

STUDIES ON AERIAL BLIGHT OF SOYBEAN CAUSED BY *RHIZOCTONIA SOLANI* KUHN

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Abstracts: Soybean (*Glycine max* (L.) Merrill) is one of the most important oil seed crop of India. It was wonder of the twentieth century. Soybean rank first among world oilseed with an annual production of about 105 mt. Among the different growing countries of the world, USA, China, Brazil, Argentina and India are main which accounts more than 90% of the world's acreage (Taware *et al.*, 2007). Soybean (*Glycine max* (L.) Merrill) a grain legume is widely crop due to its high quality protein (40%) and edible oil (20%). Aerial blight caused by *Rhizoctonia solani* is one of the most soil borne diseases of soybean particularly in the northern zone comprising the states of Haryana, Punjab, Uttar Pradesh and Uttarakhand.

Keywords: Soyabean, *Rhizoctonia solani*, Disease, Chemical, Fungicide

INTRODUCTION

Soybean is mainly grown during Kharif season in sandy loam to clay loam soil in Chhattisgarh. In Chhattisgarh, area, production and productivity of soybean are 0.82 m ha, 0.73 mt and 891 kg/ha, respectively which are much lower than national average (Anonymous, 2006b). The disease appears July-August and is characterized by sudden and complete death of the plants. This disease is considered to be one of the most destructive and causes heavy losses in the yield particularly in warm and humid parts of the countries (Anwar *et al.*, 1995). Yield losses can exceed 35-60 per cent and the disease is considered as economically important (Patel *et al.*, 1998). The use of resistant varieties is the cheapest, easiest, safest and most effective method to manage the aerial blight disease. Few tolerant cultivars were reported against aerial blight disease (Thind, 1998 and Palat *et al.*, 2004). Although various fungicides have shown promising results in controlling the aerial blight of soybean but the phytotoxicity and fungicidal residue problems leading to the environmental pollution are the major constraints in disease management. Substantial emphasis is being given these days on using eco-friendly approaches for controlling plant diseases. Plant products are the best alternatives available today. Several medicinal plant species have not been screened against plant pathogens. The literature pertaining to the aerial blight of soybean caused by *Rhizoctonia solani* Kühn has been reviewed under following heads:

The Disease

Aerial blight is an important disease of soybean (*Glycine max* (L.) Merrill). It was first reported from Philippines in 1980. Later it was reported from Malaysia, Mexico, Puerto Rico, China, Taiwan, Louisiana (Sinclair, 1982), North America, South America, Brazil, Argentina (Ram and Trikha, 1997).

It has been reported on soybean in subtropical and tropical areas. In India, it was first reported from Pantnagar (Uttarakhand) in 1967 (Mukhopadhyay and Singh, 1984). Since then it has spread to other soybean growing state like Rajasthan (Goyal and Ahmad, 1988), Sikkim (Srivastava, 1988), Haryana, Punjab, Uttar Pradesh, Bihar (Sharma and Tripathi, 2001, and Ray *et al.*, 2007), Madhya Pradesh and Chhattisgarh (Anonymous, 2007). Now it has been reported from most of the soybean growing state of India. In Chhattisgarh aerial blight becoming an important disease Aerial blight disease is also known as sudden death syndrome (Nakajima *et al.* 1996).

Economic importance

Aerial blight is an important disease of soybean, in USA and other soybean growing countries including India and causes substantial losses in yield. Several estimates of yield losses due to disease have been estimated. Sharma and Sohi (1980) reported 8.45 to 64.68 percent yield losses of green pods due to web blight of French bean caused by *R. solani* in commercially susceptible cultivars. 35% yield losses have been attributed from Louisiana by web blight of soybean (Sinclair, 1982). Patel and Bhargava (1998) reported that yield losses can exceed 35 to 60% due to aerial blight soybean caused by *R. solani* in warm and humid part of country. Sharma and Tripathi (2002) reported 30% yield losses in web blight of Urdbean caused by *R. solani* in Tarai region of Uttarakhand. Sharma and Gupta (2003) reported 60% yield losses due to web blight of French bean caused by *R. solani* in Himachal Pradesh. Stetina *et al.* (2006) assessed disease severity in the moderately resistant and susceptible cultivars of soybean in field plots corresponding to 0-100% of tissue affected. Based on result on regression analysis, pod number, seed number and seed weight per plot decreased as disease severity increased, whereas the proportion of partially filled pods and the weight of 100 seed were

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not affected. Yield loss appeared to be due to loss of entire pods.

