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Sclerotium Rot is a Chronic Disease of Sunflower- Comprehensive Review

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ABSTRACT: Sunflower (*Helianthus annuus* L.) is one of the most widely grown oilseed crops in the world. Sunflower mostly grown as zaid crop which requires cool climate during germination, warm weather from seedling to flowering and sunny and non-cloudy during maturity. It performs well in sandy loam and black soil with a good well-drained facility. Diseases caused by fungus, bacteria, viruses, and phytoplasma are the most common biotic factor. Among these, *S. rolfsii* is the most destructive fungal pathogen that causes collar rot of sunflower. It attacks the basal portion of the stem which causes rotting and leads to wilting of the plant. Due to wilting translocation of solutes to upper portion of the plant stopped and the plant ultimately dies. If this pathogen is not managed properly it results in yield loss of sunflower. To avoid yield loss and economic benefits of the farmer control of pathogen is a very necessary and challenging task. So, for efficient and sustainable crop production there is a need to fully understand pathogen taxonomy, biology, epidemiology, disease cycle, and management.

Keywords: Sunflower, *S. rolfsii*, Collar rot, Management.

INTRODUCTION

Sunflower (*Helianthus annuus* L.) oil used for cooking purpose and ranked third after soyabean and groundnut in the world. Oilseeds occupy major position in building up of Indian agricultural economy. With the global contribution of 10 per cent, India became the one of largest producer in the world. In India, the sunflower area is approximately 2.62 lakh hectares and production of 2.16 lakh tonnes (Indiastat.com, 2019). Due to the good quality and ample amount of oil in the sunflower seed (48-53%), the oil is used for a variety of cooking purposes. Sunflower oil has a good amount (64 percent) of linoleic acid and it helps to dissolve the cholesterol deposition which is why it is also considered as a remedy for the heart patient. As an oilseed crop, sunflower cultivation began in Russia and is now grown in the U.S.A., Argentina, Romania, Spain, Yugoslavia, Turkey, and South America. It was introduced in India in 1969 as an oilseed crop. Sunflower is a short life cycled crop that is why it can be grown in every season due to its desirable attributes like tolerance to drought, photoperiod insensitivity, better adaptability under varied soil and climatic conditions. Area and production of sunflower give the positive growth in recent years but there is also a gap present between the yield potential and yield realized at farmer's field, which is mainly caused by various biotic and abiotic factors. Among biotic stresses, collar rot caused by *Sclerotium rolfsii* Sacc. is one of the most important, wide host range (500 plant species) and destructive fungal disease of sunflower throughout the world (Gulya *et al*., 1997; Mukerji, and Ciancio, 2007). *Sclerotium rolfsii* Sacc. is a soil-borne necrotrophic pathogen, causing yield losses up to 10-11 percent with the infection of 10-11 percent (Kolte and Tewari, 1977). Sunflower requires warm and humid climatic conditions for luxurious growth and these climatic conditions are also suitable for collar rot infection.

Distribution and host range. *S. rolfsii* is very devastating against many crops which shows its wide host range, infected more than 500 species in 100 families worldwide (Agrios, 2005; Cillers *et al*., 2000). Due to the causal agent of many diseases like foot/collar rot in various crops this pathogen draws the attention of many plant researchers all over the world. This pathogen affects many kinds of cereal, pulses, oil crops, potatoes, vegetables, ornamentals, and nursery seedlings of fruits as well as forest trees (Agrios, 2005). The host range of *S. rolfsii* is not only limited to horticultural and agronomic important crops but also includes many non- economical important crops (Aycock, 1966). Godfrey (1918) observed infection of *S. rolfsii* of about 5 percent on wheat crop. Singh and Mathur (1953) reported stem rot of groundnut caused by *S. rolfsii* first time in Uttar Pradesh. Affected plants produced shriven nuts while ultimately affecting the yield of the crop. Mathur (1963) reported *S. rolfsii* causing chickpea wilt in Agra. First report on collar rot of sunflower caused by *S. rolfsii* was reported by Dattar

and Bindu (1974) at oilseed research station, Latur in Maharastra. Haware *et al*. (1990) reported that *S. rolfsii* pathogen is responsible for the wilt of chickpea. Rawath *et al*. (1991) reported a very heavy infestation of collar rot in chickpea in the area of Himachal Pradesh. In India, the peppermint crop is cultivated all around the year and it is attacked severely affected *S. rolfsii* which results in the low production of the peppermint in Tamil Nadu (Shukla *et al*., 1998).

