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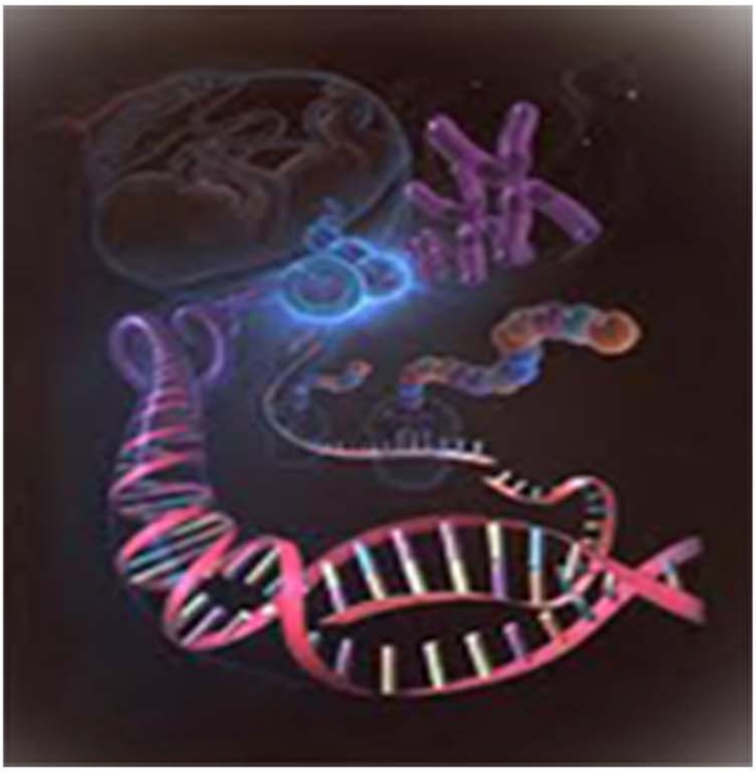

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Review Article

STEM ROT DISEASE OF GROUNDNUT (*ARACHIS HYPOGAEA L.*) INDUCED BY *SCLEROTIUM ROLFSII* AND ITS MANAGEMENT

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Groundnut (*Arachis hypogaea L.*) is an important oil seed crop. The low productivity in groundnut is attributed to many production constraints. Among these, biotic factors particularly diseases play a major role in limiting the yield of groundnut. The crop is known to be attacked by a number of fungal and bacterial diseases. Most of the soil borne diseases like stem rot, root rot, collar rot and pod rot. Among all the soil born diseases, stem rot caused by *Sclerotium rolfsii Sacc* is an important pathogen which is attacking different crops. This disease is wide spread and causes serious losses. So, to avoid this pathogen biological control using microbial antagonists is considered as good alternative of management of root diseases in many crops. Presently, greater emphasis has been replaced with biological control, in order to reduce the environmental hazards, to avoid the development of resistant strains and to reduce the cost of cultivation. This paper reviews the literature on *Sclerotium rolfsii* inducing stem rot disease and its management.

Keywords: Groundnut, Stem rot, *Sclerotium rolfsii,* Biological control

INTRODUCTION

Groundnut (*Arachis hypogaea L.*) is a major legume and an important oil seed crop in India, covering nearly half of the area under oilseeds. It is grown in over 100 countries with a total estimated area of 21.8 million ha and with production of 28.5 million tons. In India, it is grown over an area of 4 lakh ha, with an annual production of 5.5 million tons and productivity of 1007 kg ha in the year 2009-10 (Economic Survey, 2010-11). In Andhra Pradesh, it is grown in the area of 1.3 million ha (Directorate of Economics and Statistics, Hyderabad, 2010-11). According to the data provided by the State Agriculture Department, the groundnut area in Andhra Pradesh was 1.02 million ha with 1,000 million tons production during kharif 2009-10, and it has been declined to 700-800 million tons in the year 2011-12. Groundnut is grown under both subsistence and commercial systems. Under commercial cultivation, it is grown mainly as a sole crop with high levels of inputs whereas under subsistence conditions both sole crop and mixed or intercropping can be seen. Several factors are

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responsible for low productivity among which diseases like leaf spot, collar rot, stem rot, bud necrosis, etc., are very important. Out of all, stem rot caused by *Sclerotium rolfsii* Sacc. is a major problem and is an economically important soil-borne pathogen.

