INTEGRATED MANAGEMENT OF SHEATH ROT OF RICE (*Oryza sativa* L.)

By

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Thesis

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TO MY PARENTS

AND BROTHER

DECLARATION

I hereby declare that this thesis entitled "**Integrated management of sheath rot of rice (*Oryza sativa* L.)**" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

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CERTIFICATE

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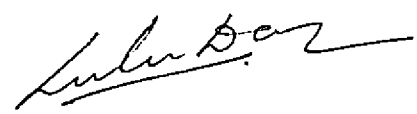

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INTRODUCTION

INTRODUCTION

Rice is one of the most important food crops of the world. Sheath rot, though a decade back was considered as a minor disease, has now emerged as one of the most destructive diseases of rice. This disease was first described in 1922 by Sawada from Formosa and named the causal organism as *Acrocylindrium oryzae* Saw. The pathogen was renamed as *Sarocladium oryzae* by Gams and Hawksworth during 1975.

In India the occurrence of this disease was reported by Agnihothrudu in 1973 from Karnataka. The occurrence of this disease in Kerala was reported by Nair and Sathyarajan (1976).

In comparison to other foliage diseases of rice, the management of sheath rot employing non-systemic chemicals has not been largely successful due to the fact that the pathogen is protected in the interior sheath portion. Further indiscriminate application of chemicals has several drawbacks, viz., health hazards, development of resistance by the pathogen as well as destruction of beneficial microflora and fauna.

Biological control in contrast to this has certain added advantages. It is free from pollution and is relatively long lasting. Chemical control still being an effective control measure cannot be neglected.

Therefore, an integrated approach involving both chemical and biological methods was adopted in the management of sheath rot in this investigation. The main items of the study included the identification of various antagonistic microorganisms and plant extracts, to find the lowest dose of the most effective fungicide, to determine the time and method of application of antagonists and to integrate the various methods for an efficient management of the disease.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

The rice plant has been reported to harbour a large number of plant pathogenic microorganisms (Padwick, 1950). One of the most important sheath disease affecting rice crop in Kerala is the sheath rot caused by *Sarocladium oryzae* Gams and Hawksworth (Nair and Sathyarajan, 1975).

Sheath rot of rice was first described from Formosa by Sawada in 1922 and the pathogen was named as *Acrocylindrium oryzae* Saw. The pathogen was later reported from Japan by Tasugi and Ikeda (1956), who established its pathogenicity in rice plants and provided more cultural and physiological information about the pathogen. Chen from Taiwan (1957), Ou from Thailand (1963), Jimenez and Panizo from Peru (1977), Shahjahan *et al.* (1977) from Peru, Buddenhagen from Madagascar (1985), Rodriguez and Nass (1990) from USA have also reported the occurrence of the disease.

Gams and Hawksworth (1975) from Netherlands introduced the new genus *Sarocladium* for *Acrocylindrium* and a new combination *Sarocladium oryzae* Gams and Hawks was made for the organism causing sheath rot of rice.

In India, the occurrence of the disease was first reported by Agnihothrudu in 1973 from Karnataka. Prabhakaran *et al.* (1974) reported the disease from Annamalainagar in Tamil Nadu.

It caused an yield loss of 85 per cent. This was followed by reports of the occurrence of the disease by Amin *et al*. (1974) from West Bengal, Nair and Sathyarajan (1975) from Kerala. Ghufran *et al*. (1980) from Bihar, Raina and Singh (1980) from Punjab, Upadhay and Diwakar (1984) from Madhya Pradesh, Singh and Roy (1987) from Manipur and Singh *et al*.(1988) from Uttar Pradesh.

Reddy *et al*. (1986) reported the occurrence of sheath rot in South and South-East Asia. Shukla *et al*. (1995) reported that sheath rot was one among the major diseases of the uplands of Bihar and West Bengal during 1990-93.

Chen (1957) observed 20 per cent damage of rice crop due to this disease. Upto 85 per cent loss in rice was stated by Ou (1972). Estrada *et al*. (1979) reported a reduction of 28 and 75 per cent, in panicle production and grain yield, respectively. In 1984, Estrada *et al*. reported an yield loss of 53 per cent from Philippines due to sheath rot infection. Ou (1984) observed that the pathogen caused damage to 10-20 per cent of tillers in all the rice growing areas. Tikoo (1985) reported that sheath rot reduced the number of spikelets/panicle, number of grains/panicle and 1000 grain weight, resulting losses in crop yield.

Chakravarthy and Biswas (1978) evaluated the yield loss due to sheath rot in India and recorded a reduction of 79 per cent grain weight of diseased panicles. Yield reduction due to

this disease was observed from Tamil Nadu by Mohan and Subramanian (1979), Srinivasan (1980) and Vidyasekaran *et al.* (1984). Reddy and Ghosh (1985) reported that combined infection of rice tungro virus and sheath rot fungus caused greater reduction in grain yield, 1000 grain weight and per cent normal grains and increase in chaff and discoloured grains.

Singh *et al.* (1985) reported that loss in yield due to sheath rot varied between 1.7 and 54.7 per cent. Surin (1977) observed a positive relationship between the disease incidence, disease severity and yield difference. Velazhahan *et al.* (1989) reported that *S. oryzae* reduced seed germination of several rice varieties. Reddy (1991) reported the effect of sheath rot on panicle and grain weight percentage of diseased grains, sterile spikelets, panicle length and seed germination.

Symptomatology

Tasugi and Ikeda (1956) reported that the fungus chiefly attacked the uppermost leaf sheath and caused rotting. The greyish brown lesions coalesce and form irregular blotches. The symptoms of the sheath rot disease was also described by Ou (1972), Amin *et al.* (1974), Shajahan *et al.* (1977) and Surin (1977). Ou (1985) observed that the rot occurred on the upper most leaf sheath enclosing the panicle. The lesions started as oblong spots with brown margin and grey centres. The young

panicles remained within the sheath or only partially emerged. Abundant whitish growth could be noticed on the affected sheath.

In Kerala, Nair and Sathyarajan (1975) described the symptoms of the disease in detail. They found that young spots appeared on the boot leaf sheath and turned whitish grey with a dark margin. In infected fields, the panicles could be observed at various stages of emergence. A whitish powdery mass of fungal growth could be detected over the natural lesions inside the affected sheath.

Some basic work on the sheath rot pathogen, the etiology of the disease, control measures and effect of management practices on sheath rot disease have been carried out at the College of Agriculture, Vellayani (Balakrishnan, 1981; Nair, 1986; Nair *et al.*, 1988; George, 1995).

Isolation of the pathogen

The fungus *Sarocladium oryzae* Gams and Hawksworth causing sheath rot of rice belongs to the form family Moniliaceae of the form order Moniliales in the form class Deuteromycetes (Ainsworth *et al.*, 1973).

Antagonistic organisms

Garrett (1965) suggested that biological control can be brought about either by introduction or by augmentation in numbers of one or more species of controlling organisms, or by a

change in the environmental conditions designed to favour the multiplication and activity of such organisms or by a combination of both procedures. He proposed two methods for biological control, namely inoculation of soil or plant tissues with antagonistic microorganisms and modification of soil environment. The former can be achieved by direct introduction of antagonists mass cultured in the laboratory.

Direct introduction of antagonists

The direct application of biocontrol agent against plant pathogen was first attempted by Hartley (1921), who inoculated forest nursery soil with thirteen fungi proved to be antagonistic to *Rhizoctonia solani*, the causal organism of damping off of pine seedlings.

Ever since the work of Weindling in 1932, *Trichoderma* spp. has remained the most exhaustively researched microorganism. *Aspergillus niger* and *T. harzianum* are used for the control of coffee collar rot (Venkatasubbaiah and Safeeulla, 1984; Venkatasubbaiah *et al.*, 1984). Species of *Trichoderma* and *Aspergillus* have been identified as potent biocontrol agents of several plant pathogenic fungi (Papavizas, 1985; Chet, 1987).

Mukhopadhyay (1994) reviewed the biological control of plant diseases in India and focussed on the components, namely, antagonism, antibiosis, competition and mycoparasitism. The

application of the competitor *Pseudomonas fluorescens* Migula for the control of *S. oryzae* has been discussed.

