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ALTERNARIA DISEASES OF VEGETABLE CROPS AND ITS MANAGEMENT CONTROL TO REDUCE THE LOW PRODUCTION

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Abstract- Vegetables belonging to family Cucurbitaceae, Brassicaceae and Solanaceae are important due to their nutritional and have also cost-effective values. Farmers bearing heavy yield losses both in their quality and quantity of these crops due to various diseases. Diseases caused by *Alternaria* species are common and are worldwide in their occurrence. The different crops plants as a host *viz*. apples, broccoli, cauliflower, carrots, potatoes, Chinese cabbage, tomatoes, bok choy, citrus and many plants used as ornamentals and a no. of weeds. These crops inflicted serious damage as a early blight diseases caused by fungal pathogen *Alternaria* spp. Different *Alternaria* spp. was found to be associated with various Angiospermic families but *A. alternata* (with a few morphological differences) usually infects members of these three vegetable providing families. Besides these pathogenic infections are reported due to *A. tenuissima* and *A. cucumerina* on cucurbitaceous; *A. brassicae, A. brassicicola* and *A. raphani* on brassicaceous and *A. solani, A. longipes and A. crassa* on solanaceous plants. For controlling the diseases a number of new chemicals were synthesized and evaluated and so also the biological control agents including bacteria, Actinomycetes and fungi. Some plants and plant products were also found to be useful in controlling Alternaria infection.

Keywords- *Alternaria*, Early blight, Cucurbitaceae, Brassicaceae, Solanaceae

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Introduction

Vegetables constitute the most important and cheap constituents of a balanced diet, which people now realize due to their high nutritive values indispensable for the body. There are reports about the increasing demand of brassicaceous vegetables in market [51]. India has second position in vegetable production in the world, next only to China with an annual production of 81 million tonnes from 5.1 million hectares of land [28]. During the last two decades, considerable emphasis has been laid on increasing production of vegetable crops in India [6]. However, the diseases caused by *Alternaria are the* major factors responsible for low production of cucurbitaceous, brassicaceous and solanaceous. The whole crop destroyed by the blights and caused the serious disease rapidly in a few days. Therefore, the problem deserves immediate and effective measures of control.

The Pathogen: The Genus Alternaria

Classification

Phylum	: Ascomycota
Division	: Deuteromycotina
Sub-division	: Pezizomycotina
Class	: Hyphomycetes
Order	: Pleosporales
Family	: Dematiaceae

Alternaria Nees. ex Fr. are cosmopolitan, surviving both as saprophytes as well as weak parasites. The formation of polymorphous conidia either singly or in short or longer chains is distinguishing this genus. It has longitudinal as well as oblique septa and longer or short beaks.

The spores of these polyphagus fungi occur commonly in the atmosphere and also in soil. The telomorphs (sexual stage) are known in a very few species and placed in the genus Pleospora of class Loculoascomycetes of sub-division Ascomycotina, in which sleeper-shaped, muriform ascospores are produced in bitunicate asci.

History

The genus *Alternaria* was first recognised by Nees [42] Berkeley [4] identified the causal fungus on plants belonging to family Brassicaceae as Macrosporium brassicae Berk., which was later renamed as *Alternaria brassicae* (Berk.) [49]. Thereafter, Elliot studied the taxonomy of *Alternaria* in detail [16]. Wiltshire pioneered the basic studies of this group of hyphomycetes. His descriptive literature was fundamental to the prevailing concepts of *Alternaria, Macrosporium* and *Stemphylium* [73,74]. Later, Neergaard made an extensive study on the taxonomy, parasitism and economic significance of this genus [41]. The morphological variations of *Alternaria* species were described [26] and later he divided these in three sections and proposed a simple key for identification and determination of the most common species [27]. In India, the first report of *Alternaria* was made from Pusa (Bihar) on a herbarium material of Sarson (*Brassica* sp.) [34]. The appearance of pathogen *Alternaria* spp. was noticed *by* Dey [14] in Uttar Pradesh. A complete account of distinguishing characters of the

Indian species of *Alternaria* has been described [63].

Ellis [17,18] *reported t*he characteristic features of a number of *Alternaria* species described in "Dematiaceous Hyphomycetes" and "More Dematiaceous Hyphomycetes".

The spores of *Alternaria* species are always multi-celled and often beaked. The cells are separated transversely and longitudinally.. Spores are dark and borne singly or in chains.

The subsequent diseases principally affect the foliage of these crops and can result in losses in commercial fields and home gardens.