Occurrence on sunflower. Collar rot of sunflower caused by *S. rolfsii* was first reported in India, at oil seed research station, Latur, Maharashtra in 1972. Kolte and Mukbopadbyay (1973) observed that collar rot disease of sunflower is of economic importance in India which reduces yield by 10% in Northern parts of India, causing loss upto 10% of the yield. The fungus causes pre-and and post-emergence damping-off, root/collar rot, and wilt in sunflowers, and is one of India's most commercially significant diseases. (Hebbar *et al*., 1991; Prasad *et al*., 1999).

Yield Losses in different crops. *Sclerotium rolfsi* Sacc. is a well-known nectrotrophic pathogen that also polyphagous, widespread, and soil-inhabiting. The pathogen affects the crops in various way and causes the disease like rot i.e., collar rot, root rot, damping off and foot rot which results in losses of plant population, and subsequently yield. Sclerotium wilt of groundnut caused by *S. rolfsii* noticed in Talgaon, Dule, Ahmednagar, Satara, Pune, Akole, and Osmonabad districts of district of Maharastra. of Maharashtra and caused 10 to 50 percent losses due to the disease (Viswanath, 2003). In a survey carried out by Siddaramaiah *et al*., (1979) of Dharwad district during 1975-76 and 1976-77 of groundnut areas and observed the complete mortality of groundnut varieties in 70 to 90 days with an infection of 7.8 percent by *S. rolfsii*. Harlapur *et al*., (1988) observed foot rot disease incidence in wheat with the 4.66 percent to 9.85 percent infection under irrigated and rainfed conditions. Mehan *et al*., (1995) reported that groundnut disease caused by *S. rolfsii* reduced crop yield 10-25 percent and in heavily infected fields there was more than 80 percent pod loss of groundnut. Tewari and Mukhopadhyay (2001) reported that in chickpea wilt *complex S. rolfsii, Rhizoctonia solani*, and *Fusarium oxysporum* f.sp. ciceri considered as major disease-causing pathogens causing 60-70 per cent yield loss.

History of pathogen *S. rolfsii.* *S. rolfsii* is widely distributed, and very damaging soil borne pathogen. Rolfs (1892) was the first who identified the fungus responsible for tomato blight in Florida (USA). He identified the spherical sclerotia, which were the most important morphological feature of the fungus, and named *Sclerotium* in 1893. Later, Saccardo (1905) in honor of Rolfs named the fungus *Sclerotium rolfsii* Sacc. Shaw and Ajrekar (1915) identified the organism as *Rhizoctonia destructens* Tassi after isolating it from rotting potatoes. Later, research revealed that the pathogen was *S. rolfsii* (Ramakrishnan, 1930). Higgins (1927) detailed studied physiology and parasitism of the fungus *S. rolfsii*, and his study established the groundwork for the modern context of *S. rolfsii* research. Curzi (1931) reported the teleomorph stage and gave the name *Corticium rolfsii*, Tu and Kimbrough (1978) suggested that the pathogen be placed in the genus Athelia, then named the fungus *Athelia rolfsii* (Cruzi) Tu and Kimbrough. Sclerotia of the fungus start to develop after 4-7 days old mycelium growth when hyphae start clustering as a compact mass. Initially, the sclerotia appear whitish in color and then becomes dark brown (Aycock, 1966). Sclerotia serve as the primary inoculum source in the development of disease as it contains viable hyphae.

Disease Symptoms. Aycock (1966) explained the general symptoms produced by the fungus *S. rolfsii* which varies with different hosts. Generally, the infection develops on the collar region as lesion of dark brown-colored just below the soil lane (Fig. 1).

