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Review Article

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A Review on Collar Rot Disease of Soybean Caused by *Sclerotium rolfsii* Sacc.

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Abstract

Soybean (*Glycine max* (L.) Merrill) is high value legume oilseed crop grown throughout world as well as India. The crop is gaining popularity as it is an excellent source of vegetable protein (40-42% protein and 20-22% edible oil on dry weight basis). Collar rot disease caused by *Sclerotium rolfsii* Sacc. is a major constraint in soybean production leading to substantial yield losses. Favourable environmental conditions are indispensable for any plant disease in addition to the virulence of pathogen, age and susceptibility of host, date of planting and survival ability. It is also important in order to forecast the occurrence of disease and in devising management practices. Analysis of weather parameters provides a base to take pre- emptive decision against the disease under a given set of environmental conditions for better management practices. Keeping these points in view, the present review has attempted to compile findings on collar rot disease of soybean, the pathogen associated with it, symptoms, mode of spread, disease cycle, strategies on integrated disease management and influence of weather parameters on occurrence of the disease.

Keywords: Collar rot, *Sclerotium rolfsii*, soybean, weather parameters

1. Introduction

Soybean (*Glycine max L.* Merr.), popularly known as 'miracle bean', is a legume oilseed crop belonging to the Pea family. It is grown throughout the globe in different climatic regions *viz.,* tropical, sub-tropical and temperate regions. The crops center of origin is China from where it spread to different parts of the world. In the current scenario, Brazil ranks first in soybean bean production. It is closely followed by USA, Argentina, China and India. The major soybean growing states in India are Madhya Pradesh, Maharashtra, Rajasthan, Karnataka, Andhra Pradesh, and Chattisgarh. The crop is gaining popularity as it is an excellent source of vegetable protein (40-42% protein and 20-22% edible oil on dry weight basis). Like the other crops, it too suffers from various diseases *viz.,* anthracnose, mosaic, collar rot, aerial blight, etc. Collar rot disease caused by *Scelrotium rolfsii* Sacc. is one such destructive disease that causes huge losses in the field. Reports of yield loss of 10-25% under normal conditions and 50-80% under severe diseased conditions have been documented (Patil and Rane, 1982).

India is the fifth largest producer of soybean in the world with an annual production of 13.5 million ton in 11.8-million-hectare area. Presently soybean is contributing 42% share of total oil seed and 22% to total oil production in the country. With increase in population, the demand of edible oil is increasing and 40% of the demand is being fulfilled by different oil seed crops and rest 60% demand is being made up by import. The cost of import of edible oil put a high pressure on our foreign exchange. Among all the oil seed crops, soybean is having the highest potential to meet the challenge of being self-sufficient in production of edible oil. The national productivity of soybean (~1 ton ha^{-1}) is quite lower than the world average (2.76-ton ha^{-1}) (Anonymous, 2021). Major soybean producing states in India are Madhya Pradesh, Maharashtra, Rajasthan, Karnataka and Andhra Pradesh. With the climatic adversities, disease and pest attack in soybean has appeared to be almost epidemic in nature. Enhancement of lower productivity of the crop is one of the major challenges in front of the soybean researchers. Biotic and abiotic stresses such as rainfall pattern, diseases and pests impede to harness the full potential of the present-day ruling varieties. Collar rot of soybean caused by *Sclerotium rolfsii* Sacc. is gaining a serious status. It is widely prevalent in major soybean growing areas of India (Prabhu and Patil, 2004; Khodke and Raut, 2010; Borah and Saikia, 2019). In Assam and other North Eastern states, collar rot caused by *Sclerotium rolfsii* Sacc. has been found to be a major disease-causing plant death and low productivity (Borah and Saikia, 2019). Reports of yield loss of 10-25% under normal conditions and 50-80% under severe diseased conditions have been documented (Patil and Rane, 1982).