Table-1 *Some Alternaria species and the diseases they cause on specific hosts*

S. No.	*Alternaria* species	Cause on specific hosts
1.	*Alternaria dauci*	Carrot leaf blight
2.	*Alternaria radicina*	Black rot of carrot
3.	*Alternaria brassicae* and *Alternaria brassicicola*	Leaf spot of crucifers, infests many vegetables and roses
4.	*Alternaria solani*	Tomato early blight and fruit rot
5.	*Alternaria brassicicola*	Broccoli headrot, grows on cole crops
6.	*Alternaria tenuis* and *Alternaria alternata*	Fruit spot on peppers
7.	*Alternaria arborescens*	Stem canker of tomato
8.	*Alternaria arbusti*	Leaf lesions on Asian pear
9.	*Alternaria blumeae*	Lesions on Blumea aurita
10.	*Alternaria brunsii*	Cumin bloosem blight
11.	*Alternaria carotiincultae*	leaf blight on carrot
12.	*Alternaria carthami*	Grows on parsnip
13.	*Alternaria cinerariae*	Grows on parsnip
14.	*Alternaria citri*	grows on parsnip
15.	*Alternaria conjuncta*	grows on parsnip
16.	*Alternaria dianthi* *Alternaria dianthicola Alternaria euphorbiicola*	Infests cole crops
17.	*Alternaria gaisen*	Ringspot disease of pears
18.	*Alternaria helianthicola* *Alternaria hungarica* *Alternaria infectoria*	Infests wheat
19	*Alternaria japonica*	Infests cole crops
20.	*Alternaria limicola*	Earliest diverging lineage of Section Porri
21.	*Alternaria linicola*, *Alternaria longipes*	Infects tobacco
22.	*Alternaria molesta*	Skin lesions on porpoises
23.	*Alternaria panax*	Causes ginseng blight
24.	*Alternaria petroselini*	Causes parsley leaf blight
25.	*Alternaria radicina*	Causes carrot decay
26.	*Alternaria raphani*, *Alternaria saponariae*, *Alternaria selini*	Causes parsley crown decay
27.	*Alternaria senecionis*, *Alternaria solani*	Causes early blight in potatoes and tomatoes
28.	*Alternaria smyrnii, Alternaria tenuissima*, *Alternaria triticina*, *Alternaria zinniae*	Infests alexanders and parsleys

Biology of the Disease: *Alternaria* Leaf Blight

The fungal disease of carrot leaf and petioles *caused by Alternaria* is common. While this disease not hurts directly but yield loss occurs when petioles become so brittle due to mechanical harvest leaving carrot foliage and root in the ground. The spots of *Alternaria* leaf spread out speedily in warm and moist weather so that the entire field may appear to have been injured by chemicals and frost.

Severity of crop loss will be additional when plants become infected early in the season. On watermelon and muskmelon *Alternaria* leaf blight is mainly found, but may occur on, squash cucumber, gourds and pumpkin. This disease have an impact on foliage and rarely on fruit. *Alternaria* leaf blight caused by fungus *Alternaria dauci*, basically attacks older plants, even though seedlings may also be infected.

Symptoms

Among the different diseases caused by the genus *Alternaria*, blight disease is most dominant one that causes average yield loss in the range of 32-57% [11]. Symptoms of this disease include presence of irregular, often circular brown to dark brown colour leaf spots having concentric lines within the spots. Disease symptoms first appear on older leaves as small necrotic spots that may be surrounded by a yellow halo. Often the circular spots coalesce to form large patches resulting in the leaf blight. In quite a few cases dark coloured small spots are also formed on pods and tender twigs [68]. For *Alternaria* blight management, early sowing [37] of properly stored clean certified seeds after deep ploughing along with clean cultivation, suitable weeding and optimum plant population , avoidance of irrigation at flowering and pod formation stages are few steps followed for well organized management of the disease.

With the disease progression, the round spots might grow to 1⁄2 inch (1 cm) or more in diameter and are usually gray, gray-tan, or near black in color, leaves curl and die, leading eventually to plant decline. Due to fluctuating environmental circumstances, Pathogen growth rate is not uniform, thus spots develop in a target

pattern of concentric rings. Where host leaves are large enough to allow unrestricted symptom development, the target spots are diagnostic for *Alternaria* as there will be few pathogens causing this type of diagnostic expression. Apart from the target pattern, a fine, black and fuzzy growth often covered the lesion. This growth is the *Alternaria* fungus sporulating upon the dying host tissues.
Many species of *Alternaria* also produce toxins that diffuse into host tissues ahead of the fungus. That is why Yellow halo is not uncommon to see that fades into the healthy host tissues that surround the mark spot. Shady, sunken lesions are generally the appearance of *Alternaria* infections on roots, tubers, stems, and fruits. In these cankers, fungus may sporulate, causing fine, black, velvety growth of fungus and spores to cover the affected area.

