not available	Pakistan	Akhtar *et al.*, 2008; 2009
Shoot fasciation (flattening), short internodes, and proliferation of leaf and flower buds	-	Electron microscopy	-	Iraq	Tamimi *et al.*, 1989
Virescence	Aster yellows, 16SrI-B	PCR/RFLP	AB558132	Myanmar	Win *et al.*, 2010
Phyllody and witches' broom	Peanut witches' broom, 16SrII-D	PCR/RFLP	EU072505, EU072504	Oman	Khan *et al.*, 2007
Phyllody	Peanut witches' broom, 16SrII-A	PCR	EF193357, GU004373	Thailand	Martini *et al.*, 2007; Lee *et al.*, 2010
Phyllody	Peanut witches' broom, 16SrII-D	PCR	JN006075, JN006079	Thailand	Panthong *et al.*, 2011, Genbank submission

The following insects have been identified as transmitters of the phytoplasm: Circulifer (=Neoaliturus) haematoceps (Mulsant and Rey), Orosius orientalis (Matsumura) = albicinctus (Distant), Orosius cellulosus,

Hishimonus phycitis. [DRL comment: others have been identified in other publications: *Orosius argentatus*, *Empoasca* sp., *Empoasca lybica*, *Empoasca motti*, and *Deltocephalus* spp.]

- C. Chattopadhyay et al. (2019) reported the following symptoms of phyllody: Affected sesame plants express symptoms, depending on the stage of crop growth and time of infection. A plant infected in its early growth remains stunted to about two-thirds of a normal plant, and the entire plant may be affected. The entire inflorescence is replaced by a growth consisting of short, twisted leaves closely arranged on a stem with very short internodes. However, when infection takes place at later stages, normal capsules are formed on the lower portion of the plants, and phylloid flowers are present on the tops of the main branches and on the new shoots that are produced from the lower portions. The most characteristic symptom of the disease is transformation of flower parts into green leaflike structures followed by abundant vein clearing in different flower parts. The calyx becomes polysepalous and shows multicostate venation compared to its gamosepalous nature in healthy flowers. The sepals become leaf like but remain smaller in size. The phylloid flowers become actinomorphic in symmetry, and the corolla becomes polypetalous. The corolla may become deep green, depending upon the stage of infection. The veins of the flowers become thick and quite conspicuous. The stamens retain their normal shape, but they may become green in color. Sometimes, the filaments may, however, become flattened, showing its tendency to become leaf like. The anthers become green and contain abnormal pollen grains. In a normal flower, there are only four stamens, but a phylloid flower bears five stamens. The carpels are transformed into a leaf outgrowth, which forms a pseudosyncarpous ovary by their fusion at the margins. This false ovary becomes very enlarged and crop. In Sudan, red varieties of sesame have been found to be affected to the extent of 100%. Inside the ovary, instead of ovules, there are small petiole-like outgrowths, which later grow and burst through the wall of the false ovary producing small shoots. These shoots continue to grow and produce more leaves and phylloid flowers. The stalk of the phylloid flowers is generally elongated, whereas the normal flowers have very short pedicels. Increased IAA content appears to be responsible for proliferation of ovules and shoots. Sometimes, these symptoms are found to be accompanied with yellowing, cracking of seed capsule, germination of seeds in capsules, and formation of dark exudates on the foliage (K.P. Akhtar et al. 2009a {Pakistan}; D.M. Pathak et al. 2012 {India}). Normal-shaped flowers may be produced on the symptomless areas of the plants, but such flowers are usually dropped before capsule formation, or the capsules are dropped later leaving the stalk completely bared.

  Affected plants remain partially or completely sterile, resulting in total loss in yield. As much as 10-100% incidence of the disease has been recorded in the sesame crop in India. The yield loss due to phyllody in India is estimated to about 39-74%. The losses in plant yield, germination, and oil content of sesame seeds may be as high as 93.7%, 37.8%, and 25.9%, respectively. It is estimated that a 1% increase in phyllody incidence decreases the sesame yield by 8.4 kg under Coimbatore conditions in India. H.F. Robertson (1928) from Burma reported up to 90% incidence of the disease in the Sagaing and Lower Chin districts. A survey conducted in Thailand during 1969 and 1970 indicated that the phyllody was so severe in northeastern Thailand that farmers decreased the acreage for the sesame. Phyllody is a very serious disease, which can inflict up to 80% yield loss with a disease intensity of 1-80% (P. Kumar and U.S. Mishra 1992 {India}; M. Salehi and K. Izadpanah 1992 {Iran}). The average phyllody incidence is reported to be about 20% with yield losses in sesame seed yield due to phyllody ranges to be 7%–28% in Pakistan (G. Sarwar and M.A. Haq 2006 {Pakistan}; G. Sarwar and K.P Akhtar 2009 {Pakistan}).

  The pathogen is now investigated to be phytoplasma (formerly referred to as mycoplasma-like organism—wall-less bacteria belonging to the class Mollicutes). Light microscopy of hand-cut sections treated with Dienes stain shows blue areas in the phloem region of phyllody-infected sesame plants (K.P. Akhtar et al. 2009a {Pakistan}). The phytoplasma pleomorphic bodies are reported to be present in phloem sieve tubes of affected sesame plants. Electron microscopy has revealed that the big pleomorphic bodies, ranging from 100 nm diameter to 625 nm diameter, are present in the sieve tubes. Generally, the phytoplasmas are round, but some may be 1500 nm long and 200 nm wide. Bodies with beaded structures can also be noticed. The phytoplasmas are bounded by a single unit membrane as is typical for the Mollicutes and show ribosome-like structure and DNA-like strands within. Phytoplasma cells contain one circular double-stranded DNA chromosome with a low G + C contents (up to only 23%), which is thought to be the threshold for a viable genome (A. Bertaccini and B. Duduk 2009 {Italy}). They also contain extrachromosomal DNA such as plasmids. Since phytoplasmas cannot be grown in axenic culture, advances in their study are mainly achieved by molecular techniques. Molecular data on sesame phytoplasmas have provided considerable insight into their molecular diversity and genetic interrelationships, which has in turn served as a basis for sesame phytoplasma phylogeny and taxonomy. Classification of phyllody phytoplasma associated with sesame has been attributed to at least three distinct

strains worldwide including aster yellows, peanut witches' broom, and clover proliferation group (M.A. Al-Sakeiti et al. 2005{Oman}; A.J. Khan et al. 2007 {Oman}). Based on restriction fragment length polymorphism (RFLP) analysis of polymerase chain reaction–amplified 16S rDNA, sesame phyllody phytoplasma infecting sesame in Myanmar (termed as SP-MYAN) belongs to the group 16SrI and subgroup 16SrI-B. Sequence analysis has confirmed that SP-MYAN is a member of *Candidatus Phytoplasma asteris* and it is closely related to that of sesame phyllody phytoplasma from India (DQ 431843) with 99.6% similarity (A.J. Khan et al. 2007 {Oman}; N.K.K. Win et al. 2010 {Thailand}). RFLP profiling and sequencing reveal that phytoplasma associated with sesame phyllody in Pakistan has the greatest homology to 16SrII-D group phytoplasmas (K.P. Akhtar et al. 2009a {Pakistan}), whereas in a separate study from the same country (i.e., in Pakistan), molecular evidence of the cause of the sesame phyllody has been found to be phytoplasma belonging to subgroup 16SrII and its sequence is essentially reported to be identical to that of the phytoplasma causing sesame phyllody in Oman (K.P. Akhtar et al. 2008 {Pakistan). Similarly, phytoplasma causing sesame phyllody in Yazd Province of Iran belongs to the 16SrII group, which is peanut witches' broom phytoplasma (S.A. Esmailzadeh-Hosseini et al. 2007 {Iran}). Interestingly, in the neighboring Turkey, phytoplasma associated with sesame phyllody belongs to 16S rDNA group closely related to clover proliferation group 16SrVI-A (G. Sertkaya et al. 2007 {Turkey}). Witches' broom symptom in sesame resembling sesame phyllody in Oman is caused by the phytoplasma strains (SIL, SIF) clustered with Omani Lucerne witches' broom forming a distinct lineage separate from groundnut witches' broom and sesame phyllody (Thailand) phytoplasma strains (Nakashima et al. 1995, 1999, M.A. Al-Sakeiti et al. 2005{Oman}; A.J. Khan et al. 2007 {Oman}).

The pathogen is transmitted by the leafhopper vectors (order: Homoptera). In India, Thailand, and Upper Volta, sesame phyllody is transmitted by *Orosius orientalis* (Matsumura) (*O. albicinctus*), whereas in Turkey and Iran, sesame phyllody is transmitted by *Circulifer haematoceps* (Mulsant and Rey) (D. Ali et al. 2009 {Iran}). However, S.A. Esmailzadeh-Hosseini et al. (2007) first reported transmission of a phytoplasma associated with sesame phyllody in Iran by *O. albicinctus*. Attempts to transmit the pathogen through sap in Iran and through seed in Thailand have given negative results (A.S. Tan 2010 {Turkey}).

The pathogen has a wide host range and survives on alternate hosts like *Brassica campestris* var. *toria*, *B. rapa*, and *Cicer arietinum*, which serve as source of inoculum. Most optimum acquisition period of vector is 3-4 days, and inoculation feeding period is 30 min. The incubation period of the pathogen in leafhoppers may be 15–63 days and 13–61 days in sesame. Nymphs are incapable of transmitting the phytoplasma. Vector population is more during summer and less during cooler months. There is a significant positive correlation between phyllody incidence with maximum and minimum temperature and negative correlation with maximum relative humidity and rainy days, which could be then consequently related to increase or decrease in vector population in the respective environmental conditions (C.S. Choudhary and S.M. Prasad 2007 {India}). The incubation period is considerably increased during winter months (October-January) due to low temperature. Among the weather factors, the night temperature (minimum temperature) prevailing from the 30th to the 60th day after sowing is found to have a greater increase of disease incidence. The minimum acquisition feeding period has been observed to be 8 h, while the minimum infection feeding period is 30 min during May and June. Both male and female insects are equally efficient in transmitting the pathogen. The nymphs of the insect are capable of acquiring the pathogen, but they are unable to transmit it, as by the time the incubation period is completed, they reach the adult stage. Once the leafhoppers have picked up the pathogen and become infective, the adult leafhoppers remain so throughout the remainder of their lives without replenishment of the pathogen from infected plants. Even a single leafhopper may be able to cause infection. It is interesting that leafhoppers show a marked preference for the diseased plants over healthy ones. The diseased plants have been reported to harbor an insect population about two to six times the population on healthy plants—due to higher moisture, higher nitrogen, and lower calcium and potassium contents of the diseased plants. Lower content of calcium and potassium in the diseased plants is suspected to be the factor vulnerable for easy stylet and ovipositor penetration. Higher incidence of phyllody occurs when sesame crop is fertilized with phosphorus without nitrogen (S.G. Borkar and A. Krishna 2000 {India}); there also exists a positive correlation between days to maturity of sesame crop and phyllody incidence (K. Gopal et al. 2005 {India}).

Selections of disease-resistant sesame lines, which would flower within 40–50 days after sowing, appear to be desirable and important from the yield viewpoint under Indian conditions (S.J. Kolte 1985 {India}; V. Selvanarayanan and T. Selvamuthukumaran 2000 {India}). A single recessive gene governs resistance in cultivated varieties (KMR 14 and Pragati), whereas wild species possess a single dominant gene conferring resistance to phyllody (P.K. Singh et al. 2007 {India}). Phyllody resistance in a land race of sesame is reported to be under the control of two dominant genes with complementary (9:7) gene action (G.G. Shindhe et al. 2011

{India}). Advanced phyllody disease–resistant sesame mutant lines with earliness, more capsules, and high harvest index have been developed in Pakistan These mutant lines can be of great potential use in breeding for disease resistance (G. Sarwar and K.P Akhtar 2009 {Pakistan}).

Insect vector management is the method of choice for limiting the outbreaks of phytoplasmas in sesame. At the time of sowing, soil may be treated with Thimet® 10 G at the rate of 10 kg/ha or with Phorate 10 G at the rate of 11 kg/ha or with Temik® 10 G at the rate of 25 kg/ha to get the management of the disease through vector control (N. Nagaraju and V. Muniyappa 2005 {India}). An effective degree of management is obtained if the aforementioned treatment is combined with spraying of the crop with Metasystox® (0.1%) or with any other effective chemical (H.P. Misra 2003 {India}; T.S. Rajpurohit 2004b {India}). Tetracycline sprays at 500 ppm concentration at the flower initiation stage have proved to be effective against phyllody, but recovery is temporary. A possibility of biochemical control by spraying manganese chloride has been indicated. It appears that manganese chloride oxidizes the phenol and protects or inhibits the enzymes, bringing the auxin level to normal. Once hyperauxin is oxidized, the plant can gain its normal conditions (S.D. Purohit and H.C. Arya 1980 {India}).

An appropriate sowing date may be useful in avoiding severe occurrence of the disease. The incidence of the disease is reported to be reduced considerably by sowing the crop in early August under Indian conditions. The reduced population of the vector in the growth period of sesame plants is perhaps important in keeping the disease under check (S.B. Mathur and J.P. Verma 1973 {India}; N. Nagaraju and V. Muniyappa 2005 {India}).

- N. Ransingh et al. (2021) reported the following symptoms of phytoplasma (Phyllody): The inflorescence is converted into vegetative parts. Except for the stamens, the whole flower is transformed into a leaf-like structure or shows a marked tendency to become leafy. The stamens seldom contain functional pollen, and the plant becomes completely sterile. In the flowering stage, floral parts get transformed; produce abundant vegetative growth and become short in stature. Shoot apex fasciation, flattening of shoot apex, shortened internodes, intense proliferation of leaf and flower buds in a sesame plant are associated with mycoplasma like organism. K.P. Akhtar et al. (2009a) {Pakistan} studied symptomatology of sesame phyllody and reported the following symptoms: seed capsule cracking; formation of dark exudates on foliage; yellowing, shoot apex fasciation; internode elongation; and reduced leaf size and stunting. The disease also shows other symptoms like pale green and bushy plant due to reduction in leaf size, reduced internode length, excessive axillary proliferation, floral malformation, abnormal green structure developed in place of normal flower. The capsule of infected plant after flowering is very small.

  Sesame phyllody is not transmitted mechanically or by seeds. The disease is transmitted from one plant to another by phloem-feeding leafhopper (*Orosius albicinctus*). Nymphs of insect are incapable of transmitting the phytoplasma. Vector population is generally high during summer and low during winter months. Sesame phyllody phytoplasma has a wide host range. It attacks 91 plant species belonging to 36 genera distributed in 12 families. It includes important crop plants like Egyptian clover, carrot, Indian mustard, lucerne, radish, sun hemp, and Indian rape (H.S. Sahambi 1970 {India}). Phyllody disease also seen in chickpea (M. Saqib et al. 2005 {Australia}; K.P. Akhtar et al. 2009b {Pakistan}), brinjal (A.K. Das and D.K. Mitra 1998 {India}), parthenium (T. Tessema et al. 2010 {Ethiopia}; K. Kirdat et al. 2018 {Pakistan}), wild niger and periwinkle (M. Omidi et al. 2010 {Iran}).

  Phyllody can be managed by various ways. The population of the vector should be low during the growth period of the sesame crop to keep the disease under check (S.B. Mathur and J.P. Verma 1973 {India}). Seed treatment with imidacloprid and spraying of thiamethoxam effectively reduces vector population and thereby reduces the disease incidence

AUSTRALIA

- D.F. Beech (1981a) reported the presence of mycoplasma-like organisms (Witches broom and big bud) in sesame in 1958, 1975, and 1977. The brown leafhopper – *Orosius argentatus* is considered a serious pest since it ìs the vector for phyllody.
- D.F. Beech (1981b) reported phyllody (“Green flowers”) is possibly the most destructive disease, particularly in India (as high as 100%) and Myanmar (as high as 90%) [Authors comment: Beech spent considerable time in Myanmar and thus, he was very familiar with the disease]. In Australia it has been as high as 40%. The disease is characterized by the transformation of the floral parts into green leafy structures. Inside the ovary, a few small petiole-like outgrowths are produced instead of ovules. These may grow, burst through the wall of the ovary, and develop into tiny shoots which continue further growth and bear more leaves and phylloid flowers. From this it appears as if the stalk of the flower is growing through the ovary. It is accompanied by abundant

vegetative growth and the plants bear small-sized leaves showing marked vein-clearing. The internodes are considerably shortened, and there is abundant branching due to the stimulation of axillary buds. Affected plants may be partially or completely phylloid depending on the stage of growth at infection. In partially affected plants, the disease expressed itself only at the ends of branches or on new shoots produced on the stem due to stimulation of the axillary buds. The lower portions of the branches may bear capsules just like a normal plant. These capsules, however, contain shriveled non-viable seeds. The capsules just below the first formed phylloid flowers burst by irregular slits thus exposing green immature ovules fused together in rows.

Phyllody has been shown to be associated with the presence in the phloem of a mycoplasma-like organism (MLO), which is transmitted by cicadellid leafhoppers in the genus *Orosius* spp. In common with most other MLO, the sesame MOLO can be transmitted to a range of other corps. Where rainfall is low, allowing only one crop per year, there is almost no infection, but in multiple-cropping situations the incidence is often high. Some of the possible solutions suggested for the control of phyllody are the use of insecticides, crop rotation, crop hygiene, varietal resistance to both the mycoplasma and the jassid, and cultural practices which minimize infestation by the vector (early roguing of the diseased plants).

- B.D. Conde (1995) reported the following pathogen: tomato big bud mycoplasma (Little leaf or phyllody) affects floral parts, proliferation of axillary buds and little leaves. It is transmitted by *Orosius argentatus*). Overseas phyllody has been quite severe, but it has been of little consequence in the Northern Territories.
- M.R. Bennett and B. Conde (2003) reported Little Leaf (Mycoplasma). This disease causes greening of floral parts, axillary bud proliferation and little leaves. It is caused by a bacterium called Mycoplasma which is transmitted by the common brown leafhopper (*Orosius argentatus*). Control is not necessary as level of infection is usually very low.
- M.R. Bennett (pers. comm. 2016): Phyllody in flowers was recorded on our recording sheets. These plants were generally not selected because data confounded by effects to plant morphology.

BRAZIL

- V.P. Queiroga et al. (2008b) and V.P. Queiroga et al. (2019) reported the following pest: green leafhopper – *Empoasca* sp. The damages are characterized by the suction of the sap and inoculation of the toxins, which compromise the development of the plant and its production. The attacked plants have the leaves with a yellowish-green coloration, with rolled up edges and weakening of the tender branches. The sooner this insect is controlled, lower will be the damages in production. The leafhoppers are agents that transmit viruses and the sesame phyllody, especially when there are black-eyed bean crops (*Vigna unguiculata* L. Walp.) and mallow plants (fanpetals and sidas) infected with viruses in areas close to the planting. Chemical control should be performed with systemic insecticides, such as demeton-methyl, thiometon or pirimicarb (N.E.M. Beltrao and E.C. Freire, 1986).
- N.H.C. Arriel et al. (2009) reported phyllody. The cause of this disease is not yet fully understood. Some studies report that this anomaly is associated with the presence of structures similar to mycoplasmas (phytoplasmas), while others claim that the etiological agent of the disease is a virus. This disease is characterized by the shortening of the internodes and by the abundant proliferation of leaves and branches in the apical region of the affected plant. In this pathological process, transformation occurs of flowers into leaves and, as a consequence, the plant becomes sterile. Green leafhoppers, common in sesame plantations, are reported as most frequent transmitters.
- N.E.M. Beltrao et al. (2013) reported phyllody. The characterization of this anomaly is the shortening of the internodes and by the abundant proliferation of leaves and branches in the apical region of the plant, giving the plants an over-budding aspect. The flowers turn into leaves making the plant sterile. This anomaly is transmitted by jassid insects, *Deltocephalus* sp. (N.A. Wulff and S.F. Pascholati, 2005). The cause of this disease is still unknown. A.A. Cook (1981) states that the disease may be associated with structures such as mycoplasmas. The most efficient control measure for this disease is to combat jassid insects, present in the area.
- N.H.C. Arriel et al. (n.d.) Brazil descriptor: FILOIDIA (Phyllody). This anomaly is characterized by shortening of the internodes and abundant proliferation of leaves and branches in the apical part of the affected plant, which exhibits a potting aspect, with overgrowth of branches and/or fruits (successive shoots appear from points next to each other). The following are the ratings to be used.
  - 1 : 0 to 5%
  - 2 : 6 to 25%
  - 3 : 26 to 50%
  - 4 : 51 to 75%

- 5 : 76 to 100%

BURKINA FASO

- M.T. Cousins et al. (1970) reported the ultra structure of mycoplasmas was found in affected plants infected by phyllody. [Cited by G.S. Saharan, 1989]
- M. Desmidts and J. Laboucheix (1974) reported cotton phyllody disease was transmitted by *Orosius cellulosus* from sesame plants with phyllody symptoms to cotton. The symptoms produced were identical with those obtained in transmission tests from diseased to healthy cotton. Sesame may play an indirect role in the disease cycle as an alternate host for the vector, but it is unlikely to be a direct natural source of inoculum for cotton. [Based on abstract]
- M.M. Satour (1981) reported the presence of mycoplasma-like organism (phyllody).

CHINA

- H.M. Miao and H.Y. Liu (2010) reported the following pathogen: mycoplasma-like organism (MLO).
- D.R. Langham comments, 2019. In walking a sesame field in Xinjiang there was one plant with phyllody. I kept on looking for more but did not see any more in 3 subsequent fields.

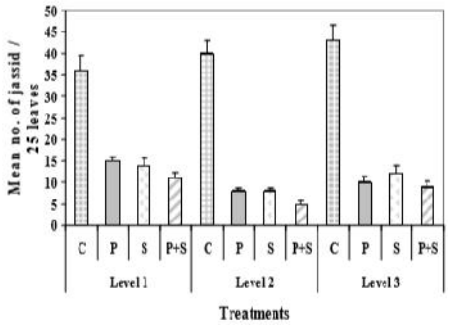
EGYPT

- M.M. Satour (1981) reported the presence of mycoplasma-like organism (phyllody).
- M.F. Mahmoud (2013) studied the effects of potassin-F and salicylic acid foliar sprays on the populations of leafhopper *Empoasca lybica*, *Creontiades* sp., and *Nezara viridula*. The leafhopper is known to transmit phyllody to healthy plants. He applied the following levels of foliar sprays.

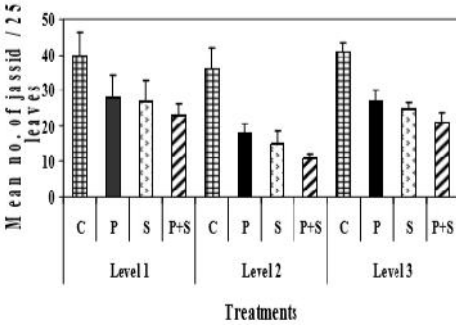
Levels	Treatments		
	Potassin –F (P) (0 N: 8P: 30K)	Salicylic Acid (S)	*P + S
Control	0.0	0.0	0.0
Level 1	1cm/l	10^{-2} M	1cm/l + 10^{-2} M
Level 2	2.5 cm/l	10^{-3} M	2.5 cm/l + 10^{-3} M
Level 3	4 cm/l	10^{-4} M	4 cm/l – 10^{-4} M

* P= Potassin- F foliar application, S= Salicylic foliar application.

The results showed that the sprays reduced the populations of *Empoasca lybica* as follow (C = control, P = potassin-F, and S = salicylic acid).

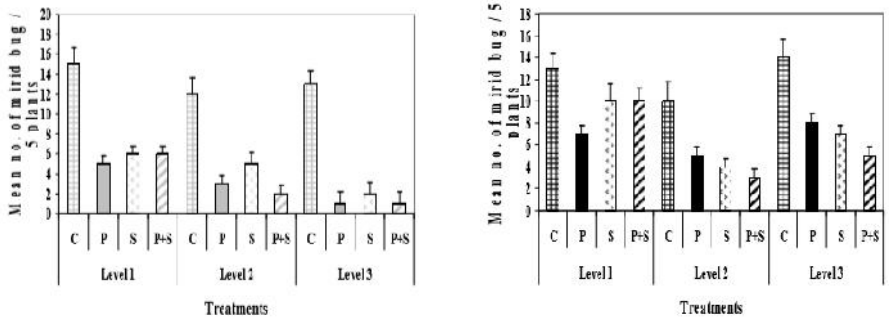


2010

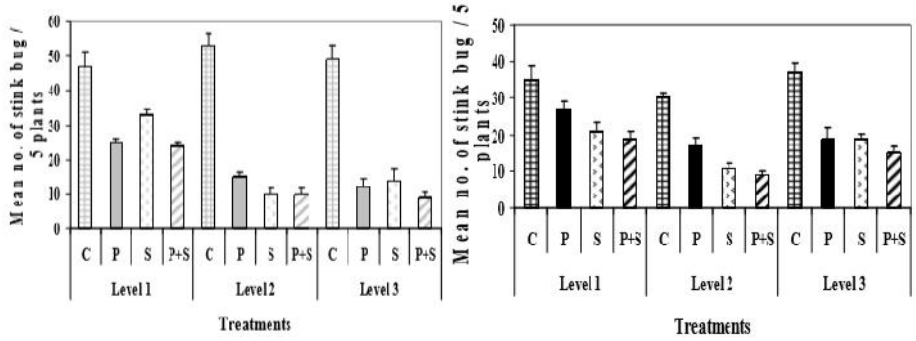


2011

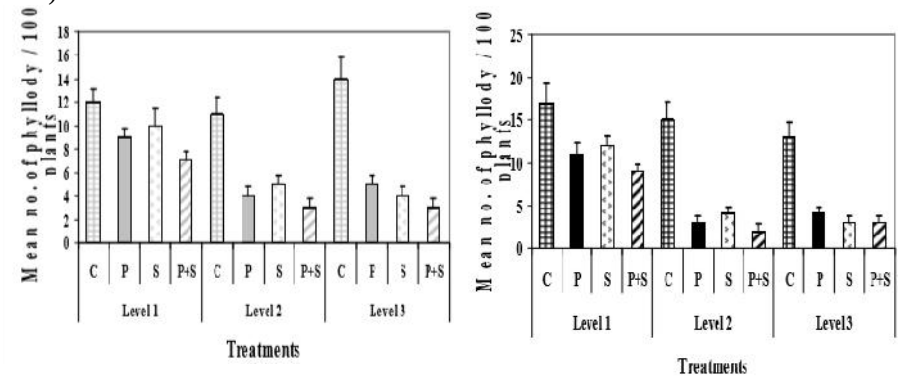
The results showed that the sprays reduced the populations of *Creontiades* sp. as follow (C = control, P = potassin-F, and S = salicylic acid).



The results showed that the sprays reduced the populations of *Nezara viridula* as follow (C = control, P = potassin-F, and S = salicylic acid).



The results showed that the sprays reduced the phyllody as follow (C = control, P = potassin-F, and S = salicylic acid).



2010 2011

The following photos illustrate the effects of phyllody on the sesame plants.

The flowers do not become capsules

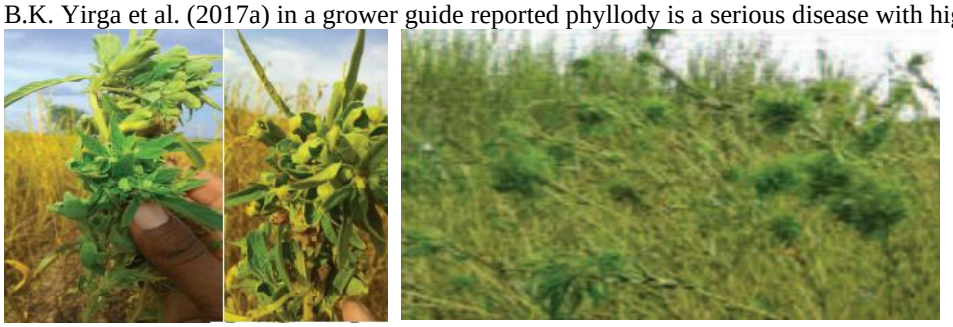
Normal plant on the left, phyllody on the right

ETHIOPIA

- T. Geremew et al. (1992, 2009, and 2012) reported the following diseases are a minor problem: phyllody. Infection from phyllody ranged from 0-40% and increased with increasing nitrogen level, but the correlations were not significant. Phyllody is most destructive disease of sesame in drier areas. The disease causes

deformation of leaves and flowers, which remain green with the calyx and corolla, sometimes stiff, forming a half-open hood. The deformed top parts have shorter internodes, much brunched, and change to broom shape or become bunchy. Phyllody infected plants do not bear capsule; if a capsule is affected it is deformed and cracks before maturity and seeds are shriveled. Phyllody and other virus diseases are transmitted by jassids and whiteflies, thus, managing these pests reduce further spread of the disease. Destroy sesame plants with disease symptom from field and burn them immediately. Alternate host of jassids should also be destroyed from field edges.

- B.K. Yirga et al. (2017a) in a grower guide reported phyllody is a serious disease with high yield losses.



- B.K Yirga et al. (2018a) surveyed 10 locations representative low land areas of western zone of Tigray for 3 years (2015, 2016, and 2017). *Xanthomonas campestris* pv. *sesami* – bacterial blight (83.24%) recorded the highest disease incidence followed by *Sphaerotheca fuliginea* – powdery mildew (78.13%), *Fusarium oxysporum* f. sp. *sesami* – fusarium wilt (78%), phyllody (72.01%) and *Alternaria* spp. – blight leaf spot (72%). Whereas blight leaf spot recorded highest severity (31.33%), followed by fusarium wilt (27.2%), phyllody (25.24%), bacterial blight (22.76%) and powdery mildew (22.6%). The phyllody is vectored by *Orosius albicinctus.*
- B.K. Yirga et al. (2018b) evaluated 17 sesame genotypes in northern Ethiopia during 2014-2015 main seasons against phyllody. Phyllody was recorded 2.5 to 17.5%, and 2.5 to 7.5% disease incidence and severity respectively. ACC202514, HuRC-4, Abuseffa, HuRC-3, Acc 202300, Acc111824, Acc 27913 and Setit -1 were among the highest resistant (HR) sesame genotypes for phyllody disease. HuRC-4 and HuRC3 genotypes were found resistant to bacterial blight, fusarium wilt and phyllody. Those genotypes could be used for diseases resistant breeding program across different locations.

INDIA

- Kashi Ram (1930) reported phyllody as stenosis. [Cited by R.S. Vasuveda, 1961, D. Choopanya, 1973, and G.S. Saharan, 1989]
- S.C. Roy (1931) reported phyllody as sepaloidy. [Cited by R.S. Vasuveda, 1961]
- B.P. Pal and P. Nath (1935) reported sesame plants at New Delhi were affected by a ‘phyllody’. Affected plants bear flowers in which the stamens are transformed into leaf like organs or show a marked tendency to became leafy. The stamens seldom contain functional pollen, and the plants may be completely sterile. The condition may begin with the first flower, all subsequent flowers then becoming affected, or it may occur later in which case the flowers formed previously are normal, but the tips of the branches and main axis and the new growth from the base are phylloid. Shortening of the upper internodes always occur, so that the abnormal flowers are crowded together, the foliage leaves are dwarfed, and in the floral region they may be pale. Phylloid flowers are radially symmetrical. Glandular hairs are found in parts where they are normally absent, while varieties, which

develop normally develop only one flower I axil. The calyx is polysepalous, and the primary veins of the sepals are thick and prominent, the apices of the petals are rounded. A fifth (anterior) stamen is usually developed while the ovary is enlarged, the style is reduced, and the carpellary well transformed into folliaceous structures. The results suggest that the disease is systemic and may be due to a virus. Some evidence was obtained that early sowings develop a large proportion of affected plants than late ones. [Cited by G.S. Saharan, 1989]

- P.R. Mehta (1951) reported phyllody was a disease that affected sesame. [Cited by G.S. Saharan, 1989]
- R.S. Vasudeva (1954) reported phyllody was more severe in the early crop than in the late. [Cited by G.S. Saharan, 1989]
- R.S. Vasudeva and H.S. Sahambi (1955) reported studies showed in phyllody of sesame the causal agent to be a virus transmitted by the Jassid *Deltocephalus* sp. Various insects were collected from naturally infected plants in the field and refed on sesame, the transmissions being obtained (on 11 out of 13 plants) only with *Deltocephalus* sp. Symptoms which appeared in 33-59 days from first feeding were identical with those on naturally infected plants. [Cited by G.S. Saharan, 1989]
- M.K.S. Ghauri (1966a) reported *Orosius albicinctus* was a vector of phyllody in sesame. [Cited by Mahadevaprasad et al., 2017]
- D.R. Langham comments, 1967/68: In the 9 months in India visiting sesame fields, two of the most common problems were phyllody and *Antigastra catalaunalis.* In several meetings, I was told that there were lines that had tolerance to both problems, but 54 years later, there are still reports that these two problems continue to be extensive. Either the tolerant alleles have not bred into current varieties, or phyllody and *A. catalaunalis* have evolved to overcome the tolerance.
- G.S. Saharan and J.S. Chohan (1972) reported phyllody. [Cited by G.S. Saharan, 1989]
- Y.K. Mathur and J.P. Verma (1973) studied the relation between date of sowing and the incidence of phyllody and abundance of its cicadellid vector (*Orosius albicinctus*) using a local variety in Sumerpur, Rajasthan (25.15N 73.08E). The results were as follow.

Date of sowing (1969)	Average vector population per sweep during the crop season	Phyllody percentage Arc sin $\sqrt{p}$
6th July	7.72	23.11 (28.69)
16th July	8.44	24.90 (29.93)
26th July	5.49	16.42 (23.84)
6th August	3.00	8.56 (16.94)
C.D. at 5%	1.63	3.05

The values in parentheses are angular transformations.

- A. Muheet and L.S. Chauhan (1975) conducted an experiment to control the sesame phyllody in 1972/73, 1973/74 and 1974/75 by using variety 6/53, which is highly susceptible to phyllody. Thimet granules (10 g) were applied to the soil at the time of sowing and the application was repeated after 45 DAS. Four insecticides (Imidan 50 W, Endrin, Metasystox and Thimet) were used separately and in combination with Thimet. The results showed that Thimet + Metasystox were found to be most effective in preventing the spread of disease while Thimet + Endrin and Thimet + Imidan 50 WP did not differ significantly among themselves. Attempts were made to check sesame phyllody by controlling its vector with insecticides. At the time of sowing, soil treated with Phorate 10 G @ 11 kg/ha and with Temik 10 G @ 25 kg/ha (Brar and Sandhu, 1976) to control the disease. Effective control of disease is obtained when the above treatment is combined with spraying crop with Metasystox @ 0.1% or with any other systemic insecticide. [Cited by R. Thangjam, 2012]
- O.P. Verma and L.N. Daftari (1976b) reported phyllody generally appears at flowering stage. Warm weather during flowering stage favors the disease. *Orosius albicinctus* an insect vector is the carrier of the virus. Losses in the plant yield, germination and oil content in infected plants may be as high as 94, 38, and 26% respectively.
- E.V. Abraham et al. (1977) evaluated the effect of sowing time on the occurrence of phyllody in 1974/75 at Tamil Nadu. Phyllody was highest (33.9%) in crops sown in November and lowest (0.21-0.83%) in those sown in January, February and September.
- N.D. Desai and S.N. Goyal (1981b) reported that TMV3 and TMV1 are resistant to phyllody.
- M.M. Satour (1981) reported the presence of mycoplasma-like organism (phyllody).
- S.M. Prasad and H.S. Sahambi (1982) confirmed *Orosius albicinctus* was a vector of phyllody in sesame.
- R. Krishnamurthy and S. Jayarajan (1984) reported amelioration of phyllody symptoms have been observed when infected plants were sprayed with Tetracycline hydrochloride at minimum concentration of 500 ppm. [Cited by R. Thangjam, 2012]
- S.G. Kolte (1985) reported *Orosius albicinctus* vectored phyllody in sesame. [Cited by K.P. Akhtar et al., 2009]

- S. Maiti et al. (1985) reported phyllody is the most destructive disease in India.
- O.P. Verma and L.M. Daftari (1985) reported phyllody reduced plant yield, test weight, germination percentage and oil content of seeds. A transformation of 25% of the productive length into phyllody caused 39.73% reduction in seed yield.
- C.D. Kaushik et al. (1986) screened 175 genotypes over 3 years (1983 to 1985) against phyllody (MLO), root rot (*Macrophomina phaseoli*), and leaf curl (virus). There were other diseases: Bacterial leaf blight (*Xanthomonas* sp.), powdery mildew (*Erysiphe* sp.) and Phytophthora blight. Out of 175 germplasm lines/varieties 16, 51 and 65 lines were resistant to leaf curl, phyllody and root rot; 49, 41, and 14 were moderately susceptible and rest of the lines were susceptible to these diseases. Although there are reports on the evaluation of germplasm lines/varieties of Sesamum against different diseases, no one has indicated-multiple disease resistant sources in sesame.
- S. Thangavelu et al. (1989b) reviewed the sesame pests in India and identified the following potential pest: Jassid – *Orosius albicinctus.* The Jassid is the vector of phyllody which is a major disease of sesamum caused by MLO. The jassid is infective for life after latent period of 10-11 days. Time of planting may influence the severity of attack. For instance, in Kanpur, mid-July sowings were found to greatly reduce the incidence. In Madras, early planting is recommended, while in Uttar Pradesh, it is late planting. The incidence of the disease, and the jassid prevalence seem to be correlated. Those varieties flowering in 41-50 days were less affected by phyllody. Breeding or selection of strains resistant to the jassid within this group would appear to offer the greatest opportunities of increasing resistance to phyllody. Insecticidal control of the jassid with Dimethoate can substantially reduce the incidence of the disease.
- R.K. Baskaran and N.R. Mahadevan (1991a) studied the effect of sowing time on incidence *A. catalaunalis* and phyllody and also on the yield in 1987 and 1988. 'TMV 4' sesame sown on 1 June in rainy season and 1 February in summer season recorded significantly highest yield of 278 and 411 kg/ha respectively. Different dates of sowing during cold season did not show significant effect on yield. The crop sown on 1 July in rainy season, 1 November in cold season and 1 March in summer season recorded the lowest incidence of shoot webber, i.e., 11.2, 3.2 and 3.5%, respectively; whereas, that sown on 1 June, 1 December and 16 January of rainy, cold and summer seasons recorded 15.9, 3.5 and 1.7% incidence of phyllody respectively. Positive association was observed between shoot webber and yield during rainy (r= -0.87), cold (r = 0.34) and summer (r= 0.71), and negative association between phyllody and yield during rainy (r= -0.71) and summer (r= -0.53) seasons and positive during cold (r= 0.99) season. [Based on abstract]
- Anon (1992a) in a grower guide reported *Mycoplasma* (Phyllody) appears at flowering. All floral parts are transformed into green leafy structures. Infected plants produce little leaves in bunches, show excessive branching and shortening of internodes. Such plants generally do not bear capsules but if capsules are formed, they do not yield quality seeds.
- S. Jebaraj and M.N. Sheriff (1992) reported releasing a new variety (SV PR.1) with more tolerance to phyllody, Powdery mildew, Alternaria leaf spot, and *Antigastra catalaunalis* with a higher yield than the existing varieties (TMV.3 and TMV.4) in Tamil Nadu.
- A.R.G. Ranganatha et al. (1993) evaluated the tolerance of 1,040 lines against phyllody at Bangalore (12.97N 77.60E). Phyllody is very destructive resulting in losses as high as 54.5% (Marimuthu et al., 1973). A major proportion of the lines derived from C-7 x local were less susceptible, while a greater proportion of lines derived from 3-way crosses were more susceptible probably because of greater recombination. Earlier lines were superior to late lines. Lines isolated by selection when compared with randomly sampled lines revealed more susceptible types. This suggest that care is required while selecting for seed yield to retain certain levels of resistance to disease in sesame.
- B. Srinivasulu and P. Narayanasamy (1995) detected phyllody in both sesame and the leafhopper *Orosius albicinctus.* [Based on abstract]
- I.S. Bisht et al. (1998) classified 4,316 accessions from India using *Incidence of Phyllody*.
  - 1 = Low susceptibility
  - 2 = Medium susceptibility
  - 3 = High susceptibility
- U.C. Singh and R. Singh (1997) studied the effects on phyllody of 7 plant products (neem leaves extract, neem seed kernel extract, tobacco decoction, neem oil, karanji [*Pongamia pinnata*] oil, mahua oil [*Madhuca longifolia*] and tumba [*Citrullus colocynthis*] oil) and endosulfan sprayed twice during kharif 1992-93 at Gwalior, Madhya Pradesh (26.22N 78.18E) using 1 cultivar (Jt-7). The incidence of phyllody was statistically similar in all treatments. [Based on abstract]

- I.S. Bisht et al. (1999) classified Incidence of phyllody disease as predominance of moderate to highly susceptible.
- S.G. Borkar and A. Krishna (2000) evaluated the effects of nitrogen (0,15, 30 and 45 kg/ha) and phosphorus (0, 15, 30 and 45 kg/ha) on phyllody. The incidence of phyllody was recorded after the emergence of inflorescence. The highest disease incidence was 7.2% (15 kg P/ha without N), followed by 6.0% (45 kg P/ha + 30 kg N/ha) and 5.0% (30 kg P/ha + 15 kg N/ha).
- V. Selvanarayanan and T. Selvamuthukumaran (2000) evaluated the incidence of phyllody and the presence of *Orosius albicinctus* using 4 varieties. The incidence of phyllody was as follows.

Cultivars	Percentage of incidence				Percentage of branches damaged				Percentage of capsules damaged			
	51 DAS	58 DAS	65 DAS	72 DAS	51 DAS	58 DAS	65 DAS	72 DAS	51 DAS	58 DAS	65 DAS	72 DAS
CO 1	10.00 [a]	32.00 [c]	44.00 [b]	56.00 [bc]	26.67	46.67	66.67	83.33 [b]	7.53	17.95	30.99	44.04
	(14.02)	(34.29)	(41.54)	(48.46)	(25.05)	(43.05)	(57.90)	(73.95)	(10.28)	(19.70)	(30.51)	(38.32)
SVPR 1	14.00 [ab]	18.00 [d]	26.00 [a]	48.00 [ab]	34.00	34.00	41.33	51.33 [ab]	18.41	29.86	37.57	46.13
	(21.69)	(24.64)	(30.43)	(42.69)	(35.18)	(35.18)	(39.95)	(45.79)	(22.37)	(30.02)	(34.60)	(39.58)
TMV 3	20.00 [b]	28.00 [b]	48.00 [b]	62.00 [c]	24.00	43.00	77.00	86.00 [b]	20.67	32.36	45.20	53.35
	(25.97)	(31.76)	(43.85)	(52.02)	(23.31)	(10.85)	(67.15)	(72.89)	(18.41)	(31.28)	(42.21)	(47.39)
TMV 4	4.00 [a]	10.00 [a]	22.00 [a]	38.00 [a]	7.33	21.33	33.33	36.33 [a]	12.12	13.05	27.38	33.88
	(7.37)	(16.37)	(27.89)	(37.98)	(10.13)	(21.67)	(34.72)	(36.95)	(15.90)	(16.50)	(31.44)	(35.52)
CD (p=0.05)	14.65	5.93	6.28	6.21	NS	NS	NS	34.67	NS	NS	NS	NS

NS – Non significant
Values mean of five replications
Values in parentheses are arc sine transformed
values with different alphabets differ significantly

Leafhopper population was minimal during the early phases of the crop, rose to a peak on 51 DAS and declined afterwards. The presence of *Orosius albicinctus* was as follows.

Cultivars	Number of leafhoppers/ trap						
	30 DAS	37 DAS	44 DAS	51 DAS	58 DAS	65 DAS	72 DAS
CO 1	0.4	0.2	0.6	0.8	0.2	0.4	0.2
SVPR 1	0.6	0.4	0.4	1.0	0.4	0.2	0.2
TMV 3	0.2	0.2	0.6	0.8	0.4	0.4	0.2
TMV 4	0.2	0.4	0.4	0.8	0.4	0.4	0.4
CD (p=0.05)	NS	NS	NS	NS	NS	NS	NS

Values mean of five replications
NS – Non significant

- H.P. Misra (2003) evaluated 6 new combination insecticides (rocket (Cypermethrin 4% + Profenophos 40%) @ 440g a.i./ha; Nurelle D (Chlorpyriphos 50% + Cypermethrin 5%) @ 550g a.i./ha; Koranda (Acephate 25% + Fenvalerate 3%) @ 560g a.i./ha; Spark (Deltamethrin 1% + Triazophos 35%) @ 360g a.i./ha; Viraat (Cypermethrin 3% + Quinalphos 20%) @ 230g a.i./ha, and Nagata (Ethion 40% + Cypermethrin 5%) @ 450g a.i./ha) along with a conventional insecticide (endosulfan) against phyllody. The % phyllody infestation remained significantly lower among the insecticides (3.9-6.7%) as compared to the control (12%). Nagata and Viraat showed potential in reducing incidence by controlling the vector. [Cited by R. Thangjam, 2012]
- T.S. Rajpurohit (2004b) evaluated the effects of plant extracts [Neem gold (0.3%) and Neem leaf extract (2%)] fungicides [Mancozeb (0.2%), Propiconazole (0.1%), Difenconazole (0.1%) and Penconazole (0.1%)] and in combination with an insecticide (Mancozeb at 0.25% + Methyl demeton at 1 ml/l) against *Alternaria sesami*, leaf curl, and phyllody in 2001 and 2003. Two years of pooled results indicated that all the treatments reduced significantly Alternaria blight (*Alternaria sesami*), phyllody and leaf curl (Nicotinia virus-10) diseases and increased seed yield as compared to the control. Two foliar sprays of Mancozeb at 0.25% + methyl demeton at 1 ml/l. reduced Alternaria blight from 39.35 to 10.1%, phyllody and leaf curl from 5.24 to 0.83% and increased seed yield from 416 to 721 kg/ha.
- C.S. Choudhary and S.M. Prasad (2007) reported sesame sown on 5 June in Ranchi, Bihar, recorded the highest incidence of phyllody (28.6 and 26.5%) during kharif 2002/03 and 2003/04, respectively. A relatively lower

disease incidence was recorded with advancement of date of sowing and maximum (15.0 and 15.1) leaf hopper vector (*Orosius albicinctus* [*O. orientalis*]) populations in the crop sown on 15 and 25 July, respectively. Significant positive correlation between phyllody incidence with maximum and minimum temperature and negative correlation with maximum relative humidity and rainy days were observed. Vector population was statistically non-significant and showed negative effect on phyllody incidence. Maximum temperature was negatively correlated while minimum relative humidity was positively correlated with vector population.

- R.K. Mahajan et al. (2007) classified 2,168 accessions to develop a core collection from around the world (basically the A. Ashri FAO collection with seed from Afghanistan, Bangladesh, China, Egypt, Greece, India, Iran, Israel, Korea, Japan, Mexico, Pakistan, USA, USSR, Venezuela, and many other countries). He scored *Incidence of phyllody disease* as:
  - 1 = Low susceptibility
  - 2 = Medium susceptibility
  - 3 = High susceptibility
- P.K. Singh et al. (2007) studied the inheritance of phyllody. Initially 150 germplasm, 32 released varieties and 4 wild spp. of sesame were evaluated under field conditions during Kharif-2005 and promising lines selected under artificial conditions during subsequent two seasons. Three intra- and two interspecific crosses were selected to study the inheritance of phyllody resistance in sesame whereas, two each of intra- and interspecific crosses were identified to test the allelic relationship between resistant genes. The F_2 and backcross segregation analysis in intraspecific crosses revealed that a single recessive gene governs phyllody resistance whereas that of interspecific combinations suggested the involvement of a single dominant gene. Allelic test on intraspecific crosses revealed recessive resistance to be governed by two independent non-allelic genes exhibiting duplicate dominance whereas, interspecific crosses showed the dominance nature of resistance with the involvement of one dominant and one recessive gene.

- R.M. Ahirwar et al. (2010b) studied the efficacy of some indigenous neem products, insecticides, and their admixtures (Neem oil (NO), neem leaf extract in cow urine (NLE), neen seed kernel extract in cow urine (NSKE), garlic bud + red pepper extract (GB + RPE), cow urine (CU), cow butter milk (CBM), and endosulfan) on three sucking pests (*Orosius albicinctus*, *Nesidiocoris tenuis*, and *Bemisia tabaci*). *Orosius albicinctus* is a transmitter of phyllody. They concluded the endosulfan was the best yield and the highest return per hectare. The population results were as follow. The detail is provided to show that there is no total elimination of *Orosius albicinctus*.

Mean population of jassid/10 plants

Plots	2004 PBS (34D)	2004 First Spray	2004 Second Spray	2004 Mean	2005 PBS (34D)	2005 First Spray	2005 Second Spray	2005 Mean	2006 PBS (34D)	2006 First Spray	2006 Second Spray	2006 Mean	Pooled Mean
T1- Neem oil, 10 ml/l	7.2 (2.7)	5.8 (2.5)	3.0 (1.7)	4.4 (2.1)	15.0 (3.9)	9.5 (3.0)	3.6 (2.0)	6.5 (2.5)	6.5 (2.6)	3.5 (2.0)	2.2 (1.6)	2.8 (1.8)	4.6 (2.1)
T2- NLE (in cow urine), 30 ml/l	6.7 (2.6)	5.8 (2.5)	3.1 (1.9)	4.4 (2.2)	16.5 (4.0)	9.5 (3.0)	3.6 (2.0)	6.5 (2.5)	5.2 (2.3)	3.7 (1.9)	2.2 (1.6)	2.9 (1.7)	4.6 (2.1)
T3- NSKE (in cow urine), 30 ml/l	8.5 (3.0)	5.5 (2.4)	2.8 (1.8)	4.1 (2.1)	16.2 (4.1)	9.2 (3.0)	3.5 (2.0)	6.3 (2.5)	7.5 (2.8)	3.2 (1.9)	2.0 (1.6)	2.6 (1.7)	4.3 (2.1)
T4- Cow butter milk, 40 ml/l	7.2 (2.7)	7.0 (2.7)	4.3 (2.1)	5.6 (2.4)	16.0 (4.0)	10.5 (3.1)	4.2 (2.1)	7.3 (2.6)	7.7 (2.8)	4.7 (2.2)	3.2 (1.9)	3.9 (2.0)	5.6 (2.3)
T5- Cow urine, 30 ml/l	8.0 (2.9)	6.2 (2.6)	3.8 (2.0)	5.0 (2.3)	19.5 (4.4)	9.9 (3.1)	3.9 (2.0)	6.9 (2.5)	7.5 (2.8)	4.5 (2.1)	2.5 (1.7)	3.5 (1.9)	5.1 (2.2)
T6- GB + RPE (1:1), 5 ml/l	8.0 (2.9)	6.5 (2.6)	3.8 (2.0)	5.1 (2.3)	18.0 (4.3)	10.3 (3.2)	4.1 (2.1)	7.2 (2.6)	9.2 (3.0)	4.5 (2.1)	2.7 (1.8)	3.6 (1.9)	5.3 (2.3)
T7- GB + RPE (1:1), 10 ml/l	6.7 (2.6)	5.9 (2.5)	3.6 (1.9)	4.7 (2.2)	16.2 (4.0)	9.6 (3.0)	3.7 (2.0)	6.6 (2.5)	8.5 (3.0)	3.7 (2.0)	2.5 (1.7)	3.1 (1.8)	4.8 (2.2)
T8- Endosulfan 0.07%, 2 ml/l	7.7 (2.8)	5.4 (2.4)	2.8 (1.8)	4.1 (2.1)	16.5 (4.1)	9.0 (2.9)	3.5 (1.9)	6.2 (2.4)	10.5 (3.3)	3.2 (1.9)	1.7 (1.5)	2.4 (1.7)	4.2 (2.1)
T9- Untreated	7.2 (2.7)	9.2 (3.1)	6.8 (2.7)	8.0 (2.9)	26.5 (5.1)	17.1 (4.1)	6.9 (2.7)	12.0 (3.4)	6.2 (2.5)	7.7 (2.8)	5.2 (2.5)	6.9 (2.6)	9.0 (3.0)
LSD (P=0.05)	NS	0.16	0.30	0.16	NS	0.30	0.30	0.21	NS	0.60	0.31	0.06	0.09

Figures in parenthesis denote transformed values $\sqrt{x + 0.5}$
D: Age in days; GB: Garlic bud; LSD: Least significant difference; NLE: Neem leaf extract; NSKE: Neem seed kernel extract; NS: Non significant; T: Treatments; PBS: Population before sprays; RPE: Red pepper extract

The yields were as follow (Left). Sesame plant affected by phyllody (Right)

Mean grain yield (kg / ha)

Plots	2004	2005	2006	Pooled Mean
T1-Neem oil, 10 ml/l	460	657	600	572
T2- NLE (in cow urine), 30 ml/l	448	655	568	557
T3- NSKE (in cow urine), 30 ml/l	490	659	666	605
T4- Cow butter milk, 40 ml/l	419	493	518	476
T5- Cow urine, 30 ml/l	434	611	533	526
T6- GB + RPE (1:1), 5 ml/l	419	560	523	500
T7- GB + RPE (1:1), 10 ml/l	441	620	564	541
T8-Endosulfan 0.07%, 2 ml/l	507	677	683	622
T9- Untreated	367	457	450	424
LSD (P=0.05)	74.3	78.0	132.0	49.42

- S. Rajeswari et al. (2010) reported hybrids between *Sesamum indicum* and *Sesamum alatum* had moderate resistance to phyllody.
- G.G. Shindhe et al. (2011b) reported F_3 pooled segregation analysis revealed that phyllody resistance is under the control of two dominant genes with complementary gene action (9:7).
- R. Thangjam (2012) and R. Thangjam and A.A. Vastrad (2015) assessed the effect of insecticides along with conventional ones like monocrotophos 36 SL, a plant product, nimbecidine and an antibiotic, tetracycline against leafhopper, *Orosius albicinctus* Distant which is a vector of sesame phyllody in sesame. The results revealed that all the systemic insecticides were superior. Among these treatments T1 (imidacloprid 600FS seed treatment + imidacloprid 17.8 SL spraying.) and T5 (imidacloprid 600FS seed treatment + lambda cyhalothrin 5 EC spraying) were highly superior. Seed yields were highest in all the insecticidal treatments compared to control, and among treatments T1 and T5 recorded maximum seed yields (447 and 441kg/ha, respectively).
- R. Thangjam (2012) and R. Thangjam and A.A. Vastrad (2017) reported 4 species of leafhoppers (*Orosius albicinctus* Distant, *Amrasca biguttula* Ishida, *Hishimonas phycitis* Distant and *Balclutha incisa* Matsumura) were found to infest the crop. They evaluated which leafhopper was responsible for transmitting phyllody by testing the DNA in the leafhoppers and phyllody. They determined the vector was *O. albicinctus.*


Normal plants


Early phyllody infection


Late phyllody infection

- D.M. Pathak et al. (2013) surveyed in 6 sesame growing areas during Kharif and Summer in 2008 and 2009. The incidence of phyllody during kharif and summer seasons ranged from 0-1.5% and 0-4.7%, respectively, in scattered manner. The spread was very slow, and the first affected plant was observed at 40 days and maximum at 75 days after sowing. They reported the leafhoppers (*Orosius albicinctus* Distant) infected the crops with phyllody. They examined 5 plants at different ages of appearance of the phyllody and took the following data.

Age	Number of capsules/plant	Seed yield (g)	Number of branches	Plant height (cm)	1000-seed weight (g)
50	11.5	0.23	2.3	69.4	0.476
55	22.2	1.10	3.3	90.7	0.667
60	35.1	2.30	3.5	104.4	1.139
65	47.5	3.90	3.8	113.4	1.644
Healthy	55.8	4.30	4.2	118.8	2.784

- N. Ranasingh and T. Samal (2013) reported seed treatment with Imidacloprid (7.5/kg) and foliar spray of Profenophos 50 EC 2 ml/l was most effective in reducing phyllody as well as capsule borer incidence. The highly infected phyllody plants should be uprooted and burned. Use varieties like Nirmala, Uma and Prachi which are resistance to phyllody.
- D. Sridhar and M.S. Patil (2013) surveyed phyllody in Karnataka in five districts in 2009. The infected plants showed different symptoms like phyllody, cracking of capsule, vivipary, twisting of stem, early drying of plant. Invariably leafhoppers were found feeding on the sesame in most of the field surveyed and aphids in some fields. The following table shows the great variation in the level of phyllody in different districts of the same state.

District	Incidence		Symptoms observed	Insects recorded
	Range	Average		
Dharwad	2.62-4.50	3.46	Phyllody, Floral virescence, twisting of stem, fruit cracking, germination of seeds in capsule	Jassids Aphids Leaf hoppers
Haveri	6.65-26.50	16.57	Phyllody, yellowing of leaves, twisting of stem at tip, cracking of capsule,floral virescence.	Jassids Aphids
Gadag	37.1-42.0	39.55	Phyllody, yellowing of leaves, twisting of stem, capsule cracking	Jassids Aphids Leaf hoppers
Raichur	49.02-55.77	52.39	Phyllody,floral virescence, shortening of internodes, twisting of stem at tip	Jassids Leaf hoppers
Gulbarga	50.15-50.95	50.55	Phyllody, twisting of stem at tip, cracking of capsule	Jassids Leaf hoppers

- D.S. Gangwar et al. (2014) evaluated the infestation of major insect pests of sesamum for 2 years. The population of Jassid (*Orosius albicinctus*) first appeared in 21 to 23 days and remained until maturity. Its peak population 1.33 and 1.73 jassids/plant was observed at 37th and 38th standard week when the crops were 56 to 63 days old. The maximum infestation of shoot (17.62 and 20.89%) flower (22.73 and 24.13%) and capsule (16.63 and 20.89%) was observed at 56 and 51 DAS, 77 and 79 DAS and 91 and 93 DAS, respectively during first and second year. The maximum infestation of phyllody disease (3.00 and 3.7%) was observed at 37th standard week when the crop was 56 and 58 days old.
- T.N. Mahadevaprasad et al. (2017) evaluated the tolérance of 43 genotypes in 2015 at Bengaluru (12.97N 77.59E). They identified *Orosius albicinctus* and *Hishimonus phycitis* in the fields. The incidence of phyllody

ranged from 4.6-28.2%. Among the sesame lines screened against phyllody disease under field conditions, 3 genotypes were resistant, 27 were moderately resistant, and 13 were susceptible.

- B. Khamari et al. (2018c) conducted an intensive survey at flowering to ripening of capsule to record the incidence of sesame diseases in 10 agroclimatic zones of Odisha during rabi 2014-15 with the following results.

Sl. No.	Place	Variety	Mac (%)	Fus (%)	Alt (Grade)	PM (Grade)	Cer (Grade)	Phy (%)
1	Bheden	Bheden local	18.09	9.78	3	0	2	0
2	Balianta	VRI-1	23.8	8.0	4	3	2	2.3
3	Nuagaon	Nuagaon local	12.8	3.0	3	0	2	0.6
4	Papadahandi	Papdahandi local	15.2	4.1	2	0	2	1.0
5	Betanati	Betanati local	18.8	0.5	2	2	1	0
6	Kalimela	Kalimela local	11.3	0.8	3	1	2	0.8
7	Agarpada	Agarpada local	8.0	1.0	3	1	1	0.6
8	Kirei	Sundergarh local	15.8	3.9	2	0	1	1.4
9	Khajuripada	Phulbani local	10.5	2.9	3	3	1	0.0
10	Bhawanipatna	Narla local	19.2	4.8	4	0	2	1.4

Mac=*Macrophomina*, Fus= *Fusarium*, Alt= *Alternaria*, PM= Powdery Mildew, Cer= *Cercospora*, Phy= Phyllody

- D. Pallavi and L. Vijaykumar (2019) assessed polyphenol oxidase content in controlled and open field conditions. There was an increased trend from 58 to 72 days after sowing in the open field. Compared to controlled condition genotypes in open field the genotypes had a higher content of polyphenol oxidase. Generally. Resistant genotypes had higher contents than the susceptible ones as shown below.

Sl. No.	Genotypes	Category	Polyphenol oxidase (units of purpurogallin/ ml/min)						
			Controlled			Open field			Per cent increase from controlled to open field (%)
			58 DAS	65DAS	72 DAS	58 DAS	65DAS	72 DAS	
1	OSC-207	HR	3.56^{c}	3.91^{ab}	4.79^{bcd}	4.79^{bc}	6.15^{bc}	8.16^{c}	41.30
2	VS-07-023	HR	3.26^{d}	3.61^{abc}	6.33^{ab}	4.49^{cd}	5.85^{bc}	8.05^{c}	21.37
3	RT-363	R	3.8^{b}	4.66^{a}	6.36^{ab}	5.03^{ab}	6.39^{bc}	$8.6b^{c}$	26.05
4	JLS-9707-2	R	3.15^{d}	4.16^{ab}	5.26^{abc}	4.38^{d}	5.74^{c}	7.95^{c}	33.84
5	G-TIL-2	MR	4.15^{a}	4.82^{a}	6.09^{ab}	5.38^{a}	6.74^{ab}	9.4^{b}	35.21
6	RT-367	MR	2.91^{e}	3.67^{de}	6.67^{a}	4.14^{d}	7.52^{a}	11^{a}	39.36
7	RT-366	S	1.84^{i}	2.1^{de}	3.12^{e}	2.47^{g}	3.84^{ef}	5.1^{def}	38.82
8	RT-368	S	1.84^{j}	2.11^{de}	3.49^{de}	2.47^{g}	3.85^{ef}	4.87^{ef}	28.34
9	AT-231	S	2.71^{f}	2.97^{bcd}	4.04^{cde}	3.34^{e}	4.71^{d}	5.74^{d}	29.62
10	GT-1	HS	1.28^{j}	1.55^{e}	3.83^{cde}	1.91^{h}	3.29^{e}	4.31^{f}	11.14
11	DS-5	HS	2.28^{i}	2.55^{cd}	3.82^{cde}	2.91^{f}	4.29^{ab}	5.31^{de}	28.06
12	AT-249	HS	2.43^{g}	2.69^{cd}	4.04^{cde}	3.06^{ef}	4.43^{a}	5.46^{de}	26.01
S.Em±			0.03	0.11	0.13	0.09	0.12	0.18	
CD 5%			0.25	0.30	0.42	0.33	0.38	0.61	

Polyphenol oxidase activity changes in OD at 420 nm (units of purpurogallin/ ml/min), Means in the column followed by same letters are not significantly different at p=0.05(F-test), DAS-days of sowing

- K. Divya et al. (2020) screened 133 genotypes for tolerance to phyllody, Alternaria leaf spot, Cercospora leaf spot, and downy mildew. They identified LW-2 and SDSN-15-98 as being resistant to phyllody. The incidence of phyllody in the susceptible genotypes ranged from 86-92% indicating enough disease pressure to evaluate phyllody.
- D.R. Langham comments, 2021. In India in 1967/68 I viewed thousands of hectares of sesame in most of the country and walked in hundreds of hectares. I was overwhelmed by the destruction of the leaf roller and capsule borer (*Antigastra catalaunalis*) and phyllody (vectored by leafhoppers). In visiting breeders, I found that many had identified tolerant lines, but there was a gap between research and application in farmer fields. Reading so many publications in this document shows that 54 years later the gap has closed a bit, but not enough.

IRAN

- M. Salehi et al. (1992) reported phyllody is a destructive disease in Iran. The major symptoms of the disease are floral virescence, phyllody and proliferation. Other symptoms which sometimes accompany the disease are yellowing, cracking of seed capsules, germination of seeds in the capsules and formation of dark exudates on the foliage. Light microscopy of hand-cut sections of sesame stems treated with Dienes' stain showed blue areas in the phloem region of phyllody infected plants. Mycoplasma-like bodies were found in the sieve cells of

infected sesame stems when thin sections were examined m an electron microscope. Sesame phyllody was successfully transmitted from sesame to sesame by grafting. Among various leafhoppers collected in sesame fields only Neoaliturus haematoceps transmitted the disease. The species of vector and host range of MLO indicate that sesame phyllody in Iran is different from that reported in India and Upper Volta. [Based on abstract]

- D. Ali et al. (2009) reported in recent years, outbreak of sesame phyllody (SP) has inflicted heavy losses to sesame crop in Khuzestan. In a survey in 2000 and 2001 in sesame growing regions of Khuzestan the rate of infection was 0.5 to 100%. Infected tissue showed positive reaction with dienes stain and on the basis of this result, SP disease has phytoplasmatal etiology. Among various leaf hoppers collected from sesame fields, only *Circulifer haematoceps* transmitted the disease agent. The effect of five sowing dates (June 8, 22 July 6, 16 and 28) and spraying with Metasistox -R on SP and crop yield was evaluated in Hamidieh. The results showed that spraying had no significant effect on the yield although the rate of infection was significantly decreased at 5% level. Date of planting had significant effect on the yield (at 5% level) and disease incidence rate (at 1% level). Highest yield and lowest disease incidence were obtained with the latest sowing date (July 28) plus spraying. [Based on abstract]

IRAQ

- K.M. Tamini et al. (1989) reported shoot apex fasciation was observed in sesame crops in central Iraq. The symptoms included flattening of the shoot apex, shortened internodes, and intense proliferation of leaf and flower buds. Mycoplasma like organisms were detected by electron microscopy in sieve elements of fasciated plants but not in normal plants. Plants sown in July showed less fasciation than plants sown in June or May. Almost no fasciation occurred on plants grown inside insect-proof cages, irrespective of their origin from seed of fasciated or normal plants. Insect-borne and not seedborne transmission is therefore suggested.

ISRAEL

- M. Klein (1977) reported incidence of phyllody has been known for some time, but no importance was attached to it. As area increases introductions and varieties are being screened for tolerance to the disease.
- M.M. Satour (1981) reported the presence of mycoplasma-like organism (phyllody).

JAPAN

- T. Ishihara (1982) reported *Orosius orientalis* occurs in Honshu and the Ryukyu Is. As well as Taiwan, is a fairly well known species that is a vector of the agent causing witches' broom disease of legumes in the Ryukyu Is. and sesame phyllody in India. [Based on abstract]

KENYA

- H.A. Van Rheenen (1981d) reported the goal of developing resistance to phyllody.

MALAWI

- W. Van Den Bos and C.J. Zee (2016) in a grower guide reported the following: phyllody. It can severely effect sesame particularly in dry cultivation areas. The disease causes deformation of leaves and flowers, which remain green with the calyx and corolla, sometimes stiff, forming a half-open hood. The deformed top parts have shorter internodes, much branched, and change to broom shape or become bunchy. Phyllody infected plants do not bear capsule, or are deformed, crack before maturity and seeds are shriveled. Phyllody and other virus diseases are transmitted by aphids and whiteflies; managing these pests reduce further spread of the disease. Destroy sesame plants with disease symptom from field and burn them immediately.


MEXICO

- C. Chattopadhyay et al. (2019) reported the presence of phyllody.

MYANMAR

- T.D. McGibbon (1924) was the first to identify phyllody in sesame. [Cited by R.S. Vasuveda, 1961, and Salehi et al., 2016]
- H.F. Robertson (1928) reported The so called ‘pothe’ or ‘green flowering’ disease of sesamum was exceptionally severe in the Sagaing and lower Chinwin Districts where up to 90% of plant were affected. At Tatkon the disease was milder. Almost all the local varieties of sesame are affected. The symptoms became noticeable only at the flowering stage when the floral parts are transformed into green leaf like structures and branching is abnormally abundant. Affected plants seldom fruit. The disease is stated to be the most severe during prolonged drought or when sowing is very early. Several other plants showing similar symptoms have been observed. [Cited by G.S. Saharan, 1989]
- D. Rhind et al. (1937) reported examination of plants affected by phyllody have failed to reveal any fungoid or bacterial infection, and their presence is extremely unlikely since no necrotic lesions develop in the plants affected with phyllody alone. Two theories as to the cause of the condition are held: (1) it is due to a virus and (2) it is purely a physiological disturbance, sesamum being extremely affected by small changes in conditions. The disease is also called sepalody (“green flowers”).

  The results of sowing seed from the affected plants gives no indication that the disease is transmitted through the seed.

  The growers reported there was a higher incidence when planting in May or July versus the usual planting time in mid-June. They also reported there was more incidence in heavy rainfall or drought. They felt early (monsoon) varieties were more susceptible than late (winter) crops, while white-seeded types were more susceptible than black or dark-seeded varieties. There was no general agreement on the influence of soil and fertility on the severity of the disease although they felt rich soils favored the disease more than poor soils.

  In 1923 seeds were collected from all over Myanmar and planted in plots. In each succeeding year, the only planted plants with no phyllody and the incidence of phyllody decreased over time. The incidence ranged 7.8 to 12.7%. In planting single rows daily from 15 May to 28 June, the incidence of phyllody decrease in the later plantings.

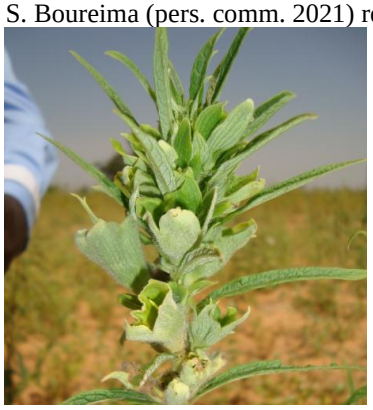
  They tried different methods of transferring the disease: inoculation by implantation, grafting, juice injection, and inter-connection with capillary tubes. All methods did not have any significant increase over the control plants.

  They dissected the seeds from normal capsules on phylloid plants and found they were not normal. In embryos which are slightly affected, the only abnormality may be a somewhat elongated and pointed radicle. In more serious cases, the cotyledons have become enlarged and crumpled, the edges convolute or undulate. The hypocotyl becomes elongated and distorted with pressure while the radicle develops with a long whiplike member twisted and tanged inside the seed-coat. The cotyledons in bad cases are usually thin and may be only a few cells thick. The general effect is that the embryos have not entered into a resting stage when formed but have at once continued growth and attempted germination but in an abnormal manner.

  They found a higher mineral content in the diseased plants than the normal plants.
- U.T. Myint (1981) reported that phyllody may be controlled by Endrin (75-100 cc/ha) applied 20-25 days after germination.
- D. Myint et al. (2014) reported phyllody is a serious disease, and one of the main goals is to identify resistance.

NIGER

- S. Boureima (pers. comm. 2021) reported phyllody is the main disease.



NIGERIA

- M.C. Dike, M.C. and A.M. Oparaeke. (1997) reported the following vegetative pest: *Deltocephalus* spp. when present in large numbers may be injurious to sesame plants especially in the transmission of viral disease known as phyllody. The insect becomes infective for life after a latent period varying with the season, the maximum period being 11 days.
- J.B. Kabeh (2017b) reported phyllody a major disease that affects the stem apex, floral parts, and nodes. He tested 5 varieties in 2014 and 2015 in terms of agronomic traits and tolerance to diseases and pests (Leaf curl – Tobacco mosaic virus, Fungal leaf spot = *Cercospora sesami*, galls are from the insect *Asphondylia sesami* – gall fly) on a 1-5 scale with 1 being tolerant.

Varieties	Severity of Leaf Curls	Severity of Fungal Leaf Spot	Number of galled capsules	Number of dead stands due to phyllody
2014				
Yandev 55	1.29±0.33^{ab}	1.93±0.06^{a}	5.79±0.64^{a}	1.96±0.23^{ab}
NCRIBEN-01M	1.87±0.00^{a}	1.31±0.09^{c}	5.70±0.38^{a}	1.83±0.37^{ab}
E-8	0.97±0.15^{b}	1.86±0.11^{ab}	5.73±0.51^{a}	1.65±0.07^{b}
Ex-Sudan	1.85±0.18^{a}	1.80±0.07^{ab}	5.46±0.32^{a}	1.59±0.34^{a}
ICEASE-00018	1.97±0.22^{a}	1.65±0.07^{b}	4.63±0.61^{a}	1.81±0.28^{ab}
2015				
Yandev 55	1.27±0.21^{bc}	1.92±0.16^{a}	5.14±0.99^{a}	1.92±0.13^{ab}
NCRIBEN-01M	1.86±0.11^{a}	1.40±0.10^{b}	5.41±0.41^{a}	1.72±0.32^{b}
E-8	1.18±0.18^{c}	1.63±0.19^{ab}	5.40±0.79^{a}	1.86±0.11^{ab}
Ex-Sudan	1.79±0.13^{ab}	1.72±0.14^{ab}	5.91±0.53^{a}	2.65±0.27^{a}
ICEASE-00018	1.83±0.21^{a}	1.57±0.13^{ab}	4.67±0.39^{a}	2.10±0.35^{ab}

PAKISTAN

- M. Sharif (1985) reported phyllody is a major disease.
- D.A. Shambharkar et al. (1997) evaluated 30 genotypes from 9 countries for tolerance to *Alternaria sesami*, *Leveillula taurica*, *Macrophomina phaseolina*, and phyllody. The phyllody incidence ranged from 0 to 20.8%. The genotypes SIK-113 and SIK-104 from Kenya exhibited better tolerance under high as well as low input conditions. Other good genotypes were Krishna, Padma, and Tapi. These genotypes should be used for breeding programs.
- G. Sarwar et al. (2006) evaluated 106 genotypes to determine the major yield components. The range of phyllody was 3.8-20%. Phyllody or green flowers is associated with a mycoplasma like organism (MLO). The disease is transmitted by *Orosius albicinctus*. Its incidence in sesame is sometimes 90-100% - a level of infection that cause total crop loss. It has been observed that 1% increase in disease intensity reduces the yield by 8.36 kg/ha (Maiti et al., 1988).
- G. Sarwar and K.P. Akhtar (2009) evaluated 27 mutant lines in M_4 generation in 2006 for yield and disease. The phyllody incidence under high inoculum pressure ranged from 0-2.75% indicating the highly resistant reaction of all the genotypes. Sesame leaf curl disease (SLCD) did not appear during this season. In 2007-08 in the first trial, seed yield ranged from 281-1,580 kg/ha and phyllody from 1-8% and SLCD from 11-25% causing maximum losses from 28-86%. In the second trial, seed yield ranged between 511-1,785 kg/ha, phyllody

incidence from 1-8% and leaf curl disease from 2-9%. The losses in seed yield in the second trial due to phyllody and virus ranged from 2-32% and 7-28% respectively.

- F. Akbar et al. (2011b) classified 105 accessions from diverse ecologies in Pakistan. They used 16 traits. They classified *Phyllody disease incidence* as:
  - 1 = Very low
  - 3 = Low
  - 5 = Intermediate
  - 7 = High
  - 9 = Very high

PARAGUAY

- Anon. (2015a) Paraguay descriptor: 1.10 Incidence of *Phylodia*. The following ratings are used:
  - 0 = Sin informacion [No information]
  - 1 = Resistente [Resistant]
  - 2 = Medianamente resistente [Moderately resistant]
  - 3 = Medianamente susceptible [Moderately susceptible]
  - 4 = Susceptible [Susceptible]

PHILIPPINES

- N.M. Tepora (1989) reported the following disease: phyllody.

REPUBLIC OF KOREA

- S.U. Kim (pers. comm. 2015): The following is a photo of phyllody on sesame**.**

SENEGAL

- M.N. Beko (pers. comm. 2021) reported phyllody is the main disease in her research fields..



SIERRA LEONE

- F.C. Deighton (1932) reported phyllody in Uganda, Tanzania, and Sierra Leone. [Cited by G.S. Saharan, 1989]

SRI LANKA

- Anon (2017a) reported the presence of phyllody (caused by a mycoplasma-like organism transmitted by plant hoppers). The symptoms are flower buds are changed to leaf buds. For control (1) Cultivation in the correct time, (2) Uproot and burn diseased plants, and (3) control plant hoppers with Acetamaprid 20% SP or Acephate 75% SP 10g/10l of water. Some new introductions are tolerant to plant hoppers.

SUDAN

- Anon. (1949a) reported Red variety of sesamum was severely affected with phyllody which eventually swept through the crop giving almost 100% infection. [Cited by G.S. Saharan, 1989]
- A.R.C. Umaima (pers. Comm. 2021) reported phyllody is a current problem. The symptoms are vein clearing of leaves during flowering stage. Floral parts transformed into green leafy structures. The veins are thick and prominent. The plant is stunted with reduced internodes and abnormal branching.

TANZANIA

- F.C. Deighton (1932) reported phyllody in Uganda, Tanzania, and Sierra Leone. [Cited by G.S. Saharan, 1989]
- Kafiriti, E. and O. Mponda (n.d.) in a grower guide reported the following disease: phyllody.

THAILAND

- S. Kulthongkham (1948) reported the presence of phyllody. [Cited by D. Choopanya, 1973]
- D. Choopanya (1972) reported in the field 2 of 14 cultivars showed no symptoms. No phyllody was observed on plants grown from normal seed or phyllody infected plants. [Cited by G.S. Saharan, 1989]
- D. Choopanya (1973) reported phyllody was observed in Northeast Thailand. Electron microscope studies showed the presence of mycoplasma-like bodies in the diseased tissue and not in the healthy tissue. No viruses were observed. A survey conducted in several provinces in northeastern Thailand during 1969 and 1970 indicated the phyllody was so severe in some areas that farmers decreased their acreage of sesame.

TURKEY

- Z. Turkmengoglu and U. Ari (1959) reported sesame phyllody virus has been noted sporadically in recent years on local sesame varieties in West Turkey. Foreign varieties imported in 1957-1959 were up to 50% infected but local varieties growing nearly resistant. Other symptoms such as severe distortion, fasciation and leaf crinkle have appeared in the imported varieties and have not been diagnosed with certainty. Destruction of diseased plants is advocated.
- H. Baspinar et al. (1993) reported two different insects, *Circulifer haematoceps* (Mulsant and Rey) and *Orosius orientalis* (Matsumura) were identified and reported as vectors of *Spiroplasma citri* and phyllody disease in Turkey. The populations and the disease incidence changed in the spring and late summer as shown in the following graphs.

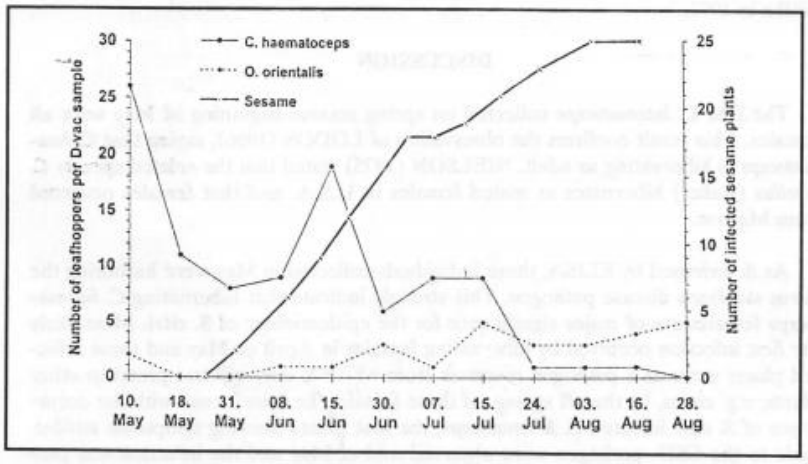


Figure 1 : Population changes of **Circulifer haematoceps** and **Orosius orientalis** as well as number of **Spirolasma citri** and sesame phyllody infected sesame plants in spring sesame in Adana in 1991.

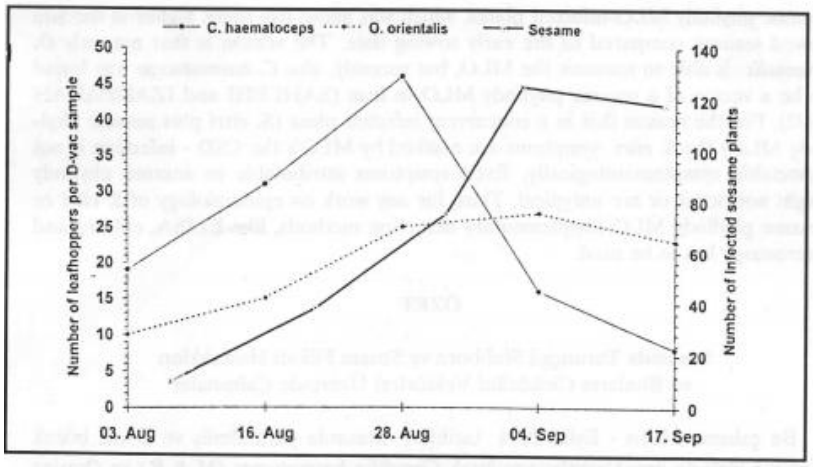
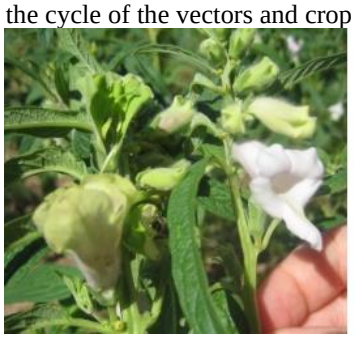


Figure 2 : Population changes of **Circuliferr opacipennis** and **Orosius orientalis** as well as number of **Spirolasma citri** and sesame phyllody infected sesame plants in summer sesame in Adana in 1991.

- U. Kersting (1993) reported two different insects, *Circulifer haematoceps* (Mulsant and Rey) and *Orosius orientalis* (Matsumura) were identified and reported as vectors of phyllody disease in Turkey. [Cited by M.I. Cagirgan et al., 2013]
- A.S. Tan (2010) studied whether or not phyllody is transmitted by seed. Seed transmission for phyllody (MLO) were estimated in plants grown from seeds obtained from symptomatic sesame plants naturally infected with the phyllody disease. Phyllody infected and severely damaged 30 single plants of eleven varieties were selected from eight registered and three candidate sesame in Izmir in 2001. The seed samples of pods were collected from the different part of phyllody infected plants. In order to prevent vectors phyllody infected single plant seed were planted in the screenhouse and evaluated under field conditions during first and second crop production seasons in 2002. None of the plants from 11 varieties showed disease symptom, and all of plants were found to be phyllody disease free in both seasons. Phyllody disease transmission was observed 0% from infected plants of seed. The results suggested that this disease is not seed-born and seed transmission from phyllody infected plants is virtually nonexistent.




- M.I Cagirgan et al. (2013) studied phyllody symptomatology and incidence in three groups of plant material: (1) in a 2- year agronomic performance trial, (2) in the breeding nurseries (on the regenerated branches in the stubbles and unselected left-plants), and (3) in the M_1 plant progenies (grown as M_2 families beyond the commercial growing season for a training purpose). Unexpectedly, in 2010, there was no phyllody incidence (0%) in the first and second group material in comparison to the previous years, e.g., 6.0% in 2009). Although the incidence was nil in the third group material of M_2 families until onset of capsules (sown very late), phyllody symptoms started to appear as capsules grew and reached at 3% at the physiologic maturity. Also, stubbles of cut plants and unselected-left plants in the field after harvest (especially of F_1s with heterosis) grew new late branches like ratoon crop and developed phyllody in them, providing a good match between vectors and plant growth. Much of the impact of climate change and variability on sesame phyllody may be through the vectors of the disease and, thus, subject to the effects of fluctuating climate variables on their biology and population dynamics. The climate data clearly indicated a cool and rainy season and possibly a mismatch for the cycle of the vectors and crop growth.







- Z. Ozdemir (2015) surveyed farmer fields in 2010-2014 in Antalya 2 to 5 times per year and reported maximum disease incidence was an average of 11%, but there were fields with 100%. The four-year survey has shown that phyllody disease is endemic in Antalya.
- N. Isler et al. (n.d.) reported the following disease: phyllody. For control remove diseased plants from the field and control the insect vectors.

UGANDA

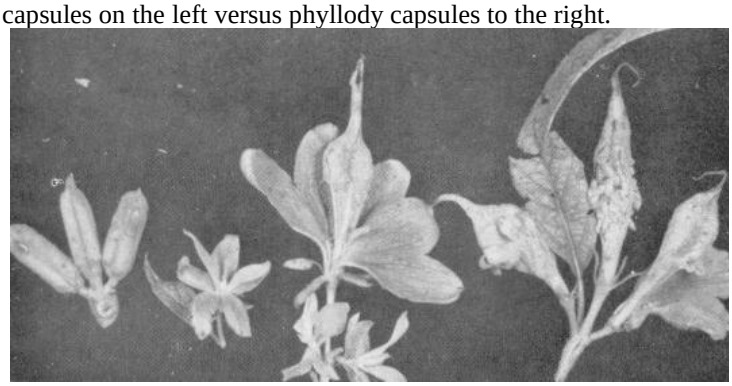
- F.C. Deighton (1932) reported phyllody in Uganda, Tanzania, and Sierra Leone. [Cited by G.S. Saharan, 1989]

UNITED STATES

- M.L. Kinman (1955) reported a phyllody disease (which causes flower parts to develop into leaf-like structures), presumably caused by an insect-transmitted virus.
- A. Ashri (pers. comm., 1996): He and Michael Roose found one plant in Roose's nursery in Riverside, California, in 1986 that looked like phyllody. Roose preserved some of the plant in alcohol. The plant did have capsules with seed in them.

VENEZUELA

- B. Mazzani and G. Malaguti (1952b) reported phyllody was recorded on sesame and *Sesamum radiatum.* The characteristics were very short internodes, longer peduncle, leafy, and green flowers. Photos below are the apex of the plant and normal capsules on the left versus phyllody capsules to the right.

- M.M. Satour (1981) reported the presence of mycoplasma-like organism (phyllody).

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C6 Order: **Acholeplasmatales** Freundt et al. 1984

(Wikipedia, 3 May 2021) The **Acholeplasmatales** are an order in the class Mollicutes, containing only one family, **Acholeplasmataceae**, comprising the genera *Acholeplasma* and *Phytoplasma*. Yet, *Phytoplasma* has the candidatus state because members still could not be cultured. Etymology: The name Acholeplasmatales is derived from the Greek *a* = not, *cholè* = bile and *plasma* = anything molded or formed. Species in the order Acholeplasmatales can grow in a medium without cholesterol, unlike species in the order Mycoplasmatales. Cholesterol, a sterol, is an important component of the cell membrane of mycoplasmas, whereas in acholeplasmas and in bacteria in general it is absent.

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C6.1 Family: **Acholeplasmataceae** Edward and Freundt 1970

(Wikipedia, 3 May 2021) **Acholeplasmataceae** has two genera *Acholeplasma* and *Phytoplasma*.

The following species have been reported to cause diseases, produce a toxin, inhibit germination, or affect seed quality.

- C6.1.1 *Phytoplasma* spp.
- C6.1.1a *Candidatus* Phytoplasma asteris (Group 16SrI)
- C6.1.1b *Peanut witches'-broom phytoplasma* (Group 16SrII)
- C6.1.1c *Candidatus* Phytoplasma trifolii (Group 16SrVI)
- C6.1.1d *Pigeon pea witches' broom phytoplasma* (Group 16SrIX)

C6.1.1 *Phytoplasma* spp. (3 May 2021)

(Wikipedia, 3 May 2021) **Phytoplasmas** are obligate bacterial parasites of plant phloem tissue and of the insect vectors that are involved in their plant-to-plant transmission. Phytoplasmas were discovered in 1967 by Japanese scientists who termed them mycoplasma-like organisms. Since their discovery, phytoplasmas have resisted all attempts at *in vitro* culture in any cell-free medium; routine cultivation in an artificial medium thus remains a major challenge. Although phytoplasmas have recently been reported to be grown in a specific artificial medium, experimental repetition has yet to be reported. Phytoplasmas are characterized by the lack of a cell wall, a pleiomorphic or filamentous shape, a diameter normally less than 1 μm, and a very small genome.

Phytoplasmas are pathogens of agriculturally important plants, including coconut, sugarcane, and sandalwood, in which they cause a wide variety of symptoms ranging from mild yellowing to death. Phytoplasmas are most prevalent in tropical and subtropical regions. They are transmitted from plant to plant by vectors (normally sap-sucking insects such as leafhoppers) in which they both survive and replicate.

Family: Acholeplasmataceae; Genus: Phytoplasma

Definition: Amount of tolerance to *Candidatus* Phytoplasma spp. Firrao et al. 2004

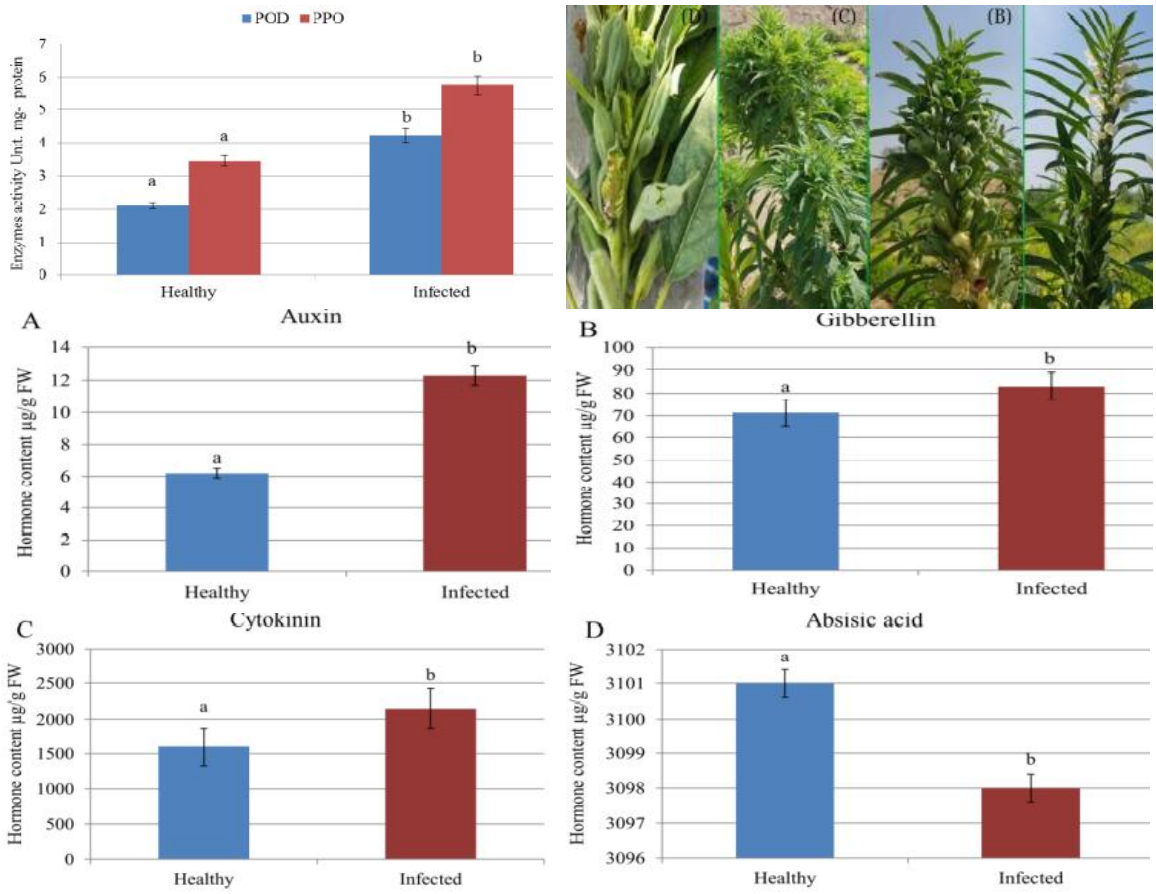
References:

INTERNATIONAL

- CAB International (accessed 12 Apr 2021) reported sesame was a minor host of soybean phyllody phytoplasma (Soyabean phyllody).

EGYPT

- S.A. Yousef et al. (2018) studied effect of the phytoplasma infection on plant enzymes such as peroxidase (POD) and polyphenol oxidase (PPO) and hormones like auxins, cytokinin, gibberellins and abscisic acid. The plants formed many defense mechanisms, and the enzymes play one of the most important roles in the infection process and pathogenesis. Plant hormones assume a significant part in controlling the manner by which plants develop. The following compares healthy versus infected tissues. On the plant photos, the healthy plant is on the right.



ETHIOPIA

- H. Tadesse (1985) in a presentation reported phyllody (caused by phytoplasma) was a major disease. An affected plant bears cluster of leaves and a malformed flower at the top. It is prevalent in irrigated sesame.

INDIA

- J. Diraviam (2014) made regular visits to farmer fields in South India and found the phytoplasma disease phyllody transmitted by *Orosius albicinctus* Distant. Although vector activity was not that prominent, the phyllody incidence that was low initially (5-10%) went up to 25% at the time of harvest.
- K. Satyagopal et al. (2014) in an IPM manual reported phyllody symptoms were as follows:
  - All floral parts are transformed into green leafy structures followed by abundant vein clearing in different flower parts.
  - In severe infection, the entire inflorescence is replaced by short, twisted leaves closely arranged on a stem with short internodes, abundant abnormal branches bend down.
  - Finally, plants look like witches' broom.
  - If capsules are formed on lower portion of plant, they do not yield quality seeds.

The disease is transmitted through jassids and the phytoplasma survives in leaf hopper throughout its life. For cultural control: Intercropping of sesamum + redgram (6:1). For biological control: Spray neem oil @ 5 ml/l for vector (leaf hopper) control.

- V. Singh et al. (2017) reported phytoplasmas are wall-less plant pathogenic bacteria that are transmitted through sap-feeding insects. Phytoplasma colonization in the host plant has been shown to depend on the affecting phytoplasma group and the properties of the host plant. Vegetative tissues were collected from progressive stages of sesame phyllody from pre/post-blooming infection. Results revealed a wide range of phytoplasma titer across the organs of phyllody affected sesame plants, i.e., 22 cells to 4.2 x 10^7 cells/mg plant DNA. The lowest titer was observed in the roots, whereas the maximum number of phytoplasma cells was observed in the leaves. Phytoplasma concentration positively correlated with disease severity during the initial three stages of disease progression; however, a decline was observed at a later stage. In addition, significant variation was observed in the upper and lower plant parts, and the pattern showed a reversal with respect to early and late stages of disease. The study indicates that the lower plant parts of sesame are advantageous for phytoplasma detection at early stages. However, for experiments with pre-requisite of high phytoplasma abundance, leaves from later stages of phyllody will be beneficial. The outcomes will prove useful in effective sampling of sesame tissues for research and quarantine purposes.
- K.N. Gupta et al. (2018) reported phyllody is a serious and wide spread disease caused by a pleomorphic mycoplasma– like organism (MLOs) which is now called as phytoplasma. The phyllody is transmitted by the insect vector *Orosius albicinctus.* The tolerant varieties are TKG 21, RT-125 and RT-103. In addition to common cultural, mechanical and biological practices the following reduced phyllody: intercropping of sesame + red gram (6:1) or sesame + pigeonpea (1:1); spraying of neem oil @50ml/l for vector (leaf hopper) control; seed treatment with Imidacloprid (@ 5 ml/kg seed) followed by foliar spray of Thiomethaxam @ 0.2 g/l; plant spacing of 30x10 cm; late planting (about 3 weeks after onset of monsoon); soil application of Phorate 10 g (10 kg/ha), Dimethoate (0.03%), or Profenofas/spinosad; and removal and destruction of diseased plants.

IRAQ

- Al-Hadithy (2002) studied whether *O. albicinctus* would transfer phyllody and concluded that the insect did transfer the phytoplasma. In two studied fields the incidence was 5 and 14%. The results of the chemical control revealed that disease incidences were significantly reduced over that of the control by: (a) the insecticide Actara at six different application times; (b) repeated sprays with insecticide at two week interval; and (c) seed dressing with the insecticide Cruiser. The differences in the disease incidences were not significant between the plants at five different sowing dates. Maize and sorghum crops used as plant barrier around the sesame crop caused significant reduction into the disease incidence (0.46 and 1.95% respectively), over that of the control (without barrier) (5.68%). Photos on the left are normal flower on the right and effects of phyllody. Photos on the right are normal capsule on the right and abnormal capsules. [Based on abstract]

JAPAN

- T. Kuzuyuki (2021) reported the following pathogen: *Candidatus phytoplasma* sp.

MYANMAR

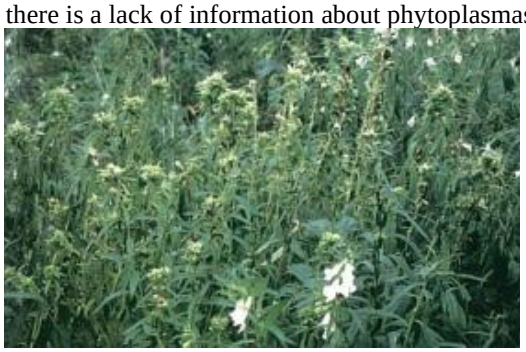
- Y.Y. Min and K. Toyota (2019) surveyed diseases in 10 farmer fields and interviewed 25 farmers. They reported the following pathogen: *Candidatus* Phytoplasma. The disease incidence ranged from 5% to 30% and was reported in 60% of the fields. The yield losses ranged from 5 to 50%. Phytoplasma can be prevalent throughout the year and is transmitted by the insect vector (*Orosius albicinctus*).

SYRIA

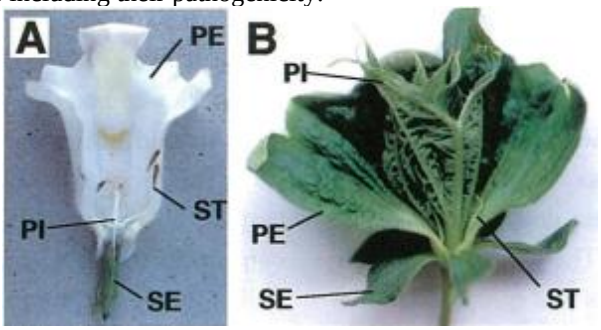
- S.E. Khabbaz et al. (2013) surveyed fields in 2010 and found phyllody incidence varied from 7-66% depending on the variety, plant age, temperature and insects present. Different types of phyllody disease symptoms viz., floral virescence, phyllody, Witches broom, formation of dark exudates on floral parts and yellowing, shoot apex fasciation, and short internodes with twisted and reduced leaves were observed. *Orosius albicinctus* was found as the most predominant insect species in most infected sesame fields, which is known to play an important role in transmitting the phytoplasma. Dienes' stain of leaves and stems sections of sesame tissue plants revealed the presence of regularly distributed dark blue areas in the phloem cells of stem sections of infected plants, which was absent in the healthy plants.

THAILAND

- K. Nakashima et al. (1999) reported specimens of sesame plants (SP) and *Richardia* sp. (RP) with phyllody were collected in a sesame field Khon Kaen. The presence of phytoplasmas in the plant tissues was confirmed by electron microscopy. 16S rDNA analysis revealed that the SP phytoplasmas are clearly related to the RP phytoplasmas phylogenetically. So far it has not been possible to culture phytoplasmas *in vitro*. Therefore, there is a lack of information about phytoplasmas including their pathogenicity.



Field with normal and infected plants



Normal vs. infected flower:
PI pistil, ST stamen, PE petal, SE sepal.

TURKEY

- C. Ikten et al. (2013c) reported sesame phyllody, known as a viral disease. Earlier, is a very serious and destructive disease and it is now associated with phytoplasmas that are uncultured wall-less bacteria (class Mollicutes) that live in the phloem of host plant and in the emolinph of insect vectors. The sesame infected plants become stunted, and the floral parts are modified in to leafy structures bearing no fruits and seeds resulting in significant yield losses. Various symptoms occur according with different growing stages and time of infection. During 2008 to 2010 growing seasons, lots of sesame plants infected with phyllody disease were observed in Antalya province located in the southern of Turkey. They showed the following symptoms of phyllody:

- R. Ustun et al. (2017) screened 542 genotypes for phyllody resistance in the field using a disease incidence scale of 1–5 (1 = resistant and 5 = susceptible) in 2012. In 2013, 238 genotypes were further tested under artificially infected field conditions. In 2013, only 30 out of 238 accessions were determined as potential resistant genotypes based on the disease incidence scale. The 30 genotypes were further evaluated for confirmation in greenhouse conditions using the phytoplasma-infected insects under choice and no-choice conditions. Real-time qPCR was used for detection and quantification of phytoplasmas to select true resistant genotypes. The sesame accessions ACS38 and ACS102 were identified as resistant in all evaluations. The following table shows resistance in 2012 and 2013.

Origin	2012						2013					
	Total number of genotypes	Disease incidence scale (1–5) The number of genotypes based on visual score					Total number of genotypes	Disease incidence scale (1–5) The number of genotypes based on visual score				
		1	2	3	4	5		1	2	3	4	5
Afghanistan	18	5	2	2	9	0	6	5	0	0	1	0
Angola	2	1	0	0	1	0	1	0	0	1	0	0
Argentina	1	0	0	1	0	0	0	0	0	0	0	0
China	14	4	3	2	2	3	4	1	3	0	0	0
Egypt	5	2	1	0	1	1	2	0	1	0	0	1
Ethiopia	1	0	0	0	1	0	0	0	0	0	0	0
Greece	11	6	1	1	2	1	7	3	4	0	0	0
Guatemala	1	0	0	0	0	1	1	0	1	0	0	0
India	6	0	0	0	0	6	6	2	2	1	0	1
Iran	18	4	0	1	1	12	16	1	1	10	2	2
Iraq	13	2	2	4	1	4	4	1	2	0	1	0
Israel	22	5	2	13	2	0	5	2	1	2	0	0
Italy	1	1	0	0	0	0	1	0	0	1	0	0
Japan	4	2	0	2	0	0	2	0	1	0	1	0
Jordan	2	1	0	1	0	0	1	0	0	1	0	0
Korea	1	0	0	1	0	0	0	0	0	0	0	0
S. Korea	12	5	0	5	2	0	6	1	0	2	2	1
Morocco	1	1	0	0	0	0	0	0	0	0	0	0
Myanmar	3	1	0	0	2	0	1	0	1	0	0	0
Nigeria	1	1	0	0	0	0	0	0	0	0	0	0
Pakistan	17	10	2	4	1	0	3	3	0	0	0	0
Russia	23	3	4	13	3	0	4	2	0	0	1	1
South America	2	0	0	1	0	1	0	0	0	0	0	0
Sri Lanka	1	0	0	1	0	0	0	0	0	0	0	0
Syria	2	0	0	2	0	0	0	0	0	0	0	0
Thailand	1	0	0	1	0	0	0	0	0	0	0	0
Turkey	342	120	13	113	50	46	164	9	40	48	39	28
USA	13	1	0	6	3	3	1	0	1	0	0	0
Venezuela	4	3	0	1	0	0	3	0	0	2	0	1

C6.1.1a *Candidatus* Phytoplasma asteris (Group 16SrI) (3 May 2021)

Family: Acholeplasmataceae; Genus: Phytoplasma

Definition: Amount of tolerance to *Candidatus* Phytoplasma asteris (Group 16SrI)

References:

INTERNATIONAL

- CAB International (accessed 12 Apr 2021) reported sesame was a major host of *Candidatus* Phytoplasma asteris (yellow disease phytoplasmas).

INDIA

- M.S. Khan et al. (2007) reported 12-30% phyllody in farmer fields in Uttar Pradesh. They identified the pathogen as 16SrI – '*Candidatus* Phytoplasma asteris'.
- N. Manjunatha et al. (2012) reported 17-75% phyllody in farmer fields in Karnataka. They identified the pathogen as 16SrI.
- Madhupriya et al. (2015) reported during 2011-2013, 7-55% incidence of sesame phyllody and witches' broom symptoms on sesame plants in nine states of India. '*Candidatus* Phytoplasma asteris' of the subgroup 16SrI-B was present in sesame plants in two states (Uttar Pradesh and West Bengal), while 16SrII-C subgroup phytoplasma was found in sesame plants grown in four states (Uttar Pradesh, Madhya Pradesh, Chhattisgarh and Rajasthan). Phytoplasma belonging to 16SrII-D subgroup was found as the most widely distributed phytoplasma strain on sesame from five states (Delhi, Rajasthan, Gujarat, Tamil Nadu and Maharashtra).



