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Review article

AN OVERVIEW OF STEM ROT DISEASE OF RICE (*Sclerotium oryzae* Catt.) AND IT'S COMPREHENSIVE MANAGEMENT

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ABSTRACT: Rice (*Oryzae sativa* L.) is one of the important staple food crops for more than 60 per cent of the world's population. Over 90 per cent of the rice produced in the world is consumed in the Asian countries only. India is the number one country in the world in cultivating rice in an area of 43.5 million hectares with an annual production of 893.1 million tones and it ranks second to china in the production (Centre for Monitoring Indian Economy Report, 2010).

Stem rot disease caused by *Sclerotium oryzae* which was earlier considered as a minor disease has now became one of the major limiting factors in rice cultivation especially in delayed transplanted conditions. Although the disease manifests from panicle initiation stage but the conspicuous diagnostic symptoms are usually seen at later growth stages of crop i.e., from milky to grain hardening stage. In severe cases, lodging of the crop may occur and sclerotia of the pathogen are found within the host tissues.

The yield losses upto a maximum of 80 per cent in different rice cultivars has been reported by several workers form varied agro climatic regions in India and aboard. (Hernandez, 1923; Srivastava *et al.*, 1971; Kang *et al.*, 1970; Webster *et al.*, 1972; and Krause and Webster 1972; Al Heeti and El–Bahadli, 1982; Li *et al.*, 1984; Ou, 1985; Cother and Nicol, 1999).

In this chapter we have critically reviewed disease occurrence and yield losses, symptomatology, pathogen, isolation of the pathogen, maintenance and mass multiplication of the pathogen under laboratory conditions, pathogenicity test, host range, viability and source of survival, pathogenic variability and management aspects of stem rot of rice.

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DISEASE OCCURRENCE AND YIELD LOSSES

Stem rot of rice, *Sclerotium oryzae* Catt., has been reported practically from every rice growing country of the world. Shaw made first Indian collection of disease in Noakhali (now in Pakistan) in 1913. Since then the disease has been reported from Madras (Shaw 1913), Bihar (Shaw 1913; Butler 1918), Punjab (Luthra and Sattar, 1936); Assam (Nandi, 1941), Paracer and Luthra, 1944 and Madhya Pradesh (Nikam, 1954).

In Philippines, losses ranging 30 to 80% have been estimated in Tarlac Province (Hernandez, 1923) and in Arkanansas, USA (Anon., 1930), and as high as 75% in certain fields, with an annual average of 10% in severely infected areas.

Stem rot of rice caused by *Sclerotium oryzae* Catt. was present in all rice growing region world wide (Ou, 1972 and 1985), including in California (Krause and Webster, 1972, 1973; Webster *et al*., 1971, 1972). Yield losses of up to 18 % have been recorded under field conditions in California (Krause and Webster, 1972 and Webster *et al.*, 1972). The pathogen has been reported to cause 5–80 per cent losses in grain yield in different parts of the world (Al Heeti and El–Bahadli, 1982; Li *et al.*, 1984; Ou, 1985; Cother and Nicol, 1999).

Stem rot disease of rice incited by *Sclerotium oryzae* (Perfect state - *Magnaporthe salvinii* Krause and Webster, conidial state – *Nakataea sigmoidea* Cav.) has been one of the major limiting factors in rice cultivation (Bedi, 1953; Ghose *et al*., 1960).

Singh and Pavgi (1966) reported up to 70% loss in grain yield due to stem rot disease in Uttar Pradesh.

During 1962 and 1963, the fungus was widespread on paddy in the months of October – November in the Shahabad district of Bihar, especially in the areas under Intensive Agricultural Development Programme at Bikramgunj and Buxar, where the variety 2206-B (BR 34) was mostly grown (Misra and Mohammad, 1964).

The disease was known to cause losses in yield up to 60% (Chauhan *et al.*, 1968). It was also reported to be most destructive in Punjab (Kang *et al.*, 1970; Srivastava, 1971)

Stem rot of rice incited by sclerotial fungi such as *Sclerotium oryzae* Catt., *S. hydrophilum* Sacc. and *Sclerotium oryzae* var. *irregulare* Roger was a common disease in rice growing areas of India. It was more destructive in Punjab, Haryana and Tamil nadu (Padmanabhan 1974, Ahuja *et al.*, 1981), particularly on high yielding varieties.

The disease was much prevalent in Haryana and adjoining areas (Ahuja *et al.*, 1981; Yadav and Mehrotra, 1982; Sharma *et al.*, 1984). Konthoujam (1998) reported the endemic nature of stem rot infecting due to monoculturing of rice in Manipur.

Stem rot of rice was rapidly spread through out the Manipur valley during past 9 years (1997-2005). Production oriented survey for the occurrence of stem rot rice conducted by Directorate of Rice Research, Rajendranagar, Hyderabad in different states of India Andhra Pradesh. (DRR Production Oriented Survey Reports 2004, 2006, 2007 and 2008) varied from 0 – 15 %.

Table-1: Stem rot incidence in India

Year	Andhra Pradesh	Bihar	Chhattisgarh	Haryana	Uttaranchal	West Bengal
2004	L – M	L –M	T	L	M	-
2006	L – S	-	-	L – M	-	-
2007	-	-	-	L – M	-	L
2008	L	-	-	M - S	-	-

L – low, M – medium, S - severe, T - traces

Low –0-5%, Medium –5.1-10.00%, Severe – 10.10 – 15%, Traces – 0

Table-2: Stem rot incidence in Andhra Pradesh

Year	West Godavari	East Godavari	Krishna	Kadappa	Nalgonda	Chittor
2004	L	T	-	L-M	-	L
2006	L	L - S	L	-	L	-
2007	-		-	-	-	-
2008	L	L	-	-	-	-

L – low, M – medium, S - severe, T - traces

Low –0-5%, Medium –5.1-10.00%, Severe – 10.10 – 15%, Traces – 0

SYMPTOMATOLOGY

Only a few workers have studied and described symptoms of stem rot of rice.

Ferreria and Webster (1976) observed the stem rot of rice symptoms caused by *Sclerotium oryzae* in the field first appeared as small dark lesions on the leaf sheath at the water level. Disease progression was characterized by the death and sloughing of the infected sheath followed by penetration of the entire culm. When the culm was infected both grain quality and panicle size were reduced. When infection occurs early in the season, tillers were killed or fail to produce panicles. Further, they observed that additional reduction in yield resulted from increased lodging of infected plants.

Inspite of several published reports, stem rot by and large had remained difficult to diagnose because the symptoms were not pronounced till flowering and were often confused with symptoms caused by other diseases and pests. Severe lodging due to the stem rot was ascribed to weak stem and was ignored (Amin, 1976).

Ou (1985) reported that symptoms are usually seen at the later growth stages. Necrotic lesions begin on the outer leaf sheath near the water line, these spread gradually to the inner sheaths and the stem base. At maturity lodging may occur and sclerotia found within the tissues.

Similarly Kumar *et al.,* (2003 a) reported that this disease mainly affects the stem resulting in rotting and subsequent lodging of the crop.

Pathogen

Sclerotium oryzae was first described from Italy by Cattaneo, (1876) in the sclerotial state and was named *Sclerotium oryzae* Catt. Cavara (1889) later reported *Helminthosporium sigmoideum* Cav. on rice.

Mundkur (1935) found *Sclerotium oryzae* to be pathogenic on rice seedlings but under field conditions it was considered to be a weak parasite. Luthra and Sattar (1936) and Paracer and Luthra (1944) however found it to be pathogenic under field conditions.

Ferreira and Webster (1975) reported that stem rot of rice was caused by *Magnoprothe salvinii* (Catteneo). This fungus has best known for its sclerotial state *Sclerotium oryzae* Catt. The conidial state had been referred as *Nakates sigmoidea* (Cav.) Hara, *Vakrabeeja sigmoidea* (Cav.) or *Helminthosporium sigmoideum* (Cav.). Futher, they described the fungus as heterothallic; two allelels at one locus which determine the compatible mating reaction for the ascomycetous state.