Cause and Disease Development

Conidiophores of majority of the species of *Alternaria* produce asexual spores (conidia) measuring between 160- 200 μm long. Under *in vitro* conditions, sporulation occurs at a temperature range of 8-24 ºC, whereas after 14-24 h mature spores occur. Favourable temperatures are between 16 ºC and 24 ºC where sporulation time ranges from 12 to 14 h. Presence of moisture in the form of rain, dew or high humidity are essential for infection and a minimum of 9-18 h are required for majority of the species [23]. Continuous moisture of 24 h or longer practically guarantees infection [47,10]. Large number of Mature spores produce in 24 h if Relative humidity is greater than 91.5% (at 20 ºC) [23].
Between crops, plant pathogenic *Alternaria* species survive as spores and mycelium in infected plant residues or in and on seeds. Seed borne fungus may attack seedlings, resulting damping-off, stem lesions, or collar rot. Most often, how- ever, the fungus grows and sporulates upon plant residues during rain, heavy dew, or under conditions of good soil moisture. Spores are windblown or splashed onto plant surfaces where infection occurs. For germination and infection, spores must have good moisture. Host penetrates directly either through wounds, or through stomata. Stressed, weak, old, or wounded tissues are more liable to invasion than sound, vigorous tissues.
Alternaria cucumerina causing leaf blight overwinters as a saprophyte on decaying crop debris in the soil. It is spread from plant to plant when wind and splashing water carried conidia from diseased plants to susceptible tissues. Germinating spores can penetrate the host directly, as well as through wounds and natural openings. Wet conditions and warm temperatures favor disease development.
It was found that *Alternaria* affects all the aerial parts of the plants i.e. stem, leaves, fruits, pods and heads. A comprehensive, comparative account of morphological differentiation of different *Alternaria* species occurring on cucurbitaceous, brassicaceous and solanaceous crops [40,31,13]. It is observed that with increasing in leaf wetness duration, disease severity increases at all temperatures. The maximum observed mean disease severity occurred after 24 hrs duration of wetness at 180C [21]. There are reports that the disease appeared in the first fortnight of July and maximum disease intensity was noticed when the temperature ranged in between 25 to 28^{0}C and average relative humidity was more than 80%. Rainfall was held greatly responsible for the severity of infection and disease development [2]. However, others [35] had found that on radish leaves, the disease developed at a temperature range of 15-25^{0}C and 100% relative humidity for 10-12 hrs.

Fig-1 *Alternaria* leaf blight on Muskmelon leaves

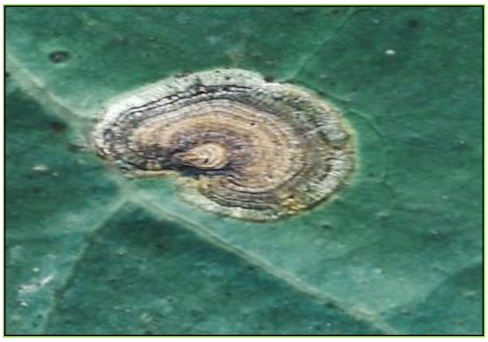

Fig-2 Leafspot of crucifers caused by *Alternaria brassicae*, showing the typical target spot composed of concentric rings.

Disease Cycle

The fungi that cause *Alternaria* leaf blight overwinter in diseased plant debris and on wild perennial hosts. The fungus can survive in debris for 2 years. *Alternaria* may also spread on or in contaminated seed- the primary means of transmission to new production areas. During the growing season, spores are spread by wind, water, and field equipment. Infection requires leaf wetness, which allows spores to enter through pores in the leaves. Lesions appear 3-5 days later and soon become source for new inoculums. However, they cannot persist free in the soil for too long once the tissues are thoroughly decomposed. The length of time the crop residue persists in soil is dependent on type of soil and favourable environmental conditions. The rate at which disease spread in the field is dependent on the available initial level of inoculum (contamination of seed and/or effected residues), air temperature, and the presence of water in the form of dew, rain, irrigation or high humidity. Infection caused by *Alternaria dauci* is favored by moderate to warm temperatures and wetness of the leaf. With the increase in temperature, the duration of leaf wetness decreases to required for infection to occur between 8-12 h infection occurs at temperatures of 16-25ºC (61-77ºF). Upon dead necrotic tissue, the fungus readily sporulates resulting in the germination of spores in water droplets and dew.

Disease Management

Alternaria is difficult to control so prevention is the best strategy. A number of *Alternaria* species infect the vegetable crops belonging to several families and reduce yield both qualitatively and quantitatively. Hence, there is a strong need to effectively control this polyphagus, destructive group of fungi. There are several methods, which are being employed for this purpose.