Symptoms

Kucharek (1981) described the symptoms as lesion in leaflets can range in size from a single pinpoint to coverage of entire leaflets. Usually the lesion is brown to pale green in colour. If the lesion is fresh it may have a greasy appearance. Lesions do not have a distinct shape; lesion shape is determined by tissue colonized by the fungus. Fungal hyphae can be seen on infected tissue, it appear as a brown spider like web and is apt to be seen early in the day or when the canopy is still moist. Infected pods and stem tissues looks greasy, brown and shriveled. Happerly *et al.* (1982) reported aerial and web blight like symptoms commonly formed in most tropical and subtropical parts of the world. Sinclair (1982) also described the symptoms and categorized in foliage and aerial blight. Foliar blight symptoms appear on leaves, stem and pods, beginning on the lower or middle parts of the plant and moving up. Infected leaves are water soaked at first but soon take on a greenish brown to reddish brown appearance and later become tan, brown, or black. Lesion may be small spots, or whole leaf may be blighted. Severely infected plants lose their leaves. In the aerial blight phase, infected leaves droop and adhere to the pods and stem beneath them, thus becoming sources of infection for the pods and seeds. Brownish lesions form on petioles and stems. Lesions on pods may be small, brownish spots or may blight the whole pod. Seed infection is associated with pod infection. High humidity enhance mycelial growth and sclerotial formation in the lesion and blighted areas. Mukhopadhyay and Singh (1984) reported that symptoms of the disease depend on varieties of soybean. They also reported that the brown spot found on petioles and stems. Necrotic brown spot also formed on green leaves or complete leaves may be blighted. Web like mycelium of the pathogen also seen on diseased parts and their adjoining area of leaves. Thapliyal and Dubey (1987) reported that the pathogen produces two type of sclerotia viz micro and macro sclerotia both can infect six week old plants. Yang *et al.* (1990b) reported that diseased seedlings become source of inoculum's by producing mycelium that grew to and infected neighboring plants and concluded that seedling infection at an early stage can have significant effect on subsequent disease development. Ram and Trikha (1997) reported main symptoms of disease start as blight from base of the leaf and increase towards the tip of the leaf. Fully affected leaf become dry and petiole attached with the plant. They also observed root rot under high moisture in the soil. They reported reddish brown colour dead tissue seem on the outer surface of the root and basal portion of the stem. Disease appears in all stage of plants in heavy rains. Prasad (2005) reported the symptoms of aerial blight generally appear on leaves, stems and pods when plants are 45-

60 days, infection start from lowest leaves, touching the ground. Infected leaves are water soaked brown to reddish brown and later on become tan to black. Complete leaf may be blighted slowly. Symptoms on leaves first start from the side of leaflets joined to petiole. Infected leaves droop and may adhere to stem and pods. Small oval to irregular brown to dark coloured sclerotia are present on infected surface of plant. Thind (2005) reported the symptoms as reddening of leaves. Williamson and Muller (2006) reported severe foliar blight which started at the base of the plant, then moved upward and downward, often causing complete defoliation. The disease was found in scattered areas in the field and disease incidence ranged from 25-30%.

The Pathogen

The anamorph or imperfect stage of pathogen causing aerial blight in soybean is *Rhizoctonia solani* Kühn. The detailed classification of the fungus is as follows.