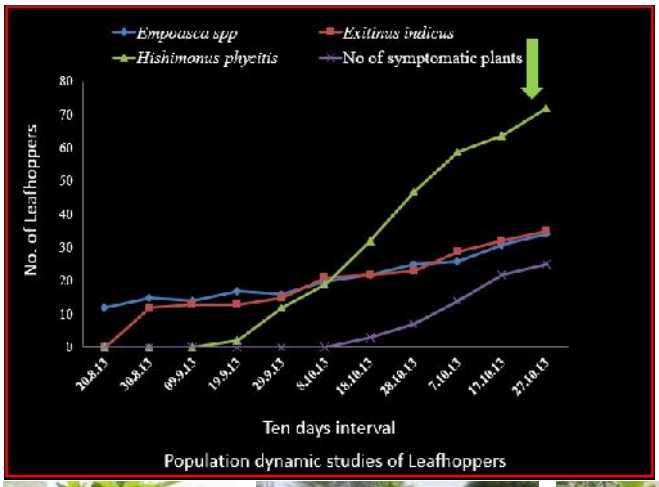
Witches' broom


Phyllody

- S.U. Nabi et al. (2015a) and S.U. Nabi et al. (2015d) reported 4 leafhoppers in a field of sesame in Kushinagar, Delhi, and Gorakhpur in 2012-2013 with phyllody. Little leaf and witches broom symptoms on the weed *Sclerocarpus africanus*. The phytoplasma is transmitted from infected to healthy plants by phloem-feeding insects, mainly leafhoppers belonging to the Hemiptera order. *Empoasca prima* (EP), *Hishimonus phycitis* (HP), *Exitinus indicus* (EI), and *Cofana unimaculata* (CU) were found as the most dominant feeding species at different stages of crop growth. The population dynamics studied showed HP as the most predominant species at the time of symptoms initiation in sesame crop and its population was also correlated with increase in sesame phyllody incidence. The leafhoppers and the plants infected with phyllody were examined, and only the *H. phycitis* had the same phytoplasma (*Candidatus* Phytoplasma asteris: 16SrI-B) as the plants as shown in the following table and figure.

Table 1 Detection of phytoplasma in major leafhopper species collected in sesame fields affected by group 16SrI phytoplasma

Location	Leafhopper species			
	Hishimonus phycitis (Distant)	*Exitinus indicus* (Distant)	*Empoasca prima* (Distant)	*Cofana unimaculata* (Signoret)
Kushinagar				
No. of Individuals	307	189	Nil	177
No. PCR positive /tested samples[a]	12/20	0/20	–	0/20
Phytoplasma group association	16SrI	–	–	–
Delhi				
No. of Individuals	255	163	42	Nil
No. PCR positive /tested samples[a]	8/20	0/20	0/20	–
Phytoplasma group association	16SrI	–	–	–
Gorakhpur				
No. of Individuals	Nil	Nil	135	Nil
No. PCR positive /tested samples[a]	–	–	0/20	–
Phytoplasma group association	–	–	–	–






- S.U. Nabi et al. (2015b) reported little leaf and witches'-broom symptoms on *Cannabis sativa* L. ssp. *Sativa* plants were recorded in sesame phyllody infected fields in Uttar Pradesh in 2013. The DNA extracted from symptomatic weeds and the Phylloid sesame plants revealed *Candidatus* Phytoplasma asteris (16SrI group). Our results suggest that *Cannabis sativa* L. ssp. *Sativa* may play an important role in perpetuation of sesame phyllody phytoplasma in nature.
- S.U. Nabi et al. (2015c) reported phyllody infected fields of three states, viz. Delhi, Uttar Pradesh and Bihar in India were surveyed during July-October 2013. There was 15-35% incidence of sesame phyllody (SP) and witches' broom (WB) disease in different fields. The study confirmed that SP and WB isolates from Uttar Pradesh belonged to 16Sr I-B and 16Sr II-C subgroups. However, isolates from Delhi and Bihar belonged to 16Sr I-B subgroup.
- S.U. Nabi et al. (2016) reported a survey of sesame phyllody infected field in September 2014, recorded 15-35% incidence of sesame phyllody (SP) and witches' broom (WB) in different fields. BLAST analysis and phylogenetic analysis of 16SrRNA and tuf sequences revealed that the phytoplasma associated with SP & WB disease belonged to the *Candidatus* Phytoplasma asteris (16SrI) group.
- A.K. Singh et al. (2018) reported little leaf and phyllody symptoms were observed on 8% of sesame crop in Jammu in 2016. Witches' broom symptoms on *Cannabis sativa* subsp. *Sativa* were also observed in and around sesame fields with the incidence varied from 5 to 12% in different fields. They identified phytoplasma strains of the 16SrI-B subgroup.

MYANMAR

- N.K.K. Win et al. (2010) reported the plants with phyllody were infected by phytoplasma belonging to the group 16SrI and subgroup 16SrI-B.

PARAGUAY

- E.J.G. Junior et al. (2019) reported 16SrI-B phytoplasm was identified in commercial fields. The results implicate sesame as being a new host of 16SrI-B phytoplasma in Latin America. Since representatives of this subgroup have shown low specificity in relation to hosts, the study suggests that the phytoplasma could be associated with other species cultivated in Paraguay. Furthermore, our report should alert other sesame-producing countries in Latin America to scout for the presence of phyllody.

VIETNAM

- N.B. Quoc et al. (2021) reported phloem-limiting phytoplasmas are known to be causal agents of phyllody, which is recognized by the abnormal development of floral structures resulting in serious yield losses in sesame plants. Currently, identification of the various groups of phytoplasmas that cause sesame phyllody (SP) is conducted by nested PCR, RFLP, and multiplex real-time qPCR assays. However, these methods require intensive labor and are costly and time-consuming so can only be undertaken in well-equipped labs. Here, diagnostic loop-mediated isothermal amplification (LAMP)–based assays allowing rapid detection of specific groups of phytoplasmas within 30 min were developed based on detection of the 16S rRNA sequence of phytoplasmas. Results demonstrated that the 16SrI and 16SrII group phytoplasmas were causal agents of sesame phyllody in Vietnam. [Based on abstract]

C6.1.1b Peanut witches' broom phytoplasma (Group 16SrII) (3 May 2021)

Family: Acholeplasmataceae; Genus: Phytoplasma

Definition: Amount of tolerance to Peanut witches' broom phytoplasma (Group 16SrII)

References:

INTERNATIONAL

- CAB International (accessed 12 Apr 2021) reported sesame was a host of Phytoplasma aurantifolia (lime witches' broom phytoplasma).

INDIA

- G.P. Rao Madhupriya et al. (2015) reported during 2011-2013, 7-55% incidence of sesame phyllody and witches' broom symptoms on sesame plants in nine states of India. '*Candidatus* Phytoplasma asteris' of the subgroup 16SrI-B was present in sesame plants in two states (Uttar Pradesh and West Bengal), while 16SrII-C subgroup phytoplasma was found in sesame plants grown in four states (Uttar Pradesh, Madhya Pradesh, Chhattisgarh and Rajasthan). Phytoplasma belonging to 16SrII-D subgroup was found as the most widely distributed phytoplasma strain on sesame from five states (Delhi, Rajasthan, Gujarat, Tamil Nadu and Maharashtra).



Witches' broom Phyllody

- S.U. Nabi et al. (2015c) reported phyllody infected fields of three states, viz. Delhi, Uttar Pradesh and Bihar in India were surveyed during July-October 2013. There was 15-35% incidence of sesame phyllody (SP) and witches' broom (WB) disease in different fields. The study confirmed that SP and WB isolates from Uttar Pradesh belonged to 16SrI-B and 16SrII-C subgroups. However, isolates from Delhi and Bihar belonged to 16Sr I-B subgroup.
- V. Venkataravanappa et al. (2017) used 41 samples to identify the cause of phyllody in Uttar Pradesh where the infection ranged from 30 to 70% as the 16SrII-D subgroup, the peanut witches' broom group – *Candidatus* Phytoplasma australasia.

- G.P. Rao et al. (2019) reported little leaf, phyllody and witches' broom symptoms with incidence of 8% to 20% were recorded in cluster bean, sesame and a weed (*Phyllanthus niruri*) in farmer's fields at Haryana, India during Sep-Oct 2017-2018. The phytoplasma in the three species plus the leafhopper *Empoasca motti* was '*Candidatus* Phytoplasm aurantifolia' in the 16SrII-D group.

- P. Devanna et al. (2020) surveyed fields in Karnataka during April–June 2010 (summer) and in Telangana, Maharashtra and Karnataka during July–September 2010 (*Kharif*). In summer, disease incidence of 19–32% was recorded, whereas, in *Kharif*, incidences of 45-68%, 13-47% and 32% were recorded, respectively. All summer crop isolates were classified under the 16SrII-D subgroup; whereas, *Kharif* season isolates were grouped under the 16SrII-A and 16SrII-D groups. [Based on abstract]

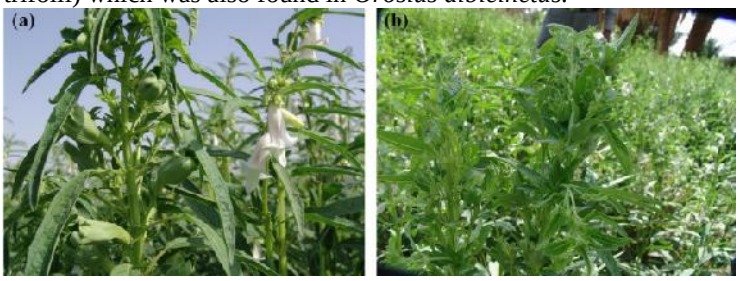
IRAN

- S.A. Esmailzadeh-Hosseini et al. (2007) surveyed for phytoplasmas in sesame fields in Yazd province in 2003–05. The leafhopper *Orosius albicinctus* was collected and found to contain a phytoplasma. Transmission tests

were performed under greenhouse conditions. The indicator plants were alfalfa, rapeseed, garden beet, sesame, radish, periwinkle and garden cress. Testing confirmed that sesame, garden cress and garden beet plants were infected by the phytoplasma. The detected phytoplasma belonged to the 16SrII group (Peanut witches' broom phytoplasma). This is the first report of transmission of a phytoplasma associated with sesame phyllody by *O. albicinctus* in Iran.

Field with phyllody.

- S.A. Esmailzadeh-Hosseini et al. (2015) surveyed for phytoplasmas in sesame fields in Yazd province in 2008–10. All fields had infections and one field had 100% infection. The pathogen was identified as a member of peanut witches' broom (16SrII) group. No differences were observed in plant heights of infected and healthy plants. Total seed yield was reduced by 55.1% in infected plants and 1,000 seed weight showed a 21.5% decrease. Wrinkled seeds increased in diseased plants up to 56.1%. Results of variance analysis of control methods showed that sowing date and spraying have significant effects on the rate of infection. Sowing of sesame straight after wheat harvest in May needed spraying to reduce disease incidence but delay in the sowing date to July 5 can reduce disease incidence up to 31% without any significant differences in seed yield. Delay in sowing date is dependent on weather and needs to be determined for each area. Spraying with Confidor reduced disease incidence at the first and second sowing date by 18.8% and 7.8% respectively, but there were no differences in seed yield. Seed treatment with Gaucho had no effect on disease incidence.
- M. Khodadadizade Mahabadi et al. (2016) reported sampling was carried out from 17 phyllody affected sesame plants in Yazd (31.90N 59.36E) and Ashkezar (32.00N 54.21E) during 2014-15. Analysis showed that the cause of the phyllody was peanut witches' broom (16SrII-D).
- M. Salehi et al. (2016) studied genetic diversity and vector transmission of phytoplasmas associated with sesame phyllody during 2010–14 surveys in the major sesame growing areas of Fars, Yazd and Isfahan provinces. *Circulifer haematoceps* and *Orosius albicinctus*, known vectors of the disease in Iran, were tested for transmission of the strains identified in this study. *C. haematoceps* transmitted 16SrII-D, 16SrVI-A, and 16SrIX-C phytoplasmas, while *O. albicinctus* only transmitted 16SrII-D strains.
- S.A. Tazehkand et al. (2017) analyzed the phytoplasm of 4 regions of Kerman Province which had an incidence of 5-30%. Based on 9 plant samples collected in the field, they reported 2 causal phytoplasmas: 16SrII-A (*Candidatus* Phytoplasma aurantifolia – Peanut witches' broom) and 16SrVI-A (*Candidatus* Phytoplasma trifolii) which was also found in *Orosius albicinctus.*



OMAN

- M.A. Al-Sakeiti et al. (2005) reported the presence of phyllody based on excessive development of short shoots and internodes resulting in little leaves. PCR analysis confirmed the presence of phytoplasm causing witches' broom (16SrII). [Based on abstract]
- A.J. Khan et al. (2007) took samples from phyllody plants in 2005/06 and determined it was caused by witches' broom (16SrII-D).

PAKISTAN

- K.P. Akhtar et al. (2008 and 2009a) reported phyllody was caused by Peanut witches' broom (16SrII-D) transmitted by the leafhopper (*Orosius albicinctus*). They studied whether *Empoasca* spp. would transfer

phyllody and concluded that the insect did not transfer the phytoplasma. They described the following symptoms of phyllody.

- The major disease symptoms were floral virescence (Fig. 1), phyllody (Fig. 2), and proliferation (Fig. 3). Additionally, seed capsule cracking (Fig. 4), seeds germinating in capsules (Fig. 4), formation of dark exudates on foliage and floral parts (Fig. 5), and yellowing (Fig. 6) sometimes accompanied the disease. Shoot apex fasciation (Fig. 7) was also observed on occasion. Phyllody infected plants exhibited symptoms that varied according to growth stage and time of infection. Infection at an early stage of growth resulted in cessation of internode elongation, reduction in leaf size, and stunting (to about two-thirds of normal plant height). The entire inflorescence was converted into twisted reduced leaves closely arranged on the top of the stem, with very short internodes (Fig. 6), Infections that occurred later in the season caused characteristic symptoms, such as virescence, phyllody, and witches' broom.
- The most characteristic symptoms of the disease are transformation of floral parts into green leaf-like structures, followed by abundant vein clearing in different floral parts. The ovary is replaced by elongated structures, almost resembling a shoot (Fig. 1 and 2). Phylloid flowers become actinomorphic in symmetry and the corolla becomes polypetalous and deep green. The veins of the flower become thick and quite conspicuous. The stamens retain their shape, but become flattened, showing a tendency to be leaf-like. The anthers become green and contain abnormal pollen grains. The carpels are transformed into a leaf fusion at the margins, and this false ovary enlarges and flattens, exhibiting a soft texture and a wrinkled surface due to the thickening of capillary wall veins. Instead of ovules inside the ovary, there are small petiole-like outgrowths, which later grow and burst through the walls of the false ovary, providing small shoots (Fig. 1). These shoots continue to grow and produce more leaves and phylloid flowers (Fig. 2). The stalks of the phylloid flowers are generally elongated, whereas normal flowers have very short pedicels (Fig. 1).

Fig. 1. Floral virescence

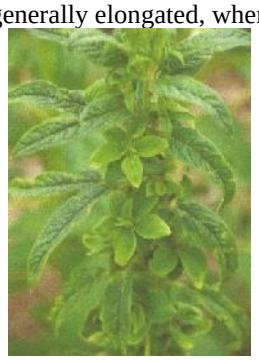


Fig. 2. Phyllody symptoms

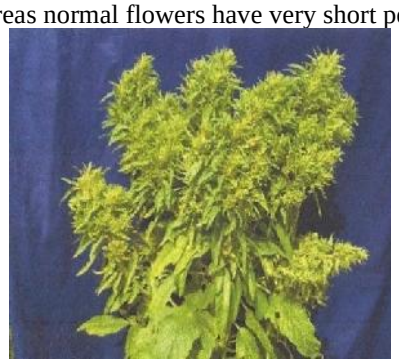


Fig. 3. Floral proliferation

Fig. 4. Germination of seeds in cracked capsules

Fig. 5. Dark exudates on foliage floral parts

Fig. 6. Short internodes with yellow, twisted, reduced leaves.

Fig. 7. Shoot apex fasciation

Fig. 8. Main vector: *Orosius albicinctus*.

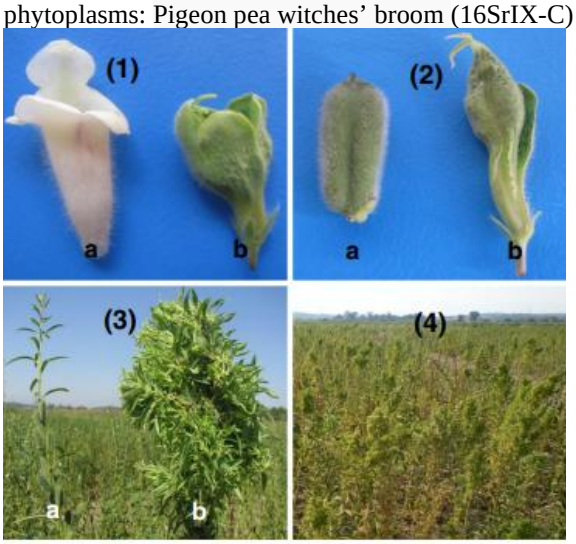
- K.P. Akhtar et al. (2013) evaluated 133 genotypes for tolerance to phyllody was caused by *Peanut witches' broom* (16SrII-D) in the field under high inoculum pressure in 2007 and 2008. In 2007, 3 genotypes showed no symptoms and thus highly resistant while 11 were rated as resistant. In 2008, all of the entries showed phyllody TAS with only 4 considered resistant. In combined scores they rated 11 entries as being resistant.

TAIWAN

- Y.W. Tseng et al (2014) reported plants exhibiting symptoms including phyllody and abnormal stem curling were observed in a field with infected plants estimated over 90%. They determined the phytoplasma was *Candidatus* Phytoplasma australasiae (16SrII-A)

TURKEY

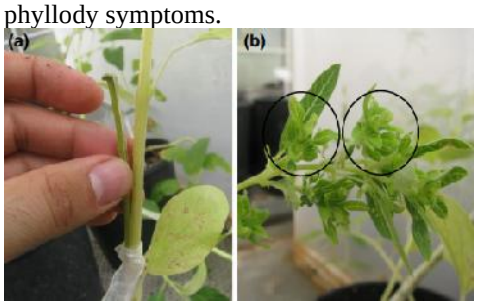
- C. Ikten et al. (2013a, 2013b, and 2014) reported phyllody is a destructive disease of sesame in Turkey. The disease has been causing significant economic losses by stunting the plants and altering their floral parts into leafy structures with no capsule and hence no seeds in sesame fields of the country. They identified two phytoplasms: Pigeon pea witches' broom (16SrIX-C) and Peanut witches' broom (16SrII-D).



Symptoms of sesame phyllody disease. (1a) healthy flower, (1b) infected flower. (2a) healthy capsule, (2b) infected capsule. (3a) healthy sesame plant, (3b) infected sesame plant. (4) the phyllody affected sesame plants in the field.

They tested 3 possible vectors for phyllody in his experiment: *Orosius orientalis, Empoasca decipiens* and *Bemisia tabaci*. The only insect that proved to be a vector was *O. orientalis.* The photos below show symptoms of sesame phyllody on sesame plants exposed to Orosius orientalis under greenhouse conditions.

They showed phyllody transmitted by grafting, (a) Grafting under greenhouse conditions, (b) graft-transmitted phyllody symptoms.



- C. Ikten et al. (2014) reported accurate identification, differentiation, and quantification of phyllody causing phytoplasmas are essential for effective management of this plant disease and for selection of resistant sesame varieties. They described a methodology to analyze samples from 109 sesame plants and 92 insect vectors for 16SrII and 16SrIX in a single test tube.
- F. Ozdemir (2017) reported to detect and identify phytoplasmas of sesame and the cicadellid vector *Orosius orientalis*, samples were collected during 2011–2013 in Antalya. Identification of the phytoplasmas based on sequence homology revealed presence of the 16Sr groups II (Peanut witches'-broom, PnWB), VI (Clover proliferation, CP) and IX (Pigeon pea witches'-broom, PPWB) in sesame plants. PnWB and CP were detected in *O. orientalis*. [Based on abstract]
- F. Ozdemir (2018) tested a total of 65 *Neoaliturus haematoceps* samples collected from sesame fields in Antalya, Turkey, during 2012– 2014 for phytoplasma detection. Analysis revealed three different 16S rDNA phytoplasma groups: the peanut witches'-broom, group II; clover proliferation, group VI; and pigeon pea witches'-broom, group IX.
- B. Uzun (2019) verified that *Orosius orientalis* transmitted the phytoplasma that caused phyllody in Turkey through DNA analysis. Phyllody is a most destructive disease in sesame. The characteristic is deformation of flowers, which do not properly develop and remain green, with the calyx and corolla sometimes stiff, forming a half-open hood. World sesame germplasm (542 accessions) originated from 29 different countries was screened for possible resistance to disease under field conditions in the summer of 2012 and 2013. In the first year 304 were eliminated as highly susceptible. Screening continued down to 30 with possible tolerance. Parallel, they collected the leafhoppers from the field using vaccums and determined they had the same phytoplasma (16SrII, 16SrVI and 16SrIX) as the plants. Further testing in cages confirmed the leafhoppers could pass the phytoplasm from infected plants to healthy plants. The phytoplasmas are obligate parasites that belong to the prokaryotic class Mollicutes and are transmitted by sap-feeding insects and vegetative plant propagation materials. The phytoplasmas are found in the phloem cells of host plants and the study of phytoplasmas is very laborious because it is difficult to culture it *in vitro*.



VIETNAM

- N.B. Quoc et al. (2021) reported phloem-limiting phytoplasmas are known to be causal agents of phyllody, which is recognized by the abnormal development of floral structures resulting in serious yield losses in sesame plants. Currently, identification of the various groups of phytoplasmas that cause sesame phyllody (SP) is conducted by nested PCR, RFLP, and multiplex real-time qPCR assays. However, these methods require intensive labor and are costly and time-consuming so can only be undertaken in well-equipped labs. Here, diagnostic loop-mediated isothermal amplification (LAMP)–based assays allowing rapid detection of specific groups of phytoplasmas within 30 min were developed based on detection of the 16S rRNA sequence of phytoplasmas. Results demonstrated that the 16SrI and 16SrII group phytoplasmas were causal agents of sesame phyllody in Vietnam. [Based on abstract]

C6.1.1c *Candidatus* Phytoplasma trifolii (Group 16SrVI) (4 May 2021)

Family: Acholeplasmataceae; Genus: Phytoplasma

Definition: Amount of tolerance to *Candidatus* Phytoplasma trifolii (Group 16SrVI).

References:

INTERNATIONAL

- CAB International (accessed 12 Apr 2021) reported sesame was a major host of *Candidatus* Phytoplasma trifolii (clover proliferation phytoplasma).

IRAN

- M. Salehi et al. (2016) studied genetic diversity and vector transmission of phytoplasmas associated with sesame phyllody during 2010–14 surveys in the major sesame growing areas of Fars, Yazd and Isfahan provinces. *Circulifer haematoceps* and *Orosius albicinctus*, known vectors of the disease in Iran, were tested for transmission of the strains identified in this study. *C. haematoceps* transmitted 16SrII-D, 16SrVI-A, and 16SrIX-C phytoplasmas, while *O. albicinctus* only transmitted 16SrII-D strains.

TURKEY

- G. Sertkaya et al. (2007) collected *Empoasca* sp. and *Orosius orientalis* (= *albicinctus*) to study the transmission of phyllody phytoplasma (16SrVI group). They determined the disease was transmitted by *Orosius orientalis* but was not transmitted in *Empoasca* sp. in 14 samples.
- F. Ozdemir (2017) reported to detect and identify phytoplasmas of sesame and the cicadellid vector *Orosius orientalis*, samples were collected during 2011–2013 in Antalya. Identification of the phytoplasmas based on sequence homology revealed presence of the 16Sr groups II (Peanut witches'-broom, PnWB), VI (Clover proliferation, CP) and IX (Pigeon pea witches'-broom, PPWB) in sesame plants. PnWB and CP were detected in *O. orientalis*. [Based on abstract]
- B. Uzun et al. (2017) tested 5 phyllody plants and 2 symptomatic plants from Adana and Kas. All the samples shared 99% sequence similarity with that of the *Candidatus* Phytoplasma trifolii (16Sr-VI).
- F. Ozdemir (2018) tested a total of 65 *Neoaliturus haematoceps* samples collected from sesame fields in Antalya, Turkey, during 2012– 2014 for phytoplasma detection. Analysis revealed three different 16S rDNA phytoplasma groups: the peanut witches'-broom, group II; clover proliferation, group VI; and pigeon pea witches'-broom, group IX.
- B. Uzun (2019) verified that *Orosius orientalis* transmitted the phytoplasma that caused phyllody in Turkey through DNA analysis. Phyllody is a most destructive disease in sesame. The characteristic is deformation of

flowers, which do not properly develop and remain green, with the calyx and corolla sometimes stiff, forming a half-open hood. World sesame germplasm (542 accessions) originated from 29 different countries was screened for possible resistance to disease under field conditions in the summer of 2012 and 2013. In the first year 304 were eliminated as highly susceptible. Screening continued down to 30 with possible tolerance. Parallel, they collected the leafhoppers from the field using vaccums and determined they had the same phytoplasma (16SrII, 16SrVI and 16SrIX) as the plants. Further testing in cages confirmed the leafhoppers could pass the phytoplasm from infected plants to healthy plants. The phytoplasmas are obligate parasites that belong to the prokaryotic class Mollicutes and are transmitted by sap-feeding insects and vegetative plant propagation materials. The phytoplasmas are found in the phloem cells of host plants and the study of phytoplasmas is very laborious because it is difficult to culture it *in vitro*.



C6.1.1d *Pigeon pea witches' broom phytoplasma* (Group 16SrIX) (3 May 2021)

Family: Acholeplasmataceae; Genus: Phytoplasma

Definition: Amount of tolerance to *Pigeon pea witches' broom phytoplasma* (Group 16SrIX).

References :

IRAN

- M. Salehi et al. (2016) studied genetic diversity and vector transmission of phytoplasmas associated with sesame phyllody during 2010–14 surveys in the major sesame growing areas of Fars, Yazd and Isfahan provinces. *Circulifer haematoceps* and *Orosius albicinctus*, known vectors of the disease in Iran, were tested for transmission of the strains identified in this study. *C. haematoceps* transmitted 16SrII-D, 16SrVI-A, and 16SrIX-C phytoplasmas, while *O. albicinctus* only transmitted 16SrII-D strains.

TURKEY

- M. Catal et al. (2013) reported the first known case of Pigeon pea witches' broom (16SrIX) in Turkey. Sesame plants with phyllody disease symptoms have increasingly been observed in the fields of Antalya province since 2007. The disease incidence in these fields was found to range from 37 to 62%. Infected plants display a variety of the disease symptoms such as virescence, asymptomatic shoot proliferation, infertile flower formation, reduced leaf size, and thin and weak capsule development.

Normal plant vs phyllody plant.

- C. Ikten et al. (2013a and 2014) reported phyllody is a destructive disease of sesame in Turkey. The disease has been causing significant economic losses by stunting the plants and altering their floral parts into leafy

structures with no capsule and hence no seeds in sesame fields of the country. They identified two phytoplasm: *Pigeon pea witches' broom* (16SrIX-C) and *Peanut witches' broom* (16SrII-D). They tested 3 possible vectors for phyllody in his experiment: *Orosius orientalis, Empoasca decipiens* and *Bemisia tabaci*. The only insect that proved to be a vector was *O. orientalis.* [See Peanut witches' broom (16SrII-D) for more information]

- C. Ikten et al. (2014) reported accurate identification, differentiation, and quantification of phyllody causing phytoplasmas are essential for effective management of this plant disease and for selection of resistant sesame varieties. They described a methodology to analyze samples from 109 sesame plants and 92 insect vectors for 16SrII and 16SrIX in a single test tube.
- F. Ozdemir (2017) reported to detect and identify phytoplasmas of sesame and the cicadellid vector *Orosius orientalis*, samples were collected during 2011–2013 in Antalya. Identification of the phytoplasmas based on sequence homology revealed presence of the 16Sr groups II (Peanut witches'-broom, PnWB), VI (Clover proliferation, CP) and IX (Pigeon pea witches'-broom, PPWB) in sesame plants. PnWB and CP were detected in *O. orientalis*. [Based on abstract]
- F. Ozdemir (2018) tested a total of 65 *Neoaliturus haematoceps* samples collected from sesame fields in Antalya, Turkey, during 2012– 2014 for phytoplasma detection. Analysis revealed three different 16S rDNA phytoplasma groups: the peanut witches'-broom, group II; clover proliferation, group VI; and pigeon pea witches'-broom, group IX.
- B. Uzun (2019) verified that *Orosius orientalis* transmitted the phytoplasma that caused phyllody in Turkey through DNA analysis. Phyllody is a most destructive disease in sesame. The characteristic is deformation of flowers, which do not properly develop and remain green, with the calyx and corolla sometimes stiff, forming a half-open hood. World sesame germplasm (542 accessions) originated from 29 different countries was screened for possible resistance to disease under field conditions in the summer of 2012 and 2013. In the first year 304 were eliminated as highly susceptible. Screening continued down to 30 with possible tolerance. Parallel, they collected the leafhoppers from the field using vaccums and determined they had the same phytoplasma (16SrII, 16SrVI and 16SrIX) as the plants. Further testing in cages confirmed the leafhoppers could pass the phytoplasm from infected plants to healthy plants. The phytoplasmas are obligate parasites that belong to the prokaryotic class Mollicutes and are transmitted by sap-feeding insects and vegetative plant propagation materials. The phytoplasmas are found in the phloem cells of host plants and the study of phytoplasmas is very laborious because it is difficult to culture it *in vitro*.



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C7 Order: Enterobacterales Adeolu et al. 2016

(Wikipedia, 23 Jun 2021) **Enterobacterales** is an order of Gram-negative, non-spore forming, facultatively anaerobic, rod-shaped bacteria with the class Gammaproteobacteria. The type genus of this order is *Enterobacter*.

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C7.1 Family: Erwiniaceae Adeolu et al. 2016

(Wikipedia, 23 Jun 2021) The ***Erwiniaceae*** are a family of Gram-negative bacteria which includes a number of plant pathogens and insect endosymbionts. This family is a member of the order Enterobacterales in the class Gammaproteobacteria of the phylum Proteobacteria. The type genus of this family is *Erwinia*.

The following species have been reported to cause diseases, produce a toxin, inhibit germination, or affect seed quality.

- C7.1.1 *Erwinia* spp.
- C7.1.2 *Pantoea* spp.
- C7.1.2a *Pantoea agglomerans* (*Syn: *Erwinia herbicola*)

There are species in this family associated with sesame, but not reported to cause diseases, produce a toxin, inhibit germination, or affect seed quality. See I10.1.

C7.1.1 *Erwinia* spp. (23 Jun 2021)

Family: Erwiniaceae

Definition: Amount of tolerance to *Erwinia* spp. Winslow *et al.* Winslow et al. 1920

(Wikipedia, 23 Jun 2021) ***Erwinia*** is a genus of Enterobacterales bacteria containing mostly plant pathogenic species which was named for the famous plant pathologist, Erwin Frink Smith. It contains Gram-negative bacteria related to *Escherichia coli*, *Shigella*, *Salmonella*, and *Yersinia*. They are primarily rod-shaped bacteria.

Many infect woody plants. A well-known member of this genus is the species *E. amylovora*, which causes fire blight on apples, pears, and other Rosaceae crops; *E. tracheiphila*, though, causes bacterial wilt of cucurbits. Other familiar species, such as *E. carotovora* (another major cause of plant diseases), are more distantly related to the fire blight bacterium, and have been moved to genera *Brenneria*, *Dickeya*, and *Pectobacterium*.

Erwinia aphidocola and *E. persicina* species were both observed to be present within the floral nectar microbial community of seven different orchid (*Epipactis*) flower species. *E. aphidicola* appears to display characteristics of a pathogen as it had decimated fifty percent of a bean crop in Spain in late 2003.

Erwinia rhapontici has been identified as a plant pathogen that produces a distinct diffusible pink pigment on sucrose-peptone agar and creates pink seeds in the hosts. It is also found to be a wound pathogen. Wound pathogens are replicating microorganisms in a wound that can cause the host injury. It is possible that the bacterium can penetrate though young pea pods through wounds or injuries and infect seeds produced in the pod, causing deformed leaves.

References:

ETHIOPIA

- E. Wondmagegne et al. (1986) reported *Erwinia* spp. causes stem maceration.

C7.1.2 *Pantoea* spp. (23 Jun 2021)

Family: Erwiniaceae

Definition: Amount of tolerance to ***Pantoea* spp.** Gavini et al. 1989 emend. Brady et al. 2010

(Wikipedia, 23 Jun 2021) ***Pantoea*** is a genus of Gram-negative bacteria of the family Erwiniaceae, recently separated from the genus *Enterobacter*. This genus includes at least 20 species. *Pantoea* bacteria are yellow

pigmented, ferment lactose, are motile, and form mucoid colonies. Some species show quorum sensing ability that could drive different gene expression, hence controlling certain physiological activities.

The following species have been associated with sesame but there are no known reports of being a pathogen, producing a toxin, inhibiting germination, affecting seed quality, or being used as a biocontrol or biofertilizer.
- *Pantoea dispersa* [Japan]
- *Pantoea septica* [Japan]

C7.1.2a *Pantoea agglomerans* (23 Jun 2021)

Synonym: *Erwinia herbicola*

Family: Erwiniaceae

Definition: Amount of tolerance to *Pantoea agglomerans* (Beijerinck 1888) Gavini et al. 1989

(Wikipedia, 23 Jun 2021) ***Pantoea agglomerans*** is a Gram-negative bacterium that belongs to the family Erwiniaceae. It was formerly called *Enterobacter agglomerans*, or *Erwinia herbicola* and is an ubiquitous bacterium commonly isolated from plant surfaces, seeds, fruit, and animal or human feces and can be found throughout a honeybee's environment.

References:

ETHIOPIA
- A.P. Korobko and E. Wondimagegne (1987) reported severe infections of *Xanthomonas campestris* pv. *sesami* and *Pseudomonas syringae* pv. *sesami*. *Erwinia herbicola* was often associated with the above pathogens. Stem rotting was caused by *Erwinia* sp. [Cited by G.S. Saharan, 1989]

JAPAN
- K. Kato et al. (2021) purchased seed in local markets and identified the following bacterium: *Pantoea agglomerans.*

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C7.2 Family: Enterobacteriaceae Rahn 1937

(Wikipedia, 19 Jul 2021) **Enterobacteriaceae** is a large family of Gram-negative bacteria. It was first proposed by Rahn in 1936, and now includes over 30 genera and more than 100 species. Its classification above the level of family is still a subject of debate, but one classification places it in the order Enterobacterales of the class Gammaproteobacteria in the phylum Proteobacteria. In 2016, the description and members of this family were emended based on comparative genomic analyses by Adeolu et al.

Enterobacteriaceae includes, along with many harmless symbionts, many of the more familiar pathogens, such as *Salmonella*, *Escherichia coli*, *Klebsiella*, and *Shigella*. Other disease-causing bacteria in this family include *Enterobacter* and *Citrobacter*. Members of the Enterobacteriaceae can be trivially referred to as enterobacteria or "enteric bacteria", as several members live in the intestines of animals. In fact, the etymology of the family is enterobacterium with the suffix to designate a family (aceae)—not after the genus *Enterobacter* (which would be "Enterobacteraceae")—and the type genus is *Escherichia*.

The following species have been identified to cause diseases in humans:
- C7.2.1 *Salmonella* spp.
- C7.2.2 *Escherichia coli*

***Salmonella* spp. are not associated with the sesame plant and rhizosphere but may be picked up in the food chain of moving from the field to the consumer.**

C7.2.1 *Salmonella* spp. (19 Jul 2021)

Family: Enterobacteriaceae

Definition: Presence of *Salmonella* spp. Lignieres 1990.

(Wikipedia, 19 Jul 2021) ***Salmonella*** is a genus of rod-shaped (bacillus) Gram-negative bacteria of the family Enterobacteriaceae. The two species of *Salmonella* are *Salmonella enterica* and *Salmonella bongori*. *S. enterica* is the type species and is further divided into six subspecies that include over 2,600 serotypes. *Salmonella* was named after Daniel Elmer Salmon (1850–1914), an American veterinary surgeon.

Salmonella species are non-spore-forming, predominantly motile enterobacteria with cell diameters between about 0.7 and 1.5 μm, lengths from 2 to 5 μm, and peritrichous flagella (all around the cell body). They are chemotrophs, obtaining their energy from oxidation and reduction reactions using organic sources. They are also facultative anaerobes, capable of generating ATP with oxygen ("aerobically") when it is available, or when oxygen is not available, using other electron acceptors or fermentation ("anaerobically") get its energy.

Salmonella species are intracellular pathogens; certain serotypes causing illness. Nontyphoidal serotypes can be transferred from animal-to-human and from human-to-human. They usually invade only the gastrointestinal tract and cause salmonellosis, the symptoms of which can be resolved without antibiotics. However, in sub-Saharan Africa, nontyphoidal *Salmonella* can be invasive and cause paratyphoid fever, which requires immediate treatment with antibiotics. Typhoidal serotypes can only be transferred from human-to-human, and can cause food-borne infection, typhoid fever, and paratyphoid fever. Typhoid fever is caused by *Salmonella* invading the bloodstream (the typhoidal form), or in addition spreads throughout the body, invades organs, and secretes endotoxins (the septic form). This can lead to life-threatening hypovolemic shock and septic shock, and requires intensive care including antibiotics.

References:

S. Yada and L.J. Harris (2019) is a bibliography with many references of Salmonella outbreaks in sesame products throughout the world. There are more references in doing a search of "salmonella sesame."

***Escherichia coli* is not associated with the sesame plant and rhizosphere but may be picked up in the food chain of moving from the field to the consumer.**

C7.2.2 *Escherichia coli* (19 Jul 2021)

Family: Enterobacteriaceae

Definition: Presence of *Escherichia coli* (Migula 1895) Castellani and Chalmers 1919.

(Wikipedia, 19 Jul 2021) ***Escherichia coli*** also known as ***E. coli*** is a Gram-negative, facultative anaerobic, rod-shaped, coliform bacterium of the genus *Escherichia* that is commonly found in the lower intestine of warm-blooded organisms (endotherms). Most *E. coli* strains are harmless, but some serotypes (EPEC, ETEC etc.) can cause serious food poisoning in their hosts, and are occasionally responsible for food contamination incidents that prompt product recalls. The harmless strains are part of the normal microbiota of the gut, and can benefit their hosts by producing vitamin K_2, (which helps blood to clot) and preventing colonization of the intestine with pathogenic bacteria, having a mutualistic relationship. *E. coli* is expelled into the environment within fecal matter. The bacterium grows massively in fresh fecal matter under aerobic conditions for 3 days, but its numbers decline slowly afterwards.

E. coli and other facultative anaerobes constitute about 0.1% of gut microbiota, and fecal–oral transmission is the major route through which pathogenic strains of the bacterium cause disease. Cells are able to survive outside the body for a limited amount of time, which makes them potential indicator organisms to test environmental samples for fecal contamination. A growing body of research, though, has examined environmentally persistent *E. coli* which can survive for many days and grow outside a host.

The bacterium can be grown and cultured easily and inexpensively in a laboratory setting and has been intensively investigated for over 60 years. *E. coli* is a chemoheterotroph whose chemically defined medium must include a source of carbon and energy. *E. coli* is the most widely studied prokaryotic model organism, and an important species in the fields of biotechnology and microbiology, where it has served as the host organism for the majority of work with recombinant DNA. Under favorable conditions, it takes as little as 20 minutes to reproduce.

References:

S. Yada and L.J. Harris (2019) is a bibliography with some references of *E. coli* outbreaks in sesame products throughout the world. There are more references in doing a search of “escherichia coli sesame” or “e. coli sesame.”

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C8 Order: Bacillales Prevot 1953

(Wikipedia, 19 Apr 2021) The **Bacillales** are an order of Gram-positive bacteria[1], placed within the Firmicutes. Representative genera include *Bacillus*, *Listeria* and *Staphylococcus*.

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C8.1 Family: Bacillaceae Garrity et al. 2001

(Wikipedia, 19 Apr 2021) The **Bacillaceae** are a family of Gram-positive, heterotrophic, rod-shaped bacteria that may produce endospores. Motile members of this family are characterized by peritrichous flagella. Some Bacillaceae are aerobic, while others are facultative or strict anaerobes. Most are not pathogenic, but *Bacillus* species are known to cause disease in humans.

The following species have been identified to cause diseases in humans:

- C8.1.1 *Listeria* spp.
- C8.1.2 *Bacillus* spp.
- C8.1.2a *Bacillus cereus*

There are species in this family associated with sesame, but not reported to cause diseases, produce a toxin, inhibit germination, or affect seed quality. See I5.1. There are species in this family used for biocontrols. See F2.1.

***Listeria* spp. is not associated with the sesame plant and rhizosphere but may be picked up in the food chain of moving from the field to the consumer.**

C8.1.1 *Listeria* spp. (19 Jul 2021)

Family: Bacillaceae

Definition: Presence of *Listeria* spp. Pirie 1940.

(Wikipedia, 19 Jul 2021) ***Listeria*** is a genus of bacteria that acts as an intracellular parasite in mammals. Until 1992, 10 species were known, each containing two subspecies. By 2020, 21 species had been identified. The genus received its current name, after the British pioneer of sterile surgery Joseph Lister, in 1940. *Listeria* species are Gram-positive, rod-shaped, and facultatively anaerobic, and do not produce endospores. The major human pathogen in the genus *Listeria* is *L. monocytogenes*. It is usually the causative agent of the relatively rare bacterial disease listeriosis, an infection caused by eating food contaminated with the bacteria. Listeriosis can cause serious illness in pregnant women, newborns, adults with weakened immune systems and the elderly, and may cause gastroenteritis in others who have been severely infected.

Listeriosis is a serious disease for humans; the overt form of the disease has a case-fatality rate of around 20%. The two main clinical manifestations are sepsis and meningitis. Meningitis is often complicated by encephalitis, when it is known as meningoencephalitis, a pathology that is unusual for bacterial infections. *L. ivanovii* is a pathogen of mammals, specifically ruminants, and has rarely caused listeriosis in humans. The incubation period can vary from three to 70 days.

References:

S. Yada and L.J. Harris (2019) is a bibliography with some references of *Listeria* spp. outbreaks in sesame products throughout the world. There are more references in doing a search of “listeria sesame”.

C8.1.2 *Bacillus* spp. (3 Sep 2021)

Family: Bacillaceae

Definition: Amount of tolerance to *Bacillus* spp. Cohn 1872.

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[1] **Gram-positive:** Gram-positive bacteria give a positive result (retain the purple stain) in the Gram stain test, which is traditionally used to quickly classify bacteria into two broad categories according to their type of cell wall.

(Wikipedia, 19 Apr 2021) ***Bacillus*** (Latin “stick”) is a genus of Gram-positive, rod-shaped bacteria, a member of the phylum *Firmicutes*, with 266 named species. The term is also used to describe the shape (rod) of certain bacteria; and the plural *Bacilli* is the name of the class of bacteria to which this genus belongs. *Bacillus* species can be either obligate aerobes: oxygen dependent; or facultative anaerobes: having the ability to continue living in the absence of oxygen. Cultured *Bacillus* species test positive for the enzyme catalase if oxygen has been used or is present.

Bacillus can reduce themselves to oval endospores and can remain in this dormant state for years. The endospore of one species from Morocco is reported to have survived being heated to 420 °C. Endospore formation is usually triggered by a lack of nutrients: the bacterium divides within its cell wall, and one side then engulfs the other. They are not true spores (i.e., not an offspring). Endospore formation originally defined the genus, but not all such species are closely related, and many species have been moved to other genera of the *Firmicutes*. Only one endospore is formed per cell. The spores are resistant to heat, cold, radiation, desiccation, and disinfectants. *Bacillus anthracis* needs oxygen to sporulate; this constraint has important consequences for epidemiology and control. *In vivo*, *B. anthracis* produces a polypeptide (polyglutamic acid) capsule that kills it from phagocytosis. The genera *Bacillus* and *Clostridium* constitute the family *Bacillaceae*. Species are identified by using morphologic and biochemical criteria. Because the spores of many *Bacillus* species are resistant to heat, radiation, disinfectants, and desiccation, they are difficult to eliminate from medical and pharmaceutical materials and are a frequent cause of contamination. Not only they are they resistant to heat, radiation, etc., but they are also resistant to chemicals such as antibiotics. This resistance allows them to survive for many years and especially in a controlled environment. *Bacillus* species are well known in the food industries as troublesome spoilage organisms.

Ubiquitous in nature, *Bacillus* includes both free-living (nonparasitic) species, and two parasitic pathogenic species. These two *Bacillus* species are medically significant: *B. anthracis* causes anthrax; and *B. cereus* causes food poisoning.

Many species of *Bacillus* can produce copious amounts of enzymes, which are used in various industries, such as in the production of alpha amylase used in starch hydrolysis and the protease subtilisin used in detergents. *B. subtilis* is a valuable model for bacterial research. Some *Bacillus* species can synthesize and secrete lipopeptides, in particular surfactins and mycosubtilins.

C8.1.2a *Bacillus cereus* (3 Sep 2021)

Bacillus cereus is reported to produce toxins (C8.1.2a) and has been used as a biocontrol (F2.1.1c).

Family: Bacillaceae

Definition: Amount of tolerance to *Bacillus cereus* Frankland & Frankland 1887.

(Wikipedia, 3 Sep 2021) ***Bacillus cereus*** is a Gram-positive, rod-shaped, facultatively anaerobic, motile, beta-hemolytic, spore forming bacterium commonly found in soil and food. The specific name, *cereus*, meaning "waxy" in Latin, refers to the appearance of colonies grown on blood agar. Some strains are harmful to humans and cause foodborne illness, while other strains can be beneficial as probiotics for animals. The bacteria is classically contracted from fried rice dishes that have been sitting at room temperature for hours. *B. cereus* bacteria are facultative anaerobes, and like other members of the genus *Bacillus*, can produce protective endospores. Its virulence factors include cereolysin and phospholipase C.

The *Bacillus cereus* group comprises seven closely related species: *B. cereus sensu stricto* (referred to herein as *B. cereus*), *B. anthracis*, *B. thuringiensis*, *B. mycoides*, *B. pseudomycoides*, and *B. cytotoxicus*; or as six species in a *Bacillus cereus* sensu lato: *B. weihenstephanensis*, *B. mycoides*, *B. pseudomycoides*, *B. cereus*, *B. thuringiensis*, and *B. anthracis*.

References:

JAPAN

- K. Kato et al. (2021) purchased seed in local markets and identified the following bacterium: *Bacillus cereus*, but this strain lacked the gene encoding of the enzyme responsible for cereulide synthesis and did not produce enterotoxin.

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D Virus

(Wikipedia, 24 Apr 2021) A **virus** is a submicroscopic infectious agent that replicates only inside the living cells of an organism. Viruses infect all types of life forms, from animals and plants to microorganisms, including bacteria and archaea. Since Dmitri Ivanovsky's 1892 article describing a non-bacterial pathogen infecting tobacco plants and the discovery of the tobacco mosaic virus by Martinus Beijerinck in 1898, more than 6,000 virus species have been described in detail of the millions of types of viruses in the environment. Viruses are found in almost every ecosystem on Earth and are the most numerous type of biological entity. The study of viruses is known as virology, a subspeciality of microbiology.

When infected, a host cell is forced to rapidly produce thousands of identical copies of the original virus. When not inside an infected cell or in the process of infecting a cell, viruses exist in the form of independent particles, or *virions*, consisting of: (i) the genetic material, i.e., long molecules of DNA or RNA that encode the structure of the proteins by which the virus acts; (ii) a protein coat, the *capsid*, which surrounds and protects the genetic material; and in some cases (iii) an outside envelope of lipids. The shapes of these virus particles range from simple helical and icosahedral forms to more complex structures. Most virus species have virions too small to be seen with an optical microscope, as they are one-hundredth the size of most bacteria.

The origins of viruses in the evolutionary history of life are unclear: some may have evolved from plasmids—pieces of DNA that can move between cells—while others may have evolved from bacteria. In evolution, viruses are an important means of horizontal gene transfer, which increases genetic diversity in a way analogous to sexual reproduction. Viruses are considered by some biologists to be a life form, because they carry genetic material, reproduce, and evolve through natural selection, although they lack the key characteristics, such as cell structure, that are generally considered necessary criteria for life. Because they possess some but not all such qualities, viruses have been described as "organisms at the edge of life", and as self-replicators.

Viruses spread in many ways. One transmission pathway is through disease-bearing organisms known as vectors: for example, viruses are often transmitted from plant to plant by insects that feed on plant sap, such as aphids; and viruses in animals can be carried by blood-sucking insects. Influenza viruses are spread by coughing and sneezing. Norovirus and rotavirus, common causes of viral gastroenteritis, are transmitted by the faecal–oral route, passed by hand-to-mouth contact or in food or water. The infectious dose of norovirus required to produce infection in humans is less than 100 particles. HIV is one of several viruses transmitted through sexual contact and by exposure to infected blood. The variety of host cells that a virus can infect is called its "host range". This can be narrow, meaning a virus is capable of infecting few species, or broad, meaning it is capable of infecting many.

Viral infections in animals provoke an immune response that usually eliminates the infecting virus. Immune responses can also be produced by vaccines, which confer an artificially acquired immunity to the specific viral infection. Some viruses, including those that cause AIDS, HPV infection, and viral hepatitis, evade these immune responses and result in chronic infections. Several antiviral drugs have been developed.

Authors comment: For some of the viruses there are no known natural occurrences on sesame. Some data is based on inoculations.

References:

BRAZIL

- N.H.C. Arriel et al. (n.d.) Brazil descriptor: VIROSES (Viruses). Plants affected by viruses may be stunted, presenting leaf surface with chlorotic or yellow areas, interspersed with green areas. It appears to be transmitted by the green leafhopper from infected plants or by vigna or malvaceae beans. The following are the ratings to be used.
  - 1 : 0 to 5%
  - 2 : 6 to 25%
  - 3 : 26 to 50%
  - 4 : 51 to 75%
  - 5 : 76 to 100%

CHINA

- Anon. (2006a) China descriptor: *8.4 Resistance to virus diseases* (CCCC). They provide a methodology for artificial inoculations and observing in natural fields. The following are the ratings to be used.
  - 0 = Immune

- 1 = High resistance (HR)
- 3 = Resistance (R)
- 5 = Susceptible (S)
- 7 = High susceptibility (HS)

VENEZUELA

- D.G. Langham (1945b and 1945j) described *Wrinkled leaf* as a roughness of the veins on the ventral side of the leaves. This roughness begins near the tip of the leaf and then becomes more acute, necrotic areas are formed in the vein and the leaf begins to curl downward. The affected veins develop streaks of redish-brown color, and the leaf continues to curl. The ventral surface of the veins remains green and smooth. Usually, but not always, the conditions are accompanied by a similar necrosis in the crown of the root. Repeated attempts by pathologists were negative in isolating any organisms that brought on the condition. The plants developed flowers and capsules, and only occasionally were semi-sterile. There was a selection to eliminate the trait from the germplasm. They found that *Wrinkled leaf* was brought on by a single recessive gene.

UNITED STATES

- D.R. Langham (2020h) reported in 1986, *Wrinkled leaf* was seen in the Yuma, Arizona nurseries just prior to the first irrigation and then after the irrigation, it was gone. This pattern has repeated over the years. In digging for roots where there were normal and *Wrinkled leaf* plants side by side, the *Wrinkled leaf* plants had a root problem – usually a hard pan or a large rock had limited the root penetration to follow the moisture. It appears that wrinkled leaf comes when the leaf mass exceeds the root mass. Once the root penetrates the hard pan, it is possible for the root mass to catch up to the leaf mass and it once again looks normal.

Wrinkled leaf occurs rarely giving the appearance of a virus problem. Most of the time the plants will revert to full leaves when the root mass balances the leaf mass.

This was a common issue with the variety Sesaco 17 in the USA. It was seen temporarily many times in parts of commercial fields and then would disappear. As in 1991, in digging up roots in wrinkled and normal leaf plants side by side, the wrinkled leaf had a problem penetrating the hard pan. By the time the condition was found, S17 had been used as a parent in many crosses. In the ensuing years, some of the progeny showed the trait, and others did not. When found, the progeny was eliminated as a candidate for further selection.

Rob Myers (pers. comm., 1986) reported he first saw wrinkled leaf in 1986 at the Jefferson Institute in S17. He felt that it was caused by a virus, but the virologists at the University of Missouri could not isolate any viruses from the leaves. Several weeks after collecting the samples, he took a visitor to look at the phenomenon, and the wrinkled leaves had become ‘normal.’

D1 Order: Patatavirales

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D1.1 Family: Potyviridae

(Wikipedia, 24 Apr 2021) **Potyviridae** is a family of positive-strand RNA viruses that encompasses more than 30% of known plant viruses, many of which are of great agricultural significance. Currently, 228 species are placed in this family, divided among 12 genera with three unassigned species.

The following species have been reported to cause diseases, produce a toxin, inhibit germination, or affect seed quality.

- D1.1.1a *Watermelon mosaic virus* (WMV)
- D1.1.1b *Bean common mosaic virus* (BCMV)
- D1.1.1c *Zucchini yellow mosaic virus* (ZYMV)
- D1.1.1d *Cowpea aphid-borne mosaic virus* (CABMV)
- D1.1.1e *Peanut stripe virus* (PSV)
- D1.1.1f *Turnip mosaic virus* (TuMV)
- D1.1.1g *Tobacco vein banding mosaic virus* (TVBMV)
- D1.1.1h *Peanut mottle virus* (PeMoV)

D1.1.1 Genus: Potyvirus

(Wikipedia, 16 Apr 2021) **Potyvirus** is a genus of viruses in the family *Potyviridae*. Plants serve as natural hosts. There are currently 183 species in this genus including the type species *Potato virus Y*. The genus is named after the type virus (*pot*ato virus *Y*). Potyviruses account for ~30% of the currently known plant viruses. Like begomoviruses, members of this genus may cause significant losses in agricultural, pastoral, horticultural and ornamental crops. More than 200 species of aphids spread potyviruses and most are from the subfamily *Aphidinae* (genera *Macrosiphum* and *Myzus*).

References:

INDIA

- P. Sreenivasulu et al. (1994) described an unknown Potyvirus causing chlorosis of veins, mosaic, green banding among the veins, and downward leaf rolling. The virus was non-persistently transmitted by *Aphis craccivora* and *Myzus persicae* but was not transmitted through the sesame seeds.

D1.1.1a Watermelon mosaic virus (WMV) (16 Apr 2021)

Family: Potyviridae, Genus: Potyvirus

Definition: Amount of tolerance to *Watermelon mosaic virus* (WMV).

(Wikipedia, 16 Apr 2021) ***Watermelon mosaic virus* (WMV)** also known as ***Marrow mosaic virus*** (Raychaudhuri and Varma, 1975; Varma, 1988), ***Melon mosaic virus*** (Iwaki et al., 1984; Komuro, 1962), and until recently ***Watermelon mosaic virus type* 2** (WMV-2), is a plant pathogenic virus that causes viral infection (sometimes referred to as watermelon Mosaic disease) in many different plants. First described on squash in Florida, WMV arose from a unique recombination of genetic material contributed by *Soybean mosaic virus* (SMV) and *Bean common mosaic virus* (BCMV) along with *Peanut Stripe virus* (PSV).

References:

CHINA

- Y. Shi et al. (2015) reported a survey of viral diseases on sesame was carried out during the summer of 2014 in Henan Province, China. During the survey, 10 sesame fields in Zhengzhou and Zhumadian were investigated; in eight fields, mosaic, reduced leaf size, leaf deformation, and leaf puckering were observed on sesame plants, though the viral disease incidence was relatively low during the investigation. Two viruses were identified: *Bean common mosaic virus* and *Watermelon mosaic virus* (WMV). WMV infection in sesame which displayed symptoms of mosaic, dwarfing, reduced leaf size, and small and reduced pods threatened sesame production in

Henan Province This is the first report of natural infection of WMV infecting sesames in China. [Based on abstract]

- H.Y. Wang et al. (2017) conducted a series of field surveys in Shandong Province to investigate the viruses infecting sesame. Sesame plants (cv. Zhongzhi No. 11) showing symptoms of mosaic, etiolation, shoestring, and puckering were found in several fields at incidences of 20 to 35%. They identified three potyviruses, *Watermelon mosaic virus* (WMV), *Bean common mosaic virus* (BCMV), and *Tobacco vein banding mosaic virus* (TVBMV). [Based on abstract]
- Y. Shi et al. (2016) conducted surveys of viral diseases on sesame in the summer of 2015 in Zhengzhou, Henan Province, China, and the approximate percent of virus diseased plants during our survey was 10%. Mosaic, leaf deformation, and yellowing symptoms were observed in diseased sesame plants. identified three potyviruses, *Watermelon mosaic virus* (WMV), Bean common mosaic virus (BCMV), and Zucchini yellow mosaic virus (ZYMV). [Based on abstract]

JAPAN

- T. Inouye (1964) reported an isolate of *Watermelon mosaic virus* (WMV), causing a wide spread disease of peas in West Japan was also pathogenic to sesame.
- Anon. (2015e) NIAS Genebank Japan descriptor: 4.0 Mosaic virus resistance. Secondary essential character. Observation and measurement of a block. The degree of resistance to *Watermelon mosaic virus* (WMV) in field of in injection tests. The following are the ratings to be used:
  - 1 = Very low
  - 3 = Low
  - 4 = Slightly low
  - 5 = Intermediate
  - 6 = Slightly high
  - 7 = High
  - 9 = Very high

  [Authors comment: Descriptors list UMV rather than WMV, but think it is a typo since other Japanese authors report WMV as a problem along with TuMV.]
- T. Kuzuyuki (2021) cited the following pathogen *Watermelon mosaic virus* (WMV) is listed in the Database of Plant Diseases in Japan.

REPUBLIC OF KOREA

- M.U. Chang and C.K. Youngnan (1980) reported during the years since 1978, stunting of sesame plants, with yellow mosaic, necrotic spot, and malformation, were collected from 17 different places. Virus isolates from 27 out of 32 samples were identified as *Watermelon mosaic virus* (WMV). [Based on abstract]

D1.1.1b *Bean common mosaic virus* (BCMV) (16 Apr 2021)

Family: Potyviridae, Genus: Potyvirus

Definition: Amount of tolerance to *Bean common mosaic virus* (BCMV).

References:

CHINA

- Y. Shi et al. (2015) reported a survey of viral diseases on sesame was carried out during the summer of 2014 in Henan Province, China. During the survey, 10 sesame fields in Zhengzhou and Zhumadian were investigated; in eight fields, mosaic, reduced leaf size, leaf deformation, and leaf puckering were observed on sesame plants, though the viral disease incidence was relatively low during the investigation. Two viruses were identified: *Bean common mosaic virus* and *Watermelon mosaic virus* (WMV). [Based on abstract]
- Y. Shi et al. (2016) conducted surveys of viral diseases on sesame in the summer of 2015 in Zhengzhou, Henan Province, China, and the approximate percent of virus diseased plants during our survey was 10%. Mosaic, leaf deformation, and yellowing symptoms were observed in diseased sesame plants. identified three potyviruses, Watermelon mosaic virus (WMV), Bean common mosaic virus (BCMV), and Zucchini yellow mosaic virus (ZYMV). [Based on abstract]
- H.Y. Wang et al. (2017) conducted a series of field surveys in Shandong Province to investigate the viruses infecting sesame. Sesame plants (cv. Zhongzhi No. 11) showing symptoms of mosaic, etiolation, shoestring, and puckering were found in several fields at incidences of 20 to 35%. They identified three potyviruses,

Watermelon mosaic virus (WMV), *Bean common mosaic virus* (BCMV), and *Tobacco vein banding mosaic virus* (TVBMV). [Based on abstract]

D1.1.1c *Zucchini yellow mosaic virus* (ZYMV) (16 Apr 2021)

Family: Potyviridae, Genus: Potyvirus

Definition: Amount of tolerance to *Zucchini yellow mosaic virus* (ZYMV).

(Wikipedia, 16 Apr 2021) ***Zucchini yellow mosaic virus* (ZYMV)** is an aphid-borne potyvirus, regarded as a major pathogen of cucurbits in most regions of the world where these crops are cultivated.

ZYMV affects all cucurbits including pumpkins, squashes, vegetable marrows, courgettes, melons, watermelons, cucumbers, gherkins and various gourds especially zucchinis. The effects are severe leaf mosaic, yellowing and eventually "shoestring" symptoms in the leaves. The fruits are stunted, twisted and deformed by raised protuberances, which reduces yield and makes them unmarketable in some cultures. In cultivated crops plants cease producing marketable fruits within 1–2 weeks of infection and serious financial losses can occur, particularly in courgette and marrow crops.

The disease may be introduced in infected seed, so sourcing clean seed can help prevent the disease. Control is largely dependent on using insecticides to control the aphid vectors. A form of "inoculation" or cross protection may also be used where seedlings are inoculated with a non-virulent strain of the virus (ZYMV-WK); this prevents infection with the severe strain.

It is similar to the watermelon mosaic virus

References:

INTERNATIONAL

- CAB International (accessed 12 Apr 2021) reported sesame was a minor host of *Zucchini yellow mosaic virus*.

CHINA

- Y. Shi et al. (2016) conducted surveys of viral diseases on sesame in the summer of 2015 in Zhengzhou, Henan Province, China, and the approximate percent of virus diseased plants during our survey was 10%. Mosaic, leaf deformation, and yellowing symptoms were observed in diseased sesame plants. identified three potyviruses, Watermelon mosaic virus (WMV), Bean common mosaic virus (BCMV), and Zucchini yellow mosaic virus (ZYMV). To our knowledge, this is the first report of natural infection of ZYMV infecting sesame. [Based on abstract]

D1.1.1d *Cowpea aphid-borne mosaic virus* (CABMV) (19 May 2021)

Family: Potyviridae, Genus: Potyvirus

Definition: Amount of tolerance to *Cowpea aphid-borne mosaic virus* (CABMV).

(CAB International, 16 Apr 2021) Cowpea aphid-borne mosaic virus (CABMV) is a potyvirus capable of infecting many species in the family Fabaceae, and most strains also infect members of the Amaranthaceae, Chenopodiaceae, Cucurbitaceae, Laminaceae, Passifloraceae and Solanaceae. Its main hosts are cowpea and passionfruit, and along with East Asian Passiflora virus and passionfruit woodiness virus it induces passionfruit woodiness in passionfruit. CABMV occurs worldwide but is a particularly major and widespread disease of cowpea in Africa. The nature and severity of the symptoms induced by CABMV are extremely variable, and vary with host cultivars, virus strain and the time of infection. Symptoms can include various mosaics, mottling, interveinal chlorosis and vein-banding. Complete loss of cowpea crops has been reported from Nigeria, and CABMV is one of the main limiting factors to passionfruit yield in South America and Africa.

References:

INTERNATIONAL

- CAB International (accessed 12 Apr 2021) reported sesame was a major host of *Cowpea aphid-borne mosaic virus.*

IVORY COAST

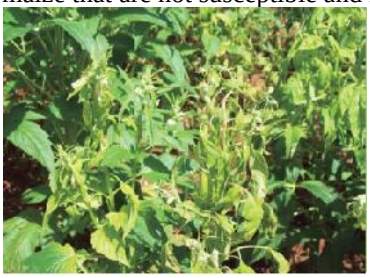
- J.C. Thouevnel et al. (1982) reported Cowpea mild mottle virus was isolated from soybeans showing severe mosaic to which sesame plants were also susceptible. [Cited by G.S. Saharan, 1989]

MEXICO

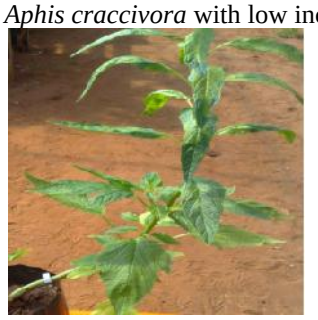
- Agrolytics.org (2021) reported sesame hosts *Cowpea aphid-borne mosaic virus.*

PARAGUAY

- N. Lezcano (2006) in a grower guide identified a disease called ka'are.
- L. Ayala et al. (2010, 2011, and 2013b) in grower guides reported one of the main pathogens is a virus that leads to Ka'are. Symptoms seem to be more drastic when sowings are later, probably due to the presence of a greater number of vectors, and especially their difficult control in varieties of tall like the INIA, and tall and susceptible like the Escoba. Environmental conditions such as prolonged droughts can induce to the appearance of large populations of transmitting insects such as the aphids that play a key role in the spread of the virus. As obligate parasites, viruses multiply in susceptible cells. One method of control is to plant barrier crops like maize that are not susceptible and keep the insect vectors out of the sesame.



- N.J.J. Zelada and M.B. Ramirez (2010) determined *Cowpea aphid-borne mosaic virus* (CABMV) is vectored from *Vigna unguiculata* by *Aphis craccivora* with low incidence of the virus.



- L. Gonzales S. et al. (2011a) reported a disease characterized by yellowing and curling down leaves and shortening of the internodes has been observed in almost all sesame-growing areas. It is referred to locally as "ka'are" because the affected sesame plant resembles *Chenopodium ambrosioides* L (Mexican tea). This disease occurred occasionally and was of marginal importance prior to 2005, but during the last five growing seasons the disease incidence has increased substantially, with some growers losing the entire crop. They identified the *Cowpea aphid-borne mosaic virus* (CABMV). The disease could be reproduced in sesame by aphid (*Myzus persicae*) transmission in a nonpersistent manner. Several cowpea fields, nearby sesame diseased crops, also contained plants exhibiting mosaic symptoms.
- L. Gonzales S. et al. (2011b) isolated *Cowpea aphid-borne mosaic virus* (CABMV) from sesame plants and then proceeded to inoculate 14 other species plus sesame. The symptoms on sesame were systematic chlorotic lesions, deformed and rolled up leaves resulting in reducing the sizes of the leaves and plants.

- M. Ramirez de Lopez and N.J. Zelada C. (2011) reported the *Cowpea aphid-borne mosaic virus* (CABMV) reduced yield and occasionally destroyed the entire crop. They determined *Myzus persicae* (left photo) and *Aphis craccivora* (right photo) were the vectors of the disease.


M. persicae had a higher rate of transmission (74%) than *A. craccivora* (6.2%). All the plants infected by *A. craccivora* showed the disease in 15 days. For *M. persicae* 27% showed it in 15 days, 57% in 21 days, and 16% in 36 days.

- L. Gonzales S. et al. (2012 and 2013) reported the *Cowpea aphid-borne mosaic virus* (CABMV) causes a disease called "ka'are" in sesame crop that is characterized by yellowing, mosaic-like staining, and downward curling of the leaves, the shortening of the internodes and the reduction of the general size of the plant. Normally, affected plants fail to flower. L. Gonzalez S. et al. (2010) evaluated the incidence of the virus in sesame plants, inoculated with the aphid *Myzus persicae*. After 30 minutes of virus acquisition, the percentage of transmission observed was 74%. The same evaluation was made, inoculating with *Aphis craccivora*, with which the percentage was 6.2%. The following photo shows the devastation that can occur in a field.


Most viruses can remain viable and survive in perennial crops, seeds or weeds. They inoculated 48 species and found the following species hosted the virus: *Amaranthus hybridus* L., *Vigna unguiculata* (L.) Walp. (Black-eyed pea), *Crotalaria incana* L., *Crotalaria juncea* L., *Crotalaria spectabilis* L., *Arachis hypogaea* L. (Peanuts). Beans and peanuts are often grown in adjacent fields to sesame; *Crotalaria* is often grown as a cover crop; and *Amaranthus* is a common weed in the area. The absence of resistant/tolerant sesame cultivars along with the ineffectiveness of disease control through the chemical control of aphid vectors indicates that the only alternative available for disease management at present is the elimination and/or reduction of the sources of inoculum immediately before starting new plantations.

UNITED STATES

- H.R. Pappu et al. (1997) reported phylogenetic analyses of the 0.9 m terminal region of a potyvirus naturally infecting sesame (*Sesamum indicum*) in Georgia indicated that the virus was Cowpea aphid-borne mosaic potyvirus (CABMV). [Based on abstract]

D1.1.1e *Peanut stripe virus* (PSV) (16 Apr 2021)

Family: Potyviridae, Genus: Potyvirus

Definition: Amount of tolerance to *Peanut stripe virus* (PSV).

(Wikipedia, 16 Apr 2021) ***Peanut stripe virus*** **(PSV)** is a plant pathogenic virus of the family *Potyviridae*. As with other members of this virus family, PSV is a flexuous filamentous virus with particles 740-750 nm long. It is transmitted by several species of aphids and by mechanical inoculation. It was first given its name in 1965 when it was isolated from peanuts (*Arachis hypogaea*) in Georgia, USA. This virus was found to be seed transmitted in this host.

References:

INTERNATIONAL

- CAB International (accessed 12 Apr 2021) reported sesame was a minor host of *Peanut stripe virus* (Groundnut stripe disease).

CHINA

- Z.L. Yan et al. (2015) reported the *Peanut stripe virus* (PSV) in sesame.

D1.1.1f *Turnip mosaic virus* (TuMV) (16 Apr 2021)

Family: Potyviridae, Genus: Potyvirus

Definition: Amount of tolerance to *Turnip mosaic virus* (TuMV).

(Wikipedia, 16 Apr 2021) ***Turnip mosaic virus*** **(TuMV)** is a *Potyvirus* of the family *Potyviridae* that causes diseases in cruciferous plants, among others. The virus is usually spread by 40-50 species of aphids in a non-persistent manner. Infected plants, especially the natural hosts, show symptoms such as chlorotic local lesions, mosaic, mottling, puckering or rugosity. TuMV is a positive-sense single stranded RNA virus, consisting of a non-enveloped, helical capsid that is filamentous and flexuous, with an average length of 720 nm. The TuMV genome is linear and monopartite (single particle). The virus has a thermal inactivation point (TIP) of 62 °C, and longevity *in vitro* (LIV) of 3–4 days.

References:

CHINA

- L.L. Li (1988) reported a new viral disease has appeared on sesame in sesame-growing areas. The diseased area has been gradually increasing since 1980. An epidemic of the disease occurred in Henan province in 1984, causing a serious loss of about 70% of the yield in some districts. Stunt and necrosis are caused by the *Turnip mosaic virus* (TuMV) which is transmitted by *Myzus persicae* and *Aphis caraccinara*. The period of incubation is about 9 days under sap inoculation. There are no effective methods for the control of the disease at present.
- S.J. Yang et al. (1988) reported a virus disease (*Turnip mosaic virus* – TuMV) which reportedly occurred as high as 85% in some sesame producing regions in recent years. *Myzus persicae* and *Aphis craccivora* can transmit the isolate in nonpersistent manner and transmission rate is 11.4% and 13.5% respectively. The virus has been found in 13 crops grown in the area to include the following families: Chenopodiaceae, Cruciferae, Leguminosae, Solanaceae, Amaranthaceae and Pediaceae, making it difficult to control in sesame.
- H.M. Miao and H.Y. Liu (2010) reported the following pathogen: *Turnip mosaic virus* (TuMV).
- Z.L. Yan et al. (2015) reported the *Turnip mosaic virus* (TuMV) in sesame.

JAPAN

- Anon. (2015e) NIAS Genebank Japan descriptor: 4.0 Mosaic virus resistance. Secondary essential character. Observation and measurement of a block. The degree of resistance to *Turnip mosaic virus* (TuMV) in field of in injection tests. The following are the ratings to be used:
  - 1 = Very low
  - 3 = Low
  - 4 = Slightly low
  - 5 = Intermediate
  - 6 = Slightly high
  - 7 = High
  - 9 = Very high
- T. Kuzuyuki (2021) cited the following pathogen *Turnip mosaic virus* (TuMV) is listed in the Database of Plant Diseases in Japan.

D1.1.1g *Tobacco vein banding mosaic virus* (TVBMV) (1 May 2021)

Family: Potyviridae, Genus: Potyvirus

Definition: Amount of tolerance to *Tobacco vein banding mosaic virus* (TVBMV).

References:

CHINA

- H.Y. Wang et al. (2017) conducted a series of field surveys in Shandong Province to investigate the viruses infecting sesame. Sesame plants (cv. Zhongzhi No. 11) showing symptoms of mosaic, etiolation, shoestring, and puckering were found in several fields at incidences of 20 to 35%. They identified three potyviruses, *Watermelon mosaic virus* (WMV), *Bean common mosaic virus* (BCMV), and *Tobacco vein banding mosaic virus* (TVBMV). [Based on abstract]

D1.1.1h *Peanut mottle virus* (PeMoV) (3 May 2021)

Family: Potyviridae, Genus: Potyvirus

Definition: Amount of tolerance to *Peanut mottle virus* (PeMoV).

(Wikipedia, 3 May 2021) ***Peanut mottle virus* (PeMoV)** is a plant pathogenic virus of the family *Potyviridae*. As with other members of this virus family, PeMoV is a flexuous filamentous virus with particles 740-750 nm long. It is transmitted by several species of aphids and by mechanical inoculation. It was first given its name in 1965 when it was isolated from peanuts (*Arachis hypogaea*) in Georgia, USA. This virus was found to be seed transmitted in this host.

References:

INTERNATIONAL

- CAB International (accessed 12 Apr 2021) reported sesame was a major host of *Peanut mottle virus* (Peanut mottle).

INDONESIA

- M. Roechan et al. (1978) reported sesame was susceptible to *Groundnut mottle virus* when inoculated mechanically. [Based on abstract]

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D2 Order: Geplafuvirales

(16 Apr 2021) **Geplafuvirales** is an order of viruses.

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D2.1 Family: Geminividirae

(Wikipedia, 16 Apr 2021) ***Geminiviridae*** is a family of plant viruses that encode their genetic information on a circular genome of single-stranded (ss) DNA. There are currently 485 species in this family, divided among 9 genera. Diseases associated with this family include: bright yellow mosaic, yellow mosaic, yellow mottle, leaf curling, stunting, streaks, reduced yields. They have single-stranded circular DNA genomes encoding genes that diverge in both directions from a virion strand origin of replication (i.e. geminivirus genomes are ambisense). According to the Baltimore classification they are considered class II viruses. It is the largest known family of single stranded DNA viruses.

Mastrevirus and curtovirus transmission is via various leafhopper species (e.g. maize streak virus and other African streak viruses are transmitted by *Cicadulina mbila*), the only known topocuvirus species, *Tomato pseudo-curly top virus*, is transmitted by the treehopper *Micrutalis malleifera*, and begomoviruses are transmitted by the whitefly species, *Bemisia tabaci*.

These viruses are responsible for a significant amount of crop damage worldwide. Epidemics of geminivirus diseases have arisen due to a number of factors, including the recombination of different geminiviruses coinfecting a plant, which enables novel, possibly virulent viruses to be developed. Other contributing factors include the transport of infected plant material to new locations, expansion of agriculture into new growing areas, and the expansion and migration of vectors that can spread the virus from one plant to another.

The following species have been reported to cause diseases, produce a toxin, inhibit germination, or affect seed quality.

- D2.1.1a *Sesame curly top virus* (SeCTV)
- D2.1.2a *Tomato yellow leaf curl virus* (TYLCV)
- D2.1.2b *Tobacco leaf curl virus* (TLCV) (*Syn: *Nicotinia 10 virus*)

D2.1.1 Genus: Turncurtovirus

(16 Apr 2021) **Turncurtovirus** is a genus of viruses, in the family *Geminiviridae*. Dicotyledonous plants serve as natural hosts. The type species is *Turnip curly top virus*.

D2.1.1a *Sesame curly top virus* (SeCTV) (16 Apr 2021)

Family: Geminividirae, Genus: Turncurtovirus

Definition: Amount of tolerance to *Sesame curly top virus* (SeCTV).

References:

IRAN

- V. Hasanvand et al. (2018) reported *Circulifer haematoceps* (a leafhopper) and sesame in the field had the same *Turncurtovirus*. They identified three symptomatic sesame plants (yellowing, boat-shaped leaf curling, vein swelling on the lower leaf surfaces) from sesame farms in Jiroft. They named it *Sesame curly top virus* (SeCTV).

D2.1.2 Genus: Begomovirus

(Wikipedia, 14 May 2021) ***Begomovirus*** is a genus of viruses, in the family *Geminiviridae*. They are plant viruses that as a group have a very wide host range, infecting dicotyledonous plants. Worldwide they are responsible for a considerable amount of economic damage to many important crops such as tomatoes, beans, squash, cassava and cotton. There are 445 species in this genus.

D2.1.2a *Tomato yellow leaf curl virus* (TYLCV) (1 May 2021)

Family: Geminiviridae, Genus: Begomovirus

Definition: Amount of tolerance to *Tomato yellow leaf curl virus* (TYLCV).

(Wikipedia, 1 May 2021) ***Tomato yellow leaf curl virus*** (**TYLCV**) is a DNA virus from the genus Begomovirus and the family Geminiviridae. TYLCV causes the most destructive disease of tomato, and it can be found in tropical and subtropical regions causing severe economic losses. This virus is transmitted by an insect vector from the family Aleyrodidae and order Hemiptera, the whitefly *Bemisia tabaci*, commonly known as the silverleaf whitefly or the sweet potato whitefly. The primary host for TYLCV is the tomato plant, and other plant hosts where TYLCV infection has been found include eggplants, potatoes, tobacco, beans, and peppers. Due to the rapid spread of TYLCV in the last few decades, there is an increased focus in research trying to understand and control this damaging pathogen. Some interesting findings include virus being sexually transmitted from infected males to non-infected females (and vice versa), and an evidence that TYLCV is transo-variably transmitted to offspring for two generations.

References:

NIGERIA

- M.E. Abo et al. (n.d.) were commissioned to survey commercial sesame fields in northern Nigeria in 2009 and 2010 looking for virus damages. They found *Tomato yellow leaf curl virus* (TYLCV) was rare in all areas. The recommended management practices include the use of resistant or tolerant varieties; maintenance of weed free plots; destruction of crop residues after harvest; roguing of the virus infected plants and burning or burying them in the soil outside the field; spray of appropriate insecticide to control or prevent insect-vector outbreak, as well as use of integrated pest management strategy.

D2.1.2b *Tobacco leaf curl virus* (TLCV) (15 May 2021)

Synonym: *Nicotinia 10 virus*

Family: Geminiviridae, Genus: Begomovirus

Definition: Amount of tolerance to *Tobacco leaf curl virus* (TLCV).

(Wikipedia, 15 May 2021) **Tobacco leaf curl viruses** (**TLCV**) are several species of plant pathogenic viruses in the genus *Begomovirus*.

References:

INTERNATIONAL

- R.S. Vasudeva (1961) reported leaf curl is responsible for heavy losses. The disease is characterized by severe downward curling of the leaves and marked thickening of the veins on the underside. The affected leaves may be reduced in size, become somewhat thick and brittle and are generally dark green in color. Some diseased plants may also bear enations on the lower surface of the leaves. If the plants get infected at an early stage, they show stunted growth and bear scanty capsules. The disease can be transmitted by *Bemisia tabaci.*
- M.O. Khidir (1981a) in a review of sesame in East Africa and the Near East reported the following disease was a problem: leaf curl.
- Anon. (2004a) IPGRI descriptor: 10.3.1. Biotic stress susceptibility to *Nicotinia 10 virus.* (Leaf curl)
  - In each case it is important to state the origin of the infestation or infection, i.e., natural, field inoculation, or laboratory. Also specify the causal organism and the corresponding symptoms. The susceptibility scale is as follows:
    - 1 = Very low or no visible sign of susceptibility
    - 3 = Low
    - 5 = Intermediate
    - 7 = High
    - 9 = Very high

- The growth state, coded according to the list below at which each reaction was recorded should be appended to the record of that reaction.
  - 1 = Seed
  - 2 = Seedling
  - 3 = Pre-flowering
  - 4 = Early flowering
  - 5 = Mid-flowering
  - 6 = Late-flowering
  - 7 = Maturity

- C. Chattopadhyay et al. (2019) reported the following symptoms of Leaf curl: Symptoms are characterized by curling of the leaves and marked thickening of the veins on the underside of the leaf, combined with a reduction in leaf size. Leaves may also become leathery and have a dark green color. Severely affected plants remain stunted and bear few flowers and capsules. The disease is considered to be serious, causing considerable reduction in yield, especially when the infection takes place at the early stage of crop growth. The incidence of the disease in certain years is reported to be 60% in India.
- CAB International (accessed 12 Apr 2021) reported sesame was a minor host of *Tobacco leaf curl virus*.

CHINA

- L.C. Tu (1985b) reported *Leaf curl virus* in Henan province with a damage level of 1 out of possible 3.

INDIA

- B.P. Singh (1963) reported 5 sesame vars. Found to be resistant to *Tobacco leaf curl virus* following and accidental contamination of 121 vars. On the Durgapura experimental farm from sesamum seeds introduced from Sudan. One of the resistant vars. Was also drought resistant.
- R.S. Vasudeva (1954) reported leaf curl of sesame was transmitted by grafting and *Bemisia tabaci*. [Cited by G.S. Saharan, 1989]
- S.M. Jani, and R.K. Bharoda (1978) reported in field trials with 10 cv-s. during 1976-78, the sesame cvs. Patan-64, B-90 and M. T. 67-52 were tolerant to sesame leaf curl virus while T-4 was the most susceptible.
- S. Maiti et al. (1985) reported leaf curl is responsible for heavy losses when it infects at early growth stages of the crop.
- B. Prasad et al. (1985a) reported *Tobacco leaf curl virus* infection greatly reduced plant yield and oil content of seeds, but the protein content was increased.
- B. Prasad et al. (1985a) reported chlorophyll and protein content of the infected leaves were increased, whereas ascorbic acid content was decreased in all the five varieties. Sodium and potassium contents were increased whereas calcium decreased in all varieties.
- C.D. Kaushik et al. (1986) screened 175 genotypes over 3 years (1983 to 1985) against phyllody (MLO), root rot (*Macrophomina phaseoli*), and leaf curl (virus). There were other diseases: Bacterial leaf blight (*Xanthomonas* sp.), powdery mildew (*Erysiphe* sp.) and Phytophthora blight. Out of 175 germplasm lines/varieties 16, 51 and 65 lines were resistant to leaf curl, phyllody and root rot; 49, 41, and 14 were moderately susceptible and rest of the lines were susceptible to these diseases. Although there are reports on the evaluation of germplasm lines/varieties of Sesamum against different diseases, no one has indicated-multiple disease resistant sources in sesame.
- T.S. Rajpurohit (2004b) evaluated the effects of plant extracts [Neem gold (0.3%) and Neem leaf extract (2%)] fungicides [Mancozeb (0.2%), Propiconazole (0.1%), Difenconazole (0.1%) and Penconazole (0.1%)] and in combination with an insecticide (Mancozeb at 0.25% + Methyl demeton at 1 ml/l) against *Alternaria sesami*, leaf curl, and phyllody in 2001 and 2003. Two years of pooled results indicated that all the treatments reduced significantly Alternaria blight (*Alternaria sesami*), phyllody and leaf curl (Nicotinia virus-10) diseases and increased seed yield as compared to the control. Two foliar sprays of Mancozeb at 0.25% + methyl demeton at 1 ml/l. reduced Alternaria blight from 39.35 to 10.1%, phyllody and leaf curl from 5.24 to 0.83% and increased seed yield from 416 to 721 kg/ha.
- K.N. Gupta et al. (2018) recommended cultural, chemical, and biocontrol practices to alleviate or control leaf curl; refer to the introduction.

MEXICO

- M.M. Satour (1981) reported the presence of Leaf curl virus.

MYANMAR

- Y.Y. Min and K. Toyota (2019) surveyed diseases in 10 farmer fields and interviewed 25 farmers. They reported the following disease: Leaf curl with a 24% incidence.

PAKISTAN

- G. Sarwar and Khalid P. Akhtar (2009) evaluated 27 mutant lines in M_4 generation in 2006 for yield and disease. The phyllody incidence under high inoculum pressure ranged from 0-2.75% indicating the highly resistant reaction of all the genotypes. Sesame leaf curl disease (SLCD) did not appear during this season. In 2007-08 in the first trial, seed yield ranged from 281-1,580 kg/ha and phyllody from 1-8% and SLCD from 11-25% causing maximum losses from 28-86%. In the second trial, seed yield ranged between 511-1,785 kg/ha, phyllody incidence from 1-8% and leaf curl disease from 2-9%. The losses in seed yield in the second trial due to phyllody and virus ranged from 2-32% and 7-28% respectively.

NIGERIA

- H.A. Van Rheenen (1972) reported the following pathogen: *Tobacco leaf curl virus* (Nicotiana virus 10). It is the worst disease in Nigeria and is vectored by *Bemisia tabaci* (Silverleaf whitefly). At the time the flower buds appear, the top of the plant becomes brownish green and its leaves curl a little. Later the leaves curl downwards along each side of the midvein and at the top, the color turns dark green or becomes even brownish and the surface looks more shiny than in healthy plants. The leaves also become brittle, and their size is reduced. Delays of sowing after the onset of the rainy season first result in increased infection but sowing after August 15th gives healthy crops. The flower buds show a light-brownish, unhealthy color, do not develop to normal size and produce small, poor-looking flowers. The capsules may be brown, dark brown or even blackish in color and may split open along the sutures. Severely attacked plants show very stunted growth, and leaves and flower buds drop off, the brown stem tops being left without capsules. The disease symptoms may appear on all or on only some aerial parts of the plant. In some cases, for example, only the main stem but not the branches were affected, or not the lower parts but only the top. Sometimes plants can grow away from the disease and produce a new series of shoots without disease symptoms. No disease symptoms have been observed on the roots. The damage caused by leaf-curl may vary from negligible to disastrous. There is apparently no seed transmission. Delays of sowing after the onset of the rainy season first result in increased infection but sowing after August 15th gives healthy crops as shown below.

	Sowing date						
Observation	20-4	31-5	21-6	12-7	2-8	23-8	13-9
Leaf-curl index	2.0	4.5	5.0	5.0	1.0	0.6	0.5
White flies (first month)	24.0	-	11.5	-	30.0	-	9.8
White flies (second month)	30.8	-	22.0	-	5.0	-	20.8
White flies (third month)	4.9	-	5.8	-	7.9	-	39.9

- J.E. Onyibe et al. (2005) in a grower guide reported the following pathogen: *Tobacco leaf curl virus.* This disease is however not very serious at the moment.

SIERRA LEONE

- F.C. Deighton (1932, 1938, and 1940) reported sesamum is commonly attacked by chlorosis, the plants apparently becoming affected after passing the seedling stage. Slightly affected leaves are mottled, the part along the veins being yellow, while the leaves on severely diseased shoots are yellow, and are often curled and dwarfed with turned up edges. Badly chlorosed leaves bear enations, frequently seen as minute foliar structures on the lower surface generally over the net veins but often over the primary branch veins or mid-rib. Diseased plants are stunted and do not flower. The disease appears belong to virus group – Tobacco leaf curl. The disease appears to be widespread because there are so many hosts. [Cited by G.S. Saharan, 1989]

SUDAN

- M.M. Satour (1981) reported the presence of Leaf curl virus.

TANZANIA

- H.H. Storey (1933) reported the green flower (leaf curl) disease important in Tanzania is suspected to be due to a virus.
- G.B. Wallace (1933) reported leaf curl is one of the most destructive diseases in sesame. [Cited by R.S. Vasudeva, 1961]

- G.B. Wallace (1934) reported leaf curl of sesame was less severe at Morogoro than in 1932 and was present also on Mafia Island. The affected leaves borne enations similar to those seen in tobacco leaf curl which may indicate that the diseases are related. [Cited by G.S. Saharan, 1989]

UGANDA

- H.H. Storey (1933) reported the green flower (leaf curl) disease important in Uganda is suspected to be due to a virus.
- J.P. Egonyu (2005) reported the following pathogen: *Leaf curl virus* was transmitted by the whitefly *Bemisia tabaci.* In the field, most severely affected crops gave no grain yield at all. Intercropping significantly affected the incidence and severity of the disease as shown below.

Cropping pattern	Leaf curl		Leaf spot		Wilt	
	Incidence (%)	Severity	Incidence (%)	Severity	Incidence (%)	Severity
Sole sesame	35.4	5	41.2	2.75	52.4	4.75
Sesame + finger millet	23.4	4.33	47.7	2.45	56.4	4.64
$LSD_{0.05}$	11.3	0.63	NS	NS	NS	NS

Time of planting did not have an effect as shown below.

Time of planting(WAO)	Leaf curl		Leaf spot		Wilt	
	Incidence (%)	Severity	Incidence(%)	Severity	Incidence(%)	Severity
0	16.4	3.05	84.8	2	17.1	3.62
2	29.4	4.05	70.7	1.1	29.9	1.62
4	11.5	3.76	42.1	1.	66.4	3.75
$LSD_{0.05}$	9.50	NS	9.02	0.3	7.29	0.539

WAO-Weeks after onset of rain.

The population did not have an effect as shown below.

Density('000 plants/ha)	Leaf curl		Leaf spot		Wilt	
	Incidence (%)	Severity	Incidence(%)	Severity	Incidence(%)	Severity
40	25.7	4.4	47	2.5	55.4	4.7
50	15.4	4.7	31.8	3.3	60.6	5
60	14.3	3	50	2	71.4	4
70	23.1	5	49.3	3.3	68.7	4.7
80	22.3	3	34.3	1	56.1	5
90	30.6	5	48.9	2.8	53.8	4.3
140	16.9	4.5	50.1	1.5	56.9	5
150	26.7	5	33.3	3	73.3	5
160	26.7	3	60	2	46.7	4
170	27.7	5	56.9	2.5	55	4.5
200	26.9	4	30.8	2	61.5	5
210	15.4	4	61.2	2	34.6	5
220	36	4	52.2	1.5	31.9	4.5
410	60	5	56	4	40	5
$LSD_{0.05}$	NS	NS	NS	1.5	NS	NS

VENEZUELA

- M.M. Satour (1981) reported the presence of Leaf curl virus.

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D3 Order: Martellivirales

(Wikipedia, 1 May 2021) ***Martellivirales*** is an order of viruses.

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D3.1 Family: Virgaviridae

(Wikipedia, 1 May 2021) ***Virgaviridae*** is a family of positive-strand RNA viruses. Plants serve as natural hosts. The name of the family is derived from the Latin word *virga* (rod), as all viruses in this family are rod-shaped. There are currently 59 species in this family, divided among seven genera.

The following species have been reported to cause diseases, produce a toxin, inhibit germination, or affect seed quality.

- D3.1.1a *Pepper mild mosaic virus* (PMMoV)
- D3.1.1b *Tobacco mosaic virus* (TMV)

D3.1.1 Genus: Tobamovirus

(Wikipedia, 1 May 2021) ***Tobamovirus*** is a genus of positive-strand RNA viruses in the family *Virgaviridae*. Many plants, including tobacco, potato, tomato, and squash, serve as natural hosts. Diseases associated with this genus include: necrotic lesions on leaves. The name *Tobamovirus* comes from the host and symptoms of the first virus discovered (*Tobacco mosaic virus*).

There are four informal subgroups within this genus: these are the tobamoviruses that infect the brassicas, cucurbits, malvaceous, and solanaceous plants. The main differences between these groups are genome sequences, and respective range of host plants.[*citation needed*] There are currently 37 species in this genus including the type species *Tobacco mosaic virus*.

D3.1.1a *Pepper mild mosaic virus* (PMMoV) (1 May 2021)

Family: Virgaviridae, Genus: Tobamovirus

Definition: Amount of tolerance to *Pepper mild mosaic virus* (PMMoV)

(Wikipedia, 1 May 2021) ***Pepper mild mottle virus*** (**PMMoV**) is a plant pathogenic virus that occurs worldwide on species of field grown bell, hot and ornamental pepper species. It is caused by members of the plant virus genus *Tobamovirus*- otherwise known as the tobacco mosaic virus family. *Tobamovirus* are viruses that contain positive sense RNA genomes that infect plants. Symptoms of the disease vary depending on the cultivar. Typical symptoms include the chlorosis of leaves, stunting, and distorted and lumpy fruiting structures. The virus is spread by mechanical transmission and infected seeds. Avoidance is the best means of controlling the disease because once a plant is infected it cannot be treated. Only seeds that have been tested and treated for the pathogen should be planted.

References:

CHINA

- L.L. Li (1988) reported a new viral disease has appeared on sesame in sesame-growing areas. The diseased area has been gradually increasing since 1980. An epidemic of the disease occurred in Henan province in 1984, causing a serious loss of about 70% of the yield in some districts. Yellowing and mosaic are caused by PMMoV which is transmitted by *Myzus persicae*, *Aphis glycines*, and *Aphis caraccinara*. The period of incubation is about 9 days under sap inoculation. There are no effective methods for the control of the disease at present.

D3.1.1b *Tobacco mosaic virus* (TMV) (1 May 2021)

Family: Virgaviridae, Genus: Tobamovirus

Definition: Amount of tolerance to *Tobacco mosaic virus* (TMV).

(Wikipedia, 1 May 2021) ***Tobacco mosaic virus*** (**TMV**) is a positive-sense single-stranded RNA virus species in the genus *Tobamovirus* that infects a wide range of plants, especially tobacco and other members of the family Solanaceae. The infection causes characteristic patterns, such as "mosaic"-like mottling and discoloration on the leaves (hence the name). TMV was the first virus to be discovered. Although it was known from the late 19th century that a non-bacterial infectious disease was damaging tobacco crops, it was not until 1930 that the infectious agent was determined to be a virus. It is the first pathogen identified as a virus.

References:

INTERNATIONAL

- CAB International (accessed 12 Apr 2021) reported sesame was a minor host of *Tobacco mosaic virus* (Tobacco mosaic).

NIGERIA

- J.B. Kabeh (2017b) reported *Tobacco curl virus* is a major disease of the leaves. He tested 5 varieties in 2014 and 2015 in terms of agronomic traits and tolerance to diseases and pests (Leaf curl – Tobacco mosaic virus, Fungal leaf spot = *Cercospora sesami*, galls are from the insect *Asphondylia sesami* – gall fly) on a 1-5 scale with 1 being tolerant.

Varieties	Severity of Leaf Curls	Severity of Fungal Leaf Spot	Number of galled capsules	Number of dead stands due to phyllody
2014				
Yandev 55	1.29±0.33^{ab}	1.93±0.06^{a}	5.79±0.64^{a}	1.96±0.23^{ab}
NCRIBEN-01M	1.87±0.00^{a}	1.31±0.09^{c}	5.70±0.38^{a}	1.83±0.37^{ab}
E-8	0.97±0.15^{b}	1.86±0.11^{ab}	5.73±0.51^{a}	1.65±0.07^{b}
Ex-Sudan	1.85±0.18^{a}	1.80±0.07^{ab}	5.46±0.32^{a}	1.59±0.34^{a}
ICEASE-00018	1.97±0.22^{a}	1.65±0.07^{b}	4.63±0.61^{a}	1.81±0.28^{ab}
2015				
Yandev 55	1.27±0.21^{bc}	1.92±0.16^{a}	5.14±0.99^{a}	1.92±0.13^{ab}
NCRIBEN-01M	1.86±0.11^{a}	1.40±0.10^{b}	5.41±0.41^{a}	1.72±0.32^{b}
E-8	1.18±0.18^{c}	1.63±0.19^{ab}	5.40±0.79^{a}	1.86±0.11^{ab}
Ex-Sudan	1.79±0.13^{ab}	1.72±0.14^{ab}	5.91±0.53^{a}	2.65±0.27^{a}
ICEASE-00018	1.83±0.21^{a}	1.57±0.13^{ab}	4.67±0.39^{a}	2.10±0.35^{ab}

- M.E. Abo et al. (n.d.) were commissioned to survey commercial sesame fields in northern Nigeria in 2009 and 2010 looking for virus damages. They found *Tobacco leaf curl virus* (TLCV) was common in all areas. The recommended management practices include the use of resistant or tolerant varieties; maintenance of weed free plots; destruction of crop residues after harvest; roguing of the virus infected plants and burning or burying them in the soil outside the field; spray of appropriate insecticide to control or prevent insect-vector outbreak, as well as use of integrated pest management strategy.

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D3.2 Family: Bromoviridae

(Wikipedia, 22 Jul 2021) ***Bromoviridae*** is a family of viruses. Plants serve as natural hosts. There are six genera in the family.

The following species have been reported to cause diseases, produce a toxin, inhibit germination, or affect seed quality.

- D3.2.1a *Alfalfa mosaic virus* (AMV)
- D3.2.2a *Cucumber mosaic virus* (CMV)

D3.2.1 Genus: Alfamovirus

D3.2.1a *Alfalfa mosaic virus* (AMV) (22 Jul 2021)

Family: Bromoviridae, Genus: Alfamovirus

Definition: Amount of tolerance to *Alfalfa mosaic virus* (AMV).

(Wikipedia, 22 Jul 2021) **Alfalfa mosaic virus** (AMV), also known as *Lucerne mosaic virus* or *Potato calico virus*, is a worldwide distributed phytopathogen that can lead to necrosis and yellow mosaics on a large variety of plant species, including commercially important crops. It is the only *Alfamovirus* of the family *Bromoviridae*. In 1931 Weimer J.L. was the first to report AMV in alfalfa (*Medicago sativa*). Transmission of the virus occurs mainly by some aphids (plant lice), by seeds or by pollen to the seed.

References:

[Authors comment: There are no known cases of natural infection on sesame. The data is based on inoculations.]

UNKNOWN

- B. Braikova (1980) reported sesame was a host of *Potato virus X*, *Potato aucuba mosaic virus* and *Alfalfa mosaic virus*. [Cited by G.S. Saharan, 1989]

D3.2.2 Genus: Cucumovirus

(Wikipedia, 22 Jul 2021) ***Cucumovirus*** is a genus of viruses, in the family *Bromoviridae*. Plants serve as natural hosts. There are four species in this genus.

D3.2.2a *Cucumber mosaic virus* (CMV) (22 Jul 2021)

Family: Bromoviridae, Genus: Cucumovirus

Definition: Amount of tolerance to *Cucumber mosaic virus* (CMV).

(Wikipedia, 22 Jul 2021) ***Cucumber mosaic virus*** (**CMV**) is a plant pathogenic virus in the family *Bromoviridae*. This virus has a worldwide distribution and a very wide host range. In fact it has the reputation of having the widest host range of any known plant virus. It can be transmitted from plant to plant both mechanically by sap and by aphids in a stylet-borne fashion. It can also be transmitted in seeds and by the parasitic weeds, *Cuscuta sp.* (dodder).

References:

[Authors comment: There are no known cases of natural infection on sesame. The data is based on inoculations.]

TAIWAN

- W. Chin (1968) reported five isolates of *Cucumber mosaic virus* considered to represent 6 strains induced local lesions on sesame. [Cited by G.S. Saharan, 1989]

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D4 Order: Mononegavirales

(Wikipedia, 5 Jul 2021) **Mononegavirales** is an order of negative-strand RNA viruses which have non-segmented genomes. Some common members of the order are Ebola virus, human respiratory syncytial virus, measles virus, mumps virus, Nipah virus, and rabies virus. All of these viruses cause significant disease in humans. Many other important pathogens of nonhuman animals and plants are also in the group.

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D4.1 Family: Bunyaviridae

(www.cdc.gov/vhf/virus-families, 13 Jul 2021) The **Bunyaviridae** are a very large family of single-strand, enveloped RNA viruses (more than 300 viruses) and consists of five genera of viruses: Orthobunyavirus, Phlebovirus, Nairovirus, Hantavirus, and Tospovirus (Tospoviruses infect only plants).

The following species have been reported to cause diseases, produce a toxin, inhibit germination, or affect seed quality.

- D4.1.1a *Tomato spotted wilt virus* (TSWV)
- D4.1.1b *Melon yellow spot virus* (MYSV)
- D4.1.1c *Groundnut bud necrosis virus* (GBNV)

D4.1.1 Genus: Tospovirus

(microbewiki.kenyon.edu, 13 Jul 2021) Tospoviruses are enveloped viruses that infect plants, leading to tissue necrosis. The first tospovirus, the tomato spotted wilt virus, was isolated in Australia in 1915 (Adkins et.al., 2005). An extremely wide variety of plants are susceptible to tospoviruses (including crops such as tomatoes, watermelon, lettuce, and groundnuts, and flowers such as irises, impatiens, lilies, and orchids), and the geographic host range of tospoviruses encompasses nearly every major agricultural area on the globe (Jones, 2005). Tospoviruses rank among the ten most detrimental plant viruses worldwide, and the recent resurgence of the virus and spread into novel hosts has sparked concern among agriculturalists and horticulturists (Prins & Goldbach, 1998).

D4.1.1a *Tomato spotted wilt virus* (TSWV) (5 Jul 2021)

Family: Bunyaviridae; Genus: Tospovirus

Definition: Amount of tolerance to *Tomato spotted wilt virus* (TSWV).

(http://vegetablemdonline.ppath.cornell.edu/factsheets/Virus_SpottedWilt.htm, accessed 5 Jul 2021) **Tomato spotted wilt virus** (TSWV) causes serious diseases of many economically important plants representing 35 plant families, including dicots and monocots. This wide host range of ornamentals, vegetables, and field crops is unique among plant-infecting viruses. Another unique feature is that TSWV is the only virus transmitted in a persistent manner by certain thrips species At least six strains of TSWV have been reported; the symptoms produced, and the range of plants infected vary among strains Although previously a threat only to crops produced in tropical and subtropical regions, today the disease occurs worldwide. Largely because of wider distribution of the western flower thrips and movement of virus-infected plant material. Early and accurate detection of infected plants and measures to reduce the vector population are discussed as critical steps for disease control.

References:

MEXICO

- Agrolytics.org (2021) reported sesame hosts *Tomato spotted wilt virus.*

D4.1.1b *Melon yellow spot virus* (MYSV) (5 Jul 2021)

Family: Bunyaviridae; Genus: Topovirus

Definition: Amount of tolerance to *Melon yellow spot virus* (MYSV).

References:

MEXICO

- Agrolytics.org (2021) reported sesame hosts *Melon yellow spot virus.*

D4.1.1c *Groundnut bud necrosis virus* (GBNV) (2 Sep 2021)

Family: Bunyaviridae; Genus: Topovirus

Definition: Amount of tolerance to *Groundnut bud necrosis virus* (GBNV).

(Google, 2 Sep 2021) Groundnut bud necrosis virus (GBNV), a member of the genus Tospovirus and the family Bunyaviridae, is a devastating thrips-transmitted virus (*Thrips palmi*). GBNV induces chlorotic and necrotic spots, mosaic, mottling and yellowing on leaves.

References:

INTERNATIONAL

- CAB International (accessed 12 Apr 2021) reported sesame hosted the *Groundnut bud necrosis virus*

INDIA

- K. Gopal et al. (2011) reported in a survey in South India the *Groundnut bud necrosis virus* was observed on groundnut, greengram, blackgram, tomato, watermelon, muskmelon, cowpea, chili, cucumber, and sesame. It was also observed in many weeds, which were abundant in the cropping areas. [Based on abstract]

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D5 Order: Picornavirales

(Wikipedia, 24 Apr 2021) ***Picornavirales*** is an order of viruses with vertebrate, invertebrate, protist and plant hosts. The name has a dual etymology. First, *picorna-* is an acronym for **p**oliovirus, **i**nsensitivity to ether, **c**oxsackievirus, **o**rphan virus, **r**hinovirus, and ribo**n**ucleic acid. Secondly, pico-, meaning extremely small, combines with RNA to describe these very small RNA viruses. The order comprises viruses that historically are referred to as picorna-like viruses.

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D5.1 Family: Secoviridae

(Wikipedia, 24 Apr 2021) ***Secoviridae*** is a family of viruses in the order *Picornavirales*. Plants serve as natural hosts. There are currently 86 species in this family, divided among 8 genera or not assigned to a genus. The family was created in 2009 with the grouping of families *Sequiviridae*, now dissolved, and *Comoviridae*, now subfamily *Comovirinae*, along with the then unassigned genera *Cheravirus*, *Sadwavirus*, and *Torradovirus*.

The following species have been reported to cause diseases, produce a toxin, inhibit germination, or affect seed quality.

- D5.1.1a *Tobacco ringspot virus* (TRSV)
- D5.1.2a *Satsuma dwarf virus* (SDV)

D5.1.1 Genus: *Nepovirus*

(Wikipedia, 24 Apr 2021) ***Nepovirus*** is a genus of viruses in the order *Picornavirales*, in the family *Secoviridae*, in the subfamily *Comovirinae*. Plants serve as natural hosts. There are currently 40 species in this genus including the type species *Tobacco ringspot virus*. Nepoviruses, unlike the other two genera (*Comovirus* and *Fabavirus*) in the subfamily *Comovirinae*, are transmitted by nematodes.

D5.1.1a Tobacco ringspot virus (TRSV) (24 Apr 2021)

Family: Secoviridae, Genus: Nepovirus

Definition: Amount of tolerance to *Tobacco ringspot virus* (TRSV).

(Wikipedia, 24 Apr 2021) ***Tobacco ringspot virus*** **(TRSV or ToBRV)** is a plant pathogenic virus in the plant virus family *Secoviridae*. It is the type species of the genus *Nepovirus*. Nepoviruses are transmitted between plants by nematodes, varroa mites and honeybees. TRSV is also easily transmitted by sap inoculation and transmission in seeds has been reported. In recent cases it has also been shown to appear in bees.