Stem Rot Pathogen

The pathogen *Sclerotium rolfsii* Sacc., is a soil-borne pathogen that commonly occurs in the tropics, sub-tropics and other warm temperate regions of the world causing root rot, stem rot, wilt and foot rot on more than 500 plant species including almost all the agricultural and horticultural crops (Aycock, 1966; Domsch *et al.,* 1980; Farr *et al.,* 1989). *Sclerotium rolfsii* was first reported by Rolfs (1892) later the pathogen was named as *Sclerotium rolfsii* by Saccardo (1911). Higgins (1927) worked in detail on physiology and parasitism of *S. rolfsii*. This was the first detailed and comprehensive study in USA. Sclerotia initially white in color, later it becomes light brown to dark brown at maturity and they are sub spherical, the surface finely wrinkled, sometimes flattened (Subramanian, 1964 and Mehan, 1995). This pathogen *Sclerotium rolfsii* forms brown scleorotia which are very well organized compact structures, built of three layers, the rind, composed of empty melanized cells; the cortex cells, filled with vesicles and the medulla (Chet, 1975). Sclerotia may be spherical or irregular in shape and at maturity resemble the mustard seed (Taubenhaus, 1919 ;Barnett and Hunter, 1972). Sclerotial size was reported to be varied from 0.1 mm to 3.0 mm (Om Prakash and Singh, 1976 ; Ansari and Agnihotri, 2000 and Anahosur, 2001).

Distribution and Economic Importance of *Sclerotium rolfsii*

The pathogen attacks more than 500 species, the most common hosts are legumes, crucifers, and cucurbits (Punja, 1985). The disease is distributed throughout the world and prevalent particularly in warm dry climates. It was first reported by Mc Clintock (1917) in Virginia. Garren (1959) has estimated the losses in southern USA as 10 to 20 million dollars annually. Weber (1931) and Garret (1956) reported that the fungus survived in the soil for years together by producing sclerotial bodies and causing the disease on various hosts. The loss of yield caused by the pathogen is 25%, but sometimes it reaches 80-90% (Grichar and Bosweel, 1987). Similarly, yield losses over 25% have been reported by Mayee and Datar (1988) .Stem rot causes pod yield losses of 10-25%, but under severe diseased conditions yield losses may range to up 80% (Rodriguez Kabana *et al*., 1975). Patil and Rane (1982) reported yield loss up to 10 to 50% due to this disease. Adiver (2003) reported the yield loss of 15-70% in groundnut is due to leaf spot, rust and stem rot singly or in combination.

Symptomatology

The fungus *sclerotium rolfsii* has been known to infect several crops including cereals, oil seeds, legumes, vegetables and fruits causing collar rots, root rots, blights, wilts, stem rot resulting in great loss. Some major diseases are as follows in Table 1.

Wilson (1953) described the symptoms of stem rot as, mycelium covering the plant stem near the soil surface and produced organic acids, which were toxic to living plant tissue. This followed the necrosis of plant cells. The mycelium invaded the stem, gynophores and also pods

Table 1: Major Symptoms of Diseases Caused by *S. rolfsii* on Certain Important Crops

Crop	Symptoms	References
Arachis hypogaea L.	Seedling blight, collar rot,wilt, root rot, stem rot andpod rot	Mayee and Datar(1988), Narain and Kar(1990)
Pyrus malus L.	Bronzing of foliage, presence of feathery mycelium on root surface, ultimately killing the seedlings.	Sonali and Gupta (2004)
Lycopersicum esculentum L.	Pre and post emergence damping off, collar/root rot and wilt of seedlings	Pranab Dutta and Das (2002)
Cyamopsis tetragonoloba (L.)Taub	Root rot at seedling stage, wilting of infected plants with vascular discoloration	Chakravarthy (2005)
Amorphophallus paeonifolius (Denmst)	Collar rot and foot rot	Srinivasulu (2005)
Sesame (*Sesamum indicum* L.)	Collar rot	Praveen Kumar N (2009)
Solanum tuberosum L.)	Sclerotium wilt or rot	Basamma (2008)

causing rotting of the tissues. The production of abundant white mycelium, and small brown spherical sclerotia on the infected parts were characteristic symptoms of the disease. Beattle (1954) also observed same symptoms on infected plants. Sclerotia developed on the surface of soil and infected stem (Baruah *et al*., 1980). Mehrotra and Aneja (1990) noticed the cortical decay of stem base at ground level and appearance of conspicuous white mycelium which extended into the soil and on organic debris. The mycelial mat may extend several centimeters up to the stem above the soil line. Numerous tan to brown, spherical sclerotia of about mustard seed size formed on infected plant material which was found on the soil surface (Nyvall, 1989 and Aken and Dashiell, 1991) also reported the similar symptom.