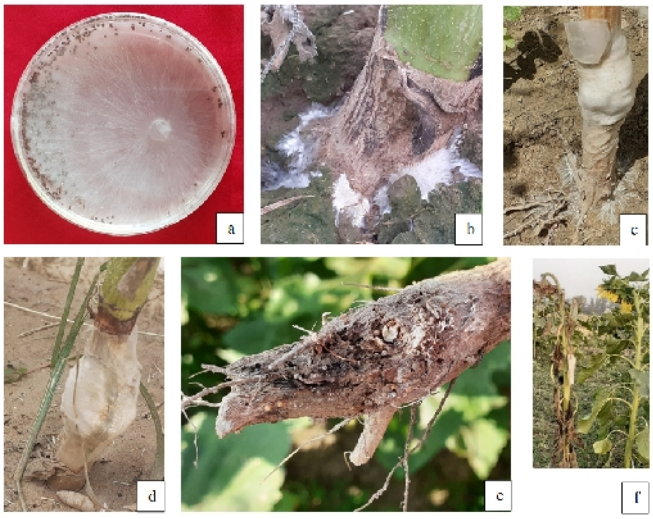

Fig. 1. a: *Sclerotium rolfsii* culture in Petri Plate, **b, c:** Mycelium infection on plant at collar region, **d: S**clerotial formation on the stem, **e:** Sclerotial formation at the infected portion of the plant, **f: P**lant wilting after infection.

Yellowing was the earliest visible symptom which leads to wilting of older leaves. This might progressively move upwards leading to wilting of the entire plant which eventually dies off. In meantime, white fungal mycelia grow both upwards and downwards leading to infection of stem and roots. Frequently, dark brown colored round sclerotia were also seen at the collar region near soil surface. Datar and Bindu (1974) described the symptoms of collar rot disease initiated by sudden wilting and drying of collar portion. The infection mostly occurred in the seedling stage. The collar region of the plant was the general point of attack, on which a tuft of white mycelium was found growing. Later on, brown-colored sclerotia were produced on the infected region of the plant. Chakrabarthy and Bhowmik (1985) explained that the fungus caused pre-and post-emergence damping-off in sunflower seedlings and collar rot in adult plants. The white mycelial growth that surrounds the stems near the soil lane produces organic acids which are toxic to living plant tissues (Cillers *et al*., 2000). After the death of the plant cells, the mycelium then affects the inside tissue stem to cause further rotting of the tissues (Fig. 1).

Mechanism of infection of the Pathogen. Oxalic acid secreted at the infection site by *S. rolfsii* secrete along with various tissue degrading enzymes such hemicellulolytic enzymes and secreted oxalic acid acts as corrosive to tissues of many genera of plants which results in the susceptibility to the pathogen (Aycock, 1966; Punja and Damiani, 1996; Ghaffar, 1976). Oxalic acid removes the calcium by reacting with the pectic compounds of plant cell walls and thereby causes the favorable condition for the activity of various cell wall-degrading enzymes (Deacon, 2006). The disintegration of the cell is caused by oxalic acid and tissue-degrading enzymes which were produced by extensive mycelial development on plant tissues. Oxalic acid and tissue-degrading enzymes also facilitate the penetration of hyphae into tissue. The pathogens then feed on the nutrients that have been extracted from the macerated tissue. (Aycock, 1966). The movement of water and nutrients through plant tissues is hampered by maceration, resulting in wilting, yellowing, and necrosis (Bateman and Beer, 1965).

Disease cycle. The soil-borne fungal pathogen *S. rolfsii* exists typically only by mycelium and sclerotia. The sclerotia serves as the primary inoculum as it survives as a hard structure which contains compact hyphae (Agrios, 2005). Sclerotia of *S. rolfsii* can be easily spread in soil by various mechanical means like implements, vehicle tires, or can be by splashing water. Upon favorable weather conditions, sclerotia become active and germinate as mycelial (Punja and Grogan, 1981). The fungus attacks the host tissue especially near the stem at the base especially by producing oxalic acid and enzymes like pectinolytic and cellulytic (Flores-Moctezuma *et al*., 2006). The compounds like oxalic acid and enzymes kill plant tissue and allow the fungus to enter into plant tissue then after entry into the plant tissue pathogen produces extensive mycelium. Sclerotia forms into plant tissue when conditions are not favorable (Mersha *et al*., 2020).