TRSV was observed for the first time in tobacco fields in Virginia and described in 1927. It is an isometric particle with a bipartite RNA genome. The virus has a wide host range that includes field grown crops, ornamentals and weeds. Its name comes from its most common symptom being chlorotic ringspots on the leaves of infected plants. In some areas this virus has caused growers to stop growing affected crops.

References:

[Authors comment: There are no known cases of natural infection on sesame. The data is based on inoculations.]

UNITED STATES

- D. M. McLean (1960) reported that the Tobacco ringspot virus (TRSV) was inoculated into sesame and found to be lethal. In local areas (Rio Grande Valley, Texas) it had necrotic (fregiye) lesions, and it had systematic necrosis.

D5.1.2 Genus: Sadwavirus

(Wikipedia, 22 Jul 2021) **Sadwavirus** is a genus of viruses in the order *Picornavirales*, in the family *Secoviridae*. Plants (specifically Satsuma mandarin trees) serve as natural hosts. There are three subgenera and five species in this

genus. Diseases associated with this genus include satsuma dwarf virus disease which causes spoon-shaped leaves on citrus tree. Symptoms are enations, multiple flushing, stunting or dwarfing, reduction in number and size of leaves and fruits. The name of this genus comes from one of its species: *Satsuma dwarf virus*.

D5.1.2a *Satsuma dwarf virus* (SDV) (18 Jul 2021)

Synonym: *Citrus dwarf virus*

Family: Secoviridae, Genus: Sadwavirus

Definition: Amount of tolerance to *Satsuma dwarf virus* (SDV).

References:

[Authors comment: There are no known cases of natural infection on sesame. The data is based on inoculations.]

CHINA

- C.Y. Zhou et al. (1993) reported Satsuma dwarf virus is tested by inoculation on indicator plants (White sesame, Blackeye cowpea and Satisfaction kidney bean) and by ELISA. Symptoms on White sesame were local lesions on inoculated leaves followed by systemic infection; the systemically infected leaves showed vein necrosis and mottled, malformed leaves.

JAPAN

- T. Kishi and S. Tanaka (1964) reported Of 27 spp. non-legumes (of 12 families) inoculated with Satsuma (citrus) dwarf virus only sesame proved susceptible (white sesame most, brown less, and black showed no local lesions). Symptoms were local lesions on the inoculated leaves and also vein clearing, vein necrosis, cutling and malformation on the upper leaves. Sesame was not however susceptible to (citrus) tristeza and vein enation viruses, both common on Satsuma orange. Young sesame plants were rather better than old as indicators for Satsuma dwarf. Such plants exposed to >34°C immediately after inoculation generally developed no symptoms or sometimes systematic infection 10 days later, but if kept 8 hrs. at 25°C, they showed striking symptoms even if exposed later to >36°C.
- T. Iwanami et al. (1993) used sesame and ELISA to index Satsuma dwarf virus from 9 citrus species.

TURKEY

- T. Azeri (1973) reported Satsuma dwarf virus causes leaf deformation in sesamum. [Cited by G.S. Saharan]

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D6 Order: Tymovirales

(Wikipedia, 22 Jul 2021) **Tymovirales** is an order of viruses with five families. The group consists of viruses which have positive-sense, single-stranded RNA genomes. Their genetic material is protected by a special coat protein.

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D6.1 Family: Alphaflexiviridae

(Wikipedia, 22 Jul 2021) **Alphaflexiviridae** is a family of viruses in the order *Tymovirales*. Plants and fungi serve as natural hosts. There are 65 species in this family, assigned to six genera. Diseases associated with this family include mosaic and ringspot symptoms.

The following species have been reported to cause diseases, produce a toxin, inhibit germination, or affect seed quality.

- D6.1.1a *Potato virus X* (PVX)
- D6.1.1b *Potato aucuba mosaic virus* (PAMV)

D6.1.1 Genus: Potexvirus

(Wikipedia, 22 Jul 2021) **Potexvirus** is a genus of pathogenic viruses in the order *Tymovirales*, in the family *Alphaflexiviridae*. Plants serve as natural hosts. There are 48 species in this genus, three of which are assigned to a subgenus. Diseases associated with this genus include mosaic and ringspot symptoms. The genus name comes from *Potato virus X*).

D6.1.1a *Potato virus X* (PVX) (22 Jul 2021)

Family: Alphaflexiviridae, Genus: Potexvirus

Definition: Amount of tolerance to *Potato virus X* (PVX).

(Wikipedia, 22 Jul 2021) ***Potato virus X* (PVX)** is a plant pathogenic virus of the family Alphaflexiviridae and the order Tymovirales. PVX is found mainly in potatoes and is only transmitted mechanically. There are no insect or fungal vectors for this virus. This virus causes mild or no symptoms in most potato varieties, but when Potato virus Y is present, synergy between these two viruses causes severe symptoms in potatoes. The virion has helical symmetry and a deeply grooved, highly hydrated surface and is made of a single-stranded positive-sense RNA genome of approximately 6.4 kb. This is wrapped in approximately 1300 units of a single coat protein (CP) type, with 8.9 CP units per helix turn. The genome is capped at the 5′-end and poly-adenylated at the 3′-terminus. It contains five open reading frames (ORFs) encoding five proteins: the RNA-dependent RNA Polymerase (RdRP), the movement proteins encoded by three overlapping ORFs that form the Triple Gene Block module (TGBp1, TGBp2, and TGBp3), and the CP (coat protein).

Virus indexing and limited generation production of potato, which starts from disease-free tissue culture plantlets, has nearly eliminated this virus from many countries' potato supply.

References:

[Authors comment: There are no known cases of natural infection on sesame. The data is based on inoculations.]

UNKNOWN

- B. Braikova (1980) reported sesame was a host of *Potato virus X, Potato aucuba mosaic virus* and *Alfalfa mosaic virus*. After 4 days incubation cvs. Susceptible to PVX reacted with local necrotic spots and rings or spots but not systemically. [Cited by G.S. Saharan]

D6.1.1b *Potato aucuba mosaic virus* (PAMV) (22 Jul 2021)

Family: Alphaflexiviridae; Genus: Potexvirus

Definition: Amount of tolerance to *Potato aucuba mosaic virus* (PAMV).

(Wikipedia, 22 Jul 2021)

References:

[Authors comment: There are no known cases of natural infection on sesame. The data is based on inoculations.]

UNKNOWN

- B. Braikova (1980) reported sesame was a host of *Potato virus X*, *Potato aucuba mosaic virus* and *Alfalfa mosaic virus*. [Cited by G.S. Saharan]

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Beneficial organisms

There are two types of organisms that help sesame: Biological control and biofertilizers

Biological control

(Wikipedia, 12 Apr 2021) **Biological control** or **biocontrol** is a method of controlling pests such as insects, mites, weeds and plant diseases using other organisms. It relies on predation, parasitism, herbivory, or other natural mechanisms, but typically also involves an active human management role. It can be an important component of integrated pest management (IPM) programs.

There are three basic strategies for biological pest control: classical (importation), where a natural enemy of a pest is introduced in the hope of achieving control; inductive (augmentation), in which a large population of natural enemies are administered for quick pest control; and inoculative (conservation), in which measures are taken to maintain natural enemies through regular reestablishment.

Natural enemies of insect pests, also known as biological control agents, include predators, parasitoids, pathogens, and competitors. Biological control agents of plant diseases are most often referred to as antagonists. Biological control agents of weeds include seed predators, herbivores, and plant pathogens.

Biological control can have side-effects on biodiversity through attacks on non-target species by any of the above mechanisms, especially when a species is introduced without a thorough understanding of the possible consequences.

Biofertilizers

(Wikipedia, 25 Sep 2021) A **biofertilizer** is a substance which contains living micro-organisms which, when applied to seeds, plant surfaces, or soil, colonize the rhizosphere or the interior of the plant and promotes growth by increasing the supply or availability of primary nutrients to the host plant. Biofertilizers add nutrients through the natural processes of nitrogen fixation, solubilizing phosphorus, and stimulating plant growth through the synthesis of growth-promoting substances. The microorganisms in biofertilizers restore the soil's natural nutrient cycle and build soil organic matter. Through the use of biofertilizers, healthy plants can be grown, while enhancing the sustainability and the health of the soil. Biofertilizers can be expected to reduce the use of synthetic fertilizers and pesticides, but they are not yet able to replace their use. Since they play several roles, a preferred scientific term for such beneficial bacteria is "plant-growth promoting rhizobacteria" (PGPR).

E Biological control or biofertilizers: Fungi

Fungal biocontrol agents (BCAs) do not cause any harm to the environment, and they generally do not develop resistance in various types of insects, pests, weeds, and pathogens due to their complex mode of action. They have been proved to be an alternative against the undesirable use of chemical pesticides.

E1 Order: Hypocreales Lindau 1897

Wikipedia (7 Apr 2021): The **Hypocreales** are an order of fungi within the class Sordariomycetes. In 2008, it was estimated that it contained some 237 genera, and 2647 species in seven families. Since then, a considerable number of further taxa have been identified, including an additional family, the Stachybotryaceae.

Species of Hypocreales are usually recognized by their brightly colored, perithecial ascomata, or spore-producing structures. These are often yellow, orange or red.

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E1.1 Family: Hypocreaceae De Notaris 1844

(Wikipedia, 12Apr 2021) The **Hypocreaceae** are a family within the class Sordariomycetes. Species of Hypocreaceae are usually recognized by their brightly colored, perithecial ascomata, typically yellow, orange or red. The family was proposed by Giuseppe De Notaris in 1844. According to the *Dictionary of the Fungi* (10th edition, 2008), the family has 22 genera and 454 species.

The following species have been identified to provide biocontrol:

- E1.1.1 *Trichoderma* spp.
- E1.1.1a *Trichoderma viride*

- E1.1.1b *Trichoderma harzianum*
- E1.1.1c *Trichoderma virens*
- E1.1.1d *Trichoderma koningii*
- E1.1.1e *Trichoderma hamatum*
- E1.1.1f *Trichoderma pseudokoningii*
- E1.1.1g *Trichoderma arundinaceum*
- E1.1.1h *Trichoderma brevicompactum*
- E1.1.2 *Gliocladium* spp.
- E1.1.3 *Sphaerostilbella* spp.
- E1.1.3a *Sphaerostilbella aureonitens* (*Syn: *Gliocladium penicillioides*)

E1.1.1 *Trichoderma* spp. (19 Apr 2021)

Family: Hypocreaceae

Definition: Amount of biocontrol provided by *Trichoderma* spp. Persoon 1801

(Wikipedia, 19 Apr 2021) ***Trichoderma*** is a genus of fungi in the family Hypocreaceae, that is present in all soils, where they are the most prevalent culturable fungi. Many species in this genus can be characterized as opportunistic avirulent plant symbionts. This refers to the ability of several *Trichoderma* species to form mutualistic endophytic relationships with several plant species. The genomes of several *Trichoderma* species have been sequenced and are publicly available from the JGI.

The following species have been associated with sesame but there are no known reports of being a pathogen, producing a toxin, inhibiting germination, affecting seed quality, or being used as a biocontrol or biofertilizer.

- *Trichoderma aureoviride* [Republic of Korea]
- *Trichoderma homingii* [Republic of Korea]
- *Trichoderma longibrachiatum* [Republic of Korea]

References:

EGYPT

- A.I.I. El-Fiki et al. (2004a) studied the effects of using certain seed treatments to control *Macrophomina phaseolina* Tassi (Goid). The seeds were planted in pots in the greenhouse and then took percentages as follows: % pre-emergence = damping off within 15 days, % post-emergence = damping off within 45 days, % charcoal rot = diseased at 90 days, and % healthy plants at 90 days. The results with antagonistic fungi were as follow.

Antagonistic fungi and bacteria	% Disease incidence			
	At seedling stage		At maturity stage	
	Pre-emergence	Post-emergence	Charcoal rot	Healthy plants
B. megtella *	16.7	16.7	23.3	43.3
Bacillus sp 3 **	13.3	10.0	23.3	53.3
Bacillus subtillus *	10.0	13.3	20.0	56.7
Chaetomium bostrycoides *	0.0	3.3	6.7	90.0
Gliocladium penicilloides *	16.7	20.0	26.7	36.7
T. hamatum *	6.7	6.7	6.7	80.0
T. viride *	16.7	6.7	6.7	70.0
Trichoderma harzianum *	0.0	0.0	3.3	96.7
Trichoderma sp 10 **	23.3	26.7	20.0	30.0
Trichoderma sp 2 **	13.3	13.3	13.3	60.0
Trichoderma sp 3 **	16.7	23.3	16.7	43.3
Trichoderma sp 5 **	6.7	0.0	10.0	83.3
Trichoderma sp 6 **	13.3	6.7	10.0	70.0
Trichoderma sp 8 **	16.7	20.0	20.0	43.3
Trichoderma sp 9 **	20.0	6.7	16.7	56.7
Control	30.0	26.7	26.7	16.7
LSD. at 5%	8.17	9.05	7.96	9.53

* Obtained from Biological Control and Onion and Oil Crops Res. Dept Agric., Res. Center Giza, Egypt.
** Isolated from rhizosphere of healthy sesame plants.

- M.G.A. Hegazy et al. (2019) evaluated the effects of biocontrols (*Aspergillus* spp. and *Penicillium* spp.) on *Fusarium oxysporum* f. sp. *sesami* in the greenhouse with the following results with and without *Trichoderma* sp. as shown below.

The species were then used in the greenhouse with the following results.

Treatments	Disease Severity (%)	Plant growth parameters					
		Shoot			Root		Number of bods
		Plant height (cm)	Fresh weight (g)	Dry weight (g)	Fresh weight (g)	Dry weight (g)	
Aspergillus niger	36 ^{c}	73 ^{ab}	11.8 ^{b}	3.66 ^{b}	3.33 ^{c}	1.3 ^{c}	10 ^{c}
Aspergillus terreus (1)	41 ^{bc}	83 ^{b}	19 ^{a}	4.66 ^{a}	7.83 ^{a}	3.43 ^{a}	16 ^{a}
Aspergillus terreus (2)	52 ^{b}	96 ^{a}	10.3 ^{bc}	3 ^{c}	7.6 ^{a}	2.66 ^{b}	11 ^{b}
Penicillium chrysogenum (1)	38.6 ^{bc}	85 ^{b}	10.6 ^{bc}	2.2 ^{d}	6.66 ^{ab}	1.46 ^{c}	10 ^{c}
Control (untreated)	94.3 ^{a}	56 ^{c}	9.6 ^{c}	2 ^{c}	4 ^{b}	1.16 ^{c}	9 ^{d}

Means followed by the same letters (s) in a column are not significantly different at ($p \leq 0.05$) according to Duncan's multiple-range test.

Treatments	Disease Severity (%)	Growth parameters					
		Shoot			Root		Number of bods
		Shoot height (cm)	Fresh weight (g)	Dry weight (g)	Fresh weight (g)	Dry weight (g)	
A. niger + *Trichoderma* sp.	16 ^{c}	91.3 ^{b}	24.6 ^{c}	9.6 ^{b}	14.6 ^{b}	7.1 ^{b}	8 ^{c}
A. terreus (1) + *Trichoderma* sp.	25.3 ^{bc}	84 ^{c}	27 ^{b}	8.5 ^{c}	15.3 ^{b}	5.6 ^{c}	12 ^{b}
A. terreus (2) + *Trichoderma* sp.	46.6 ^{a}	84 ^{c}	27.5 ^{b}	7.6 ^{d}	13 c	5.4 ^{c}	6 ^{d}
P. chrysogenum (1) + *Trichoderma* sp.	36 ^{ab}	80 ^{d}	17.5 ^{d}	6 ^{e}	9.3 ^{d}	3.5 ^{d}	13 ^{a}
Control (*Trichoderma* sp. only)	13.3 ^{c}	98 ^{a}	42.3 ^{a}	12.6 ^{a}	25.6 ^{a}	14.3 ^{a}	12 ^{b}

INDIA

- K. Satyagopal et al. (2014) in an IPM manual reported for control measures for *Rhizoctonia bataticola* (Dry root rot), *Phytophthora parasitica* var. *sesami* (Phytophthora blight), and *Alternaria sesami* (Alternaria blight) use the following seed treatments : *Trichoderma* sp. @ 4 g/Kg of seed, *Pseudomonas fluorescens* @ 2 g/Kg seed, or *Bacillus subtilis* @ 2 g/Kg seed or NSKE 4%.

IRAQ

- N.A. Saad et al. (2013) examined seed and found the following fungi: *Trichoderma* sp.

NIGERIA

- C.N. Ezekiel et al. (2014) isolated the following fungi on sesame seeds: *Trichoderma* sp.

REPUBLIC OF KOREA

- G.C. Shin et al. (1987) reported the following distribution of *Trichoderma* spp. in the soil around sesame plants.

Species	No. of isolates	Distribution rate (%)
T. viride	76	36.2
T. homingii	57	27.1
T. aureoviride	28	13.3
T. hamatum	17	8.1
T. harzianum	15	7.1
T. longibrachiatum	3	1.4
Unidentified	14	6.8
Total	210	100

SAUDI ARABIA

- A.H. Bahkali and M.A. Moslem (1996) reported the following mycoflora on 5 cultivars: *Trichoderma* sp.

VENEZUELA

- C. Zambrano and O. Tortolero (1985) conducted studies on 540 sesame cultivars, and isolations from seedling rot and soil and reported the following: *Trichoderma* sp.
- J.B. Pineda and E.R. Glonnella (1988b) isolated 12 different cultures of fungi from soil samples collected in El Playon (7.47N 73.20W) and Turen (9.33N 69.11W) where some locations showed a low incidence of dry stem disease (*Macrophomina phaseolina*). The isolates were 8 *Aspergillus* spp., 2 *Trichoderma* spp., 1 *Cladosporium* sp. and 1 *Pythium* sp. These organisms were tested against one isolate of *Macrophomina phaseolina* (Tassi) Gold, pathogenic in sesame. They determined 2 *Aspergillus* spp. and 2 *Trichoderma* spp. could inhibit the growing and sclerotia production of this pathogen. Under natural field conditions, *Trichoderma* I and *Aspergillus* 1 were highly effective in reducing sesame dead plant percentage by *M. phaseolina* until 72 days after planting, indicating a good control.

E1.1.1a *Trichoderma viride* (12 Apr 2021)

Family: Hypocreaceae

Definition: Amount of biocontrol provided by *Trichoderma viride* Persoon 1794.

(Wikipedia, 12Apr 2021) ***Trichoderma viride*** is a fungus and a biofungicide. It is used for seed and soil treatment for suppression of various diseases caused by fungal pathogens.

T. viride is a mold which produces spores asexually, by mitosis. It is the anamorph of *Hypocrea rufa*, its teleomorph, which is the sexual reproductive stage of the fungus and produces a typical fungal fruiting body. The mycelium of *T. viride* can produce a variety of enzymes, including cellulases and chitinases which can degrade cellulose and chitin respectively. The mold can grow directly on wood, which is mostly composed of cellulose, and on fungi, the cell walls of which are mainly composed of chitin. It parasitizes the mycelia and fruiting bodies of other fungi, including cultivated mushrooms, and it has been called the "green mold disease of mushrooms". The affected mushrooms are distorted and unattractive in appearance and the crop is reduced. *Trichoderma viride* is the causal agent of green mold rot of onion. A strain of *Trichoderma viride* is a known cause of dieback of *Pinus nigra* seedlings.

The fungicidal activity makes *T. viride* useful as a biological control against plant pathogenic fungi. It has been shown to provide protection against such pathogens as *Rhizoctonia*, *Pythium* and even *Armillaria*. It is found naturally in soil and is effective as a seed dressing in the control of seed and soilborne diseases including *Rhizoctonia solani*, *Macrophomina phaseolina* and *Fusarium* species. When it is applied at the same time as the seed, it colonizes the seed surface and kills not only the pathogens present on the cuticle, but also provides protection against soilborne pathogens.

References:

BANGLADESH

- M.D. Hosen and S. Shamsi (2017) isolated the following fungus from sesame seeds: *Trichoderma viride*.

EGYPT

- A.I.I. El-Fiki et al. (2004a) studied the effects of using *Trichoderma viride* to control *Macrophomina phaseolina* Tassi (Goid). The seeds were planted in pots in the greenhouse and then took percentages as follows: % pre-emergence = damping off within 15 days, % post-emergence = damping off within 45 days, % charcoal rot = diseased at 90 days, and % healthy plants at 90 days. The results with antagonistic fungi were as follow.

Antagonistic fungi and bacteria	% Disease incidence			
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Bacillus subtillus *	10.0	13.3	20.0	56.7
Chaetomium bostrycoides *	0.0	3.3	6.7	90.0
Gliocladium penicilloides *	16.7	20.0	26.7	36.7
T. hamatum *	6.7	6.7	6.7	80.0
T. viride *	16.7	6.7	6.7	70.0
Trichoderma harzianum *	0.0	0.0	3.3	96.7
Trichoderma sp 10 **	23.3	26.7	20.0	30.0
Trichoderma sp 2 **	13.3	13.3	13.3	60.0
Trichoderma sp 3 **	16.7	23.3	16.7	43.3
Trichoderma sp 5 **	6.7	0.0	10.0	83.3
Trichoderma sp 6 **	13.3	6.7	10.0	70.0
Trichoderma sp 8 **	16.7	20.0	20.0	43.3
Trichoderma sp 9 **	20.0	6.7	16.7	56.7
Control	30.0	26.7	26.7	16.7
LSD. at 5%	8.17	9.05	7.96	9.53

* Obtained from Biological Control and Onion and Oil Crops Res. Dept Agric., Res. Center Giza, Egypt.
** Isolated from rhizosphere of healthy sesame plants.

- I.S. Elewa et al. (2011) evaluated the effects of *Bacillus subtilis* and *Trichoderma viride*, a virulent *Fusarium oxysporum*, and *Glomus* spp. (Vesicular arbuscular mycorrhizae fungus - VAM) isolates and a fungicide (Benlate) on *Fusarium oxysporum* f. sp. *sesami* and *Macrophomina phaseolina*. The results were as follow.

Soil infestation	Treatment	Wilt and root-rot	
	Transplants	Infection %	Disease severity
F. oxysporum	Control	37.5 a	1.87 a
	B. subtilis	33.3 b	1.66 b
	Avirulent *F. oxysporum*	24.9 c	1.25 c
	T. viride	24.9 c	1.25 c
	(VAM)	16.6 d	0.83 d
	Benlate (0.1%)	16.6 d	0.83 d
M. phaseolina	Control	33.3 a	1.66 ab
	B. subtilis	16.6 d	0.83 d
	Avirulent *F. oxsporum*	8.3 e	0.42 e
	T. viride	16.6 d	0.63 e
	(VAM)	12.5 d	0.62 e
	Benlate (0.1%)	16.6 d	0.83 d
F. oxysporum + *M. phaseolina*	Control	20.8 ab	1.04 bcd
	B. subtilis	12.5 d	0.62 e
	Avirulent *F. oxysporum*	12.5 d	0.62 e
	T. viride	16.6 d	0.83 d
	(VAM)	8.3 e	0.42 e
	Benlate (0.1%)	12.5 d	0.62 e

- E.H. Ziedan et al. (2011) evaluated the effects of *Bacillus subtilis* and *Trichoderma viride*, and *Glomus* spp. (a Vesicular arbuscular mycorrhizae fungus [Vesicular arbuscular mycorrhizae fungus - VAM]) isolates on *Fusarium oxysporum* f. sp. *sesami* and *Macrophomina phaseolina*. The effects on *Fusarium oxysporum* f. sp. *sesami* in the pot experiments were as follow.

Treatments	Wilt disease incidence		Morphological characters/plant		
	% of diseased plants	disease severity	length [cm]	fresh weight [g]	No. of pods
Control	79.2 a	4.0 a	68.3 d	7.4 d	6.0 c
B. subtilis	66.7 ab	3.3 b	80.0 c	11.7 c	6.7 c
T. viride	50.0 b	2.5 c	103.8 ab	12.6 c	14.7 b
VAM	50.0 b	2.5 c	80.0 c	14.4 c	6.8 c
VAM + *B. subtilis*	29.2 d	1.5 d	115.6 a	18.7 b	19.0 a
VAM + *T. viride*	36.7 c	1.3 d	93.3 b	15.0 c	14.0 b
VAM + *B. subtilis* + *T. viride*	37.5 c	1.1 d	106.0 ab	25.3 a	20.0 a

The effects on *Macrophomina phaseolina* in the pot experiments were as follow.

Treatments	Root-rot incidence		Morphological characters /plant		
	% of diseased plants	disease severity	length [cm]	fresh weight [g]	No. of pods
Control	91.7 a	4.6 a	77.5 c	5.52 d	4.61 f
B. subtilis	50.0 c	2.5 c	101.9 a	19.4 a	12.6 b
T. viride	45.8 d	2.3 c	101.3 a	18.1 a	10.3 c
VAM	45.8 d	2.5 c	80.0 b	8.1 c	6.0 e
VAM + *B. subtilis*	45.8 d	2.4 c	104.4 a	18.2 a	9.8 d
VAM + *T. viride*	43.7 b	3.3 b	104.2 a	17.7 b	9.5 d
VAM + *B. subtilis* + *T. viride*	41.7 c	2.1 d	103.8 a	19.3 a	13.0 a

The effects from *Fusarium oxysporum* f. sp. *sesami* and *Macrophomina phaseolina* on seedlings in the field experiments were as follow.

Treatments	Wilt and root-rot incidence		
	% of survival plants	% of diseased plants	disease severity
Control	51.0 d	55.9 a	2.8 a
B.subtilis	54.1 c	50.0 b	2.5 b
T.viride	67.5 b	39.2 c	1.9 c
VAM	56.7 c	48.4 bc	2.4 b
VAM + *B. subtilis*	66.6 b	34.2 cd	1.7 c
VAM + *T. viride*	79.3 a	23.3 e	1.2 e
VAM + *B. subtilis*+ *T. viride*	76.0 a	30.9 d	1.5 cd

The effects from *Fusarium oxysporum* f. sp. *sesami* and *Macrophomina phaseolina* on the yield components in the field experiments were as follow.

Treatments	Shoot		Root size	Number/plant		Seed yield aradeb/ feddan	Oil [%]
	length [cm]	diameter [cm]		branches	pods		
Control	185.0 e	1.76 d	25.0 f	3.75 f	112.5 e	2.53 d	59.5
B. subtilis	196.3 c	1.99 b	50.0 b	5.3 e	197.5 c	4.55 c	56.9
T. viride	180.0 d	1.88 c	35.0 d	7.5 b	212.5 b	4.91 c	57.8
VAM	195.0 c	1.85 c	30.0 e	5.0 e	160.0 d	5.14 b	57.4
VAM + *B. subtilis*	210.0 a	1.77 d	35.0 c	6.75 c	196.3 c	4.95 c	57.1
VAM + *T. viride*	202.5 b	1.82 c	47.5 b	6.0 d	198.0 c	5.05 b	57.2
VAM + *B. subtilis* + *T. viride*	202.5 b	2.33 a	70.0 a	8.5 a	232.5 a	5.79 a	57.8

- A.F. Mahmoud and O.A. Abdalla (2018) evaluated the antagonistic capability of 24 isolates of *Trichoderma spp*. (*T. hamatum, T. harzianum, T. virens,* and *T. viride*) *vitro* against *Fusarium oxysporum* f. sp. *sesami* (Fos).

Trichoderma strains	Bioagent No.	Colony diameter of *F. ox.* f.sp. *sesami* (cm)*	Inhibition of *F. ox.* f.sp. *sesami* growth (%)
Trichoderma hamatum	T1	4.15 ^{CDE}	53.88 ^{CDE}
	T2	3.85 ^{DE}	57.22 ^{DE}
	T3	3.77 ^{DE}	58.05 ^{DE}
	T4	4.40 ^{CD}	51.11 ^{CD}
	T5	3.82 ^{DE}	57.50 ^{DE}
Average		3.998	55.557
Trichoderma harzianum	T6	3.72 ^{DE}	58.61 ^{DE}
	T7	3.65 ^{DEF}	59.44 ^{DEF}
	T8	3.92 ^{DE}	56.38 ^{DE}
	T9	2.90 ^{FG}	67.77 ^{FG}
	T10	4.20 ^{CDE}	53.33 ^{CDE}
	T11	4.37 ^{CD}	51.38 ^{CD}
	T12	4.25 ^{CDE}	52.77 ^{CDE}
Average		3.858	57.09
Trichoderma virens	T13	4.32 ^{CD}	51.94 ^{CD}
	T14	4.75 ^{BC}	47.22 ^{BC}
	T15	4.77 ^{BC}	46.94 ^{BC}
	T16	4.12 ^{CDE}	54.16 ^{CDE}
Average		4.49	50.06
Trichoderma viride	T17	4.22 ^{CDE}	53.05 ^{CDE}
	T18	4.57 ^{BC}	49.16 ^{BC}
	T19	4.12 ^{CDE}	54.16 ^{CDE}
	T20	4.25 ^{CDE}	52.77 ^{CDE}
	T21	2.67 ^{G}	70.27 ^{G}
	T22	3.95 ^{DE}	56.11 ^{DE}
	T23	4.07 ^{CDE}	54.72 ^{CDE}
	T24	3.52 ^{EF}	60.83 ^{EF}
Average		3.921	56.38
Control		9.00 A	

*Means within the same column followed by different letters are significantly different at *5% significant level*.

Two strains of *T. harzianum* and *T. viride* had high antagonistic effect against *F. oxysporum* f. sp. *sesami in vitro* with inhibition percentage about 70 and 67%, respectively. These two isolates proved to have high ability to control Fusarium wilt disease under greenhouse conditions as shown below.

Bioagent	Application time	Seedling emergence (%)*	Increase in seedling emergence (%)	Disease severity (%)*	Reduction in disease severity (%)
Application of *T. harzianum* (T9)	7 days *before* challenging with Fos	87.25^{C}	54.42^{C}	22.50^{D}	74.71^{D}
	At the same time with Fos	79.50^{D}	40.70^{D}	35.25^{BC}	60.39^{BC}
	7 days *after* challenging with Fos	70.50^{E}	24.77^{E}	40.50^{B}	54.49^{B}
	Average	79.08	39.96	32.75	63.19
Application of *T. viride* (T21)	7 days *before* challenging with Fos	93.75^{B}	65.92^{B}	20.25^{D}	77.24^{D}
	At the same time with Fos	84.50^{C}	49.55^{C}	32.75^{C}	63.20^{C}
	7 days *after* challenging with Fos	80.75^{D}	42.92^{D}	38.00^{BC}	57.30^{BC}
	Average	86.33	52.79	30.33	65.91
Infected	Challenging with Fos	56.50^{F}	0.00^{F}	89.00^{A}	0.00^{A}
Healthy	Uninfected control	100^{A}	0.00^{A}	0.00^{E}	0.00^{E}

*Means within the same column followed by different letters are significantly different *at 5 % significant level*.

- M.A.A. Hassan et al. (n.d.) evaluated the antagonistic effect of *in vitro* biocontrol agents against *Fusarium oxysporum* f. sp. *sesami.*

Microorganism	Isolate No.	*Fusarium* growth (mm)	Reduction (%)
Bacillus subtilis	1	7.807a	11.93d
	2	6.889b	21.11b
	3	6.445b	25.55a
	4	7.361ab	16.39c
	5	7.028ab	19.72b
	Mean	**7.106**	**18.94**
Streptomyces rochei	1	6.838ab	21.62b
	2	7.415a	15.85c
	3	3.89b	51.10a
	Mean	**6.048**	**29.52**
Pseudomonas fluorescens		4.4	**45.8**
Trichoderma viride		2.3	**66.84**
Control		9	0.00
L.S.D. 0.05		4.49	

The significant differences between means compared by LSD at $p \leq 0.05$, NS, not significant

In another experiment, they reported the antagonistic effect of biocontrol agents against *Fusarium oxysporum* f. sp. *sesami* in the field.

Biocontrol agents	2019				2020				Mean			
	Damping-off (%)		SurvivalPlants	Wilt %	Damping-off(%)		Survival Plants	Wilt %	Damping-off (%)		Survival Plants	Wilt %
	Pre-	Post-			Pre-	Post-			Pre-	Post-		
B. subtilis	4.16	3.32	93.82	18.09	5.27	4.15	91.88	18.65	4.72	3.74	94.85a	18.37c
P. fluorescens	4.72	4.17	91.11	25.32	6.39	3.89	89.72	23.80	5.56	4.03	90.42b	24.56b
T. viride	3.06	2.22	94.72	16.99	4.17	3.05	92.78	17.55	3.62	2.64	93.75ab	17.27c
Control	18.61	26.39	55.00	57.96	22.22	29.17	48.61	67.00	20.42	27.78	51.81c	62.48a
L.S.D. at 5%	2.92	3.42	6.25	4.14	2.75	4.13	5.18	6.50	2.84	3.78	5.72d	5.32

Means with different lowercases indicate significant differences at $p \leq 0.05$

INDIA

- I.J. Gupta and H.S. Cheema (1990) reported. the number of microsclerotia of *Macrophomina phaseolina* present on sesame seeds was positively correlated with plant infection and negatively correlated with seed germination, dry matter production and root and shoot length of seedlings. Treatment with activated clay

(attapulgite dust) or seed coating with *Trichoderma viride* increased germination by 30% and 16%, respectively, and increased seed yield by 32 and 46%.

- C. Chattopadhyay and R.K. Sastry (2002) evaluated the effects of chemicals, extracts, biocontrols, and agronomic practices in controlling *Macrophomina phaseolina* with the following *in vitro* results.

Treatment	Mycelial growth (mm)*	% Reduction in mycelial growth
Trichoderma viride	21.6	71.3
T. harzianum	36.2	52.0
Gliocladium virens	14.2	80.9
Control	75.4	-
C.D. (P < 0.01)	6.5	

*mean of five replications after 7 days on PDA at 27±1°C

The following were the results in pots.

Treatment	% seed germination*		Radicle length (mm)*	Shoot length (cm)$	% disease incidence $	
Trichoderma viride	97.3	(82.1)	50.5	40.4	20.0	(25.7)
T. harzianum	88.0	(70.5)	31.0	24.6	55.0	(47.9)
Gliocladium virens	96.0	(80.5)	35.5	35.4	53.3	(47.4)
Garlic bulb extract	53.3	(46.9)	12.0	28.0	85.0	(67.6)
Neem leaf extract	92.0	(73.9)	29.5	33.9	45.0	(41.5)
Azadirachtin#	72.0	(58.1)	14.0	29.2	80.0	(64.4)
AFF#	0.0	(4.0)	0.0	30.2	61.6	(52.1)
Salicylic acid	88.0	(69.9)	26.0	37.5	60.0	(51.0)
Carbendazim	92.0	(73.6)	29.5	30.0	51.6	(45.9)
Copper-oxychloride	84.0	(66.5)	11.7	27.5	68.3	(56.3)
Thiram	78.7	(62.5)	9.7	26.6	65.0	(53.8)
Captan	84.0	(66.5)	8.0	26.9	50.0	(44.9)
Inoculated Control	81.3	(64.4)	13.7	14.9	100.0	(90.0)
Uninoculated Control	-	-	-	32.2	-	-
C.D. (P < 0.05)	7.2		4.8	6.3	13.7	

*mean of three replicates 3 days after sowing #neem formulations

Figures in parentheses are angular transformed values

Notice that on *Trichoderma viride* they also used an induced mutation.

Treatment	% Disease incidence*		Shoot length (cm)*	cfu (x 10^3) g^{-1} soil*
P @ 20 kg ha^{-1}	61.7	(51.8)	25.3	57.3
K @ 15 kg ha^{-1}	73.3	(58.9)	25.7	50.7
Carbendazim @ 0.1% a.i	51.7	(46.0)	34.3	42.7
Salicylic acid @ 1% (w/v)	61.7	(51.8)	27.3	48.0
Neem leaf extract @ 1% (w/v)	61.7	(51.8)	32.3	49.0
Trichoderma viride (wild)	23.3	(28.9)	36.7	19.3
Trichoderma viride (Mut)	31.7	(34.2)	37.0	29.0
P + K	50.0	(45.0)	28.3	47.0
Carbendazim + P	46.7	(43.1)	34.3	44.0
Carbendazim + K	43.3	(44.0)	34.7	40.3
Carbendazim + P + K	36.7	(38.2)	35.3	38.0
Salicylic acid + P	53.3	(46.9)	27.7	43.3
Salicylic acid + K	51.7	(46.0)	28.0	40.7
Salicylic acid + P + K	48.3	(44.0)	30.3	43.3
Neem leaf extract + P	55.0	(47.9)	33.7	50.3
Neem leaf extract + K	53.3	(46.9)	34.3	46.0
Neem ;eaf extract + P + K	50.0	(45.0)	34.7	48.0
Trichoderma viride (wild) + P	23.3	(28.9)	36.7	19.3
Trichoderma viride (wild) + K	21.7	(27.7)	36.7	19.3
Trichoderma viride (wild) + P + K	20.0	(26.6)	37.0	19.0
Trichoderma viride (Mut) + P	30.0	(33.2)	37.3	27.0
Trichoderma viride (Mut) + K	28.3	(32.1)	37.3	26.3
Trichoderma viride (Mut) + Carbendazim	26.7	(31.1)	38.3	31.3
T. viride (Mut) + P + Carbendazim	20.0	(26.6)	38.7	19.3
T. viride (Mut) + K + Carbendazim	20.0	(26.6)	39.7	20.0
T. viride (Mut) + P + K	23.3	(28.8)	39.0	25.3
T.viride (Mut) + P + K + Carbendazim	8.3	(16.6)	41.7	18.0
Inoculated control	100.0	(90.0)	13.3	58.3
Uninoculated control	-	-	33.7	-
C.D. ($P < 0.01$)	4.7		1.6	3.4

*mean of three replicates 12 weeks after sowing
Figures in parentheses are angular transformed values

- M.L. Verma et al. (2002) reported antagonistic *Trichoderma viride*, *Trichoderma harzianum*, and *Pseudomonas fluorescence*, when used as seed treatment, not only reduce *Phytophthora parasitica* var. *sesami* significantly but substantially increase the sesame yield. [Cited by C. Chattopadhyay et al., 2019]
- S.U. Rani et al. (2009) reported use of *Trichoderma viride* (seed treatment) 4g/kg, soil application 5 kg/ha with FYM managed *Macrophomina phaseolina* causing root rot in sesame.
- R.B. Kakde and A.M. Chavan (2011) examined the effects of fungi on seeds in storage. Ten dominant fungi were isolated from seeds of groundnut, soybean, sesame, safflower, and sunflower. One hundred grams of seeds were inoculated with 10 ml of the fungi. The flasks were left at room temperature for 14 days and then analyzed for sugars, crude fat, and fiber. The results are as follow.

Table 1. Change in reducing sugar (g/100gm) due to seed-borne fungi

Fungi	Sunflower	Sesame	Groundnut	Soybean	Safflower
Alternaria dianthicola	5.2	4.8	1.1	1.1	1.3
Curvularia lunata	4.9	5.0	2.5	1.5	1.8
Curvularia pellescens	5.0	5.4	2.1	1.2	1.6
Fusarium oxysporum	4.7	4.4	1.8	1.7	1.1
Fusarium equiseti	4.6	4.8	1.6	1.2	1.0
Macrophomina phaseolina	5.8	3.5	2.2	2.0	2.2
Rhizopus stolonifer	6.1	5.0	1.1	1.8	2.1
Penicillium digitatum	5.5	4.6	1.9	1.7	1.4
Penicillium chrysogenum	5.2	4.9	2.0	1.6	1.6
Trichoderma viride	6.7	6.1	2.1	1.9	2.6
Control	7.2	6.9	3.1	2.4	2.8
C.D. at 0.05	0.52	0.62	1.21	0.24	0.21

Table 2. Change in crude fat (g/100gm) due to seed-borne fungi

Fungi	Sunflower	Sesame	Groundnut	Soybean	Safflower
Alternaria dianthicola	35.5	10.2	37.1	49.8	22
Curvularia lunata	43.5	14.3	32.5	48.2	26
Curvularia pellescens	45.5	10	41	49	27
Fusarium oxysporum	43	16.1	38	44	20
Fusarium equiseti	47	14.2	35	49.7	19
Macrophomina phaseolina	39	10.5	39.3	46.8	30
Rhizopus stolonifer	50	16.3	40.2	48.6	33
Penicillium digitatum	42	15.3	34.3	39	24
Penicillium chrysogenum	44	12.8	36.2	41	27
Trichoderma viride	46	17.5	40	46	35
Control	49	20	45	50	36
C.D. at 0.05	2.71	2.05	2.04	2.4	3.7

Table 3. Change in crude fiber (g/100) due to seed-borne fungi

Fungi	Sunflower	Sesame	Groundnut	Soybean	Safflower
Alternaria dianthicola	39.1	35.6	33.9	26.1	20.1
Curvularia lunata	52.3	30.6	38.8	34.5	21.8
Curvularia pellescens	46.1	41.1	42.3	31.1	21.6
Fusarium oxysporum	53.1	36.5	34.7	37.0	21.0
Fusarium equiseti	50.7	36.4	37.9	21.0	22.5
Macrophomina phaseolina	47.7	34.8	41.9	36.6	17.9
Rhizopus stolonifer	41.6	31.6	40.1	28.5	19.6
Penicillium digitatum	43.5	40.5	27.6	21.0	14.4
Penicillium chrysogenum	40.5	27.7	31.7	36.9	13.9
Trichoderma viride	47.5	35.1	38.3	37.0	19.8
Control	51.3	47.7	38.0	23.3	19.9
C.D. at 0.05	3.16	6.11	2.39	4.2	1.82

- A.S. Savitha et al. (2011) evaluated several isolates against *Alternaria sesami.* Among two *Trichoderma* isolates, maximum inhibition was noticed in *T. harzianum* to the extent of 87% followed by *T. viride*. Among four bacterial bioagents, an exogenous *Pseudomonas fluorescens* (Pf-E) was most efficient with 80% inhibition. Salicylic acid at 1% was found to be effective in suppressing the pathogen and resulted in higher vigour index (1138.28), followed by *P. fluorescens* I with good germination and vigour index of 97.75% and 1029.85, respectively. The higher vigour index is mainly due to increased germination, higher root and shoot growth by the systemic resistance inducing agents. [Based on abstract]
- V. Bharathi et al. (2013) examined the effect of seed treatments (*Trichoderma viride* + *Pseudomonas fluorescence*, *Azotobacter* + *Trichoderma*, *Rhizobium* + *Trichoderma*, *Azotobacter*, *Trichoderma*, *Pseudomonas*, Benomyl, and untreated control) to improve germination and increase survival rate. *Trichoderma* and *Pseudomonas* were treated @ 6g/kg and 10 g/kg seed, respectively. *Azotobacter* was used @ 25 g/kg seed (250g/10 kg seed). The combination inoculum was used @ half the dose of each bioagent/biofertilizer. The seeds were tested for mycoflora, and the following fungi were found: *Alternaria alternata*, *Alternaria tennissima*, *Alternaria terreus*, *Aspergillus flavus*, *Aspergillus fumigatus*, *Aspergillus niger*, *Macrophomina* spp., *Cephalosporium* spp., *Fusarium oxysporum*, *Rhizoctonia solani*, *Rhizopus stolonifer*, *Curvularia* spp., *Drechslera* spp., *Rhizopus* spp., *Cladosporium* spp., and *Penicillium* spp. Germination of the treated seeds was tested using 3 methods: blotter, paper towel, and sand. The results of the blotter method (100 seeds for 8 days) were as follows:

Treatment	Germination (%)	Seed rot	Seedling Blight	Fungal colonies
Trichoderma + Pseudomonas fluorescence	96.0	4.50	4.18	3.83
Azatobacter + Trichoderma	94.4	8.64	6.42	10.2
Rhizobium + Trichoderma	90.2	12.1	8.63	12.6
Azatobacter	88.0	18.0	9.40	14.8
Trichoderma	85.3	10.6	7.21	12.2
Pseudomonas fluorescence	84.0	9.8	8.10	15.4
Benomil	86.3	2.70	2.10	3.00
Control	75.0	32.3	21.8	36.2
SEm±	0.48	0.72	0.80	0.94
CV%	3.71	5.46	5.68	6.78
CD	1.61	1.82	2.21	2.08

The results of the paper towels method (50 seeds for 14 days) and sand method (100 seeds for 20 days) were as follows. The seedling vigor was done in petri dishes for 8 days (no temperature specified. The germination % and seedling length in cm was measured. The seedling vigor index = Mean seedling length (cm) x Germination percentage (%).

Treatments	Paper Towel Method				Sand Method				Seedling Vigor
	NS	AS	SR	HS	NS	AS	SR	HS	
Trichoderma + P. fluorescence	23	0	14	63	10	2	0	88	1660.3
Azatobacter + Trichoderma	19	2	18	61	5	4	0	92	1562.6
Rhizobium + Trichoderma	17	3	26	52	5	2	4	90	1404
Azatobacter	14	6	32	48	1	3	0	94	1386.2
Trichoderma	12	2	30	50	3	2	2	93	1489
Pseudomonas fluorescence	8	4	16	54	1	4	2	93	1356.3
Benomil	10	2	2	72	2	2	0	96	1312
Control	8	3	47	42	1	1	8	91	904.1
SEm±									69.2
CV									245.6
CD									121.2

*Viability = 76 per cent, ** Data on germination is based on 100 seeds, *** Data based on observation of normal seedling. NS = Normal seedling, AS= Abnormal Seedlings. SR = Seed rots, HS = Hard seeds.

- C. Jeyalakshmi et al. (2013) evaluated integrated disease management practices to combat major diseases (Alternaria leaf blight, *Macrophomina* root rot, and Powdery mildew) and to increase the seed yield of sesame during summer 2009 and 2010 using at Karaikal (10.93N 79.84E). The treatments were as follow.
  - M1: Soil application of neem cake @ 250 kg /ha+ seed treatment with thiram (0.2%) + carbendazim (0.1%) + foliar spray of mancozeb (0.25%) + endosulfan (0.07%) at 30 and 45 DAS.
  - M2: Seed treatment with *Trichoderma viride* (0.4 %) + soil application of *T. viride* @ 2.5 kg/ha + foliar spray of mancozeb (0.25%) + endosulfan (0.07%) at 30 and 45 DAS.
  - M3: Soil application of neem cake @ 250 kg /ha + seed treatment with *T. viride* (0.4 %) + soil application of *T. viride* @ 2.5 kg/ha + foliar spray of azadirachtin (0.03%) @ 3 mL/L on 30 and 45 DAS.
  - M4: Farmer's practices (control)

The results were as follow.

Module	2009*				2010*			
	Root rot (%)	Powdery mildew (PDI)	Seed yield (kg/ha)	C:B ratio	Root rot (%)	*Alternaria* blight (PDI)	Seed yield (kg/ha)	C:B
M1	8.28 [b]	5.10 [b]	680 [c]	1:1.03	8.80 [b]	5.44 [b]	708 [c]	1:1.18
M2	7.05 [b]	4.22 [b]	690 [b]	1:1.13	6.90 [b]	6.16 [b]	720 [b]	1:1.28
M3	3.04 [a]	2.01 [a]	760 [a]	1:1.20	2.54 [a] (9.13)	2.48 [a]	766 [a]	1:1.32
M4	17.7 [c]	11.95 [c]	545 [d]	1:1.00	18.60 [c]	19.40 [c]	495 [d]	1:0.98

- P.L. Radha (2013) evaluated the antagonistic micro-organisms like *Trichoderma harzianum* Rifai., *Trichoderma viride* Pers., *Trichoderma koningii* Qudem., *Trichoderma virens* Miller., *Pseudomonas fluorescens* Migula., and *Bacillus subtilis* Cohn. For their effect under *in vitro* condition against *A. sesami* by dual culture technique. The results were as follows.

Bioagents	Per cent inhibition
Trichoderma harzianum	77.50 (61.66)
Trichoderma viride	75.14 (60.07)
Trichoderma koenigii	73.19 (58.79)
Trichoderma virens	71.53 (57.73)
Pseudomonas fluorescens	36.22 (36.98)
Bacillus subtilis	52.02 (46.15)
S.Em±	0.90
CD at 1 %	2.51

* Arcsine transformed values

- K.N. Gupta and A.R.G. Ranganatha (2014) reported among the fungal diseases, charcoal rot of sesame caused by *Macrophomina phaseolina* is the most devastating, causing up to 55% or more disease incidence in field resulting in heavy yield losses. The pathogens survive as sclerotia in the soil and in host tissue for varying periods. The pathogen attacks plant at all growth stages and causes pre emergence rotting in seeds, soft rot in emerging seedlings, and charcoal rot in mature plants. Due to soilborne nature, practically no effective field control and no resistance variety is available so far. Thus, management of charcoal rot by fungicides is expensive and not eco-friendly. Biological control of plant disease is cost effective and environmentally safe. A field experiment was conducted on sesame during Kharif 2013 to find out the effect of *Trichoderma viride* on incidence of charcoal rot disease in sesame. On the basis of number of capsule/plant, yield/plot/ha and 1000-seed weight, it was concluded that seed treatment with *Trichoderma viride* (5g/kg seed) and before sowing mix in soil (2.5 kg/ha) were found effective and economical for the management this disease. [Based on abstract]
- V.A. Savaliya et al. (2016) evaluated biocontrols against *Macrophomina phaseolina in vitro* with the following results.

Biocontrol agents	Sclerotial formation	Per cent inhibition over control
Bacillus subtilis	+	87.03
T. viride	+ +	71.48
T. hamatum	+ + +	70.00
T. koningii	+ + +	68.14
Trichoderma harzianum	+ +	67.40
Pseudomonas fluorescens	+ +	64.07
Control		-
S. Em. ±	1.602	
CD at 5%	4.862	
CV %	4.54	

Biocontrol agents	Per cent disease incidence	Yield (kg / ha)
Bacillus subtilis	18.93(10.53)	680
Trichoderma konigii	25.43(18.44)	585
T. hamatum	26.90(20.48)	609
T. viride	28.42(22.65)	579
T. harzianum	30.02(25.02)	510
Pseudomonas fluorescens	30.93(26.42)	537
Control	32.96(29.61)	507
S. Em. ±	1.30	28.36
C.D. at 5%	3.89	87.38
C.V.%	10.46	8.59

- K.N. Gupta et al. (2018) reported seed treatment with *Trichoderma viride* helped control *Fusarium oxysporum* f. sp., *Rhizoctonia solani*, Phytophthora blight, and Macrophomina stem/root rot.
- T.K. Babu et al. (2020) evaluated the use of *Trichoderma viride* and *Pseudomonas fluorescens* in combination with neem to control *Macrophomina phaseolina* with the following results.

Treatment	Pooled data (*Kharif*, 2014, 2015 and 2015)			Pooled (Summer, 2015 and 2018)	
	Root Rot (%)	Phyllody %)	Yield (kg/ha)	Root Rot (%)	Yield (Kg/ha)
T1-Seed treatment *T. viride* @ 4 g/kg + soil application of *Tv* @ 2.5 kg/ha enriched in 100 kg of FYM at sowing.	18.5 (25.1)	21.3 (26.8)	231	11.9 (19.6)	664
T2-Seed treatment *P. flourescens* @ 10 g/kg + Soil application of Pf @ 2.5 kg/ha enriched in 100 kg of FYM at sowing.	24.0 (28.8)	22.4 (27.7)	204	12.9 (19.9)	654
T3-Seed treatment *T. viride* @ 4 g/kg + soil application of *Tv* @ 2.5 kg/ha enriched in 100 kg of FYM + neem cake @ 250 kg/ha at sowing.	23.1 (28.4)	25.0 (29.3)	226	6.8 (14.1)	611
T4-Seed treatment *P. fluorescens* @ 10 g/kg + soil application of Pf @ 2.5 kg/ha enriched in 100 kg of FYM + neem cake 250 kg/ha at sowing.	22.6 (27.6)	23.4 (28.3)	261	16.1 (23.4)	672
T5-Seed treatment Tv + Pf @ 10 g /kg + Soil application of Pf @ 2.5 kg/ha + Tv @ 2.5 kg/ha enriched in 100 kg of FYM + neem cake @ 250 kg/ha at sowing.	13.0 (20.9)	17.8 (24.7)	304	9.3 (15.8)	769
T6-Seed treatment Carbendazim @ 2 g/kg + soil drenching with Carbendazim @ 1 g/ l.	33.4 (35.1)	19.8 (25.9)	183	13.5 (21.2)	561
T7-Untreated check	41.7 (40.1)	27.8 (31.6)	127	27.7 (31.7)	473
S.Em ±	2.7	2.2	17.1	3.1	70.1
CV%	18.7	17.0	13.6	23.5	19.3
LSD (5%)	7.7	6.3	49.0	9.0	204

*mean of 3 repiications; figures in parenthesis are angular transformed values

- P. Renganathan et al. (2020b) reported many *Trichoderma* species are regarded as growth promoters by increasing fresh weight, height, and flowering while inhibiting pathogen growth. *T. viride* and *T. harzianum* inhibited the growth and caused sclerotial lysis of *M. phaseolina in vitro*. *Pseudomonas fluorescens* was also effective using various modes of action especially rhizosphere colonization, antibiotic production, and induction of systemic resistance.
- K. Vinothini et al. (2020b) evaluated 5 native *Trichoderma viride* (Tv) and *Pseudomonas fluorescens* (Pf) antagonists isolated from healthy sesame rhizosphere soil in different regions for their ability to reduce the growth of *Macrophomina phaseolina* as well as sclerotial germination. The results with the dual culture technique were as follow.

S. No.	Isolates	*T. viride*(Tv_3) Mycelial growth of *M. phaseolina* (mm)	*T. viride*(Tv_3) Percent inhibition over control	*P. fluorescens* (Pf_5) Isolates	*P. fluorescens* (Pf_5) Mycelial growth of *M. Phaseolina* (mm)	*P. fluorescens* (Pf_5) Per cent inhibition over control	*P. fluorescens* (Pf_5) Inhibition zone (mm)
1	Tv_1	20.53	77.18	Pf_1	27.33	69.63	7.53
2	Tv_2	30.56	65.93	Pf_2	28.19	68.67	6.75
3	Tv_3	18.69	79.23	Pf_3	24.38	72.91	9.26
4	Tv_4	35.42	60.64	Pf_4	26.40	70.66	8.42
5	Tv_5	23.56	73.82	Pf_5	22.30	75.22	10.04
6	Control	90.00	—	Control	90.00	-	-
	S. Ed	0.51		S. Ed	0.13		
	CD (p=0.05)	1.21	—	CD (p=0.05)	0.28	—	—

The results with the poison food technique were as follow.

S. No.	Concentration of cultural filtrates	*T. viride* (Tv_3) Mycelial growth (mm)	*T. viride* (Tv_3) Percent inhibition over control	*T. viride* (Tv_3) Mycelial dry weight (mg)	*T. viride* (Tv_3) Percent inhibition over control	*P. fluorescens* (Pf_5) Mycelial growth (mm)	*P. fluorescens* (Pf_5) Percent inhibition over control	*P. fluorescens* (Pf_5) Mycelial dry weight (mg)	*P. fluorescens* (Pf_5) Percent inhibition over control
1	10	24.33	72.96	200.86	36.10	29.57	65.84	176.96	43.50
2	20	19.46	78.37	120.95	61.52	17.39	75.23	154.92	50.54
3	30	10.13	88.74	49.93	84.12	12.64	80.37	57.65	81.60
4	40	NG	100.00	1.68	99.46	NG	100.00	1.32	99.57
5	50	NG	100.00	1.25	99.60	NG	100.00	1.05	99.67
6	Control	90.00	-	314.34	-	90.00	—	313.25	—
	S. Ed	0.54		0.98		0.49		0.52	
	CD (p=0.05)	1.96	—	2.13	—	1.11	—	1.45	—

NG-Nil Growth

The effects on number, size and sclerotial germination were as follow.

S. No.	Isolates	No. of. Sclerotia	Per cent inhibition	Sclerotial size (m)	Per cent reduction	Sclerotial germination(%)	Per cent inhibition	No. of. Germ tube per Sclerotium^{-1}	Percent reduction
1	Tv_1	94.90	44.13	75.11	37.50	49.46(44.69)	45.73	7.05	49.17
2	Tv_2	105.73	37.75	88.32	26.51	64.85(53.63)	30.22	9.39	32.29
3	Tv_3	74.21	56.31	70.24	41.55	42.62(40.75)	54.14	4.92	64.52
4	Tv_4	134.92	20.56	102.13	15.01	68.78(56.03)	25.99	10.03	27.68
5	Tv_5	102.02	39.93	85.79	28.92	56.09(48.49)	39.64	6.85	50.61
6	Control	169.86	-	120.18	-	92.94(74.59)	-	13.87	-
	S. Ed	0.42		0.62		0.45		0.12	
	CD (p=0.05)	1.091	—	1.65	—	0.99	—	0.28	—

S. No.	Isolates	No. of. Sclerotia	Percent inhibition	Sclerotial size (m)	Percent reduction	Sclerotial germination(%)	Percent inhibition	No. of. Germ tube per sclerotium^{-1}	Percent reduction
1	Pf_1	80.33	49.55	77.46	28.91	51.03 (45.59)	43.79	10.14	37.62
2	Pf_2	84.25	47.09	79.74	26.85	54.86 (47.78)	39.61	12.94	20.32
3	Pf_3	72.91	52.33	70.06	35.70	45.02 (42.14)	50.44	7.01	56.83
4	Pf_4	81.25	48.97	78.95	27.54	51.96 (46.12)	42.80	9.94	38.79
5	Pf_5	64.78	59.65	63.91	41.35	39.63 (39.01)	56.37	5.09	68.65
6	Control	159.25	-	108.97	-	90.85 (72.39)	-	16.24	-
	S. Ed			0.12		0.11		0.13	
	CD (p=0.05)	0.150.45	—	0.26	—	0.23	—	0.28	—

- P. Mahalakshmi and P.A. Devi (2021) Studied the effects of biological controls (*Trichoderma viride* and *Pseudomonas fluorescens*) and a fungicide (Carbendazim) on *Macrophomina phaseolina* in 2016 and 2017 at Vridhachalam ,Tamil Nadu (11.56N 79.33E). The results for 2016 were as follow (ST = seed treatment, SA = soil application).

Module No	Treatments	Disease incidence (%)	Yield (Kg /ha)	C:B ratio
M_1	ST with *T. viride* + SA of *T. viride* 2.5 Kg /*ha* enriched in 100 Kg FYM	28.80 (32.45)	578	1.29
M_2	ST with *P. fluorescens* +SA of *P. fluorescens* 2.5 Kg /*ha* enriched in 100 Kg FYM	25.15 (30.10)	561	1.48
M_3	ST with *T. viride* + SA of *T. viride* 2.5 Kg /*ha* enriched in 100 Kg FYM +Neem cake@250Kg/ha	18.56 (25.51)	621	2.00
M_4	ST with *P. fluorescens* +SA of *P. fluorescens* 2.5 Kg /*ha* enriched in 100 Kg FYM+ Neem cake@250Kg/ha	22.21 (28.11)	615	1.68
M_5	ST *T. viride*+ *P. fluorescens*+ SA of *T. viride*+ SA of *P. fluorescens* enriched in 100 Kg FYM +Neem cake@250Kg/ha	14.75 (22.58)	648	2.60
M_6	ST Carbendazim 2g/Kg +Soil drenching with Carbendazim 1g/l	14.32 (22.23)	651	2.62
M_7	Untreated check	37.21 (37.59)	454	
S.Ed		0.56	7.98	
CD(*P*=0.05)		1.11	17.40	

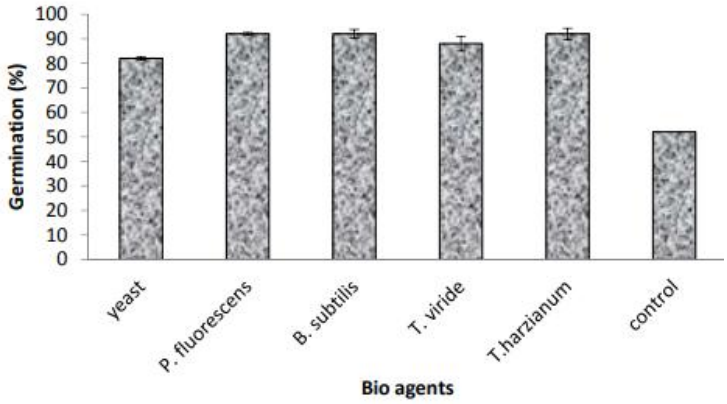
The results for 2017 were as follow.

Tr. No	Treatments	Root rot (%)	Yield (kg/ha)	C:B ratio
T_1	ST with *T. viride* + SA of *T. viride* 2.5 Kg /*ha* enriched in 100 Kg FYM	22.64 (28.41)	635	1.46
T_2	ST with *P. fluorescens* +SA of *P. fluorescens* 2.5 Kg /*ha* enriched in 100 Kg FYM	27.36 (31.53)	625	1.44
T_3	ST with *T. viride* + SA of *T. viride* 2.5 Kg /*ha* enriched in 100 Kg FYM +Neem cake@250Kg/ha	17.28 (24.56)	610	1.41
T_4	ST with *P. fluorescens* +SA of *P. fluorescens* 2.5 Kg /*ha* enriched in 100 Kg FYM+ Neem cake@250Kg/ha	23.71 (29.13)	595	1.37
T_5	ST *T. viride*+ *P. fluorescens*+ SA of *T. viride*+ SA of *P. fluorescens* enriched in 100 Kg FYM +Neem cake@250Kg/ha	11.15 (19.50)	651	1.5
T_6	ST Carbendazim 2g/Kg +Soil drenching with Carbendazim 1g/l	11.03 (19.39)	659	1.52
T_7	Untreated check	37.45 (37.73)	432	
SEd		1.31	2.92	
CD(P=0.05)		2.86	6.36	

- Anon. (n.d.k) recommends using a seed treatment with *Trichoderma viride* at 4g/kg to manage *Fusarium oxysporum* f. sp. *sesami* (Wilt) and *Macrophomina phaseolina* (Sclerotial stage: *Rhizoctonia bataticola*) (Root rot or stem rot or charcoal rot).

PAKISTAN

- B.G. Nayyar et al. (2016) evaluated different bioagents to increase the germination and inhibit the fungi on sesame seeds bioagents (*Trichoderma viride*, *T. harzianum*, *Pseudomonas fluorescens*, *Bacillus subtilis* and *Saccharomyces cerevisiae* – yeast). Seed germination was tested by following the protocol of International Seed Testing Association. Antifungal activity was tested by poisoned food technique. The effects of the bioagents were as follow.



REPUBLIC OF KOREA

- G.S. Shin et al. (1987) studied the biological control of soilborne disease of sesame, antagonistic isolates of *Trichoderma*, *Bacillus*, and *Streptomyces* to *Fusarium oxysporum* and *Rhizoctonia solani* by isolating them from the rhizosphere soils of sesame plants and some other habitats. *Trichoderma viride* TV-192 selected from antagonistic isolates of *Trichoderma* spp. was highly antagonistic to *F. oxysporum* and soil treatment with the isolate reduced notably damping-off of sesame as shown below.

Treatment	Germination of sesame (%)	Normal seedlings(%)	Damping-off(%)	Dead seedling by TV-192(%)
F. oxysporum D_3	36	16.7	83.3	0
TV-192 seed coating	88	93.2	0	6.8
TV-192 soil treatment	66	70.0	0	30.0
F. oxysporum D_3+TV-192 soil treatment	68	85.3	2.9	11.8
F. oxysporum D_3+TV-192 seed coating	75	78.7	0	21.3
F. oxysporum N_7	76	78.9	21.1	0
F. oxysporum N_7+TV-192 soil treatment	80	72.5	7.5	20.0
F. oxysporum N_7 ×TV-192 seed coating	80	77.5	7.5	15.0
Control	84	100	0	0

High density of the fungus TV-192 caused the inhibition of seed germination and seedling growth of sesame. Inhibitory effects of *Trichoderma* sp. on seed germination and seedling growth of sesame were different according to the isolates of the fungus.

Trichoderma isolates	Germination of sesame	Normal seedlings(%)	Dead seedlings(%)	Stunted seedlings	Length of normal seedlings	
					Shoot	Root
164	72	61.1	19.4	19.5	47	35
209	80	65.0	20.0	15.0	54	35
218	56	57.1	25.0	17.9	56	37
227	74	51.4	24.3	24.3	46	26
239	82	58.5	22.0	19.5	61	27
240	88	75.0	9.0	16.0	61	33
241	82	36.6	9.8	53.6	51	25
J_1	72	69.4	16.7	13.9	57	34
J_2	78	64.1	20.5	15.4	61	39
Control	84	100	0	0	50	25

- H.S. Chung and W.B. Choi (1992) reported the incidence of sesame damping off caused by *Rhizoctonia solani* and *Fusarium oxysporum* f. sp. sesami in Korea was reduced by coating seed with 3 isolates of *Trichoderma viride* or Benlate [benomyl] T (benomyl) in pot and field trials using naturally infested soils. When sesame seeds were treated with Benlate [benomyl] T or conidia (107/ml) of the antagonists, seedling emergence was significantly increased compared with the untreated control. The incidence of post-emergence damping off was significantly reduced compared with the control. Soil samples taken from the crown area of the sesame seedlings showed an increase in *Trichoderma* spp. populations during the growing season whereas those of *R. solani* and *F. oxysporum* decreased. However, no significant decline was found in the population of *F. oxysporum* from the rhizosphere at later stages. Mycoparasitism between the antagonists and the pathogens was observed after mycelial contact in dual culture. Coiling and penetration of the antagonists in the hyphae of the pathogens resulted in breaking, lysis and abnormal vacuolation.

E1.1.1b *Trichoderma harzianum* (13 Apr 2021)

Family: Hypocreaceae

Definition: Amount of biocontrol provided by *Trichoderma harzianum* Rifai 1969.

(Wikipedia, 13 Apr 2021) ***Trichoderma harzianum*** is a fungus that is also used as a fungicide. It is used for foliar application, seed treatment and soil treatment for suppression of various disease causing fungal pathogens. Commercial biotechnological products such as 3Tac have been useful for treatment of *Botrytis*, *Fusarium* and *Penicillium* sp. It is also used for manufacturing enzymes.

Most *Trichoderma* strains have no sexual stage but instead produce only asexual spores. However, for a few strains the sexual stage is known, but not among strains that have usually been considered for biocontrol purposes. The sexual stage, when found, is within the Ascomycetes in the genus *Hypocrea*. Traditional taxonomy was based upon differences in morphology, primarily of the asexual sporulation apparatus, but more molecular approaches are now being used. Consequently, the taxa recently have gone from nine to at least thirty-three species.

Most strains are highly adapted to an asexual life cycle. In the absence of meiosis, chromosome plasticity is the norm, and different strains have different numbers and sizes of chromosomes. Most cells have numerous nuclei, with some vegetative cells possessing more than 100. Various asexual genetic factors, such as parasexual recombination, mutation and other processes contribute to variation between nuclei in a single organism (thallus). Thus, the fungi are highly adaptable and evolve rapidly. There is great diversity in the genotype and phenotype of wild strains.

While wild strains are highly adaptable and may be heterokaryotic (contain nuclei of dissimilar genotype within a single organism, and hence highly variable), strains used for biocontrol in commercial agriculture are, or should be, homokaryotic (nuclei are all genetically similar or identical). This, coupled with tight control of variation through genetic drift, allows these commercial strains to be genetically distinct and non-variable. This is an extremely important quality control item for any company wishing to commercialize these organisms.

Trichoderma spp. are fungi that are present in nearly all soils. In soil, they frequently are the most prevalent culturable fungi. They also exist in many other diverse habitats.

Trichoderma readily colonizes plant roots, and some strains are rhizosphere competent i.e. able to grow on roots as they develop. Trichoderma spp. also attack, parasitize and otherwise gain nutrition from other fungi. They have evolved numerous mechanisms for both attack of other fungi and for enhancing plant and root growth. Different strains of Trichoderma control almost every pathogenic fungus for which control has been sought. However, most Trichoderma strains are more efficient for control of some pathogens than others and may be largely ineffective against some fungi.

References:

INTERNATIONAL

- CAB International (accessed 12 Apr 2021) reported sesame was associated with *Trichoderma harzianum* (Hyperparasite of *Rhizoctonia solani*).

EGYPT

- M.S. Serry (1981b) reported the presence of *Fusarium oxysporum* is a major hazard. Studies using *Trichoderma harzianum* as a fungicide have been initiated.
- A.I.I. El-Fiki et al. (2004a) studied the effects of using *Trichoderma harzianum* to control *Macrophomina phaseolina* Tassi (Goid). The seeds were planted in pots in the greenhouse and then took percentages as follows: % pre-emergence = damping off within 15 days, % post-emergence = damping off within 45 days, % charcoal rot = diseased at 90 days, and % healthy plants at 90 days. The results with antagonistic fungi were as follow.

Antagonistic fungi and bacteria	% Disease incidence			
	At seedling stage		At maturity stage	
	Pre-emergence	Post-emergence	Charcoal rot	Healthy plants
B. megtella *	16.7	16.7	23.3	43.3
Bacillus sp 3 **	13.3	10.0	23.3	53.3
Bacillus subtillus *	10.0	13.3	20.0	56.7
Chaetomium bostrycoides *	0.0	3.3	6.7	90.0
Gliocladium penicilloides *	16.7	20.0	26.7	36.7
T. hamatum *	6.7	6.7	6.7	80.0
T. viride *	16.7	6.7	6.7	70.0
Trichoderma harzianum *	0.0	0.0	3.3	96.7
Trichoderma sp 10 **	23.3	26.7	20.0	30.0
Trichoderma sp 2 **	13.3	13.3	13.3	60.0
Trichoderma sp 3 **	16.7	23.3	16.7	43.3
Trichoderma sp 5 **	6.7	0.0	10.0	83.3
Trichoderma sp 6 **	13.3	6.7	10.0	70.0
Trichoderma sp 8 **	16.7	20.0	20.0	43.3
Trichoderma sp 9 **	20.0	6.7	16.7	56.7
Control	30.0	26.7	26.7	16.7
LSD. at 5%	8.17	9.05	7.96	9.53

* Obtained from Biological Control and Onion and Oil Crops Res. Dept Agric., Res. Center Giza, Egypt.
** Isolated from rhizosphere of healthy sesame plants.

- A.F. Mahmoud and O.A. Abdalla (2018) evaluated the antagonistic capability of 24 isolates of *Trichoderma spp*. (*T. hamatum*, *T. harzianum*, *T. virens*, and *T. viride*) *vitro* against *Fusarium oxysporum* f. sp. *sesami* (Fos).

Trichoderma strains	Bioagent No.	Colony diameter of *F. ox.* f.sp. *sesami* (cm)*	Inhibition of *F. ox.* f.sp. *sesami* growth (%)
Trichoderma hamatum	T1	4.15 ^{CDE}	53.88 ^{CDE}
	T2	3.85 ^{DE}	57.22 ^{DE}
	T3	3.77 ^{DE}	58.05 ^{DE}
	T4	4.40 ^{CD}	51.11 ^{CD}
	T5	3.82 ^{DE}	57.50 ^{DE}
Average		3.998	55.557
Trichoderma harzianum	T6	3.72 ^{DE}	58.61 ^{DE}
	T7	3.65 ^{DEF}	59.44 ^{DEF}
	T8	3.92 ^{DE}	56.38 ^{DE}
	T9	2.90 ^{FG}	67.77 ^{FG}
	T10	4.20 ^{CDE}	53.33 ^{CDE}
	T11	4.37 ^{CD}	51.38 ^{CD}
	T12	4.25 ^{CDE}	52.77 ^{CDE}
Average		3.858	57.09
Trichoderma virens	T13	4.32 ^{CD}	51.94 ^{CD}
	T14	4.75 ^{BC}	47.22 ^{BC}
	T15	4.77 ^{BC}	46.94 ^{BC}
	T16	4.12 ^{CDE}	54.16 ^{CDE}
Average		4.49	50.06
Trichoderma viride	T17	4.22 ^{CDE}	53.05 ^{CDE}
	T18	4.57 ^{BC}	49.16 ^{BC}
	T19	4.12 ^{CDE}	54.16 ^{CDE}
	T20	4.25 ^{CDE}	52.77 ^{CDE}
	T21	2.67 ^{G}	70.27 ^{G}
	T22	3.95 ^{DE}	56.11 ^{DE}
	T23	4.07 ^{CDE}	54.72 ^{CDE}
	T24	3.52 ^{EF}	60.83 ^{EF}
Average		3.921	56.38
Control		9.00 A	

*Means within the same column followed by different letters are significantly different at *5% significant level*.

Two strains of *T. harzianum* and *T. viride* had high antagonistic effect against *F. oxysporum* f. sp. *sesami in vitro* with inhibition percentage about 70 and 67%, respectively. These two isolates proved to have high ability to control Fusarium wilt disease under greenhouse conditions as shown below.

Bioagent	Application time	Seedling emergence (%)*	Increase in seedling emergence (%)	Disease severity (%)*	Reduction in disease severity (%)
Application of *T. harzianum* (T9)	7 days *before* challenging with Fos	87.25^{C}	54.42^{C}	22.50^{D}	74.71^{D}
	At the same time with Fos	79.50^{D}	40.70^{D}	35.25^{BC}	60.39^{BC}
	7 days *after* challenging with Fos	70.50^{E}	24.77^{E}	40.50^{B}	54.49^{B}
	Average	79.08	39.96	32.75	63.19
Application of *T. viride* (T21)	7 days *before* challenging with Fos	93.75^{B}	65.92^{B}	20.25^{D}	77.24^{D}
	At the same time with Fos	84.50^{C}	49.55^{C}	32.75^{C}	63.20^{C}
	7 days *after* challenging with Fos	80.75^{D}	42.92^{D}	38.00^{BC}	57.30^{BC}
	Average	86.33	52.79	30.33	65.91
Infected	Challenging with Fos	56.50^{F}	0.00^{F}	89.00^{A}	0.00^{A}
Healthy	Uninfected control	100^{A}	0.00^{A}	0.00^{E}	0.00^{E}

*Means within the same column followed by different letters are significantly different *at 5 % significant level*.

INDIA

- S.J. Gaikwad and D.J. Kapgate (1990) examined the possible biological control of the fungus *Sclerotium rolfsii*, the causal agent of the root-rot disease of sesame. Laboratory studies showed that 2 fungi were capable of limiting the growth of the pathogen of the root-rot disease. Pot trials showed that in the presence of the fungi *Trichoderma harzianum* and *Penicillium pinophilum*, only 10 and 15%, respectively, of sesame plants were infected with *S. rolfsii*; infection in the absence of the 2 fungi (control plants) was 100%. [Based on abstract]
- R. Krishan et al. (1999b) evaluated the management effects of biological controls (using *Trichoderma harzianum*) on the seed and the soil, different levels of N (0, 30, and 45 N kg/ha), and seeds treated with different fungicides (Benomyl, Carboxyn, and Carbendazim) on *Rhizoctonia bataticola*. The results of using the *T. harzianum* conidia on the seed was as follow.

T. harzianum conidia g kg^{-1} seed (w/w)	Per cent disease incidence*
0	66.66 (54.76)
1.5	45.00 (42.13)
2.5	40.00 (39.23)
3.5	35.00 (36.27)
4.5	30.00 (33.21)
C.D. at 5%	6.93

*Figures in parentheses are angular transformed values

The results of using the *T. harzianum* in the soil and at different levels of N were as follow.

Level of N kg ha^{-1}	*T. harzianum* g kg^{-1} soil (w/w)	Per cent disease incidence*
30	0	75.00 (60.70)
	2	66.66 (54.75)
	4	56.66 (48.81)
	6	50.00 (45.00)
	8	46.66 (43.08)
	10	40.00 (39.21)
45	0	88.33 (70.50)
	2	78.33 (62.48)
	4	71.66 (57.86)
	6	63.33 (52.74)
	8	55.00 (47.88)
	10	45.00 (42.12)
Control	-	64.20 (53.25)
C.D. at 5%		7.51

*Figures in parentheses are angular transformed value

The results of using the *T. harzianum* on the seed with different fungicides were as follow.

Conidia g kg^{-1} seed (w/w)	Fungicide at 2%, W/V	Disease incidence (%)*
2.5	Benomyl	8.33 (16.60)
	Carboxyn	10.00 (18.05)
	Carbendazim	11.66 (19.89)
	No fungicide	42.50 (40.69)
3.5	Benomyl	5.00 (12.92)
	Carboxyn	6.66 (14.76)
	Carbendazim	6.66 (14.76)
	No fungicide	36.00 (36.87)
Control	-	66.66 (54.76)
C.D. at 5%		2.31

*Figures in parenthesis are angular transformed value

The results of using the *T. harzianum* in the soil with different fungicides were as follow.

Mycelial suspension of *T. harzianum* (g kg^{-1} soil)	Fungicide at 2% W/W	Disease incidence (%)*
4	Benomyl	8.93 (17.36)
	Carboxyn	3.58 (10.94)
	Carbendazim	7.15 (15.45)
	No fungicide	26.66 (31.11)
6	Benomyl	7.15 (15.45)
	Carboxyn	1.79 (7.71)
	Carbendazim	0.00
	No fungicide	21.66 (27.76)
Control		64.66 (50.55)
C.D. at 5%		1.37

*Figures in parenthesis are angular transformed value

- C. Chattopadhyay and R.K. Sastry (2002) evaluated the effects of chemicals, extracts, biocontrols, and agronomic practices in controlling *Macrophomina phaseolina* with the following *in vitro* results.

Treatment	Mycelial growth (mm)*	% Reduction in mycelial growth
Trichoderma viride	21.6	71.3
T. harzianum	36.2	52.0
Gliocladium virens	14.2	80.9
Control	75.4	-
C.D. ($P < 0.01$)	6.5	

*mean of five replications after 7 days on PDA at 27±1°C

The following were the results in pots.

Treatment	% seed germination*		Radicle length (mm)*	Shoot length (cm)$	% disease incidence $	
Trichoderma viride	97.3	(82.1)	50.5	40.4	20.0	(25.7)
T. harzianum	88.0	(70.5)	31.0	24.6	55.0	(47.9)
Gliocladium virens	96.0	(80.5)	35.5	35.4	53.3	(47.4)
Garlic bulb extract	53.3	(46.9)	12.0	28.0	85.0	(67.6)
Neem leaf extract	92.0	(73.9)	29.5	33.9	45.0	(41.5)
Azadirachtin[&]	72.0	(58.1)	14.0	29.2	80.0	(64.4)
AFF[¥]	0.0	(4.0)	0.0	30.2	61.6	(52.1)
Salicylic acid	88.0	(69.9)	26.0	37.5	60.0	(51.0)
Carbendazim	92.0	(73.6)	29.5	30.0	51.6	(45.9)
Copper-oxychloride	84.0	(66.5)	11.7	27.5	68.3	(56.3)
Thiram	78.7	(62.5)	9.7	26.6	65.0	(53.8)
Captan	84.0	(66.5)	8.0	26.9	50.0	(44.9)
Inoculated Control	81.3	(64.4)	13.7	14.9	100.0	(90.0)
Uninoculated Control	-	-	-	32.2	-	-
C.D. (P < 0.05)	7.2		4.8	6.3	13.7	

*mean of three replicates 3 days after sowing $neem formulations
Figures in parentheses are angular transformed values

- M.L. Verma et al. (2002) reported antagonistic *Trichoderma viride*, *Trichoderma harzianum*, and *Pseudomonas fluorescence*, when used as seed treatment, not only reduce *Phytophthora parasitica* var. *sesami* significantly but substantially increase the sesame yield. [Cited by C. Chattopadhyay et al., 2019]
- A.S. Savitha et al. (2011) evaluated several isolates against *Alternaria sesami.* Among two *Trichoderma* isolates, maximum inhibition was noticed in *T. harzianum* to the extent of 87% followed by *T. viride*. Among four bacterial bioagents, an exogenous *Pseudomonas fluorescens* (Pf-E) was most efficient with 80% inhibition. Salicylic acid at 1% was found to be effective in suppressing the pathogen and resulted in higher vigour index (1138.28), followed by *P. fluorescens* I with good germination and vigour index of 97.75% and 1029.85, respectively. The higher vigour index is mainly due to increased germination, higher root and shoot growth by the systemic resistance inducing agents. [Based on abstract]
- P.L. Radha (2013) evaluated the antagonistic micro-organisms like *Trichoderma harzianum* Rifai., *Trichoderma viride* Pers., *Trichoderma koenigii* Qudem., *Trichoderma virens* Miller., *Pseudomonas fluorescens* Migula., and *Bacillus subtilis* Cohn. For their effect under *in vitro* condition against *A. sesami* by dual culture technique. The results were as follows.

Bioagents	**Per cent inhibition**
Trichoderma harzianum	77.50 (61.66)
Trichoderma viride	75.14 (60.07)
Trichoderma koenigii	73.19 (58.79)
Trichoderma virens	71.53 (57.73)
Pseudomonas fluorescens	36.22 (36.98)
Bacillus subtilis	52.02 (46.15)
S.Em±	0.90
CD at 1 %	2.51

* Arcsine transformed values

Efficacy of fungicides, botanicals and bio-agents were tested against seedborne fungal infections of sesame (variety E-8). The results were as follows.

Sl. No.	Treatments	Percent seed Infection	Percent seed germination	Vigour index
1.	Garlic	30.33 (33.43)*	70.00 (56.82)	517
2.	Ginger	26.67 (31.11)	74.33 (59.59)	591
3.	Hexaconazole	13.33 (21.42)	89.33 (70.97)	1208
4.	Tebuconazole	30.67 (33.65)	72.00 (58.08)	697
5.	Propiconazole	26.33 (30.89)	74.00 (59.37)	729
6.	*T. harzianum*	21.33 (27.52)	80.67 (63.95)	515
7.	*P. fluoroscencs*	25.00 (30.00)	75.33 (60.03)	828
8.	Avatar72WP (Hexazconazole 4% + Zineb 68%)	14.00 (21.89)	87.67 (69.48)	1027
9.	Taqat75WP(Captan70+Hexaconazole 5%)	25.00 (30.00)	78.33 (62.34)	429
10	Control (untreated seeds)	42.00 (40.41)	57.33 (49.24)	318
	S.Em±	**0.46**	**0.78**	**13.95**
	CD at 1 %	**2.16**	**3.71**	**69.38**

* Arcsine transformed values

- V.A. Savaliya et al. (2016) evaluated biocontrols against *Macrophomina phaseolina in vitro* with the following results.

Biocontrol agents	Sclerotial formation	Per cent inhibition over control
Bacillus subtilis	+	87.03
T. viride	+ +	71.48
T. hamatum	+ + +	70.00
T. koningii	+ + +	68.14
Trichoderma harzianum	+ +	67.40
Pseudomonas fluorescens	+ +	64.07
Control		-
S. Em. ±	1.602	
CD at 5%	4.862	
CV %	4.54	

Biocontrol agents	Per cent disease incidence	Yield (kg / ha)
Bacillus subtilis	18.93(10.53)	680
Trichoderma konigii	25.43(18.44)	585
T. hamatum	26.90(20.48)	609
T. viride	28.42(22.65)	579
T. harzianum	30.02(25.02)	510
Pseudomonas fluorescens	30.93(26.42)	537
Control	32.96(29.61)	507
S. Em. ±	1.30	28.36
C.D. at 5%	3.89	87.38
C.V.%	10.46	8.59

- K. Choudhary et al. (2018) evaluated chemicals (Tebuconazole, Carbendazim, and Mancozeb) and biocontrols (*Trichoderma harzianum* and *Pseudomonas fluorescens*) to reduce the incidence of *Macrophomina phaseolina* with the following results in terms of disease incidence and yield.

Treatments	Disease incidence (%)	Disease control (%)	Yield (kg ha^{-1})
T_1 -Tebuconazole 2DS ST @ 1.5 g kg $^{-1}$	16.16 (23.70)*	73.06	435.00
T_2 - Carbendazim 12% + Mancozeb 63% WP ST @ 2 g kg $^{-1}$	18.16 (25.22)	69.73	420.10
T_3 - *T. harzianum* ST @ 10 g kg $^{-1}$	31.00 (33.83)	48.10	378.00
T_4 - *P. fluorescens* ST @ 10 g kg $^{-1}$	33.50 (35.36)	44.16	370.00
T_5 - Tebuconazole 25.9 EC SA @ 1.5 ml Lt^{-1}	19.51 (26.21)	67.48	410.00
T_6 - Carbendazim 12% + Mancozeb 63% WP SA @ 2 g Lt^{-1}	22.50 (28.32)	62.50	405.00
T_7 -*T. harzianum* SA @ 10 kg ha^{-1}	35.80 (36.64)	40.33	350.00
T_8 - *P. fluroescens* SA @ 10 kg ha^{-1}	40.00 (39.23)	33.33	330.10
T_9 - Tebuconazole 2DS ST@ 1.5 g kg $^{-1}$ + Tebuconazole 25.9 EC SD @ 1.5 ml Lt^{-1}	9.52 (17.97)	84.13	480.60
T_{10} - Carbendazim 12% ST @ 2 g kg $^{-1}$+ Mancozeb 63% WP + SD @ 2 g Lt^{-1}	13.50 (21.56)	77.50	450.00
T_{11} -*T. harzianum* ST @ 10 g kg $^{-1}$ + SA @ 10 kg ha^{-1}	23.50 (29.00)	60.83	392.00
T_{12} - *P. fluroescens* ST @ 10 g kg $^{-1}$ + SA @ 10 kg ha^{-1}	26.55 (31.01)	55.75	385.30
T_{13} - Control (without treatment)	60.00 (50.77)	-	250.00
SEm ±	1.58		22.93
CD P=0.05	4.63		66.94
CV(%)	10.23		10.21
*Figures in parentheses are angular transformed values			

ST= Seed treatment, SA= Soil application, SD=Soil drenching

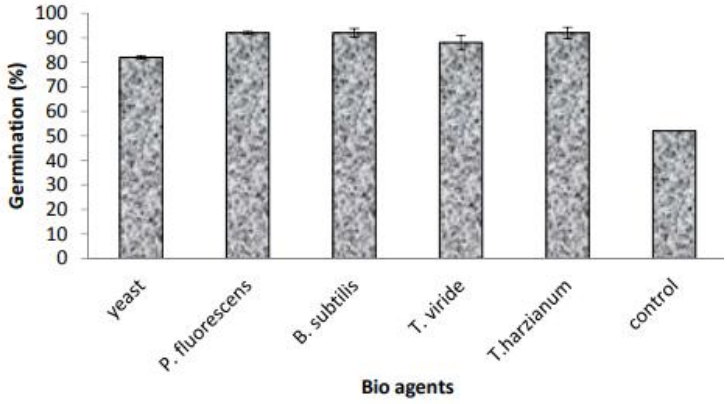
- K.N. Gupta et al. (2018) reported seed treatment with *Trichoderma harzianum* helped control Phytophthora blight, Macrophomina stem/root rot, and *Sclerotium rolfsii*.
- P. Renganathan et al. (2020b) reported many *Trichoderma* species are regarded as growth promoters by increasing fresh weight, height, and flowering while inhibiting pathogen growth. *T. viride* and *T. harzianum* inhibited the growth and caused sclerotial lysis of *M. phaseolina in vitro.* *Pseudomonas fluorescens* was also effective using various modes of action especially rhizosphere colonization, antibiotic production, and induction of systemic resistance.

IRAN

- M. Gooya et al. (2000) took one seed samples of each 17 sesame cultivars from 10 locations leading to 145 isolates during 1997/99 They identified *Trichoderma harzianum.*

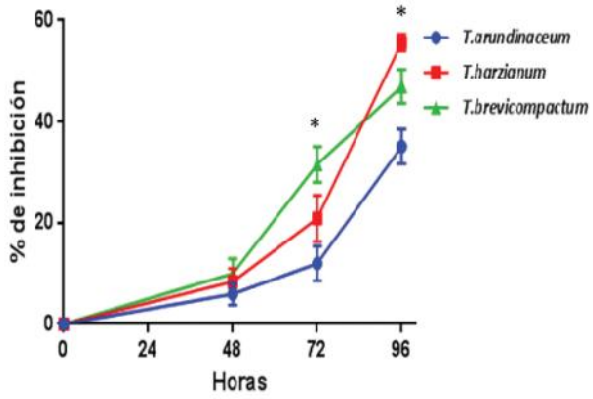
PAKISTAN

- B.G. Nayyar et al. (2016) evaluated different bioagents to increase the germination and inhibit the fungi on sesame seeds bioagents (*Trichoderma viride, T. harzianum, Pseudomonas fluorescens, Bacillus subtilis* and *Saccharomyces cerevisiae* – yeast). Seed germination was tested by following the protocol of International Seed Testing Association. Antifungal activity was tested by poisoned food technique. The effects of the bioagents were as follow.



PARAGUAY

- D.D. Ruiz et al. (2017) evaluated the effects of *Trichoderma arundinaceum, T. harzianum,* and *T. pseudokoningii* on *Macrophomina phaseolina*. The % inhibition across 96 hours is shown below.



VENEZUELA

- J.B. Pineda (2001) evaluated using *Trichoderma harzianum* in different forms (clayey soil granules impregnated with conidia of *T. harzianum* and 5% sucrose, rice grains inoculated with *T. harzianum*, sesame seed coated with conidia of *T. harzianum*, and no treatment) to control *Macrophomina phaseolina* in Turen (9.33N 69.11W). The results were as follow.

Treatment	**Dead plants (%)**	**Reduction of mortality (%)**
Clayey soil granules impregnated with conidia of *T. harzianum* and 5% sucrose	2.8 a	69.5
Sesame seed coated with conidia of *T. harzianum*	4.3 ab	53.3
rice grains inoculated with *T. harzianum*	6.8 bc	26.1
No treatment	9.2 c	0

- R. Cardona and H. Rodríguez (2006) studied the effects of *Trichoderma harzianum* on *Macrophomina phaseolina* using 3 methods: application on the seed; application in clay granules, and application in rice grains versus a control with no application. Across 3 years, These results do not show any difference of *T. Harzianum* on the incidence of the charcoal rot, also evidenced the necessity of evaluating cultural practices that might improve the environmental conditions that allows the fungus *T. Harzianum* to develop all its antagonist capacity.
- R. Cardona (2008) studied the effects of *Trichoderma harzianum* and green manure of *Crotalaria spp.* on the number of sclerotia/g of soil (SG) of *Macrophomina phaseolina* and the incidence of charcoal rot in sesame with 3 treatments: a) green manure (GM) and absolute control (AC); b) GM, green manure + *Trichoderma* (GMT) and c) GM, GMT and AC. The results indicates that the GM slows down the *M. phaseolina* development at the beginning, but when advancing the crop cycle the levels of inoculums reaches equal values to the AC; whereas the GMT treatment showed diminution in the SG throughout the cycle in comparison with the treatment GM. In the third essay, a high significant difference ($P \leq 0.01$) in the incidence of charcoal rot with the GMT treatment constitutes a viable alternative for controlling *M. phaseolina* in sesame.

E1.1.1c *Trichoderma virens* (15 May 2021)

Synonym: *Gliocladium virens*

Family: Hypocreaceae

Definition: Amount of biocontrol provided by *Trichoderma virens* (J.H. Miller, Giddens & A.A. Foster) Arx 1987

References:

EGYPT

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	T7	3.65 ^{DEF}	59.44 ^{DEF}
	T8	3.92 ^{DE}	56.38 ^{DE}
	T9	2.90 ^{FG}	67.77 ^{FG}
	T10	4.20 ^{CDE}	53.33 ^{CDE}
	T11	4.37 ^{CD}	51.38 ^{CD}
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	T16	4.12 ^{CDE}	54.16 ^{CDE}
Average		4.49	50.06
Trichoderma viride	T17	4.22 ^{CDE}	53.05 ^{CDE}
	T18	4.57 ^{BC}	49.16 ^{BC}
	T19	4.12 ^{CDE}	54.16 ^{CDE}
	T20	4.25 ^{CDE}	52.77 ^{CDE}
	T21	2.67 ^{G}	70.27 ^{G}
	T22	3.95 ^{DE}	56.11 ^{DE}
	T23	4.07 ^{CDE}	54.72 ^{CDE}
	T24	3.52 ^{EF}	60.83 ^{EF}
Average		3.921	56.38
Control		9.00 A	

*Means within the same column followed by different letters are significantly different at *5% significant level*.

Two strains of *T. harzianum* and *T. viride* had high antagonistic effect against *F. oxysporum* f. sp. *sesami in vitro* with inhibition percentage about 70 and 67%, respectively. These two isolates proved to have high ability to control Fusarium wilt disease under greenhouse conditions as shown below.

Bioagent	Application time	Seedling emergence (%)*	Increase in seedling emergence (%)	Disease severity (%)*	Reduction in disease severity (%)
Application of *T. harzianum* (T9)	7 days *before* challenging with Fos	87.25^{C}	54.42 ^{C}	22.50 ^{D}	74.71 ^{D}
	At the same time with Fos	79.50 ^{D}	40.70 ^{D}	35.25 ^{BC}	60.39 ^{BC}
	7 days *after* challenging with Fos	70.50 ^{E}	24.77 ^{E}	40.50^{B}	54.49 ^{B}
	Average	79.08	39.96	32.75	63.19
Application of *T. viride* (T21)	7 days *before* challenging with Fos	93.75^{B}	65.92 ^{B}	20.25 ^{D}	77.24^{D}
	At the same time with Fos	84.50 ^{C}	49.55 ^{C}	32.75 ^{C}	63.20 ^{C}
	7 days *after* challenging with Fos	80.75 ^{D}	42.92 ^{D}	38.00^{BC}	57.30 ^{BC}
	Average	86.33	52.79	30.33	65.91
Infected	Challenging with Fos	56.50^{F}	0.00 ^{F}	89.00^{A}	0.00 ^{A}
Healthy	Uninfected control	100^{A}	0.00 ^{A}	0.00 ^{E}	0.00 ^{E}

*Means within the same column followed by different letters are significantly different *at 5 % significant level*.

INDIA

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Control	75.4	-
C.D. (P < 0.01)	6.5	

*mean of five replications after 7 days on PDA at 27±1°C

The following were the results in pots.

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Gliocladium virens	96.0	(80.5)	35.5	35.4	53.3	(47.4)
Garlic bulb extract	53.3	(46.9)	12.0	28.0	85.0	(67.6)
Neem leaf extract	92.0	(73.9)	29.5	33.9	45.0	(41.5)
Azadirachtin*	72.0	(58.1)	14.0	29.2	80.0	(64.4)
AFF*	0.0	(4.0)	0.0	30.2	61.6	(52.1)
Salicylic acid	88.0	(69.9)	26.0	37.5	60.0	(51.0)
Carbendazim	92.0	(73.6)	29.5	30.0	51.6	(45.9)
Copper-oxychloride	84.0	(66.5)	11.7	27.5	68.3	(56.3)
Thiram	78.7	(62.5)	9.7	26.6	65.0	(53.8)
Captan	84.0	(66.5)	8.0	26.9	50.0	(44.9)
Inoculated Control	81.3	(64.4)	13.7	14.9	100.0	(90.0)
Uninoculated Control	-	-	-	32.2	-	-
C.D. (P < 0.05)	7.2		4.8	6.3	13.7	

*mean of three replicates 3 days after sowing *neem formulations

Figures in parentheses are angular transformed values

- P.L. Radha (2013) evaluated the antagonistic micro-organisms like *Trichoderma harzianum* Rifai., *Trichoderma viride* Pers., *Trichoderma koningii* Qudem., *Trichoderma virens* Miller., *Pseudomonas fluorescens* Migula., and *Bacillus subtilis* Cohn. For their effect under *in vitro* condition against *A. Sesami* by dual culture technique. The results were as follows.

Bioagents	Per cent inhibition
Trichoderma harzianum	77.50 (61.66)
Trichoderma viride	75.14 (60.07)
Trichoderma koenigii	73.19 (58.79)
Trichoderma virens	71.53 (57.73)
Pseudomonas fluorescens	36.22 (36.98)
Bacillus subtilis	52.02 (46.15)
S.Em±	0.90
CD at 1 %	2.51

* Arcsine transformed values

REPUBLIC OF KOREA

- S.W. Kang and H.K Kim (1989) reported sesame seeds coated with conidia of *Gliocladium virens*, were sown in the field where sesame had been cultivated for five to six straight years. The antagonistic fungus was evaluated for biocontrol potentials over Benomyl fungicide against Damping-off and Fusarium wilt of sesame for two years with randomized block design with three replicates throughout the growing period of 1987 and 1988. Pathogenic fungi associated with sesame seedling disease in the field plot was predominantly *Fusarium* sp. and *Pythium* sp. at 32.9% and 27%, respectively. Disease incidence of Damping-off and Fusarium wilt at earlier growth stages was 20.1% in 1987 and 15.2% in 1988 for plots of seed-dusted with conidia of G. virens, which was far effective compared to the infection rate at average of 35.2% of the untreated plot. It was especially remarkable that *G. virens* seed-dusting was superior to fungicide seed treatment by Benomyl wp. [Based on abstract]

E1.1.1d *Trichoderma koningii* (15 May 2021)

Family: Hypocreaceae

Definition: Amount of biocontrol provided by *Trichoderma koningii* Oudemans 1902.

References:

INDIA

- P.L. Radha (2013) evaluated the antagonistic micro-organisms like *Trichoderma harzianum* Rifai., *Trichoderma viride* Pers., *Trichoderma koningii* Qudem., *Trichoderma virens* Miller., *Pseudomonas fluorescens* Migula., and *Bacillus subtilis* Cohn. For their effect under *in vitro* condition against *A. sesami* by dual culture technique. The results were as follows.

Bioagents	Per cent inhibition
Trichoderma harzianum	77.50 (61.66)
Trichoderma viride	75.14 (60.07)
Trichoderma koenigii	73.19 (58.79)
Trichoderma virens	71.53 (57.73)
Pseudomonas fluorescens	36.22 (36.98)
Bacillus subtilis	52.02 (46.15)
S.Em±	0.90
CD at 1 %	2.51

* Arcsine transformed values

- V.A. Savaliya et al. (2016) evaluated biocontrols against *Macrophomina phaseolina in vitro* with the following results.

Biocontrol agents	Sclerotial formation	Per cent inhibition over control
Bacillus subtilis	+	87.03
T. viride	+ +	71.48
T. hamatum	+ + +	70.00
T. koningii	+ + +	68.14
Trichoderma harzianum	+ +	67.40
Pseudomonas fluorescens	+ +	64.07
Control		-
S. Em. ±	1.602	
CD at 5%	4.862	
CV %	4.54	

Biocontrol agents	Per cent disease incidence	Yield (kg / ha)
Bacillus subtilis	18.93(10.53)	680
Trichoderma konigii	25.43(18.44)	585
T. hamatum	26.90(20.48)	609
T. viride	28.42(22.65)	579
T. harzianum	30.02(25.02)	510
Pseudomonas fluorescens	30.93(26.42)	537
Control	32.96(29.61)	507
S. Em. ±	1.30	28.36
C.D. at 5%	3.89	87.38
C.V.%	10.46	8.59

E1.1.1e *Trichoderma hamatum* (12 Jul 2021)

Family: Hypocreaceae

Definition: Amount of biocontrol provided by *Trichoderma hamatum* (Bonord.) Bainier 1906.

(Wikipedia, 12 Jul 2021) ***Trichoderma hamatum*** is a species of fungus in the family Hypocreaceae. It has been used a biological control of certain plant diseases.

References:

EGYPT

- A.F. Mahmoud and O.A. Abdalla (2018) evaluated the antagonistic capability of 24 isolates of *Trichoderma spp*. (*T. hamatum, T. harzianum, T. virens*, and *T. viride*) *vitro* against *Fusarium oxysporum* f. sp. *sesami* (Fos).

Trichoderma strains	Bioagent No.	Colony diameter of *F. ox.* f.sp. *sesami* (cm)*	Inhibition of *F. ox.* f.sp. *sesami* growth (%)
Trichoderma hamatum	T1	4.15 ^{CDE}	53.88 ^{CDE}
	T2	3.85 ^{DE}	57.22 ^{DE}
	T3	3.77 ^{DE}	58.05 ^{DE}
	T4	4.40 ^{CD}	51.11 ^{CD}
	T5	3.82 ^{DE}	57.50 ^{DE}
Average		3.998	55.557
Trichoderma harzianum	T6	3.72 ^{DE}	58.61 ^{DE}
	T7	3.65 ^{DEF}	59.44 ^{DEF}
	T8	3.92 ^{DE}	56.38 ^{DE}
	T9	2.90 ^{FG}	67.77 ^{FG}
	T10	4.20 ^{CDE}	53.33 ^{CDE}
	T11	4.37 ^{CD}	51.38 ^{CD}
	T12	4.25 ^{CDE}	52.77 ^{CDE}
Average		3.858	57.09
Trichoderma virens	T13	4.32 ^{CD}	51.94 ^{CD}
	T14	4.75 ^{BC}	47.22 ^{BC}
	T15	4.77 ^{BC}	46.94 ^{BC}
	T16	4.12 ^{CDE}	54.16 ^{CDE}
Average		4.49	50.06
Trichoderma viride	T17	4.22 ^{CDE}	53.05 ^{CDE}
	T18	4.57 ^{BC}	49.16 ^{BC}
	T19	4.12 ^{CDE}	54.16 ^{CDE}
	T20	4.25 ^{CDE}	52.77 ^{CDE}
	T21	2.67 ^{G}	70.27 ^{G}
	T22	3.95 ^{DE}	56.11 ^{DE}
	T23	4.07 ^{CDE}	54.72 ^{CDE}
	T24	3.52 ^{EF}	60.83 ^{EF}
Average		3.921	56.38
Control		9.00 A	

*Means within the same column followed by different letters are significantly different at *5% significant level*.

Two strains of *T. harzianum* and *T. viride* had high antagonistic effect against *F. oxysporum* f. sp. *sesami in vitro* with inhibition percentage about 70 and 67%, respectively. These two isolates proved to have high ability to control Fusarium wilt disease under greenhouse conditions as shown below.

Bioagent	Application time	Seedling emergence (%)*	Increase in seedling emergence (%)	Disease severity (%)*	Reduction in disease severity (%)
Application of *T. harzianum* (T9)	7 days *before* challenging with Fos	87.25^{C}	54.42 ^{C}	22.50 ^{D}	74.71 ^{D}
	At the same time with Fos	79.50 ^{D}	40.70 ^{D}	35.25 ^{BC}	60.39 ^{BC}
	7 days *after* challenging with Fos	70.50 ^{E}	24.77 ^{E}	40.50^{B}	54.49 ^{B}
	Average	79.08	39.96	32.75	63.19
Application of *T. viride* (T21)	7 days *before* challenging with Fos	93.75^{B}	65.92 ^{B}	20.25 ^{D}	77.24^{D}
	At the same time with Fos	84.50 ^{C}	49.55 ^{C}	32.75 ^{C}	63.20 ^{C}
	7 days *after* challenging with Fos	80.75 ^{D}	42.92 ^{D}	38.00^{BC}	57.30 ^{BC}
	Average	86.33	52.79	30.33	65.91
Infected	Challenging with Fos	56.50^{F}	0.00 ^{F}	89.00^{A}	0.00 ^{A}
Healthy	Uninfected control	100^{A}	0.00 ^{A}	0.00 ^{E}	0.00 ^{E}

*Means within the same column followed by different letters are significantly different *at 5 % significant level*.

INDIA

- V.A. Savaliya et al. (2016) evaluated biocontrols against *Macrophomina phaseolina in vitro* with the following results.

Biocontrol agents	Sclerotial formation	Per cent inhibition over control
Bacillus subtilis	+	87.03
T. viride	+ +	71.48
T. hamatum	+ + +	70.00
T. koningii	+ + +	68.14
Trichoderma harzianum	+ +	67.40
Pseudomonas fluorescens	+ +	64.07
Control		-
S. Em. ±	1.602	
CD at 5%	4.862	
CV %	4.54	

Biocontrol agents	Per cent disease incidence	Yield (kg / ha)
Bacillus subtilis	18.93(10.53)	680
Trichoderma konigii	25.43(18.44)	585
T. hamatum	26.90(20.48)	609
T. viride	28.42(22.65)	579
T. harzianum	30.02(25.02)	510
Pseudomonas fluorescens	30.93(26.42)	537
Control	32.96(29.61)	507
S. Em. ±	1.30	28.36
C.D. at 5%	3.89	87.38
C.V.%	10.46	8.59

E1.1.1f *Trichoderma pseudokoningii* (14 Aug 2021)

Family: Hypocreaceae

Definition: Amount of biocontrol provided by *Trichoderma pseudokoningii* Rifai 1969.