2. Pathogenic Variability of *Sclerotium rolfsii* in India

Sclerotium rolfsii Sacc. causes the collar rot disease in soybean. The pathogen is ubiquitous, soilborne, polyphagous, facultative parasite. *S. rolfsii* has a wide host range of over 500 plant species which includes field and horticultural crops, woody ornamentals, herbaceous and perennial plants *viz.,* maize, wheat, gram, khesari, lentil, mashkalai, mungbean, sunflower, sesame, brinjal, bitter gourd, bottle gourd, cowpea, cucumber, okra, radish, tomato, radish, chilli, coriander, garlic, onion, apple, peanut, soybean, potato ageratum, aucuba, azalea, begonia, columbine, coneflower, forsythia, hydrangea, marigold pansy, petunia, viburnum, and zinnia (Punja, 1985; Mullen, 2001). *Sclerotium rolfsii* was first reported from blight infected tomato plants in Florida, USA (Rolfs, 1892). Saccardo (1911) named the fungus as *Sclerotium rolsii*. In India, the perfect state of *S.rolfsii* was first time successfully isolated by Mundkur (1934).

Hyphae of *S. rolfsii* on PDA appears cottony white and spread to the periphery of the Petri dishes in a radial fashion. Microscopic examination of the cultures shows that the mycelium was well separated with branched hyphae. Clamp connections and septate hyphae were visible. Sclerotia begins to form and become visible after 10 days. The sclerotia turns from white to yellow and finally to a dark brown. Sclerotia are spherical or irregularly elliptical, with a smooth, shiny surface, and measures 0.5–1.2 mm in diameter (Zheng et al*.,* 2021). Two types of hyphae are produced by the *S. rolfsii*. First type of hyphae is coarse, straight, with large cells (2-9um x 150- 250um) and two clamp connections at each septation, might exhibit branching in place of one of the clamps. The second type of hyphae is slender (1.5-2.5um in diameter), tends to grow irregularly, more commonly branched and lack clamp connections. Slender hyphae are often observed penetrating the substrate. Sclerotia (0.5-2.0mm diameter) begin to develop after 4-7 days of mycelial growth. Initially white in appearance, sclerotia quickly melanize to a dark brown coloration (Fichtner).

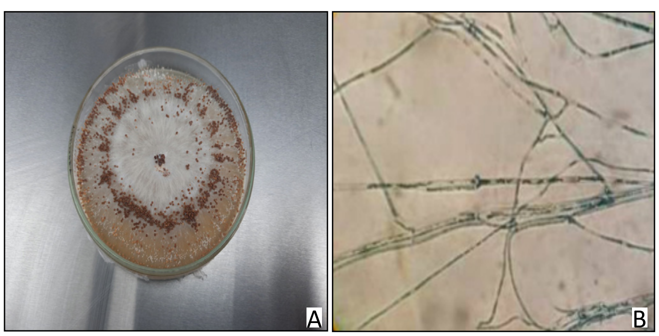

Figure 1(A): Isolation and pure culture of the fungus *Sclerotium rolfsii* Sacc.; (B): Microscopic observation of isolate showing clamp connections and septate hyphae

3. Symptomatic Variations of *Sclerotium rolfsii* Sacc. Infection in Soybean

Symptoms as pre-emergence and post emergence killing of seedlings were documented by Agarwal and Kotasthane (1971). Nyvall (1989) reported that infected leaves turn brown, dry and cling to the dead stem. Other symptoms include sudden yellowing, browning and wilting of the entire plant. White fan like mat of fungal mycelium appears on the infected stem base, leaf debris and soil surface. Tan to brown, spherical sclerotia, about the size of mustard seeds form on the infested plant and on soil surface. Zheng et al., (2021) observed at collar rot disease onset in soybean plants, the leaves gradually wilted from the bottom of the plants to the top. When humidity was high, a cottony-white mycelium appeared at the base of the stems at the soil surface, followed by the development of sclerotia. In the field, disease symptoms mainly occurred at the base of the main stem of the soybean plants and the diseased plants usually died within a few days. Asghari and Mayee (1991) reported that in stem rot of groundnut caused by *S. rolfsii* similar symptoms were produced like yellowing and wilting of branches, presence of white mycelial growth at collar region and production of mustard seed like sclerotia. Banyal et al*.* (2008) reported that *S. rolfsii* infected at collar region of tomato plants leads to drying of the whole plant thereby depicting wilting symptoms. Similar symptoms were reported by various other researchers *viz.,* Anahosur (2001) in potato.