Cultural Practices

Harvesting crops on time will contribute to reduced crop loss as a result of the leaf blight diseases. Immediate plowing below the crop debris will decrease inoculum build-up and survival of leaf blight pathogens. For decomposition of crop residue and also for reducing fungal and bacterial leaf blight pathogens and their diseases, it is more significant to practice a minimum of a 2 year crop rotation. Practices like wider row spacing, breaking compacted layer, and planting on raised ridges helps in reducing leaf witness duration and soil mloisture will be helpful. Generally, Alternaria leaf blight is more severe on poorly fertilized and stressed carrots. Therefore, keeping injured free crops and vigorously growing (proper fertility, gibberellic acid application) resulting from chemical applications will aid in the control of Alternaria leaf blight.
By Planning In fields, the planting of prone varieties shall be avoided with infected residues from a previous crop retained on the surface.
By Ground Preparation Earlier crop residue shall be incorporated. A part from this, balanced crop nutrition especially of potassium should be provided.
By seed treatment this method is an effective measure in controlling *Alternaria* diseases as it helps in reducing primary inoculums. The best way to proactively reduce the severity of the leaf blight diseases is to use vigorous, healthy and treated seeds for reducing or eliminating this potential inoculum source. To control *Alternaria* diseases in cabbage, seeds were treated in hot water for 30 min at

50°C was recommended by Walker [71] while, to eradicate *Alternaria* infection from *Brassicaceae* seeds [19] recommended same temperature for 25 min. Seed treatment with Mycostop -a powdery formulation of spores and mycelium of *Streptomyces griseoviridis* was recommended to control *A. brassicicola* damping-off [72]. Mixed fungicide treatments have also been found to effectively control various *Alternaria* infections. In chilli seed treatment with Thiram + Captan (1:1) 0.3% and four sprays of Zineb (0.25%) were found quite effective to control *Alternaria* diseases [25].

