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A Review on Blight and Bulb Rot of Onion caused by *Sclerotium rolfsii* Sacc.

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ABSTRACT: Onion is an important crop that is well known for its culinary and medicinal purposes throughout the world. Blight and bulb rot of onion *Sclerotium rolfsii* Saccardo has been reported from different areas. The above ground symptoms includes blighting and wilting while underground symptoms includes soft and watery rots accompanied by white mycelium of the fungus. The disease is favoured by moist soil and cool temperature. The pathogen produces sclerotia for survival. The pathogen is omnivorous and soil borne. The disease also developed after harvest during storage which is also characterized by soft rots and presence of mycelium as well as sclerotia. This reduces commercial value and marketableness of the harvested produce. Thus, efficacious management practices should be adopted to avoid both pre harvest as well as post harvest economic loses. Several approaches are efficiently adopted for efficiently managing *S. rolfsii in vivo* conditions. Newer approaches which are alternatives to harmful chemicals are also adopted for managing the disease. Further research work in regards to the onset of the disease, impact of prevailing environmental conditions, variability of different isolates of the pathogen and different disease management practices are considered indispensable.

Keywords: Onion, *Sclerotium rolfsii,* Blight, Bulb rot, Sclerotia.

INTRODUCTION

Onion is a bulb crop of economic importance that is cultivated widely throughout the world and is utilized as vegetable and spice. The onion is derived from Latin word which means "large pearl" (Shigyo and Kik, 2008). Onion is commonly used in the preparation of cuisine including curry, sauce, salad, chutney, puree and considerably more. It is also used in the processing of various products including onion juice, oil, salt, pickle and dehydrated products in the form of rings, powder and kibbles (Lawande, 2012). It is indeed being quoted as "Queen of the Kitchen" (Selvaraj, 1976). Bulb colour of onion may be red, yellow, pink or white and this variation is attributed to mutations in structural and regulatory genes of the flavonoid biosynthesis pathway which is complex and involves multiple genes interaction (Khandagale and Gawande, 2019). Onion is rich in flavonoids and phenolics which are responsible for antioxidant and anti-neuroinflammatory capacities (Li *et al.,* 2020). Onion is shallow rooted crop. Water stress, excessive moisture, day length, temperature, CO_2 concentration in the atmosphere and soil salinity influenced bulb formation, growth, yield and quality (Rao, 2016). Onion suffers from several major diseases including white rot (*Sclerotium cepivorum* Berk.), damping off (*Pythium* species., *Phytophthora* species, *Rhizoctonia solani* and *Fusarium* species), purple blotch (*Alternaria porri*), stemphylium blight (*Stemphylium vesicarium*), downy mildew (*Peronospora destructor),* basal rot (*Fusarium oxysporum* f. sp. *cepae*), onion smut (*Urocystis cepulae*), black mold (*Aspergillus niger*), anthracnose (*Colletotrichum gloeosporiodes*), pink root rot (*Phoma terristris*), neck rot (*Botrytis allii*), sour skin (*Pseudomonas cepacia*), skin blotch (*Embellisia allii*), bacterial brown rot (*Pseudomonas aeruginosa*), iris yellow spot (*Iris yellow spot virus*), onion yellow dwarf (*Onion yellow dwarf virus*) and root-knot nematode (*Meloidogyne* sp.) which devasted onion cultivation greatly in India (Mishra *et al*., 2014). Blight and bulb rot of onion is caused by *Sclerotium rolfsii* Saccardo and it is an emerging disease which has been reported by several researchers. The disease becomes prominent only late in the cropping season when the crop is partially matured and close to harvesting period. This disease reduced fresh onion bulb productivity to a considerable degree causing huge economic losses. The main purpose of this review are to inquire the details in regards to blight and bulb rot of onion induced by *Sclerotium rolfsii* Saccardo, its occurrence, its characteristic symptoms, biology and etiology of the causal pathogen, variability among isolates, epidemiology and different management practices undertaken against the causal pathogen *S. rolfsii*.