Survival and Viability of Sclerotia. After completion of its life cycle fungus produced sclerotia at the collar region of the sunflower plant. Sclerotia are the survival structure of *S. rolfsii* during unfavorable climatic conditions. Sclerotia are aggregated masses of mycelium strands (Deacon, 2006). Depth in the soil affects the survival of sclerotia. Sclerotia can survive from 2 months to 7 months depending on the conditions of the field (Aycock 1966). Gurjar *et al.* (2004) found that after being buried in soil for more than 4 cm, the viability of *S. rolfsii* sclerotia was reduced, and after 19 months, they totally lost their viability. After twelve months, Sclerotia on the soil surface exhibited the maximum viability (57.5%), followed by Sclerotia at 5 cm deep (12.5%), and Sclerotia at 10 cm depth (2.5%). (Duncan *et al.,* 2006). According to Punja and Jenkins (1984), rising gravitational pressure at deeper depths may increase substrate leakage from sclerotia, resulting in viability loss. Gandhi *et al.* (2017) found that at 15 cm depth burial in soil none of the sclerotia germinated after 8 months buried in soil as compared to 55.75 % germination observed at the same depth but after one month of burial in soil. Maiti and Sen (1988) found that sclerotia of *S. rolfsii* survived in natural soil for 225 days under the condition of controlled moisture (50%) but after that viability of the sclerotia decreases.

Management of Sclerotium Rot/ collar rot. Plants are exposed to a variety of diseases on a regular basis, and as a result, they have developed defensive systems to detect and protect themselves against a wide range of pathogens. The introduction of resistant cultivars, botanicals, bioagents, and synthetic fungicides are all used to control the disease (Draz *et al.,* 2015; Barro *et al.*, 2017).

Evaluation of Botanicals. Uses of plant extracts against many of pathogens are therefore being developed as one of the successful methods. Botanical pesticides are substances found in plants that are detrimental to plant diseases. (Dubey *et al*., 2008; Wang *et al*., 2004). Botanical pesticides are becoming more popular, and several plant products are being employed as green pesticides all over the world. Mahato (2018) observed that maximum inhibition (84.89 %) of *S. rolfsii* infection was shown by *Allium sativum* (20% concentration) respectively followed by neem (80.86%). Most of synthetic fungicides develop resistance against the pathogen and nowadays this issue is of great concern in relation to increasing food production. So, now the researchers are focusing on a better approach for the controlling of the disease. The botanicals can be seen as the best alternative for disease management due to their safe ecological solution as compared to other management practices. Botanicals contain biologically active compounds which are the true antimicrobial compounds (Table 1). Plant extract of *Pongamia pinnata* was found most effective in inhibition mycelium growth (56.72%) of *S. rolfsii* at 10% concentration (Barnwal, 2012; Akram *et al*., 2016). Sarphagandha and Neem leaves extract effectively reduced infection of *S. rolfsii* under *in vitro*

conditions (Mundhe *et al*., 2009; Suryawanshi *et al*., 2015; Butt *et al*., 2016). Plant extracts reduced the mycelium growth as well as the sclerotia formation of *S. rolfsii* under *in vitro* conditions (Singh and Dwevedi, 1989; Bhaskar and Ali, 2005). Subhadarshini *et al*., (2020) obtained the most promising results with clove oil, neem oil which were able to fully inhibit infection of stem rot (*S. rolfsii*) of groundnut.

Table 1: List of plant having antimicrobial activity.