Figure 2 (A), (B): Infection of *Sclerotium rolfsii* Sacc. causing collar rot disease of soybean in Assam

4. Information of Mode of Transmission and Diseases Cycle of *Sclerotium rolfsii* Sacc

Sclerotia serve as the principle overwintering structures and primary inoculum for disease (Aycock, 1966). Sclerotia can be found at the soil surface, either free in the soil or in association with plant debris. Those buried deep in the soil may only last a year or less, whereas those at the surface remain viable and may germinate in reaction to alcohols and other volatiles emitted by decomposing plant matter (Clark and Moyer, 1988). Thus, deep ploughing serves as a cultural control tactic by burying sclerotia deep in the soil. High temperatures and moist conditions are associated with germination of sclerotia (Punja, 1985). High soil moisture, dense planting, and frequent irrigation promote infection (Paolo, 1933). While *S. rolfsii* does not produce spores, it relies on sclerotia present in the infested soil and infected plant debris to spread. Sclerotia can be transmitted to uninfested fields by using contaminated equipment and machinery.

Sclerotium rolfsii is both seed borne and soil borne pathogen (Fakir et al., 1991). When the cottony growth of the fungus comes into contact with susceptible roots, leaves or stems, direct penetration occurs, but the fungus can also infect through wounds. It produces chemicals that cause soft rots in 2-4 days after infection. When the soft rots girdle the stem, the foliage wilts and death of the plant follows soon after. The fungal growth can easily be seen with the naked eye. About 7 days after infection, the cottony growth begins to form sclerotia. These are 0.5-2 mm diameter and made up of tightly packed strands of the fungus. They are white becoming light brown as they mature. Sclerotia keep the fungus alive when there are no plants to infect. They remain alive for several years in soil or potting mix. Other than sclerotia, the fungus can survive between crops in the remains of plants (Fichtner).

5. Influence of Weather Parameters on Development of the Pathogen *Sclerotium rolfsii*

Contributing significantly to food security, national income, and employment, the agricultural sector has a significant impact on economic development. Despite its importance, agriculture confronts a number of difficulties, the most prominent of which is climate change, which has a negative impact on crop system due to increased temperatures, rainfall variability, and the frequency and intensity of extreme weather events (OECD, 2015). Changes in environmental conditions strongly associate with difference in the level of losses caused by a given disease. *Sclerotium rolfsii* occurs worldwide but is more widespread throughout the most tropics and warmer regions of the temperate zones (Punja, 1985, Dasgupta and Mandal, 1989). Limited studies have been carried relating to the influence of weather variables on the occurrence of collar rot disease in Assam (Borah and Saikia, 2019), although reports revealed it as a major disease in North East India. Climate change, such as fluctuation in monsoon rainfall and temperature changes within a season, affects food production in India. The effect of climate change might vary in different pathosystems, depending on the host specificity, physiological interaction with host and mode of infection. Pathogen biology, its dissemination and expression of susceptibility or resistance of the host plant after infection are all influenced by environmental variables (Bana et al., 2020). Though *S. rolfsii* is a soil borne fungi, infecting the collar region and roots of various crops, the environmental factors like temperature, relative humidity and rainfall play significant role on growth and development of the pathogen, as well as on disease incidence (Garibaldi et al*.,* 2013).

S. rolfsii incite a severe disease outbreak in warm weather or summer months (Pinheiro et al*.,* 2010). The incidence of collar rot in betelvine increases with increase in temperatures at inside and outside the burrow, maximum & minimum soil temperature and maximum relative humidity inside the burrow. An optimum temperature of 30ºC favours maximum germination of sclerotia and mycelial growth in *S. rolfsii.* The soil moisture level also plays important role in survival of the sclerotia, its germination and mycelial growth of the pathogen. Increase in soil moisture has been reported to decreases the viability of the sclerotia of *S. rolfsii*. Seedling mortality up to 65% has been reported under high soil moisture conditions (Gupta and Nair, 2015). In Assam, the disease is highly sporadic requiring specific environmental conditions to develop. Disease incidence can vary greatly from year to year but is most damaging when prolonged wet conditions prevail. The percent disease incidence of collar rot shall be high as rainfall increases and thereby the pattern of rainfall can be a warning sign for the disease to appear (Borah and Saikia, 2019). Rainfall was found to be positively correlated with severity of leaf spot and dry fruit rot (*Coniella granati*) of pomegranate (Kumari and Ram, 2015).