BLIGHT AND BULB ROT OF ONION

Report of bulb rot of onion caused by *Sclerotium rolfsii* Saccardo

Blight and bulb rot of onion caused by *Sclerotium rolfsii* Saccardo is also referred to as southern blight, white rot, *Sclerotium* rot and soft rot of onion. White rot of onion caused by *S. rolfsii* was reported from Kikrail and adjoining areas of Lucknow by Mukherji and

Tewari (1969). Mathur and Sharma (2002) also reported bulb rot of onion induced by *S. rolfsii* as a new threat to onion cultivation in Rajasthan. Ramanathan *et al.* (1988) gave an account of bulb rot disease of onion caused by *S. rolfsii* in Sri Lanka. Valez-Rodriguez and Rivera-Vargas (2007) gave first report of *S. rolfsii* causing soft rot of onion in Puerto Rico and the Caribbean. Kwon *et al.* (2011) reported *Sclerotium* rot of onion occurring sporadically at Daehap, Changnyeong in Korea. Pawar and Chavan (2015) reported occurrence of southern blight of onion caused by *S. rolfsii* from Sirur, Rajgurunagar, Lasalgaon, Yaola, Niphad and Manmad areas of Maharastra. White rot of onion was reported from several onion cultivation sites in the valley districts of Manipur (Konjengbam *et al*., 2021b).

SYMPTOMS AND SIGNS

The symptoms of the disease commenced by yellowing and drying of the leaves from the tip that subsequently extend downwards. Eventually the leaves become blighted and stoop down. It is followed by wilting and drying of the whole plants (Kwon *et al.,* 2011). The disease becomes prominent only late in the cropping season near the harvesting period. During harvesting, when the plants are uprooted, the bulbs are watery and decayed. The soft decayed bulbs are also covered by mycelial growth of the fungus and white, brown and black colour sclerotia are interspersed among the mycelial growth and infected bulb tissues (Ramanathan *et al*., 1988; Valez-Rodriguez and Rivera-Vargas, 2007; Konjengbam *et al*., 2021b). Healthy onion bulbs harvested from heavily infected field later developed soft watery rot in storage (El-Helaly *et al*., 1962; Chandra and Tandon, 1964). This renders onion bulbs unmarketable resulting in great economic losses. The symptoms and sign of this disease are similar to white rot of onion caused by related species *S. cepivorum* Berk.

Fig. 1. Above ground symptoms showing blighting and drooping of leaves.

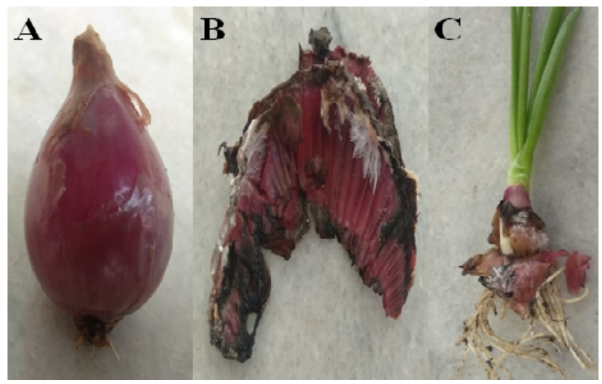

Fig. 2. Underground symptoms. (A) soft watery decayed bulb, (B) white mycelium of the pathogen underneath onion peel of decayed bulb, (C) white mycelium on the underlying scales of decayed bulb.

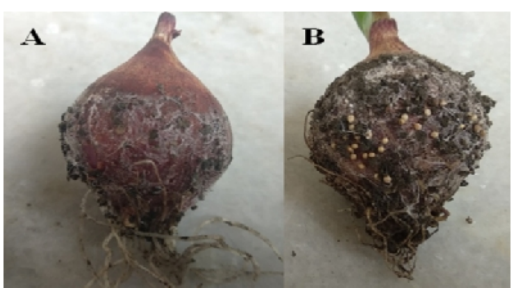

Fig. 3. Underground sign of the pathogen. (A). white mycelial growth on the surface of the diseased bulb, (B). sclerotia on the surface of the diseased bulb.