Stem rot an important disease of rice in the states of Tamil Nandu, Punjab, Haryana and Uttar Pradesh was known to be incited by *Sclerotium oryzae* Catt., *Sclerotium oryzae* Catt. var *irregulare* Roger and *S. hydrophillum* Sacc. Among these, *Sclerotium oryzae* and *Sclerotium oryzae irregulare* were common while *S. hydrophillum* had been reported from Bengal, Haryana, Punjab and Andhra Pradesh. The later was regarded as a weak parasite which may cause lodging (Ahuja *et al*., 1988).

Isolation of the pathogen

In order to test the pathogenicity of *Sclerotium oryzae,* Misra and Mohammad (1964) isolated the pathogen from diseased culms of cv. 2206-B (BR 34) and brought into pure culture by plating a single sclerotium on PDA.

Singh (1982) isolated and maintained eight isolates of *Sclerotium oryzae* isolated from the specimens collected from different parts of India. Gangopadhyay and Das (1983) isolated *Sclerotium oryzae* on to the artificial medium containing rice hills (10g), $CaCO_3$ (4g), $CaNO_3$ (1g), KC1 (0.25g), MgSO4 (0.25g), Sucrose (2g) and Agar (10g per liter of sterile water).

Inagaki *et al.* (1987) isolated *S. hydrophilum* from the infected plant residue at 90 days and more frequently from the sclerotia exposed on the soil surface.

Ali and Singh (1994 (a)) isolated *Sclerotium oryzae* from the infected rice samples showing stem rot symptoms. The fungus was successfully grown on PDA medium at a temperature ranging between 20 – 35 °C.

Kadowaki *et al.* (1995) isolated *S. hydrophilum* from different parts of rice plants such as roots, non elongated internodes and leaf sheaths and the isolation rate was high in lower leaf sheaths compared to the upper parts of the plants.

Lanoiselet *et al.* (2001) isolated *S. hydrophilum* on to PDA medium from the infected leaf sheaths prior to which the samples were surface sterilized in 2% sodium hypochlorite for 2 min followed by thorough rinsing in sterile distilled water.

Maintenance and Mass Multiplication of the pathogen under Laboratory Conditions

Misra and Mohammad (1964) recorded good growth and sclerotial production of the fungus when multiplied on sterilized soil–oats or sand-maize medium (soil 95g, crushed oats or maize 5g) and potato dextrose agar.

Amin (1976) recorded good growth of *Sclerotium oryzae* on peptone-sucrose-agar medium which was incubated at 25 - 30^0 C for 10 to 15 days. The inoculum was also mass multiplied on mass scale on sucrose–coated stem pieces.

Ferreira and Webster (1976) used rice hull and unmilled rice by mixing in 2:1 ratio and wetted a solution consisting of 4 g CaCo3; 1g CaNo3; 0.25g MgSO4; 0.25g KCl; 0.25g KH2PO4; 1g Sucrose and 2 liters distilled water for production of Sclerotia.

Sclerotium oryzae was mass multiplied on a 2:1 mixture of rice and rice husk, typha (*Typha angustata*) pieces, rice stem pieces of susceptible cultivar PR 106 and rice grain husk + sand medium (2:1) in 250 ml Erlenmeyer flasks at 28 $\pm$ 2^0 C for 20 days (Kumar *et al.*, 2003 a).

Sclerotium oryzae inoculum multiplied on rice grain husk + sand medium produced maximum disease (62%) under pot conditions followed by inoculum raised on rice stem and typha pieces (Kumar *et al.,* 2003 (b))

Pathogenicity Test

Shaw (1913), Butler (1918) and Mundkur (1935) observed heavy infection during pathogenicity test conducted on rice seedlings grown in test tubes, but under natural conditions the fungus was as weak parasite. On the other hand Luthra and Sattar (1936) and Paracer and Luthra (1944) showed the pathogenicity of *Sclerotium oryzae* and carried tests for varietal resistance under natural conditions.

Misra and Mohammad (1964) reported the occurrence of stem rot disease by using cv. 2206-B, when the inoculum of *Sclerotium oryzae* was mixed in the upper layers of steam sterilized soil at seven days before sowing of the seed or transplanting the seedlings.

Kang *et al.,* 1970) infected the soil with infected stubbles and produced the sclerotia in the laboratory and they stated that it was possible to induce stem rot by soil infestation but, the progress of the disease was slow.

Krause (1971) did not find the effect of the pathogen on disease development when plants were inoculated at mid tillering or booting stage. In all India coordinated rice improvement project, it was proposed to inoculate the main tiller 20 days after transplantation (40-50 days after sowing). This gives enough time for pathogen to infect, penetrate and develop the disease, as *Sclerotium oryzae* was a weak and refined parasite. Further, the incidence of disease had increased when sheaths were slightly scraped with finger nails before placing inoculum over it by stem tape method.

The cut stem technique followed by Ou (1972), in which roots and top parts were cut off and the inoculum was placed at the bottom cut end, could not give the plants opportunity to express their potential for resistance.

Various pathogenicity tests *viz.*, soil infestations and inoculations of plants by spraying inoculum on plants and by stem tape inoculation were carried out by Amin (1976) in the green house. The stem tape inoculation method was found suitable for screening a large number of rice varieties.

While undertaking pathogenicity studies Kumar *et al.* (2003 a) noted that inoculation of injured plants with air-dried sclerotia produced more disease vis-a-vis uninjured plants.

Host Range

Cralley and Tullis (1934) isolated *S. hydrophilum* from *Echinochloa crusgalli* (L), *E. colonum* (L) and *Typha latifolia* (L).

Nakata and Kawamura (1939) from Japan reported the occurrence of stem rot on several plants other than rice in nature and the fungus when artificially inoculated resulting in invading several graminaceous and cyperaceous plants.

Chen (1971, 1973) reported 10 species of graminae, three of cyperaceae and one of liliaceae, as hosts of *Sclerotium oryzae* var. '*sigmoidea'* and 13 of graminea, two of cyperaceae and one of juncaceae as host for *Sclerotium oryzae* var. *'irregulare'*

Ou (1972) also mentioned that *Zizania latifolia* (T) and *Juncellus serotines* (R.) and *Digitaria sanguninalus* (L.) are the hosts of this fungus.

Johnson *et al.,* 1976 successfully inoculated *S. hydrophilum* on to healthy *Nymphea odoranta* leaves, which being first report on the occurrence of the fungus on these hosts.

Punter *et al.* (1984) isolated a *S. hydrophilum*, a sclerotium forming fungus from a wild rice species occurring over a wide range of temperature and tropical aquatic macrophyte.

Li and Wang (1985) reported the occurrence of *S. hydrophilum*, *Fusarium* spp. and *Rhizoctina* spp. on 11 aquatic plants.

Viability and source of Survival

Park and Bertus (1932) recovered viable sclerotia after 190 days from air-dry soil and after 132 days from moist rice field soils.

Studies on longevity of *L. salvinii* showed that the sclerotia can remain viable for at least six years in cultivated rice soil (Tullis and Cralley, 1941). After two years viable sclerotia were recovered from stubbles in the field and from stubbles stored in laboratory under less variable conditions after about two and half years. Thus rotation period of 4-6 years apparently did not eliminate disease.

Tullis and Cralley (1941) buried infested rice straw and sclerotia 10-15cms deep in field soil and reported that 3.7% of the sclerotia were viable after 6 years.

Krause and Webster (1972) studied the effect of varying inoculum levels and changes in variability of sclerotia of *Sclerotium oryzae* on the occurrence and severity of stem rot and enabled the desirable methods for quantitative recovery and determination of the viability of sclerotia from infested soil.

Studies on the effect of soil moisture and temperature on viability of *Sclerotium oryzae* showed that alternate wetting and drying resulted in substantial loss of sclerotial weight accompanied by reduction in viability. Viabilities of sclerotia recovered form wet soils after incubation at 24^0c were significantly lower than the viabilities of those incubated at 1^0C and those incubated at 24^0c after they were recovered from soils that had been allowed to dry. They were also lower than viabilities of sclerotia subjected to alternate wetting and drying. It would appear that a soil fungistatic factor was imbibed by sclerotia and retained after their recovery from soil. (Keim and Webster, 1974 a).