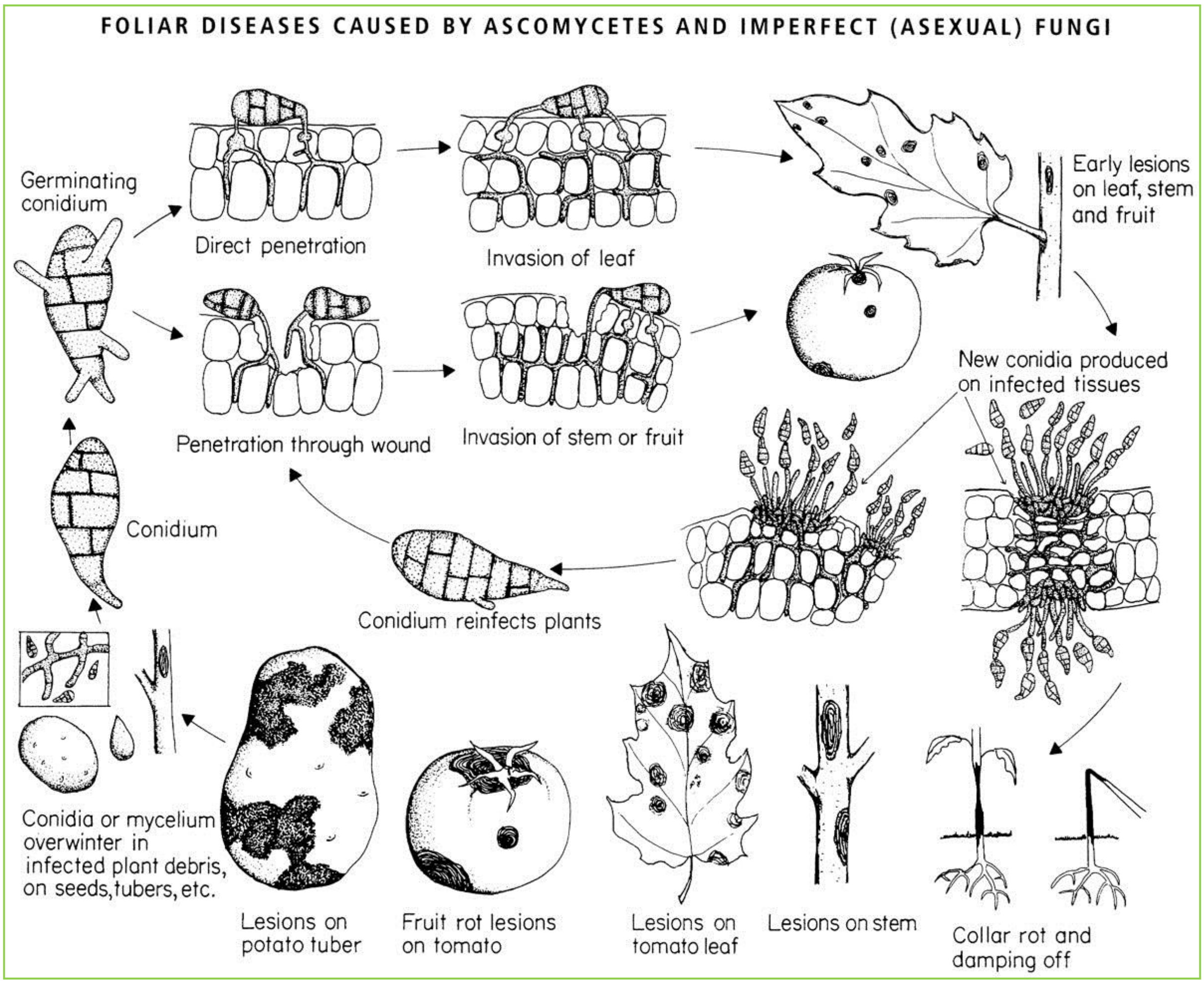

Fig-3 Development and symptoms of diseases caused by *Alternaria.*

By disease Resistant Varieties

For releasing various disease resistant varieties, the in-built resistance is increased and it becomes cost-effective for the farmers making it efficient right through their life. For example, *Cucumis melo* line MR-1 is resistant to *A. cucumerina* [66] whereas [36] found watermelon varieties Sel-1 and Sugar baby to be resistant and Meetha, Durgapura, AY, highly susceptible WHY & WHY-4 and RW-177-3, RW-1, RW-187-2 and Milan as moderately susceptible against *Alternaria* leaf spot. [29] found three varieties of bottle gourd namely, Azad Harit, 7002 and 7003 to be resistant against *A. cucumerina*. CA 87-4 and CA 748 are the two extremely resistant chilli genotypes were identified against fruit rot caused by *Alternaria* [64] while genotypes of tomato *viz*. Arka Alok, Arka Abha, Arka meghali, Arka Saurabh, IIHR-305, IIHR-308, IIHR-2266, IIHR-2285 and IIHR-2288 against early blight found to be resistant [35]. Mora and Earle [39] obtained transgenic broccoli (*Brassica oleracea* var. italica hybrid green comet) plants expressing a *Trichoderma harzianum endochitinase (chitinase) gene*. The primary transformants (T0) and selfed progeny (T1) were examined for their resistance to the fungal pathogen *A. brassicicola*. Leaves of most mature T0 plants in comparison to control plants had 14-37 times more endochitinase activity. When T0 plants detached leaves were inoculated with *A. brassicicola*, lesion size showed a significant negative correlation with the level of endochitinase. Inoculation with *A. brassicicola* of all the 15 transgenic lines of T0 plants, which are one month old, showed significantly less severe disease symptoms than the control plants. Similarly, many researchers are working on the expression of different genes encoding for proteins vital for inducing resistance in various crops across the world.

Chemical management

Alternaria, Cercospora and bacterial leaf blight are control by various effective materials that are listed in the Integrated Crop and Pest Management Guidelines for Commercial Vegetable Production provided by Cornell's Cooperative Extension program. In Canada, research showed that the 25% disease occurrence as a threshold for timing the first fungicide application for controling *Alternaria* and *Cercospora* disease. In New York, field data collected over a number of growing seasons had verified and validated the use of the first fungicide application as the trigger for the 25% disease occurrence under New York growing conditions. Due to differences in variety susceptibility, it is essential to scout and make management decisions by variety, since different varieties at different times will attain the level of disease threshold. Once the first fungicide application is made, subsequent sprays may be determined based on: 1) Foliar application according to calendar schedule, based on recommended intervals for the specific fungicide used; 2) by continue looking to investigate disease progress and monitoring temperature and forecasted rainfall (a spray is compulsory if severity of disease has increased, rainfall is predicted for the following 5 days and/or night temperature is greater than 60ºF) or 3) using of Tom-Cast model (early blight model for Tomato) which is available for some IPM weather stations through the Northeast Weather Association (NEWA). Model of Tom-Cast takes into account temperature and leaf wetness for calculating a disease severity value (DSV). It is suggested that a fungicide application be made once >15 DSV's have accumulated since the earlier spray. Once a fungicide is made the accumulated DSV's go back to zero and the process begins again. Research results have indicated that to control *Alternaria* and/or *Cercospora* application of a copper-based bactericide may delay the need for the next fungicide application. Careful monitoring of disease incidence severity and weather conditions will diminish the number of sprays needed to manage blight diseases, thus enabling the grower to diminish environmental impact and decrease input costs too. For preventing resistance development and to reduce costs alternation of fungicides is recommended. Results showed that alternating one of the registered fungicides in managing *Alternaria* and *Cercospora* with a copper material were also effective and may prove beneficial in keeping bacterial leaf blight under control.