Sakthivel and Gnanamanickam (1986) suggested that sheath rot may be controlled by treatment of rice seeds or plants with strains of *P. fluorescens*. Bacterisation with *P. fluoresans* enhanced plant growth by 12-27 per cent (Sakthivel *et al.*, 1986), plant height, number of tillers and grain yield from 3 to 160 per cent. There was 54 per cent reduction in the length of sheath rot lesions. Disease severity was reduced by 20 to 42 per cent (Sakthivel and Gnanamanickam, 1987).

Narasimmaraj (1991) could effectively control sheath rot by spraying the suspension of *Bacillus* sp. ($1x10^4$ cells/ml). Kumar (1992) and Pandiarajkumar *et al.* (1995) observed that pre inoculation of *P. fluorescens* and *Bacillus* sp. were effective than their post-inoculation in reducing sheath rot disease. Spraying of *P. fluorescens* and *B. subtilis* was effective in controlling *S. oryzae* (Eswaramurthy *et al.*, 1995: Radhika *et al.*, 1995).

Joseph and Philip (1980) reported that *T. viride*, *Myrothecicum roseum* and *Chaetomium gracile* exerted specific antagonistic effect on the common pathogens associated with rice seeds. Natarajan *et al.* (1987) found that *T. viride* had antagonistic effect against sheath rot pathogen. Viswanathan and Narayanasamy (1990) observed that *Bipolaris zeicola* (*Cochliobolus carbonum*) could inhibit the mycelial growth of *S. oryzae*. The

undiluted culture of *C. carbonum* was also inhibitory to the pathogen.

Viswakumar (1989) isolated several fungi from rhizosphere and phylloplane and tested them for antagonism against *Rhizoctonia solani*. Several soil fungi isolated from paddy soil were found to exhibit antagonism towards *R. solani* (Zacharia, 1990).

George (1995) found that *Chaetomium* sp., *Pestalotia* sp. and *P. fluorescens* strains 2 and 87 were antagonistic against *S. oryzae in vitro*. Under *in vivo* conditions, *Chaetomium* sp. was found to minimise the disease.

Paneerselvam and Saravanamuthu (1996) tested the antagonistic interactions of some soil fungi, viz., *Aspergillus candidus*, *A. flavus*, *A. fumigatus*, *A. nidulans*, *A. niger*, *A. sulphureus*, *A. terreus*, *A. variecolor*, *Gliocladium* sp., *Penicillium citrinum*, *P. funiculosum* and *T. viride* against *S. oryzae in vitro* in dual culture and in petriplates on nutrient medium amended with staled products of these test fungi. The maximum per cent inhibition was with *T. viride* followed by *Gliocladium* sp., *A. nidulans*, *P. citrinum*, *P. funiculosum*, *A. sulphureus*, *A. candidus*, *A. niger*, *A. terreus*, *A. flavus*, *A. variecolor* and *A. fumigatus*. *A. flavus* and *A. nidulans* showed mutual intermingling growth with *S. oryzae*. The staling products of the antagonistic fungi inhibited the growth of *S. oryzae* at 20 per cent concentration.

Plant extracts in the management of sheath rot

Narasimhan and Pillai (1992) observed that the constraints in disease control in recent years, especially those involving fungicides is due to their acquired resistance to the pathogen, ecological hazard and their expensive nature have led to the necessity to find an alternate source. Seed extract of neem (*Azadirachta indica* L.) was found to be effective against *Sarocladium oryzae*. There was significant inhibitory effect on spore germination and mycelial growth of the pathogen and the effects were either equal or next to that of the standard fungicides tested. Field application of neem seed kernel extract (3 per cent) as foliar spray at panicle initiation stage and fifteen days later significantly reduced the sheath rot and increased the grain yield of rice.

Jeeva and Ramabadran (1992) found that water extracts of several plants screened *in vitro* inhibited conidial germination of *S. oryzae*. The extracts of *Caesalpinia pulcherrima* and *Ipomoea crassicaulis* at 10 and 5 per cent when sprayed before inoculation, before and also after inculation and after disease development reduced the sheath rot incidence in pot culture experiments. Ten per cent spray was more effective than five per cent and the extracts sprayed both before and after inoculation showed the lowest disease incidence. Jeeva and Ramabadran (1993) screened for inhibition of conidial germination of *S. oryzae*, *Arachis hypogoea*, *C. pulcherrima*, *Euphorbia hirta* and

I. crassicaulis. The cold water extracts of all the plants were inhibitory to *S. oryzae*. Ethanol extract from *I. crassicaulis* gave the maximum inhibition. George (1995) reported that the water extracts of *Azadirachta indica*, *Allium sativum*, *Phyllanthus niruri* and *Ocimum sanctum* L. reduced the germination of the spores at 1 per cent and 10 per cent concentration.

Naidu and John (1981) observed that leaf extracts of *Polyalthia longifolia* L., *Parthenium hysterophorus* L. and *Cymbopogon* sp., and rhizome extracts of *Zingiber officinale* L., and *Curcuma longa* L., inhibited the growth of *S. oryzae in vitro*. The radial growth and the mycelial dry weight of *S. oryzae* were reduced by garlic bulb extract. Kanagarajan (1988) reported that neem leaf extract was effective against *S. oryzae*. Komala *et al*. (1988) found that leaf extracts of *Ocimum sanctum* L., *Curcuma longa* L., *Datura metal* L., and *Azadirachta indica* L. inhibited the spore germination of *S. oryzae*. The leaf extracts of *O. sanctum* and *A. indica* were effective against sheath rot disease under pot culture also (Kumar, 1992). The seed extracts (10 per cent) from *Tribulus terrestris* and leaf extract (10 per cent) from *Agave americana* effectively inhibited the spore germination, germ tube elongation and radial growth of *S. oryzae* and the sporulation of the fungus was reduced by the extracts from young stem of *Euphorbia tirucalli* and natured leaf of *Urginea indica* (Selvaraj and Narayanasamy, 1993).

Narasimhan *et al*. (1993) found that in field trials during the wet seasons of 1990-'92, neem seed kernel extract (5 per cent) applied as foliar sprays at booting and 10 days later controlled of *S. oryzae* and improved yield, comparable to that achieved with 0.1 per cent Carbendazim. Pandiarajkumar *et al*. (1995) reported that maximum inhibition of fungal growth was in *Azadirachta indica*, which was followed by *Ocimum sanctum*, *Acalypha indica*, *Acacia leucophloea*, *Ipomoea corynea*, *Datura stramonium* and *Prosopis juliflora*. Further, they inhibited the germination of spore and germ tube elongation of the pathogen. Pre-inoculation spraying of leaf extracts and biocontrol agents recorded significant reduction in sheath rot disease index over control. Radhika *et al*. (1995) reported that neem oil (3 per cent) ranked next only to 0.1 per cent Carbendazim in the control of sheath rot. Spraying the leaf extracts (10 per cent) of *O. sanctum* and *P. juliflora*, basal application of neem cake, coir pith and FYM also gave control. The grain yield was highest for carbendazim, but neem cake application was the next. Eswaramurthy *et al*. (1995) observed that spraying 10 per cent leaf extracts (twice at fortnight intervals at boot leaf stage) of *I. cornea*, *P. juliflora*, *Peltophorum ferrugineum* and *Acacia arabica* were effective in controlling *S. oryzae*. The best among them was *I. cornea*.

Eswaramurthy *et al*. (1988) reported that among low release nitrogen compounds which reduced sheath rot, the best

was coal tar coated urea. Neem coated urea had the highest grain and straw yield. Neem seed extract (2 per cent) and neem cake extract 5 per cent also reduced the disease intensity. Narayanasamy and Narayanasamy (1988) reported that neem oil (1 per cent) and neem seed kernel extract (2 per cent) were equally effective and significant as other treatments including the fungicide. Eswaramurthy *et al*. (1989) reported that neem leaf extract inhibited *S. oryzae*.

The leaf extracts (10 per cent) from *O. tenuiflorum* and *Catharanthus roseus* and seed extracts from *Tribulus terrestris* effectively reduced sheath rot both in pot culture as well as field. However, the effect of these extracts persisted only for a period of five days (Selvaraj and Narayanasamy, 1993). Foliar application of neem oil (3 per cent) at 30, 40 and 50 days after transplanting showed minimum sheath rot incidence, while neem cake (150 kg/ha) combined with foliar spray of neem seed kernel extract (5 per cent) was the next in the order of merit. The yield was also significantly maximum in neem oil and neem seed kernel extract combination (Narasimhan *et al*., 1993).