References:

EGYPT

- M.E. Ibrahim and A.M. Abdel-Azeem (2007) evaluated soil solarization in combination with fungal antagonists and soil amendments as a potential disease management strategy for the control of charcoal rot of sesame caused by *Macrophomina phaseolina*. Solarization alone or in combination with *Trichoderma pseudokoningii* and *Emericella nidulans* singly or in mixed inocula reduced disease incidence from 30% (control) to 80%, 91%, 82% and 85% respectively. It is noted that while pairing improved the biocontrols potentiality of *E. nidulans* by increasing the number of healthy plants in both unsolarized and solarized soils it leads to decrease in the biocontrol potentiality of *T. pseudokoningii*. On the other hand, the combination of solarization with soil amendment with Eucalyptus powdered leaves showed a synergistic effect by increasing number of healthy plants from 65% in amended unsolarized soil to 77% in amended solarized soil.

E1.1.1g *Trichoderma arundinaceum* (29 Aug 2021)

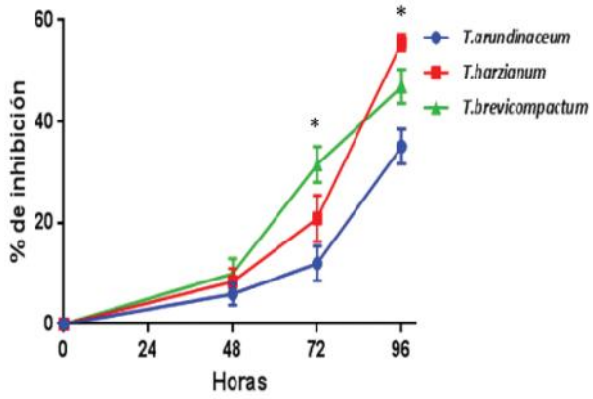
Family: Hypocreaceae

Definition: Amount of biocontrol provided by *Trichoderma arundinaceum* Zafari, Graf. & Samuels 2008**.**

References:

PARAGUAY

- D.D. Ruiz et al. (2017) evaluated the effects of *Trichoderma arundinaceum*, *T. harzianum*, and *T. pseudokoningii* on *Macrophomina phaseolina*. The % inhibition across 96 hours is shown below.



E1.1.1h *Trichoderma brevicompactum* (29 Aug 2021)

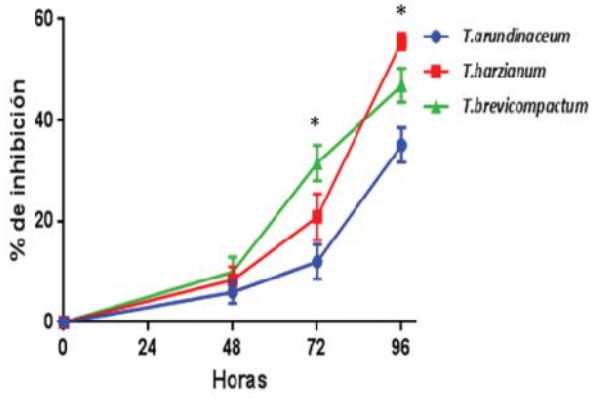
Family: Hypocreaceae

Definition: Amount of biocontrol provided by *Trichoderma brevicompactum* G.F. Kraus, C.P. Kubicek & W. Gams 2004.

References:

PARAGUAY

- D.D. Ruiz et al. (2017) evaluated the effects of *Trichoderma arundinaceum, T. harzianum,* and *T. pseudokoningii* on *Macrophomina phaseolina*. The % inhibition across 96 hours is shown below.



E1.1.2 *Gliocladium* spp. (19 Apr 2021)

Family: Hypocreaceae

Definition: Amount of biocontrol provided by *Gliocladium* spp. Corda 1840.

(Wikipedia, 19 Apr 2021) ***Gliocladium*** is an asexual fungal genus in the Hypocreaceae. Certain other species including *Gliocladium virens* were recently transferred to the genus *Trichoderma* and *G. roseum* became *Clonostachys rosea f. rosea* in the Bionectriaceae. *Gliocladium* is a mitosporic, filamentous fungus. Species of *Gliocladium* rarely produce a sexual state. Most pathogenic, disease-causing fungi in humans are mitosporic like *Gliocladium*. *Gliocladium* is filamentous; it grows tubular, elongated, and thread-like. It can be considered a contaminant.

The following species has been associated with sesame but there are no known reports of being a pathogen, producing a toxin, inhibiting germination, affecting seed quality, or being used as a biocontrol or biofertilizer.

- *Gliocladium roseum* [India] [Authors comment: present classification: *Clonostachys rosea*]

References:

EGYPT

- M.M.I. Abdel-Hafez et al. (2012) examined the soils around the roots of sesame and reported *Gliocladium* sp. in the rhizosphere.
- M.M.I. Abdel-Hafez et al. (2014) took ten samples of sesame from local markets in Assiut city. They found the following: *Gliocladium* sp.

E1.1.3 *Sphaerostilbella* spp. (29 Sep 2021)

Family: Hypocreaceae

Definition: Amount of biocontrol provided by *Sphaerostilbella* spp. (Henn.) Sacc. & D. Sacc. 1905

E1.1.3a *Sphaerostilbella aureonitens* (29 Sep 2021)

Synonym: *Gliocladium penicillioides*

Family: Hypocreaceae

Definition: Amount of biocontrol provided by *Sphaerostilbella aureonitens*.

References:

EGYPT

- A.I.I. El-Fiki et al. (2004a) studied the effects of using *Gliocladium penicillioides* to control *Macrophomina phaseolina* Tassi (Goid). The seeds were planted in pots in the greenhouse and then took percentages as follows: % pre-emergence = damping off within 15 days, % post-emergence = damping off within 45 days, % charcoal rot = diseased at 90 days, and % healthy plants at 90 days. The results with antagonistic fungi were as follow.

Antagonistic fungi and bacteria	% Disease incidence			
	At seedling stage		At maturity stage	
	Pre-emergence	Post-emergence	Charcoal rot	Healthy plants
B. megtella *	16.7	16.7	23.3	43.3
Bacillus sp 3 **	13.3	10.0	23.3	53.3
Bacillus subtillus *	10.0	13.3	20.0	56.7
Chaetomium bostrycoides *	0.0	3.3	6.7	90.0
Gliocladium penicilloides *	16.7	20.0	26.7	36.7
T. hamatum *	6.7	6.7	6.7	80.0
T. viride *	16.7	6.7	6.7	70.0
Trichoderma harzianum *	0.0	0.0	3.3	96.7
Trichoderma sp 10 **	23.3	26.7	20.0	30.0
Trichoderma sp 2 **	13.3	13.3	13.3	60.0
Trichoderma sp 3 **	16.7	23.3	16.7	43.3
Trichoderma sp 5 **	6.7	0.0	10.0	83.3
Trichoderma sp 6 **	13.3	6.7	10.0	70.0
Trichoderma sp 8 **	16.7	20.0	20.0	43.3
Trichoderma sp 9 **	20.0	6.7	16.7	56.7
Control	30.0	26.7	26.7	16.7
LSD. at 5%	8.17	9.05	7.96	9.53

* Obtained from Biological Control and Onion and Oil Crops Res. Dept Agric., Res. Center Giza, Egypt.
** Isolated from rhizosphere of healthy sesame plants.

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E1.2 Family: Clavicipitaceae O.E. Erikss

(Wikipedia, 14 Sep 2021) The **Clavicipitaceae** are a family of fungi within the order Hypocreales. A 2008 estimate placed 43 genera in the family, but recent work has increased this number to 97.

The following species have been identified on sesame plants as a biocontrol of sesame insect pests:

- E1.2.1 *Metarhizium* spp.
- E1.2.1a *Metarhizium rileyi* (*Syn: *Nomuraea rileyi*)
- E1.2.1b *Metarhizium anisopliae*

E1.2.1a *Metarhizium* spp. (14 Sep 2021)

Family: Clavicipitaceae

Definition: The presence on insects in sesame of *Metarhizium* spp. Sorokin 1879.

(Wikipedia, 14 Sep 2021) ***Metarhizium*** is a genus of entomopathogenic fungi in the Clavicipitaceae family. With the advent of genetic profiling, placing these fungi in proper taxa has now become possible. Most turn out to be the asexual forms (anamorphs) of fungi in the phylum Ascomycota, including *Metacordyceps* spp.

E1.2.1a *Metarhizium rileyi* (14 Sep 2021)

Synonym: *Nomuraea rileyi*

Family: Clavicipitaceae

Definition: The presence on insects in sesame of *Nomuraea rileyi* (Farl.) Kepler, Rehner & Humber,2015.

Wikipedia, 14 Sep 2021) ***Metarhizium rileyi*** is a species of entomopathogenic fungus in the family Clavicipitaceae; there is extensive literature under its synonym *Nomuraea rileyi*

(sciencedirect.com, 23 Nov 2020) *Nomuraea rileyi*, another potential insect-infecting fungus, is a dimorphic hyphomycete that can cause epizootic death in various insects. The mycelium is septate, white, with flocculent overgrowth, sparse in culture to dense on insects (often completely covering the hosts), usually becoming green, or purple-gray to purple as sporulation proceeds. Its conidiogenous cells are short, with blunt apices. The host specificity of *N. rileyi* and its eco-friendly nature encourage its use in insect pest management. Its mode of infection and development have been reported for several insects hosts such as *Trichoplusia* sp., *Heliothis zea*, *Plathypena scabra*, *Bombyx mori*, etc.

References:

INDIA

- R. Thangjam (2012) and R. Thangjam and A.S. Vastrad (2018) reported the following fungi on sesame from flowering to pod formation: *Nomuraea rileyi* (Farlow) Samson. The fungus attacks two major insect pest of sesame: *Acherontia styx* and *Spodoptera litura*.


Nomuraea rileyi on *Acherontia styx* (right) and on *Spodoptera litura* (left).

E1.2.1b *Metarhizium anisopliae* (27 Nov 2020)

Family: Cordycipitaceae

Definition: The presence on insects in sesame of *Metarhizium anisopliae* (Metschn.) Sorokin 1883.

(Wikipedia, 27 Nov 2020) ***Metarhizium anisopliae***, formerly known as *Entomophthora anisopliae* (basionym), is a fungus that grows naturally in soils throughout the world and causes disease in various insects by acting as a parasitoid. Ilya I. Mechnikov named it after the insect species from which it was originally isolated – the beetle *Anisoplia austriaca*. It is a mitosporic fungus with asexual reproduction, which was formerly classified in the form class Hyphomycetes of the phylum Deuteromycota (also often called Fungi Imperfecti). According to Paul Stamets, it could be the answer to prevent colony collapse disorder and catastrophic famine.

The disease caused by the fungus is sometimes called green muscardine disease because of the green color of its spores. When these mitotic (asexual) spores (called conidia) of the fungus come into contact with the body of an insect host, they germinate and the hyphae that emerge penetrate the cuticle. The fungus then develops inside the body, eventually killing the insect after a few days; this lethal effect is very likely aided by the production of insecticidal cyclic peptides (destruxins). The cuticle of the cadaver often becomes red. If the ambient humidity is high enough, a white mould then grows on the cadaver that soon turns green as spores are produced. Most insects living near the soil have evolved natural defenses against entomopathogenic fungi like *M. anisopliae*. This fungus is, therefore, locked in an evolutionary battle to overcome these defenses, which has led to a large number of isolates (or strains) that are adapted to certain groups of insects.

Cockroach killed by *Metarhizium anisopliae.*
Photo: Wikipedia, 27 Nov 2020

References:

INDIA

- H.S. Chaitra et al. (2020) evaluated 9 biopesticides against *Bemisia tabaci* and *Antigastra catalaunalis* using 1 variety (G Til-3) in 2015 at Amand, Gujarat. Two sprays of all treatments were applied on the experimental trial field at 15 days interval. For recording observations on number of nymphs and adults of *Bemisia tabaci*, three leaves (upper, middle and lower) each from five randomly selected plants were examined and for *Antigastra catalaunalis*) leaf, flower and capsule damage was recorded before as well as 3, 7, 10 and 15 days after spraying from five randomly selected plants in each plot. The treatments were as follow.
  - T1: Neem seed kernel extract 5%
  - T2: Azadirachtin 1500 ppm 0.0006%
  - Neem oil 0.3%
  - Mahua oil 0.3%
  - Tobacco decoction 2%
  - *Metarrhizium anisopliae* (1× 1010 cfu/g) 0.1%
  - *Beauveria bassiana* (1× 1010 cfu/g) 0.1%
  - *Verticillium leccani* (1× 1010 cfu/g) 0.1%
  - Control

  The results for *Bemisia tabaci* were as follow.

Treatment	No. of whiteflies/ 3 leaves					
	Summer			Kharif		
	Pooled over periods		Pooled over periods and sprays	Pooled over periods		Pooled over periods and sprays
	First spray	Second spray		First spray	Second spray	
T1	1.72^{a}	1.60^{a}	1.66^{a}	0.23^{a}	0.18^{a}	0.21^{a}
T2	2.10^{b}	1.95^{ab}	2.02^{bc}	0.34^{de}	0.30^{ef}	0.32^{ef}
T3	1.88^{ab}	1.71^{ab}	1.80^{ab}	0.26^{ab}	0.22^{b}	0.24^{b}
T4	2.14^{b}	1.99^{b}	2.06^{c}	0.36^{e}	0.32^{f}	0.34^{f}
T5	2.06^{b}	1.93^{ab}	2.00^{bc}	0.33^{de}	0.27^{de}	0.30^{de}
T6	2.02^{ab}	1.92^{ab}	1.97^{bc}	0.31^{cd}	0.26^{cd}	0.28^{cd}
T7	2.12^{b}	1.97^{ab}	2.04^{c}	0.35^{e}	0.31^{f}	0.33^{ef}
T8	1.96^{ab}	1.80^{ab}	1.88^{bc}	0.29^{bc}	0.23^{bc}	0.26^{bc}
T9	2.54^{c}	2.39^{c}	2.47^{d}	0.46^{f}	0.39^{g}	0.42^{g}

  The results for *Antigastra catalaunalis* were as follow [() = transformed values].

Treatment	No. of larvae/ plant*			Leaf damage (%) **			Flower damage (%) **	Capsule damage (%) **
	Pooled over periods		Pooled over periods and sprays	Pooled over periods		Pooled over periods and sprays	Pooled over periods	Pooled over periods
	First spray	Second spray		First spray	Second spray			
T1	1.49^{a} (1.72)	1.41^{a} (1.49)	1.45^{a} (1.60)	21.01^{a} (12.85)	20.04^{a} (11.74)	20.53^{a} (12.30)	21.07^{a} (12.92)	19.17^{a} (10.78)
T2	1.64^{ab} (2.19)	1.63^{abc} (2.16)	1.63^{abc} (2.16)	22.56^{ab} (14.72)	21.86^{ab} (13.86)	22.21^{abc} (14.29)	22.31^{a} (14.41)	19.86^{ab} (11.54)
T3	1.54^{ab} (1.87)	1.51^{abc} (1.78)	1.53^{ab} (1.84)	22.18^{ab} (14.25)	21.23^{ab} (13.11)	21.70^{abc} (13.67)	22.23^{a} (14.31)	19.55^{ab} (11.20)
T4	1.75^{ab} (2.56)	1.75^{bc} (2.56)	1.75^{bc} (2.56)	23.57^{ab} (15.99)	23.10^{ab} (15.39)	23.33^{bcd} (15.68)	23.32^{a} (15.67)	22.65^{c} (14.83)
T5	1.66^{ab} (2.26)	1.67^{abc} (2.29)	1.66^{abc} (2.26)	22.62^{ab} (14.79)	22.08^{ab} (14.13)	22.35^{abcd} (14.46)	23.19^{a} (15.51)	22.07^{bc} (14.12)
T6	1.84^{b} (2.89)	1.83^{cd} (2.85)	1.83^{c} (2.85)	25.02^{b} (17.89)	24.68^{b} (17.43)	24.85^{d} (17.66)	23.52^{a} (15.93)	23.15^{c} (15.46)
T7	1.53^{a} (1.84)	1.48^{ab} (1.69)	1.50^{a} (1.75)	22.05^{ab} (14.09)	21.06^{ab} (12.91)	21.55^{ab} (13.49)	22.05^{a} (14.09)	19.30^{a} (10.92)
T8	1.79^{ab} (2.70)	1.81^{bcd} (2.78)	1.80^{c} (2.74)	24.30^{ab} (16.93)	23.98^{b} (16.52)	24.14^{cd} (16.73)	23.46^{a} (15.85)	23.07^{c} (15.36)
T9	2.17^{c} (4.20)	2.15^{d} (4.12)	2.16^{d} (4.17)	30.91^{c} (26.39)	32.40^{c} (28.71)	31.66^{e} (27.55)	29.74^{b} (24.61)	29.74^{d} (24.61)

The effects on yield, avoidable losses, and economics were as follow.

Treatment	Summer				Kharif			
	Yield	Yield over control (%)	Avoidable losses (%)	NICBR	Yield	Yield over control (%)	Avoidable losses (%)	NICBR
T1	529.80^{a}	56.65	0.00	1 : 5.93	495.66^{a}	93.27	0.00	1 : 7.90
T2	437.99^{bc}	29.50	17.33	1 : 1.47	426.21^{ab}	66.19	14.01	1 : 3.91
T3	508.09^{ab}	50.23	4.10	1 : 8.50	440.10^{ab}	71.61	11.21	1 : 9.36
T4	409.89^{cd}	21.19	22.63	1 : 2.63	409.24^{ab}	59.57	17.44	1 : 7.87
T5	464.23^{abc}	37.26	12.38	1 : 7.23	418.50^{ab}	63.18	15.57	1 : 9.86
T6	477.43^{abc}	41.16	9.88	1 : 4.11	355.23^{b}	38.51	28.33	1 : 2.33
T7	426.42^{bc}	26.08	19.51	1 : 1.87	441.65^{ab}	72.21	10.90	1 : 6.12
T8	499.63^{abc}	47.73	5.69	1 : 5.08	364.49^{b}	42.12	26.46	1 : 2.74
T9	338.21^{d}	-	36.16	-	256.46^{c}	0.00	48.26	-

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E1.3 Family: Cordycipitaceae Kreisel ex G.H. Sung, J.M. Sung, Hywel-Jones & Spatafora 2007

(Wikipedia, 23 Nov 2020) The **Cordycipitaceae** are a family of parasitic fungi in the Ascomycota, class Sordariomycetes and order Hypocreales. The family was first published in 1969 by mycologist Hanns Kreisel, but the naming was invalid according to the code of International Code of Nomenclature for algae, fungi, and plants. It was validly published in 2007.

The following species have been identified on sesame plants as a biocontrol of sesame insect pests:

- E1.3.1 *Beauveria* spp.
- E1.3.1a *Beauveria bassiana*
- E1.3.2 *Lecanicillium* spp.
- E1.3.2a *Lecanicillium leccani*

E1.3.1 *Beauveria* spp. (14 Sep 2021)

Family: Cordycipitaceae

Definition: The presence on insects in sesame of *Beauveria* spp Vuillemin 1912.

(Wikipedia, 14 Sep 2021) ***Beauveria*** is a genus of asexually-reproducing fungi allied with the ascomycete family Cordycipitaceae. Its several species are typically insect pathogens. The sexual states (teleomorphs) of *Beauveria* species, where known, are species of *Cordyceps*.

Beauveria species are white entomopathogenic fungi. They form unicellular conidia that are typically hydrophobic and very small. The conidia are formed holoblastically from basally inflated conidiogenous cells. After conidium production, the conidiogenous cell elongates before producing another conidium atop a small denticle (a narrow projection bearing a conidium or sporangium). The result is the formation of a distinctive, slender, zig-zag rachis. Colonies of *Beauveria* species are typically white or off-white on artificial culture media.

Species of *Tritirachium* resemble *Beauveria* species in having a zig-zag conidiogenous cells, but differ in lacking conspicuous denticles and in producing yellow-brown to purple colonies.

Beauveria species are commonly found associated with insects or habitats supporting insects, including soil and private dwellings. *B. bassiana*, the most widely known member of this genus, has been developed as a biological pesticide for various insect pests.

E1.3.1a *Beauveria bassiana* (26 Nov 2020)

Family: Cordycipitaceae

Definition: The presence on insects in sesame of *Beauveria bassiana* (Bals.-Criv.) Vuillemin 1912.

(Wikipedia, 26 Nov 2020) ***Beauveria bassiana*** is a fungus that grows naturally in soils throughout the world and acts as a parasite on various arthropod species, causing **white muscardine disease**; it thus belongs to the entomopathogenic fungi. It is being used as a biological insecticide to control a number of pests such as termites, thrips, whiteflies, aphids and different beetles. Its use in the control of bedbugs and malaria-transmitting mosquitos is under investigation.

Grasshoppers killed by *Beauveria bassiana*.
Photo: Wikipedia, 26 Nov 2020

References:

CHINA

- H.M. Miao and H.Y. Liu (2010) reported *Beauveria bassiana* attacked several sesame pests.

INDIA

- H.S. Chaitra et al. (2020) evaluated 9 biopesticides against *Bemisia tabaci* and *Antigastra catalaunalis* using 1 variety (G Til-3) in 2015 at Amand, Gujarat. Two sprays of all treatments were applied on the experimental trial field at 15 days interval. For recording observations on number of nymphs and adults of *Bemisia tabaci*, three leaves (upper, middle and lower) each from five randomly selected plants were examined and for *Antigastra catalaunalis*) leaf, flower and capsule damage was recorded before as well as 3, 7, 10 and 15 days after spraying from five randomly selected plants in each plot. The treatments were as follow.
  - T1: Neem seed kernel extract 5%
  - T2: Azadirachtin 1500 ppm 0.0006%
  - Neem oil 0.3%
  - Mahua oil 0.3%
  - Tobacco decoction 2%
  - *Metarrhizium anisopliae* (1× 1010 cfu/g) 0.1%

- *Beauveria bassiana* (1× 1010 cfu/g) 0.1%
- *Verticillium leccani* (1× 1010 cfu/g) 0.1%
- Control

The results for *Bemisia tabaci* were as follow.

Treatment	No. of whiteflies/ 3 leaves					
	Summer			Kharif		
	Pooled over periods		Pooled over periods and sprays	Pooled over periods		Pooled over periods and sprays
	First spray	Second spray		First spray	Second spray	
T1	1.72^{a}	1.60^{a}	1.66^{a}	0.23^{a}	0.18^{a}	0.21^{a}
T2	2.10^{b}	1.95^{ab}	2.02^{bc}	0.34^{de}	0.30^{ef}	0.32^{ef}
T3	1.88^{ab}	1.71^{ab}	1.80^{ab}	0.26^{ab}	0.22^{b}	0.24^{b}
T4	2.14^{b}	1.99^{b}	2.06^{c}	0.36^{c}	0.32^{f}	0.34^{f}
T5	2.06^{b}	1.93^{ab}	2.00^{bc}	0.33^{de}	0.27^{de}	0.30^{de}
T6	2.02^{ab}	1.92^{ab}	1.97^{bc}	0.31^{cd}	0.26^{cd}	0.28^{cd}
T7	2.12^{b}	1.97^{ab}	2.04^{c}	0.35^{c}	0.31^{f}	0.33^{ef}
T8	1.96^{ab}	1.80^{ab}	1.88^{bc}	0.29^{bc}	0.23^{bc}	0.26^{bc}
T9	2.54^{c}	2.39^{c}	2.47^{d}	0.46^{f}	0.39^{g}	0.42^{g}

The results for *Antigastra catalaunalis* were as follow [() = transformed values].

Treatment	No. of larvae/ plant*			Leaf damage (%) **			Flower damage (%) **	Capsule damage (%) **
	Pooled over periods		Pooled over periods and sprays	Pooled over periods		Pooled over periods and sprays	Pooled over periods	Pooled over periods
	First spray	Second spray		First spray	Second spray			
T1	1.49^{a} (1.72)	1.41^{a} (1.49)	1.45^{a} (1.60)	21.01^{a} (12.85)	20.04^{a} (11.74)	20.53^{a} (12.30)	21.07^{a} (12.92)	19.17^{a} (10.78)
T2	1.64^{ab} (2.19)	1.63^{abc} (2.16)	1.63^{abc} (2.16)	22.56^{ab} (14.72)	21.86^{ab} (13.86)	22.21^{abc} (14.29)	22.31^{a} (14.41)	19.86^{ab} (11.54)
T3	1.54^{ab} (1.87)	1.51^{abc} (1.78)	1.53^{ab} (1.84)	22.18^{ab} (14.25)	21.23^{ab} (13.11)	21.70^{abc} (13.67)	22.23^{a} (14.31)	19.55^{ab} (11.20)
T4	1.75^{ab} (2.56)	1.75^{bc} (2.56)	1.75^{bc} (2.56)	23.57^{ab} (15.99)	23.10^{ab} (15.39)	23.33^{bcd} (15.68)	23.32^{a} (15.67)	22.65^{c} (14.83)
T5	1.66^{ab} (2.26)	1.67^{abc} (2.29)	1.66^{abc} (2.26)	22.62^{ab} (14.79)	22.08^{ab} (14.13)	22.35^{abcd} (14.46)	23.19^{a} (15.51)	22.07^{bc} (14.12)
T6	1.84^{b} (2.89)	1.83^{cd} (2.85)	1.83^{c} (2.85)	25.02^{b} (17.89)	24.68^{b} (17.43)	24.85^{d} (17.66)	23.52^{a} (15.93)	23.15^{c} (15.46)
T7	1.53^{a} (1.84)	1.48^{ab} (1.69)	1.50^{a} (1.75)	22.05^{ab} (14.09)	21.06^{ab} (12.91)	21.55^{ab} (13.49)	22.05^{a} (14.09)	19.30^{a} (10.92)
T8	1.79^{ab} (2.70)	1.81^{bcd} (2.78)	1.80^{c} (2.74)	24.30^{ab} (16.93)	23.98^{b} (16.52)	24.14^{cd} (16.73)	23.46^{a} (15.85)	23.07^{c} (15.36)
T9	2.17^{c} (4.20)	2.15^{d} (4.12)	2.16^{d} (4.17)	30.91^{c} (26.39)	32.40^{c} (28.71)	31.66^{e} (27.55)	29.74^{b} (24.61)	29.74^{d} (24.61)

The effects on yield , avoidable losses, and economics were as follow.

Treatment	Summer				Kharif			
	Yield	Yield over control (%)	Avoidable losses (%)	NICBR	Yield	Yield over control (%)	Avoidable losses (%)	NICBR
T1	529.80^{a}	56.65	0.00	1 : 5.93	495.66^{a}	93.27	0.00	1 : 7.90
T2	437.99^{bc}	29.50	17.33	1 : 1.47	426.21^{ab}	66.19	14.01	1 : 3.91
T3	508.09^{ab}	50.23	4.10	1 : 8.50	440.10^{ab}	71.61	11.21	1 : 9.36
T4	409.89^{cd}	21.19	22.63	1 : 2.63	409.24^{ab}	59.57	17.44	1 : 7.87
T5	464.23^{abc}	37.26	12.38	1 : 7.23	418.50^{ab}	63.18	15.57	1 : 9.86
T6	477.43^{abc}	41.16	9.88	1 : 4.11	355.23^{b}	38.51	28.33	1 : 2.33
T7	426.42^{bc}	26.08	19.51	1 : 1.87	441.65^{ab}	72.21	10.90	1 : 6.12
T8	499.63^{abc}	47.73	5.69	1 : 5.08	364.49^{b}	42.12	26.46	1 : 2.74
T9	338.21^{d}	-	36.16	-	256.46^{c}	0.00	48.26	-

E1.3.2 *Lecanicillium* spp. (14 Sep 2021)

Family: Cordycipitaceae

Definition: The presence on insects in sesame of *Lecanicillium* spp. W. Gams & Zare 2001.

(Wikipedia, 14 Sep 2021) ***Lecanicillium*** is a genus of fungi in the order Hypocreales and is described as anamorphic Cordycipitaceae; 21 species are currently described. Some of these entomopathogenic fungus species were

previously widely known as *Verticillium lecanii* (Zimmerman) Viegas. This genus was first named and introduced by Rasoul Zare (IRIPP) and Walter Gams (CBS).

E1.3.2a *Lecanicillium leccani* (27 Nov 2020)

Synonym: *Verticillium leccani*

Family: Cordycipitaceae

Definition: The presence on insects in sesame of *Lecanicillium leccani* R. Zare & W. Gams 2001.

(Wikipedia, 27 Nov 2020) ***Lecanicillium lecanii*** is now an approved name of an entomopathogenic fungus species, that was previously widely known as *Verticillium lecanii* (Zimmerman) Viegas), but is now understood to be an anamorphic form in the *Cordyceps* group of genera in the Clavicipitaceae. Isolates formerly classified as *V. lecanii* could be *L. attenuatum, L. lecanii, L. longisporum, L. muscarium* or *L. nodulosum*. For example, several recent papers, such as Kouvelis *et al.* who carried out mitochondrial DNA studies, refer to the name *L. muscarium*.

L. lecanii itself appears primarily to be a pathogen of soft scale insects (Coccidae).

This fungus was first described in 1861 and has a worldwide distribution. Insects are infected when they come into contact with the sticky fungal spores which then grow and invade the body, thus the internal organs are consumed, leading to their death. In horticulture and agriculture, "*V. lecanii*" isolates were developed for controlling insect pests such as whitefly, thrips and aphids, by RA Hall and HD Burges (scientists at the Glasshouse Crops Research Institute, now Warwick HRI: formerly part of Horticulture Research International). Biological pesticides based on *Lecanicillium* spp. are now marketed as 'Mycotal' (now *L. muscarium*) and 'Vertalec' (now *L. longisporum*) by Koppert in the Netherlands (who provide good illustrations of the fungus). Other products based on these fungi have been developed elsewhere for use in cash crops, oil seeds, soybeans, ornamentals and vegetables.

Lecanicillium leccani on aphids
Photo: sciencesource.com, 27 Nov 2020

References:

INDIA

- H.S. Chaitra et al. (2020) evaluated 9 biopesticides against *Bemisia tabaci* and *Antigastra catalaunalis* using 1 variety (G Til-3) in 2015 at Amand, Gujarat. Two sprays of all treatments were applied on the experimental trial field at 15 days interval. For recording observations on number of nymphs and adults of *Bemisia tabaci*, three leaves (upper, middle and lower) each from five randomly selected plants were examined and for *Antigastra catalaunalis*) leaf, flower and capsule damage was recorded before as well as 3, 7, 10 and 15 days after spraying from five randomly selected plants in each plot. The treatments were as follow.
  - T1: Neem seed kernel extract 5%
  - T2: Azadirachtin 1500 ppm 0.0006%
  - Neem oil 0.3%
  - Mahua oil 0.3%
  - Tobacco decoction 2%
  - *Metarrhizium anisopliae* (1× 1010 cfu/g) 0.1%
  - *Beauveria bassiana* (1× 1010 cfu/g) 0.1%
  - *Verticillium leccani* (1× 1010 cfu/g) 0.1%
  - Control

  The results for *Bemisia tabaci* were as follow.

Treatment	No. of whiteflies/ 3 leaves					
	Summer			Kharif		
	Pooled over periods		Pooled over periods and sprays	Pooled over periods		Pooled over periods and sprays
	First spray	Second spray		First spray	Second spray	
T1	1.72^{a}	1.60^{a}	1.66^{a}	0.23^{a}	0.18^{a}	0.21^{a}
T2	2.10^{b}	1.95^{ab}	2.02^{bc}	0.34^{de}	0.30^{ef}	0.32^{ef}
T3	1.88^{ab}	1.71^{ab}	1.80^{ab}	0.26^{ab}	0.22^{b}	0.24^{b}
T4	2.14^{b}	1.99^{b}	2.06^{c}	0.36^{e}	0.32^{f}	0.34^{f}
T5	2.06^{b}	1.93^{ab}	2.00^{bc}	0.33^{de}	0.27^{de}	0.30^{de}
T6	2.02^{ab}	1.92^{ab}	1.97^{bc}	0.31^{cd}	0.26^{cd}	0.28^{cd}
T7	2.12^{b}	1.97^{ab}	2.04^{c}	0.35^{e}	0.31^{f}	0.33^{ef}
T8	1.96^{ab}	1.80^{ab}	1.88^{bc}	0.29^{bc}	0.23^{bc}	0.26^{bc}
T9	2.54^{c}	2.39^{c}	2.47^{d}	0.46^{f}	0.39^{g}	0.42^{g}

The results for *Antigastra catalaunalis* were as follow [() = transformed values].

Treatment	No. of larvae/ plant*			Leaf damage (%) **			Flower damage (%) **	Capsule damage (%) **
	Pooled over periods		Pooled over periods and sprays	Pooled over periods		Pooled over periods and sprays	Pooled over periods	Pooled over periods
	First spray	Second spray		First spray	Second spray			
T1	1.49^{a} (1.72)	1.41^{a} (1.49)	1.45^{a} (1.60)	21.01^{a} (12.85)	20.04^{a} (11.74)	20.53^{a} (12.30)	21.07^{a} (12.92)	19.17^{a} (10.78)
T2	1.64^{ab} (2.19)	1.63^{abc} (2.16)	1.63^{abc} (2.16)	22.56^{ab} (14.72)	21.86^{ab} (13.86)	22.21^{abc} (14.29)	22.31^{a} (14.41)	19.86^{ab} (11.54)
T3	1.54^{ab} (1.87)	1.51^{abc} (1.78)	1.53^{ab} (1.84)	22.18^{ab} (14.25)	21.23^{ab} (13.11)	21.70^{abc} (13.67)	22.23^{a} (14.31)	19.55^{ab} (11.20)
T4	1.75^{ab} (2.56)	1.75^{bc} (2.56)	1.75^{bc} (2.56)	23.57^{ab} (15.99)	23.10^{ab} (15.39)	23.33^{bcd} (15.68)	23.32^{a} (15.67)	22.65^{c} (14.83)
T5	1.66^{ab} (2.26)	1.67^{abc} (2.29)	1.66^{abc} (2.26)	22.62^{ab} (14.79)	22.08^{ab} (14.13)	22.35^{abcd} (14.46)	23.19^{a} (15.51)	22.07^{bc} (14.12)
T6	1.84^{b} (2.89)	1.83^{cd} (2.85)	1.83^{c} (2.85)	25.02^{b} (17.89)	24.68^{b} (17.43)	24.85^{d} (17.66)	23.52^{a} (15.93)	23.15^{c} (15.46)
T7	1.53^{a} (1.84)	1.48^{ab} (1.69)	1.50^{a} (1.75)	22.05^{ab} (14.09)	21.06^{ab} (12.91)	21.55^{ab} (13.49)	22.05^{a} (14.09)	19.30^{a} (10.92)
T8	1.79^{ab} (2.70)	1.81^{bcd} (2.78)	1.80^{c} (2.74)	24.30^{ab} (16.93)	23.98^{b} (16.52)	24.14^{cd} (16.73)	23.46^{a} (15.85)	23.07^{c} (15.36)
T9	2.17^{c} (4.20)	2.15^{d} (4.12)	2.16^{d} (4.17)	30.91^{c} (26.39)	32.40^{c} (28.71)	31.66^{e} (27.55)	29.74^{b} (24.61)	29.74^{d} (24.61)

The effects on yield, avoidable losses, and economics were as follow.

Treatment	Summer				Kharif			
	Yield	Yield over control (%)	Avoidable losses (%)	NICBR	Yield	Yield over control (%)	Avoidable losses (%)	NICBR
T1	529.80^{a}	56.65	0.00	1 : 5.93	495.66^{a}	93.27	0.00	1 : 7.90
T2	437.99^{bc}	29.50	17.33	1 : 1.47	426.21^{ab}	66.19	14.01	1 : 3.91
T3	508.09^{ab}	50.23	4.10	1 : 8.50	440.10^{ab}	71.61	11.21	1 : 9.36
T4	409.89^{cd}	21.19	22.63	1 : 2.63	409.24^{ab}	59.57	17.44	1 : 7.87
T5	464.23^{abc}	37.26	12.38	1 : 7.23	418.50^{ab}	63.18	15.57	1 : 9.86
T6	477.43^{abc}	41.16	9.88	1 : 4.11	355.23^{b}	38.51	28.33	1 : 2.33
T7	426.42^{bc}	26.08	19.51	1 : 1.87	441.65^{ab}	72.21	10.90	1 : 6.12
T8	499.63^{abc}	47.73	5.69	1 : 5.08	364.49^{b}	42.12	26.46	1 : 2.74
T9	338.21^{d}	-	36.16	-	256.46^{c}	0.00	48.26	-

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E2 Order: Eurotiales G.W. Martin ex Benny& Kimbr 1980

(Wikipedia, 17 Apr 2021) The **Eurotiales** are an order of sac fungi, also known as the green and blue molds. The order contains three families, 49 genera, and 928 species. It was circumscribed in 1980.

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E2.1 Family: Trichocomaceae E. Fisch. 1897

(Wikipedia, 17 Apr 2021) The **Trichocomaceae** are a family of fungi in the order Eurotiales. Taxa are saprobes with aggressive colonization strategies, adaptable to extreme environmental conditions. Family members are cosmopolitan in distribution, ubiquitous in soil, and common associates of decaying plant and food material. The family contains some of the most familiar fungi, such as *Penicillium* and *Aspergillus*. It has been proposed that the family should be split into the three families Aspergillaceae, Thermoascaceae and Trichocomaceae.

The following species have been identified to provide biocontrol:

- E2.1.1 *Penicillium* spp.
- E2.1.1a *Penicillium bilaiae*
- E2.1.1b *Penicillium aurantiogriseum*
- E2.1.1c *Penicillium chrysogenum*
- E2.1.1d *Penicillium crustosum*
- E2.1.2 *Aspergillus* spp.
- E2.1.2a *Aspergillus niger*
- E2.1.2b *Aspergillus fumigatus*
- E2.1.2c *Aspergillus clavatus*
- E2.1.2d *Aspergillus terreus*
- E2.1.2e *Aspergillus sydowii*
- E2.1.2f *Aspergillus nidulans* (*Syn: *Emericella nidulans*)
- E2.1.2g *Aspergillus flavus*
- E2.1.3 *Cordyceps spp.*
- E2.1.3a *Cordyceps fumosorosea* (*Isaria fumosorosea*)
- E2.1.4 *Talaromyces* spp.
- E2.1.4a *Talaromyces pinophilus*

There are species in this family associated with sesame, but not reported to cause diseases, produce a toxin, inhibit germination, or affect seed quality. See H11.1.

There are species in this family that cause a disease, produce a toxin, inhibit germination, or affect seed quality. See A13.1.

E2.1.1 *Penicillium* spp. (22 Apr 2021)

There are *Penicillium* spp. that affect seed quality (A13.1.2) while other species have been proposed as biocontrols (E2.1.1). *Penicillium spp.* have been reported to occur from the field in Bangladesh, Cuba, Egypt, India, Iran, Iraq, Nigeria, Pakistan, Paraguay, Saudi Arabia, Sierra Leone, and Venezuela.

Family: Trichocomaceae

Definition: Amount of biocontrol provided by *Penicillium* spp. Link, 1809.

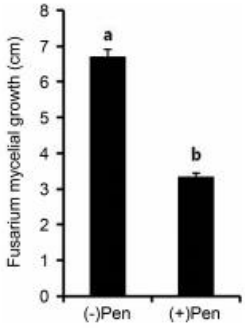
(Wikipedia, 22 Apr 2021) ***Penicillium*** is a genus of ascomycetous fungi that is part of the mycobiome of many species and is of major importance in the natural environment, in food spoilage, and in food and drug production.

Some members of the genus produce penicillin, a molecule that is used as an antibiotic, which kills or stops the growth of certain kinds of bacteria. Other species are used in cheesemaking. According to the *Dictionary of the Fungi* (10th edition, 2008), the widespread genus contains over 300 species.

References:

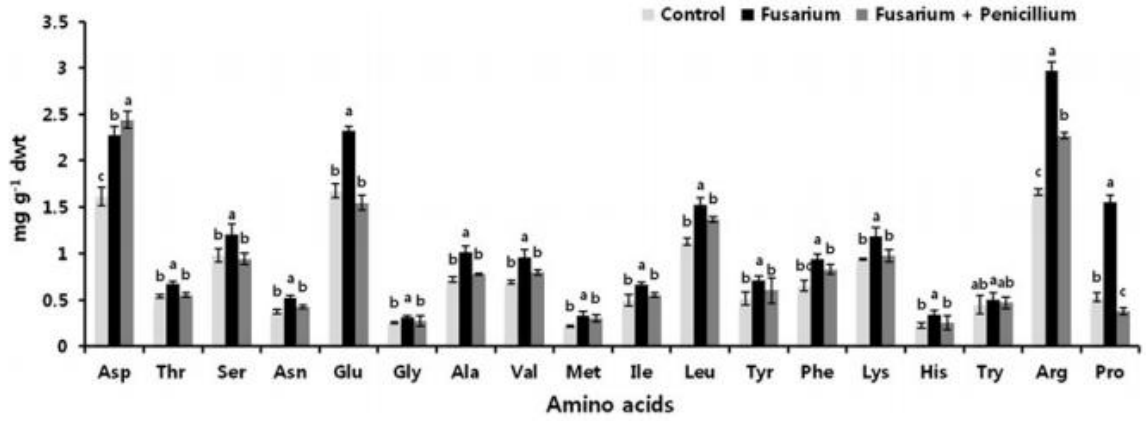
REPUBLIC OF KOREA

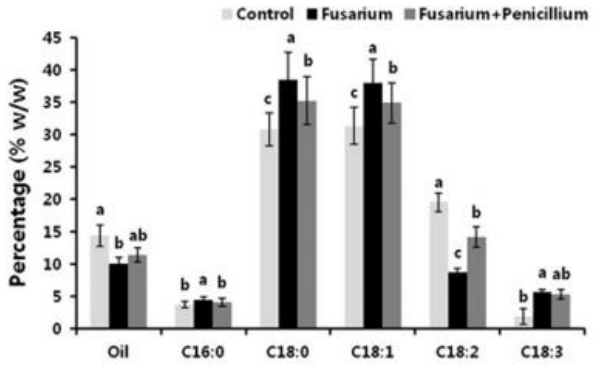
- R. Radhakrishnan et al. (2013a) reported *Penicillium* sp. is a potent plant growth promoting fungus that has the ability to ameliorate damage caused by *Fusarium* infection in sesame cultivation. The *in vitro* biocontrol activity of *Penicillium* sp. against *Fusarium* sp. was exhibited by a 49% inhibition of mycelial growth in a dual culture bioassay and by hyphal injuries as observed by scanning electron microscopy.



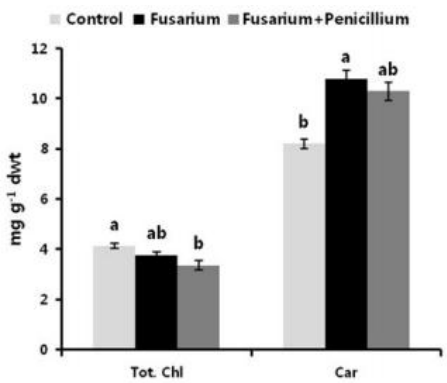
In addition, greenhouse experiments revealed that *Fusarium* inhibited growth in sesame plants by damaging lipid membranes and reducing protein content. Co-cultivation with *Penicillium* sp. mitigated *Fusarium*-induced oxidative stress in sesame plants by limiting membrane lipid peroxidation, and by increasing the protein concentration, levels of antioxidants such as total polyphenols, and peroxidase and polyphenoloxidase activities.

- R. Radhakrishnan et al. (2013b) studied the differences in amino acids and fatty acids between a control, Fusarium and Fusarium + Penicillium. Compared with healthy plants, *Fusarium*-infected plants accumulated higher concentrations of free amino acids, fatty acids, carotenoids, γ-Aminobutyric acid (GABA), and some lignans, and showed decreased concentrations of oil and chlorophyll. Furthermore, *Penicillium* treatment mitigated the *Fusarium*-induced changes in amino acids, fatty acids, carotenoids, and secondary metabolite contents in infected plants. The results were as follow.

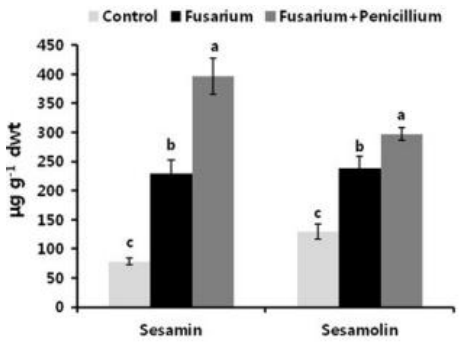




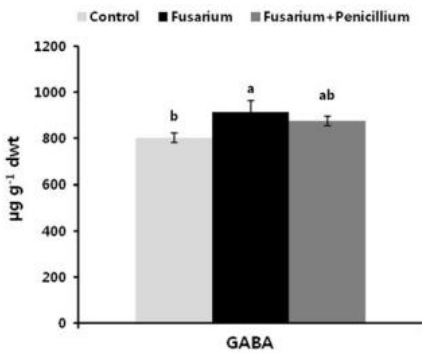
Fatty acid content



Chlorophyll and carotene content

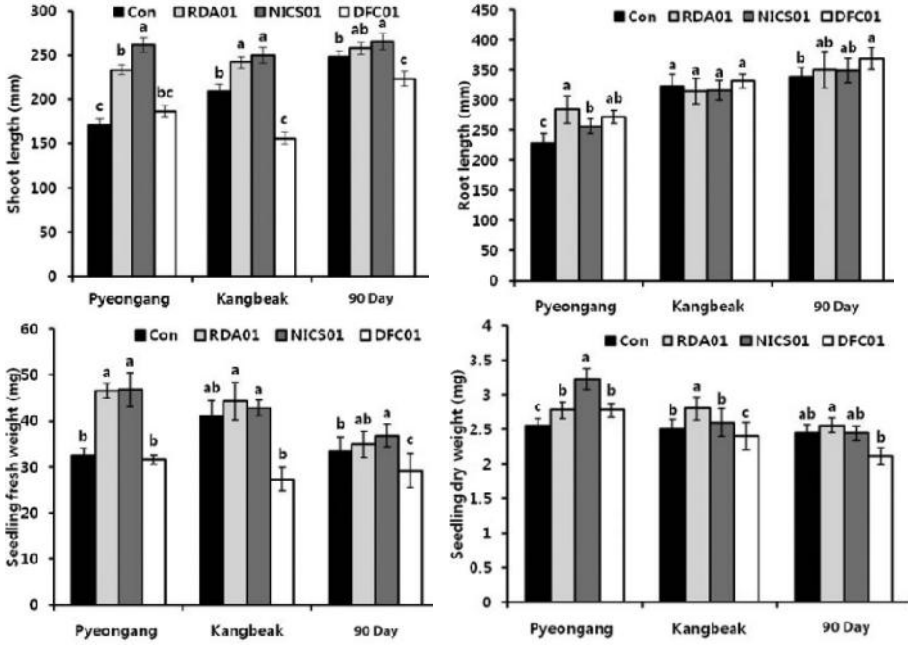


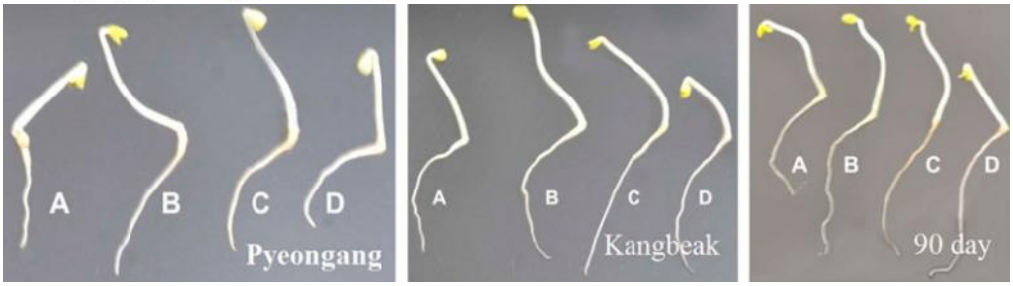
Sesamin and sesamolin content



γ-Aminobutyric acid (GABA)

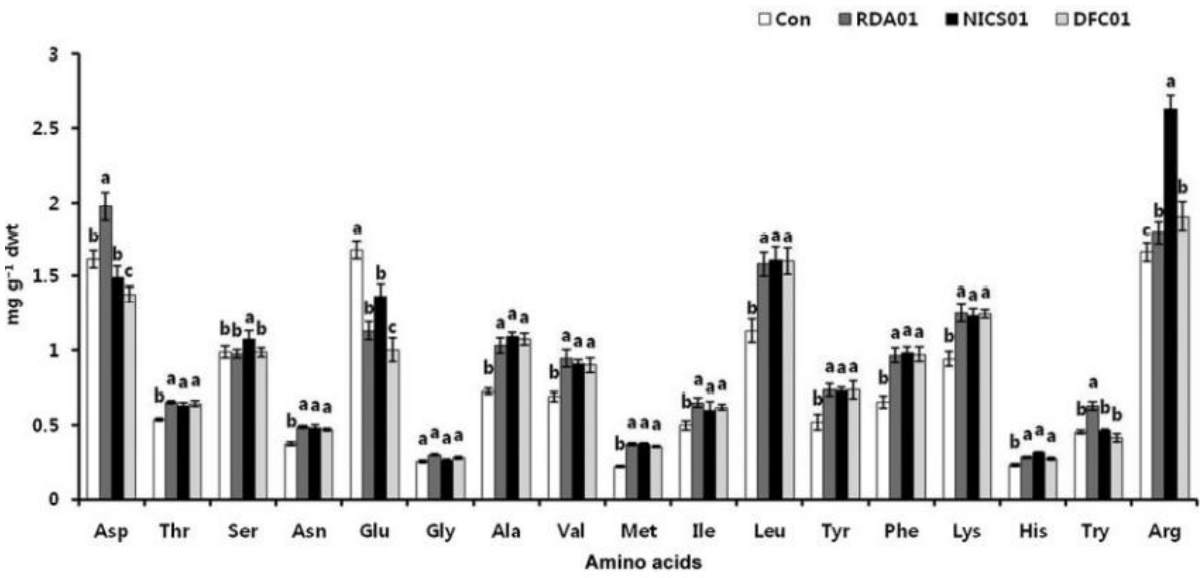
- R. Radhakrishnan et al. (2014b) evaluated the effects of 3 Penicillium species (RDA01, NICS01, and DFC01) on 3 cultivars (Pyeongang, Kangbaek, and 90 Day). They determined the differences in germination, amino acids, chlorophylls, amino acids, and lignans. They also studied the effects of salt stress and *Fusarium* sp. The germination results were as follow.



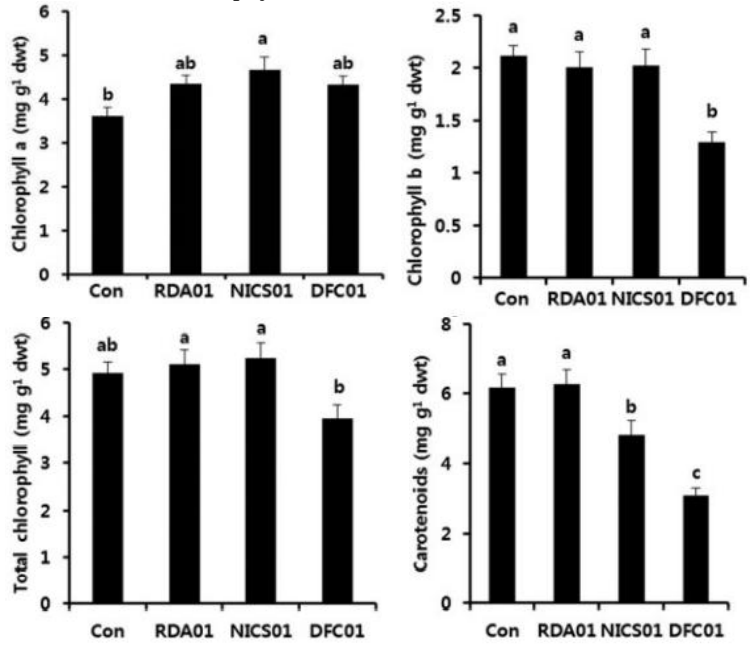


A = Control, B = RDA01, C = NIC501, and D = DFC01

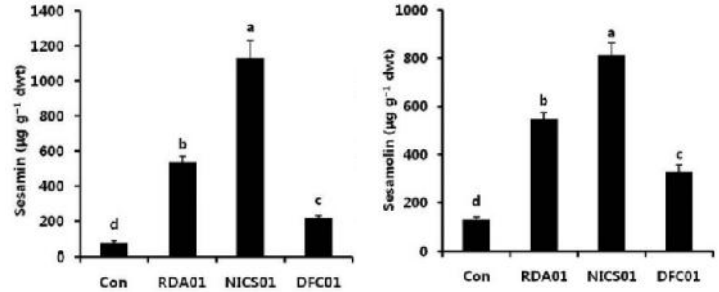
The following were the amino acids produced.



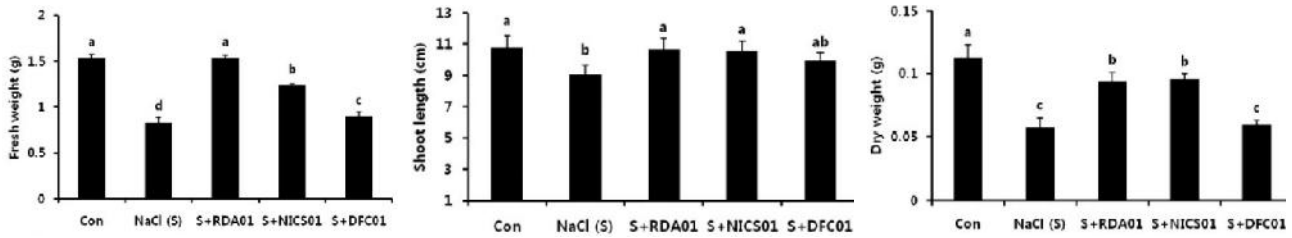
The effects on chlorophyll and carotenoids were as follow.



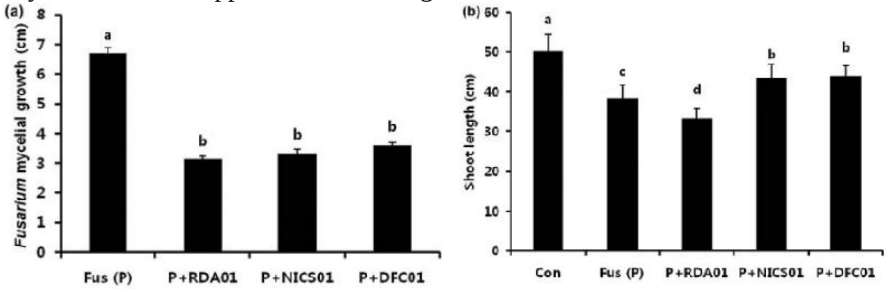
The effects on sesamin and sesamolin were as follow.



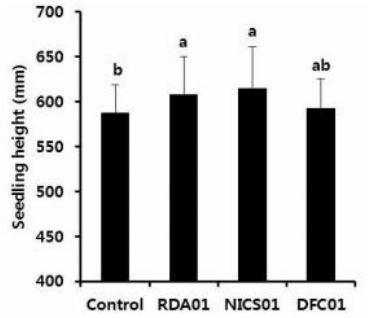
The fungi-pretreated seeds were placed in autoclaved Baroker soil and distilled water was applied at regular intervals. After 15 days, uniformly sized seedlings were transplanted into pots containing sterilized Baroker soil. The 45-day-old sesame plants were treated with 150 mM NaCl for salinity stress. The aerial parts of the plants were harvested, and shoot length and fresh and dry shoot weights were measured at 50 days. The effects when salt stress was added were as follow.



Seven-day-old RDA01, NICS01, DFC01 and *Fusarium* sp. cultures in PDB broth were applied to a 4-mm disc placed on the opposite side of Petri dishes containing potato dextrose agar (PDA) medium. The Petri dishes were incubated for 14 days at 28 ± 2°C and *Fusarium* mycelium growth was measured. The surface-sterilized seeds were sown in pots containing RDA01-, NICS01-, and DFC01-treated Baroker soil in a greenhouse. Fusarium culture was applied to the Penicillium-inoculated plants at 50 days. Shoot length was measured 15 days after the first appearance of wilting. The results were as follow.

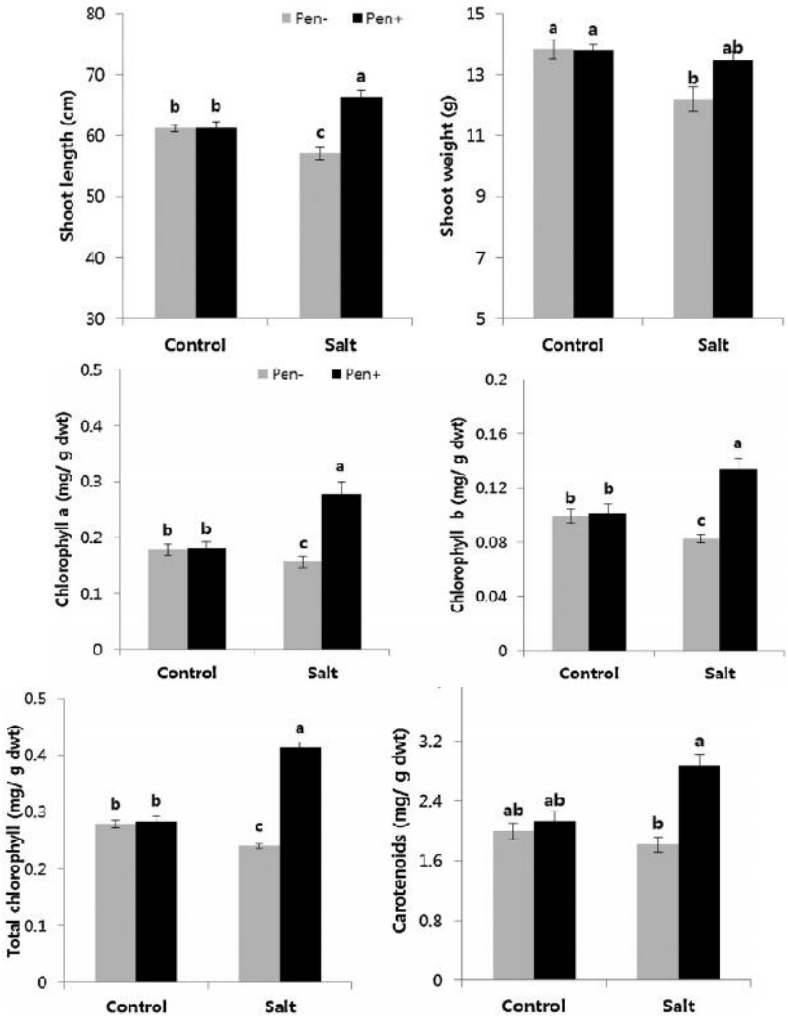


- R. Radhakrishnan et al. (2014c) evaluated the effects of *Penicillium* spp. on the growth of sesame seedlings using 3 isolates with the following results.



The individual treatment of *Penicillium* spp. RDA01 and NICS01 on sesame seeds showed higher seedling growth than DFC01 fungi treated and untreated controls. Amino acid analysis in sesame roots revealed that aspartic acid, threonine, serine, alanine, valine, methionine, isoleucine, leucine, tyrosine, phenylalanine, histidine, lysine, arginine and gamma-aminobutyric acid increased, while asparagine, glutamine and glycine were decreased by association with RDA01 and NICS01.

- R. Radhakrishnan and I.J. Lee (2015) evaluated the effects of *Penicillium* spp. against salinity. Salt stress decreased the length and weight of sesame shoots but applying *Penicillium* sp. NICS01 significantly ($p \leq 0.05$) increased these parameters in plants grown under salt-stress conditions by enhancing photosynthetic pigment levels (chlorophylls and carotenoids), sugar concentrations (sucrose, glucose, and fructose), fatty acid contents (palmitic acid, linolenic acid, arachidic acid, and cis-11-eicosenoic acid), and ionic transport (K and Ca, ($p \leq 0.05$)). In addition, salt-induced oxidative damage was reduced by lowered lipid peroxidation (5%) and salicylic acid (15%) and Na (18%) contents and raised peroxidase activity (more than five-fold), while amino acid (Thr, Gly, Val, Met, Ile, Leu, Tyr, Phe, Arg, Asp, Ser, Asn, Glu, Ala, and GABA) synthesis was regulated by the fungal interaction. Asp, Thr, Ser, Glu, Ala, and Arg contents were significantly ($p \leq 0.05$) enhanced in salinity affected plants due to the effect of fungal inoculation. Our findings revealed that *Penicillium* sp. NICS01 regulates the biosynthesis of primary and defense metabolites in sesame plants under salt stress, suggesting that this fungus can ameliorate damage caused by salt stress in crop plants.



E2.1.1a *Penicillium bilaiae* (17 Apr 2021)

Family: Trichocomaceae

Definition: Amount of biocontrol provided by *Penicillium bilaiae* Chalabuda 1950.

(Wikipedia, 17 Apr 2021) ***Penicillium bilaiae*** is a species of native soil fungus that can be used as a PGPM (plant growth-promoting microorganism). R. Kucey first identified that organic acids excreted by the microorganism can solubilize soil-bound phosphate. The organism can live in symbiosis with several plant species by enhancing phosphate uptake by the root structure while feeding off plant waste products. Native soil populations are often low and can be increased by application as an agricultural inoculant.

References:

CHINA

- X.B. Zhao et al. (2021a) studied the effects of *Penicillium bilaiae* on *Fusarium oxysporum.* Isolate 47M-1 was isolated from rhizosphere soil samples of tobacco and identified as Penicillium bilaiae. Isolate 47M-1 inhibited the mycelial growth of F. oxysporum by 81.3% and overgrew the colonies of F. oxysporum in co-cultures. In a potting test, the control efficiency of isolate 47M-1 against Fusarium wilt of sesame was 50%, which was superior to that of Bacillus subtilis ($P = 0.022$). There was no significant difference ($P = 0.068$) in the control of Fusarium wilt between treatment with the fungicide carbendazim and treatment with isolate 47M-1. The results also showed that isolate 47M-1 and its culture filtrate significantly promoted the growth of sesame. In

conclusion, isolate 47M-1 can control Fusarium wilt of sesame via multiple mechanisms, including competition, production of inhibitory substances, promotion of plant growth and induction of disease resistance. [Based on abstract]

E2.1.1b *Penicillium aurantiogriseum* (10 Jul 2021)

Family: Trichocomaceae

Definition: Amount of biocontrol provided by *Penicillium aurantiogriseum* Dierckx 1901.

(Wikipedia, 10 Jul 2021) ***Penicillium aurantiogriseum*** is a plant pathogen infecting asparagus and strawberry. Chemical compounds isolated from Penicillium aurantiogriseum include anicequol and auranthine.

References:

CHINA

- X.B. Zhao et al. (2021b) studied the effects of *Penicillium aurantiogriseum* on *Fusarium oxysporum.* Isolate 44M-3 secreted extracellular enzymes such as protease, cellulase, and β-1,3-glucanase on agar plates. Treatment with a spore suspension of isolate 44M-3 significantly reduced the incidence of Sesame Fusarium wilt ($P = 0.036$) in pot experiments, achieving a maximum control efficacy of 75.88%, which did not differ significantly from carbendazim treatment ($P = 0.292$). Treatment with isolate 44M-3 spore suspension increased the dry weight of whole sesame plants, likely due to the isolate's ability to dissolve insoluble inorganic phosphorus and secrete siderophores and indole acetic acid. Consequently, isolate 44M-3 provides a promising candidate for plant growth promotion and prevention of sesame Fusarium wilt disease. [Based on abstract]

E2.1.1c *Penicillium chrysogenum* (17 Jul 2021)

Penicillium chrysogenum affects seed quality (A13.1.2i) and has been proposed as a biocontrol (E2.1.1c). *Penicillium chrysogenum* has been reported to occur from the field in Egypt, India, and Iran.

Family: Trichocomaceae

Definition: Amount of biocontrol provided by *Penicillium chrysogenum* Thom 1910.

(Wikipedia, 17 Jul 2021) ***Penicillium chrysogenum*** is a species of fungus in the genus *Penicillium*. It is common in temperate and subtropical regions and can be found on salted food products, but it is mostly found in indoor environments, especially in damp or water-damaged buildings. It has been recognized as a species complex that includes *P. notatum*, *P. meleagrinum*, and *P. cyaneofulvum*, but molecular phylogeny established that it is a distinct species and that *P. notatum* (its popular synonym) is *P. rubens.* It has rarely been reported as a cause of human disease. It is the source of several β-lactam antibiotics, most significantly penicillin. Other secondary metabolites of *P. chrysogenum* include roquefortine C, meleagrin, chrysogine, 6-MSA YWA1/melanin, andrastatin A, fungisporin, secalonic acids, sorbicillin, and PR-toxin.

Like the many other species of the genus *Penicillium*, *P. chrysogenum* usually reproduces by forming dry chains of spores (or conidia) from brush-shaped conidiophores. The conidia are typically carried by air currents to new colonization sites. In *P. chrysogenum*, the conidia are blue to blue-green, and the mold sometimes exudes a yellow pigment. However, *P. chrysogenum* cannot be identified based on color alone. Observations of morphology and microscopic features are needed to confirm its identity and DNA sequencing is essential to distinguish it from closely related species such as *P. rubens*. The sexual stage of *P. chrysogenum* was discovered in 2013 by mating cultures in the dark on oatmeal agar supplemented with biotin, after the mating types (MAT1-1 or MAT1-2) of the strains had been determined using PCR amplification.

The airborne asexual spores of *P. chrysogenum* are important human allergens. Vacuolar and alkaline serine proteases have been implicated as the major allergenic proteins.

P. chrysogenum has been used industrially to produce penicillin and xanthocillin X, to treat pulp mill waste, and to produce the enzymes polyamine oxidase, phosphogluconate dehydrogenase, and glucose oxidase.

References:

EGYPT

- M.G.A. Hegazy et al. (2019) evaluated the effects of biocontrols (*Alternaria alternate, Aspergillus* spp. and *Penicillium* spp.) on *Fusarium oxysporum* f. sp. *sesami* with the following results.

Isolate No.	Endophytic fungi isolate	Average of inhibition zone diameter (mm)
1	*Alternaria alternate*	1.5 ^{ef}
2	*Aspergillus clavatus*	9.2 ^{b}
3	*Aspergillus fumigatus*	0.8 ^{ef}
4	*Aspergillus niger*	11.6 ^{a}
5	*Aspergillus sydowii*	1.3 ^{ef}
6	*Aspergillus terreus* $_{(1)}$	2.3 ^{e}
7	*Aspergillus terreus* $_{(2)}$	5.9 ^{cd}
8	*Penicillium chrysogenum* $_{(1)}$	9.2 ^{b}
9	*Penicillium chrysogenum* $_{(2)}$	2.3 ^{e}
10	*Penicillium crustosum* $_{(1)}$	7.1 ^{bc}
11	*Penicillium crustosum* $_{(2)}$	8.2 ^{b}
12	*Penicillium crustosum* $_{(3)}$	2.8 ^{e}
13	Control	0.0 ^{f}

Means followed by the same letters (s) in a column are not significantly different at ($p \leq 0.05$) according to Duncan's multiple-range test.

The species with the highest levels of inhibition were further tested using different concentrations.

Endophytic fungi	Concentration (%)	Average of colony diameter (mm)	Inhibition (%)
Aspergillus niger	1	73.30	18.55 ^{i}
	2	69.30	23.00 ^{ghi}
	5	63.30	29.66 ^{fgh}
	10	57.00	36.66 ^{ef}
	20	45.00	50.00 ^{d}
Aspergillus terreus $_{(1)}$	1	68.30	24.11 ^{ghi}
	2	55.00	38.88 ^{e}
	5	45.00	50.00 ^{d}
	10	36.60	59.33 ^{bc}
	20	26.60	70.44 ^{a}
Aspergillus terreus $_{(2)}$	1	73.30	18.55 ^{i}
	2	65.30	27.44 ^{gh}
	5	56.60	37.11 ^{ef}
	10	43.30	51.88 ^{cd}
	20	33.30	63.00 ^{ab}
Penicillium chrysogenum $_{(1)}$	1	75.00	16.66 ^{i}
	2	70.00	22.22 ^{hi}
	5	62.00	31.11 ^{efgh}
	10	55.00	38.88 ^{e}
	20	44.00	51.11 ^{cd}
Control		90.00	00.00 ^{j}

Means followed by the same letters (s) in a column are not significantly different at ($p \leq 0.05$) according to Duncan's multiple-range test.

The species were then used in the greenhouse with the following results.

Treatments	Disease Severity (%)	Plant growth parameters					
		Shoot			Root		Number of bods
		Plant height (cm)	Fresh weight (g)	Dry weight (g)	Fresh weight (g)	Dry weight (g)	
Aspergillus niger	36 ^{c}	73 ^{ab}	11.8 ^{b}	3.66 ^{b}	3.33 ^{c}	1.3 ^{c}	10 ^{c}
Aspergillus terreus $_{(1)}$	41 ^{bc}	83 ^{b}	19 ^{a}	4.66 ^{a}	7.83 ^{a}	3.43 ^{a}	16 ^{a}
Aspergillus terreus $_{(2)}$	52 ^{b}	96 ^{a}	10.3 ^{bc}	3 ^{c}	7.6 ^{a}	2.66 ^{b}	11 ^{b}
Penicillium chrysogenum $_{(1)}$	38.6 ^{bc}	85 ^{b}	10.6 ^{bc}	2.2 ^{d}	6.66 ^{ab}	1.46 ^{c}	10 ^{c}
Control (untreated)	94.3 ^{a}	56 ^{c}	9.6 ^{c}	2 ^{c}	4 ^{b}	1.16 ^{c}	9 ^{d}

Means followed by the same letters (s) in a column are not significantly different at ($p \leq 0.05$) according to Duncan's multiple-range test.

The species were then compared to using *Trichoderma* spp. alone or in combination with the following results.

Treatments	Disease Severity (%)	Growth parameters					
		Shoot			Root		Number of bods
		Shoot height (cm)	Fresh weight (g)	Dry weight (g)	Fresh weight (g)	Dry weight (g)	
A. niger + *Trichoderma* sp.	16 ^{c}	91.3 ^{b}	24.6 ^{c}	9.6 ^{b}	14.6 ^{b}	7.1 ^{b}	8 ^{c}
A. terreus $_{(1)}$ + *Trichoderma* sp.	25.3 ^{bc}	84 ^{c}	27 ^{b}	8.5 ^{c}	15.3 ^{b}	5.6 ^{c}	12 ^{b}
A. terreus $_{(2)}$ + *Trichoderma* sp.	46.6 ^{a}	84 ^{c}	27.5 ^{b}	7.6 ^{d}	13 c	5.4 ^{c}	6 ^{d}
P. chrysogenum $_{(1)}$ + *Trichoderma* sp.	36 ^{ab}	80 ^{d}	17.5 ^{d}	6 ^{e}	9.3 ^{d}	3.5 ^{d}	13 ^{a}
Control (*Trichoderma* sp. only)	13.3 ^{c}	98 ^{a}	42.3 ^{a}	12.6 ^{a}	25.6 ^{a}	14.3 ^{a}	12 ^{b}

E2.1.1d *Penicillium crustosum* (17 Jul 2021)

Penicillium crustosum affects seed quality (A13.1.2g) and has been proposed as a biocontrol (E2.1.1d). *Penicillium crustosum* has been reported to occur from the field in Egypt.

Family: Trichocomaceae

Definition: Amount of biocontrol provided by *Penicillium crustosum* Thom 1930.

(Wikipedia, 17 Jul 2021) ***Penicillium crustosum*** is a blue-green or blue-grey mold that can cause food spoilage, particularly of protein-rich foods such as meats and cheeses. It is identified by its complex biseriate conidiophores on which phialides produce asexual spores. It can grow at fairly low temperatures (it is a psychrophile), and in low water activity environments.

Penicillium crustosum produces mycotoxins, most notoriously the neurotoxic penitrems, including the best known penitrem toxin, penitrem A, and including penitrems A through G. Penitrem G has been shown to have insecticidal activity. In addition, *P. crustosum* can produce thomitrems A and E, and roquefortine C. Consumption of foods spoiled by this mold can cause transient neurological symptoms such as tremors. In dogs, symptoms can include vomiting, convulsion, tremors, ataxia, and tachycardia.

References:

EGYPT

- M.G.A. Hegazy et al. (2019) evaluated the effects of biocontrols (*Alternaria alternate, Aspergillus* spp. and *Penicillium* spp.) on *Fusarium oxysporum* f. sp. *sesami* with the following results.

Isolate No.	Endophytic fungi isolate	Average of inhibition zone diameter (mm)
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11	*Penicillium crustosum* $_{(2)}$	8.2 ^{b}
12	*Penicillium crustosum* $_{(3)}$	2.8 ^{e}
13	Control	0.0 ^{f}

Means followed by the same letters (s) in a column are not significantly different at ($p \leq 0.05$) according to Duncan's multiple-range test.

E2.1.2 *Aspergillus* spp. (22 Apr 2021)

There are *Aspergillus* spp. that affect seed quality (A13.1.1) while other species have been proposed as biocontrols (E2.1.2). *Aspergillus* spp. have been reported to occur from the field in International lists, Algeria, Bangladesh, Cuba, Egypt, Greece, India, Iran, Iraq, Nigeria, Pakistan, Paraguay, Saudi Arabia, Senegal, Sierra Leone, Sudan, Thailand, United States, and Venezuela.

Family: Trichocomaceae

Definition: Amount of biocontrol provided by *Aspergillus* spp. P. Micheli ex Haller 1768.

(Wikipedia, 22 Apr 2021) ***Aspergillus*** is a genus consisting of a few hundred mould species found in various climates worldwide. *Aspergillus* was first catalogued in 1729 by the Italian priest and biologist Pier Antonio Micheli. Viewing the fungi under a microscope, Micheli was reminded of the shape of an *aspergillum* (holy water sprinkler), from Latin *spargere* (to sprinkle), and named the genus accordingly. Aspergillum is an asexual spore-forming structure common to all *Aspergillus* species; around one-third of species are also known to have a sexual stage. While some species of *Aspergillus* are known to cause fungal infections, others are of commercial importance.

E2.1.2a *Aspergillus niger* (17 Jul 2021)

Aspergillus niger affects seed quality (A13.1.1b) and has been used as a biocontrol (E2.1.2a). *Aspergillus niger* has been reported to occur from the field in International lists, Algeria, Bangladesh, Egypt, India, Iran, Iraq, Nigeria, Pakistan, Sudan, and Venezuela.

Family: Trichocomaceae

Definition: Amount of biocontrol provided by *Aspergillus niger* Tieghem 1867.

(Wikipedia, 22 Apr 2021) ***Aspergillus niger*** is a fungus and one of the most common species of the genus *Aspergillus*. It causes a disease called "black mold" on certain fruits and vegetables such as grapes, apricots, onions, and peanuts, and is a common contaminant of food. It is ubiquitous in soil and is commonly reported from indoor environments, where its black colonies can be confused with those of *Stachybotrys* (species of which have also been called "black mold").

Some strains of *A. niger* have been reported to produce potent mycotoxins called ochratoxins; other sources disagree, claiming this report is based upon misidentification of the fungal species. Recent evidence suggests some true *A. niger* strains do produce ochratoxin A. It also produces the isoflavone orobol.

References:

EGYPT

- M.G.A. Hegazy et al. (2019) evaluated the effects of biocontrols (*Alternaria alternate, Aspergillus* spp. and *Penicillium* spp.) on *Fusarium oxysporum* f. sp. *sesami* with the following results.

Isolate No.	Endophytic fungi isolate	Average of inhibition zone diameter (mm)
1	*Alternaria alternate*	1.5 ^{ef}
2	*Aspergillus clavatus*	9.2 ^{b}
3	*Aspergillus fumigatus*	0.8 ^{ef}
4	*Aspergillus niger*	11.6 ^{a}
5	*Aspergillus sydowii*	1.3 ^{ef}
6	*Aspergillus terreus* $_{(1)}$	2.3 ^{e}
7	*Aspergillus terreus* $_{(2)}$	5.9 ^{cd}
8	*Penicillium chrysogenum* $_{(1)}$	9.2 ^{b}
9	*Penicillium chrysogenum* $_{(2)}$	2.3 ^{e}
10	*Penicillium crustosum* $_{(1)}$	7.1 ^{bc}
11	*Penicillium crustosum* $_{(2)}$	8.2 ^{b}
12	*Penicillium crustosum* $_{(3)}$	2.8 ^{e}
13	Control	0.0 ^{f}

Means followed by the same letters (s) in a column are not significantly different at ($p \leq 0.05$) according to Duncan's multiple-range test.

The species with the highest levels of inhibition were further tested using different concentrations.

Endophytic fungi	Concentration (%)	Average of colony diameter (mm)	Inhibition (%)
Aspergillus niger	1	73.30	18.55 ^{i}
	2	69.30	23.00 ^{ghi}
	5	63.30	29.66 ^{fgh}
	10	57.00	36.66 ^{ef}
	20	45.00	50.00 ^{d}
Aspergillus terreus (1)	1	68.30	24.11 ^{ghi}
	2	55.00	38.88 ^{e}
	5	45.00	50.00 ^{d}
	10	36.60	59.33 ^{bc}
	20	26.60	70.44 ^{a}
Aspergillus terreus (2)	1	73.30	18.55 ^{i}
	2	65.30	27.44 ^{gh}
	5	56.60	37.11 ^{ef}
	10	43.30	51.88 ^{cd}
	20	33.30	63.00 ^{ab}
Penicillium chrysogenum (1)	1	75.00	16.66 ^{i}
	2	70.00	22.22 ^{hi}
	5	62.00	31.11 ^{efg}
	10	55.00	38.88 ^{e}
	20	44.00	51.11 ^{cd}
Control		90.00	00.00 ^{j}

Means followed by the same letters (s) in a column are not significantly different at ($p \leq 0.05$) according to Duncan's multiple-range test.

The species were then used in the greenhouse with the following results.

Treatments	Disease Severity (%)	Plant growth parameters					
		Shoot			Root		Number of bods
		Plant height (cm)	Fresh weight (g)	Dry weight (g)	Fresh weight (g)	Dry weight (g)	
Aspergillus niger	36 ^{c}	73 ^{ab}	11.8 ^{b}	3.66 ^{b}	3.33 ^{c}	1.3 ^{c}	10 ^{c}
Aspergillus terreus (1)	41 ^{bc}	83 ^{b}	19 ^{a}	4.66 ^{a}	7.83 ^{a}	3.43 ^{a}	16 ^{a}
Aspergillus terreus (2)	52 ^{b}	96 ^{a}	10.3 ^{bc}	3 ^{c}	7.6 ^{a}	2.66 ^{b}	11 ^{b}
Penicillium chrysogenum (1)	38.6 ^{bc}	85 ^{b}	10.6 ^{bc}	2.2 ^{d}	6.66 ^{ab}	1.46 ^{c}	10 ^{c}
Control (untreated)	94.3 ^{a}	56 ^{c}	9.6 ^{c}	2 ^{c}	4 ^{b}	1.16 ^{c}	9 ^{d}

Means followed by the same letters (s) in a column are not significantly different at ($p \leq 0.05$) according to Duncan's multiple-range test.

The species were then compared to using *Trichoderma* spp. alone or in combination with the following results.

Treatments	Disease Severity (%)	Growth parameters					
		Shoot			Root		Number of bods
		Shoot height (cm)	Fresh weight (g)	Dry weight (g)	Fresh weight (g)	Dry weight (g)	
A. niger + *Trichoderma* sp.	16 ^{c}	91.3 ^{b}	24.6 ^{c}	9.6 ^{b}	14.6 ^{b}	7.1 ^{b}	8 ^{c}
A. terreus (1) + *Trichoderma* sp.	25.3 ^{bc}	84 ^{c}	27 ^{b}	8.5 ^{c}	15.3 ^{b}	5.6 ^{c}	12 ^{b}
A. terreus (2) + *Trichoderma* sp.	46.6 ^{a}	84 ^{c}	27.5 ^{b}	7.6 ^{d}	13 c	5.4 ^{c}	6 ^{d}
P. chrysogenum (1) + *Trichoderma* sp.	36 ^{ab}	80 ^{d}	17.5 ^{d}	6 ^{e}	9.3 ^{d}	3.5 ^{d}	13 ^{a}
Control (*Trichoderma* sp. only)	13.3 ^{c}	98 ^{a}	42.3 ^{a}	12.6 ^{a}	25.6 ^{a}	14.3 ^{a}	12 ^{b}

E2.1.2b *Aspergillus fumigatus* (17 Jul 2021)

Aspergillus fumigatus affects seed quality (A13.1.1h) and has been used as a biocontrol (E2.1.2b). *Aspergillus fumigatus* has been reported to occur from the field in Bangladesh, India, and Nigeria.

Family: Trichocomaceae

Definition: Amount of biocontrol provided by *Aspergillus fumigatus* Fresenius 1863.

(Wikipedia, 12 May 2021) ***Aspergillus fumigatus*** is a species of fungus in the genus *Aspergillus*, and is one of the most common *Aspergillus* species to cause disease in individuals with an immunodeficiency.

Aspergillus fumigatus, a saprotroph widespread in nature, is typically found in soil and decaying organic matter, such as compost heaps, where it plays an essential role in carbon and nitrogen recycling. Colonies of the fungus produce from conidiophores; thousands of minute grey-green conidia (2–3 µm) which readily become airborne. For many years, *A. fumigatus* was thought to only reproduce asexually, as neither mating nor meiosis had ever been

observed. In 2008, *A. fumigatus* was shown to possess a fully functional sexual reproductive cycle, 145 years after its original description by Fresenius. Although *A. fumigatus* occurs in areas with widely different climates and environments, it displays low genetic variation and a lack of population genetic differentiation on a global scale. Thus, the capability for sex is maintained, though little genetic variation is produced.

References:

EGYPT

- M.G.A. Hegazy et al. (2019) evaluated the effects of biocontrols (*Alternaria alternate, Aspergillus* spp. and *Penicillium* spp.) on *Fusarium oxysporum* f. sp. *sesami* with the following results.

Isolate No.	Endophytic fungi isolate	Average of inhibition zone diameter (mm)
1	*Alternaria alternate*	1.5 ^{ef}
2	*Aspergillus clavatus*	9.2 ^{b}
3	*Aspergillus fumigatus*	0.8 ^{ef}
4	*Aspergillus niger*	11.6 ^{a}
5	*Aspergillus sydowii*	1.3 ^{ef}
6	*Aspergillus terreus* $_{(1)}$	2.3 ^{e}
7	*Aspergillus terreus* $_{(2)}$	5.9 ^{cd}
8	*Penicillium chrysogenum* $_{(1)}$	9.2 ^{b}
9	*Penicillium chrysogenum* $_{(2)}$	2.3 ^{e}
10	*Penicillium crustosum* $_{(1)}$	7.1 ^{bc}
11	*Penicillium crustosum* $_{(2)}$	8.2 ^{b}
12	*Penicillium crustosum* $_{(3)}$	2.8 ^{e}
13	Control	0.0 ^{f}

Means followed by the same letters (s) in a column are not significantly different at ($p \leq 0.05$) according to Duncan's multiple-range test.

E2.1.2c *Aspergillus clavatus* (17 Jul 2021)

Aspergillus clavatus affects seed quality (A13.1.1k) and has been used as a biocontrol (E2.1.2c). *Aspergillus clavatus* has been reported to occur from the field in India.

Family: Trichocomaceae

Definition: Amount of biocontrol provided by *Aspergillus clavatus* Desmazieres 1834.

(Wikipedia, 2 Jun 2021) ***Aspergillus clavatus*** is a species of fungus in the genus *Aspergillus* with conidia dimensions 3–4.5 x 2.5–4.5 µm. It is found in soil and animal manure. The fungus was first described scientifically in 1834 by the French mycologist John Baptiste Henri Joseph Desmazieres.

The fungus can produce the toxin patulin, which may be associated with disease in humans and animals. This species is only occasionally pathogenic. *A. clavatus* is allergenic, causing the occupational hypersensitivity pneumonitis known as malt-worker's lung.

References:

EGYPT

- M.G.A. Hegazy et al. (2019) evaluated the effects of biocontrols (*Alternaria alternate, Aspergillus* spp. and *Penicillium* spp.) on *Fusarium oxysporum* f. sp. *sesami* with the following results.

Isolate No.	Endophytic fungi isolate	Average of inhibition zone diameter (mm)
1	*Alternaria alternate*	1.5 ^{ef}
2	*Aspergillus clavatus*	9.2 ^{b}
3	*Aspergillus fumigatus*	0.8 ^{ef}
4	*Aspergillus niger*	11.6 ^{a}
5	*Aspergillus sydowii*	1.3 ^{ef}
6	*Aspergillus terreus* $_{(1)}$	2.3 ^{e}
7	*Aspergillus terreus* $_{(2)}$	5.9 ^{cd}
8	*Penicillium chrysogenum* $_{(1)}$	9.2 ^{b}
9	*Penicillium chrysogenum* $_{(2)}$	2.3 ^{e}
10	*Penicillium crustosum* $_{(1)}$	7.1 ^{bc}
11	*Penicillium crustosum* $_{(2)}$	8.2 ^{b}
12	*Penicillium crustosum* $_{(3)}$	2.8 ^{e}
13	Control	0.0 ^{f}

Means followed by the same letters (s) in a column are not significantly different at ($p \leq 0.05$) according to Duncan's multiple-range test.

E2.1.2d *Aspergillus terreus* (17 Jul 2021)

Aspergillus terreus is a pathogen (A13.1.1r) and has been used as a biocontrol (E2.1.2d). *Aspergillus terreus* has been reported to occur from the field in Egypt, India, Iran, and Nigeria.

Family: Trichocomaceae

Definition: Amount of biocontrol provided by *Aspergillus terreus* Thom 1918.

(Wikipedia, 17 Jul 2021) ***Aspergillus terreus***, also known as *Aspergillus terrestris*, is a fungus (mold) found worldwide in soil. Although thought to be strictly asexual until recently, *A. terreus* is now known to be capable of sexual reproduction. This saprotrophic fungus is prevalent in warmer climates such as tropical and subtropical regions. Aside from being located in soil, *A. terreus* has also been found in habitats such as decomposing vegetation and dust. *A. terreus* is commonly used in industry to produce important organic acids, such as itaconic acid and *cis*-aconitic acid, as well as enzymes, like xylanase. It was also the initial source for the drug mevinolin (lovastatin), a drug for lowering serum cholesterol.

Aspergillus terreus can cause opportunistic infection in people with deficient immune systems. It is relatively resistant to amphotericin B, a common antifungal drug. *Aspergillus terreus* also produces aspterric acid and 6-hydroxymellein, inhibitors of pollen development in *Arabidopsis thaliana*.

References:

EGYPT

- M.G.A. Hegazy et al. (2019) evaluated the effects of biocontrols (*Alternaria alternate, Aspergillus* spp. and *Penicillium* spp.) on *Fusarium oxysporum* f. sp. *sesami* with the following results.

Isolate No.	Endophytic fungi isolate	Average of inhibition zone diameter (mm)
1	*Alternaria alternate*	1.5 ^{ef}
2	*Aspergillus clavatus*	9.2 ^{b}
3	*Aspergillus fumigatus*	0.8 ^{ef}
4	*Aspergillus niger*	11.6 ^{a}
5	*Aspergillus sydowii*	1.3 ^{ef}
6	*Aspergillus terreus* $_{(1)}$	2.3 ^{e}
7	*Aspergillus terreus* $_{(2)}$	5.9 ^{cd}
8	*Penicillium chrysogenum* $_{(1)}$	9.2 ^{b}
9	*Penicillium chrysogenum* $_{(2)}$	2.3 ^{e}
10	*Penicillium crustosum* $_{(1)}$	7.1 ^{bc}
11	*Penicillium crustosum* $_{(2)}$	8.2 ^{b}
12	*Penicillium crustosum* $_{(3)}$	2.8 ^{e}
13	Control	0.0 ^{f}

Means followed by the same letters (s) in a column are not significantly different at ($p \leq 0.05$) according to Duncan's multiple-range test.

The species with the highest levels of inhibition were further tested using different concentrations.

Endophytic fungi	Concentration (%)	Average of colony diameter (mm)	Inhibition (%)
Aspergillus niger	1	73.30	18.55 ^{i}
	2	69.30	23.00 ^{ghi}
	5	63.30	29.66 ^{fgh}
	10	57.00	36.66 ^{ef}
	20	45.00	50.00 ^{d}
Aspergillus terreus (1)	1	68.30	24.11 ^{ghi}
	2	55.00	38.88 ^{e}
	5	45.00	50.00 ^{d}
	10	36.60	59.33 ^{bc}
	20	26.60	70.44 ^{a}
Aspergillus terreus (2)	1	73.30	18.55 ^{i}
	2	65.30	27.44 ^{gh}
	5	56.60	37.11 ^{ef}
	10	43.30	51.88 ^{cd}
	20	33.30	63.00 ^{ab}
Penicillium chrysogenum (1)	1	75.00	16.66 ^{i}
	2	70.00	22.22 ^{hi}
	5	62.00	31.11 ^{efg}
	10	55.00	38.88 ^{e}
	20	44.00	51.11 ^{cd}
Control		90.00	00.00 ^{j}

Means followed by the same letters (s) in a column are not significantly different at ($p \leq 0.05$) according to Duncan's multiple-range test.

The species were then used in the greenhouse with the following results.

Treatments	Disease Severity (%)	Plant growth parameters					
		Shoot			Root		Number of bods
		Plant height (cm)	Fresh weight (g)	Dry weight (g)	Fresh weight (g)	Dry weight (g)	
Aspergillus niger	36 ^{c}	73 ^{ab}	11.8 ^{b}	3.66 ^{b}	3.33 ^{c}	1.3 ^{c}	10 ^{c}
Aspergillus terreus (1)	41 ^{bc}	83 ^{b}	19 ^{a}	4.66 ^{a}	7.83 ^{a}	3.43 ^{a}	16 ^{a}
Aspergillus terreus (2)	52 ^{b}	96 ^{a}	10.3 ^{bc}	3 ^{c}	7.6 ^{a}	2.66 ^{b}	11 ^{b}
Penicillium chrysogenum (1)	38.6 ^{bc}	85 ^{b}	10.6 ^{bc}	2.2 ^{d}	6.66 ^{ab}	1.46 ^{c}	10 ^{c}
Control (untreated)	94.3 ^{a}	56 ^{c}	9.6 ^{c}	2 ^{c}	4 ^{b}	1.16 ^{c}	9 ^{d}

Means followed by the same letters (s) in a column are not significantly different at ($p \leq 0.05$) according to Duncan's multiple-range test.

The species were then compared to using *Trichoderma* spp. alone or in combination with the following results.

Treatments	Disease Severity (%)	Growth parameters					
		Shoot			Root		Number of bods
		Shoot height (cm)	Fresh weight (g)	Dry weight (g)	Fresh weight (g)	Dry weight (g)	
A. niger + *Trichoderma* sp.	16 ^{c}	91.3 ^{b}	24.6 ^{c}	9.6 ^{b}	14.6 ^{b}	7.1 ^{b}	8 ^{c}
A. terreus (1) + *Trichoderma* sp.	25.3 ^{bc}	84 ^{c}	27 ^{b}	8.5 ^{c}	15.3 ^{b}	5.6 ^{c}	12 ^{b}
A. terreus (2) + *Trichoderma* sp.	46.6 ^{a}	84 ^{c}	27.5 ^{b}	7.6 ^{d}	13 c	5.4 ^{c}	6 ^{d}
P. chrysogenum (1) + *Trichoderma* sp.	36 ^{ab}	80 ^{d}	17.5 ^{d}	6 ^{e}	9.3 ^{d}	3.5 ^{d}	13 ^{a}
Control (*Trichoderma* sp. only)	13.3 ^{c}	98 ^{a}	42.3 ^{a}	12.6 ^{a}	25.6 ^{a}	14.3 ^{a}	12 ^{b}

E2.1.2e *Aspergillus sydowii* (17 Jul 2021)

Family: Trichocomaceae

Definition: Amount of biocontrol provided by *Aspergillus sydowii* (Bainier & Sartory) Thom and Church 1926.

(Wikipedia, 17 Jul 2021) ***Aspergillus sydowii*** is a pathogenic fungus that causes several diseases in humans. It has been implicated in the death of sea fan corals (*Gorgonia* spp.) in the Caribbean Sea.

References:

EGYPT

- I.A. El-Kady et al. (1986) reported isolating *Aspergillus sydowi* on sesame.
- M.G.A. Hegazy et al. (2019) evaluated the effects of biocontrols (*Alternaria alternate, Aspergillus* spp. and *Penicillium* spp.) on *Fusarium oxysporum* f. sp. *sesami* with the following results.

Isolate No.	Endophytic fungi isolate	Average of inhibition zone diameter (mm)
1	*Alternaria alternate*	1.5 ^{ef}
2	*Aspergillus clavatus*	9.2 ^{b}
3	*Aspergillus fumigatus*	0.8 ^{ef}
4	*Aspergillus niger*	11.6 ^{a}
5	*Aspergillus sydowii*	1.3 ^{ef}
6	*Aspergillus terreus* $_{(1)}$	2.3 ^{e}
7	*Aspergillus terreus* $_{(2)}$	5.9 ^{cd}
8	*Penicillium chrysogenum* $_{(1)}$	9.2 ^{b}
9	*Penicillium chrysogenum* $_{(2)}$	2.3 ^{e}
10	*Penicillium crustosum* $_{(1)}$	7.1 ^{bc}
11	*Penicillium crustosum* $_{(2)}$	8.2 ^{b}
12	*Penicillium crustosum* $_{(3)}$	2.8 ^{e}
13	Control	0.0 ^{f}

Means followed by the same letters (s) in a column are not significantly different at ($p \leq 0.05$) according to Duncan's multiple-range test.

E2.1.2f *Aspergillus nidulans* (14 Aug 2021)

Synonym: *Emericella nidulans*

Family: Trichocomaceae

Definition: Amount of biocontrol provided by *Aspergillus nidulans* G. Winter 1884.

(Wikipedia, 14 Aug 2021) ***Aspergillus nidulans*** (also called ***Emericella nidulans*** when referring to its sexual form, or teleomorph) is one of many species of filamentous fungi in the phylum Ascomycota. It has been an important research organism for studying eukaryotic cell biology for over 50 years, being used to study a wide range of subjects including recombination, DNA repair, mutation, cell cycle control, tubulin, chromatin, nucleokinesis, pathogenesis, metabolism, and experimental evolution. It is one of the few species in its genus able to form sexual spores through meiosis, allowing crossing of strains in the laboratory. *A. nidulans* is a homothallic fungus, meaning it is able to self-fertilize and form fruiting bodies in the absence of a mating partner. It has septate hyphae with a woolly colony texture and white mycelia. The green color of wild-type colonies is due to pigmentation of the spores, while mutations in the pigmentation pathway can produce other spore colors.

References:

EGYPT

- M.E. Ibrahim and A.M. Abdel-Azeem (2007) evaluated soil solarization in combination with fungal antagonists and soil amendments as a potential disease management strategy for the control of charcoal rot of sesame caused by *Macrophomina phaseolina*. Solarization alone or in combination with *Trichoderma pseudokoningii* and *Emericella nidulans* singly or in mixed inocula reduced disease incidence from 30% (control) to 80%, 91%, 82% and 85% respectively. It is noted that while pairing improved the biocontrols potentiality of *E. nidulans* by increasing the number of healthy plants in both unsolarized and solarized soils it leads to decrease in the biocontrol potentiality of *T. pseudokoningii*. On the other hand, the combination of solarization with soil amendment with Eucalyptus powdered leaves showed a synergistic effect by increasing number of healthy plants from 65% in amended unsolarized soil to 77% in amended solarized soil.
- A. Hashem et al. (2014) collected 18 seed samples of sesame in Egypt (12 samples) and Saudi Arabia (6 samples). They identified the following mycoflora: *Aspergillus nidulans* and *Emericella nidulans.*

NIGERIA

- F.M. Afolagboye (2011) reported the following fungus from 4 sesame varieties (NCRIBEN 03L, NCRIBEN 01M, E8 and 530-6-1) at Abeokuta: *Aspergillus nidulans.*

E2.1.2g *Aspergillus flavus* (14 Sep 2021)

Aspergillus flavus affects seed quality (A13.1.1a) and has been used as a biocontrol (E2.1.2g). *Aspergillus flavus* has been reported to occur from the field.

Family: Trichocomaceae

Definition: The presence on insects in sesame of *Aspergillus flavus* Link 1809.

(Wikipedia, 22 Apr 2021) ***Aspergillus flavus*** is a saprotrophic and pathogenic fungus with a cosmopolitan distribution. It is best known for its colonization of cereal grains, legumes, and tree nuts. Postharvest rot typically develops during harvest, storage, and/or transit. Its specific name flavus derives from the Latin meaning yellow, a reference to the frequently observed color of the spores. *A. flavus* infections can occur while hosts are still in the field (preharvest), but often show no symptoms (dormancy) until postharvest storage and/or transport. In addition to causing preharvest and postharvest infections, many strains produce significant quantities of toxic compounds known as mycotoxins, which, when consumed, are toxic to mammals. *A. flavus* is also an opportunistic human and animal pathogen, causing aspergillosis in immunocompromised individuals.

Aspergillus flavus is found globally as a saprophyte in soils and causes disease on many important agriculture crops. Common hosts of the pathogen are cereal grains, legumes, and tree nuts. Specifically, *A. flavus* infection causes ear rot in corn and yellow mold in peanuts either before or after harvest. Infection can be present in the field, preharvest, postharvest, during storage, and during transit. It is common for the pathogen to originate while host crops are still in the field; however, symptoms and signs of the pathogen are often unseen. *A. flavus* has the potential to infect seedlings by sporulation on injured seeds. In grains, the pathogen can invade seed embryos and cause infection, which decreases germination and can lead to infected seeds planted in the field. The pathogen can also discolor embryos, damage seedlings, and kill seedlings, which reduces grade and price of the grains. The incidence of *A. flavus* infection increases in the presence of insects and any type of stress on the host in the field as a result of damage. Stresses include stalk rot, drought, severe leaf damage, and/or less than ideal storage conditions. Generally, excessive moisture conditions and high temperatures of storage grains and legumes increase the occurrence of *A. flavus* aflatoxin production. In mammals, the pathogen can cause liver cancer through consumption of contaminated feed or aspergillosis through invasive growth.

Aspergillus flavus infections will not always reduce crop yields alone; however, postharvest disease can reduce the total crop yield by 10 to 30%, and in developing countries that produce perishable crops, total loss can be greater than 30%. In grains and legumes, postharvest disease results in the production of mycotoxins. The largest economic loss caused by this pathogen is a result of aflatoxin production. In the United States, annual economic loss estimations of peanuts, corn, cottonseed, walnuts, and almonds are less severe when compared to Asia and Africa.

References:

INDIA

- R. Choudhary et al. (1986b) reported the following fungus that attacks *Antigastra catalaunalis*: *Aspergillus flavus* Link. [Cited by B. Naveen et al., 2019]

E2.1.3a *Cordyceps* spp. (29 Sep 2021)

Family: Trichocomaceae

Definition: The presence on insects in sesame of *Cordyceps* spp. Fries 1833.

(Wikipedia, 29 Sep 2021) ***Cordyceps*** is a genus of ascomycete fungi (sac fungi) that includes about 600 species. Most *Cordyceps* species are endoparasitoids, parasitic mainly on insects and other arthropods (they are thus entomopathogenic fungi); a few are parasitic on other fungi.

The genus has a worldwide distribution and most of the approximately 600 species that have been described are from Asia (notably Nepal, China, Japan, Bhutan, Korea, Vietnam, and Thailand). *Cordyceps* species are particularly abundant and diverse in humid temperate and tropical forests.

E2.1.3a *Cordyceps fumosorosea* (29 Nov 2020)

Synonym: *Isaria fumosorosea*

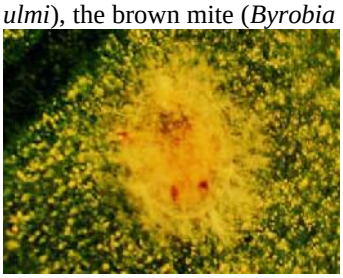
Family: Trichocomaceae

Definition: The presence on insects in sesame of *Cordyceps fumosorosea* (Wize) Kepler, B. Shrestha & Spatafora, 2017.

(Wikipedia, 26 Nov 2020) ***Isaria fumosorosea*** is an entomopathogenic fungus, formerly known as *Paecilomyces fumosoroseus*. It shows promise as a biological pesticide with an extensive host range.

When a conidium or blastospore of *Isaria fumosorosea* lands on a suitable host, it produces enzymes to penetrate the insect's cuticle. A germ tube then grows into the haemocoel and the fungus proliferates inside the insect's body. The fungus can also enter through the spiracles, the mouth or the anal opening. The mycelia spread in the haemolymph and tissues, eventually emerging from the insect and producing conidia. Mortality of the insect has been ascribed to the drainage of its nutrients, the destruction of its tissues and the release of toxins.

This fungus has a wide host range that includes insects in over twenty five different families and many species of mite. Agricultural pest insects which are susceptible to infection include the diamondback moth (*Plutella xyllostella*), the Russian wheat aphid (*Diuraphis noxia*) and the silverleaf whitefly (*Bemisia argentifolii*). Among mites, susceptible species include the spotted spider mite (*Tetranychus urticae*), the European red mite (*Panonychus ulmi*), the brown mite (*Byrobia rubrioculus*) and the apple rust mite (*Aculus schlectendali*).



*Bemisia n*ymph infected with *Isaria fumosoroseus*.
Photo: entnemdept.ufl.edu, 16 Jun 2019

References:

UNITED STATES

- The University of Florida (entnemdept.ufl.edu, accessed 16 Jun 2019) reported *Isaria fumosorosea* as a fungus on whiteflies, and has been proposed as a biological control.

E2.1.4 *Talaromyces* spp. (29 Sep 2021)

Family: Trichocomaceae

Definition: Amount of biocontrol provided by *Talaromyces* spp. C.R. Benjamin 1955.

(Wikipedia, 29 Sep 2021) ***Talaromyces*** is a genus of fungi in the family Trichocomaceae. Described in 1955 by American mycologist Chester Ray Benjamin, species in the genus form soft, cottony fruit bodies (ascocarps) with cell walls made of tightly interwoven hyphae. The fruit bodies are often yellowish or are surrounded by yellowish granules. A 2008 estimate placed 42 species in the genus, but several new species have since been described. This genus contains the teleomorph of *Penicillium*.

The following species has been associated with sesame but there are no known reports of being a pathogen, producing a toxin, inhibiting germination, affecting seed quality, or being used as a biocontrol or biofertilizer.

- *Talaromyces flavus* [Pakistan] (*Syn: *Penicillium vermiculatum*)

References:

NIGERIA

- C.N. Ezekiel et al. (2014) isolated the following fungus on sesame seeds: *Talaromyces* sp.

E2.1.4a *Talaromyces pinophilus* (29 Sep 2021)

Synonym: *Penicillium pinophilum*

Family: Trichocomaceae

Definition: Amount of biocontrol provided by *Talaromyces pinophilus* (Hedgc.) Samson, Yilmaz, Frisvad & Seifert 2011.

(Wikipedia, 24 Aug 2021) ***Penicillium pinophilum*** is a species of fungus in the genus *Penicillium* which was isolated from a radio set in Papua New Guinea. *Penicillium pinophilum* produces 3-O-methylfunicone and mycophenolic acid.

References:

INDIA

- S.J. Gaikwad and D.J. Kapgate (1990) examined the possible biological control of the fungus *Sclerotium rolfsii*, the causal agent of the root-rot disease of sesame. Laboratory studies showed that 2 fungi were capable of limiting the growth of the pathogen of the root-rot disease. Pot trials showed that in the presence of the fungi *Trichoderma harzianum* and *Penicillium pinophilum*, only 10 and 15%, respectively, of sesame plants were infected with *S. rolfsii*; infection in the absence of the 2 fungi (control plants) was 100%. [Based on abstract]

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E3 Order: Saccharomycetales Kudryatsev 1960

(Wikipedia, 19 Apr 2021) **Saccharomycetales** belongs to the kingdom of Fungi and the division Ascomycota. It is the only order in the class Saccharomycetes. There are currently 13 families recognized as belonging to Saccharomycetales.