Subdivision	:	Deuteromycotina
Form class	:	Deuteromycetes
Form subclass	:	Hyphomycetidae
Form order	:	Aganomyetales
Genus	:	<i>Rhizoctonia</i>
Species	:	<i>solani</i>

The teleomorph or perfect stage of the *R. solani* has been described as *Thanatephorus cucumeris* (Frank) Donk.

Subdivision	:	Basidiomycotina
Class	:	Basidiomycetes
Sub class	:	Holobasidiomycetidae
Order	:	Tulasnellales
Family	:	Caratobasidiaceae
Genus	:	<i>Thanatephorus</i>
Species	:	<i>cucumeris</i>

(Alexopoulos *et al.*, 2002)

The genus, *Rhizoctonia* first described by De Candolle (1815), possesses the following characteristics: (a) branching near the distal septum of cells in young vegetative hyphae, (b) formation of a septum in the branch near the point of origin, (c) constriction of the branch, (d) dolipore septum, (e) no clamp connection, (f) no conidium, except moniloid cells, (g) sclerotium not differentiated into rind and medulla and (h) no rhizomorph (Ogoshi, 1975). Tiwari and Khare (1998) reported variation rate and type of growth, colony colour, time taken for sclerotial production and nuclear status *in vitro* in isolates of *R. solani* from *Vigna radiata*.

MORPHOLOGY

Young mycelium of *R. solani* is silvery becoming yellow or brown at maturity, 8-12 µm in diameter having frequent septation and branched. Sclerotia are dark brown to black, 99.9 to 166.5µ in diameter. Sometime they unite to form a large mass in linear shape, which can be as long as 300µ. They are roughly, spherical or somewhat flattened or irregular.

Shape of microsclerotia is oval to irregular (Mukhopadhyay and Singh, 1984).

Isolation, purification and pathogenicity

Cardoso *et al* (1982) reported that the *R. solani* isolated from perennial soybean was highly pathogenic to cowpea, while cowpea root isolates attacked underground cowpea tissues only. Ploetz *et al.* (1985) studied in green house and reported that isolates from soybean were highly pathogenic to soybean seedlings. Anderson (1987) isolated the 13 genera of plant pathogens viz *Rhizoctonia solani*, *Corynespora cassicola*, *Fusarium oxysporum*, *Pythium spp* and other spp. were isolated more frequently than other fungi. Some fungi such as *C. cassicola* common on roots while others such as *Phomopsis spp.* were common on stems. The incidence of isolation of most fungi was influenced by sample date. Naito and Kanematsu (1994) reported the symptoms appeared as primary lesions consisting of small circular necrotic spots, followed by secondary lesions under humid condition and isolated *Rhizoctonia solani* from leaves with the primary and secondary lesion. Inoculation test revealed that the leaf spot isolates were highly pathogenic to soybean, *Vigna vulgaris* and *Phaseolus vulgaris* and caused severe pre-emergence and post emergence damping off. Nelson *et al.* (1996) reported *Rhizoctonia solani* was virulent on soybean seedlings and adult plants and when inoculum's was placed in direct contact with seeds caused high level of pre-and post emergence of damping off. It is suggested that *R. solani* could be an important soybean pathogen and that other rotational crops are host to *R. solani* recovered from soybean. Bhattacharyya (1998) described the disease symptoms found in all parts of potted soybeans cv. Bragg plants grown in soil infested with *R. solani*. The *R. solani* isolate from soybean was also found to infect 23 of the 26 crop and weed species tested as alternative host. Khan *et al.* (2002) assessed pathogenicity of *R. solani* isolates by tooth pick tuber inoculation and direct tuber inoculation revealed that in tooth pick tuber inoculation of *R. solani* isolates were more virulent.