Isolation and Maintenance of the Pathogen

S. rolfsii can be isolated from different plant parts, viz., collar region of the affected portion of the plant tissue (Raja Lakshmi, 2002; Yella Goud, 2011). Stem (Kajal Kumar and Chitreswar Sen, 2000). Potato Dextrose Agar (PDA) was found to be the best supporting medium for *S. rolfsii* (Harinath Naidu, 2000; Siddanagoudar. Radder, 2005; Raoof .2006, Rekha Shukla, 2008; Hulya Ozgonen, 2010; Rakh, 2011)

Pathogenicity Tests

Artificial inoculation of the plants with the pathogen was done by different methods. Soil inoculation by the pathogen was studied by several workers. Vinod Dange (2006), Datur and Bindu (1974), Seedling root dip inoculum was used to induce sclerotial wilt in bell pepper (Anitha Chowdary, 1997).

Biological Control of Stem Rot

Amar Singh and Dhanbhir Singh (1994) isolated mycoflora from the soil of brinjal which are antagonistic to *S. rolfsii* included *Aspergillus flavus, A. niger, A. fumigatus ,Pencillium* sp., *P. cyclopium, Eupencillum sp*., and *Trichoderma* *viride* sp., *T. harzianum.* of which *T. harzianum* showed highest antagonistic activity (73%) against *S. rolfsii.* Anitha Chowdary (1997) isolated mycoflora from the rhizosphere of bell pepper antagonistic to *S. rolfsii* which included *Aspergillus flavus, A. niger, Cladosporium* sp., *Fusarium* sp. *Pencillium* sp., *Rhizopus* sp., and *Trichoderma viride*. *T. Viride* isolated from bell pepper plants showed maximum inhibition (62.5%) of *S. rolfsii.* Pushpavathi and Chandrasekhara Rao (1998) reported the efficacy of isolates of *Trichoderma* and six fungicides were suppressing the growth *of S. rolfsii.* They observed *Trichoderma harzianum* (73.37%) isolate was found superior than the *T. viride* (61.47%) in reducing the colony diameter of *S. rolfsii* in dual culture technique. Saralamma (2000) isolated fungal and bacterial species from rhizosphere of groundnut plants which included *Aspergillus flavus, A. niger, A. terreus, Trichoderma harzianum, Streptomyces sp* .Hence it is observed that *T. harzianum (H1)* showed maximum inhibition (82.3%) of *S. rolfsii.* Charitha Devi (2003) isolated 5 isolates of *Trichoderma spp* and *Pseudomonas sp*, against *Sclerotium rolfsii* causing root rot of groundnut, and reported that *T. harzianum* showed maximum (66.6%) inhibition of *Sclerotium rolfsii.* Manjula (2004) isolated 57 bacterial isolates and 13 isolates of *Trichoderma spp*. were evaluated for their antagonistic activity against *Sclerotium rolfsii*. And four isolates of *Pseudomonas fluorescens*, viz., GB 4, GB 8, GB 10 and GB 27, and *T. viride pq 1* were identified as potent antagonists of *S.rolfsii. T. viride pq 1* produced extracellular chitinase and parasitized the mycelium of *S.rolfsii*. Rajani (2004) reported the efficacy of isolates of different *Trichoderma sp., of which TG-2 (Trichodermaisolate-2)* inhibited the mycelial growth and sclerotial population of *S. rolfsii* to a maximum extent of 67.83 and 92.60% in dual culture technique.