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E3.1 Family: Saccharomycetaceae G. Winter 1881

(Wikipedia, 19 Apr 2021) The **Saccharomycetaceae** are a family of yeasts in the order Saccharomycetales that reproduce by budding. Species in the family have a cosmopolitan distribution, and are present in a wide variety of habitats, especially those with a plentiful supply of carbohydrate sources. The family contains the species *Saccharomyces cerevisiae*, perhaps the most economically important fungus.

The following species have been identified to provide biocontrol:

- E3.1.1 *Saccharomyces* spp.
- E3.1.1a *Saccharomyces cerevisae*

E3.1.1 *Saccharomyces* spp. (19 Apr 2021)

Family: Saccharomycetaceae

Definition: Amount of biocontrol provided by *Saccharomyces* spp. Meyen 1883.

(Wikipedia, 19 Apr 2021) ***Saccharomyces*** is a genus of fungi that includes many species of yeasts. *Saccharomyces* is from Greek σάκχαρον (sugar) and μύκης (fungus) and means *sugar fungus*. Many members of this genus are considered very important in food production. It is known as the brewer's yeast or baker's yeast. They are unicellular and saprotrophic fungi. One example is *Saccharomyces cerevisiae*, which is used in making bread, wine, and beer, and for human and animal health. Other members of this genus include the wild yeast *Saccharomyces paradoxus* that is the closest relative to *S. cerevisiae*, *Saccharomyces bayanus*, used in making wine, and *Saccharomyces cerevisiae* var *boulardii*, used in medicine.

E3.1.1a *Saccharomyces cerevisiae* (19 Apr 2021)

Family: Saccharomycetaceae

Definition: Amount of biocontrol provided by *Saccharomyces cerevisiae* Meyen ex E.C. Hansen.

(Wikipedia, 19 Apr 2021) ***Saccharomyces cerevisiae*** is a species of yeast (single-celled fungus microorganisms). The species has been instrumental in winemaking, baking, and brewing since ancient times. It is believed to have been originally isolated from the skin of grapes (one can see the yeast as a component of the thin white film on the skins of some dark-colored fruits such as plums; it exists among the waxes of the cuticle). It is one of the most intensively studied eukaryotic model organisms in molecular and cell biology, much like *Escherichia coli* as the model bacterium. It is the microorganism behind the most common type of fermentation. *S. cerevisiae* cells are round to ovoid, 5–10 μm in diameter. It reproduces by budding.

References:

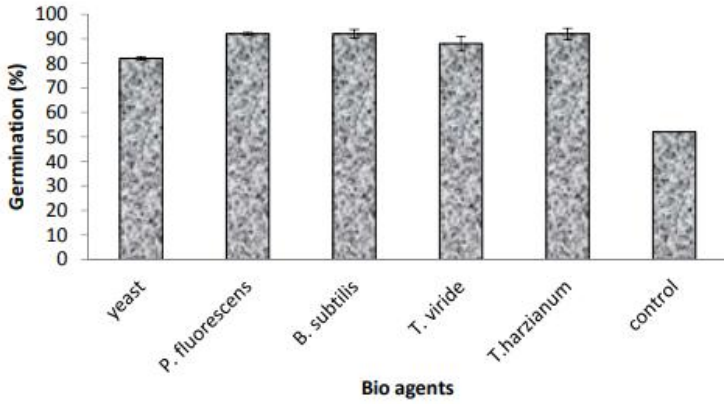
EGYPT

- E. Abdou et al. (2004) reported both salicylic acid (SA) and yeast (*Saccharomyces cerevisiae*) seed treatments affected incidence of wilt and root rot of sesame incited by *Fusarium oxysporum* f. sp *sesami*, *Macrophomina phaseolina*, *Thielaviopsis basicola* and *Mucor haemalis*. Also, yeast derivatives variously affected root rot/wilt severity. Combining SA with yeast or with its derivatives showed, in most cases, inhibition effects against the tested pathogenic fungi. [Based on abstract]

PAKISTAN

- B.G. Nayyar et al. (2016) evaluated different bioagents to increase the germination and inhibit the fungi on sesame seeds bioagents (*Trichoderma viride*, *T. harzianum, Pseudomonas fluorescens*, *Bacillus subtilis* and

Saccharomyces cerevisiae – yeast). Seed germination was tested by following the protocol of International Seed Testing Association. Antifungal activity was tested by poisoned food technique. The effects of the bioagents were as follow.



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E4 Order: Sordariales Chadef. ex D. Hawksw. & O.E. Erikss. 1986

(Wikipedia, 19 Apr 2021) The **Sordariales** are an order of fungi within the class Sordariomycetes (also known as Pyrenomycetes), subdivision Pezizomycotina, division Ascomycota.

Most Sordariales are saprobic, producing solitary perithecial ascomata. They are commonly found on dung or decaying plant matter.

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E4.1 Family: Chaetomiaceae G. Winter 1885

(Wikipedia, 19 Apr 2021) The **Chaetomiaceae** are a family of fungi in the Ascomycota, class Sordariomycetes.

The following species have been identified to provide biocontrol:
- E4.1.1 *Chaetomium* spp.
- E4.1.1a *Chaetomium penicilloides*
- E4.1.2 *Collariella* spp.
- E4.1.2a *Collariella bostrychodes* (*Syn: *Chaetomium bostrychodes*)

E4.1.1 *Chaetomium* spp. (19 Apr 2021)

Family: Chaetomiaceae

Definition: Amount of biocontrol provided by *Chaetomium* spp. Kunze 1817.

(Wikipedia, 19 Apr 2021) ***Chaetomium*** is a genus of fungi in the Chaetomiaceae family. It is a dematiaceous (dark-walled) mold normally found in soil, air, cellulose and plant debris. According to the *Dictionary of the Fungi* (10th edition, 2008), there are about 95 species in the widespread genus.

Members of this genus typically have superficial, ostiolar perithecia, covered in hairs. Asci are often clavate and evanescent, bearing eight spores. Ascospores are usually lemon-shaped, commonly colored olive-brown. Mycelia often grows in conglomerate masses that resemble ropes.

As well as being a contaminant, *Chaetomium* spp. are also encountered as causative agents of infections in humans. Many cases cause type 1 allergic reactions and infections. A few cases of fatal deep infections due to *Chaetomium atrobrunneum* have been reported in the immunocompromised people. Other clinical syndromes include brain abscess, peritonitis, and onychomycosis.

The following species have been associated with sesame but there are no known reports of being a pathogen, producing a toxin, inhibiting germination, affecting seed quality, or being used as a biocontrol or biofertilizer.
- *Chaetomium elatum* [Egypt, Iran, and Saudi Arabia]
- *Chaetomium funicolum* [Iran]
- *Chaetomium globosum* [Egypt, India, and Saudi Arabia]
- *Chaetomium olivaceum* [Iran]
- *Chaetomium spirale* [Egypt and Saudi Arabia]

References:

IRAQ
- N.A. Saad et al. (2013) examined seed and found the following fungus: *Chaetomium* sp.

SAUDI ARABIA
- A.H. Bahkali and M.A. Moslem (1996) reported the following mycoflora on 5 cultivars: *Chaetomium* sp.

SUDAN
- H.I.H. Idriss (2016) collected farmer saved red and white sesame from 7 locations in Sudan. 14 different fungi representing ten genera were identified. One of the low frequency fungi was *Chaetomium* sp.

E4.1.1a *Chaetomium penicilloides* (19 Apr 2021)

Family: Chaetomiaceae

Definition: Amount of biocontrol provided by *Chaetomium penicilloides*.

References:

EGYPT

- A.I.I. El-Fiki et al. (2004a) studied the effects of using *Chaetomium penicilloides* to control *Macrophomina phaseolina* Tassi (Goid). The seeds were planted in pots in the greenhouse and then took percentages as follows: % pre-emergence = damping off within 15 days, % post-emergence = damping off within 45 days, % charcoal rot = diseased at 90 days, and % healthy plants at 90 days. The results with antagonistic fungi were as follow.

Antagonistic fungi and bacteria	% Disease incidence			
	At seedling stage		At maturity stage	
	Pre-emergence	Post-emergence	Charcoal rot	Healthy plants
B. megtella *	16.7	16.7	23.3	43.3
Bacillus sp 3 **	13.3	10.0	23.3	53.3
Bacillus subtillus *	10.0	13.3	20.0	56.7
Chaetomium bostrycoides *	0.0	3.3	6.7	90.0
Gliocladium penicilloides *	16.7	20.0	26.7	36.7
T. hamatum *	6.7	6.7	6.7	80.0
T. viride *	16.7	6.7	6.7	70.0
Trichoderma harzianum *	0.0	0.0	3.3	96.7
Trichoderma sp 10 **	23.3	26.7	20.0	30.0
Trichoderma sp 2 **	13.3	13.3	13.3	60.0
Trichoderma sp 3 **	16.7	23.3	16.7	43.3
Trichoderma sp 5 **	6.7	0.0	10.0	83.3
Trichoderma sp 6 **	13.3	6.7	10.0	70.0
Trichoderma sp 8 **	16.7	20.0	20.0	43.3
Trichoderma sp 9 **	20.0	6.7	16.7	56.7
Control	30.0	26.7	26.7	16.7
LSD. at 5%	8.17	9.05	7.96	9.53

* Obtained from Biological Control and Onion and Oil Crops Res. Dept Agric., Res. Center Giza, Egypt.
** Isolated from rhizosphere of healthy sesame plants.

E4.1.2 *Collariella* spp. (29 Sep 2021)

Family: Chaetomiaceae

Definition: Amount of biocontrol provided by *Collariella* spp. X. Wei Wang, Samson & Crous 2016.

(Wikipedia, 29 Sep 2021) ***Collariella*** is a fungal genus in the family Chaetomiaceae.

E4.1.2a *Collariella bostrychodes* (29 Sep 2021)

Synonym: *Chaetomium bostrychodes*

Family: Chaetomiaceae

Definition: Amount of biocontrol provided by *Collariella bostrychodes* (Zopf) X. Wei Wang & Samson 2016.

References:

EGYPT

- A.I.I. El-Fiki et al. (2004a) studied the effects of using *Chaetomium bostrycoides* to control *Macrophomina phaseolina* Tassi (Goid). The seeds were planted in pots in the greenhouse and then took percentages as follows: % pre-emergence = damping off within 15 days, % post-emergence = damping off within 45 days, % charcoal rot = diseased at 90 days, and % healthy plants at 90 days. The results with antagonistic fungi were as follow.

Antagonistic fungi and bacteria	% Disease incidence			
	At seedling stage		At maturity stage	
	Pre-emergence	Post-emergence	Charcoal rot	Healthy plants
B. megtella *	16.7	16.7	23.3	43.3
Bacillus sp 3 **	13.3	10.0	23.3	53.3
Bacillus subtillus *	10.0	13.3	20.0	56.7
Chaetomium bostrycoides *	0.0	3.3	6.7	90.0
Gliocladium penicilloides *	16.7	20.0	26.7	36.7
T. hamatum *	6.7	6.7	6.7	80.0
T. viride *	16.7	6.7	6.7	70.0
Trichoderma harzianum *	0.0	0.0	3.3	96.7
Trichoderma sp 10 **	23.3	26.7	20.0	30.0
Trichoderma sp 2 **	13.3	13.3	13.3	60.0
Trichoderma sp 3 **	16.7	23.3	16.7	43.3
Trichoderma sp 5 **	6.7	0.0	10.0	83.3
Trichoderma sp 6 **	13.3	6.7	10.0	70.0
Trichoderma sp 8 **	16.7	20.0	20.0	43.3
Trichoderma sp 9 **	20.0	6.7	16.7	56.7
Control	30.0	26.7	26.7	16.7
LSD. at 5%	8.17	9.05	7.96	9.53

* Obtained from Biological Control and Onion and Oil Crops Res. Dept Agric., Res. Center Giza, Egypt.
** Isolated from rhizosphere of healthy sesame plants.

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E4.2 Family: Sordariaceae G. Winter 1885

(Wikipedia, 7 Jul 2021) The **Sordariaceae** are a family of perithecial fungi within the Sordariales order. The family includes the important model organism *Neurospora crassa* that is used in genetic research. Members of the family include the red bread molds in the genus *Neurospora*, including *Neurospora sitophila*, which is used to produce the fermented food oncom. Other species in the family inhabit herbivore dung or plant parts.

The following species have been identified to provide biocontrol:

- E4.2.1 *Neurospora* spp.
- E4.2.1a *Neurospora sitophila*

E4.2.1 *Neurospora* spp. (7 Jul 2021)

Family: Sordariaceae

Definition: Amount of biocontrol provided by *Neurospora* spp. Shear & B.O. Dodge 1927.

(Wikipedia, 7 Jul 2021) ***Neurospora*** is a genus of Ascomycete fungi. The genus name, meaning “nerve spore” refers to the characteristic striations on the spores that resemble axons.

The best known species in this genus is *Neurospora crassa*, a common model organism in biology. *Neurospora intermedia* var. *oncomensis* is used in food production to make oncom.

The following species has been associated with sesame but there are no known reports of being a pathogen, producing a toxin, inhibiting germination, affecting seed quality, or being used as a biocontrol or biofertilizer.

- *Neurospora glabra* [India]

E4.2.1a *Neurospora sitophila* (7 Jul 2021)

Family: Sordariaceae

Definition: Amount of biocontrol provided by *Neurospora sitophila* Shear & B.O. Dodge 1927.

(Wikipedia, 7 Jul 2021) *Neurospora sitophila* is used to produce the fermented food oncom.

References:

IRAQ

- K.M. Tamini and H.A. Hadwan (1985) reported the differences in the amount of inhibition of growth of a range of sesamum wilt causing fungi by gaseous metabolites from *Neurospora sitophila* and *Trichoderma harzianum*

could be accounted for by differences in their ages. The highest level of growth inhibition from test fungi ever recorded was as follows: 3-day-old *N. sitophila* was 55% on virulent *Rhizoctonia solani*, 51% on a virulent *Rhizoctonia solani*, 48% on *Fusarium oxysporum* and 40% on *Macrophomina phaseoli*. *Other* soilborne fungi were less effective than *N. sitophila*. [Cited by G.S. Saharan, 1989]

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E5 Order: Glomerales Morton and Benny 1990

(Wikipedia, 19 Apr 2021) **Glomerales** is an order of symbiotic fungi within the phylum Glomeromycota. These fungi are all biotrophic mutualists. Most employ the arbuscular mycorrhizal method of nutrient exchange with plants. They produce large (.1-.5mm) spores (azygospores and chlamydospores) with thousands of nuclei

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E5.1 Family: Glomeraceae Piroz. & Dalpe 1989

(Wikipedia, 19 Apr 2021) The ***Glomeraceae*** are a family of arbuscular mycorrhizal (AM) fungi that form symbiotic relationships (mycorrhizas) with plant roots. The family was circumscribed in 1989.

The following species have been used as biofertilizers:

- E5.1.1 *Glomus* spp.
- E5.1.1a *Glomus austrae*
- E5.1.1b *Glomus macrosporium*
- E5.1.2 *Sclerocystis* spp.
- E5.1.2a *Sclerocystis coremioides* (*Syn: *Sclerocystis dussi*)
- E5.1.3 *Funneliformis* spp.
- E5.1.3a *Funneliformis caledonium* (*Syn: *Glomus caledonium*)
- E5.1.3b *Funneliformis geosporum* (*Syn: *Glomus geosporum*)
- E5.1.3c *Funneliformis mosseae* (*Syn: *Glomus mosseae*)
- E5.1.4 *Rhizophagus* spp.
- E5.1.4a *Rhizophagus irregularis*
- E5.1.4b *Rhizophagus fasciatus* (*Syn: *Glomus fasciculatum*)
- E5.1.4c *Rhizophagus clarus* (*Syn: *Glomus clarum*)

E5.1.1 *Glomus* spp. (19 Apr 2021)

Family: Glomeraceae

Definition: Amount of improvement from biofertilizers provided by *Glomus* spp. Tulasne and C. Tulasne 1845.

(Wikipedia, 19 Apr 2021) ***Glomus*** is a genus of arbuscular mycorrhizal (AM) fungi, and all species form symbiotic relationships (mycorrhizas) with plant roots. *Glomus* is the largest genus of AM fungi, with *ca.* 85 species described, but is currently defined as non-monophyletic.

As with other AM fungi, all *Glomus* species are thought to be obligate symbionts, dependent on their mycorrhizal association with plant roots to complete their life cycle. They cannot be cultured in the laboratory in the absence of a plant host. *Glomus* species are found in nearly all terrestrial habitats, including arable land, deserts, grasslands, tropical forests, and tundras.

Arbuscular mycorrhizal fungi can provide numerous benefits to their plant hosts, including improved nutrient uptake, drought resistance, and disease resistance. However, the symbiosis is not mutualistic in all circumstances and may often be parasitic, with a detrimental effect on plant growth. Rarely, some plant species can parasitise the fungi. Spores of *Glomus* prior to germinating produce an electric current.

Glomus species were considered to be entirely asexual until recently. Spores are produced at the tips of hyphae either within the host root or outside the root in the soil. Thought to be chlamydospores, these spores germinate and the germination tube that is produced grows through the soil until it comes into contact with roots. The fungus then penetrates the root and grows between root cells, or it may penetrate the cell wall and grow within root cells. Inside the root, the fungus forms arbuscules, which are highly branched hyphal structures that serve as sites of nutrient exchange with the plant. Arbuscules are formed within plant cell walls but are surrounded by an invaginated cell membrane, so remain within the apoplast. The fungus may also form vesicles, swollen structures which are thought to function as food storage organs.

References:

EGYPT

- A.I.I. El-Fiki et al. (2004a) studied the effects of using *Glomus* sp. to control *Macrophomina phaseolina* Tassi (Goid). They tested inoculating pathogen-infested soil with different soil preparations of vesicular arbuscular-mycorrhizal fungi (Vesicular arbuscular mycorrhizae fungus - VAM). The results were as follow.

VAM soil preparation	% Disease incidence			
	At seedling stage		At mature plant stage	
	% Pre-emergence	% Post-emergence	% Charcoal rot	% Healthy plants
G. macrocarpum [G1]	3.3	10.0	10.0	76.7
G. australe [G2]	23.3	16.7	16.7	43.3
Glomus sp. [G3]	20.0	13.3	13.3	53.3
Malti VAM [G4]	13.3	10.0	13.3	63.3
G1 + G2	20.0	16.7	16.7	46.7
G1 + G3	16.7	16.7	13.3	53.3
G1 + Malti VAM [G4]	16.7	13.3	10.0	60.0
G2 + G3	13.3	13.3	10.0	63.3
G2 + Malti VAM [G4]	10.0	16.7	13.3	60.0
G3 + Malti VAM [G4]	6.7	10.0	13.3	70.0
G1+G2 + G3 + [G4]	0.0	6.7	6.7	86.7
Control	23.3	20.0	20.0	36.7
LSD. At 5%	9.63	n.s.	n.s.	8.55

- I.S. Elewa et al. (2011) evaluated the effects of *Bacillus subtilis* and *Trichoderma viride*, a virulent *Fusarium oxysporum*, and *Glomus* spp. (Vesicular arbuscular mycorrhizae fungus - VAM) isolates and a fungicide (Benlate) on *Fusarium oxysporum* f. sp. *sesami* and *Macrophomina phaseolina*. The results were as follow.

Soil infestation	Treatment	Wilt and root-rot	
	Transplants	Infection %	Disease severity
F. oxysporum	Control	37.5 a	1.87 a
	B. subtilis	33.3 b	1.66 b
	Avirulent *F. oxysporum*	24.9 c	1.25 c
	T. viride	24.9 c	1.25 c
	(VAM)	16.6 d	0.83 d
	Benlate (0.1%)	16.6 d	0.83 d
M. phaseolina	Control	33.3 a	1.66 ab
	B. subtilis	16.6 d	0.83 d
	Avirulent *F. oxsporum*	8.3 e	0.42 e
	T. viride	16.6 d	0.63 e
	(VAM)	12.5 d	0.62 e
	Benlate (0.1%)	16.6 d	0.83 d
F. oxysporum + *M. phaseolina*	Control	20.8 ab	1.04 bcd
	B. subtilis	12.5 d	0.62 e
	Avirulent *F. oxysporum*	12.5 d	0.62 e
	T. viride	16.6 d	0.83 d
	(VAM)	8.3 e	0.42 e
	Benlate (0.1%)	12.5 d	0.62 e

- E.H. Ziedan et al. (2011) evaluated the effects of *Bacillus subtilis* and *Trichoderma viride*, and *Glomus* spp. (a Vesicular arbuscular mycorrhizae fungus [VAM]) isolates on *Fusarium oxysporum* f. sp. *sesami* and *Macrophomina phaseolina*. The effects on *Fusarium oxysporum* f. sp. *sesami* in the pot experiments were as follow.

Treatments	Wilt disease incidence		Morphological characters/plant		
	% of diseased plants	disease severity	length [cm]	fresh weight [g]	No. of pods
Control	79.2 a	4.0 a	68.3 d	7.4 d	6.0 c
B. subtilis	66.7 ab	3.3 b	80.0 c	11.7 c	6.7 c
T. viride	50.0 b	2.5 c	103.8 ab	12.6 c	14.7 b
VAM	50.0 b	2.5 c	80.0 c	14.4 c	6.8 c
VAM + *B. subtilis*	29.2 d	1.5 d	115.6 a	18.7 b	19.0 a
VAM + *T. viride*	36.7 c	1.3 d	93.3 b	15.0 c	14.0 b
VAM + *B. subtilis* + *T. viride*	37.5 c	1.1 d	106.0 ab	25.3 a	20.0 a

The effects on *Macrophomina phaseolina* in the pot experiments were as follow.

Treatments	Root-rot incidence		Morphological characters /plant		
	% of diseased plants	disease severity	length [cm]	fresh weight [g]	No. of pods
Control	91.7 a	4.6 a	77.5 c	5.52 d	4.61 f
B. subtilis	50.0 c	2.5 c	101.9 a	19.4 a	12.6 b
T. viride	45.8 d	2.3 c	101.3 a	18.1 a	10.3 c
VAM	45.8 d	2.5 c	80.0 b	8.1 c	6.0 e
VAM + *B. subtilis*	45.8 d	2.4 c	104.4 a	18.2 a	9.8 d
VAM + *T. viride*	43.7 b	3.3 b	104.2 a	17.7 b	9.5 d
VAM + *B. subtilis* + *T. viride*	41.7 c	2.1 d	103.8 a	19.3 a	13.0 a

The effects from *Fusarium oxysporum* f. sp. *sesami* and *Macrophomina phaseolina* on seedlings in the field experiments were as follow.

Treatments	Wilt and root-rot incidence		
	% of survival plants	% of diseased plants	disease severity
Control	51.0 d	55.9 a	2.8 a
B.subtilis	54.1 c	50.0 b	2.5 b
T.viride	67.5 b	39.2 c	1.9 c
VAM	56.7 c	48.4 bc	2.4 b
VAM + *B. subtilis*	66.6 b	34.2 cd	1.7 c
VAM + *T. viride*	79.3 a	23.3 e	1.2 e
VAM + *B. subtilis*+ *T. viride*	76.0 a	30.9 d	1.5 cd

The effects from *Fusarium oxysporum* f. sp. *sesami* and *Macrophomina phaseolina* on the yield components in the field experiments were as follow.

Treatments	Shoot		Root size	Number/plant		Seed yield aradeb/ feddan	Oil [%]
	length [cm]	diameter [cm]		branches	pods		
Control	185.0 e	1.76 d	25.0 f	3.75 f	112.5 e	2.53 d	59.5
B. subtilis	196.3 c	1.99 b	50.0 b	5.3 e	197.5 c	4.55 c	56.9
T. viride	180.0 d	1.88 c	35.0 d	7.5 b	212.5 b	4.91 c	57.8
VAM	195.0 c	1.85 c	30.0 e	5.0 e	160.0 d	5.14 b	57.4
VAM + *B. subtilis*	210.0 a	1.77 d	35.0 c	6.75 c	196.3 c	4.95 c	57.1
VAM + *T. viride*	202.5 b	1.82 c	47.5 b	6.0 d	198.0 c	5.05 b	57.2
VAM + *B. subtilis* + *T. viride*	202.5 b	2.33 a	70.0 a	8.5 a	232.5 a	5.79 a	57.8

INDIA

- M. Vijayalakshmi and A.S. Rao (1988) reported *Glomus* sp. in the rhizosphere soil of sesame plants.

E5.1.1a *Glomus austrae* (19 Apr 2021)

Family: Glomeraceae

Definition: Amount of improvement from biofertilizers provided by *Glomus austrae* (Berk.) S.M. Berch 1983.

References:

EGYPT

- A.I.I. El-Fiki et al. (2004a) studied the effects of using *Glomus austrae* to control *Macrophomina phaseolina* Tassi (Goid). They tested inoculating pathogen-infested soil with different soil preparations of vesicular arbuscular-mycorrhizal (VAM) fungi. The results were as follow.

VAM soil preparation	% Disease incidence			
	At seedling stage		At mature plant stage	
	% Pre-emergence	% Post-emergence	% Charcoal rot	% Healthy plants
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G. australe [G2]	23.3	16.7	16.7	43.3
Glomus sp. [G3]	20.0	13.3	13.3	53.3
Malti VAM [G4]	13.3	10.0	13.3	63.3
G1 + G2	20.0	16.7	16.7	46.7
G1 + G3	16.7	16.7	13.3	53.3
G1 + Malti VAM [G4]	16.7	13.3	10.0	60.0
G2 + G3	13.3	13.3	10.0	63.3
G2 + Malti VAM [G4]	10.0	16.7	13.3	60.0
G3 + Malti VAM [G4]	6.7	10.0	13.3	70.0
G1+G2 + G3 + [G4]	0.0	6.7	6.7	86.7
Control	23.3	20.0	20.0	36.7
LSD. At 5%	9.63	n.s.	n.s.	8.55

E5.1.1b *Glomus macrocarpum* (19 Apr 2021)

Family: Glomeraceae

Definition: Amount of improvement from biofertilizers provided by *Glomus macrocarpum* Tulasne & C. Tulasne 1845.

References:

EGYPT

- A.I.I. El-Fiki et al. (2004a) studied the effects of using *Glomus macrocarpum* to control *Macrophomina phaseolina* Tassi (Goid). They tested inoculating pathogen-infested soil with different soil preparations of vesicular arbuscular-mycorrhizal (VAM) fungi. The results were as follow.

VAM soil preparation	% Disease incidence			
	At seedling stage		At mature plant stage	
	% Pre-emergence	% Post-emergence	% Charcoal rot	% Healthy plants
G. macrocarpum [G1]	3.3	10.0	10.0	76.7
G. australe [G2]	23.3	16.7	16.7	43.3
Glomus sp. [G3]	20.0	13.3	13.3	53.3
Malti VAM [G4]	13.3	10.0	13.3	63.3
G1 + G2	20.0	16.7	16.7	46.7
G1 + G3	16.7	16.7	13.3	53.3
G1 + Malti VAM [G4]	16.7	13.3	10.0	60.0
G2 + G3	13.3	13.3	10.0	63.3
G2 + Malti VAM [G4]	10.0	16.7	13.3	60.0
G3 + Malti VAM [G4]	6.7	10.0	13.3	70.0
G1+G2 + G3 + [G4]	0.0	6.7	6.7	86.7
Control	23.3	20.0	20.0	36.7
LSD. At 5%	9.63	n.s.	n.s.	8.55

E5.1.2 *Sclerocystis* spp. (8 Jul 2021)

Family: Glomeraceae

Definition: Amount of improvement from biofertilizers provided by *Sclerocystis* spp. Berk & Broome 1873.

References:

INDIA

- M. Vijayalakshmi and A.S. Rao (1988) reported *Sclerocystis* sp. in the rhizosphere soil of sesame plants.

E5.1.2a *Sclerocystis coremioides* (8 Jul 2021)

Synonym : *Sclerocystis dussi*

Family: Glomeraceae

Definition: Amount of improvement from biofertilizers provided by *Sclerocystis coremioides* Berk. & Broome.

References:

INDIA

- S.J. Sabannavar and H.C. Lakshman (2009) evaluated the effects of inoculation with arbuscular mycorrhizal fungi (AMF) *Glomus fasciculatum* (Gf), *Acaulospora laevis* (Al), *Sclerocystis dussi* (Sd) and *Gigaspora margarita* (Gm) using 2 varieties (TSES 1 and TSES 4) with phosphate solubilizing bacteria (*Pseudomonas striata* – Ps) in the presence of different doses of rock phosphate (0, 7.5, 15.0, and 22.5 mg/kg) in clay pots. The Gf was the best followed by Al.

E5.1.3 *Funneliformis* spp. (30 Sep 2021)

Family: Glomeraceae

Definition: Amount of improvement from biofertilizers provided by *Funneliformis* spp. C. Walker & A. Schüßler 2010.

(Wikipedia, 30 Sep 2021) ***Funneliformis*** is a genus of fungi in the family Glomeraceae. All species are arbuscular mycorrhizal (AM) fungi that form symbiotic relationships (mycorrhizaa) with plant roots. The genus was circumscribed in 2010 by Arthur Schüßler and Christopher Walker, with *Funneliformis mosseae* (originally described in 1968 as a species of *Endogone*) as the type species. The generic name refers to the funnel-shaped spore base present in several species.

References:

MEXICO

- Agrolytics.org (2021) reported sesame hosts *Funneliformis* spp.

E5.1.3a *Funneliformis caledonium* (30 Sep 2021)

Synonym: *Glomus caledonium*

Family: Glomeraceae

Definition: Amount of improvement from biofertilizers provided by *Funneliformis caledonium* (T.H. Nicolson & Gerd.) C. Walker & A. Schüßler 2010.

References:

IRAN

- M. Ghasemi and M. Zahedi (2021) in a pot experiment tested the effects of mycorrhizal fungi on sesame using 2 varieties (Yekta and Nas). Results showed that the effects of the interaction between mycorrhizal species and cultivars were significant on colonization rate, the contents of phosphorus, potassium, iron, zinc, chlorophyll, carotenoids and soluble carbohydrates and also on shoot dry weight. *Glomus caledonium* increased the content of iron in Yekta by 126%. [Based on abstract]

E5.1.3b *Funneliformis geosporum* (30 Sep 2021)

Synonym: *Glomus geosporum*

Family: Glomeraceae

Definition: Amount of improvement from biofertilizers provided by *Funneliformis geosporum* (T.H. Nicolson & Gerd.) C. Walker & A. Schüßler 2010.

References:

IRAN

- M. Ghasemi and M. Zahedi (2021) in a pot experiment tested the effects of mycorrhizal fungi on sesame using 2 varieties (Yekta and Nas). Results showed that the effects of the interaction between mycorrhizal species and cultivars were significant on colonization rate, the contents of phosphorus, potassium, iron, zinc, chlorophyll, carotenoids and soluble carbohydrates and also on shoot dry weight. Glomus geosporum increased the content of zinc in Yekta by 54%. [Based on abstract]

E5.1.3c *Funneliformis mosseae* (25 Sep 2021)

Synonym: *Glomus mosseae*

Family: Glomeraceae

Definition: Amount of improvement from biofertilizers provided by *Funneliformis mosseae* (T.H. Nicolson & Gerd.) C. Walker & A. Schüßler 2010.

References:

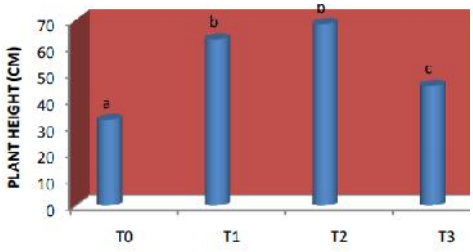
IRAN

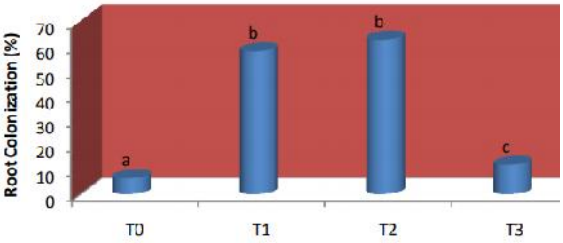
- M. Ghasemi and M. Zahedi (2021) in a pot experiment tested the effects of mycorrhizal fungi on sesame using 2 varieties (Yekta and Nas). Results showed that the effects of the interaction between mycorrhizal species and cultivars were significant on colonization rate, the contents of phosphorus, potassium, iron, zinc, chlorophyll, carotenoids and soluble carbohydrates and also on shoot dry weight. Funneliformis mosseae increased the content of potassium in Nas by 38% and increased the shoot weight of Yekta by 23%. [Based on abstract]

NIGERIA

- R. Abdullahi et al. (2013) evaluated the effects of biofertilizers and chicken manure on sesame. The treatments were as follow.
  - T0: Control
  - T1: *Azospirillum* spp. + *Glomus mosseae*
  - T2: *Azospirillum* spp. + *Glomus mosseae* + 10 t/ha poultry manure
  - T3: 10 t/ha poultry manure

  The results at 6 WAS were as follow:





Treatments	No. of branches /plant	No. of leaves /plant	Leaf (dm^{-2})	Dry biomass (g/plant) Shoot	Root
T0 Control	4.5[a]	42.3[a]	3.8[a]	4.45[a]	2.72[a]
T1 Bio-fertilizer	7.3[b]	92.8[b]	5.3[b]	5.40[b]	3.70[b]
T2 Bio-organic	8.3[b]	98.1[b]	6.2[c]	6.18[c]	3.88[bc]
T3 PM	7.3[b]	75.3[c]	5.1[b]	5.35[b]	3.62[b]
LSD (5%)	1.92	7.08	0.67	0.62	0.22

Treatments	Concentration (%)			Uptakes (kg ha^{-1})		
	N	P	K	N	P	K
T0 Control	1.82^{a}	0.32^{a}	0.98^{a}	12.47^{a}	1.34^{a}	34.56^{a}
T1Biofertilizer	3.54^{b}	0.51^{b}	1.43^{b}	36.38^{b}	5.62^{b}	50.41^{b}
T2Bio-organic	3.93^{c}	0.56^{c}	1.62^{c}	40.96^{c}	6.79^{c}	51.44^{b}
T3PM	3.20^{d}	0.46^{d}	1.30^{d}	31.42^{d}	3.02^{d}	45.47^{c}
LSD (5%)	0.11	0.02	0.09	3.76	0.54	3.98

E5.1.4 *Rhizophagus* spp. (30 Sep 2021)

Family: Glomeraceae

Definition: Amount of improvement from biofertilizers provided by *Rhizophagus* spp. P.A. Dang 1896.

(Wikipedia, 30 Sep 2021) ***Rhizophagus*** is a genus of arbuscular mycorrhizal (AM) fungi that form symbiotic relationships (mycorrhizas) with plant roots. The genome of *Rhizophagus irregularis* (formerly *Glomus intraradices*) was recently sequenced.

E5.1.4a *Rhizophagus irregularis* (30 Sep 2021)

Family: Glomeraceae

Definition: Amount of improvement from biofertilizers provided by *Rhizophagus irregularis* (Błaszk., Wubet, Renker & Buscot) C. Walker & A. Schüßler 2010.

(Wikipedia, 30 Sep 2021) ***Rhizophagus irregularis*** (previously known as *Glomus intraradices*) is an arbuscular mycorrhizal fungus used as a soil inoculant in agriculture and horticulture. In addition, it is one of the best mycorrhizal varieties of fungi available to mycoforestry, but as it does not produce fruiting bodies it "has virtually no market value as an edible or medicinal mushroom"

Rhizophagus irregularis is also commonly used in scientific studies of the effects of arbuscular mycorrhizal fungi on plant and soil improvement. Until 2001, the species was known and widely marketed as *Glomus intraradices*, but molecular analysis of ribosomal DNA led to the reclassification of all arbuscular fungi from Zygomycota phylum to the Glomeromycota phylum.

References:

IRAN

- M. Ghasemi and M. Zahedi (2021) in a pot experiment tested the effects of mycorrhizal fungi on sesame using 2 varieties (Yekta and Nas). Results showed that the effects of the interaction between mycorrhizal species and cultivars were significant on colonization rate, the contents of phosphorus, potassium, iron, zinc, chlorophyll, carotenoids and soluble carbohydrates and also on shoot dry weight. *Rhizophagus irregularis* increased the shoot weight of Yekta by 20%. [Based on abstract]

E5.1.4b *Rhizophagus fasciculatus* (30 Sep 2021)

Synonym: *Glomus fasciculatum*

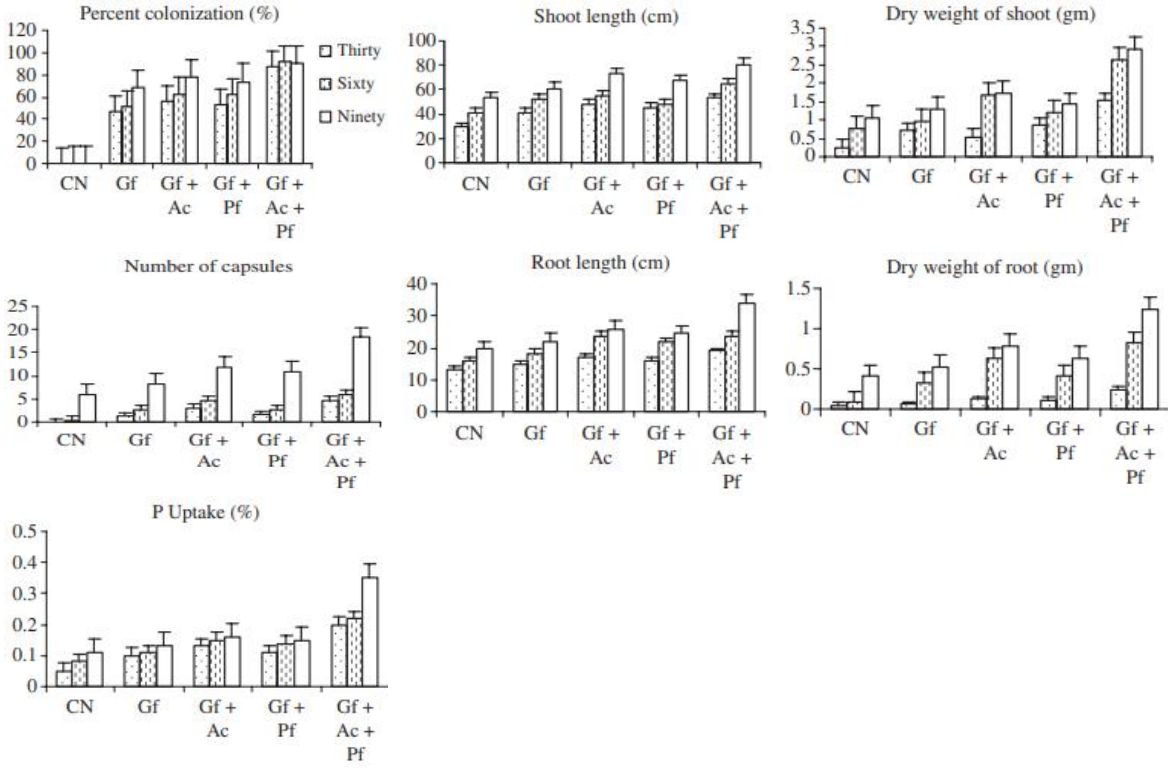
Family: Glomeraceae

Definition: Amount of biocontrol provided by *Rhizophagus fasciculatus* (Thaxt.) C. Walker & A. Schüßler 2010.

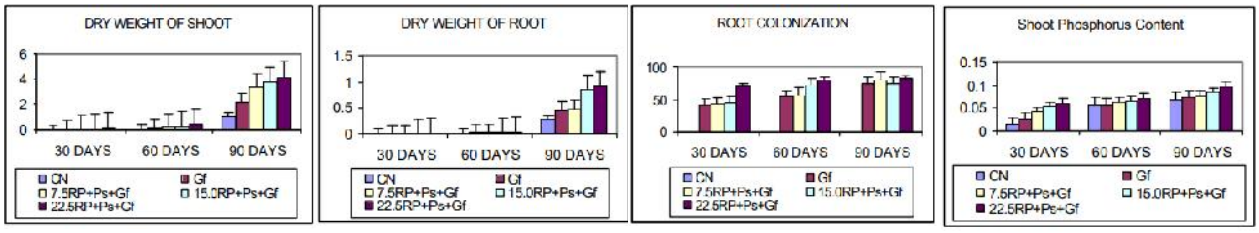
References:

INDIA

- S.J. Sabannavar and H.C. Lakshman (2008) evaluated the effects of a single inoculation of *Glomus fasciculatum* (Gf) *Acaulospora laevis* (Ac), and dual inoculation of arbuscular mycorrhizal fungi (AMF) with *Azotobacter chroococcum* (Ac) or *Pseudomonas fluorescens* (Pf) and a triple inoculation of AMF, *A. chroococcum* and *P. fluorescens* using 2 varieties (DS1 and E8) in a pot experiment. The results revealed that inoculation of AMF + Ac + Pf stimulated increased AMF colonization, plant growth, i.e., shoot, root length, fresh and dry weight of shoot and root, phosphorus uptake and number of capsules significantly over the dual and single inoculation treatments. The association of bacteria and AMF provides evidence that bacteria are involved in the beneficial effects to AMF on sesame varieties. The results for *Glomus fasciculatum* at 30, 60, and 90 days after planting were as follow (CN = control).



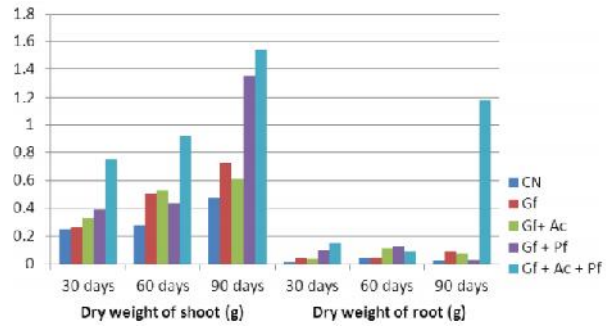
- S.J. Sabannavar and H.C. Lakshman (2009) evaluated the effects of inoculation with arbuscular mycorrhizal fungi (AMF) *Glomus fasciculatum* (Gf), *Acaulospora laevis* (Al), *Sclerocystis dussi* (Sd) and *Gigaspora margarita* (Gm) using 2 varieties (TSES 1 and TSES 4) with phosphate solubilizing bacteria (*Pseudomonas striata* – Ps) in the presence of different doses of rock phosphate (0, 7.5, 15.0, and 22.5 mg/kg) in clay pots. Phosphate solubilizing bacteria behaved as mycorrhiza helper bacteria promoting higher colonization rate and spore number of AMF which helps in solubilization of the mineral phosphate and contribute to the biogeochemical P cycling, thus promoting a sustainable nutrient supply to the crop plants for higher yield. The results for Gf on TSES 1 were as shown below.

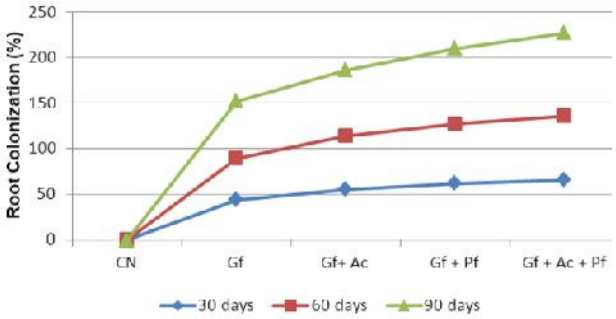


There is more data on shoot and root length, shoot and root fresh weight, number of capsules, and spore number on both Gf and Ac. There is no data for Sd or Gm.

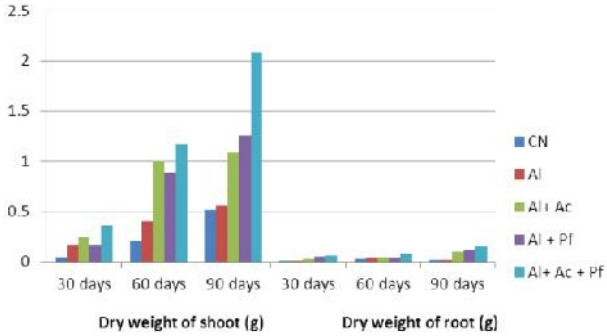
- S.J. Sabannavar and H.C. Lakshman (2011) evaluated the effect of co-inoculation with bacteria and arbuscular mycorrhizal (AM) fungi on the growth of sesame. The two varieties of sesame TSES 1 and TSES 4 were inoculated with single, double, and triple inoculations. The results revealed that triple inoculation of *Glomus fasciculatum* (Gf) + *Azotobacter chroococcum* (Ac) + *Pseudomonas fluorescens* (Pf) to TSES 1 and

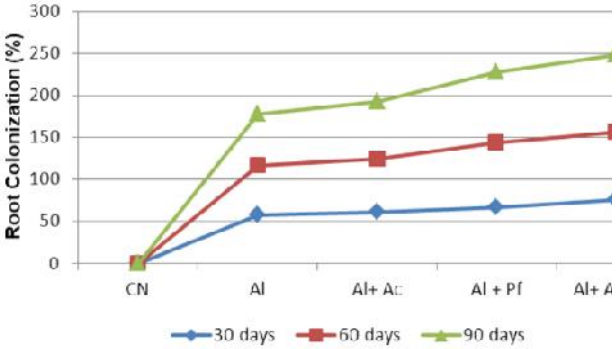
Acaulospora laevis (Al) + Ac + Pf to TSES 4 stimulated increased root colonization, plant growth, plant biomass, phosphorus content, and number of capsules significantly over the double and single inoculation treatments. These results suggest synergistic interaction among AM fungi, *Azotobacter chroococcum*, and *Pseudomonas fluorescens*. The association of bacteria and AM fungi provide evidence that bacteria are involved in the beneficial effects to AM fungi on plant growth and can improve crop production. The results for TSES 1 with Gf were as follow (CN = control).





The results for TSES 4 with Al were similar.





IRAN

- M. Ghasemi and M. Zahedi (2021) in a pot experiment tested the effects of mycorrhizal fungi on sesame using 2 varieties (Yekta and Nas). Results showed that the effects of the interaction between mycorrhizal species and cultivars were significant on colonization rate, the contents of phosphorus, potassium, iron, zinc, chlorophyll, carotenoids and soluble carbohydrates and also on shoot dry weight. *Glomus fasciculatum* increased the content of phosphorus in Yekta by 72%, the content of potassium in Nas by 38%, and the shoot weight of Nas by 17%. [Based on abstract]

E5.1.4c *Rhizophagus clarus* (28 Aug 2021)

Synonym: *Glomus clarum*

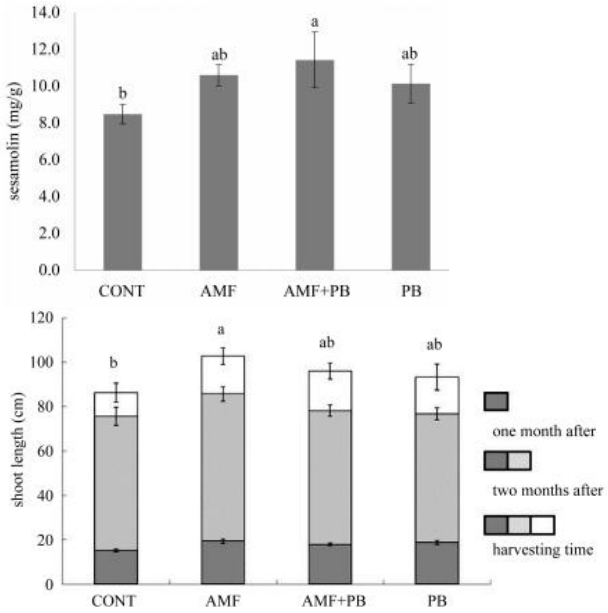
Family: Glomeraceae

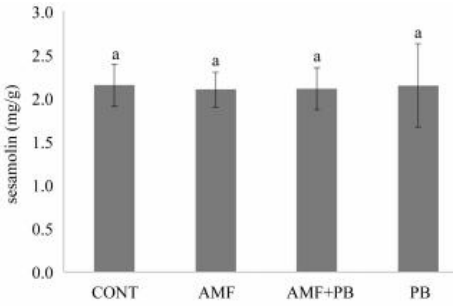
Definition: Amount of improvement from biofertilizers provided by *Rhizophagus clarus* (T.H. Nicolson & N.C. Schenck) C. Walker & A. Schüßler 2010.

References:

JAPAN

- S. Horii and T. Ishii (2014) evaluated the effect of *Pseudomonas* sp. (PB) and an arbuscular mycorrhizal fungus (AMF - *Glomus clarum*) compared to a control (CONT) on the growth and production of sesamin in sesame with the following results.





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E5.2 Family: Claroideoglomeraceae C. Walker & A. Schüßler, 2010

E5.2.1 *Claroideoglomus spp.* (30 Sep 2021)

Family: Glomeraceae

Definition: Amount of improvement from biofertilizers provided by *Claroideoglomus spp* C. Walker & A. Schüßler 2010.

The following species have been used as biofertilizers:
- E5.2.1a *Claroideoglomus etunicatum*
- E5.2.1b *Claroideoglomus claroideum*

E5.2.1a *Claroideoglomus etunicatum* (30 Sep 2021)

Family: Glomeraceae

Definition: Amount of improvement from biofertilizers provided by *Claroideoglomus etunicatum* (W.N. Becker & Gerd.) C. Walker & A. Schüßler 2010.

References:

IRAN
- M. Ghasemi and M. Zahedi (2021) in a pot experiment tested the effects of mycorrhizal fungi on sesame using 2 varieties (Yekta and Nas). Results showed that the effects of the interaction between mycorrhizal species and cultivars were significant on colonization rate, the contents of phosphorus, potassium, iron, zinc, chlorophyll, carotenoids and soluble carbohydrates and also on shoot dry weight. *Claroideoglomus etunicatum increased the content of potassium in Nas by 38%.* [Based on abstract]

E5.2.1b *Claroideoglomus claroideum* (30 Sep 2021)

Family: Glomeraceae

Definition: Amount of improvement from biofertilizers provided by *Claroideoglomus claroideum* (N.C. Schenck & G.S. Sm.) C. Walker & A. Schüßler 2010.

References:

IRAN

- M. Ghasemi and M. Zahedi (2021) in a pot experiment tested the effects of mycorrhizal fungi on sesame using 2 varieties (Yekta and Nas). Results showed that the effects of the interaction between mycorrhizal species and cultivars were significant on colonization rate, the contents of phosphorus, potassium, iron, zinc, chlorophyll, carotenoids and soluble carbohydrates and also on shoot dry weight. *Claroideoglomus clarodoium* increased the shoot weight of Nas by 41%. [Based on abstract]

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E6 Order: Diversisporales C. Walker & A. Schüßler 2010

(Wikipedia, 14 Jun 2021) The *Diversisporales* are an order of generally hypogeous (underground) arbuscular mycorrhizal fungi within the division Glomeromycota. Many have vesicles for energy storage, or auxiliary cells. Species produce a wide range of spore types, hence the name.

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E6.1 Family: Acaulosporaceae J.B. Morton & Benny 1990

(Wikipedia, 14 Jun 2021) The ***Acaulosporaceae*** are a family of fungi in the order Diversisporales. Species in this family are widespread in distribution and form arbuscular mycorrhiza and vesicles in roots. The family contains two genera and 31 species.

The following species have been used as a biofertilizer:
- E6.1.1 *Acaulospora* spp.
- E6.1.1a *Acaulospora laevis*

E6.1.1 *Acaulospora* spp. (14 Jun 2021)

Family: Acaulosporaceae

Definition: Amount of improvement from biofertilizers provided by *Acaulospora* ssp. Gerd. & Trappe 1974.

(Wikipedia, 14 Jun 2021) ***Acaulospora*** is a genus of fungi in the family Acaulosporaceae. Species in this genus are widespread in distribution and form arbuscular mycorrhiza and vesicles in roots.

E6.1.1a *Acaulospora laevis* (14 Jun 2021)

Family: Acaulosporaceae

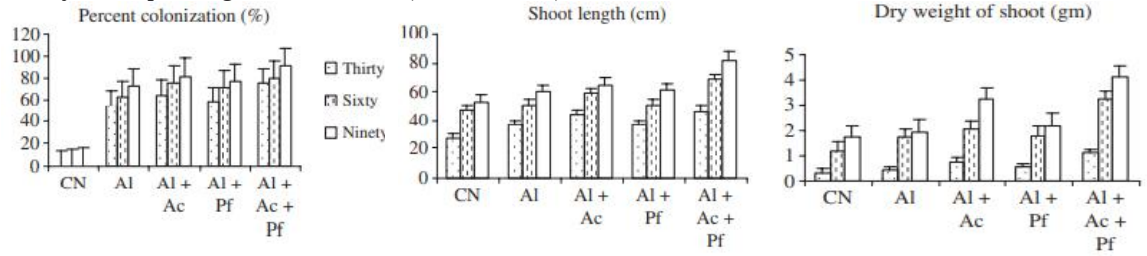
Definition Amount of improvement from biofertilizers provided by *Acaulospora laevis* Gerd. & Trappe 1974.

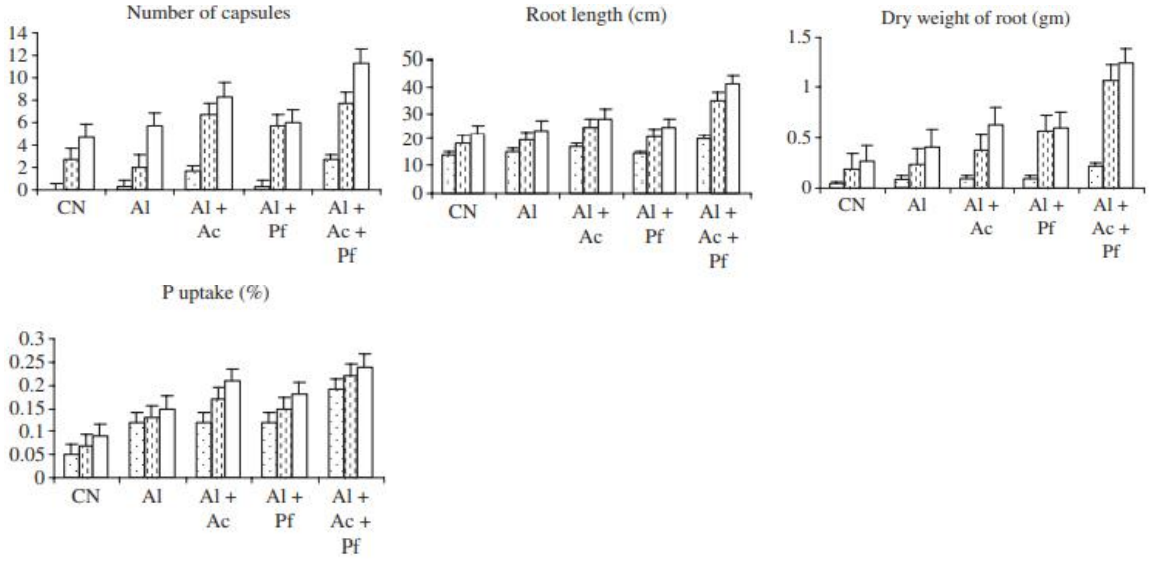
(Wikipedia, 14 Jun 2021) ***Acaulospora laevis*** is a species of fungi in the family Acaulosporaceae. It forms arbuscular mycorrhiza and vesicles in roots.

References:

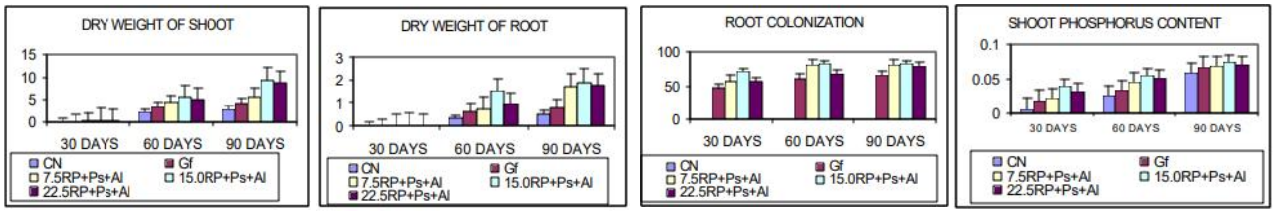
INDIA

- S.J. Sabannavar and H.C. Lakshman (2008) evaluated the effects of a single inoculation of *Glomus fasciculatum* (Gf) and *Acaulospora laevis* (Al), dual inoculation of arbuscular mycorrhizal fungi (AMF) with *Azotobacter chroococcum* (Ac) or *Pseudomonas fluorescens* (Pf) and a triple inoculation of AMF, *A. chroococcum* and *P. fluorescens* using 2 varieties (DS1 and E8) in a pot experiment. The results revealed that inoculation of AMF + Ac + Pf stimulated increased AMF colonization, plant growth, i.e., shoot, root length, fresh and dry weight of shoot and root, phosphorus uptake and number of capsules significantly over the dual and single inoculation treatments. The association of bacteria and AMF provides evidence that bacteria are involved in the beneficial effects to AMF on sesame varieties. The results for *Acaulospora laevis* at 30, 60, and 90 days after planting were as follow (CN = control).



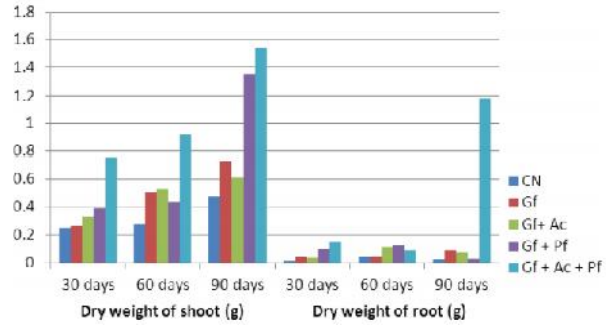


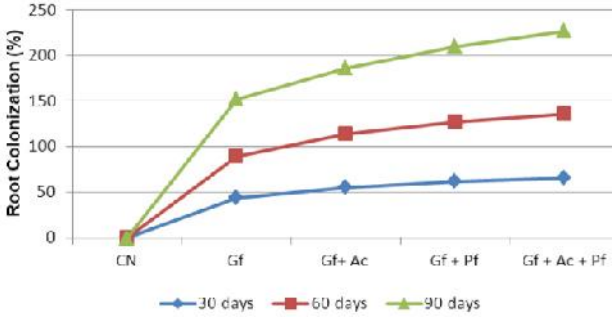
- S.J. Sabannavar and H.C. Lakshman (2009) evaluated the effects of inoculation with arbuscular mycorrhizal fungi (AMF) *Glomus fasciculatum* (Gf), *Acaulospora laevis* (Al), *Sclerocystis dussi* (Sd) and *Gigaspora margarita* (Gm) using 2 varieties (TSES 1 and TSES 4) with phosphate solubilizing bacteria (*Pseudomonas striata* – Ps) in the presence of different doses of rock phosphate (0, 7.5, 15.0, and 22.5 mg/kg) in clay pots. Phosphate solubilizing bacteria behaved as mycorrhiza helper bacteria promoting higher colonization rate and spore number of AMF which helps in solubilization of the mineral phosphate and contribute to the biogeochemical P cycling, thus promoting a sustainable nutrient supply to the crop plants for higher yield. The results for Al on TSES 4 are shown below.



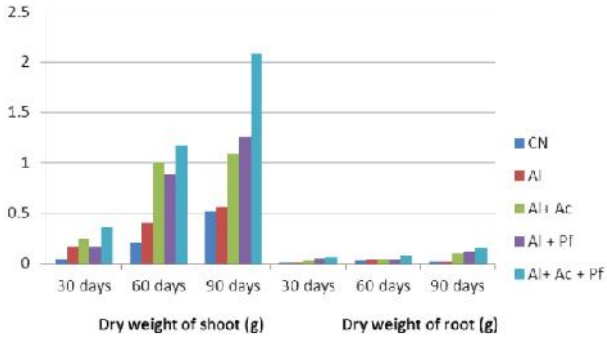
There is more data on shoot and root length, shoot and root fresh weight, number of capsules, and spore number on both Gf and Al. There is no data for Sd or Gm.

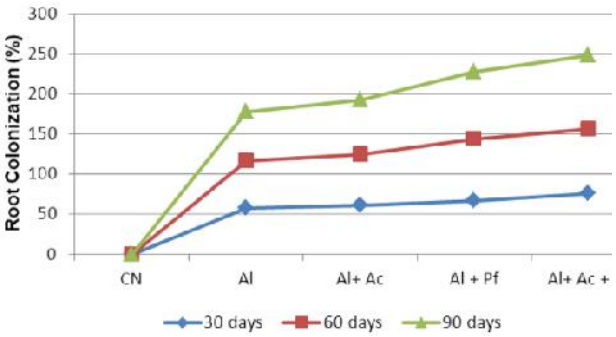
- S.J. Sabannavar and H.C. Lakshman (2011) evaluated the effect of co-inoculation with bacteria and arbuscular mycorrhizal (AM) fungi on the growth of sesame. The two varieties of sesame TSES 1 and TSES 4 were inoculated with single, double, and triple inoculations. The results revealed that triple inoculation of *Glomus fasciculatum* (Gf) + *Azotobacter chroococcum* (Ac) + *Pseudomonas fluorescens* (Pf) to TSES 1 and *Acaulospora laevis* (Al) + Ac + Pf to TSES 4 stimulated increased root colonization, plant growth, plant biomass, phosphorus content, and number of capsules significantly over the double and single inoculation treatments. These results suggest synergistic interaction among AM fungi, *Azotobacter chroococcum*, and *Pseudomonas fluorescens*. The association of bacteria and AM fungi provide evidence that bacteria are involved in the beneficial effects to AM fungi on plant growth and can improve crop production. The results for TSES 1 with Gf were as follow (CN = control).





The results for TSES 4 with Al were similar.





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E6.2 Family: Gigasporaceae J.B. Morton & Benny

(Wikipedia, 8 Jul 2021) The **Gigasporaceae** are a family of fungi in the order Diversisporales. Species in this family are widespread in distribution and form arbuscular mycorrhiza in roots.

The following species have been used as biofertilizers:

- E6.2.1 *Gigaspora* spp.
- E6.2.1a *Gigaspora margarita*

E6.2.1 *Gigaspora* spp. (8 Jul 2021)

Family: Gigasporaceae

Definition: Amount of improvement from biofertilizers provided by *Gigaspora* spp. Gerd. & Trappe 1974.

References:

INDIA

- M. Vijayalakshmi and A.S. Rao (1988) reported *Gigaspora* sp. in the rhizosphere soil of sesame plants.

E6.2.1a *Gigaspora margarita* (8 Jul 2021)

Family: Gigasporaceae

Definition: Amount of improvement from biofertilizers provided by *Gigaspora margarita* W.N. Becker & I.R. Hall 1976.

References:

INDIA

- S.J. Sabannavar and H.C. Lakshman (2009) evaluated the effects of inoculation with arbuscular mycorrhizal fungi (AMF) *Glomus fasciculatum* (Gf), *Acaulospora laevis* (Al), *Sclerocystis dussi* (Sd) and *Gigaspora margarita* (Gm) using 2 varieties (TSES 1 and TSES 4) with phosphate solubilizing bacteria (*Pseudomonas*

striata – Ps) in the presence of different doses of rock phosphate (0, 7.5, 15.0, and 22.5 mg/kg) in clay pots. The Gf was the best followed by Al.

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E7 Order: Entomophthorales Winter 1880

(Wikipedia, 2 Mar 2021) The **Entomophthorales** are an order of fungi that were previously classified in the class Zygomycetes. A new subdivision, Entomophthoromycotina, has recently been circumscribed for them.

Most species of the Entomophthorales are pathogens of insects. A few attack nematodes, mites, and tardigrades, and some (particularly species of the genus *Conidiobolus*) are free-living saprotrophs.

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E7.1 Family: Entomophthoraceae A.B. Frank 1874

(Wiktionary.org, 2 Mar 2021) A taxonomic family within the order Entomophthorales – fungi pathogens that infect insects and certain other invertebrates.

The following species have been identified to provide biocontrol of insects that are pests of sesame:
- E7.1.1 *Zoophthora* spp.
- E7.1.1a *Zoophthora radicans*

E7.1.1a *Zoophthora* spp. (14 Sep 2021)

Family: Entomophthoraceae

Definition: The presence on sesame plants of *Zoophthora* spp. A. Batko 1964.

(Wikipedia, 14 Se; 2021) *Zoophthora* is a genus of fungi in the family Entomophthoraceae. Like other taxa in this family, *Zoophthora* species cause disease in insects and as such are considered entomopathogenic fungi.

Like most entomopathogenic fungal taxa, *Zoophthora* has been studied largely in the context of biological control of insect pest species. However, recent research indicates that many fungal taxa that have historically been considered entomopathogenic (e.g., *Zoophthora*) may serve diverse ecological roles as free-living members of the rhizosphere, as endophytes of plant tissue, and as saprobes.

E7.1.1a *Zoophthora radicans* (2 Mar 2021)

Family: Entomophthoraceae

Definition: The presence on sesame plants of *Zoophthora radicans* A. Batko 1964.

(mycocosm.jgi.doe.gov, 2 Mar 2021) *Zoophthora radicans* is well known representative of the family Entomophthoraceae. This ubiquitous insect pathogens were found in various ecosystems and agricultural areas in all continents except Antarctica. The ARSEF-USDA fungal collection (Ithaca, New York, USA) preserves over 500 isolates of this fungus mostly from USA, Brazil, Mexico, Argentina, France, Denmark, former republics of Yugoslavia, Israel, Japan. *Zoophthora radicans* is a typical generalist pathogen able to infect the arthropods from several unrelated families: Lepidoptera, Diptera, Homoptera and Hymenoptera. Many of its numerous hosts are important pests of agricultural crops: aphids, leafhoppers, planthoppers, Nematocera and cabbage flies, hoverflies, pine sawflies, spruce budworms, rice leafrollers, painted bugs; diamondback, tomato, codling and cabbage moth; cabbage loopers, Lepidoptera larvae and potato/tomato psyllids (1). As many other Entomophthorales this fungus mostly infects adult arthropods but also insects' larvae and nymphaea.

Zoophthora radicans affecting *Zyginidia pullala*.
Photo: bulletinofinsectology.org, 2 Mar 2021

References:

BRAZIL

- J.E. Miranda and L.H.A. Araujo (2003) reported *Zoophthora radicans* is a pathogen of *Empoasca* spp.

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G Biological control: Bacteria

(Wikipedia, 21 Feb 2021) **Bacteria:** common noun **bacteria**, singular **bacterium**) are a type of biological cell. They constitute a large domain of prokaryotic microorganisms. Typically a few micrometers in length, bacteria have a number of shapes, ranging from spheres to rods and spirals. Bacteria were among the first life forms to appear on Earth, and are present in most of its habitats. Bacteria inhabit soil, water, acidic hot springs, radioactive waste, and the deep biosphere of the earth's crust. Bacteria also live in symbiotic and parasitic relationships with plants and animals. Most bacteria have not been characterized, and only about 27 percent of the bacterial phyla have species that can be grown in the laboratory. The study of bacteria is known as bacteriology, a branch of microbiology.

Nearly all animal life is dependent on bacteria for survival as only bacteria and some archaea possess the genes and enzymes necessary to synthesize vitamin B_{12}, also known as cobalamin, and provide it through the food chain. Vitamin B_{12} is a water-soluble vitamin that is involved in the metabolism of every cell of the human body. It is a cofactor in DNA synthesis, and in both fatty acid and amino acid metabolism. It is particularly important in the normal functioning of the nervous system via its role in the synthesis of myelin. There are typically 40 million bacterial cells in a gram of soil and a million bacterial cells in a milliliter of fresh water. There are approximately 5×10^{30} bacteria on Earth, forming a biomass which is only exceeded by plants. Bacteria are vital in many stages of the nutrient cycle by recycling nutrients such as the fixation of nitrogen from the atmosphere. The nutrient cycle includes the decomposition of dead bodies; bacteria are responsible for the putrefaction stage in this process. In the biological communities surrounding hydrothermal vents and cold seeps, extremophile bacteria provide the nutrients needed to sustain life by converting dissolved compounds, such as hydrogen sulfide and methane, to energy.

In humans and most animals, the largest number of bacteria exist in the gut, and a large number on the skin. The vast majority of the bacteria in the body are rendered harmless by the protective effects of the immune system, though many are beneficial, particularly in the gut flora. However, several species of bacteria are pathogenic and cause infectious diseases, including cholera, syphilis, anthrax, leprosy, and bubonic plague. The most common fatal bacterial diseases are respiratory infections. Tuberculosis alone kills about 2 million people per year, mostly in sub-Saharan Africa. Antibiotics are used to treat bacterial infections and are also used in farming, making antibiotic resistance a growing problem. In industry, bacteria are important in sewage treatment and the breakdown of oil spills, the production of cheese and yogurt through fermentation, the recovery of gold, palladium, copper and other metals in the mining sector, as well as in biotechnology, and the manufacture of antibiotics and other chemicals.

Once regarded as plants constituting the class *Schizomycetes* ("fission fungi"), bacteria are now classified as prokaryotes. Unlike cells of animals and other eukaryotes, bacterial cells do not contain a nucleus and rarely harbor membrane-bound organelles. Although the term *bacteria* traditionally included all prokaryotes, the scientific classification changed after the discovery in the 1990s that prokaryotes consist of two very different groups of organisms that evolved from an ancient common ancestor. These evolutionary domains are called *Bacteria* and *Archaea*.

F1 Order: Pseudomonadales Orla-Jensen 1921

(Wikipedia, 9 Apr 2021) The **Pseudomonadales** are an order of Proteobacteria. A few members are opportunistic pathogens, such as species of *Pseudomonas*, *Moraxella*, and *Acinetobacter*, which may cause pneumonia.

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F1.1 Family: Pseudomonadaceae Winslow et al. 1917

(Wikipedia, 17 Apr 2021) The **Pseudomonadaceae** are a family of bacteria which includes the genera *Azomonas*, *Azorhizophilus*, *Azotobacter*, *Mesophilobacter*, *Pseudomonas* (the type genus), and *Rugamonas*. The family Azotobacteraceae was recently reclassified into this family.

The following species have been identified to be a biocontrol or as a biofertilizer in sesame:

- F1.1.1 *Pseudomonas* spp.
- F1.1.1a *Pseudomonas fluorescens*
- F1.1.1b *Pseudomonas putida* (*Syn: *Pseudomonas striata*)
- F1.1.1c *Pseudomonas veronii*
- F1.1.1d *Pseudomonas aeruginosa*

- F1.1.2 *Azotobacter* spp.
- F1.1.2a *Azotobacter chroococcum*

F1.1.1 *Pseudomonas* spp. (25 Apr 2021)

There are *Pseudomonas* species that damage sesame (C1.1.1) and species have been used as biocontrols (F1.1.1).

Family: Pseudomonadaceae

Definition: Amount of biocontrol provided by *Pseudomonas* spp. Migula 1894 emend. Yang et al. 2013.

(Wikipedia, 25 Apr 2021) ***Pseudomonas*** is a genus of Gram-negative, Gammaproteobacteria, belonging to the family Pseudomonadaceae and containing 191 validly described species. The members of the genus demonstrate a great deal of metabolic diversity and consequently are able to colonize a wide range of niches. Their ease of culture *in vitro* and availability of an increasing number of *Pseudomonas* strain genome sequences has made the genus an excellent focus for scientific research; the best studied species include *P. aeruginosa* in its role as an opportunistic human pathogen, the plant pathogen *P. syringae*, the soil bacterium *P. putida*, and the plant growth-promoting *P. fluorescens*, *P. lini*, *P. migulae*, and *P. graminis*.

Because of their widespread occurrence in water and plant seeds such as dicots, the pseudomonads were observed early in the history of microbiology. The generic name *Pseudomonas* created for these organisms was defined in rather vague terms by Walter Migula in 1894 and 1900 as a genus of Gram-negative, rod-shaped, and polar-flagellated bacteria with some sporulating species, the latter statement was later proved incorrect and was due to refractive granules of reserve materials. Despite the vague description, the type species, *Pseudomonas pyocyanea* (basonym of *Pseudomonas aeruginosa*), proved the best descriptor.

References:

INDIA

- M. Muthamilan and S. Balakrishnan (2021) evaluated seed treatments with *Bacillus amyloliquefaciens* and *Pseudomonas* spp. at different concentrations. The effects on 10 day seedlings 90 days after seed treatments were as follow.

S. No.	Treatments	Ten days old seedlings*	
		Shoot length (cm)	Root length (cm)
1	ST with LF of *Pseudomonas spp.* @ 10 ml/kg seed	10.64	8.18
2	ST with LF of *Pseudomonas spp.* @ 15 ml/kg seed	11.10	8.62
3	ST with LF of *Pseudomonas spp.* @ 20 ml/kg seed	12.86	9.92
4	ST with LF of *Pseudomonas spp.* @ 25 ml/kg seed	12.24	9.44
5	ST with LF of *B. amyloliquefaciens* @ 10 ml/kg seed	10.56	7.84
6	ST with LF of *B. amyloliquefaciens* @ 15 ml/kg seed	11.38	8.32
7	ST with LF of *B. amyloliquefaciens* @ 20 ml/kg seed	12.42	9.34
8	ST with LF of *B. amyloliquefaciens* @ 25 ml/kg seed	12.12	8.88
9	ST with carbendazim @ 2 g/kg seed	11.76	9.12
10	Control (ST with plain broth @ 25 ml/kg seed)	6.62	5.80
	CD (P=0.05)	0.68	0.49

* Mean of three replications ST- Seed treatments LF- Liquid formulation

UNITED STATES

- D.C. Erwin reported species of *Pseudomonas*, *Bacillus*, and *Streptomyces*, which are most active at 25-27°C at field capacity moisture level, can be suppressive to Phytophthora species in soil (Cited by C. Chattopadhyay et al., 2019).

F1.1.1a *Pseudomonas fluorescens* (17 Apr 2021)

Family: Pseudomonadaceae

Definition: Amount of biocontrol provided by *Pseudomonas fluorescens* Migula 1895.

(Wikipedia, 17 Apr 2021) ***Pseudomonas fluorescens*** is a common Gram-negative, rod-shaped bacterium. It belongs to the *Pseudomonas* genus; 16S rRNA analysis as well as phylogenomic analysis has placed *P. fluorescens* in the *P. fluorescens* group within the genus, to which it lends its name.

Pseudomonas fluorescens has multiple flagella. It has an extremely versatile metabolism, and can be found in the soil and in water. It is an obligate aerobe, but certain strains are capable of using nitrate instead of oxygen as a final electron acceptor during cellular respiration.

Optimal temperatures for growth of *P. fluorescens* are 25–30°C. It tests positive for the oxidase test. It is also a nonsaccharolytic bacterial species.

Heat-stable lipases and proteases are produced by *P. fluorescens* and other similar pseudomonads. These enzymes cause milk to spoil, by causing bitterness, casein breakdown, and ropiness due to production of slime and coagulation of proteins.

Some *P. fluorescens* strains (CHA0 or Pf-5, for example) present biocontrol properties, protecting the roots of some plant species against parasitic fungi such as *Fusarium* or the oomycete *Pythium*, as well as some phytophagous nematodes.

It is not clear exactly how the plant growth-promoting properties of *P. fluorescens* are achieved; theories include:
- The bacteria might induce systemic resistance in the host plant, so it can better resist attack by a true pathogen.
- The bacteria might outcompete other (pathogenic) soil microbes, e.g., by siderophores, giving a competitive advantage at scavenging for iron.
- The bacteria might produce compounds antagonistic to other soil microbes, such as phenazine-type antibiotics or hydrogen cyanide.

References:

EGYPT

- M.A.A. Hassan et al. (n.d.) evaluated the antagonistic effect of *in vitro* biocontrol agents against *Fusarium oxysporum* f. sp. *sesami.*

Microorganism	Isolate No.	*Fusarium* growth (mm)	Reduction (%)
Bacillus subtilis	1	7.807a	11.93d
	2	6.889b	21.11b
	3	6.445b	25.55a
	4	7.361ab	16.39c
	5	7.028ab	19.72b
	Mean	**7.106**	**18.94**
Streptomyces rochei	1	6.838ab	21.62b
	2	7.415a	15.85c
	3	3.89b	51.10a
	Mean	**6.048**	**29.52**
Pseudomonas fluorescens		4.4	**45.8**
Trichoderma viride		2.3	**66.84**
Control		9	0.00
L.S.D. 0.05		4.49	

The significant differences between means compared by LSD at $p \leq 0.05$, NS, not significant

In another experiment, they reported the antagonistic effect of biocontrol agents against *Fusarium oxysporum* f. sp. *sesami* in the field.

Biocontrol agents	2019				2020				Mean			
	Damping-off (%)		SurvivalPlants	Wilt %	Damping-off(%)		Survival Plants	Wilt %	Damping-off (%)		Survival Plants	Wilt %
	Pre-	Post-			Pre-	Post-			Pre-	Post-		
B. subtilis	4.16	3.32	93.82	18.09	5.27	4.15	91.88	18.65	4.72	3.74	94.85a	18.37c
P. fluorescens	4.72	4.17	91.11	25.32	6.39	3.89	89.72	23.80	5.56	4.03	90.42b	24.56b
T. viride	3.06	2.22	94.72	16.99	4.17	3.05	92.78	17.55	3.62	2.64	93.75ab	17.27c
Control	18.61	26.39	55.00	57.96	22.22	29.17	48.61	67.00	20.42	27.78	51.81c	62.48a
L.S.D. at 5%	2.92	3.42	6.25	4.14	2.75	4.13	5.18	6.50	2.84	3.78	5.72d	5.32

Means with different lowercases indicate significant differences at $p \leq 0.05$

INDIA

- K. Jayashree et al. (2000) reported *Pseudomonas fluorescens* strain Pf1, effectively inhibited the mycelial growth of *Macrophomina phaseolina*, the pathogen causing dry root-rot in sesame. Application of Pf1 as a seed treatment (10g/kg seed) followed by soil application (2.5 kg/ha) effectively supported higher plant growth and grain yield. Sclerotial number and root rot incidence were also greatly reduced. The rhizosphere soil recorded a higher number of Pf1 population. The germination percentage were as follow.

ST - Pf 1	92.0^{cd}
ST + SA - Pf 1	97.5^{e}
SA - Pf 1	89.0^{bc}
ST - Carbendazim	90.2^{bcd}
ST + SD - Carbendazim	94.2^{d}
SD - Carbendazim	86.8^{ab}
ST - Pf 1 + SD - Carbendazim	93.5^{d}
ST – Carbendazim + SA - Pf 1	92.5^{cd}
Control	82.5^{a}

The data at 30 days after sowing was as follow.

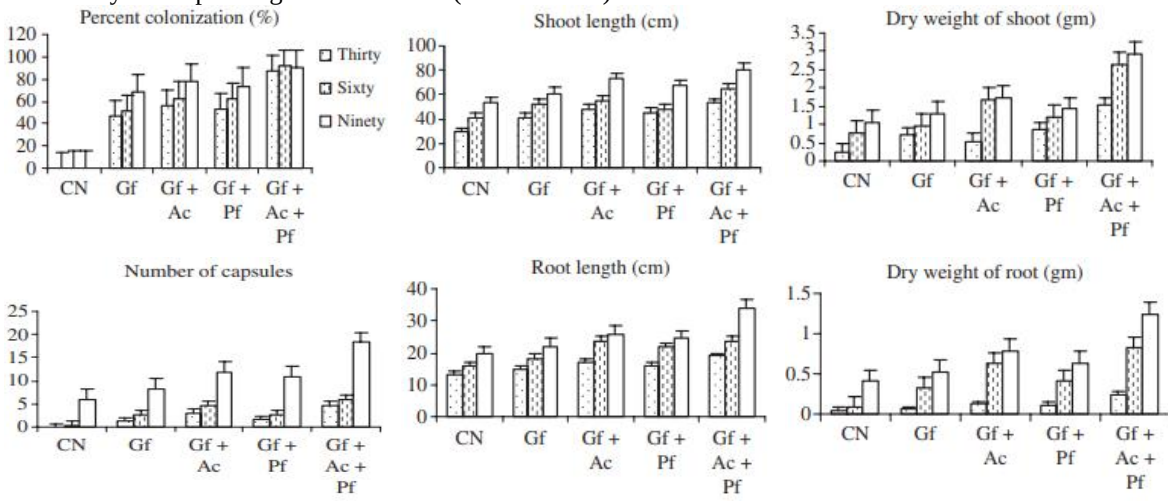
	Root length (cm)	Shoot length (cm)	*Pseudomonas* population / 100 g of soil	Sclerotia/ g of soil
ST - Pf 1	6.0 e	41.4 e	30.5 f	12.42 b
ST + SA - Pf 1	7.5 I	48.6 h	61.7 I	7.03 a
SA - Pf 1	5.3 c	35.0 c	54.3 h	26.11 d
ST – Carbendazim	5.7 d	40.5 d	7.5 d	14.32 b
ST + SD – Carbendazim	7.0 h	44.2 g	3.2 c	8.97 a
SD – Carbendazim	4.9 b	31.8 b	3.0 d	26.12 d
ST - Pf 1 + SD – Carbendazim	6.8 g	42.7 f	24.5 e	16.00 bc
ST – Carbendazim + SA - Pf 1	6.4 f	41.1 e	46.8 g	18.35 c
Control	4.2 a	25.6 a	2.6 a	35.66 e

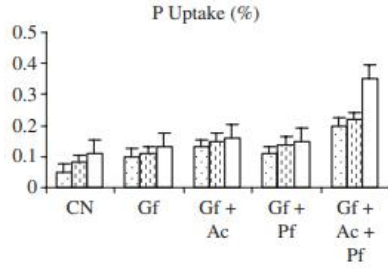
ST-Seed Treatment; SA-Soil Application; SD-Soil Drenching

The final results were as follow.

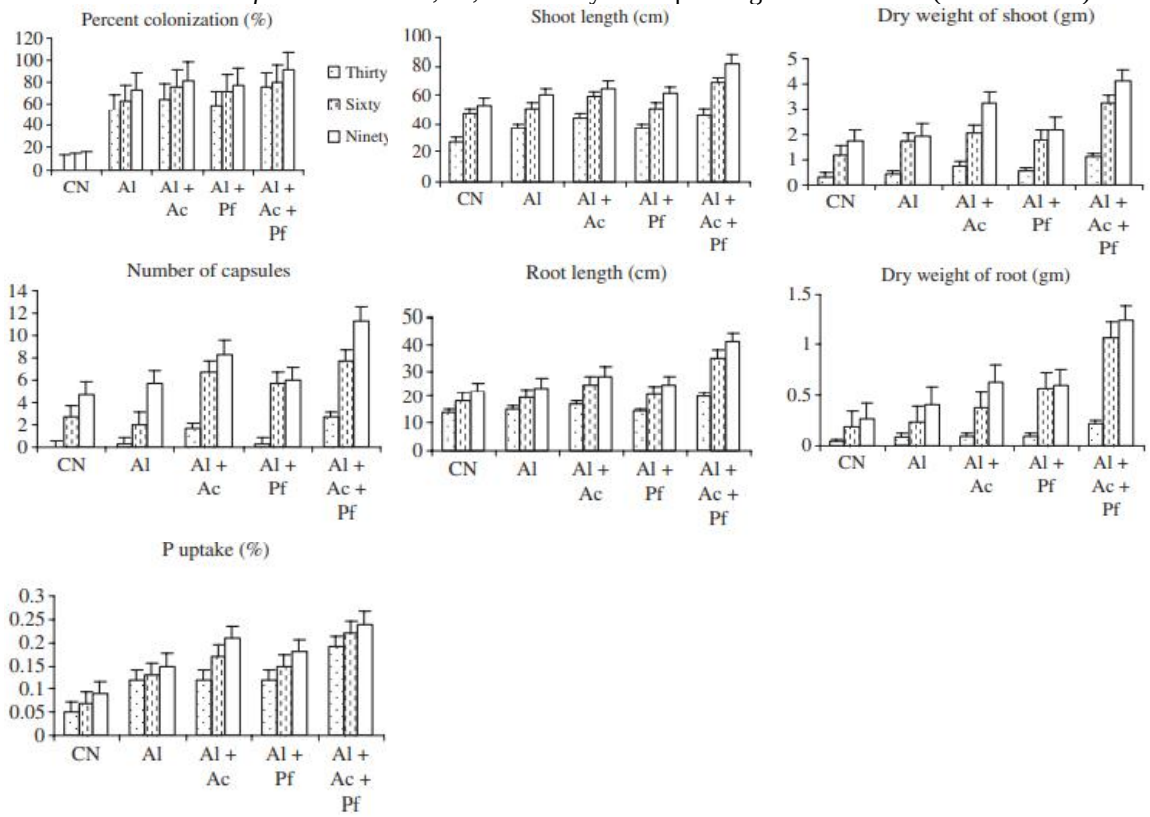
	Root rot incidence (%)	Grain yield (kg / ha)
ST - Pf 1	38.5 ^{c}	320 ^{b}
ST + SA - Pf 1	23.2 ^{a}	1200 ^{g}
SA - Pf 1	35.4 ^{bc}	680 ^{e}
ST – Carbendazim	40.3 ^{c}	400 ^{bc}
ST + SD – Carbendazim	26.8 ^{ab}	820 ^{f}
SD – Carbendazim	37.1 ^{c}	460 ^{cd}
ST - Pf 1 + SD – Carbendazim	27.9 ^{ab}	900 ^{f}
ST – Carbendazim + SA - Pf 1	31.2 ^{abc}	560 ^{d}
Control	58.3 ^{d}	190 ^{a}

- M.L. Verma et al. (2002) reported antagonistic *Trichoderma viride*, *Trichoderma harzianum*, and *Pseudomonas fluorescence*, when used as seed treatment, not only reduce *Phytophthora parasitica* var. *sesami* significantly but substantially increase the sesame yield. [Cited by C. Chattopadhyay et al., 2019]
- S.J. Sabannavar and H.C. Lakshman (2008) evaluated the effects of a single inoculation of *Glomus fasciculatum* (Gf) and *Acaulospora laevis* (Al), dual inoculation of arbuscular mycorrhizal fungi (AMF) with *Azotobacter chroococcum* (Ac) or *Pseudomonas fluorescens* (Pf) and a triple inoculation of AMF, *A. chroococcum* and *P. fluorescens* using 2 varieties (DS1 and E8) in a pot experiment. The results revealed that inoculation of AMF + Ac + Pf stimulated increased AMF colonization, plant growth, i.e., shoot, root length, fresh and dry weight of shoot and root, phosphorus uptake and number of capsules significantly over the dual and single inoculation treatments. The association of bacteria and AMF provides evidence that bacteria are involved in the beneficial effects to AMF on sesame varieties. The results for *Glomus fasciculatum* at 30, 60, and 90 days after planting were as follow (CN = control).

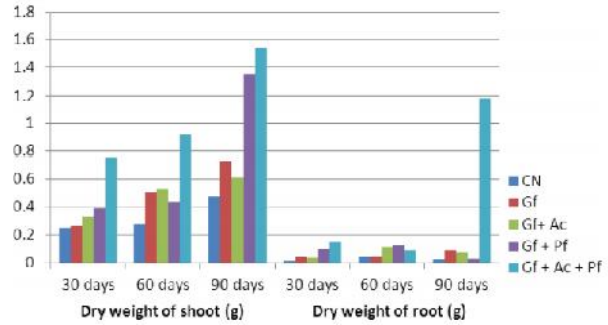


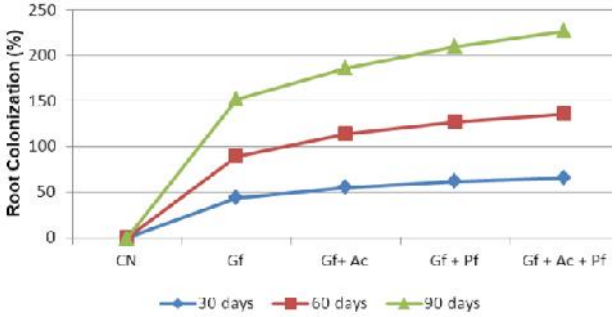


The results for *Acaulospora laevis* at 30, 60, and 90 days after planting were as follow (CN = control).

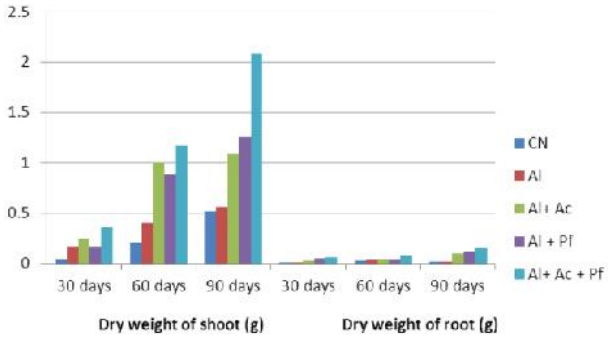


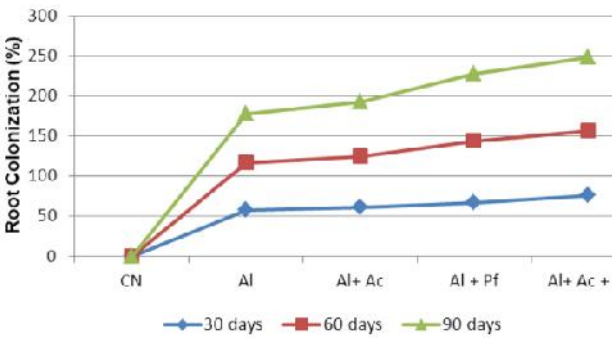
- S.J. Sabannavar and H.C. Lakshman (2011) evaluated the effect of co-inoculation with bacteria and arbuscular mycorrhizal (AM) fungi on the growth of sesame. The two varieties of sesame TSES 1 and TSES 4 were inoculated with single, double, and triple inoculations. The results revealed that triple inoculation of *Glomus fasciculatum* (Gf) + *Azotobacter chroococcum* (Ac) + *Pseudomonas fluorescens* (Pf) to TSES 1 and *Acaulospora laevis* (Al) + Ac + Pf to TSES 4 stimulated increased root colonization, plant growth, plant biomass, phosphorus content, and number of capsules significantly over the double and single inoculation treatments. These results suggest synergistic interaction among AM fungi, *Azotobacter chroococcum*, and *Pseudomonas fluorescens*. The association of bacteria and AM fungi provide evidence that bacteria are involved in the beneficial effects to AM fungi on plant growth and can improve crop production. The results for TSES 1 with Gf were as follow (CN = control).





The results for TSES 4 with Al were similar.





- A.S. Savitha et al. (2011) evaluated several isolates against *Alternaria sesami.* Among two *Trichoderma* isolates, maximum inhibition was noticed in *T. harzianum* to the extent of 87% followed by *T. viride*. Among four bacterial bioagents, an exogenous *Pseudomonas fluorescens* (Pf-E) was most efficient with 80% inhibition. Salicylic acid at 1% was found to be effective in suppressing the pathogen and resulted in higher vigour index (1138.28), followed by *P. fluorescens* I with good germination and vigour index of 97.75% and 1029.85, respectively. The higher vigour index is mainly due to increased germination, higher root and shoot growth by the systemic resistance inducing agents. [Based on abstract]
- A.S. Savitha et al. (2012) reported *Alternaria sesami* (the incitant of leaf blight of sesame) produced toxic metabolite in culture. The toxin produced necrotic symptoms on sesame and tomato seedlings at various concentrations. The maximum inhibition of seed germination and shoot and root length was noticed at 2,000 ppm concentration. Least inhibition of root and shoot length was observed at 50 ppm concentration. Different resistance inducing chemicals were tested for inhibition of growth and induction of resistance. Among them, salicylic acid (10 mM) was effective in inhibiting the mycelial growth of *A. sesami* (68.8%). The least inhibition of mycelial growth was observed in potassium nitrate (55.81%). The resistance inducing chemicals, plant extracts and bioagents when tested *in vivo*, with challenge inoculation of *A. sesami*, salicylic acid at 1% concentration was found to be effective in suppressing the pathogen and resulted in higher vigor index (1138.28), which was followed by *Pseudomonas fluorescens* I with good germination per cent of 97.35 and vigor index of 1029.85. The higher vigor index obtained in these treatments is mainly due to their support for increased germination, good root and shoots growth by the systemic resistance inducing agents. [Based on abstract]
- V. Bharathi et al. (2013) examined the effect of seed treatments (*Trichoderma viride* + *Pseudomonas fluorescence*, *Azotobacter* + *Trichoderma*, *Rhizobium* + *Trichoderma*, *Azotobacter*, *Trichoderma*, *Pseudomonas*, Benomyl, and untreated control) to improve germination and increase survival rate. *Trichoderma* and *Pseudomonas* were treated @ 6g/kg and 10 g/kg seed, respectively. *Azotobacter* was used @ 25 g/kg seed (250g/10 kg seed). The combination inoculum was used @ half the dose of each bioagent/biofertilizer. The seeds were tested for mycoflora and the following fungi were found: *Alternaria alternata*, *Alternaria tennissima*, *Alternaria terreus*, *Aspergillus flavus*, *Aspergillus fumigatus*, *Aspergillus niger*, *Macrophomina* spp., *Cephalosporium* spp., *Fusarium oxysporum*, *Rhizoctonia solani*, *Rhizopus stolonifer*, *Curvularia* spp., *Drechslera* spp., *Rhizopus* spp., *Cladosporium* spp., and *Penicillium* spp. Germination of the treated seeds was tested using 3 methods: blotter, paper towel, and sand. The results of the blotter method (100 seeds for 8 days) were as follows:

Treatment	Germination (%)	Seed rot	Seedling Blight	Fungal colonies
Trichoderma + Pseudomonas fluorescence	96.0	4.50	4.18	3.83
Azatobacter + Trichoderma	94.4	8.64	6.42	10.2
Rhizobium + Trichoderma	90.2	12.1	8.63	12.6
Azatobacter	88.0	18.0	9.40	14.8
Trichoderma	85.3	10.6	7.21	12.2
Pseudomonas fluorescence	84.0	9.8	8.10	15.4
Benomil	86.3	2.70	2.10	3.00
Control	75.0	32.3	21.8	36.2
SEm±	0.48	0.72	0.80	0.94
CV%	3.71	5.46	5.68	6.78
CD	1.61	1.82	2.21	2.08

The results of the paper towels method (50 seeds for 14 days) and sand method (100 seeds for 20 days) were as follows. The seedling vigor was done in petri dishes for 8 days (no temperature specified. The germination % and seedling length in cm was measured. The seedling vigor index = Mean seedling length (cm) x Germination percentage (%).

Treatments	Paper Towel Method				Sand Method				Seedling Vigor
	NS	AS	SR	HS	NS	AS	SR	HS	
Trichoderma + P. fluorescence	23	0	14	63	10	2	0	88	1660.3
Azatobacter + Trichoderma	19	2	18	61	5	4	0	92	1562.6
Rhizobium + Trichoderma	17	3	26	52	5	2	4	90	1404
Azatobacter	14	6	32	48	1	3	0	94	1386.2
Trichoderma	12	2	30	50	3	2	2	93	1489
Pseudomonas fluorescence	8	4	16	54	1	4	2	93	1356.3
Benomil	10	2	2	72	2	2	0	96	1312
Control	8	3	47	42	1	1	8	91	904.1
SEm±									69.2
CV									245.6
CD									121.2

*Viability = 76 per cent, ** Data on germination is based on 100 seeds, *** Data based on observation of normal seedling. NS = Normal seedling, AS= Abnormal Seedlings. SR = Seed rots, HS = Hard seeds.

- P.L. Radha (2013) evaluated the antagonistic micro-organisms like *Trichoderma harzianum* Rifai., *Trichoderma viride* Pers., *Trichoderma koningii* Qudem., *Trichoderma virens* Miller., *Pseudomonas fluorescens* Migula., and *Bacillus subtilis* Cohn. For their effect under *in vitro* condition against *A. sesami* by dual culture technique. The results were as follows.

Bioagents	**Per cent inhibition**
Trichoderma harzianum	77.50 (61.66)
Trichoderma viride	75.14 (60.07)
Trichoderma koenigii	73.19 (58.79)
Trichoderma virens	71.53 (57.73)
Pseudomonas fluorescens	36.22 (36.98)
Bacillus subtilis	52.02 (46.15)
S.Em±	0.90
CD at 1 %	2.51

* Arcsine transformed values

Efficacy of fungicides, botanicals and bio-agents were tested against seedborne fungal infections of sesame (variety E-8). The results were as follows.

Sl. No.	Treatments	Percent seed Infection	Percent seed germination	Vigour index
1.	Garlic	30.33 (33.43)*	70.00 (56.82)	517
2.	Ginger	26.67 (31.11)	74.33 (59.59)	591
3.	Hexaconazole	13.33 (21.42)	89.33 (70.97)	1208
4.	Tebuconazole	30.67 (33.65)	72.00 (58.08)	697
5.	Propiconazole	26.33 (30.89)	74.00 (59.37)	729
6.	*T. harzianum*	21.33 (27.52)	80.67 (63.95)	515
7.	*P. fluoroscencs*	25.00 (30.00)	75.33 (60.03)	828
8.	Avatar72WP (Hexazconazole 4% + Zineb 68%)	14.00 (21.89)	87.67 (69.48)	1027
9.	Taqat75WP(Captan70+Hexaconazole 5%)	25.00 (30.00)	78.33 (62.34)	429
10	Control (untreated seeds)	42.00 (40.41)	57.33 (49.24)	318
	S.Em±	**0.46**	**0.78**	**13.95**
	CD at 1 %	**2.16**	**3.71**	**69.38**

* Arcsine transformed values

- K. Satyagopal et al. (2014) in an IPM manual reported for control measures for *Rhizoctonia bataticola* (Dry root rot), *Phytophthora parasitica* var. *sesami* (Phytophthora blight), and *Alternaria sesami* (Alternaria blight) use the following seed treatments: *Trichoderma* sp. @ 4 g/Kg of seed, *Pseudomonas fluorescens* @ 2 g/Kg seed, or *Bacillus subtilis* @ 2 g/Kg seed or NSKE 4%.
- V.A. Savaliya et al. (2016) evaluated *Pseudomonas fluorescens* against *Macrophomina phaseolina in vitro* with the following results.

Biocontrol agents	Sclerotial formation	Per cent inhibition over control
Bacillus subtilis	+	87.03
T. viride	+ +	71.48
T. hamatum	+ + +	70.00
T. koningii	+ + +	68.14
Trichoderma harzianum	+ +	67.40
Pseudomonas fluorescens	+ +	64.07
Control		-
S. Em. ±	1.602	
CD at 5%	4.862	
CV %	4.54	

Biocontrol agents	Per cent disease incidence	Yield (kg / ha)
Bacillus subtilis	18.93(10.53)	680
Trichoderma konigii	25.43(18.44)	585
T. hamatum	26.90(20.48)	609
T. viride	28.42(22.65)	579
T. harzianum	30.02(25.02)	510
Pseudomonas fluorescens	30.93(26.42)	537
Control	32.96(29.61)	507
S. Em. ±	1.30	28.36
C.D. at 5%	3.89	87.38
C.V.%	10.46	8.59

- K. Choudhary et al. (2018) evaluated chemicals (Tebuconazole, Carbendazim, and Mancozeb) and biocontrols (*Trichoderma harzianum* and *Pseudomonas fluorescens*) to reduce the incidence of *Macrophomina phaseolina* with the following results in terms of disease incidence and yield.

Treatments	Disease incidence (%)	Disease control (%)	Yield (kg ha^{-1})
T_1 -Tebuconazole 2DS ST @ 1.5 g kg $^{-1}$	16.16 (23.70)*	73.06	435.00
T_2 - Carbendazim 12% + Mancozeb 63% WP ST @ 2 g kg $^{-1}$	18.16 (25.22)	69.73	420.10
T_3 - *T. harzianum* ST @ 10 g kg $^{-1}$	31.00 (33.83)	48.10	378.00
T_4 - *P. fluorescens* ST @ 10 g kg $^{-1}$	33.50 (35.36)	44.16	370.00
T_5 - Tebuconazole 25.9 EC SA @ 1.5 ml Lt^{-1}	19.51 (26.21)	67.48	410.00
T_6 - Carbendazim 12% + Mancozeb 63% WP SA @ 2 g Lt^{-1}	22.50 (28.32)	62.50	405.00
T_7 -*T. harzianum* SA @ 10 kg ha^{-1}	35.80 (36.64)	40.33	350.00
T_8 - *P. fluroescens* SA @ 10 kg ha^{-1}	40.00 (39.23)	33.33	330.10
T_9 - Tebuconazole 2DS ST@ 1.5 g kg $^{-1}$ + Tebuconazole 25.9 EC SD @ 1.5 ml Lt^{-1}	9.52 (17.97)	84.13	480.60
T_{10} - Carbendazim 12% ST @ 2 g kg $^{-1}$+ Mancozeb 63% WP + SD @ 2 g Lt^{-1}	13.50 (21.56)	77.50	450.00
T_{11} -*T. harzianum* ST @ 10 g kg $^{-1}$ + SA @ 10 kg ha^{-1}	23.50 (29.00)	60.83	392.00
T_{12} - *P. fluroescens* ST @ 10 g kg $^{-1}$ + SA @ 10 kg ha^{-1}	26.55 (31.01)	55.75	385.30
T_{13} - Control (without treatment)	60.00 (50.77)	-	250.00
SEm ± CD P=0.05 CV(%)	1.58 4.63 10.23		22.93 66.94 10.21
*Figures in parentheses are angular transformed values			

ST= Seed treatment, SA= Soil application, SD=Soil drenching

- K.N. Gupta et al. (2018) reported seed treatment with *Pseudomonas fluorescens* helped control Macrophomina stem/root rot.
- T.K. Babu et al. (2020) evaluated the use of *Trichoderma viride* and *Pseudomonas fluorescens* in combination with neem to control *Macrophomina phaseolina* with the following results.

Treatment	Pooled data (*Kharif*, 2014, 2015 and 2015)			Pooled (Summer, 2015 and 2018)	
	Root Rot (%)	Phyllody %)	Yield (kg/ha)	Root Rot (%)	Yield (Kg/ha)
T1-Seed treatment *T. viride* @ 4 g/kg + soil application of *Tv* @ 2.5 kg/ha enriched in 100 kg of FYM at sowing.	18.5 (25.1)	21.3 (26.8)	231	11.9 (19.6)	664
T2-Seed treatment *P. flourescens* @ 10 g/kg + Soil application of Pf @ 2.5 kg/ha enriched in 100 kg of FYM at sowing.	24.0 (28.8)	22.4 (27.7)	204	12.9 (19.9)	654
T3-Seed treatment *T. viride* @ 4 g/kg + soil application of *Tv* @ 2.5 kg/ha enriched in 100 kg of FYM + neem cake @ 250 kg/ha at sowing.	23.1 (28.4)	25.0 (29.3)	226	6.8 (14.1)	611
T4-Seed treatment *P. fluorescens* @ 10 g/kg + soil application of Pf @ 2.5 kg/ha enriched in 100 kg of FYM + neem cake 250 kg/ha at sowing.	22.6 (27.6)	23.4 (28.3)	261	16.1 (23.4)	672
T5-Seed treatment Tv + Pf @ 10 g /kg + Soil application of Pf @ 2.5 kg/ha + Tv @ 2.5 kg/ha enriched in 100 kg of FYM + neem cake @ 250 kg/ha at sowing.	13.0 (20.9)	17.8 (24.7)	304	9.3 (15.8)	769
T6-Seed treatment Carbendazim @ 2 g/kg + soil drenching with Carbendazim @ 1 g/ l.	33.4 (35.1)	19.8 (25.9)	183	13.5 (21.2)	561
T7-Untreated check	41.7 (40.1)	27.8 (31.6)	127	27.7 (31.7)	473
S.Em ±	2.7	2.2	17.1	3.1	70.1
CV%	18.7	17.0	13.6	23.5	19.3
LSD (5%)	7.7	6.3	49.0	9.0	204

*mean of 3 repiications; figures in parenthesis are angular transformed values

- P. Renganathan et al. (2020b) reported many *Trichoderma* species are regarded as growth promoters by increasing fresh weight, height, and flowering while inhibiting pathogen growth. *T. viride* and *T. harzianum* inhibited the growth and caused sclerotial lysis of *M. phaseolina in vitro*. *Pseudomonas fluorescens* was also effective using various modes of action especially rhizosphere colonization, antibiotic production, and induction of systemic resistance.
- K. Vinothini et al. (2020b) evaluated 5 native *Trichoderma viride* (Tv) and *Pseudomonas fluorescens* (Pf) antagonists isolated from healthy sesame rhizosphere soil in different regions for their ability to reduce the growth of *Macrophomina phaseolina* as well as sclerotial germination. The results with the dual culture technique were as follow.