Disease cycle

Rhizoctonia solani pathogen is soil borne and seed borne in nature perpetuates in soil through sclerotia and mycelium. There are report that mycelium in soybean debris can remain viable. Park and Berteus (1932) reported that the sclerotia of *R. solani* remained viable for 130 days in air dried soil kept at room temperature (30°C). Atkins and Lewis (1954) reported that secondary infection take place through sclerotia and disseminate through air and water and reach to healthy plants from infected plants. Das and Western (1959) observed that *R. solani* can survive in crop debris in natural soil for three months. Ou (1975) found that sclerotia of sheath blight fungus of rice survived in soil for one to two years. Tiwari (1993) reported survival of *R. solani* in infected rice

bean crop debris upto 11 months storage at room temperature (10-42 °C). He also reported viability of sclerotia upto 22 months when placed in sterilized soil at room temperature. Sati (1998) reported that decreased viability of *R. solani* with increase in soil depth and loss of viability of sclerotia after 8 months when placed at 2.5 cm deep in soil. The loss in viability of *R. solani* at depth of 10 and 15 cm may be due to competition with other microorganisms, since activity of soil micro flora remains optimum at the soil depth of 10-15 cm. She also reported the survival of *R. solani* causing sheath blight of rice upto 270 days when infected rice crop debris was exposed at 28°C. Sati and Sinha (1999) reported that the *R. solani* survived in infected plant debris up to 150 days and in the form of sclerotia up to the next crop season. The percentage of infected plant pieces/sclerotia yielding colonies decreased with increase in time of storage. Sharma and Tripathi (2002) reported that the survival of the *R. solani* declined sharply over a period of time and also with increase in soil depth. The sclerotia and crop debris buried at 25 and 20 cm deep in natural soil showed significant reduction in survival after 8 months. The survival was lost in infected crop debris buried at 25 cm deep over a period of 9 months. However, highest survival of fungus through sclerotia and crop debris was recorded when placed at 5 cm deep soil followed by 10 cm over a period of 9 months. Rain off water and flood irrigation permit good dispersal of the floating sclerotia and consequently, provide the primary foci of the infection through the stretches of soybean field. Secondary spread take place through direct contact. Sinclair (1982) reported that *R. solani* attacks on common bean (*Phaseolus vulgaris*), lima bean (*P. limensis*), clovers (*Trifolium spp*), cowpeas (*Vigna spp.*), fescue (*festuca spp.*), fig (*Ficus spp.*), lespedezas (*Lespedeza spp.*), rice (*Oryza sativa*), wild soybeans (*Glycine javanica*) and tung (*Aleurites spp.*). Srivastava and Gupta (1989) reported that *Rhizoctonia solani* was found to cause aerial blight on *Vigna mungo*, *V. radiata*, *Phaseolus vulgaris*, groundnut and soybean during a survey in Sikkim in 1987 and 1988. Sinclair (1982) reported that web blight occurs in areas characterized by prolonged periods of high humidity and warm temperature, which enhances mycelial growth and sclerotial formation in the lesion and blighted area. Cultivars with more shorter and more compact growth habit are most severely infected. Thapliyal and Dubey (1987) reported 37 °C temperature and pH 6 are congenial for disease development. Ram and Trikha (1997) that maximum temperature (26-32 °C), water holding capacity of soil 70% and more than 6.6 pH are favourable for disease development. Kucharek (1981) also found seedling blight and root rot symptoms caused by *R. solani*. Aerial blight may be present at low levels across the field and when frequent rains occur, disease spread fast. Within one week or less an entire field may appear scorched.