Siddanagouda r. Radder (2005) isolated *Trichoderma sp.*, viz., *T. harzianum*, *T. viride*, *T. virens* and *T. Koningii* and reported that *T. harzianum* - Dwd (72.58%) inhibited the maximum mycelial growth in dual culture technique against *S. rolfsii*. Johnson, (2006) isolated six isolates of rhizosphere *mycoflora sps* and recorded maximum colony diameter sr1(90.00 mm) against *S.rolfsii* under *in vitro* condition. Varadharajan Karthikeyana (2007) isolated three isolates of *Trichoderma viride, T harzianum* and *Pseudomonas fluorescens,* which inhibited the growth of *Sclerotium rolfsii* (Sacc.) under dual culture technique, and reported Tv1 of *T. viride* caused 69.40% inhibition of the mycelial growth of the pathogen. Vinod Babu (2008) isolated nine antagonistic rhizosphere fungal mycoflora of groundnut, *Trichoderma harzianum*-3 (Th-3) inhibited mycelial growth of *Sclerotium rolfsii* by 83% in dual culture technique. *Pseudomonas fluorescens*-1 (Pf-1) was found very effective as it totally inhibited (100%) mycelial growth and sclerotial population of *S. rolfsii*. Rakh (2011) isolated 11 *Pseudomonas spp*., from rhizospheric soil, were evaluated for their antagonistic activity against *Sclerotium rolfsii*. A soil bacterium identified as, *Pseudomonas cf. monteilii 9*, showed highest antagonistic activity against the pathogen *Sclerotium rolfsii*. He reported, the *Pseudomonas cf. monteilii 9* inhibited the *Sclerotium rolfsii* to up 94 % in terms of dry weight. Rekha, (2012) isolated forty four isolates of *Trichoderma* (Tri-1 to Tri-44) against *Sclerotium rolfsii* was done through dual culture technique for their efficacy to reduce mycelial growth and formation of sclerotial bodies. Among the 44 tested isolates 10 isolates viz., Tri-8, Tri-13, Tri- 15, Tri- 16, Tri- 19, Tri-23, Tri-27, Tri- 29, Tri- 41 and Tri- 44 were found to be efficient in reducing both mycelial growth and formation of sclerotial bodies by the pathogens.

Effect of Chemical Fungicides Against Stem Rot

Kulkarni (1986) tested 19 fungicides against *S. Rolfsii* under *in vitro* condition and reported that fungicides vivatax (carboxin) at a concentration of 50 ppm was effective in complete inhibition of *S. rolfsii.* Kammanna *et al.* (1992) conducted *in vitro* tests and reported that tradimefon (Baleton 25 WP) and chlorothalonil (Kavach 75 WP) were most effective inhibiting the mycelial growth of *S. rolfsii* in soft rot of coffee. Anitha Chowdary (1997) evaluated *in vitro* sensitivity of bell pepper isolate of *S. rolfsii* to captan, thiram @ 25, 50, 100, 250, 500 and 1000 ppm and propiconazole @ 10, 20, 25, 50, 100, 250 and 500 ppm and observed that propiconazole at a concentration of 250 ppm was effective in complete inhibition of *S. rolfsii*. Chowdhury *et al.* (1998) carried out *in vitro* evaluation of triazoles (i.e*.,* hexa-conazole, triademefon, propiconazole and bitertanol) and some non-systemic fungicides against *S. rolfsii* causing *sclerotium wilt* in bell pepper, of these non-systemic fungicides like captan, thiram and mancozeb tested were completely inhibitory to the pathogen at 1000 ppm concentration and proved that hexaconazole was significantly superior.

El-Wakil and Ghonim (2000) tested fungicides like Topsin-M , Vitavax, Thiram, Rizolex-T and were tested against pod rot incidence caused by *S. rolfsii.* Among them carboxin, thiram and Rizolex-T were found more efficient to reduce the pod rot infection. Palaiah (2002) observed sensitivity of various isolates of *S. rolfsii* to chemicals. Among the chemicals tested, chloropyriphos showed maximum inhibition of about 57.10% followed by thiram with inhibition of 45.70 and 44.30 %, respectively. Pranab Dutta and Das (2002) studied *in vitro* efficacy of thiram and mancozeb at 0.1% concentration against tomato isolate of *S. rolfsii* and reported that thiram had inhibited 70.3% of mycelial growth and 96.5% of sclerotial production of *S. rolfsii*. Narayana Bhat and Srivastava (2003) evaluated *in vitro* efficacy of captan, thiophanate-methyl and propiconazole at 250, 500 and 1000 ppm concentrations against *S. rolfsii*. They found that propiconazole was effective even at 250 ppm concentration against *S. rolfsii*. Cilliers (2003) tested different fungicides against *S. rolfsii* under *in vitro* condition and reported that Difenoconazole significantly reduced the growth rate of *S. rolfsii*. Manjula (2004) reported that Under controlled environment conditions, *P. fluorescens* GB 10, GB 27, T. viride pq 1 and the systemic fungicide Thiram® reduced the mortality of *S. rolfsii* inoculated to groundnut seedlings by 58.0%, 55.9%, 70.0% and 25.9%, respectively. Sheoraj *et al.* (2005) studied the efficacy of mancozeb, thiram, carboxin, dithane M-45, sulfur dust, carbendazim, ziram, streptocycline, thiophanate methyl and blue copper at 2500 ppm in controlling *S. rolfsii* causing collar rot in lentil *in vitro*. Mancozeb, thiram and carboxin recorded 100% per cent control against the pathogen. Johnson and Reddy (2008) evaluated *in vitro* efficacy of fungicides (hexaconazole, propiconazole, mancozeb, Chlorpyriphos and Quinalphos) against *S. rolfsii* . Among the five pesticides tested for their efficacy, hexaconazole at a concentration of 1000, 1500 and 2000 ppm and propiconazole at a concentration of 500, 750 and 1000 ppm completely inhibited the growth of *S. rolfsii*.