S. No. Isolates		*T. viride*(Tv_s) Mycelial growth of *M. phaseolina* (mm)	Percent inhibition over control	*P. fluorescens* (Pf_s) Isolates	Mycelial growth of *M. Phaseolina* (mm)	Per cent inhibition over control	Inhibition zone (mm)
1	Tv_1	20.53	77.18	Pf_1	27.33	69.63	7.53
2	Tv_2	30.56	65.93	Pf_2	28.19	68.67	6.75
3	Tv_3	18.69	79.23	Pf_3	24.38	72.91	9.26
4	Tv_4	35.42	60.64	Pf_4	26.40	70.66	8.42
5	Tv_5	23.56	73.82	Pf_5	22.30	75.22	10.04
6	Control	90.00	—	Control	90.00	-	-
	S. Ed	0.51		S. Ed	0.13		
	CD (p=0.05)	1.21	—	CD (p=0.05)	0.28	—	—

The results with the poison food technique were as follow.

S. No. Concentration of cultural filtrates		*T. viride* (Tv_3) Mycelial growth (mm)	Percent inhibition over control	Mycelial dry weight (mg)	Percent inhibition over control	*P. fluorescens* (Pf_5) Mycelial growth (mm)	Percent inhibition over control	Mycelial dry weight (mg)	Percent inhibition over control
1	10	24.33	72.96	200.86	36.10	29.57	65.84	176.96	43.50
2	20	19.46	78.37	120.95	61.52	17.39	75.23	154.92	50.54
3	30	10.13	88.74	49.93	84.12	12.64	80.37	57.65	81.60
4	40	NG	100.00	1.68	99.46	NG	100.00	1.32	99.57
5	50	NG	100.00	1.25	99.60	NG	100.00	1.05	99.67
6	Control	90.00	-	314.34	-	90.00	—	313.25	—
S. Ed		0.54		0.98		0.49		0.52	
CD (p=0.05)		1.96	—	2.13	—	1.11	—	1.45	—

NG-Nil Growth

The effects on number, size and sclerotial germination were as follow.

S. No.	Isolates	No. of. Sclerotia	Per cent inhibition	Sclerotial size (m)	Per cent reduction	Sclerotial germination(%)	Per cent inhibition	No. of. Germ tube per Sclerotium^{-1}	Percent reduction
1	Tv_1	94.90	44.13	75.11	37.50	49.46(44.69)	45.73	7.05	49.17
2	Tv_2	105.73	37.75	88.32	26.51	64.85(53.63)	30.22	9.39	32.29
3	Tv_3	74.21	56.31	70.24	41.55	42.62(40.75)	54.14	4.92	64.52
4	Tv_4	134.92	20.56	102.13	15.01	68.78(56.03)	25.99	10.03	27.68
5	Tv_5	102.02	39.93	85.79	28.92	56.09(48.49)	39.64	6.85	50.61
6	Control	169.86	-	120.18	-	92.94(74.59)	-	13.87	-
	S. Ed	0.42		0.62		0.45		0.12	
	CD (p=0.05)	1.091	—	1.65	—	0.99	—	0.28	—

S. No.	Isolates	No. of. Sclerotia	Percent inhibition	Sclerotial size (m)	Percent reduction	Sclerotial germination(%)	Percent inhibition	No. of. Germ tube per sclerotium^{-1}	Percent reduction
1	Pf_1	80.33	49.55	77.46	28.91	51.03 (45.59)	43.79	10.14	37.62
2	Pf_2	84.25	47.09	79.74	26.85	54.86 (47.78)	39.61	12.94	20.32
3	Pf_3	72.91	52.33	70.06	35.70	45.02 (42.14)	50.44	7.01	56.83
4	Pf_4	81.25	48.97	78.95	27.54	51.96 (46.12)	42.80	9.94	38.79
5	Pf_5	64.78	59.65	63.91	41.35	39.63 (39.01)	56.37	5.09	68.65
6	Control	159.25	-	108.97	-	90.85 (72.39)	-	16.24	-
S. Ed				0.12		0.11		0.13	
CD (p=0.05)		0.150.45	—	0.26	—	0.23	—	0.28	—

- P. Mahalakshmi and P.A. Devi (2021) Studied the effects of biological controls (*Trichoderma viride* and *Pseudomonas fluorescens*) and a fungicide (Carbendazim) on *Macrophomina phaseolina* in 2016 and 2017 at Vridhachalam ,Tamil Nadu (11.56N 79.33E). The results for 2016 were as follow (ST = seed treatment, SA = soil application).

Module No	Treatments	Disease incidence (%)	Yield (Kg /ha)	C:B ratio
M_1	ST with *T. viride* + SA of *T. viride* 2.5 Kg /*ha* enriched in 100 Kg FYM	28.80 (32.45)	578	1.29
M_2	ST with *P. fluorescens* +SA of *P. fluorescens* 2.5 Kg /*ha* enriched in 100 Kg FYM	25.15 (30.10)	561	1.48
M_3	ST with *T. viride* + SA of *T. viride* 2.5 Kg /*ha* enriched in 100 Kg FYM +Neem cake@250Kg/ha	18.56 (25.51)	621	2.00
M_4	ST with *P. fluorescens* +SA of *P. fluorescens* 2.5 Kg /*ha* enriched in 100 Kg FYM+ Neem cake@250Kg/ha	22.21 (28.11)	615	1.68
M_5	ST *T. viride*+ *P. fluorescens*+ SA of *T. viride*+ SA of *P. fluorescens* enriched in 100 Kg FYM +Neem cake@250Kg/ha	14.75 (22.58)	648	2.60
M_6	ST Carbendazim 2g/Kg +Soil drenching with Carbendazim 1g/l	14.32 (22.23)	651	2.62
M_7	Untreated check	37.21 (37.59)	454	
S.Ed		0.56	7.98	
CD(*P*=0.05)		1.11	17.40	

The results for 2017 were as follow.

Tr. No	Treatments	Root rot (%)	Yield (kg/ha)	C:B ratio
T_1	ST with *T. viride* + SA of *T. viride* 2.5 Kg /*ha* enriched in 100 Kg FYM	22.64 (28.41)	635	1.46
T_2	ST with *P. fluorescens* +SA of *P. fluorescens* 2.5 Kg /*ha* enriched in 100 Kg FYM	27.36 (31.53)	625	1.44
T_3	ST with *T. viride* + SA of *T. viride* 2.5 Kg /*ha* enriched in 100 Kg FYM +Neem cake@250Kg/ha	17.28 (24.56)	610	1.41
T_4	ST with *P. fluorescens* +SA of *P. fluorescens* 2.5 Kg /*ha* enriched in 100 Kg FYM+ Neem cake@250Kg/ha	23.71 (29.13)	595	1.37
T_5	ST *T. viride*+ *P. fluorescens*+ SA of *T. viride*+ SA of *P. fluorescens* enriched in 100 Kg FYM +Neem cake@250Kg/ha	11.15 (19.50)	651	1.5
T_6	ST Carbendazim 2g/Kg +Soil drenching with Carbendazim 1g/l	11.03 (19.39)	659	1.52
T_7	Untreated check	37.45 (37.73)	432	
SEd		1.31	2.92	
CD(P=0.05)		2.86	6.36	

PAKISTAN

- H.N. Farhan et al. (2010) investigated the biological effects of *Pseudomonas putida* and *Pseudomonas fluorescens* as biocides to inhibit *Fusarium* fungi growth and as biofertilizers to improve growth characters of sesame crop grown in contaminated soil with *Fusarium* under field conditions compared with Dithen and Radiomil. The results were as follow.

Treatments	Fusarium growth (mm)	% inhibition
Pseudomonas putida 2 + Fusarium	4.80	94.2
Pseudomonas fluorescens 3+ Fusarium	4.43	94.6
P. putida2 + P. *fluorescens 3*+ Fusarium	0.0	100.0
Dithen Fungicide + Fusarium	29.0	64.9
Radiomil + Fusarium	33.0	60.1
Control (Fusarium only)	82.7	-
LSD at 5%	11.2	-

Treatments	Chlorophyll a+b (mg/gm)	% N	% P	% K
Pseudomonas putida 2 + Fusarium	2.29	3.82	0.35	2.23
Pseudomonas fluorescens 3+ Fusarium	2.17	3.06	0.23	3.11
P. putida2 + P. *fluorescens 3*+ Fusarium	3.21	4.18	0.44	3.87
Dithen Fungicide + Fusarium	1.78	2.70	0.27	3.06
No addition	1.86	3.03	0.18	3.31
Control (Fusarium only)	0.85	1.77	0.11	1.34
LSD at 5%	0.81	1.52	0.07	0.98

Treatments	Leaf no./plant	Pods no./plant	Grains no./pod
Pseudomonas putida 2 + Fusarium	297.3	101.3	51.2
Pseudomonas fluorescens 3+ Fusarium	374.7	106.0	52.8
P. putida2 + P. *fluorescens 3*+ Fusarium	428.3	146.7	69.1
Dithen Fungicide + Fusarium	269.3	88.3	47.0
No addition	272.3	94.0	49.3
Control (Fusarium only)	162.7	44.0	31.3
LSD at 5%	77.82	17.3	8.0

Treatments	Branch no./plant	Height of plant (cm)	Leaf area/plant (cm^2)
Pseudomonas putida 2 + Fusarium	32.9	105.7	41.2
Pseudomonas fluorescens 3+ Fusarium	34.6	106.7	43.2
P. putida2 + P. *fluorescens 3*+ Fusarium	45.8	151.7	59.7
Dithen Fungicide + Fusarium	23.6	104.0	41.2
No addition	27.4	105.3	40.5
Control (Fusarium only)	14.6	53.3	25.5
LSD at 5%	5.8	13.7	10.7

Treatments	Weight of 1000 grain (gm)	Total yield of grains per plot (gm)	% Oil in grains
Pseudomonas putida 2 + Fusarium	2.24	362.1	50.6
Pseudomonas fluorescens 3+ Fusarium	2.46	442.2	51.3
P. putida2 + P. *fluorescens 3*+ Fusarium	2.92	982.3	56.2
Dithen Fungicide + Fusarium	1.81	303.5	41.9
No addition	2.29	352.4	46.3
Control (Fusarium only)	0.94	112.4	26.6
LSD at 5%	0.38	49.0	10.5

- H.N. Farhan et al. (2011) investigated the biological activity of *Pseudomonas* bacteria as biocides to protect sesame crop from some fungi and to evaluate its efficiency as plant growth promoting. The first experiment investigated the effects of *Pseudomonas putida* (Pp) and *Pseudomonas fluorescens* (Pf) on germination and seedlings growth of sesame crop against Pythium, Alternaria, and Fusarium under plastic house conditions. The following are the results.

Treatments	Sterilized soil		Non sterilized soil	
	Germination (%)	Seedlings (cm)	Germination (%)	Seedlings (cm)
Pythium + Pp	80	4.0	70	3.2
Fusarium + Pp	84	3.5	85	2.5
Alternaria + Pp	86.7	4.5	82	3.3
Pythium + Pf	65	3.2	65.3	2.2
Fusarium + Pf	61.6	4.0	71	3.0
Alternaria + Pf	75.7	3.0	77	1.0
Pythium	0.0	0.0	21	2.0
Fusarium	2.0	0.0	10	0.5
Alternaria	0.0	0.0	19	2.0
Control (no addition)	38.3	1.9	49.3	2.4

The second experiment grew the plants to harvest.

Treatments	Germination percentage	Leaf no. per plant (cm^2/plant)	Leaf area/plant	Chlorophyll content (mg/gm)
Pp + Fusarium	89.7	27	22	3.27
Pp + Pythium,	84.0	28	20	2.29
Pp + Alternaria	86.7	25	18	1.28
Pf + Fusarium	70.7	22	19	3.23
Pf + Pythium	71.0	19	17	1.96
Pf + Alternaria	80.0	19	18	2.25
Fusarium	3.0	6	4	0.21
Pythium	2.3	4	4	0.32
Alternaria	0.0	0	0	0.00
Control (no addition)	52.0	11	9	0.76
LSD 5 %	10.9	3.98	5.12	0.167

Treatments	Height of plant (cm)	Branch no. per plant	Total dry weight of shoot gm/plant
Pp + Fusarium	76.7	5.3	6.9
Pp + Pythium	88.3	8.3	7.7
Pp + Alternaria	67.7	6.3	6.7
Pf + Fusarium	73.3	4.7	4.8
Pf + Pythium	69.7	4.3	5.7
Pf + Alternaria	62.3	5.7	5.6
Fusarium	37.3	1.3	0.23
Pythium	36.3	2.7	0.3
Alternaria	0.0	0.0	0.0
Control (no addition)	55.0	3.3	3.3
LSD 5%	11.4	1.78	1.26

Treatments	Seeds no. per pod per plant	Weight of 1,000 seeds per plant (gm)	Pods no. per plant
Pp + Fusarium	50.7	2.2	33.7
Pp + Pythium	64.0	2.5	37.3
Pp + Alternaria	53.7	2.1	35.9
Pf + Fusarium	53.3	1.9	35.0
Pf + Pythium	54.7	1.6	26.7
Pf + Alternaria	43.7	1.8	32.3
Fusarium	8.3	0.4	1.3
Pythium	13.0	0.7	1.0
Alternaria	0.0	0.0	0.0
Control (no addition)	35.3	1.2	19.0
LSD 5%	4.58	0.22	3.3

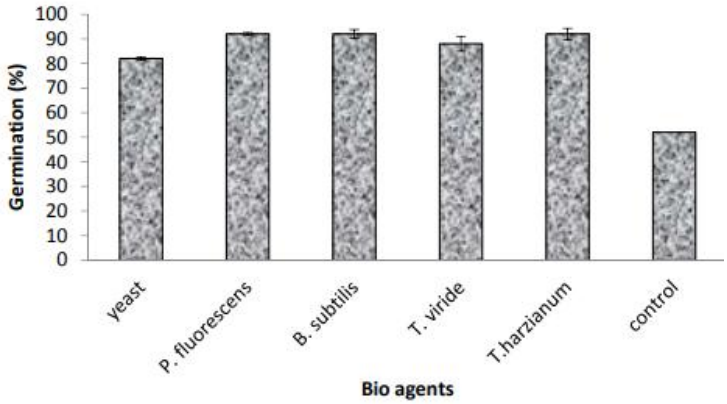
Treatments	N% in shoot	P% in shoot	K% in shoot	Oil% in seeds
Pp + Fusarium	0.55	0.67	4.73	43.3
Pp + Pythium,	0.72	0.85	5.53	48.0
Pp + Alternaria	0.63	0.73	4.30	45.0
Pf + Fusarium	0.40	0.61	4.43	42.7
Pf + Pythium	0.32	0.71	4.43	44.0
Pf + Alternaria	0.41	0.66	4.52	43.7
Fusarium	0.07	0.03	2.2	5.3
Pythium	0.06	0.04	1.43	4.7
Alternaria	0.0	0.0	0.0	0.0
Control (no addition)	0.21	0.42	3.05	27.7
LSD 5 %	0.033	0.042	0.576	3.11

- S.F. Naqvi et al. (2013) evaluated biocontrol efficiency using 4 sesame lines (95001, 96007, 96019, and 20003) that were found to be moderately resistant to *Xanthomonas campestris* pv. *sesami* in previous studies. The results were as follow (isolates FD-9, FD-17, ID-3, TTS-7 and GJ-1 were *Pseudomonas fluorescens* and isolates FD-21, ID-12 and GJ-4 were *Bacillus subtilis* and TTS5 as *Paenibacillus polymyxa*).

Isolates/Lines	**95001**		**96007**		**96019**		**20003**	
	DI (%)	**BE (%)**	**DI (%)**	**BE (%)**	**DI (%)**	**BE (%)**	**DI (%)**	**BE (%)**
FD-9	9 a	51 bc	10 def	48 bcd	8 de	49 d	6 defg	55 abc
FD-17	11 cd	40 cd	11 cde	43 cd	9 cd	35 cde	7 cdef	43 bcd
FD-21	12 c	34 d	13 c	33 de	10 c	32 de	8 bcd	33 bcde
ID-3	4 f	77 a	5 g	77 a	3 g	81 a	3 g	78 a
ID-12	6 ef	64 ab	8 f	60 ab	5 f	63 ab	4 fg	62 ab
TTS-5	12 c	32 d	11 cde	41 cd	11 bc	22 e	8 bcd	28 cdef
TTS-7	8 e	55 bc	9 ef	53 bc	7 ef	55 bc	5 efg	62 ab
GJ-1	16 b	14 e	16 b	17 e	12 b	16 ef	10 ab	11 ef
GJ-4	11 cd	43 cd	12 cd	37 cd	11 bc	24 e	9 abc	23 def
Control	18 a	0 e	19 a	0 f	15 a	0 f	12 a	0 f

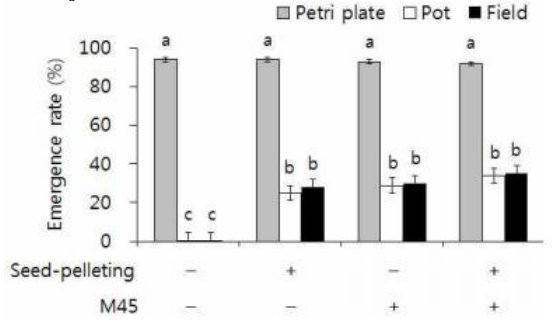
DI= Disease Incidence, BE= Biocontrol efficiency
Figures with different alphabets are significantly different from each other

- B.G. Nayyar et al. (2016) evaluated different bioagents to increase the germination and inhibit the fungi on sesame seeds bioagents (*Trichoderma viride*, *T. harzianum, Pseudomonas fluorescens, Bacillus subtilis* and *Saccharomyces cerevisiae* – yeast). Seed germination was tested by following the protocol of International Seed Testing Association. Antifungal activity was tested by poisoned food technique. The effects of the bioagents were as follow.



REPUBLIC OF KOREA

- Choi et al. (2014) evaluated *Pseudomonas fluorescens* M45 in powder form using clay and vermiculite for its effect on biological control of soilborne pathogens in sesame cultivation. In the petri dish trial, the emergence rate was overall good (> 92%) regardless of seeds being pelleted and/or M45-treated. In both pot and field trials containing disease-conducive soils, seed-pelleting substantially reduced emergence rate, whereas seed-pelleting with M45 significantly improved the emergence rate (> 26%). The emergence rate of sesame seeds treated with the strain M45 was greater than 30% regardless of seed pelletization. We also found that M45 colonized in the roots at the density of 1.6×10^5 cfu/g. With aid of the bioformulation, however, root colonization of the strain was significantly increased to 4.0×10^6 cfu/g. The powder formulation with strain M45 enhanced the rate of healthy stand establishment in disease-conducive soil.



F1.1.1b *Pseudomonas putida* (12 May 2021)

Synonym : *Pseudomonas striata*

Family: Pseudomonadaceae

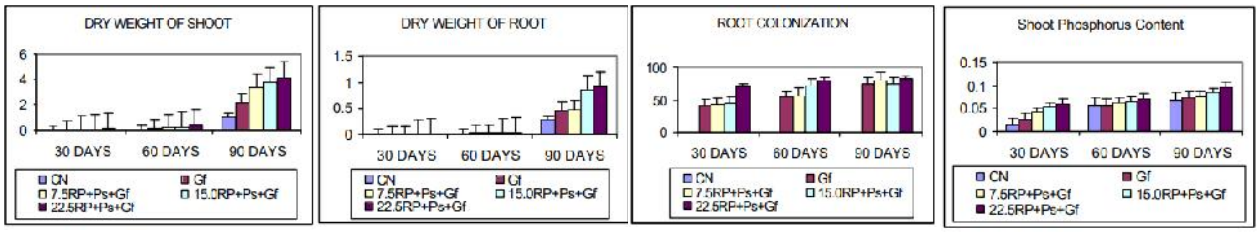
Definition: Amount of improvement from biofertilizers provided by *Pseudomonas putida* (Trevisan 1889) Migula 1895.

(Wikipedia, 12 May 2021) ***Pseudomonas putida*** is a Gram-negative, rod-shaped, saprotrophic soil bacterium.

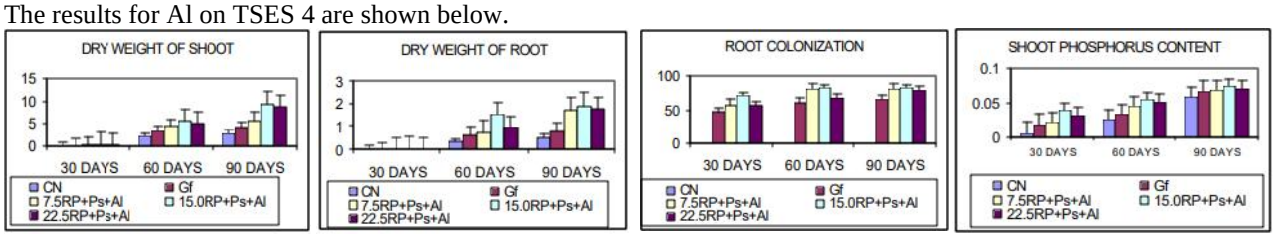
References:

INDIA

- S.J. Sabannavar and H.C. Lakshman (2009) evaluated the effects of inoculation with arbuscular mycorrhizal fungi (AMF) *Glomus fasciculatum* (Gf), *Acaulospora laevis* (Al), *Sclerocystis dussi* (Sd) and *Gigaspora margarita* (Gm) using 2 varieties (TSES 1 and TSES 4) with phosphate solubilizing bacteria (*Pseudomonas striata* – Ps) in the presence of different doses of rock phosphate (0, 7.5, 15.0, and 22.5 mg/kg) in clay pots. Phosphate solubilizing bacteria behaved as mycorrhiza helper bacteria promoting higher colonization rate and spore number of AMF which helps in solubilization of the mineral phosphate and contribute to the biogeochemical P cycling, thus promoting a sustainable nutrient supply to the crop plants for higher yield. The results for Gf on TSES 1 were as shown below.



The results for Al on TSES 4 are shown below.



There is more data on shoot and root length, shoot and root fresh weight, number of capsules, and spore number on both Gf and Al. There is no data for Sd or Gm.

PAKISTAN

- H.N. Farhan et al. (2010) investigated the biological effects of *Pseudomonas putida* and *Pseudomonas fluorescens* as biocides to inhibit *Fusarium* fungi growth and as biofertilizers to improve growth characters of sesame crop grown in contaminated soil with *Fusarium* under field conditions compared with Dithen and Radiomil. The results were as follow.

Treatments	**Fusarium growth (mm)**	**% inhibition**
Pseudomonas putida 2 + Fusarium	4.80	94.2
Pseudomonas fluorescens 3+ Fusarium	4.43	94.6
P. putida2 + P. *fluorescens 3*+ Fusarium	0.0	100.0
Dithen Fungicide + Fusarium	29.0	64.9
Radiomil + Fusarium	33.0	60.1
Control (Fusarium only)	82.7	-
LSD at 5%	11.2	-

Treatments	Chlorophyll a+b (mg/gm)	% N	% P	% K
Pseudomonas putida 2 + Fusarium	2.29	3.82	0.35	2.23
Pseudomonas fluorescens 3+ Fusarium	2.17	3.06	0.23	3.11
P. putida2 + P. *fluorescens 3*+ Fusarium	3.21	4.18	0.44	3.87
Dithen Fungicide + Fusarium	1.78	2.70	0.27	3.06
No addition	1.86	3.03	0.18	3.31
Control (Fusarium only)	0.85	1.77	0.11	1.34
LSD at 5%	0.81	1.52	0.07	0.98

Treatments	Leaf no./plant	Pods no./plant	Grains no./pod
Pseudomonas putida 2 + Fusarium	297.3	101.3	51.2
Pseudomonas fluorescens 3+ Fusarium	374.7	106.0	52.8
P. putida2 + P. *fluorescens 3*+ Fusarium	428.3	146.7	69.1
Dithen Fungicide + Fusarium	269.3	88.3	47.0
No addition	272.3	94.0	49.3
Control (Fusarium only)	162.7	44.0	31.3
LSD at 5%	77.82	17.3	8.0

Treatments	Branch no./plant	Height of plant (cm)	Leaf area/plant (cm^2)
Pseudomonas putida 2 + Fusarium	32.9	105.7	41.2
Pseudomonas fluorescens 3+ Fusarium	34.6	106.7	43.2
P. putida2 + P. *fluorescens 3*+ Fusarium	45.8	151.7	59.7
Dithen Fungicide + Fusarium	23.6	104.0	41.2
No addition	27.4	105.3	40.5
Control (Fusarium only)	14.6	53.3	25.5
LSD at 5%	5.8	13.7	10.7

Treatments	Weight of 1000 grain (gm)	Total yield of grains per plot (gm)	% Oil in grains
Pseudomonas putida 2 + Fusarium	2.24	362.1	50.6
Pseudomonas fluorescens 3+ Fusarium	2.46	442.2	51.3
P. putida2 + P. *fluorescens 3*+ Fusarium	2.92	982.3	56.2
Dithen Fungicide + Fusarium	1.81	303.5	41.9
No addition	2.29	352.4	46.3
Control (Fusarium only)	0.94	112.4	26.6
LSD at 5%	0.38	49.0	10.5

- H.N. Farhan et al. (2011) investigated the biological activity of *Pseudomonas* bacteria as biocides to protect sesame crop from some fungi and to evaluate its efficiency as plant growth promoting. The first experiment investigated the effects of *Pseudomonas putida* (Pp) and *Pseudomonas fluorescens* (Pf) on germination and seedlings growth of sesame crop against Pythium, Alternaria, and Fusarium under plastic house conditions. The following are the results.

Treatments	Sterilized soil		Non sterilized soil	
	Germination (%)	Seedlings (cm)	Germination (%)	Seedlings (cm)
Pythium + Pp	80	4.0	70	3.2
Fusarium + Pp	84	3.5	85	2.5
Alternaria + Pp	86.7	4.5	82	3.3
Pythium + Pf	65	3.2	65.3	2.2
Fusarium + Pf	61.6	4.0	71	3.0
Alternaria + Pf	75.7	3.0	77	1.0
Pythium	0.0	0.0	21	2.0
Fusarium	2.0	0.0	10	0.5
Alternaria	0.0	0.0	19	2.0
Control (no addition)	38.3	1.9	49.3	2.4

The second experiment grew the plants to harvest.

Treatments	Germination percentage	Leaf no. per plant (cm^2/plant)	Leaf area/plant	Chlorophyll content (mg/gm)
Pp + Fusarium	89.7	27	22	3.27
Pp + Pythium,	84.0	28	20	2.29
Pp + Alternaria	86.7	25	18	1.28
Pf + Fusarium	70.7	22	19	3.23
Pf + Pythium	71.0	19	17	1.96
Pf + Alternaria	80.0	19	18	2.25
Fusarium	3.0	6	4	0.21
Pythium	2.3	4	4	0.32
Alternaria	0.0	0	0	0.00
Control (no addition)	52.0	11	9	0.76
LSD 5 %	10.9	3.98	5.12	0.167

Treatments	Height of plant (cm)	Branch no. per plant	Total dry weight of shoot gm/plant
Pp + Fusarium	76.7	5.3	6.9
Pp + Pythium	88.3	8.3	7.7
Pp + Alternaria	67.7	6.3	6.7
Pf + Fusarium	73.3	4.7	4.8
Pf + Pythium	69.7	4.3	5.7
Pf + Alternaria	62.3	5.7	5.6
Fusarium	37.3	1.3	0.23
Pythium	36.3	2.7	0.3
Alternaria	0.0	0.0	0.0
Control (no addition)	55.0	3.3	3.3
LSD 5%	11.4	1.78	1.26

Treatments	Seeds no. per pod per plant	Weight of 1,000 seeds per plant (gm)	Pods no. per plant
Pp + Fusarium	50.7	2.2	33.7
Pp + Pythium	64.0	2.5	37.3
Pp + Alternaria	53.7	2.1	35.9
Pf + Fusarium	53.3	1.9	35.0
Pf + Pythium	54.7	1.6	26.7
Pf + Alternaria	43.7	1.8	32.3
Fusarium	8.3	0.4	1.3
Pythium	13.0	0.7	1.0
Alternaria	0.0	0.0	0.0
Control (no addition)	35.3	1.2	19.0
LSD 5%	4.58	0.22	3.3

Treatments	N% in shoot	P% in shoot	K% in shoot	Oil% in seeds
Pp + *Fusarium*	0.55	0.67	4.73	43.3
Pp + *Pythium*,	0.72	0.85	5.53	48.0
Pp + *Alternaria*	0.63	0.73	4.30	45.0
Pf + *Fusarium*	0.40	0.61	4.43	42.7
Pf + *Pythium*	0.32	0.71	4.43	44.0
Pf + *Alternaria*	0.41	0.66	4.52	43.7
Fusarium	0.07	0.03	2.2	5.3
Pythium	0.06	0.04	1.43	4.7
Alternaria	0.0	0.0	0.0	0.0
Control (no addition)	0.21	0.42	3.05	27.7
LSD 5 %	0.033	0.042	0.576	3.11

F1.1.1c *Pseudomonas veronii* (12 Aug 2021)

Family: Pseudomonadaceae

Definition: Amount of biocontrol provided by *Pseudomonas veronii* Elomari et al. 1996.

(Wikipedia, 12 Aug 2021) ***Pseudomonas veronii*** is a Gram-negative, rod-shaped, fluorescent, motile bacterium isolated from natural springs in France. It may be used for bioremediation of contaminated soils, as it has been shown to degrade a variety of simple aromatic organic compounds. Based on 16S rRNA analysis, *P. veronii* has been placed in the *P. fluorescens* group.

References:

PAKISTAN

- S. Ali et al. (2018) reported *Pseudomonas veronii* KJ contains the acdS gene, which encodes for the enzyme 1-aminocyclopropane-1-carboxylate (ACC) deaminase. ACC deaminase cleaves the substrate ACC to produce an α-ketobutyrate and ammonia and mitigates the adverse effect of prolonged water stress as shown below.

Treatment	S.L. (cm)	R.L. (cm)	F.B. (g)	D.B. (g)
Control	24.5 ± 0.60^{a}	9.1 ± 1.04^{a}	9.22 ± 2.24^{a}	3.15 ± 0.82^{a}
Bacterized	25.5 ± 0.28^{a}	15.6 ± 4.4^{b}	14.18 ± 1.6^{b}	5.31 ± 0.87^{b}
Flooded	14.6 ± 2.32^{b}	4.4 ± 0.51^{c}	3.54 ± 0.23^{c}	0.55 ± 0.15^{c}
Flooded + bacterized	17.8 ± 1.75^{c}	7.03 ± 0.85^{d}	4.00 ± 0.47^{d}	0.82 ± 0.08^{d}

The values in each column represent the mean ± SD

S.L., shoot length; *R.L.*, root length; *F.B.*, fresh biomass; *D.B.*, dry biomass

Those marked with different letters in each column are significantly different at $P \leq 0.05$, as analyzed by *t* test

F1.1.1d *Pseudomonas aeruginosa* (20 Aug 2021)

Family: Pseudomonadaceae

Definition: Amount of biocontrol provided by *Pseudomonas aeruginosa* (Schröter 1872) Migula 1900.

(Wikipedia, 20 Aug 2021) ***Pseudomonas aeruginosa*** is a common encapsulated, Gram-negative, strict aerobic (although can grow anaerobically in the presence of nitrate), rod-shaped bacterium that can cause disease in plants and animals, including humans. A species of considerable medical importance, *P. aeruginosa* is a multidrug resistant pathogen recognized for its ubiquity, its intrinsically advanced antibiotic resistance mechanisms, and its association with serious illnesses – hospital-acquired infections such as ventilator-associated pneumonia and various sepsis syndromes.

The organism is considered opportunistic insofar as serious infection often occurs during existing diseases or conditions – most notably cystic fibrosis and traumatic burns. It generally affects the immunocompromised but can also infect the immunocompetent as in hot tub folliculitis. Treatment of *P. aeruginosa* infections can be difficult due to its natural resistance to antibiotics. When more advanced antibiotic drug regimens are needed adverse effects may result.

It is citrate, catalase, and oxidase positive. It is found in soil, water, skin flora, and most man-made environments throughout the world. It thrives not only in normal atmospheres, but also in low-oxygen atmospheres, thus has colonized many natural and artificial environments. It uses a wide range of organic material for food; in animals, its versatility enables the organism to infect damaged tissues or those with reduced immunity. The symptoms of such infections are generalized inflammation and sepsis. If such colonizations occur in critical body organs, such as the lungs, the urinary tract, and kidneys, the results can be fatal. Because it thrives on moist surfaces, this bacterium is also found on and in medical equipment, including catheters, causing cross-infections in hospitals and clinics. It is also able to decompose hydrocarbons and has been used to break down tarballs and oil from oil spills. *P. aeruginosa* is not extremely virulent in comparison with other major pathogenic bacterial species – for example *Staphylococcus aureus* and *Streptococcus pyogenes* – though *P. aeruginosa* is capable of extensive colonization, and can aggregate into enduring biofilms.

References:

EGYPT

- M.S. Abdel-Salam et al. (2007) reported *Pseudomonas aeruginosa* controls the soilborne plant pathogen *Fusarium oxysporum* f. sp. *sesame*.

F1.1.2 *Azotobacter* spp. (15 May 2021)

Family: Pseudomonadaceae

Definition: Amount of biocontrol provided by *Azotobacter* spp. Beijerinck 1901.

(Wikipedia, 15 May 2021) ***Azotobacter*** is a genus of usually motile, oval or spherical bacteria that form thick-walled cysts and may produce large quantities of capsular slime. They are aerobic, free-living soil microbes that play an important role in the nitrogen cycle in nature, binding atmospheric nitrogen, which is inaccessible to plants, and releasing it in the form of ammonium ions into the soil (nitrogen fixation). In addition to being a model organism for studying diazotrophs, it is used by humans for the production of biofertilizers, food additives, and some biopolymers. The first representative of the genus, *Azotobacter chroococcum*, was discovered and described in 1901 by Dutch microbiologist and botanist Martinus Beijerinck. *Azotobacter* species are Gram-negative bacteria found in neutral and alkaline soils, in water, and in association with some plants.

References:

INDIA

- V. Bharathi et al. (2013) examined the effect of seed treatments (*Trichoderma viride* + *Pseudomonas fluorescence*, *Azotobacter* + *Trichoderma*, *Rhizobium* + *Trichoderma*, *Azotobacter*, *Trichoderma*, *Pseudomonas*, Benomyl, and untreated control) to improve germination and increase survival rate. *Trichoderma* and *Pseudomonas* were treated @ 6g/kg and 10 g/kg seed, respectively. *Azotobacter* was used @ 25 g/kg seed (250g/10 kg seed). The combination inoculum was used @ half the dose of each bioagent/biofertilizer. The seeds were tested for mycoflora and the following fungi were found: *Alternaria alternata*, *Alternaria tennissima*, *Alternaria terreus*, *Aspergillus flavus*, *Aspergillus fumigatus*, *Aspergillus niger*, *Macrophomina* spp., *Cephalosporium* spp., *Fusarium oxysporum*, *Rhizoctonia solani*, *Rhizopus stolonifer*, *Curvularia* spp., *Drechslera* spp., *Rhizopus* spp., *Cladosporium* spp., and *Penicillium* spp.

Germination of the treated seeds was tested using 3 methods: blotter, paper towel, and sand. The results of the blotter method (100 seeds for 8 days) were as follows:

Treatment	Germination (%)	Seed rot	Seedling Blight	Fungal colonies
Trichoderma + Pseudomonas fluorescence	96.0	4.50	4.18	3.83
Azatobacter + Trichoderma	94.4	8.64	6.42	10.2
Rhizobium + Trichoderma	90.2	12.1	8.63	12.6
Azatobacter	88.0	18.0	9.40	14.8
Trichoderma	85.3	10.6	7.21	12.2
Pseudomonas fluorescence	84.0	9.8	8.10	15.4
Benomil	86.3	2.70	2.10	3.00
Control	75.0	32.3	21.8	36.2
SEm±	0.48	0.72	0.80	0.94
CV%	3.71	5.46	5.68	6.78
CD	1.61	1.82	2.21	2.08

The results of the paper towels method (50 seeds for 14 days) and sand method (100 seeds for 20 days) were as follows. The seedling vigor was done in petri dishes for 8 days (no temperature specified. The germination % and seedling length in cm was measured. The seedling vigor index = Mean seedling length (cm) x Germination percentage (%).

Treatments	Paper Towel Method				Sand Method				Seedling Vigor
	NS	AS	SR	HS	NS	AS	SR	HS	
Trichoderma + P. fluorescence	23	0	14	63	10	2	0	88	1660.3
Azatobacter + Trichoderma	19	2	18	61	5	4	0	92	1562.6
Rhizobium + Trichoderma	17	3	26	52	5	2	4	90	1404
Azatobacter	14	6	32	48	1	3	0	94	1386.2
Trichoderma	12	2	30	50	3	2	2	93	1489
Pseudomonas fluorescence	8	4	16	54	1	4	2	93	1356.3
Benomil	10	2	2	72	2	2	0	96	1312
Control	8	3	47	42	1	1	8	91	904.1
SEm±									69.2
CV									245.6
CD									121.2

*Viability = 76 per cent, ** Data on germination is based on 100 seeds, *** Data based on observation of normal seedling. NS = Normal seedling, AS= Abnormal Seedlings. SR = Seed rots, HS = Hard seeds.

- B.N. Aglawe et al. (2021) studied the effects of biofertilizers on the growth and yield of sesame with the following results. (PSB = phosphate solubilizing bacteria)

Treatments	No. of seeds capsule^{-1}	Seed yield plant^{-1}(g)	Weight of Capsules plant^{-1} (g)	Test weight (g)
T1- RDF (50:25:00) Kg NPK ha^{-1}	55.60	5.42	15.97	2.87
T2- 50% RDF + Azotobacter	50.00	4.85	13.80	2.67
T3 - 75% RDF + Azotobacter	53.20	5.31	15.80	2.82
T4 – 100% RDF + Azotobacter	59.35	5.80	17.20	2.95
T5 – 50% RDF + Azotobacter + PSB	52.65	5.02	15.20	2.76
T6- 75% RDF + Azotobacter + PSB	58.21	5.65	16.30	2.90
T7-100% RDF +Azotobacter + PSB	63.30	6.13	17.90	3.05
T8-Control	48.20	4.10	13.00	2.60
SE+	3.67	0.31	0.90	0.21
CD at 5%	7.61	0.64	1.86	NS
C.V.	8.16	7.13	7.04	8.92
General Mean	55.06	5.29	15.65	-

Treatments	Seed yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest index (%)
T1-RDF 50:25:00 Kg NPKha^{-1}	583	2702	3285	17.69
T2- 50% RDF + Azotobacter	495	25/2	3067	16.15
T3 - 75% RDF + Azotobacter	553	2655	3208	17.25
T4 – 100% RDF + Azotobacter	717	2940	3657	19.61
T5 -50% RDF + Azotobacter + PSB	525	2603	3128	16.80
T6- 75% RDF + Azotobacter + PSB	665	2802	3467	19.19
T 7- 100% RDF + Azotobacter + PSB	780	3060	3840	20.55
T8-Control	443	2405	2848	15.43
SE+	37	120	199	-
CD at 5%	77	353	412	-
C.V.	7.62	7.66	8.22	-
General Mean	595	2717	3313	-

F1.1.2a *Azotobacter chroococcum* (31 May 2021)

Family: Pseudomonadaceae

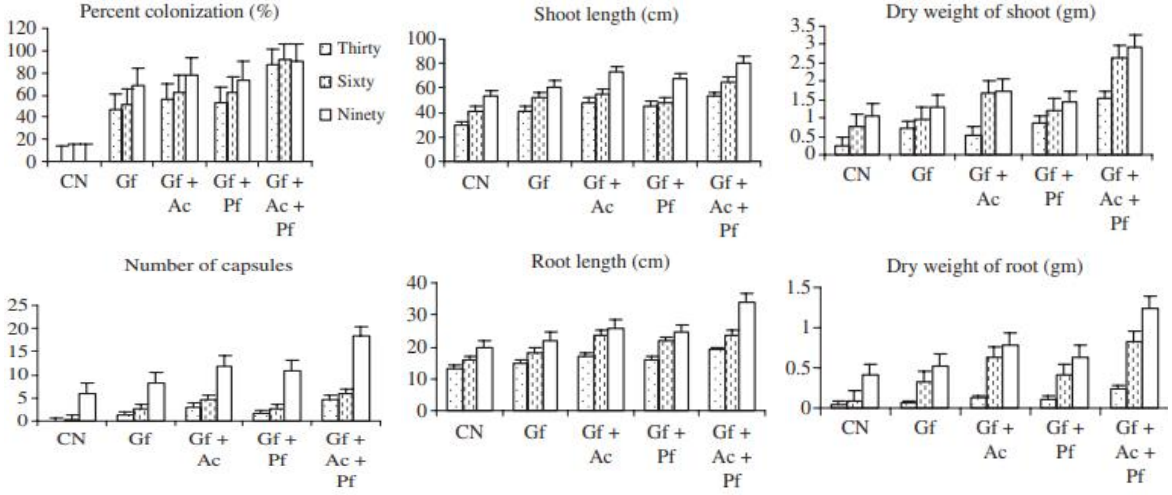
Definition: Amount of improvement from biofertilizers provided by *Azotobacter chroococcum* Beijerinck 1901.

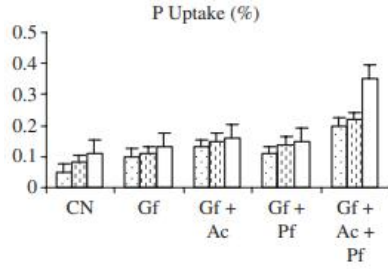
(Wikipedia, 31 May 2021) ***Azotobacter chroococcum*** is a bacterium that has the ability to fix atmospheric nitrogen. It was discovered by Martinus Beijerinck in 1901, and was the first aerobic, free-living nitrogen fixer discovered. *A. chroococcum* could be useful for nitrogen fixation in crops as a biofertilizer, fungicide, and nutrient indicator, and in bioremediation.

References:

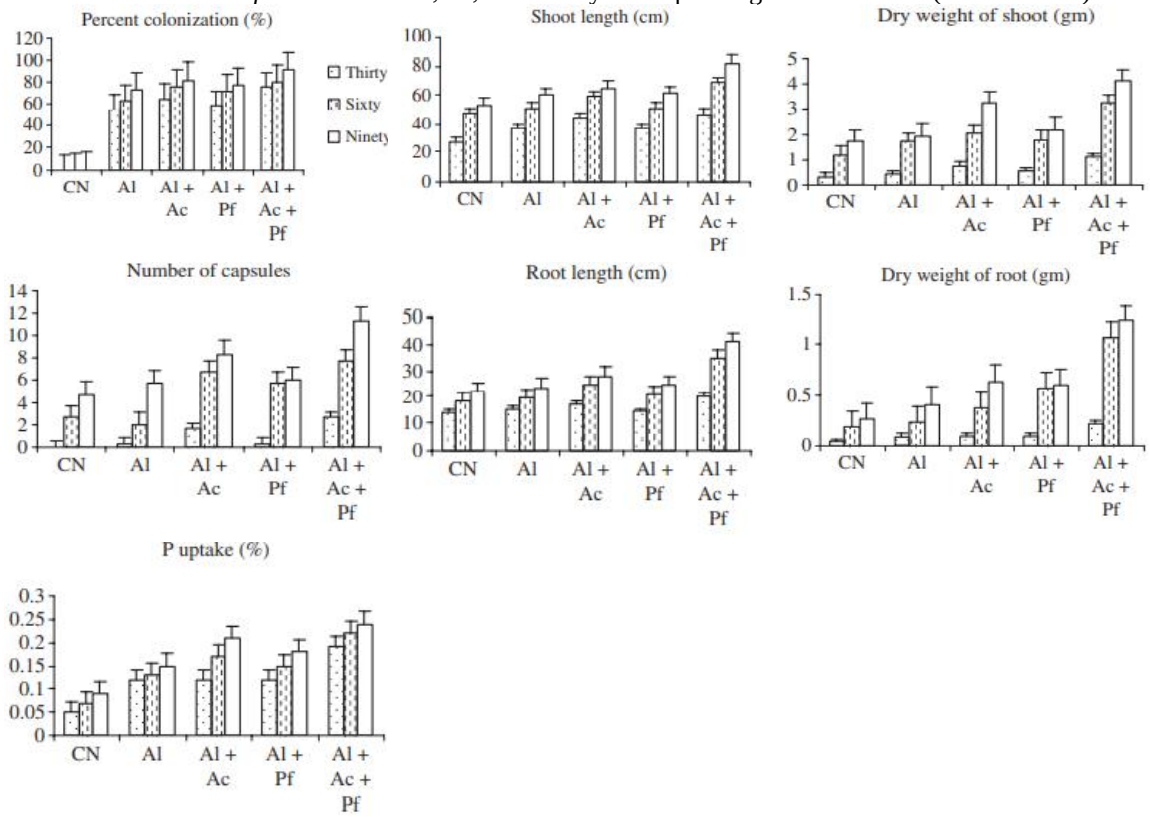
INDIA

- S.J. Sabannavar and H.C. Lakshman (2008) evaluated the effects of a single inoculation of *Glomus fasciculatum* (Gf) and *Acaulospora laevis* (Al), dual inoculation of arbuscular mycorrhizal fungi (AMF) with *Azotobacter chroococcum* (Ac) or *Pseudomonas fluorescens* (Pf) and a triple inoculation of AMF, *A. chroococcum* and *P. fluorescens* using 2 varieties (DS1 and E8) in a pot experiment. The results revealed that inoculation of AMF + Ac + Pf stimulated increased AMF colonization, plant growth, i.e., shoot, root length, fresh and dry weight of shoot and root, phosphorus uptake and number of capsules significantly over the dual and single inoculation treatments. The association of bacteria and AMF provides evidence that bacteria are involved in the beneficial effects to AMF on sesame varieties. The results for *Glomus fasciculatum* at 30, 60, and 90 days after planting were as follow (CN = control).

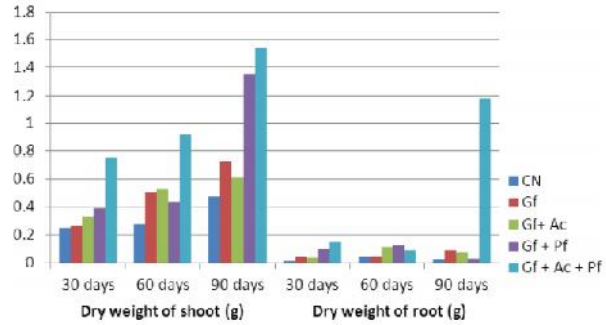


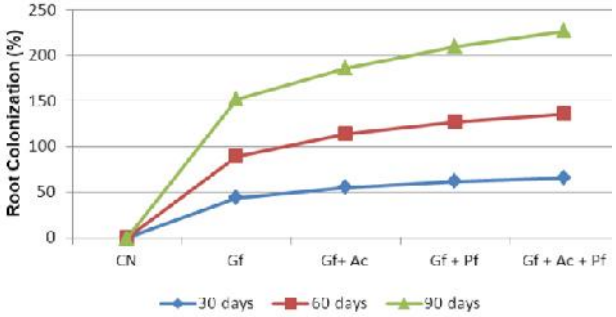


The results for *Acaulospora laevis* at 30, 60, and 90 days after planting were as follow (CN = control).

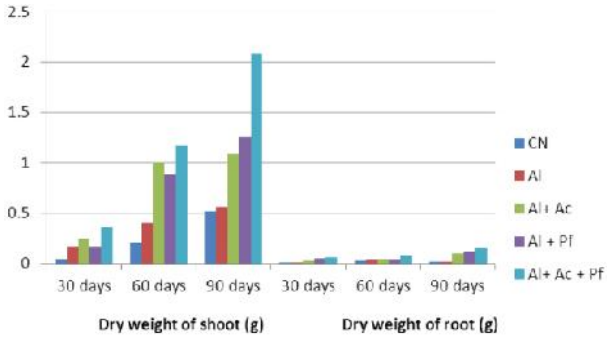


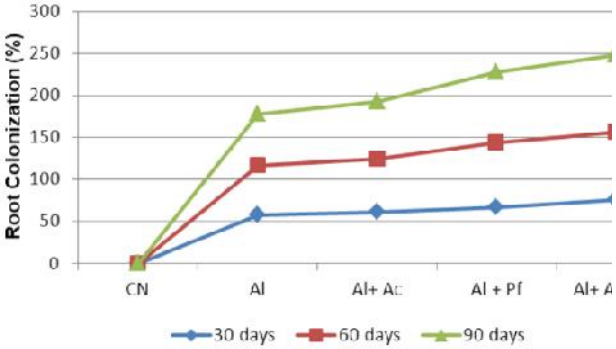
- S.J. Sabannavar and H.C. Lakshman (2011) evaluated the effect of co-inoculation with bacteria and arbuscular mycorrhizal (AM) fungi on the growth of sesame. The two varieties of sesame TSES 1 and TSES 4 were inoculated with single, double, and triple inoculations. The results revealed that triple inoculation of *Glomus fasciculatum* (Gf) + *Azotobacter chroococcum* (Ac) + *Pseudomonas fluorescens* (Pf) to TSES 1 and *Acaulospora laevis* (Al) + Ac + Pf to TSES 4 stimulated increased root colonization, plant growth, plant biomass, phosphorus content, and number of capsules significantly over the double and single inoculation treatments. These results suggest synergistic interaction among AM fungi, *Azotobacter chroococcum*, and *Pseudomonas fluorescens*. The association of bacteria and AM fungi provide evidence that bacteria are involved in the beneficial effects to AM fungi on plant growth and can improve crop production. The results for TSES 1 with Gf were as follow (CN = control).





The results for TSES 4 with Al were similar.





- D.K. Maheshwari et al. (2012) evaluated the use of *Azotobacter chroococcum* TR2 against *Macrophomina phaseoli* and *Fusarium oxysporum* along with growth promoting attributes in conjunction with fertilizers. It caused degradation and digestion of cell wall components, resulting in hyphal perforations, empty cell (halo) formation, shrinking and lysis of fungal mycelia along with significant degeneration of conidia. The effects on the pathogens were as follow.

Fungal Pathogen	Incubation (h)	Growth in dual culture (mm)	Growth in control (mm)	Growth inhibition (%)
M. phaseolina	48	25.0 ± 0.03	48.2 ± 0.02	48.1
	72	28.3 ± 0.05	60.4 ± 0.05	53.1
	96	29.7 ± 0.01	70.7 ± 0.03	57.9
	120	30.9 ± 0.06	89.3 ± 0.02	65.3
F. oxysporum	48	28.0 ± 0.03	40.0 ± 0.07	30.0
	72	39.1 ± 0.02	65.5 ± 0.06	40.3
	96	41.0 ± 0.03	76.7 ± 0.11	46.5
	120	41.8 ± 0.07	88.1 ± 0.12	52.5

They evaluated the effects of the plant growing promoting attributes in conjunction with chemical fertilizers ($N_{40+40+40}P_{30}K_{30}$) in 2010 and 2011 using 1 cultivar (ST-1) at Dehradun (30.50N 77.87E, elevation 640 m) The results were as follow.

Treatment	Germination (%)	Root			Shoot			Leaf area	Capsules
		Length (cm)	Fresh weight (g)	Dry weight (g)	Length (cm)	Fresh weight (g)	Dry weight (g)	Leaf area (cm^2)	Capsules/ plant
A. chroococcum TRA2	90.0^{de}	13.5^{c}	30.2^{b}	14.3^{b}	145^{bc}	163^{bc}	97.5^{b}	702^{b}	68.5^{b}
A.chroococcum TRA2 + half dose fertilizers	93.0^{e}	16.2^{de}	39.5^{c}	19.8^{cd}	186^{de}	200^{de}	109.2^{d}	775^{d}	99.7^{d}
Half dose of fertilizers	86.7^{bc}	12.0^{bc}	32.4^{b}	18.4^{c}	149^{c}	165^{c}	96.4^{bc}	721^{c}	73.7^{b}
Full dose of chemical fertilizers	87.3^{c}	17.0^{e}	40.9^{c}	22.0^{d}	191^{e}	208^{e}	102.5^{cd}	781^{d}	104.0^{d}
Control	74.1^{a}	8.6^{a}	23.6^{a}	10.4^{a}	111^{a}	125^{a}	61.4^{a}	499^{a}	47.2^{a}

Treatment	Seeds yield (kg/ha)			1000 seeds weight (g)		
	2010	2011	Mean	2010	2011	Mean
A. chroococcum TRA2	670[b]	672[b]	671[b]	2.73[b]	2.78[b]	2.78[b]
A. chroococcum TRA2 + half dose fertilizers	937[c]	940[c]	938.5[c]	3.10[d]	3.04[c]	3.08[c]
Half dose of fertilizers	671[b]	674[b]	672.5[b]	2.59[ab]	2.61[b]	2.66[b]
Full dose of fertilizers	939[c]	942[c]	940.5[c]	3.03[d]	2.87[c]	2.94[c]
Control	397[a]	398[a]	397.5[a]	2.48[a]	2.39[a]	2.42[a]

Tr treatment	Oil content (%)	Oil yield (kg/ha)	Protein content (%)	Protein yield (kg/ha)
A. chroococcum TRA2	47.5[b]	340[b]	18.1[b]	131[b]
A. chroococcum TRA2 + half dose fertilizers	49.2[c]	390[d]	20.0[c]	140[d]
Half dose of fertilizers	46.6[b]	346[bc]	18.6[b]	135[c]
Full dose of fertilizers	49.8[c]	494[c]	20.4[c]	142[d]
Control	45.0[a]	314[a]	17.4[a]	103[a]

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F2 Order: Bacillales Prevot 1953

(Wikipedia, 19 Apr 2021) The **Bacillales** are an order of Gram-positive bacteria, placed within the Firmicutes. Representative genera include *Bacillus*, *Listeria* and *Staphylococcus*.

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F2.1 Family: Bacillaceae Garrity et al. 2001

(Wikipedia, 19 Apr 2021) The **Bacillaceae** are a family of Gram-positive, heterotrophic, rod-shaped bacteria that may produce endospores. Motile members of this family are characterized by peritrichous flagella. Some Bacillaceae are aerobic, while others are facultative or strict anaerobes. Most are not pathogenic, but *Bacillus* species are known to cause disease in humans.

The following species have been identified to be a biocontrol in sesame:

- F2.1.1 *Bacillus* spp.
- F2.1.1a *Bacillus megtella*
- F2.1.1b *Bacillus subtillis*
- F2.1.1c *Bacillus cereus*
- F2.1.1d *Bacillus amyloliquefaciens*
- F2.1.1e *Bacillus velezensis*
- F2.1.1f *Bacillus methylotrophicus*
- F2.1.1g *Bacillus thuringiensis*
- F2.1.2 *Priestia* spp.
- F2.1.2a *Priestia megaterium* (*Syn: *Bacillus megaterium*)

There are species in this family that cause a disease, produce a toxin, inhibit germination, or affect seed quality. See C8.1. There are species in this family associated with sesame, but not reported to cause diseases, produce a toxin, inhibit germination, or affect seed quality. See I5.1.

F2.1.1 *Bacillus* spp. (19 Apr 2021)

Family: Bacillaceae

Definition: Amount of biocontrol provided by *Bacillus* spp. Cohn 1872.

(Wikipedia, 19 Apr 2021) ***Bacillus*** (Latin “stick”) is a genus of Gram-positive, rod-shaped bacteria, a member of the phylum *Firmicutes*, with 266 named species. The term is also used to describe the shape (rod) of certain bacteria; and the plural *Bacilli* is the name of the class of bacteria to which this genus belongs. *Bacillus* species can be either obligate aerobes: oxygen dependent; or facultative anaerobes: having the ability to continue living in the absence of oxygen. Cultured *Bacillus* species test positive for the enzyme catalase if oxygen has been used or is present.

Bacillus can reduce themselves to oval endospores and can remain in this dormant state for years. The endospore of one species from Morocco is reported to have survived being heated to 420 °C. Endospore formation is usually triggered by a lack of nutrients: the bacterium divides within its cell wall, and one side then engulfs the other. They are not true spores (i.e., not an offspring). Endospore formation originally defined the genus, but not all such species are closely related, and many species have been moved to other genera of the *Firmicutes*. Only one endospore is formed per cell. The spores are resistant to heat, cold, radiation, desiccation, and disinfectants. *Bacillus anthracis* needs oxygen to sporulate; this constraint has important consequences for epidemiology and control. *In vivo*, *B. anthracis* produces a polypeptide (polyglutamic acid) capsule that kills it from phagocytosis. The genera *Bacillus* and *Clostridium* constitute the family *Bacillaceae*. Species are identified by using morphologic and biochemical criteria. Because the spores of many *Bacillus* species are resistant to heat, radiation, disinfectants, and desiccation, they are difficult to eliminate from medical and pharmaceutical materials and are a frequent cause of contamination. Not only they are they resistant to heat, radiation, etc., but they are also resistant to chemicals such as antibiotics. This resistance allows them to survive for many years and especially in a controlled environment. *Bacillus* species are well known in the food industries as troublesome spoilage organisms.

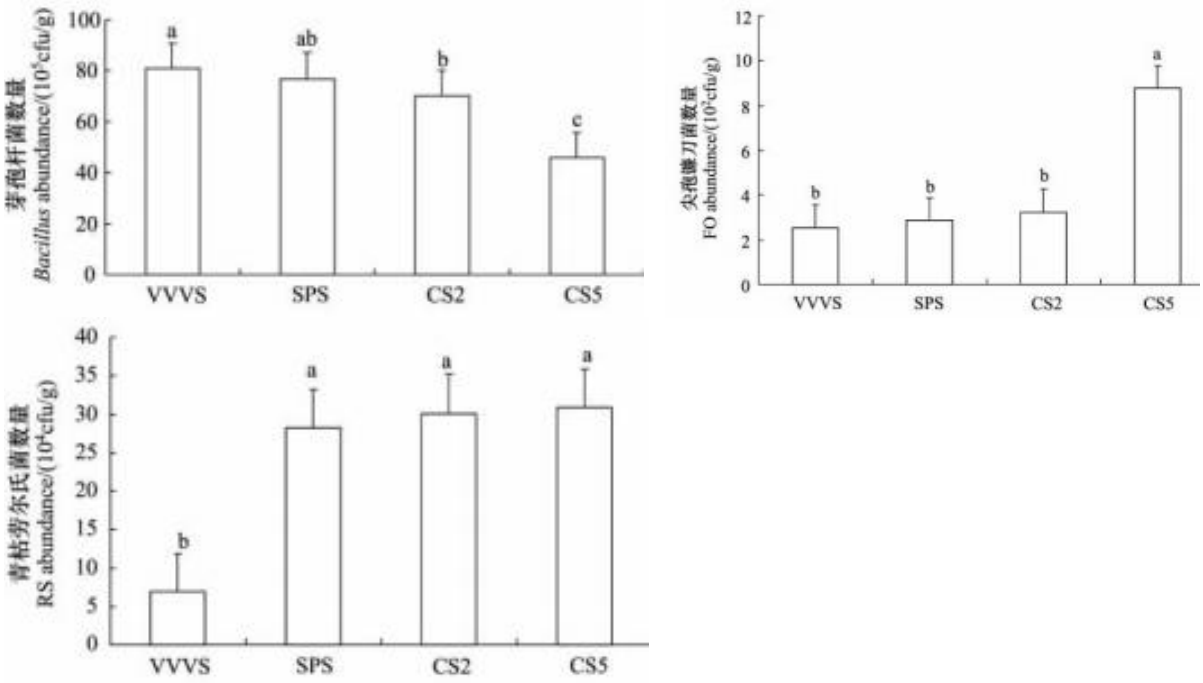
Ubiquitous in nature, *Bacillus* includes both free-living (nonparasitic) species, and two parasitic pathogenic species. These two *Bacillus* species are medically significant: *B. anthracis* causes anthrax; and *B. cereus* causes food poisoning.

Many species of *Bacillus* can produce copious amounts of enzymes, which are used in various industries, such as in the production of alpha amylase used in starch hydrolysis and the protease subtilisin used in detergents. *B. subtilis* is a valuable model for bacterial research. Some *Bacillus* species can synthesize and secrete lipopeptides, in particular surfactins and mycosubtilins.

References:

CHINA

- J.L. Hua et al. (2012) evaluated the effects of 4 normal crop rotations (vegetable crop (vegetable-vegetable-vegetable-sesame, VVVS), alternation of sesame with peanut (sesame-peanut-sesame, SPS), 2 year continuous sesame, CS2, and 5 year continuous sesame, CS5) on populations of *Bacillus* spp., *Fusarium oxysporum* (FO), and *Ralstonia solanacearum* (RS). The results were as follow.



It was clear that continuous cropping of sesame led to direct changes in the microbial composition of the rhizosphere. Bacteria and actinomycetes decreased in abundance, while fungi increased. When rhizospheric soil changes from "bacterial" to "fungal", its biological activity and fertility decline, and it is slower to recover from ecological fluctuations caused by external factors such as pathogens and waterlogging. Fusarium oxysporum and Ralstonia solanacearum continue to increase in abundance, causing worsening diseases. These factors eventually lead to continuous cultivation problems in sesame.

EGYPT

- A.I.I. El-Fiki et al. (2004a) studied the effects of using *Bacillus* sp. to control *Macrophomina phaseolina* Tassi (Goid). The seeds were planted in pots in the greenhouse and then took percentages as follows: % pre-emergence = damping off within 15 days, % post-emergence = damping off within 45 days, % charcoal rot = diseased at 90 days, and % healthy plants at 90 days. The results with antagonistic fungi were as follow.

Antagonistic fungi and bacteria	% Disease incidence			
	At seedling stage		At maturity stage	
	Pre-emergence	Post-emergence	Charcoal rot	Healthy plants
B. megtella *	16.7	16.7	23.3	43.3
Bacillus sp 3 **	13.3	10.0	23.3	53.3
Bacillus subtillus *	10.0	13.3	20.0	56.7
Chaetomium bostrycoides *	0.0	3.3	6.7	90.0
Gliocladium penicilloides *	16.7	20.0	26.7	36.7
T. hamatum *	6.7	6.7	6.7	80.0
T. viride *	16.7	6.7	6.7	70.0
Trichoderma harzianum *	0.0	0.0	3.3	96.7
Trichoderma sp 10 **	23.3	26.7	20.0	30.0
Trichoderma sp 2 **	13.3	13.3	13.3	60.0
Trichoderma sp 3 **	16.7	23.3	16.7	43.3
Trichoderma sp 5 **	6.7	0.0	10.0	83.3
Trichoderma sp 6 **	13.3	6.7	10.0	70.0
Trichoderma sp 8 **	16.7	20.0	20.0	43.3
Trichoderma sp 9 **	20.0	6.7	16.7	56.7
Control	30.0	26.7	26.7	16.7
LSD. at 5%	8.17	9.05	7.96	9.53

* Obtained from Biological Control and Onion and Oil Crops Res. Dept Agric., Res. Center Giza, Egypt.
** Isolated from rhizosphere of healthy sesame plants.

UNITED STATES

- D.C. Erwin reported species of *Pseudomonas*, *Bacillus*, and *Streptomyces*, which are most active at 25-27°C at field capacity moisture level, can be suppressive to Phytophthora species in soil (Cited by C. Chattopadhyay et al., 2019).
- M. Fay et al. (2021) reported metagenomic analysis of food is becoming more routine and can provide important information pertaining to the shelf life potential and the safety of these products. They examined 10 sesame samples and identified *Bacillus* spp. in a proportional range from <1 to 5.8%.

F2.1.1a *Bacillus megtella* (19 Apr 2021)

Family: Bacillaceae

Definition: Amount of biocontrol provided by *Bacillus megtella*.

References:

EGYPT

- A.I.I. El-Fiki et al. (2004a) studied the effects of using *Bacillus megtella* to control *Macrophomina phaseolina* Tassi (Goid). The seeds were planted in pots in the greenhouse and then took percentages as follows: % pre-emergence = damping off within 15 days, % post-emergence = damping off within 45 days, % charcoal rot = diseased at 90 days, and % healthy plants at 90 days. The results with antagonistic fungi were as follow.

Antagonistic fungi and bacteria	% Disease incidence			
	At seedling stage		At maturity stage	
	Pre-emergence	Post-emergence	Charcoal rot	Healthy plants
B. megtella *	16.7	16.7	23.3	43.3
Bacillus sp 3 **	13.3	10.0	23.3	53.3
Bacillus subtillus *	10.0	13.3	20.0	56.7
Chaetomium bostrycoides *	0.0	3.3	6.7	90.0
Gliocladium penicilloides *	16.7	20.0	26.7	36.7
T. hamatum *	6.7	6.7	6.7	80.0
T. viride *	16.7	6.7	6.7	70.0
Trichoderma harzianum *	0.0	0.0	3.3	96.7
Trichoderma sp 10 **	23.3	26.7	20.0	30.0
Trichoderma sp 2 **	13.3	13.3	13.3	60.0
Trichoderma sp 3 **	16.7	23.3	16.7	43.3
Trichoderma sp 5 **	6.7	0.0	10.0	83.3
Trichoderma sp 6 **	13.3	6.7	10.0	70.0
Trichoderma sp 8 **	16.7	20.0	20.0	43.3
Trichoderma sp 9 **	20.0	6.7	16.7	56.7
Control	30.0	26.7	26.7	16.7
LSD. at 5%	8.17	9.05	7.96	9.53

* Obtained from Biological Control and Onion and Oil Crops Res. Dept Agric., Res. Center Giza, Egypt.
** Isolated from rhizosphere of healthy sesame plants.

F2.1.1b *Bacillus subtilis* (19 Apr 2021)

Family: Bacillaceae

Definition: Amount of biocontrol provided by *Bacillus subtilis* (Ehrenberg 1835) Cohn 1872.

(Wikipedia, 19 Apr 2021) ***Bacillus subtilis***, known also as the **hay bacillus** or **grass bacillus**, is a Gram-positive, catalase-positive bacterium, found in soil and the gastrointestinal tract of ruminants and humans. As a member of the genus *Bacillus*, *B. subtilis* is rod-shaped, and can form a tough, protective endospore, allowing it to tolerate extreme environmental conditions. *B. subtilis* has historically been classified as an obligate aerobe, though evidence exists that it is a facultative anaerobe. *B. subtilis* is considered the best studied Gram-positive bacterium and a model organism to study bacterial chromosome replication and cell differentiation. It is one of the bacterial champions in secreted enzyme production and used on an industrial scale by biotechnology companies.

References:

INTERNATIONAL

- CAB International (accessed 12 Apr 2021) reported sesame was associated with *Bacillus subtilis*.

EGYPT

- A.I.I. El-Fiki et al. (2004a) studied the effects of using *Bacillus subtilis* to control *Macrophomina phaseolina* Tassi (Goid). The seeds were planted in pots in the greenhouse and then took percentages as follows: % pre-emergence = damping off within 15 days, % post-emergence = damping off within 45 days, % charcoal rot = diseased at 90 days, and % healthy plants at 90 days. The results with antagonistic fungi were as follow.

Antagonistic fungi and bacteria	% Disease incidence			
	At seedling stage		At maturity stage	
	Pre-emergence	Post-emergence	Charcoal rot	Healthy plants
B. megtella *	16.7	16.7	23.3	43.3
Bacillus sp 3 **	13.3	10.0	23.3	53.3
Bacillus subtillus *	10.0	13.3	20.0	56.7
Chaetomium bostrycoides *	0.0	3.3	6.7	90.0
Gliocladium penicilloides *	16.7	20.0	26.7	36.7
T. hamatum *	6.7	6.7	6.7	80.0
T. viride *	16.7	6.7	6.7	70.0
Trichoderma harzianum *	0.0	0.0	3.3	96.7
Trichoderma sp 10 **	23.3	26.7	20.0	30.0
Trichoderma sp 2 **	13.3	13.3	13.3	60.0
Trichoderma sp 3 **	16.7	23.3	16.7	43.3
Trichoderma sp 5 **	6.7	0.0	10.0	83.3
Trichoderma sp 6 **	13.3	6.7	10.0	70.0
Trichoderma sp 8 **	16.7	20.0	20.0	43.3
Trichoderma sp 9 **	20.0	6.7	16.7	56.7
Control	30.0	26.7	26.7	16.7
LSD. at 5%	8.17	9.05	7.96	9.53

* Obtained from Biological Control and Onion and Oil Crops Res. Dept Agric., Res. Center Giza, Egypt.
** Isolated from rhizosphere of healthy sesame plants.

- I.S. Elewa et al. (2011) evaluated the effects of *Bacillus subtilis* and *Trichoderma viride*, a virulent *Fusarium oxysporum*, and *Glomus* spp. (VAM) isolates and a fungicide (Benlate) on *Fusarium oxysporum* f. sp. *sesami* and *Macrophomina phaseolina*. The results were as follow.

Soil infestation	Treatment	Wilt and root-rot	
	Transplants	Infection %	Disease severity
F. oxysporum	Control	37.5 a	1.87 a
	B. subtilis	33.3 b	1.66 b
	Avirulent *F. oxysporum*	24.9 c	1.25 c
	T. viride	24.9 c	1.25 c
	(VAM)	16.6 d	0.83 d
	Benlate (0.1%)	16.6 d	0.83 d
M. phaseolina	Control	33.3 a	1.66 ab
	B. subtilis	16.6 d	0.83 d
	Avirulent *F. oxsporum*	8.3 e	0.42 e
	T. viride	16.6 d	0.63 e
	(VAM)	12.5 d	0.62 e
	Benlate (0.1%)	16.6 d	0.83 d
F. oxysporum + *M. phaseolina*	Control	20.8 ab	1.04 bcd
	B. subtilis	12.5 d	0.62 e
	Avirulent *F. oxysporum*	12.5 d	0.62 e
	T. viride	16.6 d	0.83 d
	(VAM)	8.3 e	0.42 e
	Benlate (0.1%)	12.5 d	0.62 e

- E.H. Ziedan et al. (2011) evaluated the effects of *Bacillus subtilis* and *Trichoderma viride*, and *Glomus* spp. (a Vesicular arbuscular mycorrhizae fungus [VAM]) isolates on *Fusarium oxysporum* f. sp. *sesami* and *Macrophomina phaseolina*. The effects on *Fusarium oxysporum* f. sp. *sesami* in the pot experiments were as follow.

Treatments	Wilt disease incidence		Morphological characters/plant		
	% of diseased plants	disease severity	length [cm]	fresh weight [g]	No. of pods
Control	79.2 a	4.0 a	68.3 d	7.4 d	6.0 c
B. subtilis	66.7 ab	3.3 b	80.0 c	11.7 c	6.7 c
T. viride	50.0 b	2.5 c	103.8 ab	12.6 c	14.7 b
VAM	50.0 b	2.5 c	80.0 c	14.4 c	6.8 c
VAM + *B. subtilis*	29.2 d	1.5 d	115.6 a	18.7 b	19.0 a
VAM + *T. viride*	36.7 c	1.3 d	93.3 b	15.0 c	14.0 b
VAM + *B. subtilis* + *T. viride*	37.5 c	1.1 d	106.0 ab	25.3 a	20.0 a

The effects on *Macrophomina phaseolina* in the pot experiments were as follow.

Treatments	Root-rot incidence		Morphological characters /plant		
	% of diseased plants	disease severity	length [cm]	fresh weight [g]	No. of pods
Control	91.7 a	4.6 a	77.5 c	5.52 d	4.61 f
B. subtilis	50.0 c	2.5 c	101.9 a	19.4 a	12.6 b
T. viride	45.8 d	2.3 c	101.3 a	18.1 a	10.3 c
VAM	45.8 d	2.5 c	80.0 b	8.1 c	6.0 e
VAM + *B. subtilis*	45.8 d	2.4 c	104.4 a	18.2 a	9.8 d
VAM + *T. viride*	43.7 b	3.3 b	104.2 a	17.7 b	9.5 d
VAM + *B. subtilis* + *T. viride*	41.7 c	2.1 d	103.8 a	19.3 a	13.0 a

The effects from *Fusarium oxysporum* f. sp. *sesami* and *Macrophomina phaseolina* on seedlings in the field experiments were as follow.

Treatments	Wilt and root-rot incidence		
	% of survival plants	% of diseased plants	disease severity
Control	51.0 d	55.9 a	2.8 a
B.subtilis	54.1 c	50.0 b	2.5 b
T.viride	67.5 b	39.2 c	1.9 c
VAM	56.7 c	48.4 bc	2.4 b
VAM + *B. subtilis*	66.6 b	34.2 cd	1.7 c
VAM + *T. viride*	79.3 a	23.3 e	1.2 e
VAM + *B. subtilis*+ *T. viride*	76.0 a	30.9 d	1.5 cd

The effects from *Fusarium oxysporum* f. sp. *sesami* and *Macrophomina phaseolina* on the yield components in the field experiments were as follow.

Treatments	Shoot		Root size	Number/plant		Seed yield aradeb/ feddan	Oil [%]
	length [cm]	diameter [cm]		branches	pods		
Control	185.0 e	1.76 d	25.0 f	3.75 f	112.5 e	2.53 d	59.5
B. subtilis	196.3 c	1.99 b	50.0 b	5.3 e	197.5 c	4.55 c	56.9
T. viride	180.0 d	1.88 c	35.0 d	7.5 b	212.5 b	4.91 c	57.8
VAM	195.0 c	1.85 c	30.0 e	5.0 e	160.0 d	5.14 b	57.4
VAM + *B. subtilis*	210.0 a	1.77 d	35.0 c	6.75 c	196.3 c	4.95 c	57.1
VAM + *T. viride*	202.5 b	1.82 c	47.5 b	6.0 d	198.0 c	5.05 b	57.2
VAM + *B. subtilis* + *T. viride*	202.5 b	2.33 a	70.0 a	8.5 a	232.5 a	5.79 a	57.8

- M.A.A. Hassan et al. (n.d.) evaluated the antagonistic effect of *in vitro* biocontrol agents against *Fusarium oxysporum* f. sp. *sesami*.

Microorganism	Isolate No.	*Fusarium* growth (mm)	Reduction (%)
Bacillus subtilis	1	7.807a	11.93d
	2	6.889b	21.11b
	3	6.445b	25.55a
	4	7.361ab	16.39c
	5	7.028ab	19.72b
	Mean	**7.106**	**18.94**
Streptomyces rochei	1	6.838ab	21.62b
	2	7.415a	15.85c
	3	3.89b	51.10a
	Mean	**6.048**	**29.52**
Pseudomonas fluorescens		4.4	**45.8**
Trichoderma viride		2.3	**66.84**
Control		9	0.00
L.S.D. 0.05		4.49	

The significant differences between means compared by LSD at $p \leq 0.05$, NS, not significant

In another experiment, they reported the antagonistic effect of biocontrol agents against *Fusarium oxysporum* f. sp. *sesami* in the field.

Biocontrol agents	2019				2020				Mean			
	Damping-off (%)		SurvivalPlants	Wilt %	Damping-off(%)		Survival Plants	Wilt %	Damping-off (%)		Survival Plants	Wilt %
	Pre-	Post-			Pre-	Post-			Pre-	Post-		
B. subtilis	4.16	3.32	93.82	18.09	5.27	4.15	91.88	18.65	4.72	3.74	94.85a	18.37c
P. fluorescens	4.72	4.17	91.11	25.32	6.39	3.89	89.72	23.80	5.56	4.03	90.42b	24.56b
T. viride	3.06	2.22	94.72	16.99	4.17	3.05	92.78	17.55	3.62	2.64	93.75ab	17.27c
Control	18.61	26.39	55.00	57.96	22.22	29.17	48.61	67.00	20.42	27.78	51.81c	62.48a
L.S.D. at 5%	2.92	3.42	6.25	4.14	2.75	4.13	5.18	6.50	2.84	3.78	5.72d	5.32

Means with different lowercases indicate significant differences at $p \leq 0.05$

INDIA

- P.L. Radha (2013) evaluated the antagonistic micro-organisms like *Trichoderma harzianum* Rifai., *Trichoderma viride* Pers., *Trichoderma koningii* Qudem., *Trichoderma virens* Miller., *Pseudomonas*

fluorescens Migula., and *Bacillus subtilis* Cohn. For their effect under *in vitro* condition against *Alternaria sesami* by dual culture technique. The results were as follows.

Bioagents	Per cent inhibition
Trichoderma harzianum	77.50 (61.66)
Trichoderma viride	75.14 (60.07)
Trichoderma koenigii	73.19 (58.79)
Trichoderma virens	71.53 (57.73)
Pseudomonas fluorescens	36.22 (36.98)
Bacillus subtilis	52.02 (46.15)
S.Em±	0.90
CD at 1 %	2.51

* Arcsine transformed values

- K. Satyagopal et al. (2014) in an IPM manual reported for control measures for *Rhizoctonia bataticola* (Dry root rot), *Phytophthora parasitica* var. *sesami* (Phytophthora blight), and *Alternaria sesami* (Alternaria blight) use the following seed treatments: *Trichoderma* sp. @ 4 g/Kg of seed, *Pseudomonas fluorescens* @ 2 g/Kg seed, or *Bacillus subtilis* @ 2 g/Kg seed or NSKE 4%.
- V.A. Savaliya et al. (2016) evaluated biocontrols against *Macrophomina phaseolina in vitro* with the following results.

Biocontrol agents	Sclerotial formation	Per cent inhibition over control
Bacillus subtilis	+	87.03
T. viride	+ +	71.48
T. hamatum	+ + +	70.00
T. koningii	+ + +	68.14
Trichoderma harzianum	+ +	67.40
Pseudomonas fluorescens	+ +	64.07
Control		-
S. Em. ±	1.602	
CD at 5%	4.862	
CV %	4.54	

Biocontrol agents	Per cent disease incidence	Yield (kg / ha)
Bacillus subtilis	18.93(10.53)	680
Trichoderma konigii	25.43(18.44)	585
T. hamatum	26.90(20.48)	609
T. viride	28.42(22.65)	579
T. harzianum	30.02(25.02)	510
Pseudomonas fluorescens	30.93(26.42)	537
Control	32.96(29.61)	507
S. Em. ±	1.30	28.36
C.D. at 5%	3.89	87.38
C.V.%	10.46	8.59

- K.N. Gupta et al. (2018) reported *Bacillus subtilis* has been used to alleviate or control *Macrophomina phaseolina.*

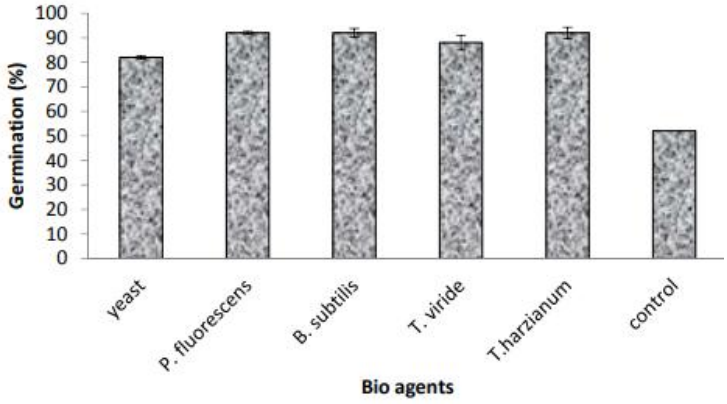
PAKISTAN

- S.F. Naqvi et al. (2013) evaluated biocontrol efficiency using 4 sesame lines (95001, 96007, 96019, and 20003) that were found to be moderately resistant to *Xanthomonas campestris* pv. *sesami* in previous studies. The results were as follow (isolates FD-9, FD-17, ID-3, TTS-7 and GJ-1 were *Pseudomonas fluorescens* and isolates FD-21, ID-12 and GJ-4 were *Bacillus subtilis* and TTS5 as *Paenibacillus polymyxa*).

Isolates/Lines	95001		96007		96019		20003	
	DI (%)	BE (%)	DI (%)	BE (%)	DI (%)	BE (%)	DI (%)	BE (%)
FD-9	9 a	51 bc	10 def	48 bcd	8 de	49 d	6 defg	55 abc
FD-17	11 cd	40 cd	11 cde	43 cd	9 cd	35 cde	7 cdef	43 bcd
FD-21	12 c	34 d	13 c	33 de	10 c	32 de	8 bcd	33 bcde
ID-3	4 f	77 a	5 g	77 a	3 g	81 a	3 g	78 a
ID-12	6 ef	64 ab	8 f	60 ab	5 f	63 ab	4 fg	62 ab
TTS-5	12 c	32 d	11 cde	41 cd	11 bc	22 e	8 bcd	28 cdef
TTS-7	8 e	55 bc	9 ef	53 bc	7 ef	55 bc	5 efg	62 ab
GJ-1	16 b	14 e	16 b	17 e	12 b	16 ef	10 ab	11 ef
GJ-4	11 cd	43 cd	12 cd	37 cd	11 bc	24 e	9 abc	23 def
Control	18 a	0 e	19 a	0 f	15 a	0 f	12 a	0 f

DI= Disease Incidence, BE= Biocontrol efficiency
Figures with different alphabets are significantly different from each other

- B.G. Nayyar et al. (2016) evaluated different bioagents to increase the germination and inhibit the fungi on sesame seeds bioagents (*Trichoderma viride, T. harzianum, Pseudomonas fluorescens, Bacillus subtilis* and *Saccharomyces cerevisiae* – yeast). Seed germination was tested by following the protocol of International Seed Testing Association. Antifungal activity was tested by poisoned food technique. The effects of the bioagents were as follow.



F2.1.1c *Bacillus cereus* (1 Jun 2021)

Bacillus cereus is reported to produce toxins (C8.1.2a) and has been used as a biocontrol (F2.1.1c).

Family: Bacillaceae

Definition: Amount of biocontrol provided by *Bacillus cereus* Frankland & Frankland 1887.

(Wikipedia, 1 Jun 2021) ***Bacillus cereus*** is a Gram-positive, rod-shaped, facultatively anaerobic, motile, beta-hemolytic, spore forming bacterium commonly found in soil and food. The specific name, *cereus*, meaning "waxy" in Latin, refers to the appearance of colonies grown on blood agar. Some strains are harmful to humans and cause foodborne illness, while other strains can be beneficial as probiotics for animals. The bacteria is classically contracted from fried rice dishes that have been sitting at room temperature for hours. *B. cereus* bacteria are facultative anaerobes, and like other members of the genus *Bacillus*, can produce protective endospores. Its virulence factors include cereolysin and phospholipase C.

References:

IRAQ

- N.A. Ramadan (2009) reported The effect of the concentrations 0, 1, 2, 3, and 4 mg/ml of alcoholic extracts of cress seeds (*Lipidium sativum*) on the growth and dry weight of root–rot fungi of sesame plants, *Pythium aphanidermatum*, *Fusarium solani* and *Macrophomina phaseolina* indicated high significant inhibitory affect as compared to the control. *M. phaseolina* was mostly inhibited than other fungi when 4mg/ml w, 86.66 and 78.26% respectively. Antagonistic test of the bacterial biocontrol agent *Bacillus cereus* showed high inhibiting effect on all tested pathogens with the maximum inhibition 80.8% on *M. phaseolina*. Culture filtrate of *B. cereus* also showed a highly inhibiting efficiency to the growth and dry weight of the biomass of all pathogenic fungi with the increase of concentrations 10%, 20%, 30% and 40% (v l v) with the 40% was mostly effective on

M. phaseolina by the ratio of 72.22% and 83.90%, respectively. The best inhibition was achieved with the use of combination of 4 mg/ml of alcoholic extract of Cress seeds and 40% of culture filtrate of *Bacillus cereus*. It showed synergistic inhibitory effect on all pathogenic fungi used, that exceeded the effect of each of the plant extract or culture filtrate of the bacteria separately. [Based on abstract]

F2.1.1d *Bacillus amyloliquefaciens* (9 Jul 2021)

Family: Bacillaceae

Definition: Amount of biocontrol provided by *Bacillus amyloliquefaciens* (ex Fukumoto 1943) Priest et al. 1987 emend. Wang et al. 2008

(Wikipedia, 9 Jul 2021) ***Bacillus amyloliquefaciens*** is a species of bacterium in the genus *Bacillus* that is the source of the BamHI restriction enzyme. It also synthesizes a natural antibiotic protein barnase, a widely studied ribonuclease that forms a famously tight complex with its intracellular inhibitor barstar, and plantazolicin, an antibiotic with selective activity against *Bacillus anthracis*.

It is used in agriculture, aquaculture, and hydroponics to fight root pathogens such as *Ralstonia solanacearum*, *Pythium*, *Rhizoctonia solani*, *Alternaria tenuissima* and *Fusarium* as well improve root tolerance to salt stress. They are considered a growth-promoting rhizobacteria and have the ability to quickly colonize roots.

References:

INDIA

- M. Muthamilan and S. Balakrishnan (2021) evaluated seed treatments with *Bacillus amyloliquefaciens* and *Pseudomonas* spp. at different concentrations. The effects on 10 day seedlings 90 days after seed treatments were as follow.

S. No.	Treatments	Ten days old seedlings*	
		Shoot length (cm)	Root length (cm)
1	ST with LF of *Pseudomonas spp.* @ 10 ml/kg seed	10.64	8.18
2	ST with LF of *Pseudomonas spp.* @ 15 ml/kg seed	11.10	8.62
3	ST with LF of *Pseudomonas spp.* @ 20 ml/kg seed	12.86	9.92
4	ST with LF of *Pseudomonas spp.* @ 25 ml/kg seed	12.24	9.44
5	ST with LF of *B. amyloliquefaciens* @ 10 ml/kg seed	10.56	7.84
6	ST with LF of *B. amyloliquefaciens* @ 15 ml/kg seed	11.38	8.32
7	ST with LF of *B. amyloliquefaciens* @ 20 ml/kg seed	12.42	9.34
8	ST with LF of *B. amyloliquefaciens* @ 25 ml/kg seed	12.12	8.88
9	ST with carbendazim @ 2 g/kg seed	11.76	9.12
10	Control (ST with plain broth @ 25 ml/kg seed)	6.62	5.80
	CD (P=0.05)	0.68	0.49

* Mean of three replications ST- Seed treatments LF- Liquid formulation

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F2.1.1e *Bacillus velezensis* (9 Jul 2021)

Family: Bacillaceae

Definition: Amount of biocontrol provided by *Bacillus velezensis* Garcia et al. 2005.

References :

ETHIOPIA

- R.A. Bayisa (2020) evaluated the impact of *Bacillus velezensis* AR1 on *Alternaria sesami*. There were 4 treatments (control – *A. sesami* alone, *B. velezensis* AR1, dithianon (fungicide), and *B. velezensis* with dithianon). The sole and alternate application of AR1 with fungicide reduced disease severity to less than 10%. Plant physiological traits also improved due to the plant growth promoting AR1. Induced plant defense-related biochemicals, i.e., total phenolic and flavonoid contents, were maximum in the plant subjected to AR1 and a fungicide. In addition, the concentration of leaf amino acid proline was doubled due to AR1 compared to the control. The concentration of the plant growth-regulating hormones gibberellic acid and indole acetic acid (IAA), as well as leaf chlorophyll, total nitrogen and phosphorus contents were also significantly increased by 203.86, 7.79, 0.31 mg gFW^{-1}, 0.15 and 0.13%, respectively, due to the treatments. Furthermore, postharvest soil

chitinase, cellulase and 1,3-β-glucanase activity results indicated the biological control and rapid soil colonization trends of AR1.

F2.1.1f *Bacillus methylotrophicus* (9 Jul 2021)

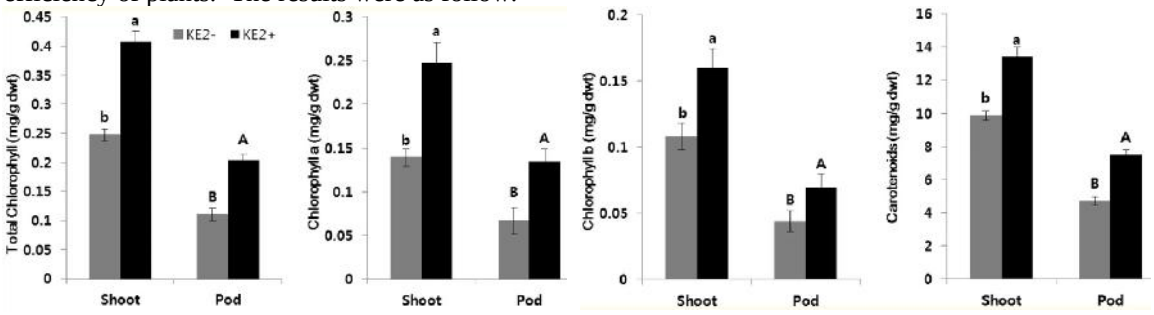
Family: Bacillaceae

Definition: Amount of biocontrol provided by *Bacillus methylotrophicus* Madhaiyan et al. 2010.

References:

REPUBLIC OF KOREA

- R. Radhakrishnan and I.J. Lee (2017) evaluated the effect of foliar spray of *Bacillus* methylotrophicus KE2 on sesame plants by analyzing photosynthesis pigments, carbohydrates, organic acid, amino acids, hormones and antioxidant content. At the time of flowering, plants were sprayed with 50% diluted B. methylotrophicus KE2 culture to eleven-week-old sesame plants. The plants and pods were harvested after one-month of treatment. The status of chlorophyll concentration in plants is one of the important factors to determine the photosynthetic efficiency of plants. The results were as follow.



The foliar spray of B. methylotrophicus KE2 successfully promoted the health of sesame plants was evidenced from the higher synthesis of physiological components such as photosynthetic pigments, sugars, malic acid, amino acids, total polyphenol and, declined level of stress hormones, salicylic acid and abscisic acid in shoots and pods of sesame plants. In this study suggest that either soil drench or spray of B. methylotrophicus KE2 can able to increase the vegetative and reproductive phage of plant health during their interaction.

F2.1.1g *Bacillus thuringiensis* (28 Nov 2020)

Family: Bacillaceae

Definition: The presence on sesame plants of *Bacillus thuringiensis* Berliner 1915.

(Wikipedia, 29 Nov 2020) ***Bacillus thuringiensis*** (or **Bt**) is a Gram-positive, soil-dwelling bacterium, commonly used as a biological pesticide. *B. thuringiensis* also occurs naturally in the gut of caterpillars of various types of moths and butterflies, as well on leaf surfaces, aquatic environments, animal feces, insect-rich environments, and flour mills and grain-storage facilities. It has also been observed to parasitize other moths such as *Cadra calidella*—in laboratory experiments working with *C. calidella*, many of the moths were diseased due to this parasite.

During sporulation, many Bt strains produce crystal proteins (proteinaceous inclusions), called δ-endotoxins, that have insecticidal action. This has led to their use as insecticides, and more recently to genetically modified crops using Bt genes, such as Bt corn. Many crystal-producing Bt strains, though, do not have insecticidal properties. The subspecies *israelensis* is commonly used for control of mosquitoes and of fungus gnats.

References:

INTERNATIONAL

- Anon. (2000a) is an organic guide for Central and South America. They recommend using Bt to control *Spodoptera exigua, S. sunia*, and *S. frugiperda* on sesame.

BRAZIL

- J.E. Miranda and L.H.A. Araujo (2003) reported using *Bacillus thuringiensis* powder to control *Antigastra catalaunalis* on sesame.

F2.1.2 *Priestia* spp. (23 Jun 2021)

Family: Bacillaceae

Definition: Amount of biocontrol provided by *Priestia* spp. Gupta et al. 2020.

(Wikipedia, 23 Jun 2021) ***Priestia*** is a genus of mostly Gram-Positive (*Priestia flexa* stains Gram-variable and *Priestia koreensis* stains Gram-negative) rod-shaped bacteria in the family *Bacillaceae* from the order *Bacillales.* The type species of this genus is *Priestia megaterium.*

Members of *Priestia* are previously species belonging to *Bacillus*, a genus that has been recognized as displaying extensive polyphyly within its members due to the vague criteria used to assign species to this clade. Multiple studies have been conducted using comparative phylogenetic analyses as a means to clarify the evolutionary relationships between *Bacillus* species, resulting in the transfer of species into numerous novel genera such as *Alkalihalobacillus*, *Brevibacillus*, *Solibacillus*, *Alicyclobacillus*, *Virgibacillus* and *Evansella*. In addition, the genus *Bacillus* has been restricted to only include species closely related to *Bacillus subtilis* and *Bacillus cereus.*

The name *Priestia* was named after the British microbiologist Professor Fergus G. Priest (Heriot-Watt University, Edinbugth; 1948–2019) for his many contributions to the systematics and uses of the members of the genus *Bacillus*.

F2.1.2a *Priestia megaterium* (23 Jun 2021)

Synonym: *Bacillus megatherium*

Family: Bacillaceae

Definition: Amount of biocontrol provided by *Priestia megaterium* (de Bary 1884) Gupta et al. 2020.

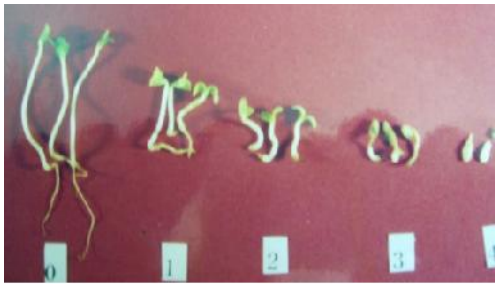
(Wikipedia, 23 Jun 2021) ***Priestia megaterium*** is a rod-like, Gram-positive, mainly aerobic spore forming bacterium found in widely diverse habitats. With a cell length of up to 4 µm and a diameter of 1.5 µm, *B. megaterium* is amongst the biggest known bacteria. The cells often occur in pairs and chains, where the cells are joined together by polysaccharides on the cell walls.

In the 1960s, prior to the utilization of *Bacillus subtilis* for this purpose, *B. megaterium* was the main model organism among Gram-positive bacteria for intensive studies on biochemistry, sporulation and bacteriophages. Recently, its popularity has started increasing in the field of biotechnology for its recombinant protein production capacity.

References:

EGYPT

- E.H. Ziedan et al. (2012) evaluated the effects of biofertilizers (Phosphoren – *Bacillus megatherium, Azospirillium brasilense* – Cerialin, rhizobacterin and blue green algae) in combination with a fungicide (Topsin) on sesame as affected by *Fusarium oxysporum* f. sp. *sesami* using the following disease severity criteria.



The following were the results of the *in vitro* studies.

Treatment	Disease %	*D.severity
Control	85.0 a	3.4 a
Topsin	49.0 c	2.0 b
Blue green algae	49.0 c	2.0 b
Rhizobacteren	56.0 b	1.2 c
Cerialin	55.0 b	2.2 b
Phosphoren	38.0 d	1.5 bc
Cerialin + Topsin	25.0 e	1.0 c
Phosphoren + Topsin	44.0 c	1.8 b
Cerialin + phosphoren	09.0 f	0.4 d
Cerialin + phosphoren + Topsin	00.0 g	0.0 e

The following table shows the effects when the materials were transplanted to the field.

Treatment	Survival plant %	Wilt incidence	
		Infection %	D.severity
Seed cultivation			
Seed coated V./Captan	35.3 e	81.0 a	4.1 a
Transplanting cultivation			
Control	50.7 d	56.9 b	2.8 b
Topsin	63.7 c	45.6 c	2.3 b
Cerialin	67.9 c	36.0 d	1.8 c
Phosphoren	59.7 d	47.1 c	1.7 c
Cerialin + Topsin	74.8 b	29.8	1.5 c
Phosphoren + Topsin	70.0 b	33.6 d	1.3 cd
Cerialin + phosphoren	85.3 ab	19.1 e	1.0 d
Cerialin + phosphoren + Topsin	97.8 a	17.5 e	0.9 d

The following table shows the effects on yield components.

Treatment	Shoot lengh (cm)	No branch	No pods	Seed yield aradeb/ feddan
Seed cultivation				
Seed coated V./Captan	125.0	2.3 e	33.3 f	2.7 c
Transplanting cultivation				
Control	133.3	4.0 cd	70.0 e	2.7 c
Topsin	131.0	4.6 c	105.0 d	3.0 b
Cerialin	130.0	4.6	108.3	3.4 b
Phosphoren	135.0	5.0 bc	105.0 d	3.4 b
Cerialin + Topsin	135.0	5.7 a	108.0	4.1 a
Phosphoren + Topsin	133.3	4.3 d	138.7 c	4.2
Cerialin + phosphoren	135.0	6.0	147.0	4.4 ab
Cerialin + phosphoren + Topsin	128.3	6.3 b	203.3 a	4.6 b

- M.M. Amin et al. (2017) reported *Bacillus megaterium* var. *phosphaticum* (BMP) have been used to control sesame wilt disease caused by *Fusarium oxysporum* f. sp. *sesami* in the presence of different doses of calcium super phosphate (CSP) at two successive seasons (2014 and 2015) using Giza 32. CSP was added with soil preparation at the rate of 1, 2, 3 and 4 gm/pot and 50, 100, 150 and 200 kg/fed under greenhouse and field conditions, respectively. The greenhouse results were as follow, which includes the use of a fungicide – Topsin M-70%.

Treatment	2014	2015	Mean	Decrease (%)
BMP* + 1 gm CSP**	63.35	63.35	63.35	22.40
BMP + 2 gm CSP	60.02	56.67	58.35	28.53
BMP + 3 gm CSP	50.01	43.32	46.66	42.84
BMP + 4 gm CSP	40.00	36.64	38.32	53.06
4gm CSP	43.33	46.66	45.00	44.88
BMP	63.36	66.70	65.03	20.34
Topsin M-70%	40.00	43.32	41.66	48.97
Control	79.97	83.30	81.64	-
L.S.D. at 5%	11.53	10.76	-	-

BMP* *Bacillus megaterium var. phosphaticum*and as seed dressing, CSP** calcium super phosphate/pot

The field results were as follow.

Treatment	2014	2015	Mean	Decrease (%)
BMP* + 50 kgCSP**	41.40	42.70	42.04	26.85
BMP + 100 kgCSP	39.65	41.76	40.70	29.18
BMP + 150 kgCSP	38.25	40.70	39.48	31.31
BMP + 200 kgCSP	35.70	36.80	36.25	36.92
200 kgCSP	41.05	39.65	40.35	29.79
BMP	40.00	41.05	40.53	29.48
Topsin M-70%	26.60	27.50	27.05	52.93
Control	56.06	58.88	57.47	-
L.S.D. at 5%	1.17	1.63	-	-

BMP* *Bacillus megaterium var. phosphaticum*and as seed dressing, CSP** calcium super phosphate/fed

The yields and oil contents in the field were as follow. There is additional data on plant height, number of capsules/plant, number of branches/plant, and shoot content of N, P, and K.

Treatment	Seed yield (arddab/fed)				Oil content %			
	2014	2015	Mean	Increase (%)	2014	2015	Mean	Increase (%)
BMP* + 50 kgCSP**	3.00	3.20	3.10	18.10	52.00	54.00	52.99	4.56
BMP + 100 kgCSP	3.08	3.65	3.36	28.10	53.88	54.13	54.00	6.56
BMP + 150 kgCSP	3.50	3.83	3.66	39.52	56.20	55.88	56.04	10.58
BMP + 200 kgCSP	4.33	4.55	4.44	69.05	56.58	55.00	55.79	10.09
200 kgCSP	3.25	3.63	3.44	30.95	57.25	56.75	57.00	12.48
BMP	3.28	3.48	3.38	28.57	56.25	55.70	55.98	10.46
Topsin M-70%	3.05	3.25	3.15	20.00	53.63	52.30	52.96	4.51
Control	2.58	2.68	2.63	-	50.50	50.85	50.68	-
L.S.D. at 5%	0.38	0.25	-	-	1.53	1.41	-	-

BMP* *Bacillus megaterium var. phosphaticum*and as seed dressing, CSP** calcium super phosphate/fed

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F2.2 Family: Paenibacillaceae Garrity *et al.* 2001

(Wikipedia, 19 Aug 2021) The **Paenibacillaceae** are a family of Gram-positive bacteria.

The following species have been identified to be a biocontrol in sesame:

- F2.2.1 *Paenibacillus* spp.
- F2.2.1a *Paenibacillus polymyxa* (*Syn: *Bacillus polymyxa*)

F2.2.1 *Paenibacillus* spp. (19 Aug 2021)

Family: Paenibacillaceae

Definition: Amount of biocontrol provided by *Paenibacillus* spp. Ash et al. 1994.

(Wikipedia, 19 Aug 2021) ***Paenibacillus*** is a genus of facultative anaerobic, endospore-forming bacteria, originally included within the genus *Bacillus* and then reclassified as a separate genus in 1993. Bacteria belonging to this genus have been detected in a variety of environments, such as: soil, water, rhizosphere, vegetable matter, forage and insect larvae, as well as clinical samples. The name reflects: Latin *paene* means almost, so the paenibacilli are literally "almost bacilli". The genus includes *P. larvae*, which causes American foulbrood in honeybees, *P. polymyxa*, which is capable of fixing nitrogen, so is used in agriculture and horticulture, the *Paenibacillus* sp. JDR-2 which is a rich source of chemical agents for biotechnology applications, and pattern-forming strains such as *P. vortex* and *P. dendritiformis* discovered in the early 90s, which develop complex colonies with intricate architectures as shown in the pictures:

The following species has been associated with sesame but there are known no reports of being a pathogen, producing a toxin, inhibiting germination, affecting seed quality, or being used as a biocontrol or biofertilizer.

- *Paenibacillus relictisesami* [Japan]

References:

CHINA

- E.N. Grady et al. (2019) reported the Henan Academy of Academic Agricultural sciences has used *Paenibacillus* spp. as a Bio-control bacterium for preventing and treating sesame wilt disease.

UNITES STATES

- M. Fay et al. (2021) reported metagenomic analysis of food is becoming more routine and can provide important information pertaining to the shelf life potential and the safety of these products. They examined 10 sesame samples and reported *Paenibacillus* spp.

F2.2.1a *Paenibacillus polymyxa* (19 Aug 2021)

Synonym: *Bacillus polymyxa*

Family: Paenibacillaceae

Definition: Amount of biocontrol provided by ***Paenibacillus polymyxa*** (Prazmowski 1880) Ash et al. 1994.

(Wikipedia, 19 Aug 2021) ***Paenibacillus polymyxa***, also known as ***Bacillus polymyxa***, is a Gram-positive bacterium capable of fixing nitrogen. It is found in soil, plant tissues, marine sediments and hot springs. It may have a role in forest ecosystems and potential future applications as a biofertilizer and biocontrol agent in agriculture

References:

PAKISTAN

- S.F. Naqvi et al. (2013) evaluated biocontrol efficiency using 4 sesame lines (95001, 96007, 96019, and 20003) that were found to be moderately resistant to *Xanthomonas campestris* pv. *sesami* in previous studies. The results were as follow (isolates FD-9, FD-17, ID-3, TTS-7 and GJ-1 were *Pseudomonas fluorescens* and isolates FD-21, ID-12 and GJ-4 were *Bacillus subtilis* and TTS5 as *Paenibacillus polymyxa*).

Isolates/Lines	95001		96007		96019		20003	
	DI (%)	BE (%)	DI (%)	BE (%)	DI (%)	BE (%)	DI (%)	BE (%)
FD-9	9 a	51 bc	10 def	48 bcd	8 de	49 d	6 defg	55 abc
FD-17	11 cd	40 cd	11 cde	43 cd	9 cd	35 cde	7 cdef	43 bcd
FD-21	12 c	34 d	13 c	33 de	10 c	32 de	8 bcd	33 bcde
ID-3	4 f	77 a	5 g	77 a	3 g	81 a	3 g	78 a
ID-12	6 ef	64 ab	8 f	60 ab	5 f	63 ab	4 fg	62 ab
TTS-5	12 c	32 d	11 cde	41 cd	11 bc	22 e	8 bcd	28 cdef
TTS-7	8 e	55 bc	9 ef	53 bc	7 ef	55 bc	5 efg	62 ab
GJ-1	16 b	14 e	16 b	17 e	12 b	16 ef	10 ab	11 ef
GJ-4	11 cd	43 cd	12 cd	37 cd	11 bc	24 e	9 abc	23 def
Control	18 a	0 e	19 a	0 f	15 a	0 f	12 a	0 f

DI= Disease Incidence, BE= Biocontrol efficiency
Figures with different alphabets are significantly different from each other

REPUBLIC OF KOREA

- J.W. Hyun et al. (1999) reported *Bacillus polymyxa* was isolated as an antibiotic compound that was an antagonist against *Fusarium oxysporum* f. sp. *sesami*. Under greenhouse conditions *Bacillus polymyxa* was

shown its minimum inhibitory concentrations were 12.8 µg/ml for *F. oxysporum* and *Alternaria mali*, 6.4 µg/ml for *Colletotrichum gloeosporioides* and *Rhizoctonia solani*, and 3.2 µg/ml for *Phytophthora capsici.*

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F3 Order: **Hyphomicrobiales** Douglas 1957

(Wikipedia, 2 Jun 2021) The ***Hyphomicrobiales*** are an order of Gram-negative Alphaproteobacteria. The rhizobia, which fix nitrogen and are symbiotic with plant roots, appear in several different families. The four families *Nitrobacteraceae*, *Hyphomicrobiaceae*, *Phyllobacteriaceae*, and *Rhizobiaceae* contain at least several genera of nitrogen-fixing, legume-nodulating, microsymbiotic bacteria. Examples are the genera *Bradyrhizobium* and *Rhizobium*. Species of the *Methylocystaceae* are methanotrophs; they use methanol (CH_3OH) or methane (CH_4) as their sole energy and carbon sources. Other important genera are the human pathogens *Bartonella* and *Brucella*, as well as *Agrobacterium* (useful in genetic engineering).