Bockus *et al.* (1978) studied the saprophytic ability of *Sclerotium oryzae* derived from sclerotia. The saprophytic ability of *Sclerotium oryzae* was too low to enable it to use residual organic material in either non-autoclaved or autoclaved soil. In autoclaved soil amended with rice sheaths, the sclerotia germinated, the fungus colonized the sheaths, and the number of sclerotia increased within the non-autoclaved soil amended with rice sheaths, a few sclerotia were produced as a result of colonization of the sheaths but they did not contribute significantly to the population of sclerotia in the soil.

Ali and Singh (1994 b) reported that the fungus survives for several years through sclerotia over the infected stubbles left over in the field which serve as primary source of inoculum.

Inagaki *et al.* (2004) obtained *S. hydrophilum* and *Rhizoctonia oryzae-. sativae* more frequently from stubble than from surface soil, while there was no significant difference in the isolation frequency of *Rhizoctonia fumigata* between surface soil and stubble, indicating that the survival of *S. hydrophilum* and *R. oryzae-sativae* was highly related to the availability of stubble, where as *R. fumigata* relates to both isolation sources. *R. fumigata,* which had caused sclerotial disease over a wide area (25-30%) of rice fields, over wintered at higher rate in the fields, as compared with fungi such as *R. oryzae-sativae, R. oryzae, R. solani* which had caused disease only within a limited area (0-15%) of those same fields.

Konthoujam and Chhetry (2005) studied the viability and survival of *Sclerotium oryzae* under natural conditions, compared to those preserved aseptically in the laboratory over the period of 12 months. Their studies revealed that the sclerotia in these free state was less viable than those over wintering naturally inside left over stubbles or in degenerated plant tissue debris in the top soil in the fields. Viability decreased with age in all the isolates collected from different sources. Age and over wintering medium of sclerotia did not have any significant effect on their vigor in germination and formation of fresh sclerotia *in-vitro* conditions.

Pathogenic variability

Culture filterate of different fungi are known to produce either stimulatory or inhibitory effect to the young seedlings (Das and Srivastava, 1971; Anahosur, 1976; Prasad and Hirenath 1983).

Quantitative differences in the rate and amount of conidia and sclerotia produced were determined for isolates of *Sclerotium oryzae* differing in rating type and virulence to determine differences in fitness of *Sclerotium oryzae* in nature (Ferreira and Webster, 1975).

Ferreira and Webster (1976) developed a test to measure the disease reaction of individual *Sclerotium oryzae* isolate-host combinations by estimating the ability of isolates to incite lesions. Since the ability of isolates to incite lesions was correlated with the ability to kill seedlings, virulence of individual isolates can be determined by measuring the ability to cause lesions. They concluded that seedling test can be used to evaluate rice cultivars for stem rot resistance as well as virulence in *Sclerotium oryzae.*

Ali and Singh (1992) investigated to find out the pathogenic variability and the effect of culture filtrate of *Sclerotium oryzae* on inhibition of radical and pumule length in rice. The results indicated that variation in virulence exists in the different isolates of the pathogen and indicating different degree of resistance in rice cultivars against the disease. Culture filtrate of all the isolates inhibited the radicle and plumule elongation which was directly correlated with the concentration of culture filtrate to untreated control. The maximum inhibition of radicle and plumule occurred in undiluted culture filtrate followed by 50 and 25% filtrate.

MANAGEMENT OF STEM ROT

Identification of sources of resistance

The sources of resistance to stem rot under natural and artificial conditions were reported by only a few workers (Cralley, 1936; Kang *et al.,* 1970; Goto and Fukatsu, 1954) from different parts of the country. The details of which are furnished here under.

Misra and Mohammed (1964) carried out varietal reactions at three stages in sterilized and infected soil. Out of ten varieties 115BK, 141Bk, 16BK, 88BK, 36BK, 498-2A, 818-3, 2206-B, CH-10 and CH1007 tested for infection at seedling and after transplantation, none of the varieties proved resistant, though there were differences in the percentage of infection. Among the ten varieties tested for infection at tillering stage, varieties 115BK, 141BK, 16BK, 88BK, 36BK and 818-3 developed stem rot symptoms with sclerotia inside the culms.

Varietal resistance carried out by Srivastava *et al.,* 1971 revealed that out of 44 varieties tested for their resistance to stem rot, 7 were highly resistant, 12 resistant, 5 moderately resistant, 2 moderately susceptible, 4 susceptible and 14 highly susceptible. Among the resistant varieties TN-1, Taichung 65 and Jaya were high yielders where as Basmati 217 and Basmati 370 were of good quality. Tainan 3', TN-1, Taichung 65 and Jaya were good for hybridization because there were not only resistant to stem rot but also for blast and *Helminthosporium* to some extent.

Sixty-nine rice varieties including Pankaj, Jaya, Sabarmati Improved, TKM-6, Sigadis, RP 5-32 and Tadukan were found tolerant to stem rot and other major diseases (Amin, 1976)

Ahuja *et al.* (1988) studied relative preponderance of sclerotial species on rice and varietal resistance. Their observations on 16 varieties showed occurrence of *Sclerotium oryzae, Sclerotium oryzae* irregulare and *S. hydrophilum* on the same hill. *Sclerotium oryzae* was predominant over *S. irregulare* and *S. hydophilum* in prevalence and severity except in entries CR188-10, Pusa 2-21, HKR 102 and Pusa169 where *S. hydrophilum* and *S. irregulare* were predominant.

Ali and Singh (1994 a) screened 52 cultivars against *Sclerotium oryzae* by artificial inoculation during *kharif,* 1989 at Pantnagar. Improved Sona, IR 22, Rasi and VL 8 were identified as resistant varieties against stem rot.

Screening of rice genotypes was carried out by Kumar *et al.* (2003 a) under field conditions and high disease pressure with location severity indices of 7.38 and 7.39 on 0-9 scale during *kharif* 1998 and 1999. Of 234 rice genotypes screened against stem rot, none of the genotypes were consistently resistant. However, 38 genotypes showed moderately resistant reaction.

Konthoujam *et al.* (2007 a) noted symptomatological significance characterization of susceptibility resistance group low land rice cultivars towards stem rot of rice in Manipur valley. None of the 33 cultivars studied were resistant or highly resistant against the disease. The degree of susceptibility among cultivars differed with marked symptomological difference in size, number and position of lesions on infected stems above the field water level. Highly susceptible cultivars exhibited more number of lesions (3.0 to 8.5), larger coalesced lesion size (72.6 sq mm – 406.2 sq mm) at crop maturity and extended to higher portions on the stems up to 6.6" above soil, in fields with 2" water level during cropping period. The size, number and portions of lesions decreased with increasing resistance of individual cultivars.

Cultural Practices

Paracer and Luthra (1944) recommended the burning of stubbles soon after harvest, drawing the stagnant water and the allowing of fresh water. Similar measures have been recommended by Tullis and Cralley (1941), and Park and Bertus (1932). Cralley and Adair (1943), however found only a slight reduction in severity of infection and no increase in crop yield as a result of either alternate drawing or flooding of field or from with holding water for some time prior to harvest.

Cintas and Webster (2001) reported that fall incorporation of the straw residue, rolling of the straw to enhance soil contact, baling and removal of residue, and fall burning the straw followed by winter flooding appears to be the best alternative to rice straw burning for disposal of residue and management of stem rot.

Konthoujam *et al.* (2007) by using cv. Sana phou (susceptible to stem rot of rice) as the test plant during *kharif,* 2004-2005 reported that maximizing soil amendment with N-P-K from 0-0-0 to 80-60-30 kg ha^{-1} increased the yield by 76.8%. However, further increase of N-P to 120-80 kg ha^{-1} increased the stem rot incidence by 57.8%, disease severity by 54.3% and resulted to an abrupt decline in yield by 13.6%.

Efficacy of fungicides and herbicides against *Sclerotium oryzae*

Misra and Das (1967) tested 11 fungicides pertaining to copper, mercury and the dithiocarbamates against *Sclerotium oryzae*. Out of which Blue copper – 50 (ED 50 in ppm 138) in copper group, mercuric chloride (ED 50 in ppm 10.5) in mercury group and ferbam (ED 50 in ppm 240) in dithiocarbamates were highly toxic for mycelial growth.