In vivo Studies on Stem Rot Disease

Seed Treatment (or) Seedling Treatment

Papavizas and Lewis (1989) reported that, *T. harzianum* and *Gliocladium virens* reduced the damping off and blight of soybean caused by *S. rolfsii* under green house conditions. Seed treatment with *G. virens* 109 spores/ml reduced the stem rot of groundnut caused by *S. rolfsii* (Sreenivasa Prasad and Manibhusan Rao, 1993). Kulkarni (1994) and Prabhu *et al.* (1997) showed that, seed and soil treatment with *T. viride* and *T. harzianum* were the most effective in reducing the mortality percentage of groundnut incited by *S. rolfsii.* Ram and Bhanushally (2003) reported that, collar rot of groundnut caused by *Aspergillus niger* was significantly reduced (7.77%) as compared to check (25.81%) when seeds were treated with *Trichoderma harzianum* (10 g kg^{-1} seed) in combination with soil application of *T. harzianum* (@ 4 kg ha^{-1}) against *S. rolfsii.* Vanitha and Suresh (2002) observed that application of the inoculum *T. harzianum* in the seed treatment and soil application of adathoda leaf powder and FYM exhibited , the lowest collar rot of brinjal (9.44%) caused by *Sclerotium rolfsii.* Saralamma and Vithal Reddy (2003) observed and reported that seed treatment @ 10 conidia ml^{-1} and soil application @ 5g kg^{-1} soil with *T. harzianum* (H) were found to be optimum in increasing percent seedling emergence to an extent of 80 and 84, reducing disease incidence to 26.6 and 13.0% with an increasing yield of 1373 and 1413 kg /ha^{-1} .

Soil Application

Mishra and Bais (1987) found that soil treatment with thiram (2000 ppm) minimized pre and post-emergence mortality of barley caused by *S. rolfsii* and reported the efficacy of different fungicides hexaconazole (0.1% and 0.2%), carbendazim (0.2%), and thiophanate-methyl (0.2%) under *in vivo* conditions against *S. rolfsii* of gram and sunflower. Hexaconazole was found to be highly effective. Thribhuvanamala (1999) reported that, effect of BCA against *Sclerotium rolfsii* by soil application under pot culture ,observed *Trichoderma harzianum* was highly effective against the stem rot pathogen. Biswas *et al.* (2000) observed that application of *T. harzianum* inoculum to soil and seed dressing at the time of sowing in the pots exhibited percent disease reduction through seed dressing was 33 to 50% and through direct soil application was 72 to 83%. Sclerotial wilt of groundnut caused by *S. rolfsii* was effectively reduced (92.58%) when *T. harzianum* was applied @ 10 g/kg soil (Patibanda *et al.,* 2002). Ram and Bhanushally (2003) reported that, *Trichoderma harzianum* (10 g kg-1 seed) in combination with soil application of *T. harzianum* (@ 4 kg ha^{-1}). Shanmugam (2003) reported that both seed treatment and soil application was found to be effective in reducing disease incidence to the extent of 23.2% against *Sclerotium rolfsii.* Soil application of *T.harzianum (H)* inoculum was superior in reducing the percentage disease incidence and increased shoot length (24 g), root length (17.0), and yield 1509 $kgha^{-1}$ against root rot of groundnut caused by *Sclerotium rolfsii* Saralamma and Vithal Reddy (2003)