Common Name	Scientific Name	Compound
Neem	*Azardirachta indica*	Azadirachtin
Onion	*Allium cepa*	Allicin
Turmeric	*Curcuma longa*	Cucumin
Garlic	*Allium sativum*	Allicin
Golden shower tree	*Cassia fistula*	Alkaloids, Flavonoids
Marigold	*Tagetes erecta*	Phenolic compounds
Gillardia Spp.	*G. aristata*	Phenolic compounds
Eucalyptus	*Eucalyptus glibolus*	Polyphenols, Flavonoids, Quinones, Terpenoids,
Chrysanthemum spp.	*C. indicum*	Flavonoids and caffeoylquinic acids
Calotropis	*C. gigantea*	Saponin Flavonoid Coumarin Phenol
Marijuana	*Cannabis sativa*	cannabinoids and terpenes

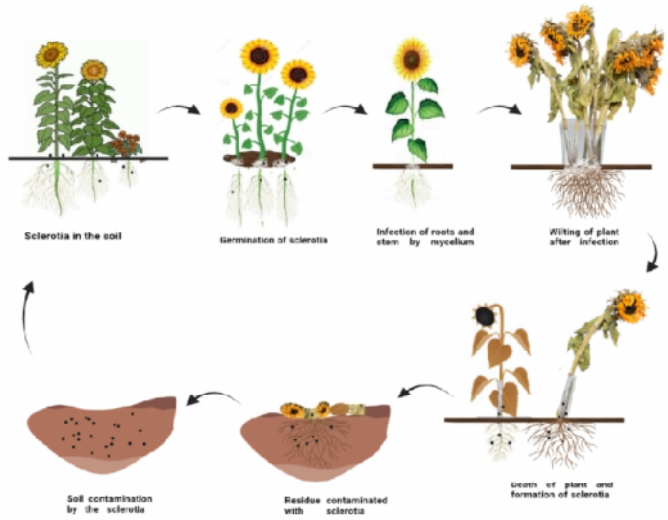

Fig. 2. Disease cycle of *S. rolfsii* infecting sunflower.

Antagonists Mechanism of bioagents. *S. rolfsii* is a damaging soil-borne necrotrophic pathogen that survives the overwinter in the soil or on plant debris as sclerotia. The soil microbes play an important role in minimizing pathogen inoculum. Among these microbes like bacteria and fungi, play a vital role in degrading the sclerotia. Variations in environmental conditions such as soil temperature, moisture, and relative humidity cause fractures in the sclerotial rinds, resulting in cell component leakage and parasitization by hostile microorganisms in the soil (Rakesh *et al*., 2016). These microbial agents are efficient biological control agents of soil-borne diseases, inhibiting pathogens by mechanisms like direct antagonism, hyperparasitism, antibiosis, or secretion of various cell wall degrading enzymes, antibiotics, or a combination of these mechanisms. (Sivan *et al*., 1984 and Coley-Smith *et al*., 1991).

Evaluation of bio-agents against *S. rolfsii.* The bio-control agents decrease the target pathogen's inoculum level below a potentially damaging and economically significant level (Baker, 1987). Cook and Baker (1983) said that "Biological control is the reduction of the amount of inoculum or disease-producing activity of the pathogen accomplished by or through one or more organisms other than a man". *Trichoderma* is one of the most promising plants pathogenic fungal biocontrol agents. Under a range of environmental conditions, specific strains can tackle a variety of diseases. (Papavizas, 1985). *Trichoderma* hyphae have been found to parasitize a variety of harmful fungi. (Chet *et al*., 1981; Wolfechechel and Jenson, 1992; Kumar and Mukherji, 1996; Bandyopadhyaya *et al*., 2002; Yasmin *et al*., 2014). Chakarbortys and Bhawmik (1985) observed that Under field conditions, *Trichoderma viride* and *Trichoderma harzianum* are highly successful in controlling sunflower collar rot disease. Muthamilan and Jeyarajan (1992) found that sclerotial development was reduced by 68.70% by different isolates of bioagents. *Trichoderma* spp. was shown to be particularly efficient in reducing *S. rolfsii* on ginger rhizomes and numerous other plants (Mukherjee and Raghu, 1997). *T. harzianum* isolates inhibited *S. rolfsii* mycelial development by 61.40 percent, whereas *G. virens* isolates inhibited mycelium growth by 39.90 percent (Prasad et al., 1999). Mesta and Amaresh, (2000) found that the *T. harzianum* local isolate-controlled disease up to 96 percent and increased yield by 26 percent over control. The antagonistic effect of ten *Trichoderma spp.* (native isolates) and the