Jeeva and Ramabadran (1995) reported that plant extracts (10 per cent) of *Caesalpinia pulcherrima* and *I. crussicaulis* increased seed germination, shoot and root length and vigour index. Among the two, the former was more effective than the latter. Eswaramurthy *et al*. (1996) observed that leaf

extracts (10 per cent) of *Ipomoea cornea* and *Prosphis juliflora* were highly effective in controlling sheath rot. Jagannathan and Sivaprakasam (1996) found that various neem derivatives reduced sheath rot incidence. Plants treated with neem seed kernel extract, nochi (*Vitex negundo*), white babul (*Acacia leucocephala*) and *Polyalthia longifolia* yielded more than untreated control.

Effect of fungicides on sheath rot

The Kerala Agricultural University has recommended the use of Carbendazim, Carboxin, Captafol or Ediphenphos for the control of sheath rot in the 'Package of Practices Recommendations' (Kerala Agricultural University, 1993).

Laboratory evaluation of fungicides by Ragunathan and Vijayaraghavan (1976) revealed that Carbendazim and Ediphenphos at 0.005 and 0.05 per cent, respectively could effectively inhibit the growth of the sheath rot pathogen. However, Mancozeb and Captafol were inhibitory only at a higher concentration.

Bavistin (Carbendazim), HMP-MBC (Carbendazim), Aureofungin and Hinosan (Edifenphos) were reported to be effective against *S. oryzae* (Chinnaswamy *et al.*, 1977). Raina and Singh (1980) found that Carbendazim 0.1 per cent was effective in controlling sheath rot in the field.

Raju and Singh (1981) observed that the fungicides Carbendazim and Benomyl could effectively check the incidence and

intensity of sheath rot under field conditions. Balakrishnan (1981) reported that Ediphenphos 0.1 per cent is effective against sheath rot in field. Balakrishnan and Nair (1982) suggested the efficacy of Ediphenphos and Carboxin in reducing the incidence and intensity of sheath rot disease under field conditions in Kerala. Lakshmanan (1984) reported from Tamil Nadu that a Calixin-Bavistin mixture (each at 100 g/ha) could effectively control sheath rot under field conditions.

Reddy *et al*. (1985) observed Carbendazim to be the most efficient fungicide in controlling sheath rot, followed by Blue copper and Antracol (Propineb). In China during 1982-'83, Bayleton (Triadimefon) was found effective in controlling sheath rot in hybrid, rice when applied at early heading stage at the rate of 105 g active ingredient/ha. In 1985, Bayleton gave 70-80 per cent control, with yield increases of 487.5 - 825 kg ha^{-1}.

Murthy (1986) conducted fungicide trials in 1980 and 1982 (Kharif) and found that Ediphenphos, Carbendazim and Mancozeb significantly reduced *S. oryzae* infection compared to untreated plots and other test chemicals. Lewin and Vidhyasekaran (1987) reported that even though several fungicides inhibited the growth of *S. oryzae in vitro*, none was effective in field trials. Vidhyasekaran and Lewin (1987) achieved complete control of *S. oryzae* by application of Carbendazim every three or five days. Captafol at third, fifth or tenth days or

Carbendazim at ten days interval gave substantial protection. Fungicides sprayed at longer intervals were ineffective.

Misra and Vir (1990) found that seed treatment with 0.3 per cent Phenyl Mercury Acetate, Captan, Carboxin, Carbendazim + Thiram, Carbendazim, Thiram or Thiophanate methyl protected the seeds affected by *S. oryzae* and resulted in a distinct improvement in germination rate. Islam *et al*. (1992) reported that several fungicides, except Herodione, were effective against *S. oryzae*.

Karmakar *et al*. (1992) found that spraying twice with 0.1 per cent Carbendazim to control *S. oryzae* made some cultivars of rice superior to others. Tricyclazoles at 1000 to 1500 ppm was required to inhibit *S. oryzae*. Mancozeb at 200 ppm was inhibitory to the mycelial growth of the pathogen (Viswanathan and Narayanasamy, 1991). Viswanathan and Narayanasamy (1993a,b) reported that a combination of Mancozeb and Tricyclazole was superior to the other treatments in controlling sheath rot disease. Spraying Tricyclazole twice as well as Tricyclazole along with Mancozeb increased number of productive tillers, 1000 grain weight and grain yield in both field as well as in pot culture. These sprayings did not leave any residue of Tricyclazole either in the paddy grain or straw (Viswanathan and Narayanasamy, 1993b).

Dodan *et al*. (1996) proved that Propiconazole (Tilt 25 EC) was the most efficient one and it reduced sheath rot incidence by 46.5 per cent with a corresponding increase of 8.7 per cent in grain yield. This was followed by Carbendazim. Mancozeb proved to be the least effective.

Mass multiplication of antagonistic fungi

Ease and cheapness of production and application are the principal characteristics of a desirable biocontrol agent (Butcher, 1958).

Backman and Rodriguez-Kabana (1975) reported that diatomaceous earth granule impregnated with blackstrap molasses was suitable for mass multiplication of *Trichoderma harzianum*. Application of 140 kg/ha of granules gave control of *Sclerotium rolfsii* equivalent to that achieved by 10 per cent PCNB granules at 112 kg/ha. This system has low bulk, no residue and applicable to other pathogen antagonist systems also.

Henis *et al*. (1978) used wheat bran for mass multiplication of *T. harzianum*. One gram culture contained 4.1×10^9 conidia. When applied to soil at the rate of 0.04 to 0.15 g/kg (dry weight basis), it protected radish seedlings from damping off caused by *Rhizoctonia solani* and increased radish germination in non-infested fields.

Large scale inoculum production of *Fusarium oxysporum* f. sp. *cannabis* Snyol., a pathogen of *Cannabis sativa* L. was

achieved on a mixture of barley straw with glycine succinate, sodium nitrate solution, alfalfa straw, cotton seed meal or soybean meal (Hildebrand and Mc Cain, 1978). Sorghum and bajra grains appeared to be the most suitable for the mass production of *F. moniliforme* var. *subglutinans* (Beevi, 1979).

Hadar *et al.* (1979) successfully used a wheat bran culture of the fungus *T. harzianum* to control damping off of bean, tomato and egg plant seedlings caused by *R. solani*. Chet and Elad (1982) used wheat bran cultures of *T. harzianum* to control damping off of beans, peanuts and egg plants caused by *R. solani* or *Sclerotium rolfsii*. Lewis and Papavizas (1987) reported that application of wheat bran culture of *T. hamatum* containing actively growing mycelium could reduce the *R. solani* inoculum in soil.

Elad *et al.* (1980) grew *T. harzianum* on a wheat bran saw dust : tap water mixture (3:1:4 v/v) and observed that the fungus decreased disease caused by *S. rolfsii* or *R. solani* in field experiments with beans, cotton or tomatoes. A significant yield increase was noticed in beans.

Large batches of biomass of *Gliocladium virens*, *T. hamatum*, *T. harzianum*, *T. viride* and *Talaromyces flavus* were produced in liquid fermentation in 20 L vessels stimulating industrial conditions by utilizing commercially available, inexpensive ingredients (molasses and brewers yeast). However,

conidia of *Trichoderma* or *Gliocladium* added without food base, did not proliferate in soil (Papavizas *et al.*, 1984).

Soundarajan *et al.* (1984) used sorghum grains for mass multiplication of *Cephalosporium lecanii*, a fungus entomopathogenic on *Coccus viridis*. It was cultured in polyethylene bags, which could be used for transportation to the field and can then be discarded. This eliminates the necessity for transporting and afterwards washing the conical glass flasks previously used for culturing fungi.

Jones and his associates in 1984, tested a lignite stillage carrier system for applying the biocontrol agents like *Gliocladium virens* and *T. harzianum* to soil. After four days of storage, fungal viability remained above 90 per cent as determined by plating of granules.

It was found that *Trichoderma* spp. can be multiplied in bark pellets (Sundheim, 1977), wheat bran plus peat (Sivan *et al.*, 1984), barley grains (Abd-El Moity and Shatla, 1981), composted hardwoodbark (Hoitink, 1980; Nelson and Hoitink, 1983) and in pellet forms containing *T. harzianum* and *T. polysporum* (Richard, 1983).

A method to encapsulate microorganisms was developed by Fravel *et al.* (1985). Aqueous solution containing 1 per cent alginate and 10 per cent pyrax were mixed in a blender.