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F3.1 Family: **Rhizobiaceae** Conn 1938

(Wikipedia, 2 Jun 2021) The **Rhizobiaceae** is a family of proteobacteria comprising multiple subgroups that enhance and hinder plant development. Some bacteria found in the family are used for plant nutrition and collectively make up the rhizobia. Other bacteria such as *Agrobacterium tumefaciens* and *Rhizobium rhizogenes* severely alter the development of plants in their ability to induce crown galls or hairy roots, respectively. The family has been of an interest to scientists for centuries in their ability to associate with plants and modify plant development. The *Rhizobiaceae* are, like all Proteobacteria, Gram-negative. They are aerobic, and the cells are usually rod-shaped. Many species of the *Rhizobiaceae* are diazotrophs which are able to fix nitrogen and are symbiotic with plant roots.

The following species have been identified to be a biocontrol in sesame:

- F3.1.1 *Rhizobium* spp.

F3.1.1 *Rhizobium* spp. (15 May 2021)

Family: Rhizobiaceae

Definition: Amount of biocontrol provided by *Rhizobium* spp. Frank 1889.

(Wikipedia, 15 May 2021) ***Rhizobium*** is a genus of Gram-negative soil bacteria that fix nitrogen. *Rhizobium* species form an endosymbiotic nitrogen-fixing association with roots of legumes and *Parasponia*.

The bacteria colonize plant cells within root nodules, where they convert atmospheric nitrogen into ammonia using the enzyme nitrogenase and then provide organic nitrogenous compounds such as glutamine or ureides to the plant. The plant, in turn, provides the bacteria with organic compounds made by photosynthesis. This mutually beneficial relationship is true of all of the rhizobia, of which the genus *Rhizobium* is a typical example. *Rhizobium* is also capable to solubilize phosphorus.

The taxon has largely subsumed genera *Agrobacterium* Conn 1942 and *Allorhizobium* following in phelogenetic research from the late 1990s to the early 2000s when the two genera were shown to be not very different from *Rhizobium*. A confusing result is that *Agrobacterium tumefaciens*, now *Rhizobium radiobacter*, remains as the type species of *Agrobacterium*. The division of genera under Rhizobiaceae remains fluid.

The following species have been associated with sesame but there are no known reports of being a pathogen, producing a toxin, inhibiting germination, affecting seed quality, or being used as a biocontrol or biofertilizer.

- *Rhizobium radiobacter* [International lists]
- *Rhizobium rhizogenes* [International lists]

References:

INDIA

- V. Bharathi et al. (2013) examined the effect of seed treatments (*Trichoderma viride* + *Pseudomonas fluorescence*, *Azotobacter* + *Trichoderma*, *Rhizobium* + *Trichoderma*, *Azotobacter*, *Trichoderma*, *Pseudomonas*, Benomyl, and untreated control) to improve germination and increase survival rate. *Trichoderma* and *Pseudomonas* were treated @ 6g/kg and 10 g/kg seed, respectively. *Azotobacter* was used @ 25 g/kg seed (250g/10 kg seed). The combination inoculum was used @ half the dose of each bioagent/biofertilizer. The seeds were tested for mycoflora and the following fungi were found: *Alternaria*

alternata, *Alternaria tennissima*, *Alternaria terreus*, *Aspergillus flavus*, *Aspergillus fumigatus*, *Aspergillus niger*, *Macrophomina* spp., *Cephalosporium* spp., *Fusarium oxysporum*, *Rhizoctonia solani*, *Rhizopus stolonifer*, *Curvularia* spp., *Drechslera* spp., *Rhizopus* spp., *Cladosporium* spp., and *Penicillium* spp. Germination of the treated seeds was tested using 3 methods: blotter, paper towel, and sand. The results of the blotter method (100 seeds for 8 days) were as follows:

Treatment	Germination (%)	Seed rot	Seedling Blight	Fungal colonies
Trichoderma + Pseudomonas fluorescence	96.0	4.50	4.18	3.83
Azatobacter + Trichoderma	94.4	8.64	6.42	10.2
Rhizobium + Trichoderma	90.2	12.1	8.63	12.6
Azatobacter	88.0	18.0	9.40	14.8
Trichoderma	85.3	10.6	7.21	12.2
Pseudomonas fluorescence	84.0	9.8	8.10	15.4
Benomil	86.3	2.70	2.10	3.00
Control	75.0	32.3	21.8	36.2
SEm±	0.48	0.72	0.80	0.94
CV%	3.71	5.46	5.68	6.78
CD	1.61	1.82	2.21	2.08

The results of the paper towels method (50 seeds for 14 days) and sand method (100 seeds for 20 days) were as follows. The seedling vigor was done in petri dishes for 8 days (no temperature specified. The germination % and seedling length in cm was measured. The seedling vigor index = Mean seedling length (cm) x Germination percentage (%).

Treatments	Paper Towel Method				Sand Method				Seedling Vigor
	NS	AS	SR	HS	NS	AS	SR	HS	
Trichoderma + P. fluorescence	23	0	14	63	10	2	0	88	1660.3
Azatobacter + Trichoderma	19	2	18	61	5	4	0	92	1562.6
Rhizobium + Trichoderma	17	3	26	52	5	2	4	90	1404
Azatobacter	14	6	32	48	1	3	0	94	1386.2
Trichoderma	12	2	30	50	3	2	2	93	1489
Pseudomonas fluorescence	8	4	16	54	1	4	2	93	1356.3
Benomil	10	2	2	72	2	2	0	96	1312
Control	8	3	47	42	1	1	8	91	904.1
SEm±									69.2
CV									245.6
CD									121.2

*Viability = 76 per cent, ** Data on germination is based on 100 seeds, *** Data based on observation of normal seedling. NS = Normal seedling, AS= Abnormal Seedlings. SR = Seed rots, HS = Hard seeds.

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F4 Order: Rhodospirillales Pfennig and Truper 1971

(Wikipedia, 23 Jun 2021) The **Rhodospirillales** are an order of Proteobacteria

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F4.1 Family: Azospirillaceae Hördt et al. 2020

(Wikipedia, 23 Jun 2021) The ***Azospirillaceae*** are a family of bacteria from the order Rhodospirillales.

The following species have been identified to be a biocontrol in sesame:

- F4.1.1 *Azospirillum* spp.
- F4.1.1a *Azospirillum brasilense*

F4.1.1 *Azospirillum* spp. (23 Jun 2021)

Family: Azospirillaceae

Definition: Amount of biocontrol provided by *Azospirillum* spp. Tarrand et al. 1979

(Wikipedia, 23 Jun 2021) ***Azospirillum*** is a Gram-negative, microaerophilic, non-fermentative and nitrogen-fixing bacterial genus. *Azospirillum* bacteria can promote plant growth.

References:

INDIA

- V. Geetha et al. (2020) evaluated the effects of pelletizing the seed with biofertilizers and botanicals on sesame. The treatments were as follow.
  - T1 – Control
  - T2 – Seed pelleted with Neem leaf powder (760 g), biofertilizer such as Azospirillum (120 g), and phosphobacteria, @120g kg-1 of seeds using maida 10 per cent as an adhesive.

  The results were as follow:

Treatments	Plant height (cm)	No. of branches/ plant	No. of capsules/ plant	No. of seeds/ capsule
T_1 - Control	112.6	6.4	97.2	51.3
T_2- Pelleted	126.7	7.6	104.1	58.5

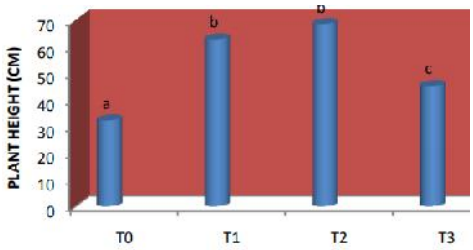
Treatments	1000 seed weight (g)	Seed yield (kg/ha)	Gross cost	Profit	BC ratio
T_1 - Control	4.20	375	21,000/-	30,000/-	1.43
T_2- Pelleted	4.41	530	22,000/-	42,400/-	1.93

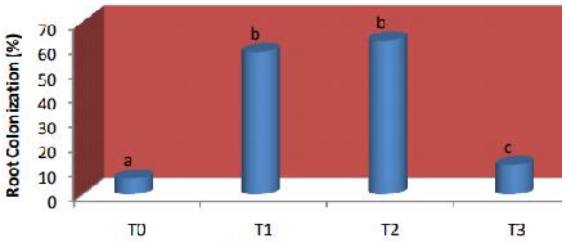
Treatments	Germination %	Root length (cm)	Shoot length (cm)	Vigor index
T_1 - Control	94	8.9	7.1	1504
T_2- Pelleted	100	10.6	8.5	1910

NIGERIA

- R. Abdullahi et al. (2013) evaluated the effects of biofertilizers and chicken manure on sesame. The treatments were as follow.
  - T0: Control
  - T1: *Azospirillum* spp. + *Glomus mosseae*
  - T2: *Azospirillum* spp. + *Glomus mosseae* + 10 t/ha poultry manure
  - T3: 10 t/ha poultry manure

  The results at 6 WAS were as follow:





Treatments	No. of branches /plant	No. of leaves /plant	Leaf (dm^{-2})	Dry biomass (g/plant) Shoot	Root
T0 Control	4.5[a]	42.3[a]	3.8[a]	4.45[a]	2.72[a]
T1 Bio-fertilizer	7.3[b]	92.8[b]	5.3[b]	5.40[b]	3.70[b]
T2 Bio-organic	8.3[b]	98.1[b]	6.2[c]	6.18[c]	3.88[bc]
T3 PM	7.3[b]	75.3[c]	5.1[b]	5.35[b]	3.62[b]
LSD (5%)	1.92	7.08	0.67	0.62	0.22

Treatments	Concentration (%)			Uptakes (kg ha^{-1})		
	N	P	K	N	P	K
T0 Control	1.82[a]	0.32[a]	0.98[a]	12.47[a]	1.34[a]	34.56[a]
T1Biofertilizer	3.54[b]	0.51[b]	1.43[b]	36.38[b]	5.62[b]	50.41[b]
T2Bio-organic	3.93[c]	0.56[c]	1.62[c]	40.96[c]	6.79[c]	51.44[b]
T3PM	3.20[d]	0.46[d]	1.30[d]	31.42[d]	3.02[d]	45.47[c]
LSD (5%)	0.11	0.02	0.09	3.76	0.54	3.98

F4.1.1a *Azospirillum brasilense* (23 Jun 2021)

Family: Azospirillaceae

Definition: Amount of biocontrol provided by *Azospirillum brasilense* Tarrand et al. 1979.

(Wikipedia, 23 Jun 2021) ***Azospirillum brasilense*** is a well-studied, nitrogen-fixing (diazotroph), genetically tractable, Gram-negative, alpha-proteobacterium bacterium, first described in Brazil (in a publication in 1978) by the group of Johanna Döbereiner and then receiving the name "brasilense". *A. brasilense* is able to fix nitrogen in the presence of low oxygen levels, making it a microaerobic diazotroph. An isolate from the genus *Azospirillum* was isolated from nitrogen poor soils in the Netherlands in 1925, however the species *A. brasilense* was first described in 1978 in Brazil, since this genus is widely found in the rhizospheres of grasses around the world where it confers plant growth promotion. Whether growth promotion occurs through direct nitrogen flux from the bacteria to the plant or through hormone regulation is debated. The two most commonly studied strains are Sp7 (ATCC 29145) and Sp245, both are Brazilian isolates isolated from Tropical grasses from Seropedica, Brazil.

The genome of *A. brasilense* Sp245 has been sequenced and is 7Mbp in size and spread across 7 chromosomes. The high GC content (70%) makes it challenging to engineer. Sp245 can be transformed with OriV origin of replication plasmids through conjugation and electroporation. The strain is natively resistant to both spectinomycin and ampicillin antibiotics. Kanamycin resistance is used as a selectable marker. *A. brasilense* has a high evolutionary adaptation rate driven by codon mutation and transposon hopping.

A strain originally classified as *Roseomonas fauriae* was reclassified as *A. brasilense*. It was first isolated from a hand wound of a woman in Hawaii in 1971 and was named for Yvonne Faur "for her contributions to public health bacteriology and, specifically, for her contribution to the recognition of pink-pigmented bacteria."

References:

EGYPT

- E.H. Ziedan et al. (2012) evaluated the effects of biofertilizers (Phosphoren – *Bacillus megatherium*, *Azospirillium brasilense* – Cerialin, rhizobacterin and blue green algae) in combination with a fungicide (Topsin) on sesame as affected by *Fusarium oxysporum* f. sp. *sesami* using the following disease severity criteria.

The following were the results of the *in vitro* studies.

Treatment	Disease %	*D.severity
Control	85.0 a	3.4 a
Topsin	49.0 c	2.0 b
Blue green algae	49.0 c	2.0 b
Rhizobacteren	56.0 b	1.2 c
Cerialin	55.0 b	2.2 b
Phosphoren	38.0 d	1.5 bc
Cerialin + Topsin	25.0 e	1.0 c
Phosphoren + Topsin	44.0 c	1.8 b
Cerialin + phosphoren	09.0 f	0.4 d
Cerialin + phosphoren + Topsin	00.0 g	0.0 e

The following table shows the effects when the materials were transplanted to the field.

Treatment	Survival plant %	Wilt incidence	
		Infection %	D.severity
Seed cultivation			
Seed coated V./Captan	35.3 e	81.0 a	4.1 a
Transplanting cultivation			
Control	50.7 d	56.9 b	2.8 b
Topsin	63.7 c	45.6 c	2.3 b
Cerialin	67.9 c	36.0 d	1.8 c
Phosphoren	59.7 d	47.1 c	1.7 c
Cerialin + Topsin	74.8 b	29.8	1.5 c
Phosphoren + Topsin	70.0 b	33.6 d	1.3 cd
Cerialin + phosphoren	85.3 ab	19.1 e	1.0 d
Cerialin + phosphoren + Topsin	97.8 a	17.5 e	0.9 d

The following table shows the effects on yield components.

Treatment	Shoot lengh (cm)	No branch	No pods	Seed yield aradeb/ feddan
Seed cultivation				
Seed coated V./Captan	125.0	2.3 e	33.3 f	2.7 c
Transplanting cultivation				
Control	133.3	4.0 cd	70.0 e	2.7 c
Topsin	131.0	4.6 c	105.0 d	3.0 b
Cerialin	130.0	4.6	108.3	3.4 b
Phosphoren	135.0	5.0 bc	105.0 d	3.4 b
Cerialin + Topsin	135.0	5.7 a	108.0	4.1 a
Phosphoren + Topsin	133.3	4.3 d	138.7 c	4.2
Cerialin + phosphoren	135.0	6.0	147.0	4.4 ab
Cerialin + phosphoren + Topsin	128.3	6.3 b	203.3 a	4.6 b

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F5 Order: Streptomycetales Kampfer 2012

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F5.1 Family: Streptomycetaceae Waksman and Henrici 1943

(Wikipedia, 21 Jun 2021) The ***Streptomycetaceae*** are a family of *Actinobacteria*, making up the monotypic order ***Streptomycetales***. It includes the important genus *Streptomyces*. This was the original source of many antibiotics, namely streptomycin, the first antibiotic against tuberculosis.

The following species have been identified to be a biocontrol in sesame:

- F5.1.1 *Streptomyces* spp.
- F5.1.1a *Streptomyces bikiniensis*
- F5.1.1b *Streptomyces rochei*

F5.1.1 *Streptomyces* spp. (21 Jun 2021)

Family: Streptomycetaceae

Definition: Amount of biocontrol provided by *Streptomyces* spp. Waksman and Henrici 1943.

(Wikipedia, 21 Jun 2021) ***Streptomyces*** is the largest genus of Actinobacteria and the type genus of the family Streptomycetaceae. Over 500 species of *Streptomyces* bacteria have been described. As with the other Actinobacteria, Streptomycetes are gram-positive, and have genomes with high GC content. Found predominantly in soil and decaying vegetation, most streptomycetes produce spores, and are noted for their distinct “earthy” odor that results from production of a volatile metabolite, geosmin.

Streptomycetes are characterized by a complex secondary metabolism. They produce over two-thirds of the clinically useful antibiotics of natural origin. (e.g., neomycin, cypemycin, grisemycin, bottromycins and chloramphenicol). The antibiotic streptomycin takes its name directly from *Streptomyces*. Streptomycetes are infrequent pathogens, though infections in humans, such as mycetoma, can be caused by *S. somaliensis* and *S. sudanensis*, and in plants can be caused by *S. caviscabies*, *S. acidiscabies*, *S. turgidiscabies* and *S. scabies*.

References:

UNITED STATES

- D.C. Erwin reported species of *Pseudomonas*, *Bacillus*, and *Streptomyces*, which are most active at 25-27°C at field capacity moisture level, can be suppressive to Phytophthora species in soil (Cited by C. Chattopadhyay et al., 2019).

F5.1.1a *Streptomyces bikiniensis* (21 Jun 2021)

Family: Streptomycetaceae

Definition: Amount of biocontrol provided by *Streptomyces bikiniensis* Johnstone and Waksman 1947.

(Wikipedia, 21 Jun 2021) ***Streptomyces bikiniensis*** is a bacterium species from the genus of *Streptomyces* which has isolated from soil from the island Bikini atoll. *Streptomyces bikiniensis* produces streptomycin II and carboxypeptidase.

References:

REPUBLIC OF KOREA

- B.K. Chung and K.S. Hong (1991) and B.K. Chung and S.O. Ser (1992) isolated *Streptomyces bikiniensis* and reported it is antagonistic to *Phytophthora nicotianae* var. *parasitica* and *Fusarium oxysporum* f. sp. *vasinfectum.*

F5.1.1b *Streptomyces rochei* (13 Jul 2021)

Family: Streptomycetaceae

Definition: Amount of biocontrol provided by ***Streptomyces rochei*** Berger et al. 1953.

(Wikipedia, 13 Jul 2021) ***Streptomyces rochei*** is a bacterium species from the genus of *Streptomyces* which has been isolated from soil in Russia. *Streptomyces rochei* produces borrelidin, butyrolactol A, butyrolactol B, uricase and streptothricin. *Streptomyces rochei* has antifungal activity against *Fusarium oxysporum* f. sp. *lycopersici* and *Aspergillus fumigatus*

References:

EGYPT

- M.A.A. Hassan et al. (n.d.) evaluated the antagonistic effect of *in vitro* biocontrol agents against *Fusarium oxysporum* f. sp. *sesami.*

Microorganism	Isolate No.	*Fusarium* growth (mm)	Reduction (%)
Bacillus subtilis	1	7.807a	11.93d
	2	6.889b	21.11b
	3	6.445b	25.55a
	4	7.361ab	16.39c
	5	7.028ab	19.72b
	Mean	**7.106**	**18.94**
Streptomyces rochei	1	6.838ab	21.62b
	2	7.415a	15.85c
	3	3.89b	51.10a
	Mean	**6.048**	**29.52**
Pseudomonas fluorescens		4.4	**45.8**
Trichoderma viride		2.3	**66.84**
Control		9	0.00
L.S.D. 0.05		4.49	

The significant differences between means compared by LSD at $p \leq 0.05$, NS, not significant

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F6 Order: Nostocales Borzi 1914

(Wikipedia, 12 Aug 2021) The **Nostocales** are an order of cyanobacteria containing most of its species. It includes filamentous forms, both simple or branched, and both those occurring as single strands or multiple strands within a sheath. Some members show a decrease in width from the base, and some have heterocysts.

Environmentally, Nostocales (*Sphaerospermopsis aphanizomenoides*) is largely disregarded and not widely studied. However, a recent study suggests that the invasive cyanobacterium is occupying temperate lakes and thriving in them. Using principal component analysis (PCA) and the Mann-Whitney U test, results showed that total phosphorus concentration was the primary causation for the increasing abundance of *S.aphanizomenoides*. Nostocales is known to grow in temperate environments consisting of poor light conditions and high phytoplankton biomass, commonly found in shallow lakes.

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F6.1 Family: Nostocaceae Eichler 1886

(Wikipedia, 12 Aug 2021) The **Nostocaceae** are a family of cyanobacteria that forms filament-shaped colonies enclosed in mucus or a gelatinous sheath. Some genera in this family are found primarily in fresh water (such as *Nostoc*), while others are found primarily in salt water (such as *Nodularia*). Other genera (e.g. *Anabaena*) may be found in both fresh and salt water. Most benthic algae of the order Nostocales belong to this family.

Like other cyanobacteria, these bacteria sometimes contain photosynthetic pigments in their cytoplasm to perform photosynthesis. The particular pigments they contain gives the cells a bluish-green color.

Species of the Nostocaceae are particularly known for their nitrogen-fixing abilities, and they form symbiotic relationships with certain plants, such as the mosquito fern, cycads, and hornworts. The cyanobacteria provide nitrogen to their hosts. Certain species of *Anabaena* have been used on rice paddy fields. Mosquito ferns carrying the cyanobacteria grow on the water in the fields during the growing season. They and the nitrogen they contain are then plowed into the soil following the harvest, which has proved to be an effective natural fertilizer.

The family Nostocaceae belongs to the order Nostocales. Members of the family can be distinguished from those in other families by their unbranched filaments of cells arranged end-to-end, and development of heterocysts among the cells of the filaments.

The following species have been identified to be a biocontrol in sesame:

- F6.1.1 *Nostoc* spp.

F6.1.1 *Nostoc* spp. (12 Aug 2021)

Family: Nostocaceae

Definition: Amount of biocontrol provided by *Nostoc* spp. Vaucher, 1888, ex Bornet and Flahaul.

(Wikipedia, 12 Aug 2021) ***Nostoc*** is a genus of cyanobacteria found in various environments that forms colonies composed of filaments of moniliform cells in a gelatinous sheath. The name *Nostoc* was coined by Paracelsus.

Nostoc can be found in soil, on moist rocks, at the bottom of lakes and springs (both fresh- and saltwater), and rarely in marine habitats. It may also grow symbiotically within the tissues of plants, providing nitrogen to its host through the action of terminally differentiated cells known as heterocysts. These bacteria contain photosynthetic pigments in their cytoplasm to perform photosynthesis.

References:

EGYPT

- H.A.H. Ahmed et al. (2013) studied biological control of *Fusarium solani* and *Macrophomina phaseolina* causing wilt and charcoal rot diseases *in vitro* as well as under pot conditions. Culture technique showed that the addition of intact *Nostoc* sp. SAG2306 or its sonicate inhibited the radial mycelial growth of the test pathogens. Application of *Nostoc* sonicates resulted in the lowest infection percentage (11.1% and 17.8% of *Fusarium* and *Macrophomina* respectively) whereas in the control it was 95.6% and 97.7%. Under pot

conditions, plant height, fresh and dry weight of plants increased significantly as a result of the inhibition of fungal by *Nostoc*. Similar results were observed in chlorophyll (ch.la & ch.lb) content of the treated plants. Infection enhanced proline accumulation that was lowered upon *Nostoc* addition, indicating alleviation of infection ascribed stress. The effect of sonicated (NS) or intact (NI) *Nostoc* sp 2306 cells on seed infection of sesame *in vitro* was as follow.

Treatements	*F. solani*	*M.Phaseolina*
NS	11.11	17.78
NI	26.67	33.34
Control	95.55	97.7

The effects in pots in the greenhouse in 2010 and 2011 seasons was as follow.

Treatments	*F.solani*				*M.phaseolina*			
	Percentage of infected plants				Percentage of infected plants			
	Root-rot		Wilt		Root-rot		Charcoal	
	2010	2011	2010	2011	2010	2011	2010	2011
*N.*sonicated	16.66	20	16.66	16.66	16.66	20	20	16.66
*N.*intact	26.66	26.66	20	23.33	20	23.33	23.33	20
Control	36.66	33.33	56.66	60	33.33	33.33	60	63.33

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F7 Order: Enterobacterales Adeolu et al. 2016

(Wikipedia, 23 Jun 2021) **Enterobacterales** is an order of Gram-negative, non-spore forming, facultatively anaerobic, rod-shaped bacteria with the class Gammaproteobacteria. The type genus of this order is *Enterobacter*.

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F7.1 Family: Enterobacteriaceae Rahn 1937

(Wikipedia, 19 Jul 2021) **Enterobacteriaceae** is a large family of Gram-negative bacteria. It was first proposed by Rahn in 1936, and now includes over 30 genera and more than 100 species. Its classification above the level of family is still a subject of debate, but one classification places it in the order Enterobacterales of the class Gammaproteobacteria in the phylum Proteobacteria. In 2016, the description and members of this family were emended based on comparative genomic analyses by Adeolu et al.

Enterobacteriaceae includes, along with many harmless symbionts, many of the more familiar pathogens, such as *Salmonella*, *Escherichia coli*, *Klebsiella*, and *Shigella*. Other disease-causing bacteria in this family include *Enterobacter* and *Citrobacter*. Members of the Enterobacteriaceae can be trivially referred to as enterobacteria or "enteric bacteria", as several members live in the intestines of animals. In fact, the etymology of the family is enterobacterium with the suffix to designate a family (aceae)—not after the genus *Enterobacter* (which would be "Enterobacteraceae")—and the type genus is *Escherichia*.

The following species have been identified to be a biocontrol in sesame:

- F7.1.1 *Enterobacter* spp.
- F7.1.1a *Enterobacter cloacae*

F7.1.1 *Enterobacter* spp. (20 Aug 2021)

Family: Enterobacteriaceae

Definition: Amount of biocontrol provided by *Enterobacter* spp Hormaeche & Edwards 1960.

(Wikipedia, 20 Aug 2021) ***Enterobacter*** is a genus of common Gram-negative, facultatively anaerobic, rod-shaped, non-spore-forming bacteria of the family Enterobacteriaceae. It is the type genus of the order Enterobacterales. Several strains of these bacteria are pathogenic and cause opportunistic infections in immunocompromised (usually hospitalized) hosts and in those who are on mechanical ventilation. The urinary and respiratory tracts are the most common sites of infection. The genus *Enterobacter* is a member of the coliform group of bacteria. It does not belong to the fecal coliforms (or thermotolerant coliforms) group of bacteria, unlike *Escherichia coli*, because it is incapable of growth at 44.5°C in the presence of bile salts. Some of them show quorum sensing properties.

One clinically important species from this genus is *E. cloacae*.

Researchers in 2018 reported, after detecting the presence on the International Space Station (ISS) of five *Enterobacter bugandensis* bacterial strains, none pathogenic to humans, that microorganisms on ISS should be carefully monitored to continue assuring a medically healthy environment for the astronauts.

F7.1.1a *Enterobacter cloacae* (20 Aug 2021)

Family: Enterobacteriaceae

Definition: Amount of biocontrol provided by *Enterobacter cloacae* (Jordan) Hormaeche and Edwards 1960.

(Wikipedia, 20 Aug 2021) ***Enterobacter cloacae*** is a clinically significant Gram-negative, facultatively-anaerobic, rod-shaped bacterium.

References:

EGYPT

- M.S. Abdel-Salam et al. (2007) reported *Enterobacter cloacae* controls the soilborne plant pathogen *Fusarium oxysporum* f. sp. *sesame*.

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FA Virus

(Wikipedia, 13 Feb 2021) A **virus** is a submicroscopic infectious agent that replicates only inside the living cells of an organism. Viruses infect all types of life forms, from animals and plants to microorganisms, including bacteria and archaea. Since Dmitri Ivanovsky's 1892 article describing a non-bacterial pathogen infecting tobacco plants and the discovery of the tobacco mosaic virus by Martinus Beijerinck in 1898, more than 6,000 virus species have been described in detail of the millions of types of viruses in the environment. Viruses are found in almost every ecosystem on Earth and are the most numerous type of biological entity. The study of viruses is known as virology, a subspeciality of microbiology.

When infected, a host cell is forced to rapidly produce thousands of identical copies of the original virus. When not inside an infected cell or in the process of infecting a cell, viruses exist in the form of independent particles, or *virions*, consisting of: (i) the genetic material, i.e., long molecules of DNA or RNA that encode the structure of the proteins by which the virus acts; (ii) a protein coat, the *capsid*, which surrounds and protects the genetic material; and in some cases (iii) an outside envelope of lipids. The shapes of these virus particles range from simple helical and icosahedral forms to more complex structures. Most virus species have virions too small to be seen with an optical microscope, as they are one-hundredth the size of most bacteria.

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FA1 Order: Lefavirales

(Wikipedia, 15 Sep 2021) ***Lefavirales*** is an order of viruses.

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FA1.1 Family: Baculoviridae

(Wikipedia, 29 Nov 2020) ***Baculoviridae*** is a family of viruses. Arthropods, Lepidoptera, Hymenoptera, Diptera, and Decapoda serve as natural hosts. There are currently 84 species in this family, divided among four genera.

Baculoviruses are known to infect invertebrates, with over 600 host species having been described. Immature (larval) forms of moth species are the most common hosts, but these viruses have also been found infecting sawflies, mosquitoes, and shrimp. Although baculoviruses are capable of entering mammalian cells in culture they are not known to be capable of replication in mammalian or other vertebrate animal cells.

Starting in the 1940s they were used and studied widely as biopesticides in crop fields. Baculoviruses contain circular double-stranded genome ranging from 80 to 180 kbp.

The following species have been identified to be a biocontrol in sesame:

- FA.1.1 *Nuclear polyhedrosis virus* (NPV)

References:

INTERNATIONAL

- Anon. (2000a) is an organic guide for Central and South America. They recommend using Baculovirus to control *Spodoptera exigua, S. sunia*, and *S. frugiperda*.

FA1.1.1 Unassigned virus (7 Oct 2021)

FA1.1.1a *Nuclear polyhedrosis virus* (NPV) (29 Nov 2020)

Family: Baculoviridae

Definition: The presence on insects in sesame of *Nuclear polyhedrosis virus*.

(Wikipedia, 29 Nov 2020) The **nuclear polyhedrosis virus** (NPV), part of the family of baculoviruses, is a virus affecting insects, predominantly moths and butterflies. It has been used as a pesticide.

NPV is transferred from insect to insect through crystals in their bodily emissions. Because the virus is in the crystal-like capsid, it must be broken down by the alkaline digestive system of the insects to be released.

Bleach and ultraviolet light have been found to be effective in killing the virus.

The virus is unable to infect humans in the way it does insects because human stomachs are acid-based and NPV requires an alkaline digestive system in order to replicate. It is possible for the virus crystals to enter human cells, but not to replicate to the point of causing illness.

Dead caterpillar infected by NPV
Photo: Wikipedia, 29 Nov 2020

References:

INDIA

- R. Thangjam (2012) and R. Thangjam and A.S. Vastrad (2018) reported the following virus on sesame from vegetative to maturity: NPV.

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G1 TOXIN PRODUCING MYCOFLORA

D.R. Langham comments, 2021: As with all agricultural products, sesame can host fungi and/or bacteria that produce toxins that in high enough quantities may harm humans when consumed. In some cases, the toxins are produced by fungi/bacteria that are hosted by the plant on the seed, capsule, or stems while the plants are growing. In other cases, (particularly with rains and/or high humidity) once the capsules open, the seeds are exposed. In mechanical harvest the plants above the lowest capsule are threshed in machines mixing the fungi/bacteria on the plants with the seed. Finally, the seeds can pick up bacteria (e.g., *Salmonella* spp., *Escherichia coli*, *Listeria* spp., etc.) in the processing of the seed from the field to the consumer.

In Venezuela in the 1940-50 time, they had problems with aflatoxin in sesame, but they traced the problem to machinery that had been in peanuts before the sesame. When moving production form Arizona to Uvalde, Texas, there was concern because there were severe problems with aflatoxin in corn. The concern was because the same combines that harvested the corn, harvested the sesame. However, after testing dozens of samples, no aflatoxins were found in the sesame.

(Wikipedia, 8 May 2021) A **mycotoxin** is a toxic secondary metabolite produced by organisms of the fungus kingdom and is capable of causing disease and death in both humans and other animals. The term 'mycotoxin' is usually reserved for the toxic chemical products produced by fungi that readily colonize crops.

Examples of mycotoxins causing human and animal illness include aflatoxin, citrinin, fumonisins, ochratoxin A, patulin, trichothecenes, zearalenone, and ergot alkaloids such as ergotamine.

One mold species may produce many different mycotoxins, and several species may produce the same mycotoxin.

Most fungi are aerobic (use oxygen) and are found almost everywhere in extremely small quantities due to the diminute size of their spores. They consume organic matter wherever humidity and temperature are sufficient. Where conditions are right, fungi proliferate into colonies and mycotoxin levels become high. The reason for the production of mycotoxins is not yet known; they are not necessary for the growth or the development of the fungi. Because mycotoxins weaken the receiving host, they may improve the environment for further fungal proliferation. The production of toxins depends on the surrounding intrinsic and extrinsic environments and these substances vary greatly in their toxicity, depending on the organism infected and its susceptibility, metabolism, and defense mechanisms.

Aflatoxins are a type of mycotoxin produced by *Aspergillus* species of fungi, such as *A. flavus* and *A. parasiticus*. The umbrella term aflatoxin refers to four different types of mycotoxins produced, which are B_1, B_2, G_1, and G_2. Aflatoxin B_1, the most toxic, is a potent carcinogen and has been directly correlated to adverse health effects, such as liver cancer, in many animal species. Aflatoxins are largely associated with commodities produced in the tropics and subtropics, such as cotton, peanuts, spices, pistachios, and maize.

Ochratoxin is a mycotoxin that comes in three secondary metabolite forms, A, B, and C. All are produced by *Penicillium* and *Aspergillus* species. The three forms differ in that Ochratoxin B (OTB) is a non-chlorinated form of Ochratoxin A (OTA) and that Ochratoxin C (OTC) is an ethyl ester form Ochratoxin A. *Aspergillus ochraceus* is found as a contaminant of a wide range of commodities including beverages such as beer and wine. *Aspergillus carbonarius* is the main species found on vine fruit, which releases its toxin during the juice making process. OTA has been labeled as a carcinogen and a nephrotoxin and has been linked to tumors in the human urinary tract, although research in humans is limited by confounding factors.

Citrinin is a toxin that was first isolated from *Penicillium citrinum* but has been identified in over a dozen species of *Penicillium* and several species of *Aspergillus*. Some of these species are used to produce human foodstuffs such as cheese (*Penicillium camemberti*), sake, miso, and soy sauce (*Aspergillus oryzae*). Citrinin is associated with yellowed rice disease in Japan and acts as a nephrotoxin in all animal species tested. Although it is associated with many human foods (wheat, rice, corn, barley, oats, rye, and food colored with Monascus pigment) its full significance for human health is unknown. Citrinin can also act synergistically with Ochratoxin A to depress RNA synthesis in murine kidneys.

Ergot Alkaloids are compounds produced as a toxic mixture of alkaloids in the sclerotia of species of *Claviceps*, which are common pathogens of various grass species. The ingestion of ergot sclerotia from infected cereals, commonly in the form of bread produced from contaminated flour, causes ergotism, the human disease historically known as St. Anthony's Fire. There are two forms of ergotism: gangrenous, affecting blood supply to extremities, and convulsive, affecting the central nervous system. Modern methods of grain cleaning have significantly reduced

ergotism as a human disease; however, it is still an important veterinary problem. Ergot alkaloids have been used pharmaceutically.

Patulin is a toxin produced by the *P. expansum*, *Aspergillus*, *Penicillium*, and *Paecilomyces* fungal species. *P. expansum* is especially associated with a range of moldy fruits and vegetables, in particular rotting apples and figs. It is destroyed by the fermentation process and so is not found in apple beverages, such as cider. Although patulin has not been shown to be carcinogenic, it has been reported to damage the immune system in animals. In 2004, the European Community set limits to the concentrations of patulin in food products. They currently stand at 50 µg/kg in all fruit juice concentrations, at 25 µg/kg in solid apple products used for direct consumption, and at 10 µg/kg for children's apple products, including apple juice.

Fusarium toxins are produced by over 50 species of *Fusarium* and have a history of infecting the grain of developing cereals such as wheat and maize. They include a range of mycotoxins, such as: the **fumonisins**, which affect the nervous systems of horses and may cause cancer in rodents; the **trichothecenes**, which are most strongly associated with chronic and fatal toxic effects in animals and humans; and **zearalenone**, which is not correlated to any fatal toxic effects in animals or humans. Some of the other major types of *Fusarium* toxins include: beauvercin and enniatins, butenolide, equisetin, and fusarins.

Aflatoxins are poisonous carcinogens and mutagens that are produced by certain molds (*Aspergillus flavus* and *Aspergillus parasiticus*) which grow in soil, decaying vegetation, hay, and grains. They are regularly found in improperly stored staple commodities such as cassava, chili peppers, cottonseed, millet, peanuts, rice, sesame seeds, sorghum, sunflower seeds, sweetcorn, tree nuts, wheat, and a variety of spices. When contaminated food is processed, aflatoxins enter the general food supply where they have been found in both pet and human foods, as well as in feedstocks for agricultural animals. Animals fed contaminated food can pass aflatoxin transformation products into eggs, milk products, and meat. For example, contaminated poultry feed is suspected in the findings of high percentages of samples of aflatoxin-contaminated chicken meat and eggs in Pakistan.

Children are particularly affected by aflatoxin exposure, which is associated with stunted growth, delayed development, liver damage, and liver cancer. An association between childhood stunting and aflatoxin exposure has been reported in some studies but could not be detected in all. Furthermore, a causal relationship between childhood stunting and aflatoxin exposure has yet to be conclusively shown by epidemiological studies, though such investigations are under way. Adults have a higher tolerance to exposure but are also at risk. No animal species is immune. Aflatoxins are among the most carcinogenic substances known. After entering the body, aflatoxins may be metabolized by the liver to a reactive epoxide intermediate or hydroxylated to become the less harmful aflatoxin M_1.

Aflatoxins are most commonly ingested. However, the most toxic type of aflatoxin, B_1, can permeate through the skin. The United States Food and Drug Administration (FDA) action levels for aflatoxin present in food or feed is 20 to 300 ppb. The FDA has had occasion to declare both human and pet food recalls as a precautionary measure to prevent exposure.

The term "aflatoxin" is derived from the name of one of the molds that produce it, *Aspergillus flavus*. It was coined around 1960 after its discovery as the source of "Turkey X disease". Aflatoxins form one of the major groupings of mycotoxins.

Aflatoxin B_1 is considered the most toxic and is produced by both *Aspergillus flavus* and *Aspergillus parasiticus*. Aflatoxin M_1 is present in the fermentation broth of *Aspergillus parasiticus*, but it and aflatoxin M_2 are also produced when an infected liver metabolizes aflatoxin B_1 and B_2.

- Aflatoxin B_1 and B_2 (AFB), produced by *Aspergillus flavus* and *A. parasiticus.*
- Aflatoxin G_1 and G_2 (AFG), produced by some Group II *A. flavus* and *Aspergillus parasiticus.*
- Aflatoxin M_1 (AFM_1), metabolite of aflatoxin B_1 in humans and animals (exposure in ng levels may come from a mother's milk).
- Aflatoxin M_2, metabolite of aflatoxin B_2 in milk of cattle fed on contaminated foods.
- Aflatoxicol (AFL): metabolite produced by breaking down the lactone ring.
- Aflatoxin Q_1 (AFQ_1), major metabolite of AFB_1 in *in vitro* liver preparations of other higher vertebrates.

AFM, AFQ, and AFL retain the possibly to become an epoxide. Nevertheless, they appear much less capable of causing mutagenesis than the unmetabolized toxin.

Aflatoxins are produced by both *Aspergillus flavus* and *Aspergillus parasiticus*, which are common forms of 'weedy' molds widespread in nature. The presence of those molds does not always indicate that harmful levels of aflatoxin are present but does indicate a significant risk. The molds can colonize and contaminate food before

harvest or during storage, especially following prolonged exposure to a high-humidity environment, or to stressful conditions such as drought.

The native habitat of *Aspergillus* is in soil, decaying vegetation, hay, and grains undergoing microbiological deterioration, but it invades all types of organic substrates whenever conditions are favorable for its growth. Favorable conditions include high moisture content (at least 7%) and high temperature. Aflatoxins have been isolated from all major cereal crops, and from sources as diverse as peanut butter and cannabis. The staple commodities regularly contaminated with aflatoxins include cassava, chilies, corn, cotton seed, millet, peanuts, rice, sorghum, sunflower seeds, tree nuts, wheat, and a variety of spices intended for human or animal consumption. Aflatoxin transformation products are sometimes found in eggs, milk products, and meat when animals are fed contaminated grains.

A study conducted in Kenya and Mali found that the predominant practices for drying and storage of maize were inadequate in minimizing exposure to aflatoxins.

Organic crops, which are not treated with fungicides, may be more susceptible to contamination with aflatoxins.

References:

INTERNATIONAL

- S. Yada and L.J. Harris (2019) is a bibliography with many references of *Salmonella, E. coli,* and *Listeria* outbreaks in sesame products throughout the world. There are more references in doing a search using the keywords "sesame + *Salmonella, E. coli,* or *Listeria*."

CHINA

- F.Q. Li et al. (2009) studied the natural occurrence of aflatoxins in Chinese sesame paste samples. Aflatoxin B_1 was the predominant toxin detected abundantly and frequently at a level up to 20.45 microg/kg in 37 of 100 sesame paste samples analyzed by liquid chromatography. Of the 100 samples, 19 and 32% of sesame paste samples contained B_1 higher than Chinese and European Union regulations, respectively. [Based on abstract]

EGYPT

- B.A. Sabry et al. (2016) in Egypt studied 28 sesame samples collected from food stores in different governates. They found the following fungi.

Governorate	NC/ TNS	Fungal load (log_{10} CFU/g)		Percentage occurrence of fungal genera				
		Range	Mean ± SD	*Alternaria*	*Aspergillus*	*Fusarium*	*Penicillium*	*Cladosporium*
Great Cairo	4/4	1.72 –2.32	1.91±0.77[a]	34.21	60.53	2.63	ND	2.63
Kalioubia	3/3	1.72 –2.32	1.97±1.03[a]	4.17	91.66	ND	4.17	ND
Alexandria	6/6	1.72 –2.67	1.99±1.63[a]	4.35	82.61	6.52	ND	6.52
El-Behera	5/5	1.72 –2.87	2.15±1.63[b]	ND	71.82	0.91	17.27	10.00
Kafr El-Sheik	5/5	1.72 –2.80	2.26±2.72[c]	3.96	60.40	1.98	17.82	15.84
Dakahlia	5/5	1.72 –3.02	2.52±0.70[d]	ND	79.68	1.59	6.37	12.35

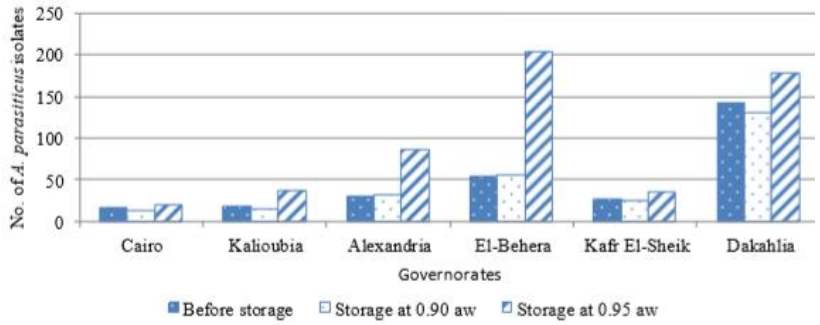
NC: Number of contaminated samples; TNS: Total number of samples
Mean with different superscript letters are significantly different

They found the following *Aspergillus* sp.

Governorate	NC/ TNS	*Aspergillus* load (log_{10}CFU/g)		Percentage occurrence of *Aspergillus* species		
		Range	Mean ± SD	*Aspergillus parasiticus*	*Aspergillus flavus*	*Aspergillus niger*
Great Cairo	1/4	1.72 –2.32	1.96±0.86[a]	69.56	8.69	21.75
Kalioubia	1/3	1.72 –2.32	2.02±1.09[a]	77.27	4.54	18.18
Alexandria	1/6	1.72 –2.67	2.02±1.77[a]	78.95	ND	21.05
El-Behera	3/5	1.72 –2.87	2.23±3.09[b]	67.08	ND	32.91
Kafr El-Sheik	3/5	1.72 –2.80	2.37±3.41[b]	42.62	ND	57.38
Dakahlia	3/5	2.20 –3.02	2.69±0.75[c]	71.00	ND	29.00

NC: Number of contaminated samples; TNS: Total number of samples

Stored sesame samples at the higher water activity (a_w 0.95) showed an increase of total fungal count compared with samples stored at a lower water activity (a_w 0.90).



They found the following percentages and levels of aflatoxins.

Governorates	TNS	Aflatoxin B_1		Aflatoxin B_2		Aflatoxin G_1		Aflatoxin G_2	
		µg/kg	%	µg/kg	%	µg/kg	%	µg/kg	%
Great Cairo	4	18.63 ± 0.79	100	ND	ND	18.27 ± 1.31	100	ND	ND
Kalioubia	3	23.25 ± 0.93	100	ND	ND	21.33 ±1.22	66.66	ND	ND
Alexandria	6	21.04 ± 2.32	66.66	0.28 ± 0.10	33.33	51.47 ± 2.18	33.33	1.55 ± 0.59	16.66
El-Behera	5	66.74 ± 1.71	60.00	0.42 ± 0.07	40.00	43.81 ± 2.10	80.00	ND	ND
Kafr El-Sheik	5	29.94 ± 1.02	100	ND	ND	14.88 ± 1.55	80.00	ND	ND
Dakahlia	5	42.37 ± 1.34	100	0.19 ± 0.10	20.00	27.51 ±1.07	100	0.12 ± 0.13	20.00

Results are mean ± SD (n=3); TNS: Total number of samples

Roasting or microwaving can reduce the amount of aflatoxins but will not eliminate them. The following table shows the percentage reduction under several trials.

Treatment Time	Roasting		Microwave (20 kgy)
	100ºC	150ºC	
5	-	-	18.14±0.024
20	5.33±0.026	11.50±0.079	-
30	7.21±0.011	14.14±0.090	-

Results are mean ±SD (n=3)

GREECE

- E. Kollia et al. (2014) in Greece reported sesame seeds are sensitive to AF-producing fungal invasion, because of their oil content, and may therefore be contaminated with Afs and particularly AFB_1. They studied the possibility of controlling *Aspergillus* with extracts from *Cynara cardunculus* L. (Asteraceae), commonly named "cardoon" or "wild artichoke". They found AFB_1 production in sesame seeds inoculated with *Aspergillus parasiticus* and addition of *C. cardunculus* head extract, was significantly lower (99.6%) compared to AFB_1 production by *A. parasiticus* in sesame seeds (control). Due to its antifungal and anti-aflatoxigenic effectiveness, *C. cardunculus* L. can be used for pre- and post-harvest AF control strategies or during storage. [Based on poster]
- E. Kollia et al. (2016) in Greece examined 30 samples of sesame products for the presence of AFB_1. Aflatoxins are a group of secondary metabolites produced by the species: *Aspergillus flavus, Aspergillus parasiticus* and the rare *Aspergillus nomius*. Among these, aflatoxin B_1 (AFB_1) is the most naturally occurring compound of toxigenic isolates of *Aspergillus* species and the most dangerous contaminant of foods and feeds due to carcinogenic and mutagenic activity. Sesame seeds are sensitive to AF-producing fungal invasion, because of their oil content, and may therefore be contaminated with Afs and particularly AFB_1. After analysis, 77.6% of samples were found to be contaminated. Eight samples exceeded the European Union (EU) limit (2 µg AFB_1 kg^{-1}). In 15 samples, AFB_1 was below the EU limit. Seven samples remained below the LOD. The most contaminated (14.49 ng AFB_1 g^{-1}) sample was unpeeled packaged sesame seeds. Aflatoxigenic fungi (*Aspergillus*) were identified in 73.3% of the investigated sesame products. Amongst these samples, cooccurrence of AFB_1 and aflatoxigenic fungi was found in 72.7% of them (n = 16) with AFB_1 contamination from 0.1 to 14.5 ng/g.

Table 2. AFB_1 and aflatoxigenic fungi occurrence in sesame products samples.

No.	Samples	Country of origin	AFB_1 (ng g^{-1})	Aflatoxigenic fungi
1	Wholegrain tahini (unpackaged)	Greek product[c]	0.1	No[a]
2	Tahini sesame peeled (unpackaged)	Greek product[c]	0.1	No[a]
3	Tahini (packaged)	Greek product[c]	0.1	No[a]
4	Organic tahini (packaged)	Greek product[c]	0.1	No[a]
5	Sesame unpeeled (packaged)	Sudan	0.4	No[a]
6	Black sesame (packaged)	Syria	<LOD	No[a]
7	Sesame peeled (packaged)	India	0.3	Yes[b]
8	Black sesame (unpackaged)	India	0.1	No[a]
9	Sesame unpeeled (unpackaged)	India	0.1	Yes[b]
10	White sesame peeled (unpackaged)	India	8.6	No[a]
11	Sesame peeled (packaged)	India	0.2	Yes[b]
12	Roasted sesame packaged)	Syria	<LOD	Yes[b]
13	Tahini halva with cocoa (packaged)	Greek product[c]	0.1	Yes[b]
14	Tahini halva with vanilla flavour (packaged)	Greek product[c]	0.1	Yes[b]
15	Tahini halva with vanilla flavour (unpackaged)	Greek product[c]	<LOD	Yes[b]
16	Tahini halva with cocoa (unpackaged)	Greek product[c]	<LOD	Yes[b]
17	Pasteli sesame bar (packaged)	Greek product[c]	<LOD	Yes[b]
18	Organic pasteli sesame bar (packaged)	Greek product[c]	<LOD	Yes[b]
19	Organic pasteli sesame bar (packaged)	Greek product[c]	<LOD	Yes[b]
20	Pasteli sesame bar (packaged)	Greek product[c]	0.1	Yes[b]
21–30	Sesame unpeeled (packaged)	Sudan	0.4–14.5	Yes[b]

[a]Absence of aflatoxigenic fungi.
[b]Presence of aflatoxigenic fungi.
[c]Country of origin of sesame seeds used as raw material is unknown.

INDIA

- A.S. Reddy and S.M. Reddy (1983b) reported 36 fungal species were obtained from 105 seed samples of sesame. Several species of *Aspergillus*, *Fusarium* as well as *Penicillium citrinum* can produce a very wide range of mycotoxins. [Cited by G.S. Saharan, 1989]

IRAN

- A. Habibi and Z. Banihashemi (2008) studied the genetic diversity of a population of *Aspergillus flavus* isolated from sesame seeds collected in 2004 and 2005 from various parts of Iran through vegetative compatibility, and their mycotoxin production. Sixteen vegetative compatibility groups (VCGs) were identified among the *nit* mutants. VCGs were not evenly distributed through Iran. With few exceptions, there was a relationship between a VCG and the amount of mycotoxins produced by its isolates.
- M. Asadi et al. (2011) surveyed 182 samples of sesame in Khoransan Province using liquid chromatography. AFB_1 was detected in 33 samples at a mean level of 1.62 ng/g, and a maximum level of 5.54 ng/g. AFB_1 levels exceeded the European Union (EU) maximum tolerated level (MTL, 2 ng/g) in 9 samples, and the Iran MTL (5 ng/g) in 1 sample. Regarding total aflatoxins (AFT), the mean level was 0.92 ng/g, and the maximum level was 5.54 ng/g. No sesame sample exceeded the Iran MTL (15 ng/g), but two samples exceeded the EU MTL (4 ng/g) for AFT. It is concluded that low levels of aflatoxins occur frequently in sesame from Iran.
- A.R. Hosseininia et al. (2014) examined 269 samples obtained from a total of 9,321 tons of sesame seeds from five importing companies. Aflatoxins at >1 µg/kg were found in 50 % of all samples, but at low levels in most cases, which is illustrated by mean AFB_1 and total AF levels of 1.25 and 1.43 µg/kg, respectively. A few (1.9 %) samples exceeded the National Iranian Standard maximum accepted level for AFB_1 (5 µg/kg) or total AF (15 µg/kg); the maximum total AF level found in one sample was 48 µg/kg. The results indicate that the risk of a violative AF contamination in imported sesame seeds is not negligible but is currently relatively low. [Based on abstract]
- A. Heshmati et al. (2021) evaluated 120 samples of sesame seeds, tahini, and tahini halva collected from markets. The highest prevalence of AF (55%) was associated with sesame seed samples, followed by tahini (45%) and tahini halva (32.5%). The AFB_1 concentration in sesame seeds, tahini, and tahini halva was in the ranges of 0.2-12.4, 0.2-5.8, and 0.3-3.56 µg/kg, respectively. The concentration of the total aflatoxin (TAF) in 7 (17.5%), 8 (20%), and 2 (5%) samples of sesame seeds, tahini, and tahini halva, respectively, was below the limit of European regulations (4 µg/kg), while the levels of AFB_1 in 10 (25%), 7 (17.5%), and 6 (15%) samples of sesame seeds, tahini, and tahini halva, respectively, were higher than the European regulations (2 µg/kg). As the percentile 50 and 95 of margin of exposure (MOE) with AFB_1 for sesame seed, tahini, and tahini halva was more than 10,000, they concluded the intake of aflatoxin through the consumption of mentioned products did pose a not remarkable cancer risk for adults.

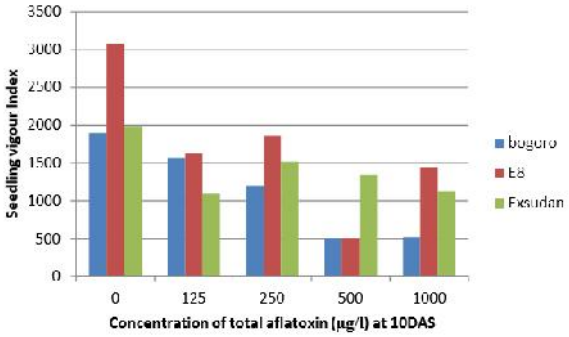
JAPAN

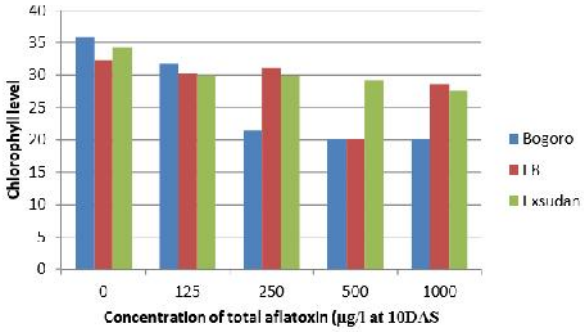
- S. Tabata (1998) collected 47 samples of sesame from commercial markets and the food industry in Tokyo and reported 5 tested positive for aflatoxins – AFB_1: 0.6-2.4 and AFB_2: 0.2-0.5.

NIGERIA

- M.C. Mbach and C.D. Akueshi (2009b) conducted an experiment with two species of seeds of sesame (*Sesamum indicum* and *Sesamum radiatum*) inoculated with a storage fungus (*Aspergillus flavus*) previously isolated from seeds of sesame. The inoculated seeds were incubated for 10, 15 and 20 day intervals at 30°C. Results showed that *S. indicum* inoculated with the test fungus *A. flavus* and incubated for a period of 20 days showed the presence of aflatoxin B_1 estimated to be 25 ppb. While seeds of *S. radiatum* inoculated with the same test fungus and inoculated for the same length of time did not show any presence of aflatoxin. All the seeds of the two species of sesamum inoculated with the test fungus and incubated for 10 and 15 day intervals showed no presence of aflatoxin. The results portray the danger of consuming infested seeds of sesame which usually appear uninfested to a casual observer when *A. flavus* grows on them and the inherent danger of using such seeds for livestock feed.
- C.N. Ezekiel et al. (2012 and 2013) examined 17 samples of sesame from 4 markets and found *Fusarium oxysporum, Fusarium semitectum* and *Fusarium verticillioides*. They found no aflatoxins. Six randomly selected isolates were screened for their ability to produce mycotoxins in ofada rice culture and the crude extracts of the mycotoxins were tested on week-old catfish (*Clarias gariepinus*) fingerlings with lethal effects. They isolated 6 toxic metabolites produced by the *Fusarium* in the rice culture: equisetin, fumonisin B_1, fumonisin B_2, methyl-equisetin, moniliformin, and zearalenone. They concluded sesame may be potential sources of toxigenic *Fusarium*.
- S.T. Anjorin and T.V. Inje (2014) examined the effects of aflatoxin level (0, 125, 250, 500, and 1000µg/l) on seedling emergence, shoot length, root length, seedling vigor and chlorophyll level of the 3 cultivars (E8, Bogoro, and Ex-Sudan). The seeds were soaked in distilled water for an hour, before 10 g of the seeds were transferred to the beaker (500ml) filled with each level of concentration of Aflastandard (product code: p22/ p22A). The setup was allowed to stay for three hours before sowing in the field. The vigor was computed by shoot length x germination %. The chlorophyll level in sesame was recorded by aid of a chlorophyll-meter (Atleaf®). The seedling data was taken 10 days after sowing. The number of leaves, leaf area, and number of flowers data was taken 56 days after sowing.

Variety	Concentration (µg /L)	Seedling emergence	Shoot length (mm)	Root length (mm)	Seedling vigour (x100)	Chlorophyll level (index)
Bogoro	0	96.00a	19.75a	16.50a	1895.96a	35.85a
	125	90.00b	17.50b	15.25b	1575.06b	31.77b
	250	70.00c	17.00b	12.25c	1190.66c	21.50c
	500	40.00d	12.75c	10.75d	510.00d	20.10d
	1000	40.00d	13.00c	10.80d	520.66d	20.20d
E8	0	99.00a	31.00a	36.75a	3068.66a	32.30a
	125	99.00a	16.50c	20.25d	1633.53c	30.22c
	250	75.00b	19.50b	32.00b	1852.56b	31.05b
	500	40.00c	12.75d	10.75e	510.00 e	20.10e
	1000	50.00c	16.00c	24.70c	1440.66d	28.60d
Ex-sudan	0	70.00a	28.25a	22.50a	1977.55a	34.24a
	125	55.00c	20.00d	20.00b	1100.66d	30.00b
	250	65.00b	23.40c	22.50a	1521.06b	29.93b
	500	55.00c	24.50c	19.80b	1343.83c	29.23b
	1000	45.00d	25.00b	18.75c	1125.66d	27.60c
Interaction (variety x level)		**	**	**	**	**





Variety	Concentration (µg /L)	No of leaves	Area of leaves (mm^2)	Number of flowers
Bogoro	0	11.16b	11.22c	3.16b
	125	19.00a	18.64a	6.66a
	250	10.33c	16.56b	2.50d
	500	9.66d	11.05c	1.80e
	1000	8.85d	15.49b	2.66c
E8	0	13.83a	29.87a	7.66a
	125	12.83b	16.86c	7.00b
	250	12.33c	22.15b	6.00b
	500	9.66d	11.05d	1.80c
	1000	11.66e	13.00d	2.16c
Ex-sudan	0	63.00a	28.35a	8.00a
	125	51.50b	22.40b	8.00a
	250	49.00c	20.25c	5.00b
	500	46.00d	16.10d	3.50b
	1000	26.50e	10.85 e	3.00c
	Interaction (varietal x level)	**	**	**

- B. Doka (2014) reported aflatoxins (B_1 B_2 and G_1 G_2) produced by *Aspergillus flavus* can be poisonous to people and livestock and cannot be exported. Aflatoxin contamination can occur in the field, before harvest, during harvesting and post-harvest handling processes, e.g. field sun-drying, storage, and transportation of product. The soil in the field is known to be an excellent storage medium for *Aspergillus* spp. Pre-harvest contamination is influenced by soil moisture and temperature and is likely to be most serious under drought conditions. Postharvest aflatoxin contamination occurs if the seeds become moist and/or damaged and can occur at harvest or later.
- C.N. Ezekiel et al. (2014) isolated the following pathogens on sesame seeds: *Alternaria*, *Aspergillus*, *Fusarium*, *Penicillium*, *Cercospora*, *Mucor*, *Rhizopus*, *Talaromyces*, and *Trichoderma*. *Aspergillus* dominated (48.1%) followed by *Fusarium* (41.6%), *Cercospora* (5.0%), *Penicillium* (1.5%), *Alternaria* (0.7%) and others (3.1%). The *Aspergillus* were identified as *A. flavus*, *A. tamarii* and *A. parvisclerotigenus*. The following were the ranges of aflatoxins found on the sesame.

Concentration (µg/kg) of aflatoxins from toxigenic species

		A. flavus		*A. parvisclerotigenus*			
		B	G	B	G	Total B	Total G
Sesame	Range	75.8–326.1	–	215.6–1011.2	363.2–1980.7	75.8–1011.2	363.2–1980.7
	Mean[1]	190.1b	–	601.3	863.9	597.1a	863.9

- A.D. Ojochenemi et al. (2015) examined 46 samples of sesame for mycotoxicological concerns. Sesame seed in this work had 50%, 4.35% and 6.52% contamination by AFB_1, AFB_2 and AFG_1 respectively. Contamination ranged from 0.79-60.05 µg/kg with a mean ± SD value of 13.67 ± 13.59. They stated 21.7% sesame samples were unsafe for human consumption.
- U.A. Umar et al. (2015b) sounded an alarm for all sesame producing countries: "The most anticipated and immediate effect of aflatoxin contamination to Nigeria's sesame industry is the fall in demand of sesame seed originated from Nigeria. This will be followed by drastic fall in prices of the crop and subsequent loss of huge foreign exchange generated from its export. The greatest negative impact will be felt by the small holder sesame

crop farmers who will incur huge losses of revenue due to a fall in demand and prices that will impact negatively on their living conditions. Productions of sesame seed will likely fall in the subsequent years, because most farmers will shift to cultivation of other crops that will give them maximum benefit."
He proposed the following actions.

- "Improve methods of harvesting and drying by ensuring that farmers harvest their crops at the end of the rainy season and allow them to be fully dried before threshing.
- Similarly improve methods of storage both from the farmers, merchants and exporters may as well help to prevent the development of aflatoxin.
- Stores should be properly ventilated to prevent the mold/fungi from growing.
- There is the need to create awareness to all stakeholders from farmers, middlemen, merchants and exporters on dangers of aflatoxin contamination to the growth and survival of the sesame industry.
- The government and all stakeholders need to impose strict quality testing for all sesame seed consignment before export. This will prevent shipment of contaminated product to foreign buyers and ensure steady and sustainable market of sesame seed from Nigeria."

- D.O. Apen et al. (2016) in Nigeria studied incidence of fungi and aflatoxin in 50 sesame samples. They reported 21.7% sesame (0.79-60.05 µg/Kg) samples were unsafe for consumption. Fungal load in sesame seeds increased with latitude. [Based on abstract]
- A.O. Esan et al. (2020) purchased 60 sesame samples from markets in Nasarawa states during 2 seasons (wet and dry) in order to determine the safety for human consumption. They identified the following fungi: *Aspergillus* section *candidi*, *Aspergillus* section *flavi* (*A. flavus* and *A. tamarii*), *Aspergillus* section *nigri*, *Cladosporium* sp., *Fusarium fujikuroi*, *Penicillium* spp., and Didymellaceae. Toxins were found in 59 of the samples as shown below.

Mycotoxins	LOD[a] (µg kg^{-1})	Sesame (n = 59)			
		N (%)[b]	Range	Mean	Median
Aflatoxicol	1	3 (5)	0.53–14.0	5.06	0.68
Aflatoxin B_1	0.24	7 (12)	0.29–79.3	14.8	2.67
Aflatoxin B_2	0.4	5 (8)	0.17–8.54	2.50	1.20
Aflatoxin G_1	0.32	4 (7)	0.17–0.90	0.49	0.45
Total aflatoxins	–	7 (12)	0.29–88.5	16.9	2.84
Aflatoxin M_1	0.4	3 (5)	0.18–2.56	1.00	0.27
Aflatoxin P_1	0.1	3 (5)	0.004–1.03	0.35	0.01
Alternariol (AOH)	0.4	7 (12)	0.49–3.78	1.85	0.84
AOHmethylether	0.032	35 (59)	0.12–47.2	4.19	0.74
Beauvericin	0.008	18 (31)	0.21–42.7	3.34	0.45
Citrinin	0.16	7 (12)	0.77–26.8	6.48	1.98
Dihydrocitrinone	1.2	2 (3)	1.35–18.3	9.84	9.84
Fumonisin B_1	2	4 (7)	5.60–24.0	13.0	11.3
Moniliformin	1.6	11 (19)	3.24–38.1	12.4	7.68
Ochratoxin A	0.4	0 (0)	<LOD	<LOD	<LOD
Ochratoxin B	0.6	0 (0)	<LOD	<LOD	<LOD
Sterigmatocystin	0.1	7 (12)	0.25–11.7	3.97	0.96

[a] Limit of detection (expressed as µg kg^{-1} sample)

[b] Number (percentage) of positive samples

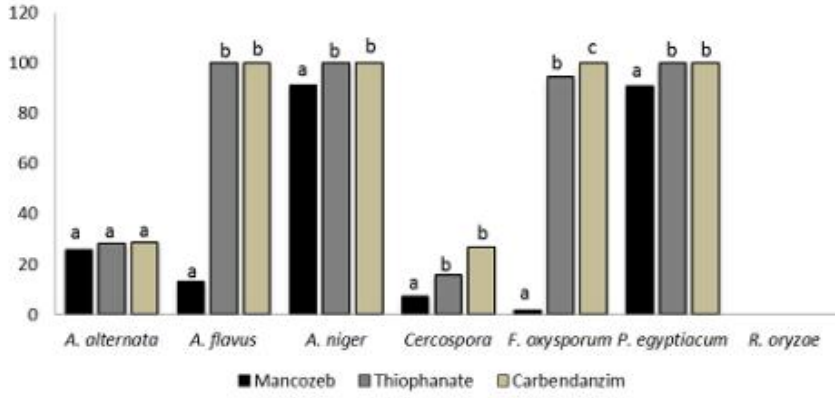
Mycotoxins	LOD[a] (μg kg^{-1})	Melon (n = 53)				Sesame (n = 59)			
		N (%)[b]	Range	Mean	Median	N (%)[b]	Range	Mean	Median
Aflatoxicol	1	12 (23)	0.15–8.01	2.04	1.06	3 (5)	0.53–14.0	5.06	0.68
Aflatoxin B_1	0.24	40 (76)	0.14–152	9.13	1.67	7 (12)	0.29–79.3	14.8	2.67
Aflatoxin B_2	0.4	28 (53)	0.003–16.2	1.66	0.57	5 (8)	0.17–8.54	2.50	1.20
Aflatoxin G_1	0.32	13 (25)	0.17–1.68	0.52	0.32	4 (7)	0.17–0.90	0.49	0.45
Total aflatoxins	–	40 (76)	0.14–168	10.5	2.16	7 (12)	0.29–88.5	16.9	2.84
Aflatoxin M_1	0.4	14 (26)	0.005–3.12	0.61	0.33	3 (5)	0.18–2.56	1.00	0.27
Aflatoxin P_1	0.1	0 (0)	<LOD	<LOD	<LOD	3 (5)	0.004–1.03	0.35	0.01
Alternariol (AOH)	0.4	2 (4)	0.09–0.97	0.53	0.53	7 (12)	0.49–3.78	1.85	0.84
AOHmethylether	0.032	5 (9)	0.28–14.5	3.72	0.62	35 (59)	0.12–47.2	4.19	0.74
Beauvericin	0.008	5 (9)	0.19–0.71	0.34	0.23	18 (31)	0.21–42.7	3.34	0.45
Citrinin	0.16	17 (32)	0.18–12.6	2.83	1.14	7 (12)	0.77–26.8	6.48	1.98
Dihydrocitrinone	1.2	9 (17)	0.92–5.93	2.21	1.39	2 (3)	1.35–18.3	9.84	9.84
Fumonisin B_1	2	0 (0)	<LOD	<LOD	<LOD	4 (7)	5.60–24.0	13.0	11.3
Moniliformin	1.6	0 (0)	<LOD	<LOD	<LOD	11 (19)	3.24–38.1	12.4	7.68
Ochratoxin A	0.4	1 (2)	<LOD–112	112	112	0 (0)	<LOD	<LOD	<LOD
Ochratoxin B	0.6	1 (2)	<LOD–94.2	94.2	94.2	0 (0)	<LOD	<LOD	<LOD
Sterigmatocystin	0.1	34 (64)	0.03–28.1	1.71	0.44	7 (12)	0.25–11.7	3.97	0.96

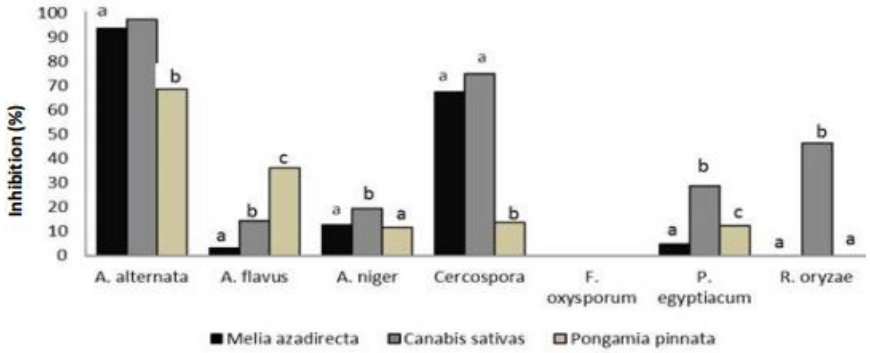
[a] Limit of detection (expressed as μg kg^{-1} sample)

[b] Number (percentage) of positive samples

PAKISTAN

- B.G. Nayyar et al. (2016) evaluated different treatments to increase the germination and inhibit the fungi of sesame seeds: application of fungicides (Mancozeb, Thiophante Methyl, and Carbendazim) and plant extracts (*Melia azedarach*, *Cannabis sativa* and *Pongamia pinnata*). Seed germination was tested by following the protocol of International Seed Testing Association. Antifungal activity was tested by poisoned food technique. The results revealed that the germination increased effectively, due to thiophanate methyl up to 46%, followed by *Cannabis sativa* (37%). Out of 7 fungi tested against fungicides and plant extracts, 4 fungi, namely *Aspergillus flavus*, *Aspergillus niger*, *Fusarium oxysporum* and *Penicillium egyptiacum*, were inhibited up to 100% by Carbendazim and Thiophanate Methyl, while Mancozeb inhibited *Penicillium egyptiacum* (100%), only. *Cannabis sativa* inhibited *Alternaria alternata* (100%) and *Rhizopus oryzae* (55.6%). Overall treatment with fungicides gave best results but they were not eco-friendly. So, this study recommends the use of plant extracts and bioagents, which may increase seed germination and inhibit seedborne fungi without any harmful effect. The treatments had the following effects on specific fungi in terms of germination and inhibition: *Alternaria alternata*, *Aspergillus flavus*, *Aspergillus niger*, *Cercospora sp.*, *Fusarium oxysporum*, *Penicillium egyptiacum* and *Rhizopus oryzae.*





- M. Ajmal et al. (2021) evaluated the incidence of mycobiota and contamination of AFB_1 in sesame seeds from rainfed and irrigated zones of the Punjab, Pakistan. *Aspergillus flavus* was the leading contaminant found in fresh and stored sesame seeds from rainfed and irrigated zone followed by *A. niger*, *Alternaria alternata* and *Fusarium oxysporum*. Least reported fungi were *Aspergillus ochraceus* and *Cladosporium oxysporum*. AFB_1 analysis revealed that 92% fresh and 99% stored samples were contaminated with AFB_1. 20% fresh and 100% stored samples from rainfed zone and 28% fresh and 60% stored samples from irrigated zone were tainted with AFB_1 levels above 20 ppb and not fit for human consumption.
- M. Ajmal et al. (2021) evaluated the incidence of mycobiota and contamination of AFB_1 in sesame seeds from rainfed and irrigated zones of the Punjab, Pakistan. They collected 100 samples from sesame growing areas and identified the mycobiota and quantified the AFB_1. They then stored the samples for 12 months and reexamined them. All samples were reported positive for fungal growth in fresh and stored conditions. Twenty-one fungal species belonging to ten different fungal genera were isolated. *Aspergillus flavus* was the leading contaminant found in fresh and stored sesame seeds from rainfed and irrigated zone followed by *A. niger*, *Alternaria alternata* and *Fusarium oxysporum*. Least reported fungi were *Aspergillus ochraceus* and *Cladosporium oxysporum*. AFB_1 analysis revealed that 92% fresh and 99% stored samples were contaminated with AFB_1. In the rainfed zone, 88% fresh and 100% stored samples were contaminated with AFB 1 with a mean concentration of 15.74ppb and 33.8ppb, respectively. Similarly, in the irrigated zone, 96% fresh and 98% stored samples were contaminated with AFB_1 with a mean concentration of 20.5ppb and 27.56ppb, respectively. 20% fresh and 100% stored samples from rainfed zone and 28% fresh and 60% stored samples from irrigated zone were tainted with AFB_1 levels above 20 ppb, not fit for human consumption as per maximum limit (20ppb) assigned by FDA and FAO. [Based on abstract]

SENEGAL

- P.M. Diedhiou et al. (2011) studied *Aspergillus* and aflatoxin colonization from 5 districts. They looked at 500 isolates (20 from each sample from 5 villages in the 5 districts). The aflatoxin content of sesame and the cfu load were very low for the two conservation methods (living room and storage) used by farmers. The results were as follow.

AEZ	District	Number isolated	Toxigenic (%)	*A. flavus* (%)	Strain S_{BG} (%)	*A. tamarii* (%)
SG	Kolda	100	51	87	13	0
	Sedhiou	100	32	75	25	0
	Mean	–	41.5	81	19	0
SS	Kaffrine	100	70	97	3	0
	Tambacounda	100	33	93	7	0
	Nioro	100	41	79	21	0
	Mean	–	48	89.6	10.3	0
	LSD[a]	–	24.6	19.5	19.5	0

		B-aflatoxin (ng/g)[a]		CFU/g[b]	
AEZ	District	Mean	Range	Mean	Range
SG	Kolda	0.3	0–1.0	483	13–2000
	Sedhiou	0.1	0–0.2	200	17–800
SS	Kaffrine	0.2	0–0.3	230	100–350
	Nioro	0.3	0–1.2	9400	200–42 800
	Tambacounda	0.1	0–0.2	120	100–200
	LSD[c]	0.4	–	11 042	–

[a]Only aflatoxin B_1 was detected in both maize and sesame samples.
[b]CFU = colony-forming units per gram of sample; mean of five locations (one field per location).

SIERRA LEONE

- F.E. Jonsyn (1988) sampled the fungi in 4 different geographical areas and found three toxigenic Aspergillus species: *A. flavus* Link ex Fries, *A. ochraceus* Wilhelm, and *A. tamarii* Kita were common to all samples. *Penicillium citrinum* Thom and two Fusarium sp. were found in samples from two localities. The mycotoxins aflatoxin B_1 and G_1, ochratoxin A and B, and citrinin were positively identified. [Based on abstract]
- F.E. Jonsyn (1990) examined 49 samples of seed. *Aspergillus spp* were the dominant group irrespective of the locality. Toxigenic Aspergillus included *Aspergillus flavus* Link ex Fries, *Aspergillus tamarii* Kita and *Aspergillus ochraceus* Wilhelm. *Penicillium citrinum* Thom was the only toxigenic Penicillium isolated. [Based on abstract]

SUDAN

- Y.M.A. Idris et al. (2010) in Sudan assessed 16 samples of unrefined sesame oil for aflatoxin B_1 (AFB_1), aflatoxin B_2 (AFB_2), aflatoxin G_1 (AFG_1), and aflatoxin G_2 (AFG_2) from markets. Seven (43.8%) of the samples had AFB_1, and no samples had the other 3 aflatoxins.
- Y.M.A. Idris et al. (2013) in Sudan examined 104 sesame oil samples collected over two seasons from traditional mills from 5 states. Levels of aflatoxin B_1, B_2, G_1, and G_2 were determined using HPLC.
  - All sesame oil samples were obtained from camel traditional oil processing mills. A camel traditional milling process was used to produce 'Normal' (N) and 'Walad' (W) sesame oils. The camel traditional mill is composed of a wooden bowl approximately 75 cm diameter and 100 cm length, a wooden stick, a wooden connector, and a camel. Milling is started by putting enough cleaned sesame seeds (approximately 50 kg) in the bowl then they are pressed by the stick which is driven by a blindfolded camel plodding round and round, which squeezes the oil out of the seeds, which forms into two layers: a clean, light color upper one, which is known as 'Normal' sesame oil, and the lower layer which produces a cloudy, dark-colored and strong-flavored oil known as 'Walad' sesame oil.
  - Samples of W and N from the five states had fluctuations in physicochemical characteristics in the two seasons. The highest percentage of contamination by aflatoxin B_1 during season II occurred in 'Normal' sesame oil which was 80.77 %, followed by 'Walad' sesame oil with 76.92 %. These percentages of contamination in season I were lower than 59.26 % for 'Normal' sesame oil and lower than 52.0 % for 'Walad' sesame oil in season II. Aflatoxin B_2 contamination recorded the highest incidence in season II (3 out of 26 samples, 11.54 %) of 'Normal' sesame oil, followed by 'Walad' sesame oil (2 out of 26 samples, 7.69 %). These percentages were lower than the 7.40 and 4.0% of 'Normal' and 'Walad' sesame oils in season I, respectively. Aflatoxin B_1 and B_2 levels in sesame oil ranged from 0.5 to 9.8 and 0.5 to 1.3 µg/kg, respectively.

THAILAND

- N. Worasatit et al. (2003b) studied aflatoxin presence taking 48 samples (6 that had been in storage 1-2 years and 42 from markets) from central and north-eastern parts using the Eliza test kit for 2 years to include the early rainy season and late rainy season cropping patterns. They also studied methods (sun-dry for 2 days, roast for 30 minutes, oven-dry at 60, 80, and 100°C) to reduce the amounts of aflatoxin. The results were as follow.

Growing Area	Growing Season	Sesame Type	Number of samples having various amount of aflatoxin				
			0-5 ppb	6-10 ppb	11-15 ppb	16-20 ppb	>20ppb
2002							
Petchaboon	Early Rainy season	Black	9	1	-	-	-
Sukhothai	Early Rainy season	Black-brown	2	1	-	1 (17.3)	1 (31.8)
Kanchanaburi	Late Rainy season	Black	1	-	-	-	-
Uban Ratchathni	Late Rainy season	Black	3	-	-	-	-
	Late Rainy season	Black-brown	2	-	-	-	-
	Late Rainy season	White	3	-	-	-	-
2003							
Buriram	Early Rainy season	Black	3	-	-	-	-
Nakornratchasima	Early Rainy season	Black	8	-	-	-	-
Petchaboon	Early Rainy season	Black-brown	6	-	-	-	-
Nakornsawan	Early Rainy season	Black-brown	5	-	-	-	-
Saraburi	Early Rainy season	Black	1	1	-	1 (18.1)	1 (27.4)
	Early Rainy season	Brown	2	-	-	-	-
	Early Rainy season	White	4	-	-	-	-
Sukhothai	Early Rainy season	Black-brown	4	1	-	-	-
Prajeanburi	Late Rainy season	Black	4	1	-	-	-

Value in parenthesis is an actual value of aflatoxin content detected in sesame seed sample.

Using a sample with 24.7 ppb, the following are the results of trying different methods to reduce aflatoxin levels.

Treatments	Amount of aflatoxin on sesame seed (ppb)
Sun-dry for 2 days	14.0
Roasted for 30 minutes	4.7
Oven-dry at 60°C for 30 minutes	20.0
Oven-dry at 80°C for 30 minutes	20.0
Oven-dry at 100°C for 30 minutes	16.7
Untreated seed	24.7
LSD $\leq$ 0.05	9.745
C.V. (%)	32.9

- A. Chinaputi (2005) sampled 375 samples of black sesame and 285 samples of white sesame collected from local markets in Bangkok over 8 months. For black seeds, the amount of aflatoxin contamination was an average of 91.7% and the amount was 0.4-179.4 microgram/kg (ppb). Among the contaminated samples, 25% were over the maximum level limit (20 ppb). Low amount and low percentage of contaminated samples were found in the white seeds. *Aspergillus flavus* was found in all the samples with aflatoxin.
- S. Krijanarat (2005) studied the effect of sweathing (cutting sesame and drying it under a tarp) on the production of aflatoxins and free fatty acids. Sweathing causes high temperature and moisture content, and consequently leads to aflatoxin contamination and free fatty acid occurrence in sesame. He compared sweathing for 7 days, sweathing for 10 days, harvested 2 weeks before physiological maturity and no sweathing, and harvesting at physiological maturity and sweathing. There was no effect on germination. The

results were as follow (SMC = seed moisture content, 1 hectare = 6.25 rai, AV = acid value).

Treatment	SMC (%)	Yield (kg/rai)	Germination (%)	Aflatoxin (ppb)	AV
Harvested at 2 wks before PM and sweathing sesame plants for 7 days	6.65	52	82	23.4 b	8.63 b
Harvested at 2 wks before PM and sweathing sesame plants for 10 days	6.42	54	80	28.3 b	8.45 b
Harvested at 2 wks before PM and no sweathing sesame plants	6.55	54	79	6.57 a	4.30 a
Harvested at PM and no sweathing sesame plants	6.63	51	80	6.3 a	4.68 a
CV (%)	4.6	21.9	3.3	24.0	17.9

In a column, means followed by a common letter are not significantly different at 5% level by DMRT

- T. Mya et al. (2010) studied the effects of planting rate (4, 6, 8, and 10 kg/ha) and harvest date (52, 56, and 60 days after flowering) using 1 variety (KU-18) for 1 year at Pak Chong (14.66N 101.43E). The results were as follow.

Trait	**4x52**	**4x56**	**4x60**	**6x52**	**6x56**	**6x60**	**8x52**	**8x56**	**8x60**	**10x52**	**10x56**	**10x60**
Seed yield (kg/ha)	1,267	775	855	1,211	924	585	1,059	919	731	1,118	695	544
Initial plants/m^2		65.8			96.3			113.6			146.8	
Final plants/m^2		49.3			58.6			67.2			71.2	
Self-thinning (%)		25			39			41			52	
Plant height (cm)	121	120	123	118	123	122	122	126	118	117	112	119
Height of first capsule (cm)	47	46	46	45	40	49	50	47	51	46	46	53
Nodes per plant	20	21	23	19	21	22	18	21	19	20	16	18
Capsules per plant	32	35	40	27	35	38	27	34	30	27	24	28
Seeds per capsule	74	71	77	75	73	73	79	72	72	76	65	74
Capsule length	3.72	4.04	3.88	3.76	4.09	3.74	3.75	3.89	3.68	3.72	3.79	3.68
1000-seed weight (g)	3.38	3.47	3.24	3.24	3.35	3.25	3.37	3.24	3.40	3.35	3.30	3.11
Aflatoxin (ppb)*	9.44	6.47	8.07	7.29	9.10	4.58	8.63	9.05	5.78	7.47	7.33	7.71
Oil content (%)	42.1	38.6	33.0	35.8	40.7	34.2	32.8	42.8	36.8	41.7	34.4	36.6
Protein content (%)	26.0	26.6	26.2	25.8	26.7	26.1	25.6	26.3	26.3	26.9	26.8	27.0

* Maximum allowable aflatoxin = 20 ppb

They found the levels of aflatoxin B_1 in the seed ranged from 4.58 to 9.44 ppb with a mean of 7.58 ppb. The allowable limit for USA consumption in 20 ppb, but there are countries with a lower level. There was no

pattern associated with planting rate or harvest date. They cited references from other crops that average air and soil temperature of 25-35°C and relative humidity of 70% were favorable to aflatoxin contamination. One source reported that 82% RH was the minimum value required for *Aspergillus flavus* spore germination and aflatoxin production.

TURKEY

- G. Yentur et al. (2006) analyzed 20 packages of sesame collected from Ankara local markets. Extraction and determination of aflatoxins have been made by immunoaffinity column technique and high-performance liquid chromatography (HPLC). Mean level of aflatoxin G_1 was found to be 0.754±0.213 ng/g. Our data revealed that aflatoxin levels found in sesame samples were within the Turkish Food Codex (TFC) values. [Based on abstract]
- E. Torlak et al. (2013b) analyzed 104 tahini samples collected from Central Anatolian region of Turkey for aflatoxin contamination. Analysis of samples was carried out by high-performance liquid chromatography with fluorescence detection. Aflatoxin B_1 was the predominant mycotoxin detected in 15 samples, with contamination levels ranging from 0.31 to 2.53 µg/kg. The mean level of total aflatoxins in contaminated samples was found to be 1.17±0.55 µg/kg. The aflatoxin B_1 and total aflatoxins levels were within the Turkish Food Codex limits. [Based on abstract]

UNITED STATES

- H.K. Abbas et al. (2019) in the USA examined the harvested grain of four sesame varieties (S34, S35, S38, and S39) planted in the Mississippi Delta in 2014 and 2015 for contamination by mycotoxins and toxigenic fungi. None of the mycotoxin levels observed in this study were significant in regard to human or animal health, but further testing is needed. This is the first report of fumonisin found in sesame seed. The results of this study indicate that sesame seed is a safe crop for growers and consumers. [Based on abstract]
- P.K. Chang et al. (2020) and H.K. Abbas (2020) reported a collection of 500 *Aspergillus flavus* isolates from four sesame varieties (S-34, S-35, S-38, and S-39) that were planted in field plots in the Mississippi Delta and in the Florida Panhandle were investigated because of low-level aflatoxin contamination detected in sesame seeds. A rapid molecular fingerprinting method was developed to assess the influence of prior applications of the atoxigenic Afla-Guard® biocontrol product whose active strain is NRRL21882 on the *A. flavus* populations within each field plot. Depending on sesame seed sampled, 66.7% to 95.9% of *A. flavus* isolates from Mississippi belonged to the NRRL21882 genotype, which lacks the aflatoxin and cyclopiazonic acid biosynthesis gene clusters. In contrast, only 5.0% to 32.5% of the isolates from Florida had lost both gene clusters. The high incidence of NRRL21882-like *A. flavus* in Mississippi sesame samples can be attributed to prior applications of Afla-Guard® in that local area. The results suggest the adaptability of this particular type of atoxigenic *A. flavus* biocontrol strain in the field. [Based on abstract]

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G2 EFFECTS ON GERMINATION

D.R. Langham comments, 2021: Germination is critical in being able to establish a productive stand in the field.

The following references will show how fungi and bacteria can reduce germination. Many of the references use organisms that cause diseases, but a high population of any kind of organism can use the seed resources and reduce germination. It is not known whether the critical seed component is the oil, protein, and/or carbohydrate content.

- Although the organism can be present on or in the seed while still in the closed capsules, much of the infestation occurs during the drying of the sesame. In shattering and non-dehiscent varieties, the tips of the capsules open and expose the seed to wind carried organisms. The longer the capsules are in the field, the greater opportunity for infestation. In most cases, the spores will remain dormant. But under the right conditions, the fungi will develop on the seed and use seed components. In many cases, it will reduce the germination of the seed.
- In manual harvest the bundles in the inside of the shock will have a micro-climate that may allow fungi to develop with higher humidity and heat. In mechanized harvest the plants are all exposed to sun and wind without any micro-climates.
- The question is which will win when the seed is planted? Will the seed germinate and emerge from the soil before the organisms can damage the seed? Cool temperatures will slow down seed germination and organism development. Although I do not have data, in many years of growers planting the same lot of seed under many different conditions, it is clear that warmer temperatures lead to better stands, ergo, the seed wins. Would love to see experiments that verified or negated this observation.
- Over the years I have done thousands of germination tests in growth chambers using seed harvested at different times. I would harvest the F_1s first since I knew they would be segregating and did not need to evaluate shatter resistance. In most years, it took as much as 3 months after maturity to evaluate the remaining 10,000 plots. There was a very clear pattern: the longer the seed was in the field, the lower the germination, and in extreme cases the fungi would take over the entire petri dish preventing any germination. Several times just out of curiosity, I took some of the late harvested seed where the fungi dominated and washed and dried the seeds. The washed seed had high germination.

Physically damaged seed will not germinate.

- In harvesting and processing planting seed, equipment can damage the seed through rough handling. In manual harvest, there is generally very little physical damage in the handling with the exception of walking on top of bags while they are being stacked. In mechanized harvest if the concaves are closed more than necessary or the rotor speed is too high in the combine, the seed can be broken. Although most broken pieces will be removed in the cleaning over screens and air, there is a continuum of the size of the broken seeds, and some broken seed will go into planting seed bags. Broken seed will not geminate. In addition, the hull of the seed may be scrapped, and that seed will often develop high acid values and will not germinate.
- Harvesting at high moistures can make the seed tender facilitating damage in the equipment. In manual harvest, there is a tendency to thresh the seed out of the shocks at a high moisture because every day the plants remain in the field, more seed is shattered out of the capsules. The outer bundles in a shock have more exposure to wind and sun and will dry first giving the appearance the entire shock is ready for harvest when it has high moisture. However, the seed generally goes into bags that breathe allowing moisture to escape from the bags. In mechanized harvest the seed may end up in silos for long periods of time. Storing seed at high moisture can heat up. In very high moisture and heat, the sesame can catch on fire.

Once the seeds emerge, there are many organisms that can attack the sesame and kill it at any stage. Nitrogen-fixing organisms in the rhizosphere obviously help the growth. Organisms that can be used as biocontrols of damaging pathogens will increase growth and yields. The question is whether there are organisms that are in the plant that actually are neutral. There are many evaluations of seedborne organisms, but most analysis of plants use diseased plants to identify the pathogen. Would be fun to evaluate organisms on healthy plants. In this document, blue lettering is used to identify seedborne organisms that have not been shown to be pathogens. Do these organisms get on the seed once they were exposed in the open capsules, or were they in the plant before?

References:

INTERNATIONAL

- N. Ransingh et al. (2021) reported 3 species of Alternaria (*A. longissima, A. alternata* and *A. sesamicola*) infect sesame, inducing symptoms such as foliage blight, stem necrosis, and spots on capsules. All 3 species also reduced seed germination and seedling stand.

BRAZIL

- N.E.M. Beltrao et al. (2013) reported *Fusarium oxysporum* It is characterized by sagging and wilting of the plant, which later it causes drought and consequently death. When making a cross section in the stem of the infected plant, there is blackening of the tissues of the vascular system. The disease affects any stage of the plant's life, from germination and seedling stage to its development and maturation (G. Malaguti, 1960). The fungus survives in the soil in the form of spores, living saprophytically on crop residues. Its dissemination it is made by soil particles and water droplets (from rain and irrigation).

CHINA

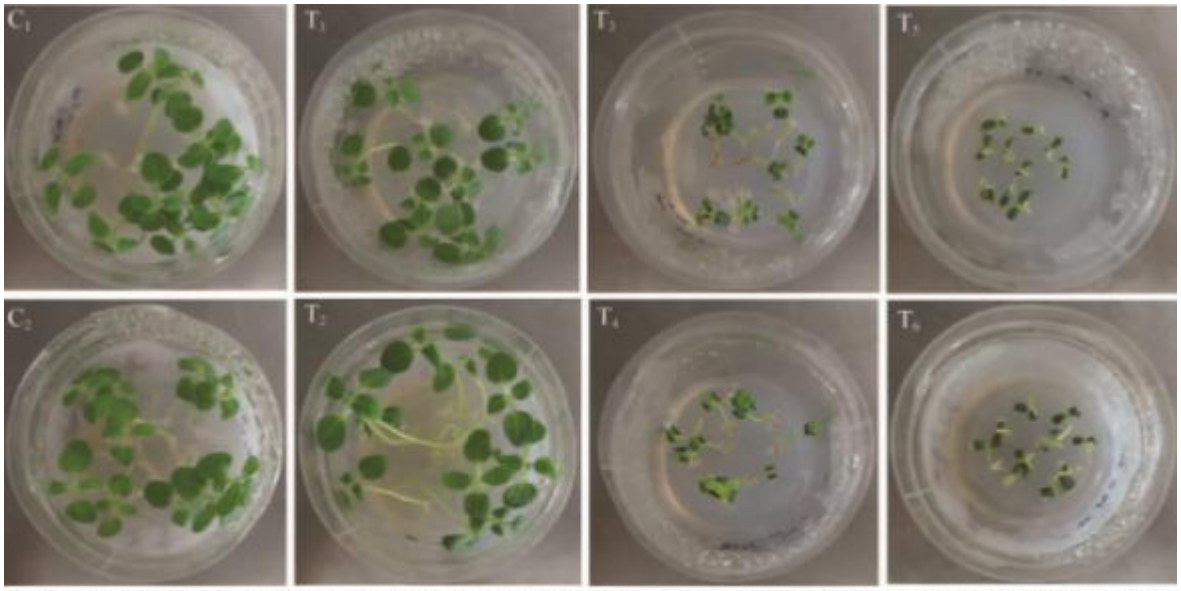
- Q.B. Zhu et al. (2016) analyzed filtered culture solutions of *Fusarium oxysporum* sp. s*esami* (FOS) to see if there were toxins that would affect germination and seedling development using 4 cultivars (Yushi 11, Zhengzhi 98N09, Rongxian black, and Ji 9014) using three concentrations (1, 5 and 10 µg/mL) of fusaric acid. They showed that these solutions inhibited the growth of sesame seedlings. The following shows the fresh weight, root length, and shoot length.

Table 4 Growth inhibition effects of FOS filtered culture solution on sesame seedlings

处理 Treatment	FA 含量/ µg·mL^{-1} FA content	豫芝 11 号 Yuzhi 11			郑芝 98N09 Zhengzhi 98N09		
		鲜N/g Fresh weight	根长/cm Root length	苗高/cm Plant height	鲜N/g Fresh weight	根长/cm Root length	苗高/cm Plant height
HSF007021	1	'0.178 ±0.005) b	'10.6 ±0.48) b	'8.5 ±0.27) b	'0.160 ±0.006) c	'12.2 ±0.44) a	'8.0 ±0.21) be
HSF009100	1	'0.197 ±0.009) a	'12.2 ±0.59) a	'8.6 ±0.27) b	'0.019 ±0.007) b	'11.9 ±0.41) a	'7.6 ±0.27) c
HSF007021	5	'0.081 ±0.003) c	'0.8 ±0.08) c	'4.1 ±0.10) c	'0.066 ±0.005) d	'0.6 ±0.07) b	'4.1 ±0.09) d
HSF009100	5	'0.066 ±0.005) c	'1.0 ±0.05) c	'3.8 ±0.15) c	'0.067 ±0.005) d	'1.1 ±0.05) b	'3.8 ±0.17) d
HSF007021	10	'0.045 ±0.004) d	'0.3 ±0.03) c	'2.2 ±0.13) d	'0.042 ±0.004) e	'0.2 ±0.01) b	'1.8 ±0.13) e
HSF009100	10	'0.038 ±0.004) d	'0.2 ±0.01) c	'2.0 ±0.11) d	'0.045 ±0.005) e	'0.2 ±0.01) b	'2.1 ±0.10) e
空白对照' 水) Water control	–	'0.205 ±0.009) a	'12.0 ±0.47) a	'9.7 ±0.26) a	'0.226 ±0.005) a	'11.7 ±0.54) a	'9.1 ±0.18) a
Richard 培养液 Richard liquid medium	–	'0.210 ±0.008) a	'10.7 ±0.33) b	'8.8 ±0.25) b	'0.186 ±0.008) b	'11.5 ±0.43) a	'8.2 ±0.13) b

处理 Treatment	FA 含量/ µg·mL^{-1} FA content	荣县黑芝麻 Rongxian black sesame			赏 9014 Ji 9014		
		鲜N/g Fresh weight	根长/cm Root length	苗高/cm Plant height	鲜N/g Fresh weight	根长/cm Root length	苗高/cm Plant height
HSF007021	1	'0.178 ±0.005) c	'10.3 ±0.60) b	'7.7 ±0.30) ab	'0.177 ±0.012) b	'11.8 ±0.25) a	'8.2 ±0.29) ab
HSF009100	1	'0.167 ±0.007) c	'12.4 ±0.27) a	'7.1 ±0.38) b	'0.183 ±0.010) b	'11.2 ±0.42) a	'8.6 ±0.22) a
HSF007021	5	'0.057 ±0.004) d	'0.8 ±0.08) c	'3.4 ±0.20) c	'0.060 ±0.005) c	'0.8 ±0.08) c	'3.5 ±0.18) c
HSF009100	5	'0.061 ±0.004) d	'1.1 ±0.07) c	'3.2 ±0.20) c	'0.053 ±0.003) cd	'0.7 ±0.08) c	'2.9 ±0.11) d
HSF007021	10	'0.048 ±0.004) de	'0.2 ±0.01) c	'1.6 ±0.16) d	'0.040 ±0.003) cd	'0.2 ±0.01) c	'1.9 ±0.08) e
HSF009100	10	'0.040 ±0.004) e	'0.2 ±0.01) c	'1.6 ±0.19) d	'0.035 ±0.003) d	'0.2 ±0.01) c	'1.5 ±0.15) e
空白对照' 水) Water control	–	'0.212 ±0.007) a	'10.6 ±0.43) b	'8.2 ±0.25) a	'0.219 ±0.009) a	'10.5 ±0.27) b	'8.7 ±0.15) a
Richard 培养液 Richard liquid medium	–	'0.192 ±0.004) b	'11.0 ±0.39) b	'7.4 ±0.16) b	'0.186 ±0.009) b	'10.3 ±0.37) b	'8.0 ±0.21) b

The following show the effects of 1, 5 and 10 µg/mL of two solutions.



T_1~T_3: 1 μg/mL FA; T_3~T_4: 5 μg/mL FA; T_5~T_6: 10 μg/mL FA。其中T_1、T_3和T_5为HSFO07021菌株滤液; T_2、T_4和T_6为HSFO09100菌株滤液; C_1: 水对照; C_2: Richard培养基对照

T_1-T_2: 1 μg/mL FA; T_3-T_4: 5 μg/mL FA; T_5-T_6: 10 μg/mL FA. T_1, T_3 and T_5 refer to the filtered culture solution treatments with HSFO07021; T_2, T_4 and T_6 refer to the filtered culture solution treatments with HSFO09100

ETHIOPIA

- A. Azanaw (2015) studied methods (30 minutes soaking of all except hot water which was 10 minutes of the following: gentamicine sulphate 500 ppm, 1% sodium hypochlorite, 5% sodium chloride, 70% ethyl alcohol, hot water at 52°C, distilled water, and untreated) to control *Xanthomonas campestris* pv. *sesami* using 3 cultivars (Abasena, Humera-1 and Gojam Azene). Seeds were put in the dark at 27°C to germinate for 7 days and then the seedlings were measured. The vigor index = germination % x length of the seedling. The bacteria viability (cfu/ml) was determined using a standard methodology.

Soaking agent	Germination (%)	Seed infection (%)	Vigor index	Viability (cfu/ml)
GS	0.29^{ab} (96)	1.89^{a} (77)	0.45^{a} (1.72)	3.41^{a} (2566)
SH	0.30^{a} (98)	1.11^{c}(24)	0.45^{a}(1.83)	2.24^{b} (176)
SC	0.28^{b} (92)	1.90^{a} (76)	0.41^{ab} (1.85)	3.40^{a} (2533)
EA	0.00^{d} (0)	1.13$_{c}$ (27)	0.00^{c} (0)	1.28^{c} (36)
HW	0.25^{c} (79)	1.50^{b} (16)	0.37^{b} (1.64)	0.00^{d} (0)
DW	0.29^{ab} (96)	1.97^{a} (94)	0.39^{ab} (1.64)	3.42^{a} (2614)
UT	0.29^{ab} (97)	1.99^{a} (97)	0.45^{a} (1.83)	3.46^{a} (2869)
CV (%)	3.74	15.54	16.12	12.24
LSD (5%)	0.0087	0.241	0.0552	0.1787

GS = Gentamicine sulphate, SH = Sodium hypochlorite, SC = Sodium chloride, EA = Ethyl alcohol, HW = Hot water, DW = Distilled water and UT = Untreated, LSD = least significance difference and CV = coefficient variation. ( ) are untransformed means.
Means in columns followed by same letter(s) are not significantly different at 5% level of significance

INDIA

- L.N. Daftari and O.P. Verma (1972 and 1975) reported efficacy of seven fungicides were tested for eradication of *Macrophomina phaseoli* on sesamum seeds under laboratory condition. Captan and Agrosan G.N. (2 gm/kg seed), Mercuric chloride, Ceresan wet (0.1% for 3 minutes), and Aureofungin (20 ppm for one hour) gave the complete control of seedborne infection in affected seeds. In addition to disease control, Captan also induced maximum germination of seeds and vigor of the seedlings. [Cited by G.S. Saharan, 1989]
- O.P. Kadian (1972) reported in sesame seeds, species of *Alternaria* sp., *Phytophthora* sp., *Fusarium* sp., *Xanthomonas* sp., and *Pseudomonas* sp. were most commonly associated whereas species of *Cercospora* sp. and *Aspergillus* sp. were detected less frequently. Seven genera namely *Alternaria* spp., *Phytophthora* spp., *Fusarium* spp., *Cercospora* spp., *Aspergillus* spp., *Xanthomonas* spp. and *Pseudomonas* spp. were internally as well as externally seedborne and were also pathogenic. The seed infestations (%) with *Phytophthora* spp. and

Alternaria spp. were comparatively higher than with other five genera. All these micro-organisms reduced seed germination and had adverse effect on the seedlings. [Cited by G.S. Saharan, 1989]

- O.P. Verma and L.M. Daftari (1974) reported the amount of *Macrophomina phaseoli* seedborne inoculum (number of sclerotia on seed surface) affects the seedling mortality and growth. Depending upon number of sclerotia per seed, seedling mortality of three varieties viz. Ex-116, G-5 and Limbdi-93 were 19-56%, 7-26%, and 26-53% respectively. [Cited by G.S. Saharan, 1989]
- O.P. Verma and L.N. Daftari (1976a) reported that seed soaking with agrimycin completely checked the infection of *Pseudomonas sesami* and enhanced germination by 94% in comparison with no germination in untreated seeds. In *in vitro* studies streptomycin sulphate was the most effective followed by streptocycline, agrimycin-100, tetracycline hydrochloride and oxytetracyline hydrochloride. [Cited by M.L. Verma, 1985, and G.S. Saharan, 1989]
- O.P. Verma and L.N. Daftari (1976b) reported phyllody generally appears at flowering stage. Warm weather during flowering stage favors the disease. *Orosius albicinctus* an insect vector is the carrier of the virus. Losses in the plant yield, germination and oil content in infected plants may be as high as 93, 38, and 26% respectively.
- S.N. Bhargava and D.N. Shukla (1979a) reported seed coat leachates and seed extracts of sesame decreased spore germination of *Fusarium oxysporum, Fusarium solani* and *Curvularia lunata* (*Cochliobolus lunatus*). Culture filtrates of the fungi inhibited seed germination of the plants. [Cited by G.S. Saharan, 1989]
- G.C. Mondal et al. (1981) studied the variation in seed moisture, fungal infection, and seed germinability of 2 cultivars of sesame kept in private storehouses for 1 year at 3-month intervals. Seed moisture was maximum during rainy months followed by a gradual decrease after longer storage. Infection by storage fungi was maximum during rainy months. A gradual decrease in field fungi with a simultaneous increase in storage fungi accompanied by a reduction in germinability occurred as storage proceeded.
- A.L. Siddaramaiah et al. (1981b) reported sesame losses in Karnataka due to *Alternaria sesami* were 0.1-5.7 g/100 fruits. The number of shriveled seeds depended on disease severity. The fungus greatly reduced germination. JT-63-117, A-6-5, JT-66-276, Anand-9, JT-62-10, VT-43 and Anand-74 are resistant cultivars. [Cited by G.S. Saharan, 1989]
- A.S. Reddy and S.M. Reddy (1983a) reported fungal succession on sesame seeds with different moisture levels was analyzed monthly. Incidence varied with moisture content. *Alternaria alternata* was abundant only in the initial stages. *Aspergillus flavus* predominated while *Macrophomina phaseolina* and *Rhizoctonia solani* were associated only with seeds of high moisture content. The seed mycoflora at first increased with storage time but subsequently decreased. Seed germination increased with storage time. [Cited by G.S. Saharan, 1989]
- R.K.S. Chauhan and S. Chauhan (1984a) evaluated the pathogenic potentials of *Myrothecium* in relation to seed viability, germination, and formation of seedlings. The toxic metabolites produced by the pathogen in culture filtrate had phytotoxic effect on seeds and healthy plants. [Cited by G.S. Saharan, 1989]
- K. Kumar et al. (1984a) reported *Fusarium moniliforme* was found to be associated with the seeds of varieties T-4 and T-12. The species was pathogenic and reduced germination by causing seed rot under laboratory conditions and produced brown necrotic lesions on roots and later became a seedling invader to cause root rot and seedling blight.
- B.K. Vaidehi et al. (1985) reported culture filtrates of *Aspergillus flavus, Fusarium oxysporum, Penicillium citrinum, Penicillium rubrum* and *Alternaria sesami* reduced germination percentage and root and shoot elongation of sesame with the maximum on the 30th day. [Cited by G.S. Saharan, 1989]
- O.P. Verma and L.M. Daftari (1985) reported phyllody reduced plant yield, test weight, germination percentage and oil content of seeds. A transformation of 25% of the productive length into phyllody caused 39.73% reduction in seed yield.
- I.J. Gupta and H.S. Cheema (1990) reported. the number of microsclerotia of *Macrophomina phaseolina* present on sesame seeds was positively correlated with plant infection and negatively correlated with seed germination, dry matter production and root and shoot length of seedlings. Treatment with thiram, captan or Bavistin [carbendazim] increased seed germination by 16-40% compared with an untreated control, increased shoot length by 0.6-28.5% and decreased incidence of disease by 14-70%. Seed yields were also increased. Treatment with activated clay (attapulgite dust) or seed coating with *Trichoderma viride* increased germination by 30% and 16%, respectively, and increased seed yield by 32 and 46%.
- K. Jayashree et al. (2000) reported *Pseudomonas fluorescens* strain Pf1, effectively inhibited the mycelial growth of *Macrophomina phaseolina*, the pathogen causing dry root-rot in sesame. Application of Pf1 as a seed treatment (10g/kg seed) followed by soil application (2.5 kg/ha) effectively supported higher plant growth and grain yield. Sclerotial number and root rot incidence were also greatly reduced. The rhizosphere soil recorded a higher number of Pf1 population. The germination percentage were as follow.