The amount of fungicides required for the inhibition of the fungus in the soil was higher than that required on agar medium. The most effective fungicide was mercuric chloride. Its ED 50 value was the lowest as compared to other fungicides.

Jain (1973) reported that the application of Hinosan, Benlate resulted in significant reduction in stem rot incidence on Ratna rice variety

Jackson *et al.* (1977) conducted a field test to control stem rot disease of rice with triphenyltin hydroxide (TPTH) for three years. A single application of TPTH at the rate of 1.12 kg ha^{-1} at the mid tillering stage resulted in significant reductions in disease severity which were accompanied by increasing in yield ranging from 6-25 per cent. Further, the results indicated that the fungicide reduced the number of early infections, delayed disease progress, and decreased final disease severity.

Gangopadhyay and Padhi (1984) reported that hinosan and lihocin proved to be the best fungicidal combination for control of stem rot of rice.

Reddy (1984) reported that among 16 fungicides, carbendazim (Bavistin 50 WP), tridemorph, tolfos – methyl, thiophanate methyl, carboxin (Vitavax 75 WP), ziram, cuman L-27 and TCM TB were highly effective even at lower concentration in checking the growth the sclerotial germination of the pathogen. The weedicide benthiocarb (Saturn 50 EC) showed the inhibitory effect on the growth and sclerotial formation of *Sclerotium oryzae.*

Stem rot caused by *Sclerotium oryzae* was one of the major limiting factors in rice cultivation. All the cultivated varieties suffer from this disease. Since resistance to stem rot in rice genotypes is rare (Raina *et al.,* 1980, Chand *et al.,* 1985), management of the disease through chemicals becomes imperative.

Sharma and Verma (1985) reported that out of 17 fungicides, namely, Bavistin, Blitox, Brassicol, Calaxin, Cuprasol, Demosan, Dithane M-45, Dithane Z-78, Difolaton, Hexathir, Hinosan, Kitazin, Thiovit, Topsin M and Vitavax tested by the poisoned food technique, Bavistin, Topsin M, Dithane Z-78, Brassicol and Hinosan were effective against *Sclerotium oryzae* Catt.

Ram Singh *et al.* (1988) reported that out of six fungitoxicants tested, carbendazim and thiophanate-methyl were effective in inhibiting sclerotial germination and mycelial growth of *Sclerotium oryzae*.

Reddy *et al.* (1988) reported that Edifenphos, Vitavax, Bromidiol, Panoctine, Dithane M-45, Bavistin, MBC, Busan, Hinosan, Calixin and Topsin were highly effective against stem rot while Brassicol was least effective

Studies conducted by Singh *et al.* (1987) indicated that carbendazim and thiophanate methyl effectively inhibited the sclerotial germination and mycelial growth of *Sclerotium oryzae.*

Sunder *et al*. (1991) reported that the stem rot incidence was reduced by the application of carbendazim at disease initiation and boot stage (two sprays) proved more effective than corresponding sprays of isoprothiolane in reducing the disease during wet season.

The superiority of mancozeb compound against *Sclerotium rolfsii* can be attributed due to inhibition of pentose phosphate pathway and chelation of required heavy metals followed by lethal catalysis in pathogen cell (Nene and Thapliyal, 1993).

Kumar *et al*. (2003 b) reported that of six resistance inducing chemicals tested, benzoic acid was found to be most effective over other chemicals followed by naphthalene acetic acid in reducing the disease incidence and severity. Benzoic acid reduced stem rot incidence to 61 per cent as against 74 per cent in the check but had no significant effect on disease severity.

Propiconazole was found to be the most promising fungicide and provided 47.5 and 26.5 per cent reduction in disease incidence and severity respectively followed by isoprothiolone (Kumar *et al.,* 2003 b).

Herbicide application has often been cited as an example of a management practice that affects plant pathogens and disease development in various cropping systems. The activity of herbicides can extend beyond their target organisms and inhibit spore germination or mycelial growth, alter the level of phytoalexins, or interfere with other physiological processes in plants (Debanjan Sanyal *et al*., 2008).

Trichoderma viride was found significantly superior over other antagonists in inhibiting the growth of *Sclerotium rolfsii*. Among five pesticides tested for their efficacy, hexaconazole (1000, 1500 and 2000 ppm) and propiconazole (500, 750 and 1000 ppm) completely inhibited the growth of *S. rolfsii*, whereas chlorpyriphos completely inhibited the pathogen at one step lower (1500 ppm) and at recommended concentration (2000 ppm), while quinalphos inhibited the growth at 2000 ppm. Of the four herbicides, pendimethalin completely inhibited the growth of *S. rolfsii* at recommended concentration (1000 ppm). Sensitivity of *T. viride* against three agrochemicals showed complete inhibition of the growth of *T. viride* with hexaconazole and 48% with pendimethalin (Johnson *et al.,* 2008).

Biological control

Isolation of antagonistic microflora from rhizosphere using serial dilution technique

Upadhyay and Mukhopadhyay (1986) isolated *Trichoderma harzianum* from sugar beet field soil on peptone-dextrose rose-bengal agar medium antagonistic to *S. rolfsii.*

Pande (1996) isolated six potential antagonistic isolates of *Pseudomonas fluorescens* from the rhizosphere of chick pea and wheat infected with *s. rolfsii* on King's B medium.

Pandey and Upadhyay (2000) isolated rhizosphere fungi of pigeonpea on martin medium *viz., Aspergillus niger, A. fumigatus, Penicillum* sp., *Fusarium udum, Pythium sp., Rhizopus sp., Trichoderma harzianum, Glicoladium virens* and bacteria were isolated on soil extract agar medium which included 3 isolates B_1, B_2 and B_3.

Rangeshwaran and Prasad (2000) isolated eleven antagonistic rhizobacteria including *Pseudomonas fluorescens, Pseudomonas sp., P. putida, Streptomyces sp., Bacillus pantothenticus* and *Alcaligenes odorans* from rhizosphere of sunflower infected with *S. rolfsii.*

Anahosur (2001) isolated antagonistic mycoflora *viz., Trichoderma* sp., *Gliocladium virens* and bacteria like *Pseudomonas fluorescens* from rhizosphere of sunflower, which were antagonistic to *S. rolfsii.*

Gupta and Ashusharma (2004) isolated promising biocontrol agents *viz., Trichoderma harzianum, T. viride, T. hamatum, Gliocladium virens* and *Chaetomium globosum* from the rhizosphere of French bean, cauliflower and ginger, antagonistic to *S. rolfsii.*

Kavitha *et al.* (2004) isolated 12 *Trichoderma* isolates from rhizospheric soil samples of different acid lime gardens, antagonistic to *Fusarium solani.*

Srinivasulu *et al.* (2005) isolated three *Trichoderma* spp. from rhizosphere soil samples surrounding the healthy and diseased plants of elephant foot yam which were antagonistic to *S. rolfsii.*

Shivani Bhatia *et al.* (2005) isolated 10 strains of fluorescent pseudomonads from the rhizosphere of sunflower, potato, maize and groundnut antagonistic to *S. rolfsii.*

In vitro* evaluation of efficacy of antagonists against *Sclerotium oryzae

Mathur and Sarbhoy (1978) reported the effectiveness of wheat bran preparation of *T. harzianum* and *T. viride* in controlling root rot of sugar beet caused by *S. rolfsii.*

The ability of *Trichoderma* to act as mycoparasite of hyphae and resting structures of plant pathogens has been demonstrated not only *in vitro* (Ayers and Adams, 1981) but also in natural soil (Cook and Baker, 1983). The proven ability of *Trichoderma* and *Gliocladium* to produce diffusible substances toxic to other fungi *in vitro* and even in organic substrates in soil also strengthens the hypothesis suggesting the importance of native *Trichoderma* in biocontrol.

Gnanamanickam *et al.* (1992) reviewed the methodology and recent research on the biological control of *Sclerotium oryzae* stem rot fungus.