Solutions were amended singly with either ascospores or conidia of *Penicillium oxalicum* or *Trichoderma viride*. Initial population ranged from 10^7 to 10^8 propagules per ml of alginate suspension. These populations declined during the test period. Losses were 10 to 100 fold after four weeks.

Mukhopadhyay (1987) used sorghum grain substrate for the control of *S. rolfsii* in sugarbeet. Upadhyay and Mukopadhyay (1986) inoculated sorghum grains presoaked in 2 per cent sucrose solution with *T. harzianum* and mixed it with equal amounts of freshly boiled sorghum grains and applied to soil at the rate of 3 g per m row before sowing sugarbeet seeds. Padmanabhan and Alexander (1987) tried sand sorghum medium for the application of *T. viride* in the field for the control of root rot of sugarcane seedlings.

Gangadharan and Jeyarajan (1988) found that mycelial weight of *T. harzianum* was significantly more when grown on tapioca rind and peat (1:2 w/w) and was found to be on par with tapioca rind, thippi and thippi + peat (1:2 w/w). The number of colony forming units was significantly more when grown on tapioca rind for both *T. viride* and *T. harzianum*. Hareendranath (1989) reported broken maize grains as suitable medium for mass multiplication of *Fusarium pallidoroseum* followed by tapioca chips and jack seeds.

Wheat bran and rice bran cultures of *Trichoderma* species were found efficient in controlling sheath blight caused by *R. solani* (Gokulapalan, 1989; Viswakumar, 1989). Faizal (1992) reported that for mass culture of *F. pallidoroseum*, wheat bran and rice bran are good substrates with regard to growth, sporulation and virulence.

Dried effluent from gobar gas plant and farm yard manure proved to be most promising for the growth and sporulation of *T. harzianum* and *T. viride*. When the moisture content of farmyard manure was 40 to 60 per cent, the fungi multiplied well. By mixing the nucleus inoculum with bulk farmyard manure at the rate of 0.5 per cent and incubating upto one month, a field inoculum could be prepared (Jacob and Sivaprakasam, 1993).

Sawant and her associates (1995) observed large scale multiplication of *T. viride*, *T. harzianum* and *Gliocladium virens* in local wastes like coffee-cherry husk and fruit skin and berry mucilage. Poultry manure and mushroom grown waste was also found suitable, giving 20-30 million cfu/g substrate. Coffee-berry mucilage was used fresh; coffee-cherry husk and fruit skin, cattle manure and poultry manure were used fresh or after composting while mushroom grown waste was used immediately after the last harvest of mushrooms. Sawant and Sawant (1996) achieved the highest colony forming unit of 92×10^2 of *T. harzianum* on coffee fruit skin-biogas slurry.

The production of biomass containing the most effective conidia, conidiophore or mycelium of *T. harzianum* by solid state fermentation using rice bran and wheat bran was reported by Mehtha and his associates (1995). Pelleted formulations are made in various concentrations with sodium alginate and inert filler like lignite. They also formulated chlamydospore inoculant in molasses corn strip liquor fermentation.

Jeyarajan and Ramakrishnan (1995) developed a talc based formulation of *T. viride* for dry seed treatment of oil seeds and pulses using fermented grown biomass in molasses-yeast medium. It maintained adequate population even after four months of storage at ambient temperature in sealed transparent alkathene bags. It had a cost-benefit ratio of 1:400 in ginger, 1:20 in chick pea, 1:360 in cotton and 1:50 in groundnut, when applied at the rate of 4 g kg^{-1} seed.

In a talc based powder formulation of *Trichoderma* sp. and *Gliocladium* sp., the number of colony forming units in the fresh product ranged from 224 to 297 x 10^6/g. The population was reduced by 19, 21, 21 and 30 per cent respectively in *T. viride*, *T. harzianum*, *T. longibrachiatum* and *G. virens* after 75 days of storage. Evenafter 120 days, nearly 50 per cent population was retained (Sankar and Jeyarajan, 1996).

Preparation of *T. harzianum*, *T. viride*, *T. koningi* and *G. virens* was developed in Pantnagar in wheat bran-sawdust

medium. The above preparation is relatively less expensive (Sharma and Basondrai, 1996).

Gogoi and Roy (1996) found that efficacy of *Aspergillus terreus* was greater, when it was grown on wheat-bran peat medium (50:50 wheat-bran peat w/w) compared to maize-meal sand medium (4 per cent maize meal sand w/w). Spraying with spore suspension simultaneously or three days before inoculation on aerial parts suppressed the incidence of sheath blight disease of rice.

Integrated management

Ohr and associates (1973) obtained control of *Armillaria mellea* by integrated effort by methyl bromide and antagonistic microorganisms like *Trichoderma* sp. They opined that controlling organism should be more tolerant to the chemical used than the pathogen or to have the ability to recover rapidly from its effects.

Hadar *et al*. (1979) observed that low concentration of PCNB improved control of damping off of bean, tomato and egg plant, when applied together with *T. harzianum*.

Elad and his associates (1980) were successful in the integrated control of soil borne diseases in potato by adopting optimal combination of physical, chemical and biological means. They combined solar heating, fumigation with methyl bromide and *T. harzianum*, for the control of *Sclerotium rolfsii*. Kraft and

Papavizas (1983) integrated host resistance, antagonists and fungicide combination to control several soil-borne diseases.

Important milestone in the integration of biological control with other control measures was the development of mutant genomes of antagonists, which can tolerate chemicals and other control measures (Papavizas, 1985). Such studies were also made by Papavizas and Lewis, 1981; Papavizas *et al.*, 1982 and Papavizas and Lewis, 1983. They discussed future prospects of modifying *Trichoderma* genome to obtain biotypes, which will tolerate fungicides for use in the integrated pest management system.

Alagarsamy and Sivaprakasam (1988) observed reduced seedling mortality caused by *Macrophomina phaseolina* by seed pelleting with Carbendazim in combination with antagonists like *T. viride* and *T. harzianum* in pot culture.

Maiti and his associates (1991) tried mechanical seed reponation (seed sunk in 20 per cent common salt solution) and different seed dressing chemicals like Carbendazim, Tricylazole and Pyroquilon for efficient controlling sheath rot control. Mechanical separation resulted in best disease management and produced highest grain yield. But since the varieties used were of short duration, it is presumed that they might have escaped secondary infection and seed treatment alone was effective in disease management.

Ramabadran and Velazhahan (1991) reviewed the management of sheath rot by cultural, biological and chemical methods. The disease spread was found to be severe in densely planted fields and in those infected by stem borers. Proper spacing between plants was recommended. In general, management of sheath rot was difficult by chemicals, but seed treatment with Benomyl and Panoctine (Guazatine) improved seed germination.

Foliar application of nitrogen and potassium together with Carboxin reduced panicle damage by sheath rot fungus and gave the highest grain yield (Nair *et al.*, 1988).

Alagarsamy and Bhaskaran (1986) reported that application of nitrogen in three split doses before flag leaf formation and potassium in two split doses viz. one applied as basal and other applied either during tillering or panicle initiation stage with foliar sprays of $CaSO_4$ and Carbendazim were found to reduce the incidence of sheath rot disease, thereby increasing grain yield in rice.

Raju *et al.* (1988) reported that during the field trials in 1986-87 in Tamil Nadu, the combined spraying of Monocrotophos with Carbendazim resulted in the lowest incidence of *Sarocladium oryzae*

Narasimhan *et al.* (1993) studied the effect of various salts which induce resistance against sheath rot on the management of the disease. In field trials, foliar spray twice

with magnesium sulphate 0.2 per cent, calcium sulphate 0.2 per cent and soil application of gypsum at 500 kg/ha showed minimum sheath rot incidence.

Kuthubutheen and Pugh (1978) found that at 50 ppm concentration, Thiram and Verdasan caused inhibition of cellulose decomposition and starch hydrolysis in the strongly cellulolytic fungus, *Trichoderma viride* Pers er Fr. Padmanabhan and Alexander (1987) found that fungicides like Fenaminosulf, Plantvax and Demosan were found to favour the growth of *Trichoderma* spp., while Difolatan and Copperoxychloride were highly inhibitory.

Krishnamoorthy and Bhaskaran (1993) tested soil drenching of fungicides *in vitro* for their inhibitory or stimulating effect on *Trichoderma* spp. Mycelial growth of *T. viride* Pers. and *T. harzianum* was unaffected by copper oxychloride. *T. viride* did not sporulate in copper oxychloride - poisoned plates. Captan was found to be lethal to *T. viride*, while it did not affect the growth and sporulation of *T. harzianum*. Fenaminosulf affected neither the growth nor the sporulation of *T. viride* and *T. harzianum*.