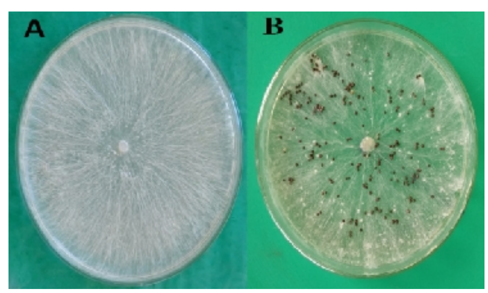

Fig. 4. *Sclerotium rolfsii* Saccardo. (A) mycelium, (B) sclerotia.

BIOLOGY AND ETIOLOGY

Sclerotium rolfsii causes bulb watery soft rot of onion. The fungus is under phylum *Ascomycota* belonging to form phylum *Fungi Imperfecti* which is also referred to as *Dueteromycota*. It is also being referred to as *Mycelia Sterilia.* Systematic classification of *S. rolfsii* (Kirk *et al.*, 2008) is as follows

Domain: *Eukarya*
Kingdom: *Fungi*
Phylum: *Ascomycota*
Class: *Agonomycetes*
Order: *Agonomycetales*
Genus: *Sclerotium*
Species: *rolfsii*

The fungus was first reported from blighted tomato plants cultivated in the fields of Florida (Rolfs, 1892). The monograph of *S. rolfsii* was published by Saccardo (1913). The teleomorph of the fungus is *Athelia rolfsii* (Curzi) Tu and Kimbrough (Curzi, 1931; Tu and Kimbrough, 1978) which is under phylum

Basidiomycota. The fungus has an immense host range and infects large number of food crops, weeds, ornamental, turf grass and several bushes and small trees (Aycock, 1966). Similarly, Punja (1988), Mordue (1974) and El-Nagar *et al*. (2013) also gave an account of wide host range of the fungus. The fungus produces spherical and globular sclerotia. Sclerotia are characterized by the presence of the three distinct layers namely; a thick walled outer rind, a thin walled middle cortex with vesicles full of reserved materials and inner medulla which contains full of reserve materials and empty cells (Chet *et al*., 1969; Punja and Damiani, 1996). There is a difference in structure, physiology and survival between sclerotia produced from infected plants in the field and those produced on culture media (Linderman and Gilbert, 1973; Punja, 1985; Xu *et al*., 2008). Oxalic acid is one of the important factors for pathogenicity and virulence of *S. rolfsii* (Kritzman *et al*., 1977; Punja *et al*., 1985; Ferrar and Walker, 1993). Bateman (1972) reported that *S. rolfsii* produce pectic enzymes complex is responsible for tissue maceration leading to soft watery rot, thereby converting pectic polymers of the plants to substrate that is utilized by the fungus during pathogenesis. Similarly, Punja *et al*. (1985) reported that the fungus also produce plant cell wall degrading enzymes including endo-polygalacturonase, endo-pectimethyl polygalacturonase and cellulase (C_x and C_1). The fungus also produces an additional enzymes which aids in pathogenicity namely, xylanase, mannanase, α-arabinosidase, acetyl esterase, and α-galactosidase (Sachslehner *et al.*, 1997).

Variability among isolates of *S. rolfsii*

Sarma *et al*. (2002) gave an account of variability in Indian isolates of *S. rolfsii* in regards to morphology of colonies, growth rate of mycelium, formation of sclerotia, size and colour of sclerotia and formation of teleomorph. Similar cultural and morphological variabily have also been reported among isolates of the fungus (Akram *et al*., 2008; Sachin *et al*., 2009; Prasad *et al*., 2012; Kumar *et al*., 2014). Genetic variability among isolates of *S. rolfsii* have been determined by several molecular approaches (Prasad *et al*., 2010; Mendes *et al*., 2012; Gawande *et al*., 2013; Daniel *et al*., 2017). Shukla and Pandey (2008), Xie *et al*. (2014), Paparu *et al*. (2020) and Yan *et al*. (2021) had also described variability in virulence and pathogenicity among isolates of the *S. rolfsii*.