commercial formulation of *Trichoderma* against *S. rolfsii* were evaluated by Padmaja *et al*., (2013). They observed that two isolates viz., T1 and T5 effectively inhibited the *S. rolfsii* infection. Jadon (2011) reported that biocontrol agent *T. viride* was found to be highly effective against *S. rolfsii*. *Pseudomonas fluorescens* was found most effective under *in vitro* conditions in reducing the growth of the mycelium of *S. rolfsii* (Devangan *et al*., 2014; Rakh *et al*., 2011; Roopa and Krishnaraj, 2017). Ganesan and Kumar (2005) also reported that *Pseudomonas* spp. showed antifungal activity under field conditions against *S. rolfsii* pathogen. *Trichoderma harzianum* NVTH2 (T4) was shown to be the most efficient in decreasing collar rot disease (by 39.18 percent), and boosting Gerbera plant height and root length, followed by *Trichoderma viride* TV1(Suneeta *et al*., 2017). The highest growth inhibition of *S. rolfsii* was recorded with *T. harzianum* (63.60%), followed by *T. virens* (51.5%), and *T. viride* (50.85%) (Kushwaha *et al*., 2018). A very few reports on *Coniothyrium spp.* as biological control agent were recorded in literature against *S. rolfsii* pathogen. However, some reports reflect that *Conityhyrium sp.* infects the other sclerotia-producing fungi and degrade the viability of sclerotia in soil. *C. minitans.* When reported at the time of harvest, *C. minitans* decreased the amount of sclerotia in the celery and lettuce crops (Budge and Whipps, 1991).

Efficacy of fungicides. Because of its soil-borne nature, vast host range, and sclerotia's ability to survive for prolonged periods of time under harsh conditions, management of *S. rolfsii* is extremely challenging. There are various reports in the literature where fungicides have been proven to best control many destructive soils borne diseases (Saoud *et al*., 1982; Iliesea *et al*., 1985). Uses of fungicides are one the most promosiong management method in controlling the *S. rolfsii* infection. The fungicide combination of Carboxin+thiram, hexaconazole, carbendazim, and thiophanatemethyl under field conditions completely inhibited the sclerotial germination and minimize the pre-and post-emergence mortality of *S. rolfsii* infected plants of gram and sunflower (Mondal and Khatua 2013; Mishra and Bais, 1987). Fungicides like Contaf 5EC with Bavistin 50WP and Topsin-M 80WP as soil treatment were tested *in vitro* and *in-vivo* on sorghum, gram, and sunflower against *S. rolfsii* in which Contaf was found best in reducing the mycelial growth and sclerotial germination (Tewari, 1995). Contaf used complete prevention of sclerotial germination suggested that it may be used as a soil treatment. Seed treatment with fungicides such as Captan, carboxin, thiram, propiconazole, and hexaconazole, as well as a dip treatment (3 g/liter water) or seed dressing (3 g/kg seeds) with thiophanatemethyl, greatly reduced root rot caused by *S. rolfsii* (Muthamilan and Jeyarajan, 1992; Hilal and Baiuomy, 2000; Charde *et al*., 2002). Dipping the seedling root in a solution of mancozeb (0.1%) and thiram (0.1%) successfully decreased tomato collar rot caused by *S. rolfsii* (Datta and Das, 2002).

FUTURE SCOPE

For sunflower collar rot, the following factors must be resolved:

During the infection, the plant and the pathogen needs to be analysed in the molecular basis

Search for Alternative management methods like uses of non-conventional chemicals of collar rot of sunflower.

Search for resistance like Induced and systemically acquired (SAR).

IPM and IDM strategies should be used efficiently.

Collaboration with other researchers from many fields, such as plant breeders, statisticians, soil scientists, and universities.

CONCLUSIONS

Collar rot of sunflower caused by fungus *S. rolfsii* is one of the most devastating diseases all over the world. Great economic losses are associated with this disease which provides great emphasis to the plant pathologist on the management of collar rot. Chemical control is the most commonly used method , but to reduce environmental hazards, bio-rational approaches like uses of botanical and bioagents are more helpful. Integrated disease management strategies like the combination of biocontrol agents and fungicides are effective in the suppression of the pathogen.

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