Puri *et al.* (1998) reported out of three biocontrol agents *viz., Trichoderma viride* 793, *Trichoderma harzianum* 795 and *Gliocladium virens* 1372, *G. virens* 1372 gave the best control.

Narasimha Rao *et al.* (2001) tested the antagonistic potential of culture filtrates of *Trichoderma koningii, Trichoderma harzianum, Trichoderma viride, G. virens, Penicillium sp., Aspergillus niger, P. fluorescens* against the *S. rolfsii* isolated from potato. They observed that the filter sterilized culture of *P. fluorescens* showed maximum inhibition of mycelial growth of *S. rolfsii* followed by *T. harzianum.*

Narasimha Rao *et al*. (2004) tested the antagonism of *Trichoderma harzianum, Trichoderma viride, P. fluorescens, Trichoderma koningii, Gliocladium virens, Aspergillus niger* and *Penicillium* sp. Against *S. rolfsii*. They observed a maximum inhibition of mycelial growth of *S. rolfsii* (81.1%) by *Trichoderma harzianum* and a reduction in sclerotial production by 96.2 per cent.

Sonali and Gupta (2004) evaluated the *in vitro* efficacy of fungi, bacteria and actinomycetes isolated from soil for their antagonistic activity against *S. rolfsii* by dual culture technique and reported that *Bacillus* sp. strain was effective in reducing the radial growth of *S. rolfsii* by 77.4 per cent

Shivani Bhatia *et al.* (2005) tested the antagonism of 10 strains of fluorescent pseudomonads against *S. rolfsii* by dual culture technique and found that the strains PS I and PS II inhibited the growth of *S. rolfsii* by 73.0 and 70.0 per cent respectively.

***In vitro* compatibility of antagonists with the fungicides**

Vyas (1987) reported that *Trichoderma* spp. and *B. subtilis* showed high degree of tolerance to thiram and carbendazim.

Singh *et al*. (1995) screened isolates of *Trichoderma spp*. against fungicides like captaf, mancozeb and thiram. The growth of the isolates was not inhibited at 500 ppm concentration with captan and mancozeb, but thiram at 200 ppm completely inhibited the growth.

Vidhyasekharan and Muthamilan (1995) reported that thiram and carbendazim were not inhibitory to *P. fluorescens* in *in vitro* conditions.

Karpagvalli (1997) studied the *in vitro* compatibility of *T. harzianum* and *T.viride* with carbendazim, thiram and copper oxychloride @ 500, 1250, 2500 ppm using poisoned food technique. These results revealed that copper oxychloride was less inhibitory on the radical growth of both the antagonists than thiram and carbendazim.

Rajeevpant and Mukhopadhyay (2001) evaluated the effect of three fungicides *viz.*, carboxin (10, 25, 50 micro grams a.i. ml^{-1}) thiram (10, 25, 50 micro grams a.i ml^{-1}) and bavistin (10, 25, 50 micro grams a.i ml^{-1}) against *Gliocladium virens* and *T. harzianum* and reported that carboxin had no effect on both the antagonists while carbendazim was found to be highly inhibitory to them.

Compatibility of *Trichoderma* spp. with mancozeb have been noticed by many workers (Moity *et al.,* 1982 Wongwathanarat and Sivasithamparam, 1991; Shanmugam, 1996; Rajan and Sharma, 1999; May and Kimati, 2000; Akbari and Parakhia, 2001).

Combination of fungicides and biocontrol agents for controlling soil borne pathogens have been successfully used by many workers (Papavizas and Lumsden, 1980 and Poddar *et al.,* 2004).

Gupta (2004) reported that bavistin completely inhibited the mycelial growth of *Trichoderma harzianum* at concentrations 1, 10,100 and 1000 ppm concentrations.

Vijayaraghavan and Abraham (2004) tested the *in vitro* compatibility of *Trichoderma harzianum, Trichoderma viride* and *Tric* Alagarsamy *hoderma longibrachiatum* with nine fungicides and found that mancozeb was compatible with all the three antagonists at 0.2, 0.3 and 0.4 per cent.

Out of three fungicides tested *viz.*, mancozeb, carbendazim and copper oxychloride against *Trichoderma harzianum*, carbendazim at 0.1 per cent completely inhibited the mycelial growth of *Trichoderma harzianum* while mancozeb and copper oxychloride showed compatibility with the antagonist at 0.2 and 0.1 per cent (Naseema Beevi *et al*., 2005)

Trichoderma viride was found significantly superior over other antagonists in inhibiting the growth of *Sclerotium rolfsii*. (Johnson *et al.,* 2008).

Mass multiplication of antagonists

Mass multiplication of *T. harzianum* on mixture of FYM and Banana Peeled Skin (BPS) produced maximum number of spore suspension and maximum number of propagules at 15 days of incubation (Pranab Dutta and Das, 1999).

Multiplied *Pseudomonas fluorescens* and *Bacillus subtilis* was multiplied in Kings B and Nutrient broth medium (Padmodaya and Reddy, 1998; Umamaheswari *et al.,* 2002 and Gogoi *et al.,* 2002).

Pre-bolied and sterilized sorghum grains supplemented with 5 per cent anhydrous dextrose was used for mass multiplication of *G. virens* and *T. harzianum* (Rajeevpant and Mukhopadhyay, 2001).

Sharma *et al.* (2002) reported that FYM + Jhingora (Barnyard millet) in 3:1 w / w was more suitable for mass multiplication of *Trichoderma harzianum.*

Wheat bran has been used as best substrate for mass multiplication of *T. viride* (Henis *et al.,* 1978; Dubey and Patel, 2001; Patibanda *et al.,* 2002; Upadhyay *et al.,* 2004 and Gaur *et al.,* 2005).

Gupta and Ashu Sharma (2004) mass multiplied three isolates of *Trichoderma* spp., *G. virens* and *Chaetomium globosum* on wheat bran: sawdust: Tapwater (3:1:4) medium supplemented with 2 per cent molasses (Mathew and Gupta, 1998).

Zaidi and Singh (2004) reported that cowdung and poultry manure supported good growth of *Trichoderma harzianum.*

Efficacy of fungicides, herbicides and antagonistic Microflora in green house

Papavizas (1985) emphasized the importance of integration of *Trichoderma sp.* or *Gliocladium* with compatible fungus or other practices in controlling soil borne pathogens.

Sharma and Verma (1985) reported that in pot experiments bavistin and topsin-M were effective in controlling the stem rot of rice disease and increasing the yield, when compared to seventeen fungicides, namely, Demosan, Dithane M-45, Dithane Z-78, Difolatan, Haxacap, Hexathiir, Hinosan, Kitazin, Thiovit, Topsin M, Vitavax Bavistin, Benlate, Blitox, Brassicol, Calixin and Cuprasol.

Ram Singh *et al.* (1988) reported that field trials showed that stem rot incidence can be economically minimized by spraying the crop once with thiophanate-methyl at the rate of 875 g/ha at the time of disease initiation.

Brahmabatt *et al*. (1989) reported excellent control of tobacco damping off by a combination of *Trichoderma* inoculum and metalaxyl seed treatment.

Integration of cultural, biological and chemical means of control has proved to be a very promising way of management soil-borne pathogens such as *S. rolfsii* (Upadhyay and Mukhopadhyay, 1986; Natarajan and Manibhushan, 1996 and Saralamma, 2000)

Many workers reported that soil application of *Trichoderma sp*. and *P. fluorescens* effectively checked the diseases caused by soil borne plant pathogens and also a synergistic effect in the growth of plants was observed (Selvan, 1997; Manoranjitham *et al.*, 1999, 2000; Bharti *et al*., 2004 and Poddar *et al*., 2004).

Paul *et al*., (2005) studied the effect of combination of *P. fluorescens* strains and some fungicides for controlling foot rot of black pepper caused by *Phytopthora capsici* and found 100 per cent survival of the infected plants when bacterial treatment was combined with metalaxyl – mancozeb @ 2 g l^{-1}.

Saralamma and Vithal Reddy (2005) studied the integrated management of root rot of groundnut and found that integration of bio-agent *T. harzianum* along with neem cake and fungicide (Thiophanate-methyl) increased the efficacy of disease control as compared to their individual treatments.