By Fungicides

Disease caused by *Alternaria* can be control by the effective application of fungicides. At 5000 ppm, thiram (75%) proved as the most successful fungicide whereas Thiram (TMTD 80%) and Arasan 50% lead to complete inhibition of *Alternaria* at 10,000 ppm [50]. A part from this, Dithane M-45 was considerably superior fungicide against *A. cucumerina* causing leaf blight of watermelon followed by Bavistin, Dithane Z-78, Difoltan, Blitox and Bordeaux mixture. Similarly, for control of *Alternaria* blight of cauliflower, Captafol as compared to Dithane M-45 was found best to provide maximum yield [62] where as for *Alternaria* blight of radish seed crop, Dithane M-45 (0.25%) proved more useful, followed by 0.4% Bordeaux mixture [24]. Mycelial development of *A. solani* was found most efficient by the use of Mancozeb (0.2%) [9]. The effectiveness of Mancozeb in controlling early blight of tomato [60]. Fruit rot caused by *A. alternate* have been delay by 30 min. by the application of different hormones such as Indole-3-Butyric Acid or Naphthalic acid at 200 µg/lit concentrations [12]. In controlling *Alternaria* blight of potato, Emisan-6 with Indofil M-45 combination found to be most effective followed by the combination of Emisan-6 with Indofil Z-78 [59]. Mancozeb followed by Thiram, Bavistin and Iprodione also proved effective as seed dresser. Under *in vitro* conditions non-systemic fungicides such as Iprodione and Mancozeb and among systemic fungicides thiophanate methyl was found to be effective [46]. Singh and Singh [61] tested efficacy of seven fungicides *viz*., Chlorothalonil, Copper oxychloride, Azoxystrobin, Propineb, Copper hydroxide, Mancozeb at different ppm i.e, 2500, 2000, 1000, 500 and 250 ppm and Hexaconazole against *A. alternata* at 1000, 500, 200, 100 and 50 ppm causing blight of tomato. Their observations revealed that the radial growth of the fungus significantly reduced by the use of all the fungicides whereas hexaconazole was very effective as it caused 100% growth inhibition [70]. The best control of *Alternaria* leaf spot disease of bottle gourd was obtained by spraying recommended @ 0.2% Indofil M- 45 followed by Copper oxychloride, Chlorothalonil, Indofil Z-78, Ridomil,Cuman L, Jkstein and Topsin-M [30]. Indofil Z-78, Vitavax, Indofil M-45 and Kavach found to be most effective in reducing the mycelial growth of *A. alternata* infecting brinjal *in vitro* followed by Thiram, Bavistin and Benlate [58]. Sidlauskiene [55] found that Amistar was very effective in controlling leaf spot of *Alternaria* in tomato, cucumber and cabbage as it reduces the disease incidence by 88-93%; whereas Euparen plus Bion were found to increase biological efficiency [70]. Singh and Singh [57] reported that three sprays of 0.25% Dithane M-45 proved superior to various fungicides e.g., Kavach, Baycor Bayleton, Foltaf and Contaf 5 EC in terms of additional yield. They advocated sprayings of Kavach (0.1%), Dithane M-45 (0.25%) or Foltof (0.25%) for 3 times at 10 days interval for adoption by the farmers for controlling *A. brassicicola* on cabbage [70]. The sulfanilamide derivatives of chitosan prepared [38] showed significant inhibiting effect on *A. solani* at 50 to 500 µg/ml concentrations. The potassium and sodium bicarbonate and Nerol had significant inhibitory effect against *A. solani* causing early blight in potato. Fungus was completely inhibited with potassium or sodium bicarbonate at 2% and Nerol at 0.5% [1]. The combined treatments of potassium or sodium bicarbonate at 1 or 2% and Nerol at 0.5% reduced the disease incidence by more than 81.6% and increased the tuber yield by 82.6 or 72% respectively, during two growing seasons. Singh [56] found three sprays of 0.25% Ridomil MZ (i.e. @ 2kg/ha) at 10 days intervals were most effective in controlling early blight of potato caused by *A. solani* followed by Melody Duo 66.75 WP (@ 2.5kg/ha and 2 kg/ha) and Antracol 70 WP.

By Bio-control agents

Various bacteria and actinomycetes have antagonistic properties. Keeping in view, use of various bio-control agents is being encouraged. These bio-control agents are eco-friendly too that is why there use is increasing day by day.. The antagonists like *T. koningii, Chaetomium globosum*, *Fusarium* spp and *Trichoderma harzianum* effectively controlled seed-borne *A. raphani* and *A. brassicicola* in radish [69]. A pigmented and xylose utilizing strain of *Streptomyces bobili* was found to be active against *A. brassicae*, *A. brassicicola* and *A. raphani* [53]. Effective inhibition of mycelial growth of *A. solani* by *Trichoderma viridae* and *Bacillus subtilis* causing leaf blight of tomato has also been reported [3].