EPIDEMIOLOGY

The fungus produces sclerotia which acts as surviving structure and remains viable for a long period (Punja, 1985; Xu *et al*., 2008; Marcuzzo and Schuller, 2014; Kator *et al*., 2015). Mullen (2001) stated that in addition to surviving as dormant sclerotia, the fungus also thrives as mycelium in the infected plant itself, plant debris and dead organic matter and occasionally developed hymenial layer. Chet *et al.* (1969) disclosed that melanin rich outer rinds and the wall structure as well as organization of cells comprising the inner layers of the sclerotium contributed to the resistance of sclerotia to the biological degradation. Sclerotia germinates either by producing individual hyphal strand from the surface of the sclerotium which is referred to as hyphal germination or germinates by producing plugs of mycelium which erupts through the sclerotial rind and this is referred to as eruptive germination (Punja and Grogan, 1981). The fungus is disseminated by course of rain and irrigation water, movement of animals and wind. The fungus is also carried along with infected plant, seeds and other vegetative propagating materials. The survival of *S. rolfsii* depends on prevailing environmental conditions. Buete and Rodriguez-Kabana (1981) relayed that moist soil is detrimental for mycelium and sclerotia of the fungus, however, the mycelium could survived for 6 months at 15 and 35 in dry soil. Sclerotia on the soil surface remain viable for a long period than sclerotia that are buried deeply as the latter are subjected to predisposition by the colonization of soil microbes (Smith *et al*., 1989). The disease commenced swiftly under high soil moisture and cool temperature. Mukherji and Tewari (1966) observed severe development of onion white rot on moist soil and low temperature resulting from flooded fields after heavy rainfall in Lucknow. Pawar and Chavan (2015) reported that rainfall and hailstorm resulted in southern blight and spoilage of onion bulb by *S. rolfsii* in different areas of Maharashtra. Konjengbam *et al.* (2021b) also disclosed that the disease progress quickly in April after rainfall in Manipur.

DISEASE MANAGEMENT PRACTICES

Several disease management practices had been successfully employed for the management of soil borne *S. rolfsii in vivo* conditions. These management approaches includes cultural, physical, biological, chemical and integrated approaches. In the last few years, the newer approaches namely, the induction resistance in plants by chemical and biological agents and utilization of nanoparticles had been employed efficiently against the pathogen.

Cultural

Cultural management are feasible for managing *S. rolfsii* and can be used in integration with other management practices. Field sanitation and removal of plant debris from the vicinity of the plants in addition to deep ploughing of organic matter so as to bury the propagule of *S. rolfsii* are reported to be efficient cultural practices (Garren, 1961; Worley *et al*., 1966). Flooding the soil just prior to cultivation reduces the viability of sclerotia and this in turn reduces disease incidence due to antagonistic activity of anaerobic microorganisms (Sariah and Tanaka, 1995). Stapleton and Duncan (1998) analyzed the impact of amending soil with different cruciferous crops against *S. rolfsii* and noticed that soil amendment with both fresh and dried bok choy and cabbage caused deleterious effect on sclerotial germination. Flores-Moctezuma et al. (2006) observed that soil amendent with *Parthenium hysterotrophus* residue coupled with soil solarization resulted in reducing sclerotial viability and disease incidence respectively which in turn increases onion bulb diameter. Blum and Rodriguez-Kabana (2004) examined the effect of adding organic residues to soil and observed that dried powder of kudzu (*Pueraria lobata)*, velvetbean *(Mucuna deeringiana)* and pine bark *(Pinus elliottii* and *P. taeda)* reduced inoculum of *S. rolfsii.* Crop rotation is less desirable for managing blight and bulb rot of onion under epiphytotic field conditions as the fungus is omnivorous, soil borne and sclerotia remains viable for considerable time (Punja, 1985; Ferreira and Boley, 1992).