Mondal *et al*. (1995) reported that *T. koningii* was compatible with Carboxin at 200 and 500 ppm. *T. harzianum* and *T. lignorum* and *T. viride* was very poor. The mycelial growth of all the *Trichoderma* spp. tested was arrested to a greater extent with the addition of 200 and 500 ppm Carbendazim and Tebuconazole

in culture medium, indicating that they may not integrate with Carbendazim. Regarding biocides, *T. viride* was compatible with formulations of neem product at 100 and 250 ppm. Other *Trichoderma* spp. were compatible but due to their inefficient bioefficacy, except neem oil at 250 ppm, none of these formulations may be utilized.

MATERIALS AND METHODS

MATERIALS AND METHODS

Isolation and culturing of rice sheath rot pathogen

The sheath rot pathogen, *Sarocladium oryzae* Gams and Hawksworth was isolated from naturally infected parts collected from Rice Research Station, Moncompu, Alappuzha, Kerala by routine mycological techniques as described hereunder. The sheath portions of infected plants showing characteristic symptoms of attack were cut into small bits and washed thoroughly in distilled water. The pieces were then surface sterilised with 0.1 per cent mercuric chloride solution for two minutes and re-washed in repeated changes of sterile water. These bits were then plated on potato dextrose agar medium (PDA) (Appendix I) in sterile petri dishes and incubated under laboratory conditions (28±2°C) for 48 to 72 hours. The organism was purified and maintained on PDA slants by periodical subculturing. The isolate was purified by hyphal tip plating. The sheath rot causing fungus, *Sarocladium oryzae* was identified by observing the characters of the organism and conidial ontogeny on slide cultures (Riddel, 1950). The method for microscopic slide culture is detailed below:

Sterile plain agar medium was poured in sterilised petri dishes to a thickness of 2 mm and after solidification, 6 mm square pieces were cut out using a sterile needle. One such square was placed at the centre of each sterile glass slide and

each of the four sides of the agar block was inoculated with small culture bits of the fungus. A cover slip was placed on top of the inoculated agar block and the slides were kept in moist petri dish chambers (sterile petri dish with wet sterile filter paper at the bottom on which two glass rods were kept to serve as support for the slide). The dish with the slide was then incubated at room temperature for two to three days. After this, the cover slip was lifted off gently, a drop of 95 per cent alcohol was placed in the centre and before drying, the cover slip was mounted using lactophenol cotton blue on another slide. The square of agar was removed from the original culture slide and another mount was prepared in a similar manner without any disturbance to the fungal growth on the slide. These slides were then examined and the morphological characters of the pathogen studied.

Rice plants of the variety Jaya were raised in earthen pots and artificially inoculated by placing the mycelial bit of the fungus in between the sheath of the flag leaf and the unemerged panicle. A high percentage of relative humidity was provided by covering with polythene bags and giving periodical water sprays for 48 to 72 hours. When the typical sheath rot symptoms developed, the fungus was reisolated from the infected tissues by following Koch's postulates. The pure culture of the sheath rot fungus thus obtained by repeated hyphal tip isolation method was utilized during the course of this study.

Isolation of spermosphere organisms

Mature grains from healthy rice plants were collected. The leaf washing and dilution plate technique (Waksman, 1922) was used to isolate the spermosphere organisms. The grains were selected and transferred aseptically to 250 ml conical flask containing 100 ml of sterile water. It was shaken for 20 minutes in a mechanical shaker to detach the propagules from the leaf surface. 0.5 ml aliquot of the washing was transferred into 20 ml of the Rosebengal streptomycin agar taken in petridishes (Appendix I). The petridishes were incubated at room temperature (28±2°C) for 48 to 72 hours. After the incubation period, colony counts were made for each group of microorganisms. The isolated organisms were maintained on PDA slants by periodical subculturing.

Isolation of phylloplane organisms

A leaf washing and dilution plate technique (Waksman, 1922) was used to study the various microflora on the leaf surface. The leaf samples were collected from weed plants like *Cyprus* sp., *Echinocloa* sp. and *Panicum repens*. Portions of the weeds and healthy rice plants were cut using sterile scissors and brought to the laboratory in fresh polythene bags. Every effort was made to avoid contamination in the field as well as in the laboratory. Representative samples of ten leaves each from the

respective plants were transfered aseptically to 250 ml flasks containing 100 ml of sterile water and shaken for 20 minutes in a mechanical shaker to detach the propagules from the leaf surface. The organisms were isolated as explained earlier.

Isolation of microorganims from soil

Soil was collected from the rhizosphere of healthy rice plants at various locations (healthy areas in a diseased field and from healthy fields in disease prone areas). The various fungi present in these soils were isolated using Dilution end point technique (Barron, 1971).

Ten g soil was taken in a flask containing 90 ml of sterile water and shaken in a mechanical shaker for 20 minutes. While the suspension was in motion, 10 ml of the sample was withdrawn and added to 90 ml of sterile water to get 10^{-1} dilution. The process was repeated to get 10^{-4} dilution. The solution was taken and plated with Rose bengal streptomycin agar on a petri dish. Microbial colonies were observed and transferred and maintained on PDA slants.

The organisms obtained from spermosphere, phylloplane and rhizosphere were maintained on PDA slants as pure cultures. The various cultures were subjected to morphological studies and the organisms were identified upto their generic level. Antagonism of microorganisms from spermosphere, phylloplane,

rhizosphere of rice and phylloplane of rice weeds against the sheath rot pathogen was studied.

For studying the antagonistic action of the fungi against the sheath rot pathogen, seven day old culture of both the pathogen and test fungi were taken. Agar discs of .5 mm were cut and placed 3.5 cm apart on PDA in a 9 cm petri dish and incubated at room temperature (28±2°C) for 20 days. Three replications were set up per combination of the pathogen and the test fungus. The paired cultures were examined at regular intervals throughout the incubation period and the nature of reaction recorded. Colony development was observed and the mode of interaction between organisms was assessed. When the growth pattern became stable, the interaction types were grouped into four different categories following the method adopted by Purkayastha and Bhattacharya (1982).

Group	Nature of interaction
A. Homogenous	Free intermingling of hyphae
B. Overgrowth	*S. oryzae* overgrown by the test organism
C. Cessation	Cessation of growth at the line of contact
D. Aversion	Development of clear zone of inhibition

The various cultures were categorised and the most potent ones were selected for *in vivo* studies and mass multiplication.

Evaluation of the efficacy of the mode of action of selected antagonists under various systems of application in checking the sheath rot disease

Pot culture trials were conducted at the College of Agriculture, Vellayani to study the comparative efficacy of the mode of action of the potent antagonists under different systems of application of *S. oryzae* in checking the sheath rot disease of rice.

Antagonists used:-

1. *Trichoderma* sp
2. *Aspergillus* sp.
3. *Penicillum* sp.

Methods of application:-

1. Seed treatment
2. Foliar application
3. Root dip method

All the antagonists were multiplied in wheat bran:sand (1:10) mixture which was autoclaved. Erlenmeyer flasks (250 ml) containing this media were inoculated with antagonists and incubated at room temperature for 8 to 10 days.

Rice seeds were coated with each of the antagonists separately by keeping in a mechanical shaker along with the antagonists for 20 minutes. These seeds were raised separately.

Seedlings of the transplantable age were carefully pulled out and the roots dipped in the antagonist suspension.

All the plants were inoculated with *S. oryzae*, the sheath rot pathogen at the boot leaf stage. For this the pathogen was mass multiplied on rice grains. The grains were autoolaved, inoculated with the pathogen and then incubated at 28±°C for 8 to 10 days. The grain along with the fungal growth was placed behind the boot leaf sheath in the boot leaf stage. The inoculated plants were incubated under high percentage of humidity by providing loose polythene wrappers. Inoculated plants were observed for th development of symptoms. After one week of appearance of symptoms, foliar application of the different antagonists was done on another set of plants. For this a spore suspension of the antagonists was prepared in water and spraying was carried out. A set of plants inoculated with the pathogen alone served as the control.

Observations were recorded from the fifth day onwards. The disease severity was worked out using a score chart developed by Amin (1976).

Score value	Description
1	No visible symptoms on sheath of any leaf, panicles are fully emerged and grains are free from discolouration.