6. Strategies for Integrated Disease Management of *Sclerotium rolfsii*

Managing the collar rot disease is not an easy task pertaining to the wide range of hosts *Sclerotium rolfsii* can attack, its prolific growth and ability to produce large numbers of sclerotia that may persist in soil for several years (Punja, 1985). Despite of these factors, the fungus can be controlled up to a certain extent by using chemical, biological, botanical, solar treatment and integrated means.

Ansari (2005) evaluated different biological agents to control collar rot (*S. rolfsii*) of soybean and recorded highest seed germination in seeds treated with *Pseudomonas fluorescence* @10 g kg^{-1} (51.11%), followed by seeds treated with *Trichoderma viride* @ 4 g kg^{-1} (47.82%). The biocontrol agents were effective in controlling collar rot incidence, increasing emergence and decreasing pre-emergence mortality. Parakhia and Akbari (2004) suggested application of *T. harzianum* II (106 cfu g^{-1}) @ 1.5 kg ha^{-1} in 300 kg of FYM just before sowing for management of stem rot of groundnut caused by *S. rolfsii*.

Konde et al. (2008) effectively controlled collar rot of soybean by seed treatment with Thiram + Carbendazim (2 + 1g kg^{-1}). Rahman et al. (2020) evaluated certain fungicides against collar rot disease of soybean. They concluded that Dithane M-45 completely inhibited the mycelial growth of collar rot pathogen *Sclerotium rolfsii in vitro* and exhibited minimum mortality percent (27.28%) of Soybean plants at 0.2% concentration *in vitro*.

Singh and Thapliyal (1998) studied the effect of seed treatment with fungicide and bioagent on seed and seedling rot of soybean caused by *S. rolfsii* and found that both pre-emergence and post-emergence seedling rot (4.8%) was effectively managed by seed treatment with integration of Vitavax 200 + *Gliocladium virens*. Khodke and Raut (2010) studied the suitability of combination of different fungicides and bioagents to control collar rot of soybean and reported maximum germination (84.54%); minimum pre and post emergence mortality (4.34%) and highest yield of 22.50 q ha^{-1} was obtained by seed treatment with Thiram @ 3 g kg^{-1} + Carbendazim @ 1g kg^{-1} + *Trichoderma. viride* @ 4g kg^{-1}.

Sahni et al. (2008) have reported that combination of $ZnSO_4$ and oxalic acid was 100% effective against the collar rot of chickpea caused *by S. rolfsii* under greenhouse condition.

Banyal et al. (2008) selected ten fungicides *viz.,* carbendazim 50 WP, carbendazim + mancozeb 75 WP, captan 50 WP, chlorothalonil 80 WP, thiabendazole 80 WP, mancozeb 75 WDG, carboxin 75 WP, propineb 70 WP, mancozeb 75 WP and tebuconazole 5 DS; five bioagents *Trichoderma harzianum* (local strain), *Trichoderma viride* (local strain), *Gliocladium virens* (local strain), *Paecilomyces lilacinus* (Bhubaneswar strain) and *T. viride* (Ecoderma). These inhibited *Sclerotium ro*lfsii causing collar rot of tomato, but the combination of tebuconazole and T. viride (local strain) controls 100% effective against *Sclerotium rolfsii*.

Soil solarization is most effective for soil pathogen *S. rolfsii* during the hot summer months where soil temperature level increased that kill many important soilborne fungal and bacterial plant pathogens. Bhardwaj and Raj (2004) reported that soil solarization with transparent polyethylene mulch (25 µm) for 40 days (June to July) was effective for the control of collar and root rot of strawberry caused by *S. rolfsii*. Soil solarization inhibit the germination of sclerotia on 40 days completely at 7 cm soil depth.

7. Conclusion

Soybean is a high value oilseed crop with multiple food, feed and industrial uses and plays a vital role in agricultural economy of India. Collar rot of soybean is a destructive soil borne disease causing considerable yield losses. The pathogen, *Sclerotium rolfsii* is very difficult to manage because of its diverse nature of survival as large number of sclerotia produced and their ability to persist in the soil for several years. In this paper, we have made an attempt to review about the collar rot disease of soybean, the pathogen associated with it, symptoms, mode of spread and disease cycle, weather parameters influencing the occurrence of disease and integrated management practices.

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