Physical

Soil solarisation is extensively used for managing several soil borne pathogens. Soil solarisation during summer season reduced the survival of *S. rolfsii* and efficiently managed the disease (Katan, 1984; Mihail and Alcorn, 1984; Ristaino *et al*., 1991). Soil solarisation had been utilized in integrated disease management alongside cultural, biological and cultural practices against *S. rolfsii* (Steven *et al*., 2003; Charirak *et al*., 2016).

Biological

Biological method of plant disease management is based on utilization of microorganism and plants based biopesticides. *Trichoderma harzianum* is a well proclaimed biocontrol agent efficient against *S. rolfsii* and it reportedly reduces disease incidence as well as disease severity (Upadhyay and Mukhopadhyay, 1986; Ciccarese, 1992; Abada, 1994; Sennoi *et al*., 2013; Hasna *et al*., 2020, Konjengbam *et al*., 2021a). Several species of *Trichoderma* species including *T. koningii* and *T. viride* had been reported to perform well under field conditions (Lotunde-Dada, 1993; Karthikeyan *et al*., 2006). Several bacterial biocontrol agents are reported to be effective against the disease by researchers. Flourescence *Pseudomonads* had been found to effective against *S. rolfsii* and are reported to reduce disease incidence and severity, thereby, enhancing crop health, growth and productivity (Bhatia *et al*., 2005; Pastor *et al*., 2010; Rakh *et al*., 2011; Eid, 2014). Several species of *Bacillus* had been relayed to be effective biocontrol agents against several diseases caused by *S. rolfsii* (Le *et al*., 2019; Yanti *et al*., 2021). Xu *et al*. (2020) reported *Bacillus pumilus* to be effective against *S. rolfsii. Streptomyces* species is also reported to be effective against *S. rolfsii* under field condition (Errakhi *et al*., 2007; Boukaew *et al*., 2011; Adhilakshmi *et al*., 2013; Jacob *et al*., 2018; Abo-Zaid *et al*., 2021). Commercial formulations of biocontrol agents are widely available which can be efficiently utilized for managing blight and bulb rot of onion. Plant based products are utilized for managing several diseases to promote organic agriculture as well as to ensure food safety as there has been growing concern regarding chemical residues in foods (Kumar and Singh, 2012). Garlic clove extract is effective against *S. rolfsii* under field condition (Rahman *et al*., 2019; Konjengbam *et al*., 2021a). Nugroho *et al*. (2019) stated that application of aqueous extract of sweet basil was effective against *S. rolfsii* and resulted in reduced disease incidence. Derbalah *et al.* (2021) examined the antifungal effects of crude

extracts of seven plant species namely, *Bauhinia purpurea, Caesalpinia gilliesii, Cassia fistula, Cassia senna*, *Chrysanthemum frutescens*, *Euonymus japonicus* and *Thespesia populnea* var. acutiloba and he observed that *T. populnea* var. acutiloba and *C. frutescens* were most effective against *S. rolfsii.*

Chemical

Fumigants are reliably utilized for managing *S. rolfsii* and are also integrated with other management approaches. McCarter *et al.* (1976) tested the efficacy of fumigants namely, vapam, chloropicrin, methyl bromide, terr-o-gel and vorlex against *S. rolfsii* and observed that vapam was the most effective fumigant. Canullo *et al.* (1992) gave an account of efficacy of 2-furfualdehyde against *S. rolfsii* and reported that repeated applications of this fumigant increases the population of *Trichoderma* species in the soil which are efficient biocontrol agents. Hoynes *et al.* (1999) relayed the feasibility of combining soil fumigation with vapam along with application of *Gliocladium virens, Trichoderma hamatum* and *T. viride* against *S. rolfsii.* Eshel *et al.* (2000) reported that utilization of methyl bromide coupled with soil solarisation was effective in controlling *S. rolfsii.* Several fungicides had been employed for managing *S. rolfsii.* Triazole fungicides have been reported to be effective against the pathogen (Sunkad, 2012; Maji *et al*., 2016; Shirsole *et al*., 2019; Sahana *et al*., 2020). Strobilurin fungicides are also effective against *S. rolfsii in vivo* condition (Bowen *et al*., 2006; Koehler and Shew, 2017). Pentacholoronitrobenzene is reported to manage *S. rolfsii* effectively (Thompson, 1978; Kulkarni, 1980). Despite various advantages and effectiveness of using the fungicides, it should not be used repeatedly as the fungicide tolerant isolates of *S. rolfsii* has been reported. Shim et al. (1998) reported that some isolates of *S. rolfsii* from peanut fields in Texas were tolerant to pentachloronitrobezene. Similarly, Franke *et al.* (1998) also reported some isolates of *S. rolfsii* resistant to tebuconazole, flutolanil and pentachloronitrobenzene from peanut fields in Georgia. Therefore, fungicides should be used alternately with other management practices or as a component of an integrated disease management.