REFERENCES

Ahuja S C, Dharam S and Singh D 1988 Relative preponderance of sclerotial species on Rice and varietal resistance. Indian Phytopathology 41(3) : 487-489.

Ahuja S C, Malik SS, Ahuja U S and Malik C V S 1981 Varietal response to bacterial blight and stem rot under artificial epiphytotic conditions. International Rice Research Newsletter 6 : 6.

Akbari L F and Parakhia A M 2001 Effect of fungicides as fungal bioagents (Abst.). Journal of Mycology and Plant Pathology 31 :101.

Ali Z and Singh R A 1994 (a) Reaction of rice varieties to stem rot (*S. oryzae*) in Uttar Pradesh. Indian Journal of Mycology and Plant Pathology 24(1) : 58-59.

Ali Z and Singh R A 1994 (b) Studies on the Saprophytic survival of *Sclerotium oryzae* under different conditions. Indian Journal of Mycology and Plant Pathology 24: 55-57.

Ali Z and Singh R A 1992 Pathogenic variability and effect of culture filtrate of *Sclerotium oryzae* on the inhibition of radicle and plumule in rice. Indian Phytopathology 45 : 416-420

Amin K S 1976 Evaluation of rice varieties tolerant to stem rot. Indian Journal of Agricultural Sciences 46 : 318-322

Anahosur K H 1976 Toxic effect of the culture filtrate of *Trichothecium roseum* on seed germination and growth of sorghum. Indian Phytopatholoy 29 : 278-280.

Anahosur K H 2001 Integrated management of potato *Sclerotium* wilt caused by *Sclerotium rolfsii*. Indian Phytopathology 54:158-166. Ahuja S C and Dharam 1988 Singh Relative prepondrence of sclerotial species on rice and varietal resistance. Haryana Agriculture University, Rice Research Station 41 : 487-489.

Anon 1930 Plant Pathology. Bulletin, Arkansas Agricultural Experiment Station No. 257 (Annual Report No. 42) : 72-85.

Ayers W A and Admas P B 1981 Mycoparasitism and its application to biological control of plant disease p.91-103.

Bedi K S 1953 Stem rot disease of rice and its control. Punjab farmer 5 : 3-6.

Bharti S L, Singh R, Verma A and Upadhyay R S 2004 Biocontrol of damping off of tomato caused by *Pythium aphanidermatum* using *Trichoderma harzianum* and Bacillus subtilis (Abstr.). Indian Phytopathology 57: 362.

Brahmabatt A B, Mukhopadhyay A N and Patel K K 1989 *Trichoderma harzianum*, a potential biocontrol agent for tobacco damping-off. PVK Research Journal 13 : 170-172.

Butler E J 1918 Fungi and diseases in plants. Thaker Spink and Co, Calcutta 547pp.

Cattaneo A 1876 Sullo *Sclerotium oryzae*, nuova parassita vegetale, che ha devastato nel conrrente anno molte risaje di Lombardia e del Novarese. Rendiconti dell'Istitulo Lombardo di Scienze e Lettere, 2 9 : 801-807 (Journal of Agricultural Reaseach 51:348).

Cavara F 1889 Materiaux de mycologie Lombarde. Revue de Mycologie 11:189 (Jounal of Agricultural Research 47 : 686)

Centre for Monitoring Indian Economy (CMIE) reports 2010 http://www.cmie.com

Chand H, Singh R and Panwar D V S 1985 Search for multiple resistance in rice. Indian Phytopathology 38 : 452-455.

Chauhan L S, Verma S C and Bajpai G K 1968 Assessment of losses due to stem rot of rice caused by *Sclerotium oryzae*. Plant Disease Reporter 52 : 963-965.

Chen C C 1971 Stem rot of rice. Proceedings Symposium JCRR, Jaipur, Taiwan, 1969, pp. 77-78.

Chen C C 1973 The study on host range of rice stem rot fungi. Memoirs of the College of Agriculture, National Taiwan University 14 : 29-45.

Cintas N A and Webster R K 2001 Effects of rice straw management on *Sclerotium oryzae* inoculum, stem rot severity, and yield of rice in California. Plant Disease 85 : 1140-1144.

Cook R J and Baker 1983 The nature and Practice of biological control of plant pathogens. St. Paul. Minnesota American Phytopathological Society pp. 539.

Cother E and Nicol H 1999 Susceptibility of Australian rice cultivars to stem rot fungus *Sclerotium oryzae*. Australasian Plant Pathology 28 : 85-91.

Cralley E M 1936 Resistance of rice varieties to stem rot. Bulletin, Arkansas Agricultural station No. 329, pp.31.

Cralley E M and Adair C R 1943 Effects of irrigation treatment on stem rot severity, plant development and yield of rice. Journal of American Society Agron. 35 : 499-507

Cralley E M and Tullis E C 1934 Rice disease investigations – stem rot. University of Arkansas Coll. Agric. Arkansas Agric. Exp. Sta. Bull No. 312 pp 52-53.

Das A M and Srivastava D N 1971 Stimulatory and productive effects of culture filtrate of *Helminthosporium sativum* on wheat seedlings. Annual Phytopathology Society, Japan 37 : 77-83.

Debanjan Sanyal and Anil Shrestha 2008 Direct effect of herbicides on Plant Pathogens and disease development in various cropping systems. Weed Science: Vol. 56, No. 1, pp. 155-160.

Dutta P, Das B and Dutta P 2002 Management of color rot of tomato by *Trichoderma* spp. and chemicals. Indian Phytopathology 55 : 235-237.

Ferreira S A and Webster R K 1975 The relationship of sporulation, sclerotia production, and growth rate to virulence and fitness of *Sclerotium oryzae*. Phytopathology 65 : 973-976.

Ferreira S A and Webster R K 1976 Evaluation of virulence in isolates of Sclerotium oryzae. Ibid.6 : 1151-1154.

Gangopadhyay S and Das M 1983 Reaction of rice to eight isolates of *S. oryzae* in India. Indian Phytopathology 36(2) : 219-222.

Gangopadhyay S and Padhi B 1984 Stem rot: Epidemiology and control. Annual Report of CRRI. P : 66-67.

Gaur R b, Sharma R N, Sharma R R and Vinod Singh Gautam 2005 Efficacy of *Trichoderma* from *Rhizoctonia* root rot control in chick pea. Journal of Mycology and Plant Pathology 35 : 144-150.

Ghose R L M, Ghatge M B and Subramanyam V 1960 Rice in India. Review Edu. New Deihi, Indian Council of Agricultural Research pp. 474.

Gnanamanickam S S, Ahmed S and Mew T W 1992 Biological control of rice diseases. Indian Review of Rice Sciences 12 : 3-22.

Gogoi N K, Phookan A K and Narzary B D 2002 Management of collar rot of elephant's foot yam. Indian Phytopathology 55 : 238-240.

Goto K and Fukatsu R 1954 Studies on the stem rot of rice plant. Varietal resistance and seasonal development. Tokaikinki National Agricultural Experimental Station Bullet. 1 : 27-39.

Gupta S K and Ashu Sharma 2004 Symptomology and management of crown rot (*Sclerotium rolfsii*) of french bean. Journal of Mycology and Plant Pathology 34 : 820-823.

Gupta V 2004 Compatibility of biocontrol agent *Trichoderma harzianum* with pesticides. Journal of Mycology and Plant Pathology 34 : 504-505.

Henis Y, Ghaffer A and Baker R 1978 Integrated control of *Rhizoctonia solani* damping off of radish. Effect of successive plantings, PCNB and *Trichoderma harzianum* pathogen and disease. Phytopathology 68 : 900-907.

Hernandez S A 1923 Report of Plant Disease Section. Report, Philippine Bureau of Agriculture 2 : 159-172.

Inagaki K, Guo Quingyuan and Arakawa Masao 2004 Overwintering of Rice Sclerotial Disease Fungi, *Rhizoctonia* and *Sclerotium s*pp. in Paddy Fields in Japan. Plant Pathology Journal 3(2) : 81-87.

Inagaki K, Tamura M and Makino M 1987 Over wintering in plant residues of rice Sclerotial disease fungi, *Rhizoctinia* and *Sclerotium* species. Proceedings of the Kansai Plant Protection Society 29 : 27-29.