2 Two or three small lesions of 0.5 to 1.0 cm long and 0.2 to 0.5 cm wide developed on flag sheath which are oval, dark, chocolate brown and surrounded by diffused light brown halo, while the colour of the healthy sheaths around the lesions remain green. Grains are not discoloured.

5. Large lesions of 2 to 3 cm long and 1 cm wide are most conspicous on flag leaf sheath, but occur on all the leaf sheaths. Lesions overlap and form irregular large chocolate brown blotches on flag leaf sheath. Emergence of panicle is affected and it is half way from leaf sheath. Grains inside are partially chaffy and covered with pink mycelium and spore masses. Affected panicles range up to an estimated 25 per cent.

7 Flag leaf sheath is completely chocolate brown in colour due to many overlapping lesions. Flag leaves of affected sheath gradually become yellow to straw coloured. Affected panicles are fully compressed by flag leaf sheath and are dark brown, chaffy and covered with white to pink mycelium and spore masses. This stage is commonly known as "choking". Affected panicles range up to 50 per cent.

9. The entire flag leaf sheath has dark chocolate brown colour. Subsequently become yellow to straw in colour. Flag leaves are straw in colour. Grains are dark brown and chaffy. Severe choking of panicles. Afected panicles range up to 100 per cent.

All the inoculated tillers were observed and the intensity of disease was expressed as mean score. Grain yield was recorded.

Effect of plant extracts on *Sarocladium oryzae in vitro*

Aqueous extracts of *Azadirachta indica* L., *Allium sativum* and *Ocimum sanctum* L. were taken. Ten per cent concentration of the extracts were prepared in sterile distilled water. The leaf extracts of *A. indica* L. and *O. sanctum* L. and the bulb extract of *Allium sativum* were used for the study. The plant materials collected were thoroughly washed with tap water, then with alcohol and finally with changes of distilled water. These were ground by using a mortar and pestle by adding sterile water at the rate of one ml per gram of leaf tissue. The extract was strained through two layers of muslin cloth and subsequently filtered through two Whatman No.1 filter paper. This formed the standard plant extract solution (100 per cent). This extract was further diluted to 10 per cent concentration for *in vitro* studies.

Effect of extracts on radial growth of *S. oryzae*

Seven day old culture of the test fungus grown on PDA in petri dishes was used for the study. Ten per cent concentration of the extracts were prepared by adding appropriate quantities of extracts into the autoclaved (1.05 kg cm^{-2} pressure for 20 minutes) PDA cooled to 45°C. They were thoroughly mixed by gently swirling the flasks. The medium containing the extract was poured aseptically into sterile petri dishes and five mm mycelial discs of the test fungus was placed in the centre of each dish. In the case of control, the PDA without the extract was used and inoculated with the mycelial discs. The mean diameter of the radial growth of the test fungus was recorded. The method adopted for this bioassay was a modified version of the poisoned food technique described by Lilly and Barnett (1951). Per cent inhibition of growth over control was calculated using the following formula,

$$\text{Per cent inhibition} = \frac{C - T}{C} \times 100$$

where, C = Radial growth in control

T = Radial growth in treatment

Effect of extracts on the dry weight of *S. oryzae*

Potato dextrose broth (Appendix I) was used for the study. Fifty ml of the medium was taken in 250 ml conical flask

and sterilised. By adding the plant extract into the medium, the concentration was made to ten per cent. The flasks were inoculated with mycelial discs of 5 mm diameter, cut out from an actively growing 7 day old culture of the fungus and incubated at room temperature (28±2°C). After 15 days of incubation, the culture was filtered through previously weighed Whatman No.1 filter paper and dry weight of the biomass was determined. Three replications were maintained for each treatment.

Effect of fungicides on *S. oryzae in vitro*

The following fungicides at different concentrations were used for laboratory assay against the pathogen.

Fungicides	Generic name	Chemical name	Concentration (%)
Hinosan	Edifenphos	O-ethyl S, S-diphenyl phosphorodithioate	0.25
			0.1
			0.075
			0.05
Bavistin	Carbendazim	2 (methoxy-carbamyl) benzimidazole	0.1
			0.075
			0.05
			0.025
			0.01

Poisoned food technique described by Lilly and Barnett (1951) was used to study the effect of the above fungicides on the radial growth of the pathogen. For this seven day old culture of the test fungus grown on PDA in petri dishes was used. The required concentrations were prepared by adding appropriate quantities of chemicals into the autoclaved PDA cooled to 45°C. They were thoroughly mixed by gently swirling the flasks. The medium containing the chemical was poured aseptically into sterile petri dishes and five mm mycelial discs of the test fungus was placed in the centre of each dish. In the case of control, the PDA without the chemical was used and inoculated with mycelial disc. The mean diameter of the radial growth of the test fungus was recorded. Per cent inhibition of growth over control was calculated using the formula,

$$\text{Per cent inhibition} = \frac{C - T}{C} \times 100$$

where C = Radial growth in control

T = Radial growth in treatment

Effect of fungicides on the dry weight of *S. oryzae*

Fifty ml of potato dextrose broth was taken in 250 ml conical flask and sterilised. By adding the appropriate quantities of chemicals into the medium, the different concentrations given above were made. The flasks were inoculated with mycelial discs of five mm diameter, cut out from an actively

growing 7 day old culture of the fungus and incubated at room temperature (28±2°C). After 15 days of inoculation, the culture was filtered through previously weighed Whatman No.1 filter paper and dry weight of the biomass was determined. Three replications were maintained for each treatment.

Mass multiplication of antagonists in different carrier materials

The following carrier materials were used for mass multiplication of the antagonists.

1. Mushroom spent beds.
2. Rice bran.
3. Rice bran : sand (1:3 w/w)
4. Wheat
5. Wheat bran : sand (1:3 w/w)
6. Wheat bran : sand (1:10 w/w)
7. Cowdung : $CaCO_3$ (100:1 w/w)
8. Papaya pulp
9. Jack seeds
10. Tapioca rind

All the above carrier materials were taken in 250 ml conical flasks and enough water was added to moisten them. The materials were sterilised at 1.05 kg cm^{-2} pressure for 20 minutes. Five mm discs from seven day old culture of the antagonistic fungi grown on PDA were taken and inoculated on the

carrier material at the rate of two discs per flask. Three replications were maintained for each carrier material. These were incubated at room temperature of 28±2°C. The spore count was taken using a haemocytometer and number of spores/ml from each substrate was evaluated.

Evaluation of the efficacy of integrated management practices on sheath rot of rice

To study the comparative efficacy of the different methods of application of antagonists together with spraying the plant extracts and the usage of the most effective fungicide at its lowest dose, a pot culture trial was undertaken at the College of Agriculture, Vellayani.

Lay out	-	Factorial CRD
Variety	-	Jaya
Replication	-	Two
Treatment combinations	-	55 x 2 = 110

Components of integrated management

	Plant extracts	Concentration
1.	Neem	10%
2.	Tulsi	10%
3.	Garlic	10%
	Fungicides	**Concentration**
1.	**Bavistin (Carbendazim)**	**0.01%**
2.	**Hinosan (Ediphenphos)**	**0.05%**

Antagonists used

1. *Trichoderma* sp.
2. *Aspergillus niger*
3. *Penicillium* sp.

Methods of application of antagonists

1. Seed treatment
2. Root dip method
3. Foliar application

The experiment was conducted in standard earthern pots uniformly filled with wet land soil collected from the paddy fields of the Instructional Farm, College of Agriculture, Vellayani. Fertilizers were added to these pots as per the Package of Practices Recommendations for rice (Kerala Agricultural University, 1993).

The method of application of antagonists was done as explained earlier. Three hills were planted per pot. Inoculation was carried out using *S. oryzae* mass multiplied in rice grains. The inoculum was placed behind the boot leaf sheath at the boot leaf stage. The plant extracts were sprayed 10 days after the appearance of symptoms. After four days of spraying the plant extracts the fungicidal spray was given. The foliar application of antagonist was done four days after the fungicide spray. Scoring was done using the score chart developed by Amin (1976) to find the disease severity. Grain yield of paddy was recorded.

RESULTS

RESULTS

The fungus, *Sarocladium oryzae* Gams and Hawksworth (*Acrocylindrium oryzae* Saw) was isolated and purified from naturally infected rice plants collected from the paddy fields of Rice Research Station, Moncompu, Alappuzha, Kerala. The identity of the organism was established by the study of morphological characters and the pathogenicity was confirmed following Koch's postulates.