Small field bordered by trees or poorly drained field are more apt to have severe aerial blight. Teo *et al.* (1988) reported that *R. solani* isolates were more virulent with early seeding and at high soil moisture. Early seeding resulted in significantly greater seedling infection and disease rating. Soil moisture had a significant effect on seedling infection. Yang *et al.* (1990a) also studied the effect of free moisture and plant growth stage on focus expansion of soybean aerial blight, caused by *R. solani* and reported that disease severity increased when free moisture is increased and showed positive correlation between each other. Patel and Bhargava (1998) investigated that disease reduced shoot length and pod at flowering, and increased with crop canopy and age. Rain was a significant factor in increasing disease development. Application of N, P and K fertilizers and herbicides reduced disease incidence, although application of 20kg N/ha as urea resulted in the maximum disease incidence. Torres *et al.* (2004) reported higher incidence of death of soybean seedlings (DSS) when the crop was planted in shallow soils and when these soils were originated from basalt. Approximately 70% of the death of soybean seedlings occurred in excess soil moisture. Only 30% of the deaths of soybean seedlings were in "latossols", which are well developed soils, deep and with good permeability. Upmanyu and Gupta (2005) reported that high soil moisture (80%) and 25 °C temperature were the most favourable for root rot development while web blight was best favoured at >85% relative humidity coupled with 25 °C temperature. Continuous leaf wetness for at least 6 hrs was essential for disease initiation, while increase in leaf wetness duration for 6-12 hrs showed corresponding disease incubation period observed with further increase in leaf wetness.

Disease management

Host resistance

The use of resistant varieties is the cheapest, easiest, safest and most effective method to manage the aerial blight disease. The efforts through conventional breeding so far made in developing commercial cultivars resistant to aerial blight. However few tolerant cultivars such as PK-262, PK-416, PK-472 and PUSA 16 (Thind, 1998), PS 564, PS 1024 and PS 1042 were reported against aerial blight (Anonymous, 2006c). Palat *et al.* (2004) screened soybean germplasm for their resistance to web blight. They found 8 cultivars free from the disease, 11 cultivars as resistant and 9 cultivars as moderate resistant. The remaining cultivars categorized in moderately susceptible (6 cultivars), susceptible (9 cultivars) or highly susceptible (6 cultivars), groups. A total of 13 entries, which were promoted to AVT-1 across the zone have been evaluated against major disease of soybean at 7 centers along with checks. At Pantnagar severity of *Rhizoctonia* aerial blight was upto desirable level in susceptible check Punjab 1 and Bragg. No entry was

absolute resistant but 5 entries viz., DS 2207, Dsb 8, MACS 1038, SL 688 and SL 751 were observed to be highly resistant. In coordinated trial held at Pantnagar, out of 35, 15 soybean entries were also observed as highly resistant to *Rhizoctonia* aerial blight during study of performance of previous year resistant entries (Anonymous, 2007).

Cultural

Cultural management practices are simple agricultural or farm practices that man has learn by his long experience as a farmer in order to reduce inoculum potential. However, the methods at least act as prophylaxis rather than a complete cure. Destruction or burning of crop residues could not eliminate sclerotia from a soil but has been suggested to be a part of integrated management practices (Lee and Courtney, 1982). Thind (1998) and Prasad (2005) reported that disease can be minimizing by summer ploughing and crop rotation. Teo *et al.* (1988) reported that early seeding and at high soil moisture significantly increased seedling infection and disease severity. Split application of potassium in a NPK combination of 40:20:20 kg/ha reduced the incidence of sheath blight and increased grain yield of rice (Baruah, 1995). Wide spacing reduced sheath blight and could even counter the effect of high nitrogen, but the yield was not consistent (Gangopadhyay and Chakrabarti, 1982). Incorporation of oil cake and some green manuring crop particularly sunhemp and green gram reduced survivals of *R. solani* (Rajan and Menon, 1975). Sharma and Gupta (2003) reported that Single polyethylene mulch along with soil amendment (mustard cake) resulted in increased temperature in soil lethal to the *Rhizoctonia solani*. They also reported that mulching for 30 and 50 days eliminate the *R. solani* from 5 and 10 cm soil depth, respectively.

Chemical

Many fungicides plant extracts, including oils and animal waste etc have been tested for toxicity against aerial blight.