Jackson L F, Webster R K, Wick C M, Bolstad J and Wilkerson J A 1977 Chemical control of stem rot of rice in California. Phytopathology 67 : 1155-1158.

Jain S S 1973 Studies on stem rot disease of rice. Annual Report of CRRI pp.174-176.

Johnson D A, Stewart E L and Kung T H 1976 A *Sclerotium* species associated with lilies in Minnesota. Plant Disease Reporter 60 : 187-188.

Johnson M, Reddy P Narayan, Reddy D Rajaram 2008 Comparative efficacy of rhizosphere mycoflora, fungicides, insecticides and herbicides against groundnut stem rot caused by *Sclerotium rolfsii*.

Kadowaki Y, Isota J and Tsukamoto T 1995 Ecology of sclerotial diseases of rice part 3. Distribution of several sclerotial fungi causing sclerotiosis in rice. Annuals of Phytopathological Society of Japan 61(1) : 63-68.

Kang M S, Srivastava M P and Maheshwari S K 1970 Studies on stem rot of paddy. Varietal reaction of certain new promising varieties. Journal of Research, PAU, Ludhiana 7 : 587-589.

Kavitha M, Gopal K, Anandam R J NAD Prasad Babu G 2004 Evaluation of native isolates of *Trichoderma* in the control of dry root rot in acid lime. Journal of Mycology and Plant Pathology 34 : 384-386.

Keim R and Webster R K 1974 (a) Effect of soil moisture and temperature on viability of sclerotia *Sclerotium oryzae*. Phytopathology 64 : 1499-1502

Konthoujam J 1998 Pest and disease Surveillance report for the year 1992-1997 Pest Surveillance and Mobile Squad, Mantripukhri, Department of Agriculture Government of Manipur pp. 56-72.

Konthoujam Jiten and Chhetry G K N 2005 Viability and survival of *Sclerotium oryzae* Catt. incitant of stem rot of rice preserved in the laboratory vis-à-vis over wintering under natural field condition in Manipur. Indian Phytopathology 58(4) : 414-418.

Konthoujam Jiten, Chhetry G K N and Ranjit Sharma 2007(a) Symptomatological significance & Characterization of susceptibility / resistance group among low land rice cultivars towards stem rot of rice in Manipur valley. Indian Phytopathology 60 (4) : 478-481.

Konthoujam Jiten, Radhacharan Irengbam, Rajen Salam and Chhetry G K N 2007 Soil amendment with N-P-K and their effects on stem rot rice. Journal of Mycopathology 45 (2) : 245-248.

Krause R A 1971 Distribution and occurrence of *Sclerotium oryzae* on rice in California. Plant Disease Reporter 55 : 757-759.

Krause R A and Webster R K 1972 Sclerotial production, viability determination and quantitative recovery of *Sclerotium oryzae* from soil. Ibid. 64 : 1333-1337.

Krause R A and Webster R K 1973 Stem rot of rice in California. Phytopathology 63 : 518-523.

Kumar A, Ram Singh and Jalali B L 2003 (a) Evaluation of resistance to stem rot and yield losses caused by the disease in rice. Indian Phytopathology 56(4) : 403-407

Kumar A, Ram Singh and Jalali B L 2003 (b) Management of stem rot of rice with resistance inducing chemicals and fungicides. Indian Phytopathology 56(3) : 266-69.

Li O X and Wang L R 1985 A preliminary study on the diseases of aquatic plants in Jiangsu province, China, Journal of Jiangsu Agricultural College 6(1) : 35-41.

Li Y G, Kang B J, Feng Y X, Huang D J, Wu D B and Li T F 1984 A brief report on the studies of rice stem rot .Guangdong Agricultural Science 5 : 35-37.

Luthra J C and Sattar A 1936 Some studies on the sclerotial disease of rice (*Sclerotium oryzae* Catt.) in the Punjab. Indian Journal of Agricultural Sciences 6:973-984 (Review of Applied Mycology 16 : 123).

Manoranjitham S K, Prakasam V and Rajappan K 1999 Effect of antagonists on *Pythium aphanidermatum* (Edson) Fitz. and the growth of chilli seedlings. Journal of biological Control 13 : 101-106.

Manoranjitham S K, Prakasham V, Rajappan K and Amutha G 2000 Effect of two antagonists on damping off disease of tomato. Indian Phytopathological 53 : 441-443.

Mathew K A and Gupta S K 1998 Biological control of root rot of french bean caused by *Rhizoctonia solani*. Journal of Mycology and Plant Pathology 28 : 202-205.

Mathur S B and Sarbhoy A K 1978 Biological control of *Sclerotium* root rot of sugar beet. Indian Phytopathology 31 : 365-367.

May L L and Kimati H 2000 Phytophthora parasitica control with fungicides and effect of these products in the mycelial growth of *Trichoderma*. Summa Phytopathologica 26 : 52-57.

Misra A P and Das P K 1967 Laboratory evaluation of fungicides for the control of stem rot of paddy. Indian Phytopathology. 20 : 36-41.

Misra A P and Mohammad A 1964 Pathogenicity and varietal reaction of paddy to *S. oryzae* Catt. in Bihar. Indian Phytopathology 17 : 168-171.

Moity T H A, Papavizas G C and Shatala M N 1982 Induction of new isolates of *Trichoderma harzianum* tolerant of fungicides and their experimental use for control of white rot of onion. Phytopathology 72 : 396-400.

Mundkur B B 1935 Parasitism of *Sclerotium oryzae* Catt. Indian Journal of Agricultural Sciences 5 : 393-414.

Nakata K and Kawamura 1939 Studies on sclerotial diseases of rice. Bureau of Agriculture, Ministry of Agriculture and Forestry, Japan, Agricultural Experimental Station records no. 139 pp.175.

Nandi H K 1941 Annual Report of the Economic Botanist Assam for the year 1939-40 Review of Applied Mycology 20 : 447.

Narasimha Rao S, Anahosur K H and Naik K S 2001 Effect of culture filtrates of antagonists on the growth of *Sclerotium rolfsii* Sacc. Indian Journal of Plant Protection 29 : 127-130.

Narasimha Rao S, Anahosur K H and Srikanth Kulkarni 2004 Eco-friendly approaches to management of wilt of potato (*Sclerotium rolfsii*). Journal of Mycology and Plant Pathology.

Naseema Beevi S, Ancy M Salim, Priya Mohan, Deepthi S and Naseema A 2005 Compatibility of *Trichoderma harzianum* Rifai with botanicals and synthetic pesticides. Geobios 32 : 80-82.

Nene Y L and Thapliyal P N 1993 Fungicides in plant disease control, Oxford and I B H publishing Co. Pvt. Ltd. New Delhi pp.531-534.

Nikam B G 1954 Diseases of paddy in Madhya Bharat in 1953-54. Plant Protection Bull. 6 : 33.

Ou S H 1972 Rice diseases. Commonwealth Mycological Institute. Kew. England pp.368.

Ou S H 1985 Rice Diseases (2nd edition). Common wealth Mycological Institute, Kew (England), 380pp.

Padmanabhan S Y 1974 Fungal Diseases of Rice in India. Indian Council of Agriculture Research, New Delhi pp.66.

Padmodaya B and Reddy H R 1998 Screening of antagonists against *Fusarium oxysporum* f.sp. *Lycopersici* causing seedling disease and wilt in tomato. Journal of Mycology and Plant Pathology 28 : 339-341.

Pande V S 1996 Studies on population dynamics, Plant growth promotion activities and antagonistic potentials of fluorescent *Pseudomonas* isolated from rhizosphere soil of wheat and chickpea. Ph. D., Thesis GBPTUA & T, Pantnagar, pp.302-303.

Pandey K K and Upadhyay J P 2000 Microbial population from rhizosphere and non-rhizosphere soil of pigeonpea: screening for resident antagonist and mode of mycoparastism. Journal of Mycology and Plant Pathology 30 : 7-10.

Papavizas G C 1985 *Trichoderma* and *Gliocladium* : Biology, Ecology and Potential for biocontrol. Annual Review of Phytopathology 23 : 23-54.