ST - Pf 1	92.0^{cd}
ST + SA - Pf 1	97.5^{c}
SA - Pf 1	89.0^{bc}
ST - Carbendazim	90.2^{bcd}
ST + SD - Carbendazim	94.2^{d}
SD - Carbendazim	86.8^{ab}
ST - Pf 1 + SD - Carbendazim	93.5^{d}
ST – Carbendazim + SA - Pf 1	92.5^{cd}
Control	82.5^{a}

ST = seed treatment, SA = soil application, SD = soil drenching

- C. Chattopadhyay and R.K. Sastry (2001) evaluated the effect of solarization on *Macrophomina phaseolina* for 2 years in Hyderabad (77.92E and 18.99N) in sandy to clay loam *alfisol* type soil. The solarization was done with transparent polyethylene mulch of 50 µm thickness during the historically hottest 6 weeks with 0, 3, and 6 weeks of cover. Six weeks of soil solarization of infested crop field sites in the summer months result in good sesame seed germination and better disease management under Indian conditions as shown below.

Table 1. Effect of soil solarization on initial plant stand of sesame*

Weeks of solarization	I/P		I/NP		NI/P		NI/NP	
	First year	Second year	First year	Second year	First year	Second year	First year	Second year
0	322.6 (−4.1)	332.0 (19.7)	322.0 (−4.3)	317.4 (14.4)	320.6 (4.7)	315.4 (13.7)	336.6	277.4 –
3	354.0 (5.1)	314.0 (13.2)	356.0 (5.8)	272.6 (−1.7)	373.4 (10.9)	283.4 (2.2)	372.6 (10.7)	330.0 (19.3)
6	466.0 (38.4)	450.6 (62.4)	431.4 (28.2)	278.6 (0.4)	417.4 (24.0)	260.6 (6.0)	426.6 (26.7)	261.4 (5.8)
C D (P <0.05)	First year (sub sub)			14.8				
	Second year (main x sub x sub–sub)			102.6				

*Mean of three replicates at 21 days after sowing
I: Irrigated; NI: Unirrigated; P: Ploughed; NP: Unploughed; Figures in parentheses are % increase over control.

Table 2. Effect of soil solarization on incidence of stem–root rot disease in sesame*

Weeks of solarization	I/P		I/NP		NI/P		NI/NP	
	First year	Second year	First year	Second year	First year	Second year	First year	Second year
0	41.6 (41.6)	59.2 (73.6)	38.7 (29.0)	68.7 (86.7)	32.6 (39.2)	67.7 (85.3)	45.9 (51.6)	73.4 (91.5)
3	35.9 (34.9)	45.7 (51.3)	31.2 (28.8)	57.8 (37.6)	32.4 (26.8)	33.6 (30.7)	28.4 (22.7)	41.8 (44.4)
6	5.2 (0.6)	4.0 (0.0)	26.0 (16.2)	28.2 (22.5)	23.7 (19.3)	29.6 (24.4)	23.2 (15.6)	32.7 (29.6)
C D (P <0.05)	First year (main x sub x sub sub)			8.8				
	Second year (main x sub x sub–sub)			7.4				

*Mean of three replicates at 100 days after sowing
Figures in parentheses are actual percent disease incidence and others are angular transformed values.
I: Irrigated; NI: Unirrigated; P: Ploughed; NP: Unploughed.

- N.O. Srikantappa et al. (2009) studied 28 samples of sesame taken from fields, farmers, retail shops and APMC markets from 5 areas. They found 34 four fungi. They tested the germination using two methods: sand and rolled paper towel. The differences in germination were significant as shown in the following tables. They recommended seed treatments are important to improve germination.

TABLE 3 : Effect of seed borne fungi on germination by Sand method

Place of collection	Germ (%)	Normal seedlings	Abnormal seedlings	Un germinated seedlings	Rotted seedlings	Fungal pathogens
Shivapura	92.0	62.0	30.0	5.0	3.0	*A. alternata, A. sesamicola, C. sesami, C. globosum, V. dahliae, M. phaseolina, C. cladosporioides, A. niger,*
Agasanakatti	88.0	50.0	38.0	10.0	2.0	*A. alternata, F. moniliforme, C. sesami, A. flavus, R. Stolonifer, A. sesamicola, M. phaseolina, A. ochraceus.*
Thumbigere	89.0	40.0	41.0	19.0	0	*A. alternata, F. moniliforme, C. sesami, A. flavus, R. Stolonifer, A. sesamicola, M. phaseolina, A. ochraceus.*
Duthidurga	91.0	53.0	37.0	8.0	2.0	*A. alternata, A. sesamicola, C. sesami, C. globosum, V. dahliae, M. phaseolina, C. cladosporioides, A. niger,*
Hulikatti	90.0	49.0	33.0	3.0	3.0	*A. alternata, F. moniliforme, C. sesami, A. flavus, R. Stolonifer, A. sesamicola, M. phaseolina, A. ochraceus.*
Mean	90	50.8	35.8	9	2	
SD	1.584	7.918	4.324	6.204	1.224	
SE	0.547	2.179	1.248	1.790	0.353	

TABLE 4 : Effect of seed borne fungi on germination by rolled paper towel method

Place of collection	Germ (%)	Normal seedlings	Abnormal seedlings	Un germinated seedlings	Rotted seedlings	Fungal pathogens
Shivapura	65.0	33.0	47.0	13.0	7.0	*A. alternata, F. moniliforme, C. sesami, A. flavus, R. Stolonifer, A. sesamicola, M. phaseolina, A. ochraceus.*
Agasanakatti	62.0	28.0	52.0	10.0	10.0	*A. alternata, A. sesamicola, C. sesami, C. globosum, V. dahliae, M. phaseolina, C. cladosporioides, A. niger,*
Thumbigere	69.0	37.0	43.0	8.0	12.0	*F. moniliforme, C. sesami, A. flavus, R. Stolonifer, A. sesamicola, M. phaseolina, A. ochraceus.*
Duthidurga	71.0	26.0	54.0	9.0	11.0	*F. moniliforme, C. sesami, A. flavus, R. Stolonifer, A. sesamicola, M. phaseolina, A. ochraceus.*
Hulikatti	74.0	29.0	51.0	3.0	17.0	*A. alternata, F. moniliforme, C. sesami, A. flavus, R. Stolonifer, A. sesamicola, M. phaseolina, A. ochraceus.*
Mean	68.2	30.6	49.4	8.6	11.4	
SD	4.764	4.393	4.393	3.646	3.646	
SE	1.375	1.268	1.268	1.052	1.053	

- A.S. Savitha et al. (2011) evaluated several isolates against *Alternaria sesami.* Among two *Trichoderma* isolates, maximum inhibition was noticed in *T. harzianum* to the extent of 87% followed by *T. viride*. Among four bacterial bioagents, an exogenous *Pseudomonas fluorescens* (Pf-E) was most efficient with 80% inhibition. Salicylic acid at 1% was found to be effective in suppressing the pathogen and resulted in higher vigour index (1138.28), followed by *P. fluorescens* (E) with good germination and vigour index of 97.75% and 1029.85, respectively. The higher vigour index is mainly due to increased germination, higher root and shoot growth by the systemic resistance inducing agents. [Based on abstract]
- A.S. Savitha et al. (2012) reported *Alternaria sesami* (the incitant of leaf blight of sesame) produced toxic metabolite in culture. The toxin produced necrotic symptoms on sesame and tomato seedlings at various concentrations. The maximum inhibition of seed germination and shoot and root length was noticed at 2,000 ppm concentration. Least inhibition of root and shoot length was observed at 50 ppm concentration. Different resistance inducing chemicals were tested for inhibition of growth and induction of resistance. Among them, salicylic acid (10 mM) was effective in inhibiting the mycelial growth of *A. sesami* (68.8%). The least inhibition of mycelial growth was observed in potassium nitrate (55.81%). The resistance inducing chemicals, plant extracts and bioagents when tested *in vivo*, with challenge inoculation of *A. sesami*, salicylic acid at 1% concentration was found to be effective in suppressing the pathogen and resulted in higher vigor index (1138.28), which was followed by *Pseudomonas fluorescens* (E) with good germination per cent of 97.35 and

vigor index of 1029.85. The higher vigor index obtained in these treatments is mainly due to their support for increased germination, good root and shoots growth by the systemic resistance inducing agents. [Based on abstract]

- V. Bharathi et al. (2013) examined the effect of seed treatments (*Trichoderma viride* + *Pseudomonas fluorescence*, *Azotobacter* + *Trichoderma*, *Rhizobium* + *Trichoderma*, *Azotobacter*, *Trichoderma*, *Pseudomonas*, Benomyl, and untreated control) to improve germination and increase survival rate. *Trichoderma* and *Pseudomonas* were treated @ 6g/kg and 10 g/kg seed, respectively. *Azotobacter* was used @ 25 g/kg seed (250g/10 kg seed). The combination inoculum was used @ half the dose of each bioagent/biofertilizer. The seeds were tested for mycoflora and the following fungi were found: *Alternaria alternata*, *Alternaria tennissima*, *Alternaria terreus*, *Aspergillus flavus*, *Aspergillus fumigatus*, *Aspergillus niger*, *Macrophomina* spp., *Cephalosporium* spp., *Fusarium oxysporum*, *Rhizoctonia solani*, *Rhizopus stolonifer*, *Curvularia* spp., *Drechslera* spp., *Rhizopus* spp., *Cladosporium* spp., and *Penicillium* spp. Germination of the treated seeds was tested using 3 methods: blotter, paper towel, and sand. The results of the blotter method (100 seeds for 8 days) were as follows:

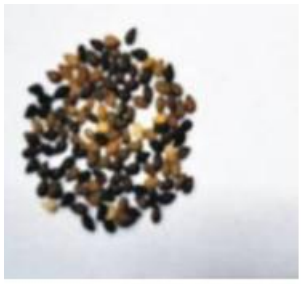
Treatment	Germination (%)	Seed rot	Seedling Blight	Fungal colonies
Trichoderma + Pseudomonas fluorescence	96.0	4.50	4.18	3.83
Azatobacter + Trichoderma	94.4	8.64	6.42	10.2
Rhizobium + Trichoderma	90.2	12.1	8.63	12.6
Azatobacter	88.0	18.0	9.40	14.8
Trichoderma	85.3	10.6	7.21	12.2
Pseudomonas fluorescence	84.0	9.8	8.10	15.4
Benomil	86.3	2.70	2.10	3.00
Control	75.0	32.3	21.8	36.2
SEm±	0.48	0.72	0.80	0.94
CV%	3.71	5.46	5.68	6.78
CD	1.61	1.82	2.21	2.08

The results of the paper towels method (50 seeds for 14 days) and sand method (100 seeds for 20 days) were as follows. The seedling vigor was done in petri dishes for 8 days (no temperature specified. The germination % and seedling length in cm was measured. The seedling vigor index = Mean seedling length (cm) x Germination percentage (%).

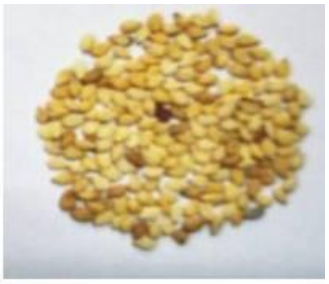
Treatments	Paper Towel Method				Sand Method				Seedling Vigor
	NS	AS	SR	HS	NS	AS	SR	HS	
Trichoderma + P. fluorescence	23	0	14	63	10	2	0	88	1660.3
Azatobacter + Trichoderma	19	2	18	61	5	4	0	92	1562.6
Rhizobium + Trichoderma	17	3	26	52	5	2	4	90	1404
Azatobacter	14	6	32	48	1	3	0	94	1386.2
Trichoderma	12	2	30	50	3	2	2	93	1489
Pseudomonas fluorescence	8	4	16	54	1	4	2	93	1356.3
Benomil	10	2	2	72	2	2	0	96	1312
Control	8	3	47	42	1	1	8	91	904.1
SEm±									69.2
CV									245.6
CD									121.2

*Viability = 76 per cent, ** Data on germination is based on 100 seeds, *** Data based on observation of normal seedling. NS = Normal seedling, AS= Abnormal Seedlings. SR = Seed rots, HS = Hard seeds.

- P.L. Radha (2013) collected 18 cultivars from 7 districts in Karnataka, and identified 9 fungi. Apparently healthy and artificially inoculated (surface sterilized and apparently healthy seed) seed samples of sesame (cv. E-8) were used to demonstrate the effect of different seed inoculum levels on per cent leaf spot severity and to prove seed to plant transmission of *Alternaria sesami* in a glass house.



Infected seeds



Apparently Healthy seeds

(cv. E-8)

Germinations were measured at 25 ± 2ºC for six days with 12 hours light, 12 days. Seedling roots and shoots were measured to determine the vigor index (Seed germination % × seedling length [shoot +root length in cm]). The results were as follows.

Sl. No.	Treatment	Per cent germination	Per cent leaf spot	
			20DAS	30DAS
1.	T_1- Un-inoculated (Apparently healthy seeds)	88.75 (70.47)*	7.75 (16.14)*	11.25 (19.57)*
2.	T_2- Seeds soaked in $5x10^6$ conidia/10 ml	12.75 (20.86)	100.00 (90.00)	100.00 (90.00)
3.	T_3- Seeds soaked in $5x10^5$ conidia/10 ml	25.25 (30.10)	95.00 (78.93)	98.25 (84.73)
4.	T_4- Seeds soaked in $5x10^4$ conidia/10 ml	38.75 (38.47)	60.00 (50.78)	87.50 (69.82)
5.	T_5- Seeds soaked in $5x10^3$ conidia/10 ml	50.00 (44.99)	3.00 (9.90)	6.50 (14.76)
SEm±		1.21	1.86	1.96
CD @ 1%		5.04	7.78	8.16

* Arcsine transformed values

Efficacy of fungicides, botanicals and bio-agents were tested against seedborne fungal infections of sesame (variety E-8). The results were as follows.

Sl. No.	Treatments	Percent seed Infection	Percent seed germination	Vigour index
1.	Garlic	30.33 (33.43)*	70.00 (56.82)	517
2.	Ginger	26.67 (31.11)	74.33 (59.59)	591
3.	Hexaconazole	13.33 (21.42)	89.33 (70.97)	1208
4.	Tebuconazole	30.67 (33.65)	72.00 (58.08)	697
5.	Propiconazole	26.33 (30.89)	74.00 (59.37)	729
6.	*T. harzianum*	21.33 (27.52)	80.67 (63.95)	515
7.	*P. fluoroscencs*	25.00 (30.00)	75.33 (60.03)	828
8.	Avatar72WP (Hexazconazole 4% + Zineb 68%)	14.00 (21.89)	87.67 (69.48)	1027
9.	Taqat75WP(Captan70+Hexaconazole 5%)	25.00 (30.00)	78.33 (62.34)	429
10	Control (untreated seeds)	42.00 (40.41)	57.33 (49.24)	318
	S.Em±	**0.46**	**0.78**	**13.95**
	CD at 1 %	**2.16**	**3.71**	**69.38**

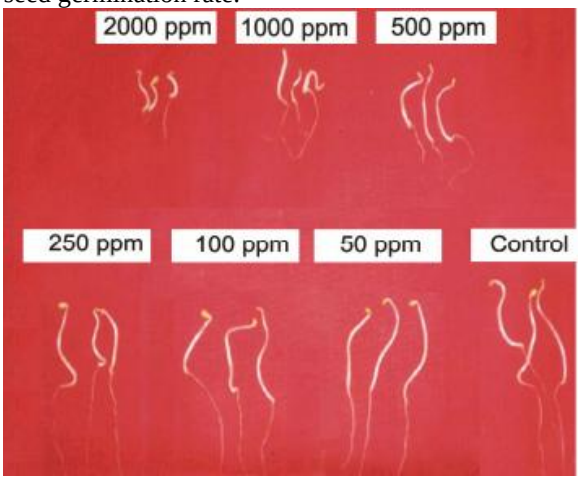
* Arcsine transformed values

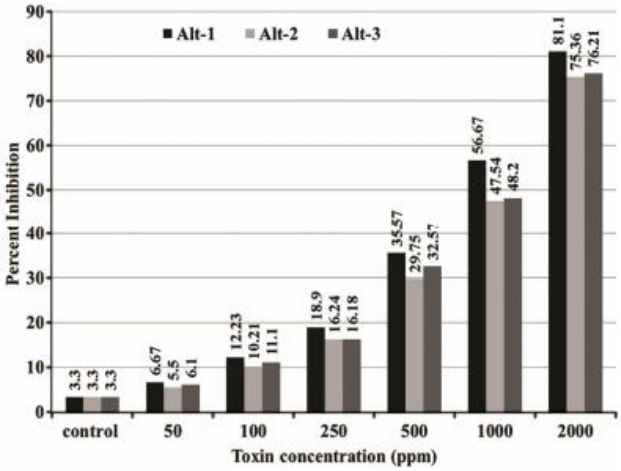
- B. Khamari et al. (2017a) reported stem and root rot and wilt diseases of sesame incited by *Macrophomina phaseolina* and *Fusarium oxysporum* f. sp. *sesami* respectively are serious biotic constraints for sesame production. Soil inoculation study revealed inoculation of Macrophomina + Fusarium recorded as low as 26.00% seed germination due to pre emergence damping off followed by in Macrophomina alone (seed

germination 34%). The control pot recorded as high as 82% germination. The effects of soil inoculation were as follow.

S. no	Treatments	Germination %	Pre emergence damping off
1	*Macrophomina*	34 (35.429)	66(54.534)
2	*Fusarium*	52 (46.311)	48(43.653)
3	*Macrophomina + Fusarium*	26 (27.586)	74(62.385)
4	Control	82 (65.332)	18(24.632)
SE(m) CD		5.020 15.179	5.022 15.186

- M.K. Naik et al. (2017) reported sesame production, particularly in India, has been declining since last decade and 'Leaf blight' caused by *Alternaria* spp. is reported to cause yield loss up to 30-40%. They investigated the fungal toxin produced by Alternaria and its pathogenicity. A total of 164 Alternaria strains (*A. alternata* [39], *A. brassicae* [10], *A. porri* [6], *A. tenuissima* [03], *A. sesami* [1] and *Alternaria* sp. [72]) were isolated on potato dextrose agar media from the infected sesame leaves showing circular concentric rings with dark brown spots symptoms. All the isolates were screened for cultural and morphological characters. Color of the fungus was grey to dark brown, formed smooth, raised, fluffy, and regular to irregular margins. Among 164 isolates, 23 showed toxigenicity, varied from highly toxigenic (*A. alternata*) to least toxigenic (*A. brassicae*). Pathogenicity of the isolates showed that they were highly virulent to less virulent when tested by the detached leaf method. Based on the toxigenicity, the toxin was partially purified, and brown colored paste was recovered. Chemistry of the toxin was confirmed based on the IR, UV, NMR and mass spectra analyses, and it resembled the structure of alternariol mono methyl ether and altenuene which are mycotoxins in nature. Further, bioassay of toxin was carried out at different concentrations (50 to 2000 ppm) on seeds and seedlings of sesame. Maximum inhibition of seed germination of 81.1% was observed at 2000 ppm and the least was 6.67% at 50 ppm. With the increase in the concentration of toxin, the manifestation of the symptom was conspicuous and quick such as marginal, veinal necrosis, drooping, and yellowing with lesion formation. From the present study, it is found that the species of Alternaria are responsible for the cause of blight disease symptoms, and the toxicity of toxin produced by the pathogen was very high. The Alternaria toxin could inhibit the growth of the plant as well as seed germination rate.





- P. Renganathan et al. (2020b) reported *Macrophomina phaseolina* attacks at different stages of plant growth and causes complex disease syndromes like root rot, seedling blight, charcoal rot, ashy stem blight, wilt, collar rot, dry rot, capsule rot, and seed rot. The fungus is not only soilborne, but also seedborne and infects plants from seedling to maturity. The inhibition of seed germination is brought about by Phaseolinone, a metabolite isolated from the culture filtrate.

IRAQ

- Y.A. Abdou et al. (1980a) reported *Macrophomina phaseoli* is a destructive pathogen of sesame, causing typical wilt with dry root rot associated with discoloration of infected tissues due to sclerotial formation. Seeds of infected plants carry the fungus on and inside the testa as sclerotia and stromatic mycelium. Infected and healthy seeds were indistinguishable. Normal germination occurred at first in infected seed, but seedling deterioration followed and pycnidia were abundant. [Cited by G.S. Saharan, 1989]

- Y.A. Abdou et al. (1980b) reported *Macrophomina phaseoli* sclerotia remained dormant in soil treated only with distilled water in the absence of the host. The presence of germinating sesame seeds and seedlings stimulated normal sclerotial germination and attraction of developing mycelium to host roots. Infection cushions and appressoria were also formed prior to infection. Remnants of PDA in soil stimulated limited sclerotial germination without subsequent development or infection. The results suggest that sclerotial germination and behavior depended on nutrients. [Cited by G.S. Saharan, 1989]
- N.A. Saad et al. (2013) examined seed from Iraq and found *Alternaria* fungi were the most prevalent, and *Alternaria alternata, Alternaria raphani, Alternaria citri*, and *Alternaria tenuissima* killed the following percentages of seed: 62, 59, 66, and 60% compared to the control of 0%.

ISRAEL

- A. Meiri and Z. Solel (1963) reported experiments using commercial sesame var. Renner 15 demonstrated *Sclerotium bataticola* (*Macrophomina phaseoli*) to which this var. is very susceptible is seedborne and a high degree of seed infection may account for the poor field germination. [Cited by G.S. Saharan, 1989]

NIGERIA

- O.A. Enikuomehin (2005) evaluated the efficacy of aqueous leaf extracts of *Aspilia africana, Chromolaena odorata, Musa paradisiaca* and *Tithonia diversifolia* to control *Cercospora* leaf spot of two sesame cultivars (530-6-1 and Pbtil No.1). Results show that all extracts significantly ($p<0.05$) reduced the incidence and severity of the disease. Germination percentage of seeds from the sprayed plants was higher (77.0 to 83.5%) than that of control (64.5 to 73.0%) as shown below.

Treatment	Fungal incidence (%)		Seed germination (%)		Grain yield (kg ha^{-1})	
	530-6-1	Pbtil No.1	530-6-1	Pbtil No.1	530-6-1	Pbtil No.1
A. africana	8.8^{c}	7.3^{c}	78.5^{c}	83.0^{a}	110.0^{abc}	139.0^{ab}
C. odorata	8.0^{b}	7.0^{b}	77.0^{d}	81.0^{c}	104.9^{ab}	99.9^{bc}
T. diversifolia	4.5^{a}	7.5^{c}	83.5^{b}	78.5^{d}	155.0^{a}	149.6^{ab}
M. paradisiaca	10.0^{d}	10.5^{d}	74.5^{e}	65.5^{e}	100.0^{bc}	110.0^{abc}
Bentex T	4.5^{a}	6.5^{a}	89.0^{a}	82.0^{b}	146.4^{ab}	112.6^{abc}
Control	10.3^{d}	13.5^{e}	73.0^{f}	64.5^{f}	86.0^{c}	72.0^{c}

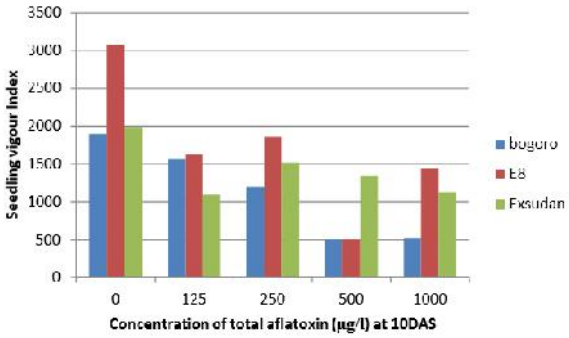
Seed was treated with the extracts for 30 and 60 minutes with the following results.

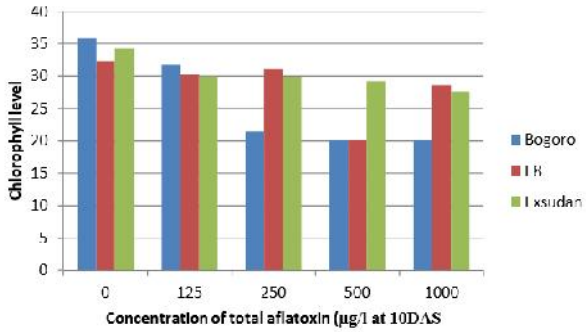
Duration of treatment/plant species	Sesame cultivars			
	530-6-1		Pbtil No.1	
	Fungal incidence (%)	Germination (%)	Fungal incidence (%)	Germination (%)
30 min.				
A. africana	4.5	79.5	5.5	79.0
C. odorata	4.0	79.5	3.5	80.5
T. diversifolia	4.5	78.5	4.5	80.5
M. paradisiaca	2.0	83.0	3.0	81.0
Bentex T	4.5	75.0	2.5	76.0
Control	15.5	72.0	12.0	74.0
LSD ($p\leq 0.05$)	3.63	2.90	2.64	2.15
60 min.				
M. paradisiaca	5.5	80.0	4.5	79.0
A. Africana	2.0	84.5	4.0	84.0
C. odorata	2.5	79.5	4.0	80.5
T. diversifolia	2.5	83.0	3.5	82.0
Bentex T	4.5	77.5	2.0	77.0
Control	25.0	62.0	13.5	76.0
LSD ($p\leq 0.05$)	6.69	6.09	3.10	2.26

- O.A. Enikuomehin (2010) evaluated The effectiveness of sesame sorting by salt density to remove seed with seedborne fungi. Results showed that 10 and 15% salt concentrations did not separate healthy from unhealthy seeds, while 2 and 5% did. Seeds floated at 2 and 5% salt concentrations wee characteristically discolored, malformed, infected, and lightweight. Fungal infection of such floated seeds was significantly ($p\leq 0.05$) higher than infection of sunken. Germination of seeds floated at 2 and 5% salt concentration was significantly ($p\leq 0.05$) lower than that of sunken or unsorted seeds. [Based on abstract]
- S.T. Anjorin and T.V. Inje (2014) in Nigeria examined the effects of aflatoxin level (0, 125, 250, 500, and 1000µg/l) on seedling emergence, shoot length, root length, seedling vigor and chlorophyll level of the 3 cultivars (E8, Bogoro, and Ex-Sudan). The seeds were soaked in distilled water for an hour, before 10 g of the seeds were transferred to the beaker (500ml) filled with each level of concentration of Aflastandard (product

code: p22/ p22A). The setup was allowed to stay for three hours before sowing in the field. The vigor was computed by shoot length x germination %. The chlorophyll level in sesame was recorded by aid of a chlorophyll-meter (Atleaf®). The seedling data was taken 10 days after sowing. The number of leaves, leaf area, and number of flowers data was taken 56 days after sowing.

Variety	Concentration (µg /L)	Seedling emergence	Shoot length (mm)	Root length (mm)	Seedling vigour (x100)	Chlorophyll level (index)
Bogoro	0	96.00a	19.75a	16.50a	1895.96a	35.85a
	125	90.00b	17.50b	15.25b	1575.06b	31.77b
	250	70.00c	17.00b	12.25c	1190.66c	21.50c
	500	40.00d	12.75c	10.75d	510.00d	20.10d
	1000	40.00d	13.00c	10.80d	520.66d	20.20d
E8	0	99.00a	31.00a	36.75a	3068.66a	32.30a
	125	99.00a	16.50c	20.25d	1633.53c	30.22c
	250	75.00b	19.50b	32.00b	1852.56b	31.05b
	500	40.00c	12.75d	10.75e	510.00 e	20.10e
	1000	50.00c	16.00c	24.70c	1440.66d	28.60d
Ex-sudan	0	70.00a	28.25a	22.50a	1977.55a	34.24a
	125	55.00c	20.00d	20.00b	1100.66d	30.00b
	250	65.00b	23.40c	22.50a	1521.06b	29.93b
	500	55.00c	24.50c	19.80b	1343.83c	29.23b
	1000	45.00d	25.00b	18.75c	1125.66d	27.60c
Interaction (variety x level)		**	**	**	**	**





Variety	Concentration (µg /L)	No of leaves	Area of leaves (mm^2)	Number of flowers
Bogoro	0	11.16b	11.22c	3.16b
	125	19.00a	18.64a	6.66a
	250	10.33c	16.56b	2.50d
	500	9.66d	11.05c	1.80e
	1000	8.85d	15.49b	2.66c
E8	0	13.83a	29.87a	7.66a
	125	12.83b	16.86c	7.00b
	250	12.33c	22.15b	6.00b
	500	9.66d	11.05d	1.80c
	1000	11.66e	13.00d	2.16c
Ex-sudan	0	63.00a	28.35a	8.00a
	125	51.50b	22.40b	8.00a
	250	49.00c	20.25c	5.00b
	500	46.00d	16.10d	3.50b
	1000	26.50e	10.85 e	3.00c
	Interaction (varietal x level)	**	**	**

- J.B. Kabeh (2017b) reported *Xanthomonas campestris* pv. *sesami* is a minor disease that attacks the leaves and branches and prevents germination and growth.

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- N. Altaf et al. (2004) tested 400 seeds from each of 10 cultivars for seedborne mycoflora. Eleven phytopathogenic fungi were found: *Alternaria brassicola*, *Alternaria redicina*, *Aspergillus alba*, *Aspergillus*

flavus, Aspergillus niger, Aspergillus viridus, Cephalosporium sp., *Curvularia* sp., *Drechslera* sp., *Fusarium* sp., *and Penicillium* sp. Infection ranged from 0.53 to 53%. One hundred seeds were germinated at 25.2°C for 7 days and then the seeds were classified as normal (well-developed root and shoot and free of symptoms), abnormal (under developed root or shoot or both and showing disease symptoms), and rotted seeds. The fungi decreased the germination as follows:

Table 3: Effect of fungi on seed germination of ten cultivars of sesame

Cultivars	Germ-iantion %	Normal seedling %	Abnormal seedling %	Rotted seeds %
Til-93	87	67	20	20
Til-89	82	65	17	18
Lateefi	71	52	19	29
Tabrezi	78	49	29	22
Nagari	65	41	24	35
Johi-1	83	43	40	17
Johi-2	76	64	12	24
Sehwani-1	89	68	21	11
Qallandari	92	81	11	8
P-37-40	84	64	20	16

- H.N. Farhan et al. (2011) investigated the biological activity of *Pseudomonas* bacteria as biocides to protect sesame crop from some fungi and to evaluate its efficiency as plant growth promoting. The first experiment investigated the effects of *Pseudomonas putida* (Pp) and *Pseudomonas fluorescens* (Pf) on germination and seedlings growth of sesame crop against Pythium, Alternaria, and Fusarium under plastic house conditions. The following are the results.

Treatments	Sterilized soil		Non sterilized soil	
	Germination (%)	Seedlings (cm)	Germination (%)	Seedlings (cm)
Pythium + Pp	80	4.0	70	3.2
Fusarium + Pp	84	3.5	85	2.5
Alternaria + Pp	86.7	4.5	82	3.3
Pythium + Pf	65	3.2	65.3	2.2
Fusarium + Pf	61.6	4.0	71	3.0
Alternaria + Pf	75.7	3.0	77	1.0
Pythium	0.0	0.0	21	2.0
Fusarium	2.0	0.0	10	0.5
Alternaria	0.0	0.0	19	2.0
Control (no addition)	38.3	1.9	49.3	2.4

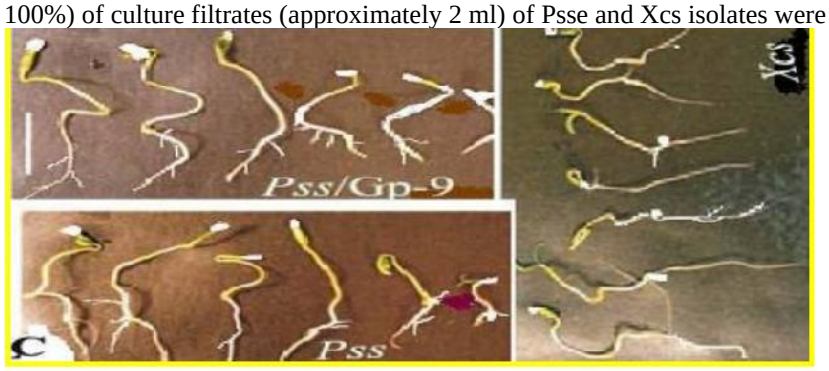
The second experiment grew the plants to harvest.

Treatments	Germination percentage	Leaf no. per plant (cm^2/plant)	Leaf area/plant	Chlorophyll content (mg/gm)
Pp + Fusarium	89.7	27	22	3.27
Pp + Pythium,	84.0	28	20	2.29
Pp + Alternaria	86.7	25	18	1.28
Pf + Fusarium	70.7	22	19	3.23
Pf + Pythium	71.0	19	17	1.96
Pf + Alternaria	80.0	19	18	2.25
Fusarium	3.0	6	4	0.21
Pythium	2.3	4	4	0.32
Alternaria	0.0	0	0	0.00
Control (no addition)	52.0	11	9	0.76
LSD 5 %	10.9	3.98	5.12	0.167

- S.S. Firdous et al. (2013) used different bioassays to detect secondary metabolites produced by *Pseudomonas syringae* pv. s*esami* (Psse) and *Xanthomonas campestris* pv. *sesami* (Xcs) virulent isolates. The bioassays were antibacterial activity, phytotoxic activity, potato tuber outgrowth and seedling assay that included qualitative, semi quantitative and quantitative. In qualitative assay, phytotoxic activity of cell free culture filtrates of Psse-1, Psse-2and IBD-1 of Xcs isolates were applied on non-host plant brinjal and host sesame leaves, and symptoms were observed. Psse-2 isolate elicited water soaking and chlorosis symptoms on both tested plants as produced by pathogen, while Psse-1 showed only water soaking and necrosis symptoms. Psse-2 isolate only induced hypertrophy outgrowth in potato tuber discs, neither Psse-1 nor IBD-1 isolate induces this outgrowth on potato tuber discs. Antibacterial activity was also checked against three pathogenic bacteria such as *Salmonella* sp., *Pseudomonas* sp., and an unknown bacterial pathogen. Results showed that Psse-1 and Xcs isolate showed

inhibition zones against only unknown bacterial pathogen, but Psse-2 isolate did not exhibit any such zones against the tested bacterial pathogens. Moreover, biological effects of different concentrations of culture filtrates of Psse and Xcs isolates on sesame susceptible and resistant seedlings showed that all tested culture filtrates illustrated sesame root and shoot inhibition, while the inhibition recorded was more against Psse-2 isolate culture filtrate than others. Xcs and Psse-1 showed less inhibition and effective at 70 and 100% concentrations. Over all inhibition was less in tolerant than susceptible genotypes. Present results showed that Psse isolates produced two different classes of toxins, chlorosis as well as necrosis. Chlorosis inducing toxins did not show antibacterial activity but could be detected in potato tuber discs bioassay. On the other hand, necrosis inducing toxin showed antibacterial activity against unknown bacterial pathogen. Seedling bioassay also shown that chlorosis inducing toxin was more effective in inhibition of seedlings then necrosis production toxin. Photo below is Xcs isolate induced blight like necrosis on sesame.

They also showed the effects on sesame seed germination. Isolates at different concentrations (0, 30, 50, 70 and 100%) of culture filtrates (approximately 2 ml) of Psse and Xcs isolates were applied 2 times within 4 days.



- I. Rehman et al. (2013) studied the effects of different filtrates (0, 1, 2, 3, and 4%) of *Xanthomonas campestris* on seed germination (height and root length) of sesame seeds. Smallest root and seedling height was obtained with 4% culture filtrate while there was normal growth in control sesame seedlings as shown below.

Effect of different concentrations of culture filtrate on length of root and whole seedling (A) control (B) 1% filtrate (C) 2% filtrate (D) 3% filtrate I 4% filtrate.

- G. Nayyar et al. (2014) studied the effects of fungal pathogens on the germination of sesame. Seven prevalent fungal species viz. *Alternaria alternata, Aspergillus flavus, Aspergillus niger, Cercospora* sp., *Fusarium oxysporum, Penicillium egyptiacum* and *Rhizopus oryzae* associated with sesame seeds were selected for this study. Mycoflora associated with seeds affected the seed health and resulted in reduced seed germination, and seedling abnormality as shown in the table below.

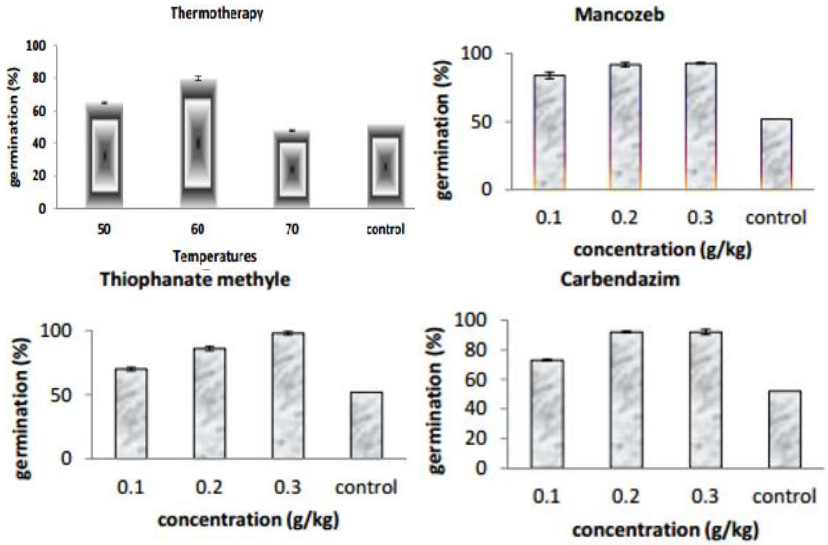
Treatments	Normal seedlings %age	Abnormal seedlings %age	Un germinated seeds %age	Fungi isolated
Surface sterilized seeds	80	14	6	*Aspergillus flavus* *Aspergillus niger* *Fusarium oxysporum*
Naturally infected seeds	64	26	10	*Alternaria alternata* *Aspergillus flavus* *Aspergillus niger* *Fusarium oxysporum* *Penicillium egyptiacum*

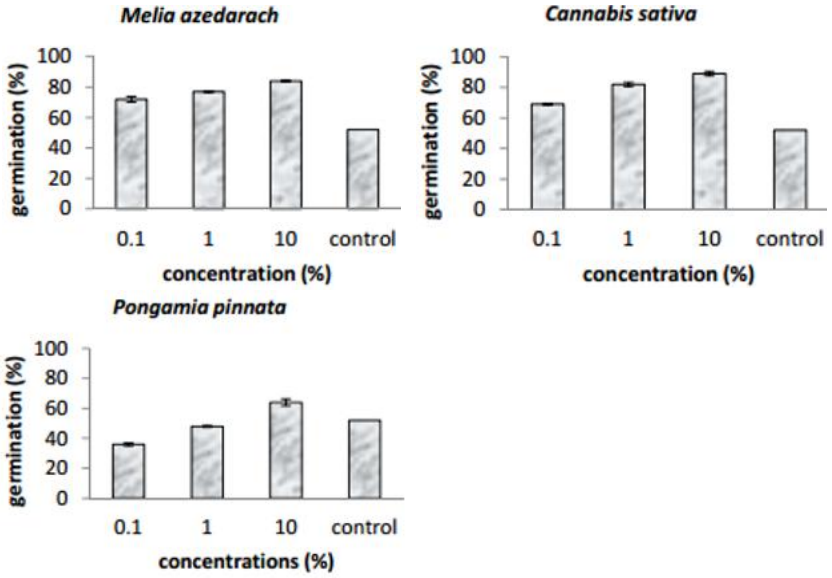
The pathogenicity of the 7 fungi was tested with the following results.

S. No.	Fungi isolated	Pathogenic Effect	Healthy Plants
1	*A. alternata*	Infected root & stem, Weak stem, Reduced growth	55%
2	*A. flavus*	Reduced growth	70%
3	*A. niger*	Reduced growth, Infected roots, Weak stem	13%
4	*Cercospora* sp.	Infected stem, Weak stem, Reduced growth	40%
5	*P. egyptiacum*	Infected root, Weak stem	26%
6	*R. oryzae*	Reduced growth, Infected roots & stem, Weak stem	30%
7	*F. oxysporum*	Reduced growth, Leaves short & infected	32%

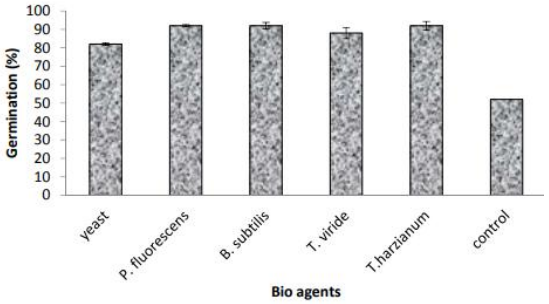
Abnormality rate of seedlings depends on the type of pathogens with which they are infected. There is also need for the management programs to control seedborne pathogens and reduce their impact on sesame production in Pakistan.

- B.G. Nayyar et al. (2016) evaluated different treatments to increase the germination and inhibit the fungi of sesame seeds: thermotherapy (by incubation at 50ºC, 60ºC and 70ºC), application of fungicides (Mancozeb, Thiophante Methyl, and Carbendazim), plant extracts (*Melia azedarach*, *Cannabis sativa* and *Pongamia pinnata*), and bioagents (*Trichoderma viride*, *T. harzianum*, *Pseudomonas fluorescens*, *Bacillus subtilis* and *Saccharomyces cerevisiae* – yeast). Seed germination was tested by following the protocol of International Seed Testing Association. Antifungal activity was tested by poisoned food technique. The results revealed that the germination increased effectively, due to thiophanate methyl up to 46%, followed by Cannabis sativa (37%). Thermotherapy increased germination (28%) at 60ºC but caused harmful effect on seeds at 70ºC, whereas, *Pseudomonas fluorescens*, *Bacillus subtilis* and *Trichoderma harzianum* increased germination up to 40%. Out of 7 fungi tested against fungicides and plant extracts, 4 fungi, namely *Aspergillus flavus*, *Aspergillus niger*, *Fusarium oxysporum* and *Penicillium egyptiacum*, were inhibited up to 100% by Carbendazim and Thiophanate Methyl, while Mancozeb inhibited *Penicillium egyptiacum* (100%), only. *Cannabis sativa* inhibited *Alternaria alternata* (100%) and *Rhizopus oryzae* (55.6%). Overall treatment with fungicides gave best results but they were not eco-friendly. So, this study recommends the use of plant extracts and bioagents, which may increase seed germination and inhibit seedborne fungi without any harmful effect. The following graphs show some of the results.

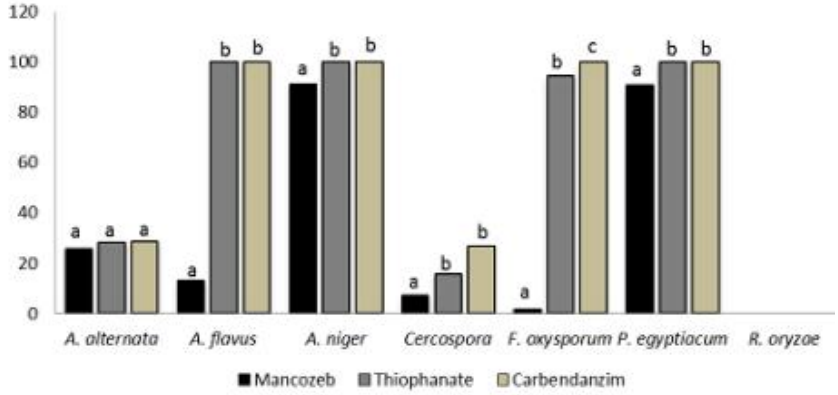


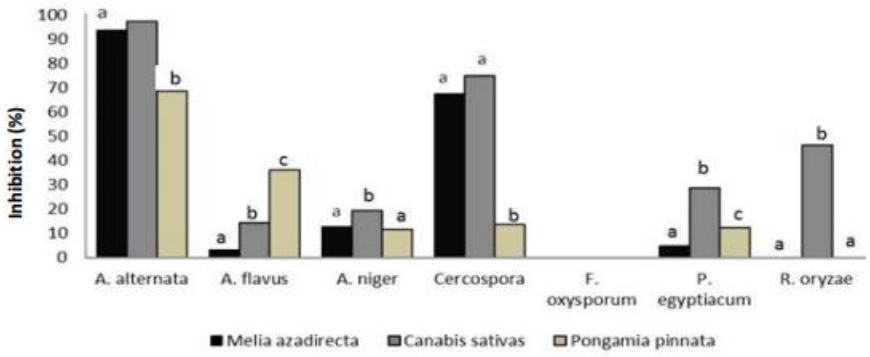


The effects of the bioagents were as follow.



The treatments had the following effects on specific fungi in terms of germination and inhibition: *Alternaria alternata*, *Aspergillus flavus*, *Aspergillus niger*, *Cercospora sp.*, *Fusarium oxysporum*, *Penicillium egyptiacum* and *Rhizopus oryzae*.





REPUBLIC OF KOREA

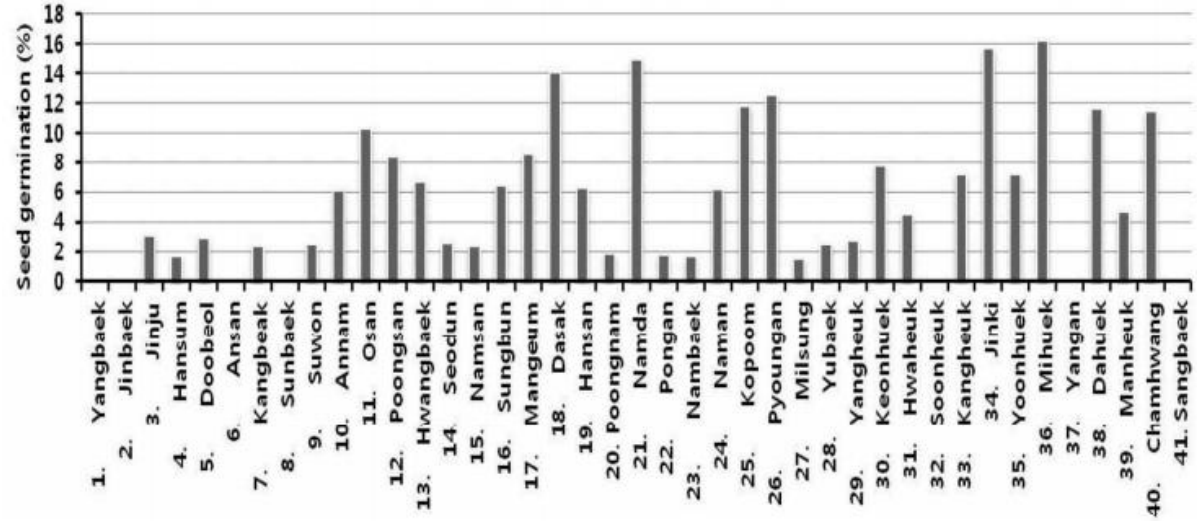
- C.Y. Choi (1964) reported most of the 10 culture filtrates of *Fusarium oxysporum* f. sp. *vasinfectum* (which is known to produce a toxin – fumaric acid) tested inhibited or retarded germination or growth of the seedling. The inhibitory capacity varied considerably. In general sesame seeds were highly susceptible. [Based on abstract]
- J.S. Park (1964) reported culture filtrates of *Fusarium oxysporum* f. *vasinfectum* strongly or weakly inhibited the germination and brought about necrosis accompanying black discoloration of sesame seeds, probably due to fusaric acid (wilt toxin). There were no varietal differences. Five strains used in this study differ greatly in the toxicity of culture filtrates inhibiting the germination of sesame seeds. In the seedling bed added with culture filtrates, the growth of shoot as well as root system of sesame seedlings are notably inhibited, and necrotic black discoloration appear on both shoot and root system. But in the seedling beds added with weaker concentration of culture filtrates (10%) the growth of shoot is slightly promoted. In culture of sesame seedlings with Knop's solution containing 1 to 3 per cent culture filtrates, the growth of shoot as well as root system are slightly retarded and till the time of development of the third leaves the whole stem and leaf petiole tissue are weakened so that they become thread like accompanying brown discoloration, interveinal light brown area appear in the second leaves, and the third leaves curl from both sides towards the middle with necrotic brown discoloration, especially symptoms of injury on the third leaves are nearly similar to that of the leaves of wilted sesame in the field. [Based on abstract]
- S.H. Yu and J.S. Park (1980) tested 12 samples of sesame seeds and found *Macrophomina phaseolina* on 7 of the samples. *M. phaseolina* caused heavy reduction in seed germination and seedling stand. It was also detected on over wintered plant debris and diseased seedlings in the field.
- Y.H. Yu et al. (1982) reported *Alternaria sesami, A. sesamicola, A. tenuis*, and *A. longissima* were detected in Korean seed samples of *Sesamum indicum* L. *A. sesamicola* was the predominant species, seed infection in some samples ranging between 30 and 68%. *A. sesami* and *A. longissima* were recorded only in low percentages of 1–3%. Based on the original descriptions and the isolates studied, it is concluded that *A. sesami* and *A. sesamicola* are two distinct species. *A. sesami* and *A. sesamicola* caused severe symptoms; seed germination and seedling stand was adversely affected. [Based on abstract]
- G.S. Shin et al. (1987) studied the biological control of soilborne disease of sesame, antagonistic isolates of *Trichoderma, Bacillus* and *Streptomyces* to *Fusarium oxysporum* and *Rhizoctonia solani* by isolating them from the rhizosphere soils of sesame plants and some other habitats. *Trichoderma viride* TV-192 selected from antagonistic isolates of *Trichoderma* spp. was highly antagonistic to *F. oxysporum* and soil treatment with the isolate reduced notably damping-off of sesame as shown below.

Treatment	Germination of sesame (%)	Normal seedlings(%)	Damping-off(%)	Dead seedling by TV-192(%)
F. oxysporum D_3	36	16.7	83.3	0
TV-192 seed coating	88	93.2	0	6.8
TV-192 soil treatment	66	70.0	0	30.0
F. oxysporum D_3+TV-192 soil treatment	68	85.3	2.9	11.8
F. oxysporum D_3+TV-192 seed coating	75	78.7	0	21.3
F. oxysporum N_7	76	78.9	21.1	0
F. oxysporum N_7+TV-192 soil treatment	80	72.5	7.5	20.0
F. oxysporum N_7 ×TV-192 seed coating	80	77.5	7.5	15.0
Control	84	100	0	0

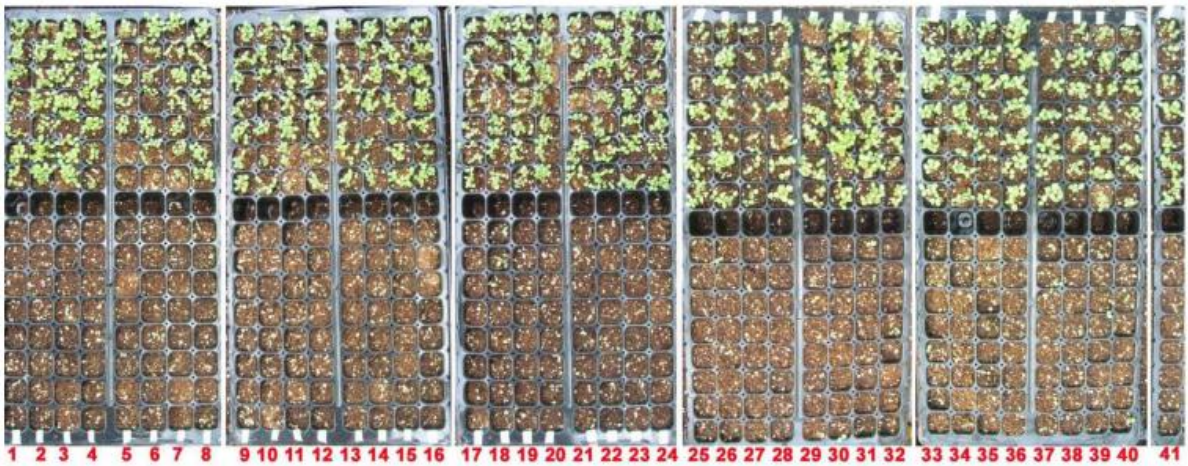
High density of the fungus TV-192 caused the inhibition of seed germination and seedling growth of sesame. Inhibitory effects of *Trichoderma* sp. on seed germination and seedling growth of sesame were different according to the isolates of the fungus.

Trichoderma isolates	Germination of sesame	Normal seedlings(%)	Dead seedlings(%)	Stunted seedlings	Length of normal seedlings	
					Shoot	Root
164	72	61.1	19.4	19.5	47	35
209	80	65.0	20.0	15.0	54	35
218	56	57.1	25.0	17.9	56	37
227	74	51.4	24.3	24.3	46	26
239	82	58.5	22.0	19.5	61	27
240	88	75.0	9.0	16.0	61	33
241	82	36.6	9.8	53.6	51	25
J_1	72	69.4	16.7	13.9	57	34
J_2	78	64.1	20.5	15.4	61	39
Control	84	100	0	0	50	25

- R. Radhakrishnan et al. (2014a) screened 41 genotypes for resistance to *Fusarium* sp. *Fusarium* sp. 40240 isolate was cultured in potato dextrose broth for 3 weeks. The Fusarium culture filtrate with mycelium was mixed into pots. The pots treated with sterile water served as control. Sterilized seed was planted in the pots with the following rates of germination.

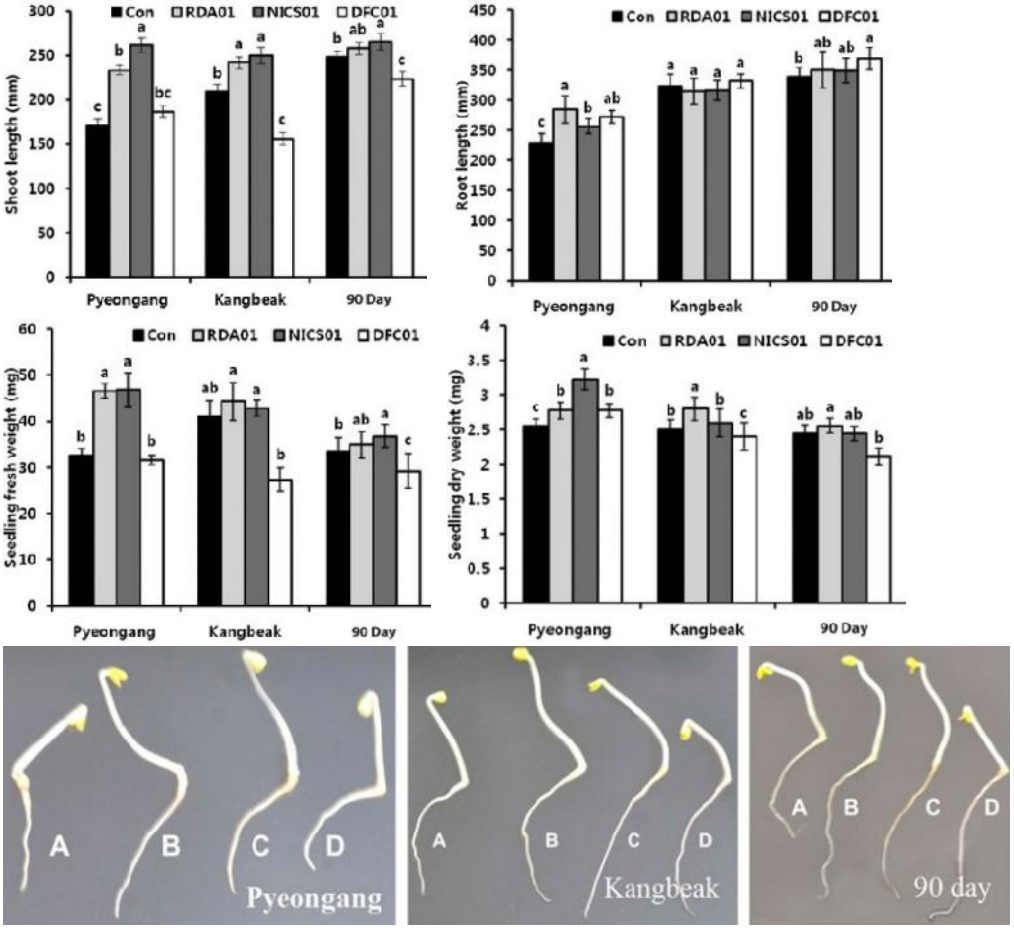


The following shows the control plots at the top and the *Fusarium* plots at the bottom for all 41 genotypes.



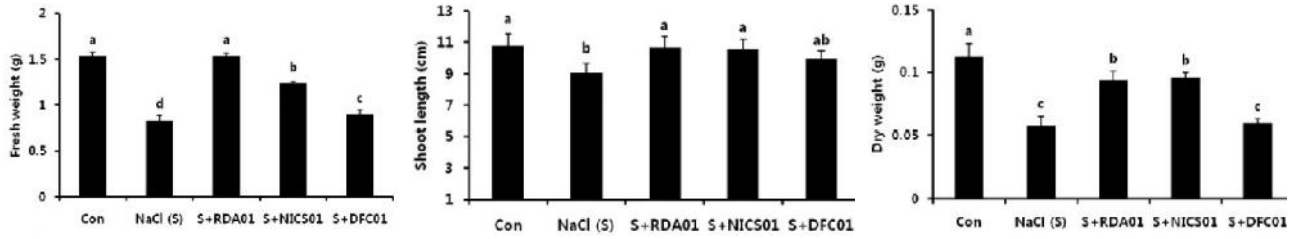
- R. Radhakrishnan et al. (2014b) evaluated the effects of 3 Penicillium species (RDA01, NICS01, and DFC01) on 3 cultivars (Pyeongang, Kangbaek, and 90 Day). They determined the differences in germination, amino

acids, chlorophylls, amino acids, and lignans. They also studied the effects of salt stress and *Fusarium* sp. The germination results were as follow.

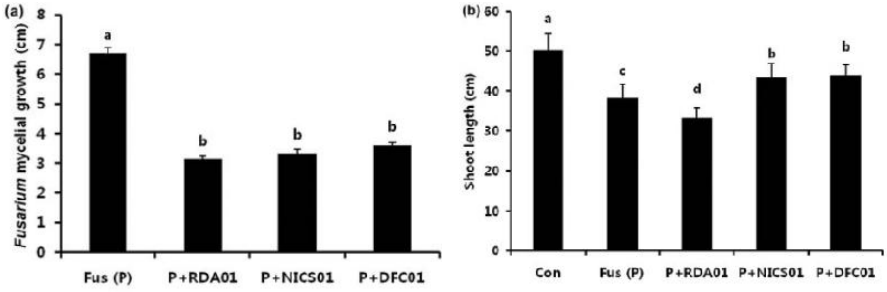


A = Control, B = RDA01, C = NIC501, and D = DFC01

The fungi-pretreated seeds were placed in autoclaved Baroker soil and distilled water was applied at regular intervals. After 15 days, uniformly sized seedlings were transplanted into pots containing sterilized Baroker soil. The 45-day-old sesame plants were treated with 150 mM NaCl for salinity stress. The aerial parts of the plants were harvested, and shoot length and fresh and dry shoot weights were measured at 50 days. The effects when salt stress was added were as follow.



Seven-day-old RDA01, NICS01, DFC01 and *Fusarium* sp. cultures in PDB broth were applied to a 4-mm disc placed on the opposite side of Petri dishes containing potato dextrose agar (PDA) medium. The Petri dishes were incubated for 14 days at 28 ± 2°C and *Fusarium* mycelium growth was measured. The surface-sterilized seeds were sown in pots containing RDA01-, NICS01-, and DFC01-treated Baroker soil in a greenhouse. Fusarium culture was applied to the Penicillium-inoculated plants at 50 days. Shoot length was measured 15 days after the first appearance of wilting. The results were as follow.



SUDAN

- H.A. Habish and A.H. Hammad (1970) reported seedling infection of sesame was most severe at soil temperatures of 20-26°C and also occurred at 39°C but not at 40°C. The incidence of leaf spot was slightly affected by variation in soil moisture between 20 and 40% and in relative humidity between 70 and 85%, but the disease was most severe at 30-40% and 75-80% respectively. Seedling resistance was increased by the applications of N at 45 kg/ha, but at 90-135 kg, germination and growth were retarded. [Cited by G.S. Saharan, 1989]

THAILAND

- P. Yowabut (1994) confirmed that the causal bacterium of sesame leaf spot in Thailand was *Pseudomonas syringae* pv. *sesami*. He tested 14 varieties and found Col 55 was resistant; Dam Dang-Phitsanulok, Col 30/nw-3, Nakornsawan, Buriram and Roi-et 1 were susceptible and the rests were intermediate. Seeds from the 14 varieties harvested from diseased plants were found to be seed-born with 62.13% infected in the seed coat. Disease control through hot water (55°C) and chemical (75 ppm streptomycin) seed treatment at 30 min each, gave the best results of 47.25 and 100 percent disease reduction with 84.4 and 88.6% seed germination, respectively. [Based on abstract]
- S. Prathuangwong and P. Yowabutra (1996) reported a preliminary seed treatment with both physical and chemical methods for efficient control of sesame bacterial leaf spot (caused by *Pseudomonas syringae* pv. *sesami*) in the laboratory indicated that either 35 min duration in 50°C hot water or 30 min soaking in aqueous solution of 75 ml/I streptomycin fitted to our test criteria of 25 or 100% disease reduction with 79.4 or 88.6% seed germination, respectively. [Based on abstract]

UGANDA

- Singh et al. (1983) reported seed infection with *Alternaria sesamicola* caused pre and post emergence loss of young seedlings and death of older plants. In a test sample of infested seed, those which failed to germinate were covered with conidia of the fungus. The pathogen was isolated from normal appearing as well as stunted plants indicating that it can invade the whole plant system without showing symptoms, and that seed from symptomless plants are not necessarily pathogen free. Stunted plants with brown-black lesions bore no flowers. [Cited by G.S. Saharan, 1989]

UNKNOWN

- A.A. Bayounis and M.A. Al-Sunaidi (2008a) showed the effect of some powder plant materials (*Azadarichta indica* seed, *Datura stramonium* seed, *Nerium oleander* leaves, *Eucalyptus camaldulensis* leaves) on the control of *Macrophomina phaseolina*. The powder plant material powder was used as 60, 40, 20g/kg of soil. Sesame seeds showed the highest germination rate in the soils treated with *A. indica* seeds powder. Germination rate in the soils treated with *A. indica* seeds powder reached about 69%, whereas germination rate for control was about 4%. The study has also indicated that the highest percentage of infected seeds under the soils treated with Eucalyptus leaves powder was 84.8%, while percentage infected seeds under *A. indica* treated soils was about 25%. All treatments with different concentrations of plant powder have shown inhibition effects on *Macrophomina phaseolina* growth. The highest percentage of inhibition was seen under the treatment with *A. indica* seed powder (73.9%) , whereas Eucalyptus leaves treatment powder was about 11.4%.

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G3 EFFECTS ON SEED QUALITY

D.R. Langham comments, 2021: There are 2 types of effects: the effect when the plant is still in the field and the effect once the seed has been harvested and stored.

Although many diseases can kill plants, there are many instances when the disease strikes late in the cycle, and there is good harvestable seed still on the plant. In manual harvest, when the plant is totally dead with some immature seed, it is not cut and put into the shocks. In mechanized harvest, the dead plants along with the healthy plants are all cut and run through the combine.

The problem is that there is a continuum from the good to the useless seed. There is a continuum on seed color, 1000-seed weight, and oil content. In combining or manual winnowing very poor seed is removed by air/wind, but there is still inferior seed in the sample. When the seed is intended for oil extraction, many processors do not attempt any further cleaning since there is still some oil in the inferior seed. In using the seed in the edible market, more inferior seed is light seed is removed by air and a gravity table, while a sortex machine can remove off-color seed. There is a subjective assessment of where to set the air, gravity, and color sorters. Too low settings may lead to rejection by the customer but too high settings leads to loss to the processors who has already paid for the seed since the higher settings will remove some good seed.

When the seed has been harvested and cleaned, organisms on the seed may feed on the seed itself lowering carbohydrate and/or oil content.

References:

EGYPT

- R.S. Farag et al. (1985a) reported *Aspergillus flavus* on the seed had an effect on seed composition as follows.

Seed component	Healthy seed	Infected seed
Proteins	22.1%	23.6%
Lipids	58.3%	49.0%
Carbohydrates	14.2%	21.7%
Crude fiber	2.1%	2.6%

- R.S. Farag et al. (1985b) studied the physical and chemical properties of oils extracted from healthy and infected seeds rich in carbohydrates. The results showed a decrease in refractive index, and iodine value and an increase in the acid value in infected oils. The fungal infection caused qualitative and quantitative differences in the free and bound fatty acids of seeds under study. The increase in the amounts of 18:1 and 18:2 fatty acids can be regarded as the most pronounced fungal effect on the fatty acid profiles. Fungal infection led to decrease or an increase in the amounts of certain fatty acids, appearance of some new fatty acids and disappearance of some medium chain-length fatty acids. [Based on abstract]
- A.I.I. El-Fiki et al. (2004b) reported the yields and oil contents decreased between healthy (H) and diseased (D) plants as follow.

Sesame entry	% Charcoal rot		Seed yield (kg/fed.)		% Seed oil content			
					1999		2000	
	1999	2000	1999	2000	H	D	H	D
Aceteru-M	3.9	6.8	150.0	141.3	54.0	51.0	54.6	51.5
Adnan 1 (5/91)	6.8	9.6	214.2	182.7	62.9	56.5	59.2	55.7
B 11	21.7	19.4	127.5	145.8	59.6	55.7	58.8	54.3
B 35	5.7	5.3	194.4	176.1	57.7	53.2	56.6	52.5
Giza 32	16.2	19.6	123.3	121.5	54.8	51.8	54.0	51.7
Mutation 48	4.3	8.6	277.5	195.6	58.4	55.1	58.6	55.4
Shandaweel 3	15.3	14.7	160.8	149.4	53.6	50.9	53.7	51.2
Strain 773	22.4	19.3	120.9	128.4	60.0	56.5	61.0	57.2
Strain 779	20.5	22.3	137.1	121.8	53.4	50.3	53.9	51.8
Strain 787	12.9	14.1	183.5	159.6	55.6	52.4	56.3	53.3
Strain 806	28.5	26.7	84.0	82.4	61.1	54.2	61.3	54.6
Taka 1	11.8	13.0	152.1	124.8	53.7	48.2	54.5	50.6
Taka 2	4.6	4.2	259.2	208.5	56.4	52.9	55.2	51.3
Taka 3	9.1	11.3	190.8	161.2	56.0	54.4	56.8	55.0
Tushka 1	19.7	20.5	148.8	126.3	54.1	51.6	54.4	50.9
Tushka 2	6.3	11.8	199.8	173.4	57.1	54.5	59.2	57.7
LSD at 5%	3.34	3.18	10.01	10.29	1.05		1.19	

- M.M. Amin et al. (2017) reported *Bacillus megaterium* var. *phosphaticum* (BMP) have been used to control sesame wilt disease caused by *Fusarium oxysporum* f. sp. *sesami* in the presence of different doses of calcium super phosphate (CSP) at two successive seasons (2014 and 2015) using Giza 32. CSP was added with soil

preparation at the rate of 1, 2, 3 and 4 gm/pot and 50, 100, 150 and 200 kg/fed under greenhouse and field conditions, respectively. The greenhouse results were as follow, which includes the use of a fungicide – Topsin M-70%.

Treatment	2014	2015	Mean	Decrease (%)
BMP* + 1 gm CSP**	63.35	63.35	63.35	22.40
BMP + 2 gm CSP	60.02	56.67	58.35	28.53
BMP + 3 gm CSP	50.01	43.32	46.66	42.84
BMP + 4 gm CSP	40.00	36.64	38.32	53.06
4gm CSP	43.33	46.66	45.00	44.88
BMP	63.36	66.70	65.03	20.34
Topsin M-70%	40.00	43.32	41.66	48.97
Control	79.97	83.30	81.64	-
L.S.D. at 5%	11.53	10.76	-	-

BMP* *Bacillus megaterium var. phosphaticum*and as seed dressing, CSP** calcium super phosphate/pot

The field results were as follow.

Treatment	2014	2015	Mean	Decrease (%)
BMP* + 50 kgCSP**	41.40	42.70	42.04	26.85
BMP + 100 kgCSP	39.65	41.76	40.70	29.18
BMP + 150 kgCSP	38.25	40.70	39.48	31.31
BMP + 200 kgCSP	35.70	36.80	36.25	36.92
200 kgCSP	41.05	39.65	40.35	29.79
BMP	40.00	41.05	40.53	29.48
Topsin M-70%	26.60	27.50	27.05	52.93
Control	56.06	58.88	57.47	-
L.S.D. at 5%	1.17	1.63	-	-

BMP* *Bacillus megaterium var. phosphaticum*and as seed dressing, CSP** calcium super phosphate/fed

The yields and oil contents in the field were as follow. There is additional data on plant height, number of capsules/plant, number of branches/plant, and shoot content of N, P, and K.

Treatment	Seed yield (arddab/fed)				Oil content %			
	2014	2015	Mean	Increase (%)	2014	2015	Mean	Increase (%)
BMP* + 50 kgCSP**	3.00	3.20	3.10	18.10	52.00	54.00	52.99	4.56
BMP + 100 kgCSP	3.08	3.65	3.36	28.10	53.88	54.13	54.00	6.56
BMP + 150 kgCSP	3.50	3.83	3.66	39.52	56.20	55.88	56.04	10.58
BMP + 200 kgCSP	4.33	4.55	4.44	69.05	56.58	55.00	55.79	10.09
200 kgCSP	3.25	3.63	3.44	30.95	57.25	56.75	57.00	12.48
BMP	3.28	3.48	3.38	28.57	56.25	55.70	55.98	10.46
Topsin M-70%	3.05	3.25	3.15	20.00	53.63	52.30	52.96	4.51
Control	2.58	2.68	2.63	-	50.50	50.85	50.68	-
L.S.D. at 5%	0.38	0.25	-	-	1.53	1.41	-	-

BMP* *Bacillus megaterium var. phosphaticum*and as seed dressing, CSP** calcium super phosphate/fed

INDIA

- B.P. Singh et al. (1972) reported infected seeds invariably yielded *Macrophomina phaseoli* . The oil content was greatly reduced. Protein and carbohydrate values were also somewhat lower. [Cited by G.S. Saharan, 1989]
- D.N. Shukla and S.N. Bhargava (1978) reported at a low moisture content (<8.5%) seeds of sesame were free from fungal associations. At 10.5% moisture, many seeds were infested. [Cited by G.S. Saharan, 1989]
- B.K. Singh and T. Prasad (1979) reported *Aspergillus flavus* and *Aspergillus niger* inoculations decreased the cholesterol level of the seed. [Cited by G.S. Saharan, 1989]

- S.N. Bhargava and D.N. Shukla (1980) reported the two most frequently encountered fungi, *Fusarium equiseti* and *Fusarium oxysporum* caused a slight reduction in oil content of seeds of sesame when incubated for 45 days. [Cited by G.S. Saharan, 1989]
- B. Nandi et al. (1981) reported *Aspergillus niger* and *A. fumigatus* caused deterioration of sesame seeds in storage.
- K.D. Sharma (1981) reported the 8 most abundant fungal spp. isolated during sesame seed storage were selected for further study. All could reduce the quantity of oil in seeds, and the quality was also considerably affected.
- A. Bose and B. Nandi (1982) reported *Aspergillus ochraceus* and *Rhizoctonia solani* caused maximum reduction in oil content of sesame seeds. Deteriorated oil samples showed change in color, iodine value and saponification with prolonged incubation depending on the fungus and substrate. [Cited by G.S. Saharan, 1989]
- A. Bose and B. Nandi (1985) reported cellulase was produced in culture best by *Aspergillus fumigatus, A. candidus* and *Rhizoctonia solani*; endopolygalacturonase and lipase by *A. flavus*. Reduction in germinability and oil content and increase in fat acidity were most pronounced in seeds inoculated with *A. flavus, A. fumigatus,* and *R. solani*. [Cited by G.S. Saharan, 1989]
- B. Prasad et al. (1985a) reported *Tobacco leaf curl virus* infection greatly reduced plant yield and oil content of seeds, but the protein content was increased.
- O.P. Verma and L.M. Daftari (1985) reported phyllody reduced plant yield, test weight, germination percentage and oil content of seeds. A transformation of 25% of the productive length into phyllody caused 39.73% reduction in seed yield.
- N. Saxena and D. Karan (1991) reported on seeds of sesame cv. T-85 collected in Andhra Pradesh the predominant fungi were *Alternaria alternata, Aspergillus flavus, Aspergillus niger* and *Fusarium moniliforme* [*Gibberella fujikuroi*]. Seed protein and carbohydrate contents were analyzed before and 10, 20 and 30 days after inoculation with each of the predominant fungi identified. *Aspergillus flavus, Aspergillus niger* and *Alternaria alternata* caused decreases in protein and carbohydrate contents; *Aspergillus flavus* caused the biggest decrease. It is suggested that the fungi contain a protein hydrolyzing enzyme, and the carbohydrate is consumed and converted into carbon dioxide and water. [Based on abstract]
- Anon (1992a) in a grower guide reported *Mycoplasma* (Phyllody) appears at flowering. All floral parts are transformed into green leafy structures. Infected plants produce little leaves in bunches, show excessive branching and shortening of internodes. Such plants generally do not bear capsules but if capsules are formed, they do not yield quality seeds.
- K. Bhattachary and S. Raha (2002) studied fungal infection, moisture content, germinability and deterioration of sesame in storage under natural conditions for a year. Different species of Aspergillus (*A. candidus*, A. *flavus, A. niger, A. terreus,* and *A. ruber*) were dominant followed by Rhizopus, Penicillium, Curvularia, Fusarium, Alternaria, etc. Seed moisture was maximum in the rainy season followed by a gradual decrease during longer storage. As storage proceeded, there was a gradual decrease in field fungi with simultaneous increase in storage fungi, and a reduction in germinability. A gradual loss of carbohydrate (both soluble and insoluble) content was recorded. A loss of protein content was recorded followed by a small increase. Oil content decreased in prolonged storage with simultaneous increase in fatty acid. [Based on abstract]
- G.C. Mondal and B. Nandi (2006) studied the deteriorative efficacy of storage fungi through change in the quality of different edible oils. Maximum loss of oil was recorded with *Aspergillus niger*. Refractive indices of oil decreased in most of the cases with concomitant increase in free fatty acids. The deteriorated oil samples showed change in color, saponification value and iodine value with longer incubation which depended partly on the fungus involved and partly on the type of substrate. Both *A. niger* and *A. fumigatus* produced higher amount of lipase than others. Production of lipase enzyme and mycelia were always higher on emulsified oil than on seed meal media. [Based on abstract]
- A.K. Dubey et al. (2011) reported besides causing blight, *Phytophthora parasitica* var. *sesami* is found to be associated with vivipary in immature seeds of sesame contained in green capsules of plants raised from naturally infected seeds. The green capsules split lengthwise due to emergence of few seedlings from the capsules. The pathogen induced emergence of the radicle, hypocotyls and cotyledons through the seed coat within the capsule. Such viviparous condition occurred in 25-48.8% of the capsules and 27.08-36.12% of the seeds. The viviparous pods were characterized by internal browning of pedicel, septum and placenta. The seeds carried white cottony growth of *P. parasitica* var. *sesami*. Such viviparous condition was not visible in capsules with normal looking seeds. Vivipary in our case might be due to fungal stimulation. Presence of pathogen in different parts of the capsules and seedlings were established by incubation and cleared preparation. In immature developing capsules, hyphae were observed in tissues of pericarp, placenta, locules and ovules. It is

an unusual phenomenon that besides increasing the seed infection also renders poor-quality seeds. The host-pathogen interaction results in abnormal seedling emergence, which lacks vigor and further survival.

- R.B. Kakde and A.M. Chavan (2011) examined the effects of fungi on seeds in storage. Ten dominant fungi were isolated from seeds of groundnut, soybean, sesame, safflower, and sunflower. One hundred grams of seeds were inoculated with 10 ml of the fungi. The flasks were left at room temperature for 14 days and then analyzed for sugars, crude fat, and fiber. The results are as follow.

Table 1. Change in reducing sugar (g/100gm) due to seed-borne fungi

Fungi	Sunflower	Sesame	Groundnut	Soybean	Safflower
Alternaria dianthicola	5.2	4.8	1.1	1.1	1.3
Curvularia lunata	4.9	5.0	2.5	1.5	1.8
Curvularia pellescens	5.0	5.4	2.1	1.2	1.6
Fusarium oxysporum	4.7	4.4	1.8	1.7	1.1
Fusarium equiseti	4.6	4.8	1.6	1.2	1.0
Macrophomina phaseolina	5.8	3.5	2.2	2.0	2.2
Rhizopus stolonifer	6.1	5.0	1.1	1.8	2.1
Penicillium digitatum	5.5	4.6	1.9	1.7	1.4
Penicillium chrysogenum	5.2	4.9	2.0	1.6	1.6
Trichoderma viride	6.7	6.1	2.1	1.9	2.6
Control	7.2	6.9	3.1	2.4	2.8
C.D. at 0.05	0.52	0.62	1.21	0.24	0.21

Table 2. Change in crude fat (g/100gm) due to seed-borne fungi

Fungi	Sunflower	Sesame	Groundnut	Soybean	Safflower
Alternaria dianthicola	35.5	10.2	37.1	49.8	22
Curvularia lunata	43.5	14.3	32.5	48.2	26
Curvularia pellescens	45.5	10	41	49	27
Fusarium oxysporum	43	16.1	38	44	20
Fusarium equiseti	47	14.2	35	49.7	19
Macrophomina phaseolina	39	10.5	39.3	46.8	30
Rhizopus stolonifer	50	16.3	40.2	48.6	33
Penicillium digitatum	42	15.3	34.3	39	24
Penicillium chrysogenum	44	12.8	36.2	41	27
Trichoderma viride	46	17.5	40	46	35
Control	49	20	45	50	36
C.D. at 0.05	2.71	2.05	2.04	2.4	3.7

Table 3. Change in crude fiber (g/100) due to seed-borne fungi

Fungi	Sunflower	Sesame	Groundnut	Soybean	Safflower
Alternaria dianthicola	39.1	35.6	33.9	26.1	20.1
Curvularia lunata	52.3	30.6	38.8	34.5	21.8
Curvularia pellescens	46.1	41.1	42.3	31.1	21.6
Fusarium oxysporum	53.1	36.5	34.7	37.0	21.0
Fusarium equiseti	50.7	36.4	37.9	21.0	22.5
Macrophomina phaseolina	47.7	34.8	41.9	36.6	17.9
Rhizopus stolonifer	41.6	31.6	40.1	28.5	19.6
Penicillium digitatum	43.5	40.5	27.6	21.0	14.4
Penicillium chrysogenum	40.5	27.7	31.7	36.9	13.9
Trichoderma viride	47.5	35.1	38.3	37.0	19.8
Control	51.3	47.7	38.0	23.3	19.9
C.D. at 0.05	3.16	6.11	2.39	4.2	1.82

- D.M. Pathak et al. (2013) surveyed in 6 sesame growing areas during Kharif and Summer in 2008 and 2009. The incidence of phyllody during kharif and summer seasons ranged from 0-1.5% and 0-4.7%, respectively, in scattered manner. The spread was very slow, and the first affected plant was observed at 40 days and maximum at 75 days after sowing. They reported the leafhoppers (*Orosius albicinctus* Distant) infected the crops with phyllody. They examined 5 plants at different ages of appearance of the phyllody and took the following data.

Age	Number of capsules/plant	Seed yield (g)	Number of branches	Plant height (cm)	1000-seed weight (g)
50	11.5	0.23	2.3	69.4	0.476
55	22.2	1.10	3.3	90.7	0.667
60	35.1	2.30	3.5	104.4	1.139
65	47.5	3.90	3.8	113.4	1.644
Healthy	55.8	4.30	4.2	118.8	2.784

- K. Satyagopal et al. (2014) in an IPM manual reported phyllody symptoms were as follows:
  - All floral parts are transformed into green leafy structures followed by abundant vein clearing in different flower parts.
  - In severe infection, the entire inflorescence is replaced by short, twisted leaves closely arranged on a stem with short internodes, abundant abnormal branches bend down.
  - Finally, plants look like witches' broom.
  - If capsules are formed on lower portion of plant, they do not yield quality seeds.

PAKISTAN

- C.A. Amienyo et al. (2015) studied the effect of mycoflora collected from 5 markets on the deterioration of lipid content of seed. Visually healthy seeds were inoculated with spores of each of the nine fungi isolated from diseased seeds and incubated at 25+20°C for 7days. The healthy and fungal infected seeds were analyzed for their lipid content. The percentage incidence at the 5 locations is shown below.

Fungi incidence	Location				
	A	B	C	D	E
Alternaria alternate	6.6	3.6	3.2	2.0	0.0
Aspergillus chevalieri	10.3	4.2	5.0	0.0	0.0
Aspergillus niger	0.0	6.1	7.4	2.6	5.2
Aspergillus oryzae	3.3	4.0	0.0	0.0	0.0
Aspergillus flavus	3.9	3.1	2.7	0.0	0.0
Aspergillus terreus	4.8	11.2	2.4	13.0	0.0
Cochliobolus Spp.	9.5	0.0	0.0	0.0	0.0
Geotrichum candidum	0.0	0.0	0.0	0.0	3.5
Phoma Spp.	5.9	2.0	0.0	0.0	0.0

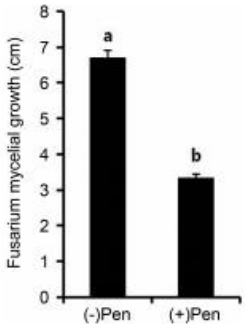
Fungi utilize basic compounds of the seeds for their metabolism and growth and may affect the germination rate of the seed. The uninoculated seed had 49.35% lipid. The following shows the lipid content after 7 days of infection.

Fungi	Lipid content (%)
Aspergillus chevalieri	42.40
Aspergillus oryzae	43.50
Aspergillus niger	45.00
Aspergillus terreus	45.45
Alternaria alternata	47.80
Cochliobolus Spp	48.10
Aspergillus flavus	48.70
Phoma Spp.	49.15
Geotrichum candidum	49.40

REPUBLIC OF KOREA

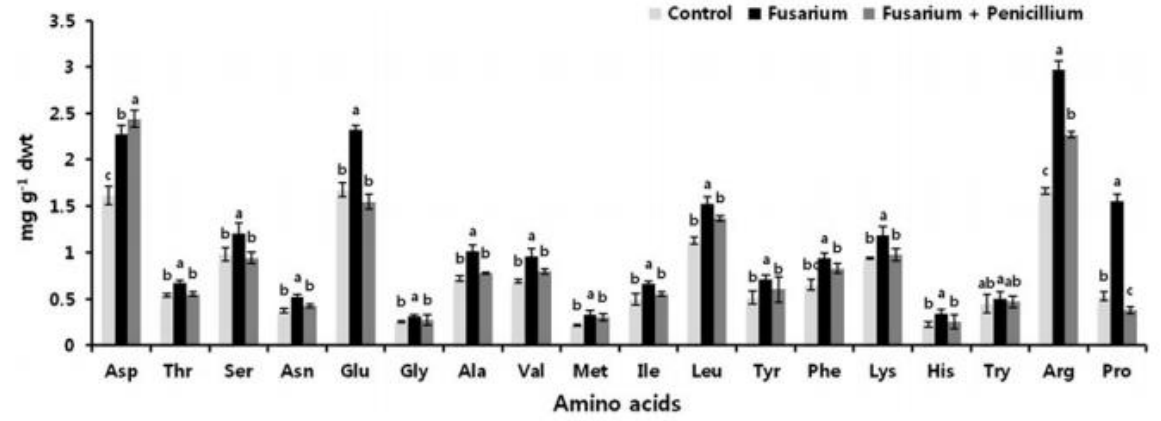
- R. Radhakrishnan et al. (2013a) reported *Penicillium* sp. is a potent plant growth promoting fungus that has the ability to ameliorate damage caused by *Fusarium* infection in sesame cultivation. The *in vitro* biocontrol

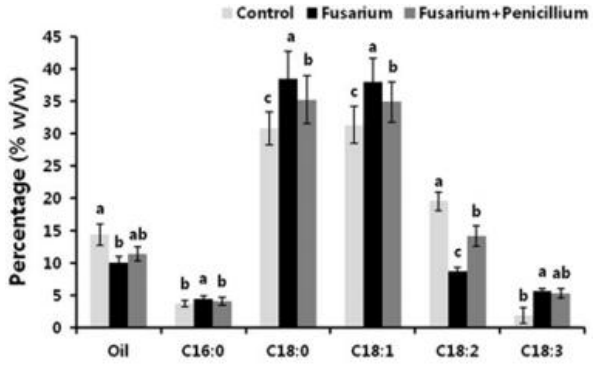
activity of *Penicillium* sp. against *Fusarium* sp. was exhibited by a 49% inhibition of mycelial growth in a dual culture bioassay and by hyphal injuries as observed by scanning electron microscopy.



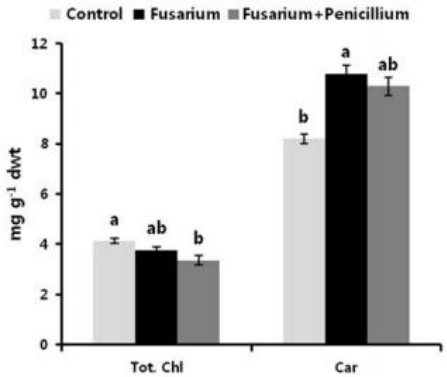
In addition, greenhouse experiments revealed that *Fusarium* inhibited growth in sesame plants by damaging lipid membranes and reducing protein content. Co-cultivation with *Penicillium* sp. mitigated *Fusarium*-induced oxidative stress in sesame plants by limiting membrane lipid peroxidation, and by increasing the protein concentration, levels of antioxidants such as total polyphenols, and peroxidase and polyphenoloxidase activities.

- R. Radhakrishnan et al. (2013b) studied the differences in amino acids and fatty acids between a control, *Fusarium* and *Fusarium* + *Penicillium*. Compared with healthy plants, *Fusarium*-infected plants accumulated higher concentrations of free amino acids, fatty acids, carotenoids, γ-Aminobutyric acid (GABA), and some lignans, and showed decreased concentrations of oil and chlorophyll. Furthermore, *Penicillium* treatment mitigated the *Fusarium*-induced changes in amino acids, fatty acids, carotenoids, and secondary metabolite contents in infected plants. The results were as follow.

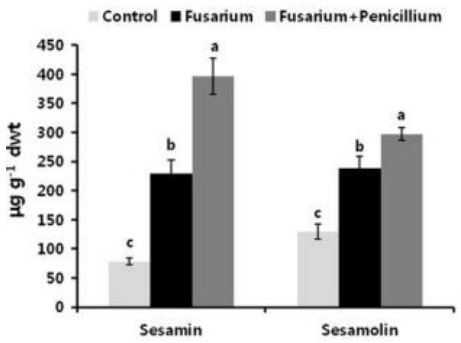




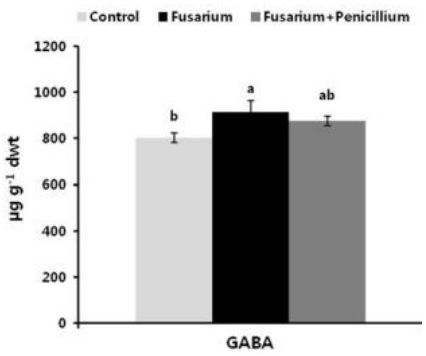
Fatty acid content



Chlorophyll and carotene content



Sesamin and sesamolin content



γ-Aminobutyric acid (GABA)

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H Fungi associated with sesame without known adverse effects

Any fungus found in sesame plants or on the seeds has the potential of affecting the plant or seed if the populations are high enough. However, there is no known report that shows the following species have had an effect.

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H1 Order: Mucorales Dumort. 1829

There are species in this order that cause a disease, produce a toxin, inhibit germination, or affect seed quality. This is the same order as *Rhizopus* spp., *Mucor* spp., and *Choanephora* spp. See A14.

H1.1 Family: Lichtheimiaceae K. Hoffm., Walther & K. Voigt 2009

The following species has been associated with sesame but there are no known reports of being a pathogen, producing a toxin, inhibiting germination, affecting seed quality, or being used as a biocontrol or biofertilizer.

- *Lichtheimia corymbifera* [India] (*Syn: *Absidia corymbifer*a)

H1.2 Family: Cunninghamellaceae Naumov ex R.K. Benj. 1959

The following species has been associated with sesame but there are known no reports of being a pathogen, producing a toxin, inhibiting germination, affecting seed quality, or being used as a biocontrol or biofertilizer.

- *Cunninghamella elegans* [India]

H1.3 Family: Syncephalastraceae Naumov ex R.K. Benj. 1959

The following species has been associated with sesame but there are known no reports of being a pathogen, producing a toxin, inhibiting germination, affecting seed quality, or being used as a biocontrol or biofertilizer.

- *Syncephalastrum* spp. [Saudi Arabia]

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H2 Order: Microascales Luttr. ex Benny & Kimbr. 1980

H2.1 Family: Ceratocystidaceae Locq. ex Réblová, W. Gams & Seifert 2011

The following species has been associated with sesame but there are known no reports of being a pathogen, producing a toxin, inhibiting germination, affecting seed quality, or being used as a biocontrol or biofertilizer.

- *Berkeleyomyces basicola* [International lists] (*Syn: *Chalara elegans*)

There are species in this family that cause a disease, produce a toxin, inhibit germination, or affect seed quality. This is the same family as *Thielaviopsis* spp. See A15.1.

H2.2 Family: Microascaceae Luttr. ex Malloch 1970

The following species have been associated with sesame but there are known no reports of being a pathogen, producing a toxin, inhibiting germination, affecting seed quality, or being used as a biocontrol or biofertilizer.

- *Scopulariopsis* spp. [Egypt]
- *Scopulariopsis brevicaulis* [Iran]

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H3 Order: Helotiales Nannf. ex Korf & Lizon 2000

H3.1 Family: Sclerotiniaceae Whetzel 1945

The following species has been associated with sesame but there are no known reports of being a pathogen, producing a toxin, inhibiting germination, affecting seed quality, or being used as a biocontrol or biofertilizer.

- *Botrytis* spp. [India]

There are species in this family that cause a disease, produce a toxin, inhibit germination, or affect seed quality. This is the same family as *Sclerotinia* spp. See A8.2.

==========

H4 Order: **Capnodiales** Woron 1925

H4.1 Family: **Mycosphaerellaceae** Lindau 1897

The following species have been associated with sesame but there are no known reports of being a pathogen, producing a toxin, inhibiting germination, affecting seed quality, or being used as a biocontrol or biofertilizer.

- *Mycosphaerella bolleana* [Pakistan] (*Syn: *Cercospora bolleana*)
- *Mycovellosiella koepkei* [Pakistan] (*Syn: *Mycovellosiella koepkei*)

There are species in this family that cause a disease, produce a toxin, inhibit germination, or affect seed quality. See A4.1.

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H5 Order: **Pleosporales** Luttr. Ex M.E. Barr 1987

H5.1. Family: **Coniothyriaceae** W.B. Cooke 1983

The following species has been associated with sesame but there are no known reports of being a pathogen, producing a toxin, inhibiting germination, affecting seed quality, or being used as a biocontrol or biofertilizer.

- *Ochrocladosporium elatum* [Iran] (*Syn: *Cladosporium elatum*)

H5.2 Family: **Pleosporaceae** Nitschke 1869

The following species have been associated with sesame but there are known no reports of being a pathogen, producing a toxin, inhibiting germination, affecting seed quality, or being used as a biocontrol or biofertilizer.

- *Pleospora* spp. [Saudi Arabia]
- *Stemphylium* spp. [Saudi Arabia]
- *Stemphylium botryosum* [Iran]
- *Ulocladium* spp. [Egypt, Iran, Iraq, Saudi Arabia, and Sudan]
- *Ulocladium atrum* [Iran]
- *Ulocladium lanuginosum* [Iran]

There are species in this family that cause a disease, produce a toxin, inhibit germination, or affect seed quality. This is the same family as *Alternaria* spp. See A3.1.

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H6 Order: **Botryosphaeriales** C.L. Schoch, Crous & Shoemaker 2007

H6.1 Family: **Botryosphaeriaceae** Theiss. & H. Sydow 1918

The following species has been associated with sesame but there are no known reports of being a pathogen, producing a toxin, inhibiting germination, affecting seed quality, or being used as a biocontrol or biofertilizer.

- *Diplodia herbarum* [Mexico]

There are species in this family that cause a disease, produce a toxin, inhibit germination, or affect seed quality. This is the same family as *Macrophomina* spp. See A2.1.

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H7 Order: **Agaricales** Underw. 1899

H7.1 Family: **Typhulaceae** Julich 1982

The following species has been associated with sesame but there are no known reports of being a pathogen, producing a toxin, inhibiting germination, affecting seed quality, or being used as a biocontrol or biofertilizer.

- *Typhula micans* [Mexico]

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H8 Order: **Glomerellales** Chadef. Ex Reblova, W. Garns & Seifert 2011

H8.1 Family: **Plectosphaerellaceae** Zare 2007

The following species has been associated with sesame but there are no known reports of being a pathogen, producing a toxin, inhibiting germination, affecting seed quality, or being used as a biocontrol or biofertilizer.

- *Plectosphaerella cucumerina* [Pakistan] (*Syn: *Fusarium tabacinum*)

There are species in this family that cause a disease, produce a toxin, inhibit germination, or affect seed quality. This is the same family as *Verticillium* spp. See A7.1.

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H9 Order: Hypocreales Lindau 1897

The following species has been associated with sesame but there are no known reports of being a pathogen, producing a toxin, inhibiting germination, affecting seed quality, or being used as a biocontrol or biofertilizer.

- *Trichothecium roseum* [Mexico]

H9.1 Family: Nectriaceae C. & L. Tulasne 1895

The following species has been associated with sesame but there are no known reports of being a pathogen, producing a toxin, inhibiting germination, affecting seed quality, or being used as a biocontrol or biofertilizer.

- *Haematonectria haematococca* [International lists]

There are species in this family that cause a disease, produce a toxin, inhibit germination, or affect seed quality. This is the same family as *Fusarium* spp., *Gibberella* spp., *Neocosmospora* spp., and *Cylindrocladium* spp. See A1.1.

H9.2 Family: Hypocreaceae De Not. 1844

The following species has been associated with sesame but there are no known reports of being a pathogen, producing a toxin, inhibiting germination, affecting seed quality, or being used as a biocontrol or biofertilizer.

- *Hypocrea rufa* [International lists]

H9.3 Family: Stachybotryaceae L. Lombard & Crous 2014

The following species have been associated with sesame but there are no known reports of being a pathogen, producing a toxin, inhibiting germination, affecting seed quality, or being used as a biocontrol or biofertilizer.

- *Stachybotrys* spp. [Egypt]
- *Stachybotrys atra* [India]
- *Stachybotrys chartarum* [India and Iran]

There are species in this family that cause a disease, produce a toxin, inhibit germination, or affect seed quality. This is the same family as *Myrothecium* spp. and *Memnoniella* spp. See A1.2.

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H10 Order: Mortierellales Caval.-Sm. 1998

H10.1 Family: Mortierellaceae A. Fisch 1892

The following species has been associated with sesame but there are no known reports of being a pathogen, producing a toxin, inhibiting germination, affecting seed quality, or being used as a biocontrol or biofertilizer.

- *Haplosporangium* spp. [India]

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H11 Order: Eurotiales G.W. Martin ex Benny& Kimbr. 1980

H11.1 Family: Trichocomaceae E. Fisch. 1897

The following species have been associated with sesame but there are no known reports of being a pathogen, producing a toxin, inhibiting germination, affecting seed quality, or being used as a biocontrol or biofertilizer.

- *Eurotium* spp. [Egypt]
- *Paecilomyces* spp. [Iran]
- *Paecilomyces digitatum* [Iran]
- *Paecilomyces variotii* [Iran]

There are species in this family that cause a disease, produce a toxin, inhibit germination, or affect seed quality. This is the same family as *Aspergillus* spp. and *Penicillium* sp. See A13.1. There are also species in this family that are used for biocontrols. See E2.1.

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H12 Order: Chaetothyriales M.E. Barr 1987

H12.1 Family: Trichomeriaceae Chomnunti & K.D. Hyde 2013

The following species has been associated with sesame but there are no known reports of being a pathogen, producing a toxin, inhibiting germination, affecting seed quality, or being used as a biocontrol or biofertilizer.

- *Trichomerium jambosae* [Mexico]

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I Bacteria associated with sesame without known adverse effects

Any bacteria found in sesame plants or on the seeds has the potential of affecting the plant or seed if the populations are high enough. However, there is no known report that shows the following species have had an effect. There are undoubtedly more bacteria to be found on sesame seeds. There is only one known report that analyzed the seed for bacteria.

I1 Order: Pseudomonadales Orla-Jensen 1921

There are species in this family that cause a disease, produce a toxin, inhibit germination, or affect seed quality. This is the same order as *Pseudomonas* spp., *Ralstonia* spp., and *Acidovorax* spp. See C1. There are also species used as biocontrols. See F1.

I1.1 Family: Moraxellaceae Rossau et al. 1991

The following species has been associated with sesame but there are no known reports of being a pathogen, producing a toxin, inhibiting germination, affecting seed quality, or being used as a biocontrol or biofertilizer.

- *Acinetobacter* spp. [United States]

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I2 Order: Synergistales Jumas-Bilak et al. 2009

I2.1 Family: Synergistaceae Jumas-Bilak et al. 2009

The following species has been associated with sesame but there are no known reports of being a pathogen, producing a toxin, inhibiting germination, affecting seed quality, or being used as a biocontrol or biofertilizer.

- *Aminivibrio* spp. [United States]

==========

I3 Order: Chitinophagales Munoz et al. 2017

I3.1 Family: Chitinophagaceae Kämpfer et al. 2011

The following species has been associated with sesame but there are no known reports of being a pathogen, producing a toxin, inhibiting germination, affecting seed quality, or being used as a biocontrol or biofertilizer.

- *Asinibacterium* spp. [United States]

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I4 Order: Flavobacteriales Bernardet 2012

I4.1 Family: Weeksellaceae García-López et al. 2020

The following species has been associated with sesame but there are no known reports of being a pathogen, producing a toxin, inhibiting germination, affecting seed quality, or being used as a biocontrol or biofertilizer.

- *Chryseobacterium* spp. [United States]

I4.2 Family: Flavobacteriaceae Reichenbach et al. 1992 emend. Bernardet et al. 2002

This family has been identified in the United States.

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I5 Order: Bacillales Prevot 1953

I5.1 Family: Bacillaceae Garrity et al. 2001

The following species has been associated with sesame but there are no known reports of being a pathogen, producing a toxin, inhibiting germination, affecting seed quality, or being used as a biocontrol or biofertilizer.

- *Falsibacillus* spp. [United States]

There are species in this family that cause a disease, produce a toxin, inhibit germination, or affect seed quality. This is the same family as *Listeria* spp. and *Bacillus* spp. See C8.1. There are species in this family used for biocontrols. See F2.1.

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I6 Order: Cytophagales Leadbetter 1974

I6.1 Family: Fulvivirgaceae García-López *et al*. 2020

The following species has been associated with sesame but there are no known reports of being a pathogen, producing a toxin, inhibiting germination, affecting seed quality, or being used as a biocontrol or biofertilizer.

- *Chryseolinea* spp. [United States]

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I7 Order: Micrococcales Prevot 1940

I7.1 Family: Microbacteriaceae Park et al. 1995

The following species has been associated with sesame but there are no known reports of being a pathogen, producing a toxin, inhibiting germination, affecting seed quality, or being used as a biocontrol or biofertilizer.

- *Okibacterium* spp. [United States]

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I8 Order: Planctomycetales Schlesner and Stackebrandt 1987

I8.1 Family: Planctomycetaceae Schlesner and Stackebrandt 1987

The following family has been associated with sesame but there are no known reports of being a pathogen, producing a toxin, inhibiting germination, affecting seed quality, or being used as a biocontrol or biofertilizer.

- Planctomycetaceae [United States]

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I9 Order: Lactobacillales Ludwig et al. 2010

I9.1 Family: Streptococcaceae Deibel and Seeley 1974

The following species has been associated with sesame but there are no known reports of being a pathogen, producing a toxin, inhibiting germination, affecting seed quality, or being used as a biocontrol or biofertilizer.

- *Streptococcus* spp. [United States]

==========

I10 Order: Enterobacterales Adeolu et al. 2016

I10.1 Family: Erwiniaceae Adeolu et al. 2016

The following species has been associated with sesame but there are no known reports of being a pathogen, producing a toxin, inhibiting germination, affecting seed quality, or being used as a biocontrol or biofertilizer.

- *Rosenbergiella* spp. [Japan]

There are species in this family that cause a disease, produce a toxin, inhibit germination, or affect seed quality. This is the same family as *Erwinia* spp. See C7.1.

I10.2 Family: Yersiniaceae Adeolu et al. 2016

The following species has been associated with sesame but there are no known reports of being a pathogen, producing a toxin, inhibiting germination, affecting seed quality, or being used as a biocontrol or biofertilizer.

- *Serratia* spp. [Japan]

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- The bibliography style adopted is specific to the objectives of these books.
- It is sorted in alphabetical order by first author and date of publication.
- Publications for a common author are listed with the oldest publication coming first.
- On the dates, the letter modifiers that match the letters in the 'Sesame Bibliography (*Sesamum indicum*)'.
- The references do not use special symbols, e.g., ñ, for the spelling of the names in order to allow the use of 'control find' to locate a specific author without having to use the special symbol.

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