Fungicide

Cardoso *et al.* (1978) tested the efficacy of five fungicides against *Rhizoctonia solani* among them Benlate (Benomyl) showed most effective to control infection. Ram and Trikha (1997) recommended Benomyl (0.5 kg/ha) and Moncozeb (2.5 kg/ha) 60 days after sowing for control of aerial blight of soybean. Seed treatment with Thiram reduced the initial inoculums (Thind, 1998). Sharma and Tripathi (2001) reported that seed treatment and two foliar spray of tilt (0.1%) at 15 days interval was most effective in reducing disease severity (30-32%) and increased grain yield (950-1012 kg/ha) as well as 1000 grain weight followed by Contaf, Bavistin and Indofil M-45 sprayed plots. Nassreen (2003) reported that the growth of *Rhizoctonia solani* was significantly reduced on PDA medium amended with 0.1% of Benomyl, Captan (Captan), Vitavax

(Carboxin), Dithane M-45 (Mancozeb) and Thiram and found that Benomyl was the most effective. Surulirajan and Kandhari (2003) tested five fungicides, Hexaconazole (Contaf), Thiram, Propiconazole, Tebuconazole and Carbendazim on radial growth of *R. solani* by poisoned food technique on PDA and stated that the mean radial growth of *R. solani* was 1.0, 1.4 and 2.5 cm in Hexaconazole (Contaf), Propiconazole and Thiram respectively. Rai *et al.* (2007) screened the twelve fungicides/antifungal antibiotics, possessing either systemic or non-systemic activity were screened against *Rhizoctonia solani* pathogen, causing aerial blight of soybean, *in vitro* conditions. Among these, Contaf Hexathir, Dhanustin and Rovral showed almost complete inhibition of the test fungus at all the concentration tested (i.e. 25, 50, 100 and 500 ppm).

Leaf extracts of medicinal plants

Singh *et al.* (1980) reported that fruit pulp of *Azadirachta indica* (Neem) suppressed the formation of sclerotia by *R. solani*. Reddy *et al.* (2002) reported that extract of, *Eucalyptus globulus*, *Allium sativum* and *Zingiber officinale* caused 61 to 100 percent inhibition of the mycelial growth of *Rhizoctonia solani* causing root rot of chickpea. Bhamare *et al.* (2003) reported that plant extracts of *Datura stramonium* reduced seed borne mycoflora (including species of *Rhizoctonia*, *Fusarium* and *Sclerotium*) significantly and increase seed germination over untreated control. Sharma *et al.* (2005) tested the efficacy of eight plant extracts against *Rhizoctonia solani* *in vitro* and reported that *Eucalyptus globules* inhibited 85% mycelial growth at 10% concentration. Kandhari and Devkumar (2006) tested the four plant extracts (*Calotropis procera*, *Allium sativum* C., *Piper betle* L., *Vitex negundo* L.) and one phytochemical (Geranio) against *Rhizoctonia solani* causing sheath blight disease of rice exhibited fungitoxic properties. Among these, *Calotropis procera* (Madar) emerged as most effective, showing highest reduction closely followed by *Piper betle* at 1500 ppm. Tiwari *et al.* (2007) tested the efficacy of medicinal plant extracts *in vitro* against *Rhizoctonia solani* and reported that out of 950 extracts, *Acorus calamus* (Butch) was highly effective against *R. solani* at all concentration (1%, 5% and 10%).

Medicinal oil

Singh and Dwivedi (1987) observed the fungitoxic activity of the oils of *Eucalyptus globules* against the sclerotial production of *S. rolfsii*. Madhukar and Reddy (1989) reported that *Eucalyptus* oil completely checked the fruit rot diseases of guava caused by *Rhizoctonia solani* and anthracnose caused by *Pestalotiopsis versicolor*. Coconut oil, castor oil and groundnut oil also effective in reducing the fruit rot of guava. Singh *et al.* (1989) evaluated 6 oils of medicinal plants for their antifungal activity against *Sclerotium rolfsii* and 10 soil inhabiting fungi. Out of these, the oil of *Azadirachta indica* was most

effective followed by *Eucalyptus globulus* and *Ocimum canum* against *S. rolfsii*.