Paracer C S and Luthra J C 1944 Further studies on stem rot of rice caused by *S. oryzae* in the Punjab. Indian Journal of Agricultural Science 14 : 44-48.

Park M and Bertus L S 1932 Sclerotial disease of rice in Ceylon. Royal Botanical Garden Peradeniya. XI, 4 : 342-359.

Patibanda A K, Upadhyay J P and Mukhopadhyay A N 2002 Efficacy of *Trichoderma harzium* Rifai alone or in combination with fungicides against *Sclerotium* wilt of groundnut. Journal of Biological Control 16 : 57-63.

Paul, Jisha P J, Sharma Y R and Anand Raj M 2005 Rhizospheric *Pseudomonas fluorescens* as rejuvenating and root proliferating agents in Black pepper. Journal of Biocontrol 19 : 173-178.

Poddar R K, Singh D V and Dubey S C 2004 Management of chickpea with through combination of fungicides and bioagents. Indian Phytopathology 57 : 39-43.

Pranab Dutta and Das B C 1999 Effect of seed pelleting and soil application of *Trichoderma harzianum* in the management of stem rot of soyabean. Journal of Mycology and Plant Pathology 29 : 317-322.

Prasad C K P S and Hirenath P C 1983 Effect of culture filtrate of *Rhizoctonia solani* Kuhn. on seed germination, seedling growth and loss of electrolytes from the roots of fenugreek. Indian Phytopathology 36 : 95-99.

Punter D Reid J and Hopkin A A 1984 Notes on *Sclerotium* forming fungi from *Zizania aquatica* (Wild rice) and other hosts. Mycologia 76(4) : 722-732.

Puri A, Aggarwal A and Mehrotra R S 1998 Biological control of stem rot of paddy *Oryza sativa* using *Trichoderma* and *Gliocladium* species. Proceedings of the National Academy of Sciences, India. Section B, Biological Sciences 68(1) : 57-60.

Raina G L, Singh G and Sidhu G S 1980 Sources of resistance to major rice diseases in Punjab. International Rice Research News 5 : 6-7.

Rajan P P and Sharma Y R 1999 Compatibility of potassium phosphate (Akomin-40) with different spices of *Trichoderma* and *Gliocladium virens*. Proceedings of the National Seminar on Biotechnology of Species and Aromatic Plants. Indian Society for Species, Calicut pp.150-155.

Ram Singh, Hari Chand, Dodan D S and Sunder S 1988 Chemical control of stem rot of paddy. Oryzae 25 : 392-395.

Rangeshwaran R and Prasad R D 2000 Biological control of *Sclerotium* rot of sunflower. Indian Phytopathology 53 : 444-449.

Reddy C S 1984 Studies on stem rot disease of rice. Annual report of CRRI. pp.96-97.

Reddy C S, Satyanarayan K and John V T 1988 Screening of pesticides (fungicides/ bactericides) against rice pathogens. Annual Report of CRRI pp. 250-251.

Saralamma S 2000 Studies on biological control of *Sclerotium rolfsii* Sacc. incitant of root rot of groundnut. M.Sc.(Ag.), Thesis submitted to Acharya N.G. Ranga Agricultural University, Hyderabad, Andhra Pradesh.

Saralamma S and Vithal Reddy T 2005 In vitro efficacy of fungicides on the radial growth of *Trichoderma harzianum* Rifai. The Andhra Agricultural Journal 51 : 141-143.

Shanmugam V 1996 Biocontrol of rhizome rot of ginger (*Zingiber officinale*) by antagonistic microorganism. M.Sc.(Ag.) Thesis, Kerala Agricultural University, Vellanikkara, Thrissur, Kerala pp.72.

Sharma Roopali, Sekhar Varsheny, Deeksha Joshi and Shalini Shinghal, Singh U S 2002 Farm yard manure: A promising substrate for mass multiplication and developing commercial formulation of *Trichoderma harzianum.* Indian Phytopathology 55 : 382.

Sharma S K, Jasbir Kaur and R S Mehrotra 1984 Effect of polythene mulching on the viability of sclerotia of *Sclerotium oryzae* ion soil. Indian Journal of Plant Pathology 2 : 33-38.

Sharma J P and Verma R N 1985 Effect of various concentration of fungicides in vitro on *Sclerotium* state of *Corticium rolfsii*. Indian Phytopathology 38 : 358-360.

Shaw F J F 1913 A sclerotial disease of rice. Memoir Department of Agriculture India Botanical Service. VI. 2 :11-23.

Shivani Bhatia, Dubey R C and Maheswari D K 2005 Enhancement of plant growth and suppression of collar rot of sunflower caused by *Sclerotium rolfsii* through fluorescent *Pseudomonas*. Indian Phytopathology 58 :17-24.

Singh R A and Pavgi M S 1966 Stem rot of rice in Uttar Pradesh India. Phytopathology 57 : 24-28.

Singh R, Chand H, Dodan D S and Sunder S 1987 Chemical control of stem rot of paddy. Oryzae 25(4) : 392-395.

Singh U D 1982 Stem rot. Annual report of CRRI. Pp. 200-201.

Singh R S, Jindal A, Singh D and Singh T 1995 Selection of *Trichoderma* isolates against common fungicides for their use integrated plant disease management. Indian Journal Mycology and Plant Pathology 25 : 127-128.

Sonali and Gupta A K 2004 Non-chemical management of seedling blight of apple caused by *Sclerotium rolfsii*. Journal of Mycology and Plant Pathology 34 : 637-641.

Srinivasulu B, Krishna Kumar KV, Aruna K, Krishna Prasadji and Rao DVR 2005 In vitro antagonism of three *Trichoderma* spp. against *Sclerotium rolfsii* Sacc., a color rot pathogen in elephant foot yam. Journal of Biological Control 19 : 167-171.

Srivastava M P, Maheshwari S K and Saini S S 1971 Varietal resistance of rice (*Oryzae sativa* L.) to stem rot. Indian Journal of Agricultural Science 41 : 93-7.

Sunder S, Dodan D S, Aluja S L and Sing R 1991 Spray schedule for control of rice stem rot. Oryzae 28(3) : 421-423.

Tullis E C and Cralley E M 1941 Longevity of sclerotia of stem rot fungus, *Leptosphaeria salvinii*. Phytopathology 31 : 279-281.

Umamaheswari M P, Muthuswamy M and Alice D 2002 Evaluation of antagonists against jasmine wilt caused by *Sclerotium rolfsii* Sacc. Journal of Biological Control 16 : 135-140.

Upadhyay J P, Lal H C and Roy S 2004 Effect of fungicides, cakes and plant by products on the development of *Trichoderma viride*. Journal of Mycology and Plant Pathology 34 : 527-529.

Upadhyay J P and Mukhopadhyay A N 1986 Biological control of *Sclerotium rolfsii* by *Trichoderma harzianum* of sugar beet. Tropical Pest Management pp.215-220.

Vyas S C 1987 Effect of seed treatment fungicides thiram and carbendazim on the antagonists of soyabean and dry root rot pathogen *Rhizoctonia bataticola* Abstract of papers presented in workshop on biological control of plant diseases. Tamil Nadu Agricultural University, Coimbatore, India p.23.

Webster R K, Hall D H, Wick C M and Krause R A 1971 Distribution and occurrence of *Sclerotium oryzae* on rice in California. Plant Disease Report 55(9) : 757-759.

Webster R K, Wick C M, Hall D H, Lindberg D and Lindberg A 1972 Effects of various methods of rice residues management on *Sclerotium oryzae* inoculum level stem rot disease severity and yield, a progress report. Page 59-60 in Proc. 14th Rice Technical Working Group, Univ. of California Davis, June. Pp101.

Yadav J P and Mehrotra R S 1982 Decline in number and viability of sclerotia of stem rot fungus in soil. International Rice Research News letter 7 : 13-14.

Zaidi N W and Singh Us 2004 Development of improved technology for mass multiplication and delivery of fungal (*Trichoderma*) and bacterial (*Pseudomanas)* biocontrol agents. Journal of Mycology and Plant Pathology 34 : 732-737.

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