Integrated Management of Stem Rot

Asghari and Mayee (1991), reported that, application of *T. harzianum* inoculum and soil drenching with 0.2 per cent carbendazim reduced the stem rot of groundnut caused by 44-60 per cent and increased the pod yields by 17-47 %. Pushpavati and Chandrasekhara (1998), reported that *T. harzianum* alone proved as a potential bio control agent against stem rot pathogen of groundnut plants under glass house conditions.Singh and Thapliyal (1998) studied the effect of seed treatment with fungicide and bioagents on seed and seedling rots and effectively managed the diseases by seed treatment with carboxin and *T. harzianum* or *G. virens*. Hanumanthe Gouda (1999) reported that, both seed treatment and soil application of *T. harzianum* recorded the low incidence of groundnut stem rot caused by *Sclerotium rolfsii*. El Wakil and Ghonim (2000) evaluated vitavax against root rot and wilt of groundnut as seed dressing and soil treatments under greenhouse and field experiments. Vitavax was more efficient to reduce the per cent of pod rot infection against all the tested isolates under both artificial and natural conditions. Sclerotial wilt of potato caused by *Sclerotium rolfsii* was effectively reduced when *T. harzianum* was applied @ 4 g/kg to the soil and FYM Anahosur (2001). Patibanda *et al.* (2002) observed effective control of sclerotium wilt of groundnut caused by *S. rolfsii* when seed coating with thiram (0.1%) integrated with soil application of *T. harzianum* @ 4.0 g/kg soil. Vanitha and Suresh (2002) conducted a study to investigate efficacy of biological control agents and organic amendments in controlling collar rot of brinjal caused by *Sclerotium rolfsii*, where *Trichoderma viridae* + FYM + dry adathoda leaf powder were found effective. Saralamma and Vithal Reddy (2003) reported that *T. harzianum* + Thiophanate methyl + neem cake proved effective against increasing efficiency of pathogen suppression and increasing yields of root rot of groundnut. Rajani (2004) reported that biological agent (TG-2) + Vermi compost + neem cake found to be superior and recorded least PDI of 6.66% against *S. rolfsii.* Siddanagoudar Radder (2005) evaluated that soil application and culture filtrate formulation with FYM was found to be effective to enhance the seed germination against *Sclerotium rolfsii.* Vinod dange 2006 evaluated that, FYM was found to be most effective against the root rot of chilli caused by *S. rolfsii* and recorded the least disease (19.34%) incidence .Integrated management of stem rot disease of groundnut using a combined application of Rhizobium and *Trichoderma harzianum* (ITCC – 4572) was performed, and it was observed that the application of these native micro-organisms successfully decreases the stem rot incidence and also increases the growth of groundnut plants (Ganesan, 2006). Varadharajan Karthikeyana (2007) tested the organic amendments under greenhouse conditions and found that, mahuacake with *T. viride* each @ 5 g/kg of soil resulted in 3.75% stem rot incidence against 39.98% in control. Kulkarni (2007) evaluated fungicides and bioagents alone or in combination as seed dressers along with soil amendments as components for integrated management of potato wilt caused by *S. rolfsii* under glasshouse conditions and recorded least disease incidence (13.33%) in treatment consisting carboxin + *T. harzianum* + farm yard manure. Johnson, and Reddy (2008) reported that integration of *Pseudomonas fluorescence* and in combination with tryptophan and Farm Yard Manure (FYM), has reduced the stem rot incidence and the highest yields were recorded against *S. rolfsii.* Basamma Kumar (2008) reported that maximum inhibition of the pathogen was recorded in *Trichoderma harzianum*, and observed that Soil solarisation in combination with carboxin + *Trichoderma harzianum* tuber treatment along with soil application of FYM and neem cake reduced the wilt incidence and increased yield of potato. Vinod Babu (2008) observed seed treatment with fungicide (mancozeb) + soil application (Th-3) potential native antagonist + soil application with potential bacterial antagonist (Pf-1) recorded least percentage disease incidence of 6.67%, maximum plant height – 30.66 cm, maximum root length – 29.13 cm of groundnut. In the integrated management of sesame collar rot, the treatment T7 (FYM + seed treatment with carboxin) was found to be most effective in reducing the disease and recorded the least per cent disease incidence (33.33%), Praveen Kumar (2009). Application of *Pseudomonas cf. monteilii 9* inoculum to the seeds has showed decreased incidence of disease to up 45.45 to 66.67% Rakh (2011).

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