Animal waste

Raja and Kurucheve (1997) tested the efficacy of animal products (dung, urine and milk) *in vitro* against *Rhizoctonia solani* and reported that urine of cow, bull and buffalo at 20% concentration totally inhibited the mycelial growth and sclerotial production of *R. solani*. More than 80% inhibition of the mycelial growth was recorded with dung of cow and buffalo. Animal milk stimulates the mycelial growth of the fungus, but interestingly the sclerotial production was totally inhibited. Such control measures would be more practicable and economical, and safer for both consumers and the natural environment due to the readily biodegradable nature. The cow urine and its combination were used for control of several soybean diseases like aerial blight, rust, target leaf spot and bacterial pustule of soybean and found that cow urine and its combination reducing the disease incidence over control and get more yield then control (Anonymous, 2004-05). Seed soaking in cow urine + asafetida followed by two spray of cow urine at 30 and 40 DAS reduced disease severity over control of aerial blight of soybean at Pantnagar (Anonymous, 2007).

Biological

Baker and Cook (1974) illustrated the concept of biological control as “the reduction of inoculum density or disease producing activities of a pathogen or a parasite in its active or dormant state by one or more organism, accomplished naturally or through manipulation of environment, host or antagonist or by introduction of one or more antagonist”. Biological control means reducing the amount or effect of pathogens that relies on biological mechanism or organism other than man (Campbell, 1989). In other words, biological control practices for direct protection of plants from pathogen involved the development of antagonistic microorganisms at the infection court before are infection take place (Agrios, 2004). Reports in respect to effectiveness of fungi and bacteria as antagonist from soybean field are available for control of aerial blight. Elad *et al.* (1983) reported that hyphae of *T. viride* and *T. harzianum* penetrated into host hyphae and caused lysis of *R. solani*. Beagle and Papavizas (1985) reported that successful disease control using fungal antagonist like *G. virens* and *T. harzianum* against *Rhizoctonia solani*. Das and Dutta (1999) assessed the efficacy of *Trichoderma harzianum* as a seed treatment along with 4 different carrier and sublethal doses of Thiram against stem rot of soybean caused by *Rhizoctonia solani* in sterilized soil. The lowest disease index was observed when seeds were treated with *T. harzianum* + methyl cellulose with a significant increase in dry weight of root and shoots and yield over the inoculated control. Cundom *et al.* (2003) evaluated the antagonistic activity of nine isolates of

Trichoderma spp. in dual culture. All isolates significantly diminished the mycelial growth of *R. solani* in dual culture. Jash and Pan (2004) reported that *Trichoderma virens* was most effective in inhibiting mycelial growth of *R. solani* in dual culture. The highest inhibition of mycelial growth of *R. solani* through production of non-volatile antibiotics at 10% concentration of culture filtrate. Ray *et al.* (2007) tested the efficacy of bio-agents under *in vitro* condition. Among the bio-agents, *T. harzianum* found most effective as it inhibited the mycelial growth of *R. solani* after 96 hr of incubation followed by *T. viride* and *P. fluorescens* where 82.43 and 80.36 mm growth were observed, respectively. Sarojaini and Nagmani, (2007) tested the antagonistic potential of *Trichoderma* isolates against rice sheath blight pathogen, *Rhizoctonia solani* Kühn. *In vitro* assessment were made on the mode of antagonism against mycelial growth and sclerotial formation of *R. solani*. All the isolates inhibited the mycelial growth of *R. solani* in dual cultures. Singh *et al.* (2007) reported that three components of integrated disease management of black scurf of potato (*Rhizoctonia solani*) were identified by conducting *in vitro* study. Soil isolates of *T. viride* (Tv-1), *T. harzianum* (Th-1), amendment of *Ranunculus muricatus* powder, Thiophanate methyl, Carbendazim and boric acid in PDA medium resulted in maximum inhibition of mycelial growth of *R. solani*. Dantre and Rathi (2008) reported that severity of rice sheath blight reduced by integration of non-conventional chemicals and Fluorescent pseudomonads.

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