The sheath rot disease of rice under artificial inoculation was characterised by initiation of light purple to brown oblong lesions on the sheath of the flag leaf (Plate 1). The young lesions were surrounded by a light yellow-brown halo, which on maturity turned dark brown with papery white or greyish white centre. The lesions were usually 0.5 to 2.5 cm long and 0.5 to 1.5 cm broad. The individual lesions coalesced together in advanced stages of infection and covered almost the entire sheath of the flag leaf. Often the panicles did not emerge leading to a choked appearance. The entire panicles remained choked within the flag leaf sheath and gradually rotted. Different stages of partially emerged panicles with discoloured and fully or partially chaffy grains were noticed in the affected plants, depending on the stage of infection.

Plate 1.

Symptom of sheath rot under artificial inoculation

Plate 2.

Antagonism between *Trichoderma* sp. and *Sarocladium oryzae*


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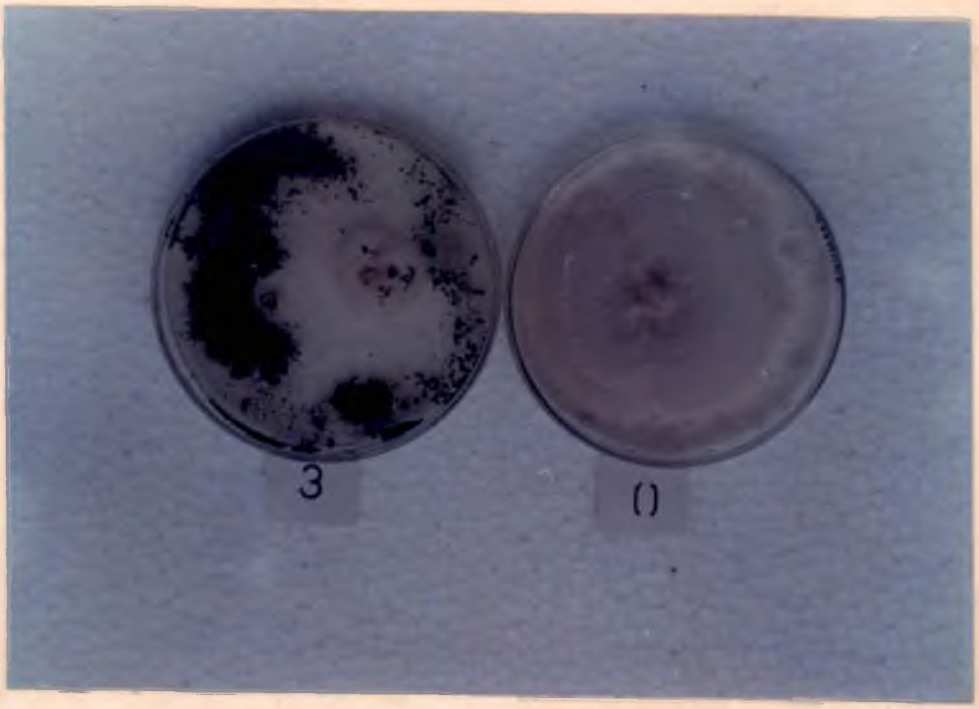
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Organisms isolated

Microorganisms isolated from the spermosphere, phylloplane, rhizosphere of rice and phylloplane of rice weeds are presented (Table 1).

Table 1 List of organisms isolated

Sl.No.	Organisms isolated
1.	*Aspergillus* spp.
2.	*Chaetomium* sp.
3.	*Colletotrichum* sp.
4.	*Curvularia* sp.
5.	*Fusarium* sp.
6.	*Helminthosporium* sp.
7.	*Mucor* sp.
8.	*Penicillium* spp.
9.	*Pestalotiopsis* sp.
10.	*Rhizopus* sp.
11.	*Trichoderma* spp.
12.	*Botrytis* sp.

Antagonism of isolated organisms to *Sarocladium oryzae*

The various organisms isolated and maintained in pure culture were tested for their antagonistic behaviour towards the sheath rot pathogen. The interaction types were grouped into

four categories (Table 2). Among the different organisms showing antagonistic reaction, *Trichoderma* spp., *Aspergillus* spp., *Penicillium* spp. and *Pestalotiopsis* sp. were found to be very potent. *Trichoderma* sp. showed overgrowth over *S. oryzae* (Plate 2). *Aspergillus* sp. and *Penicillium* sp. showed cessation of growth at the line of contact (Plates 3 and 4). *Pestalotiopsis* sp. showed a clear zone of inhibition between the two organisms. The most potent among these organisms, viz., *T. viride*, *A. niger* and *Penicillium* sp. were selected for *in vivo* studies.

Table 2 Organisms showing antagonistic reaction towards *Sarocladium oryzae* and their types of reaction

Sl.No.	Antagonistic organism	Type of reaction
1.	*Aspergillus* spp.	C
2.	*Chaetomium* sp.	D
3.	*Botrytis* sp.	A
7.	*Mucor* sp.	A
5.	*Rhizopus* sp.	A
6.	*Fusarium* sp.	B
7.	*Trichoderma* spp.	B
8.	*Pestalotiopsis* sp.	D
9.	*Penicillium* spp.	C

A Homogenous - Free intermingling between pairing organism
B Overgrowth - *S. oryzae* overgrown by the test organism
C Cessation - at the line of contact of growth
D Aversion - A clear zone of inhibition between the two organisms

Plate 3.

Antagonism between *Aspergillus* sp. and *S. oryzae*

Plate 4.

Antagonism between *Penicillium* sp. and *S. oryzae*


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Efficacy of the mode of action of antagonists under various systems of application in checking the sheath rot disease

Among the various methods of application tried (seed treatment, seedling root dip and foliar application), the highest intensity was seen in foliar application method (2.12) and the lowest intensity in root dip method (1.75). All the methods of applications differed significantly from each other (Table 3).

Table 3 Effect of the mode of action of selected antagonists under various systems of application in checking the sheath rot disease

	B_1 *T. viride*	B_2 *A. niger*	B_3 *Penicillium* sp.	Mean A (Method)
A_1 Seed treatment	4.16 (2.04)	4.0 (2.0)	4.0 (2.0)	2.01
A_2 Root dip	2.58 (1.61)	2.74 (1.66)	3.9 (1.97)	1.75
A_3 Foliar application	3.75 (1.94)	5.13 (2.26)	4.72 (2.17)	2.12
Mean B (Antagonists)	1.86	1.97	2.05	
Control	5.75 (2.4)			

( ) Values after $\sqrt{x}$ transformation
Treatment F (8,10) - 3.07 (not significant)
A F (2,10) - 4.1
B F (2,10) - 4.1 (not significant)
AB F (4,10) - 3.48 (not significant)
Trt vs Ctr. F(1,10) - 4.96

was found to be the best antagonist with a disease intensity of 1.86, followed by *A. niger* with 1.98 disease intensity. The least effective was *Penicillium* (2.05).

Regarding the different combinations of antagonists and methods of application, the application of *T. viride* as root dip was found to be the most effective, giving a disease intensity of 2.58. The foliar application of *A. niger* gave the highest disease intensity of 5.13 and hence found to be less effective. But none of the combinations differed significantly from each other.

The highest disease intensity was observed in the control (5.75). This clearly showed that all the treatments and treatment combinations were significantly different and effective than control.

Effect of the mode of action of antagonists under various systems of application on the yield of rice plant affected by sheath rot

Statistical analysis revealed that the effect of various methods of application differed significantly from each other. The highest yield was obtained with seed treatment (46.67 g). The effect of root dip method and foliar application was found to be on par with an yield of 33.5 g and 33.83 g (Table 4).

Table 4 Effect of the mode of action of antagonists under various systems of application on the yield of rice plant affected by sheath rot.