Fungicidal activities of the secondary metabolic products of an actinomycete strain, A 19 were determined *in vitro*. Its fermentation broth had inhibitory effect against *A. alternata* and some other fungi [77]. Antagonistic bacteria strains B-916, H-91, G-329, P-6854 and JND were used to control early blight of tomato caused by *A. solani* in pot and field experiments [76]. It was observed that the antagonistic bacterial solution containing 2 x 106 spores/ml when applied @ 1 ml/pot and 100 ml/m2 in field, reduced the growth of hyphae of *A. solani* by 29-85% and 61-80%, respectively. In another experiment, *Brevibacillus brevis* strain KH-7 and *Bacillus firmus* strain M-10 exhibited antagonistic activity against *A. solani* and also enhanced the growth and yield of potato [44]. Ping [45] isolated 29 strains of endophytic actinomycetes from surface – sterilized plant tissues of wild plants. Out of these the fermentation filtrate of SG 2 metabolites exhibited greater antagonism against *A. solani*. Under greenhouse conditions the control efficacy of SG 2 and SG 4 reached 89.7% on *A. solani*. The chitosanase strain BS-0409 of *Bacillus megaterium* showed antifungal activity against *A. solani* [15]. The culturable leaf-associated bacteria inhabiting a plant were considered as a promising biological control agent (BCA) candidate because they could survive on the plant [20].

It was also found that *Pantoea* and *Bacillus* showed antifungal activity both in *in-vitro* as well as *in-vivo* conditions, but *Curtobacterium* and *Sphingomonas* showed antifungal activities only in *in-vitro* against *A. solani* isolated from tomato**.** A washed cell suspension of the antagonistic yeast Pichia guilliermondii was effective in inhibiting the pathogen; also, tomato fruits treated with the antagonist inoculum concentration 10^7-10^8 CFU ml^{-1} had significantly lower incidences of disease and smaller lesion diameters [78].

By herbal extracts and natural products

The use of various herbal extracts and natural products is being encouraged because these cause no health hazard or pollution. Also, these products are cheaper than chemicals with minimal or practically no adverse side effects on hosts. The extracts of *Lawsonia inermis, Canna indica*, *A. sativum*, *Ipomoea palmata*, *Cenchrus catharticus*, *Mentha piperita*, *Prosopsis spicigera*, *Allium cepa*, *Argemone mexicana*, *Convolvulus arvensis, Datura stramonium* and *Clerodendron inerme* fully inhibited the germination of spore of *A. brassicae* isolated from leaves of cauliflower [54]. Garlic bulb extract had inhibitory effect on *A. tenuis* mycelial growth i.e, causal organism of brinjal leaf spot [12]. The strong inhibitory action of ethanolic or methanolic extract of speed weed (*Polygonum perfoliatum*) against conidial germination of *A. brassicicola* causing leaf spot of spoon cabbage [8]. The neem leaf extract showed high efficacy to inhibit the radial growth of *A. solani* (43.3% at 0.1% and 26.7% at 0.01%) [52]. Hence in controlling *Alternaria* diseases, there are a number of effective herbal extracts and herbal products with no health hazards or pollution.