Induction of resistance

Resistance against *S. rolfsii* can be intentionally induced in onion plants through the use of elicitors which includes both chemicals and biological agents. Plant growth promoting rhizobacteria functions not only as biofertilizers but also as biopesticides against several soil borne pathogen through mechanisms namely, competition, parasitism, antibiosis and most importantly, through induction of two different form of resistance namely, systemic acquired resistance (SAR) and induced systemic resistance (ISR) in plants (Verma *et al.,* 2019). Plant growth promoting rhizobacteria are reported to be effective against *S. rolfsii,* thereby, enhancing resistance and suppressing disease development in addition to promoting plant growth (Singh *et al*., 2003; Sagni *et al*., 2008; Volpiano *et al*., 2018; Sharf *et al*., 2020). Chemical elicitors including β-amino butyric acid, chitosan, salicylic acid, jasmonic acid and hydroqinone are employed for inducing resistance in plants against *S. rolfsii* (Ali *et al*., 2009; Duande *et al*., 2018; Soltys *et al*., 2020).

Nanoparticles

The utilization of nanoparticles in plant disease management has been increasing since last few years. Engineered nanoparticles including metal oxides, metalloids, non-metal and carbon are known for their antifungal properties and some nanoparticles activates defense reaction against pathogens in host plants (Elmer *et al*., 2018). El-Argawy (2017) studied the potential of some nanoparticles including magenium oxide, titanium dioxide and zinc oxide against *S. rolfsii* and reported that all the three nanoparticles were effective and he also suggested that these nanoparticles could be environmental friendly alternatives for fungicides. Desai *et al.* (2021) investigated the use of silver nanoparticles against *S. rolfsii* and confirmed the possibility of developing silver nanoparticles as bionanofungicide. Panichikkal *et al.* (2021) examined the efficiency of utilizing *Bacillus licheniformis* encapsulated in alginate-chitosan nanoparticles (CNPs) beads supplemented with rice starch (RS) against *S. rolfsii* and observed that it was effective and it enhances disease suppression.

CONCLUSION

This review specifically considers the blight and bulb rot of onion which is basically one of the important diseases of onion throughout the world. This disease reduces yield as well as economic value of the harvested onion bulbs. Therefore, it is necessary to understand the symptoms, epidemiology and etiology of the causal pathogens along with different effective disease management approaches. *S. rolfsii* is soil borne as well as omnivorous, thereby having the capacity to attack many plants. Therefore, essential management practices should be undertaken in right moment to efficiently manage this disease so as to prevent further spread of *S. rolfsii* to other host plants. However, consideration should be made regarding the repeated use of chemicals for managing this disease as there are significant drawbacks regarding residual problem, non targeted impacts on unrelated organisms, food safety issues, environment safety and vice versa. Thus, chemicals should be rarely used or as a component of integrated disease management. Environmental friendly approaches including plant and microbes based biopesticides, nanoparticles, cultural and physical management practices should also be utilized. Further studies on the use of environmental friendly disease management practices as well as pathogenicity and virulence of *S. rolfsii* on different plants under *Amaryllidaceae* are very crucial as the pathogen has been reported to cause disease on other *Allium* species.

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