It was interesting that cold-water extracts were more effective than the boiled water extracts. [75] leaves extract of *Lawsonia alba*, roots of *Datura stramonium* and inflorescence of *Mentha piperita* had fungitoxic activities against *A. brassicae* isolated from cauliflower leaves. Two sprays of 10% leaf extract of *Aegle marmelos* combined with 0.01M nickel sulphate at the age of 100 and 115 days after sowing significantly reduced the disease intensity in chilli [64]. An antifungal peptide, Ay-AMP has been isolated, from *Amaranthus hypochondriacus* seeds and was found effective in controlling *A. alternata* at very low doses [48]. Ay-AMP degrades chitin and is very resistant to proteases and heating. [8] methanol extract from stems and leaves of *Myoporum bontioides* exhibited inhibitory activity against *A. alternata* with > 58% inhibition at 10gL-1after 12 hr. The active compound responsible for inhibitory activity was identified to be (–) epingaione. The ethanol extract of *Glycyrrhiza glabra* L. (commercial Licorice) and methanol extract of *Taverniera cunefolia* (a wild plant used as a substitute for commercial licorice) at 0.02% concentrations were proved very effective against *A. brassicicola* [78,32] amongst 4 neem products tested, achook and bioneem were quite effective as compared to furpume and nimbicidine against *A. brassicae*. Bhardwaj and Laura [5] screened 20 plants for their antifungal activity against *A. brassicae* which causes leaf spot diseases of brassicaceae and brown rot of cauliflower and found that the maximum inhibitory effect was shown by leaf extracts of *Camellia sinensis* followed by root extracts of *Asparagus racemosus, Aloe vera, Acacia nilotica and Anthocephalus cadamba* whereas *Astercantha longifolia* showed moderate inhibition. Growth of *A. solani* on tomato was considerably inhibited by the extracts of garlic bulb and Prosopis leaf [60]. Maximum *in vitro* inhibition of mycelial growth and spore germination of *A. solani* was observed with (5-10%) dried root extracts of *Acorus calamus* **[**66]. Extracts from *Prosopis julifera* (10% leaf) and garlic (5% bulb) gave moderate levels of inhibition. mycelial growth also inhibited by Palmarosa oil (0.1 and 0.05%), Neem 60 EC (3%), Neem oil (3%) and Madhuca indica oil (3%). Among the antagonists, *Bacillus subtilis, Trichoderma viride* and *Gliocladium virens* also inhibited mycelial growth of *A. solani*. Lower intensity of disease symptoms on potato plants was recorded when treated with Biosept 33SL, which is a biological preparation containing 33% extract from seeds and flesh of grape fruits [33]. Statistically significant differences as compared to the control different combinations were observed, however, the efficacy of treatment was not satisfactory [43]. Conducted experiments both *in vitro* and *in vivo* to test the effect of caffeic acid phenethyl ester (CAPE; a resinous component of propolis, collected by bees having positive effects on human health) on *A. alternata* infected tomato fruits. Hence, they concluded that CAPE controls *A. alternata* infection better than a commercial fungicide having no side effects on ripening of tomato fruit and fruit quality.

By other methods

Apart from the various methods mentioned above, various different methods helps in combating devastating effects caused by *Alternaria* species. [22] *A. solani* causing early blight induced a significant reduction on intercropping of tomato with marigold (*Tagetes erecta* L.). This was achieved by three different mechanisms like:

(i) marigold allelopathic effect on conidial germination *of A. solani*,
(ii) by shifting the microclimatic conditions around the canopy, particularly by decreasing the number of hours/day with relative humidity ≥ 92%, thus diminishing conidial development and
(iii) provides a physical barrier against spreading the conidia. In addition to this, after harvesting incorporation of residues is one more measure to decrease the harmful effects of *Alternaria*. Control of alternative weed hosts also help in the same.

Scouting/ Field Monitoring: As stated previously, due to differences in disease susceptibility it is not only significant to scout carrot fields by variety, but also sample enough plants for providing correct assessment of the level of disease on that variety. While walking across a 'V' or 'W' shaped transect field, a minimum of ten sampling stops should be made (more stops considered in bigger fields). Five leaves of five adjacent plants are scored for disease incidence. If, one or more lesions are found it shows that leaf is infected. The 25% leaf blights disease (50 leaves sampled (approx. 12 leaves)) incidence threshold for *Alternaria* and *Cercospora* to trigger the first fungicide application. Disease severity is determined on a scale of 1 to 9 and on the basis of percentage of leaf surface which is blighted. A scale of A = 0% (healthy), B = up to 1%, C = 2-5%, D = 6-10%, E = 11-20%, F = 21-30%, G= 31-40%, H = 41-50% and I = over 50% of the leaf surface blighted. Disease progress is determine by disease severity and along with forecasted rainfall and temperatures, the need for additional sprays.

Conclusion

From the above study, it is concluded that the Alternaria is a very destructive fungus for vegetable crops, but with the application of advanced techniques, it is easier to control this cosmopolitan fungus. One of the most commonly used method is the use of fungicides, but these fungicides causes serious health hazards to human beings and also they cause environmental pollution. Hence, nowadays more emphasis is given on other methods of disease control like growing variety which is disease free, using plant and natural products, bio-control agents and alterations in agronomic practices etc. because they are cost-effective, eco-friendly and safe to use. The Rotation should be done for cucurbits at least 3 years. The good sanitation practices should be followed, such as cleaning up crop debris at the end of the growing season. Muskmelon plant cultivars have some resistance level; newer varieties are believed to be somewhat resistant to *Alternaria* leaf blight as compared to older, traditional cultivars. Apply fungicides that are registered for controlling this disease. Ultraviolet light has been shown to be essential for spore formation in *Alternaria* species. Therefore, incidence of some *Alternaria* diseases can be reduce by the use of ultraviolet light-absorbing film under greenhouse growing conditions, Finally, there are numerous fungicides that have activity against *Alternaria* fungi. Imazalil, Maneb,Chlorothalonil, Captan, Thiram, Iprodione, fludioxonil, Mancozeb, and selected copper fungicides have efficacy against *Alternaria* species. Consult the product label for registered uses and dosage recommendations.

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