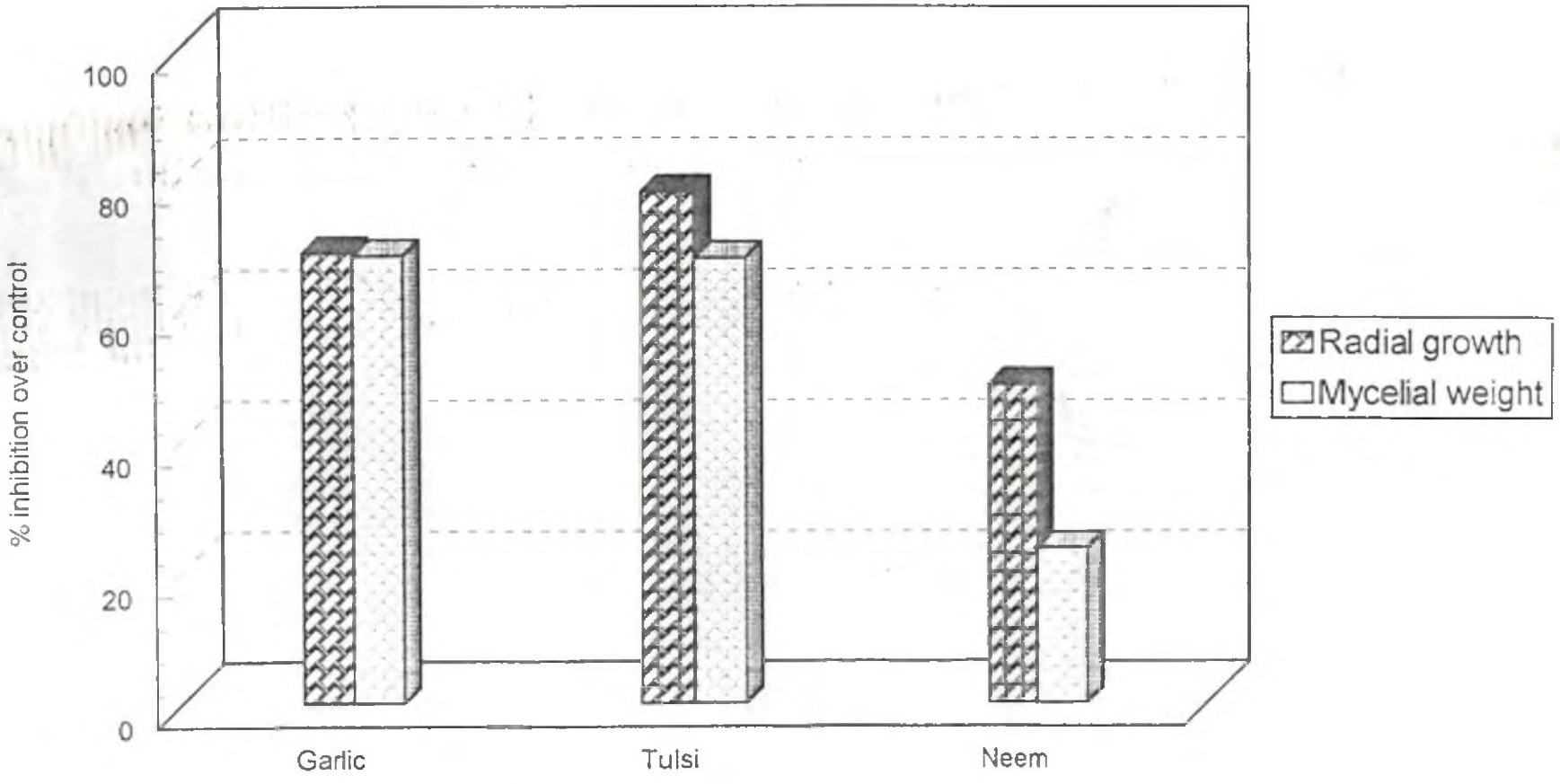
Antagonist B / Method A	B_1 *Trichoderma*	B_2 *Aspergillus*	B_3 *Penicillium*	Mean A
A_1 Seed treatment	45	49	46	46.667
A_2 Root dip	27	49.5	24	33.5
A_3 Foliar application	22	42	37	33.833
Mean B	31.333	46.833	35.833	
Control A_0B_0	39.5			

$A.F_{(2,10)}$	- 4.10	SE A	- 2.4478	CDA	-	7.7217
$B.F_{(2,10)}$	- 4.10	SE B	- 2.4478	CDB	-	7.7127
$AB.F_{(4,10)}$	- 3.48	SE AB	- 4.2397	CDAB	-	13.3587
ns Trt Vs Ctr $F_{(1,10)}$	- 4.96	SE trt	- 4.23.97	CD trt	-	13.3587

ns - Not significant

Among the different antagonists tried, *A. niger* was found to be significantly superior, giving an yield of 46.83g. The next best treatment was *Penicillium* giving an yield of 35.8 g. The lowest yield was with *T. viride* (31.33), even though the effect of *Penicillium* and *T. viride* were on par.

Fig 1 Effect of plant extracts on the growth of *S. oryzae*



The effect of *Aspergillus* applied under root dip method, seed treatment and foliar spray; *Penicillium* sp. as seed treatment and foliar spray; and *T. viride* as seed treatment were on par; the best being *A. niger* applied as root dip method (49.5 g). The effect of application of *Penicillium* sp. as foliar spray and root dip method, and *T. viride* as root dip and foliar spray on yield were on par; the highest among these being *Penicillium* sp. given as foliar spray (37 g). The least effective treatment was the application of *T. viride* as foliar spray (22 g).

Effect of plant extracts on *S. oryzae in vitro*

Effect of radial growth

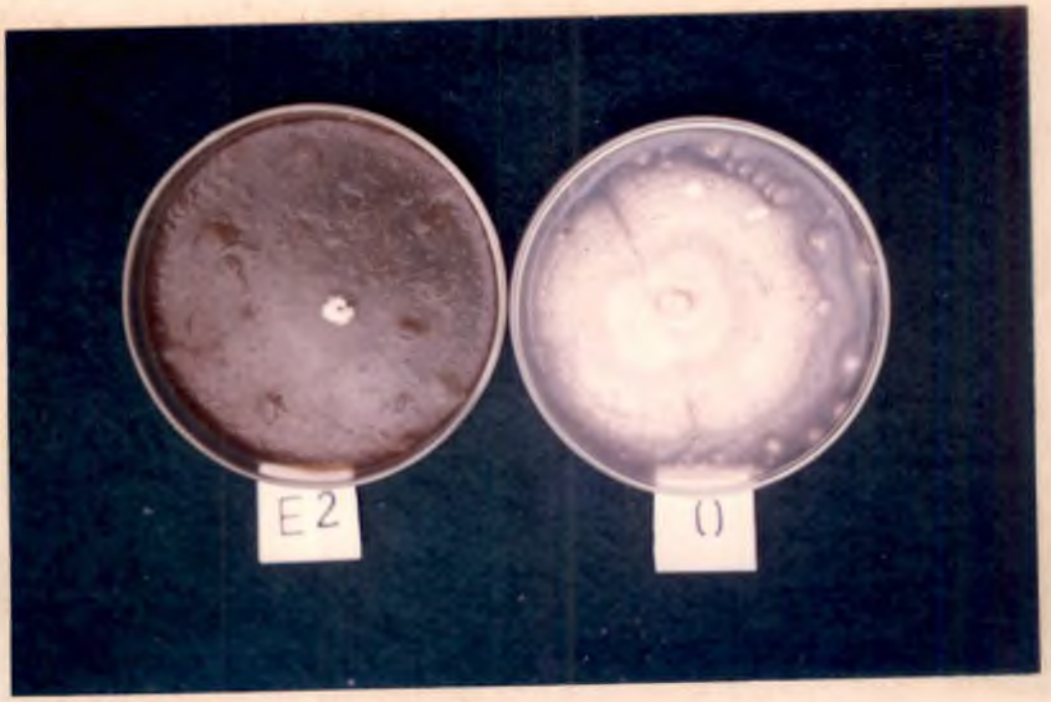
On statistical analysis of data, it was seen that among the different extracts used (*Azadirachta indica*, *Ocimum sanctum* and *Allium sativum*), there was significant difference in the inhibition of radial growth of the pathogen (Table 5, Fig. 1). The extract of *O. sanctum* gave the lowest radial growth of 1.9 cm, showing that it was the best treatment (Plate 5). The next best was *A. sativum* extract with 2.7 cm growth (Plate 6). The least effective was the extract of *Azadirachta indica* which permitted a radial growth of 4.45 cm (Plate 7). All the treatments differed significantly from control (2.94 cm).

Plate 5.

Effect of *Ocimum sanctum* on the radial growth of *S. oryzae*

Plate 6.

Effect o


E2
()


E3
()

Plate 7.

Effect of *Azadirachta indica* on the radial growth of *S. oryzae*

Plate 8.

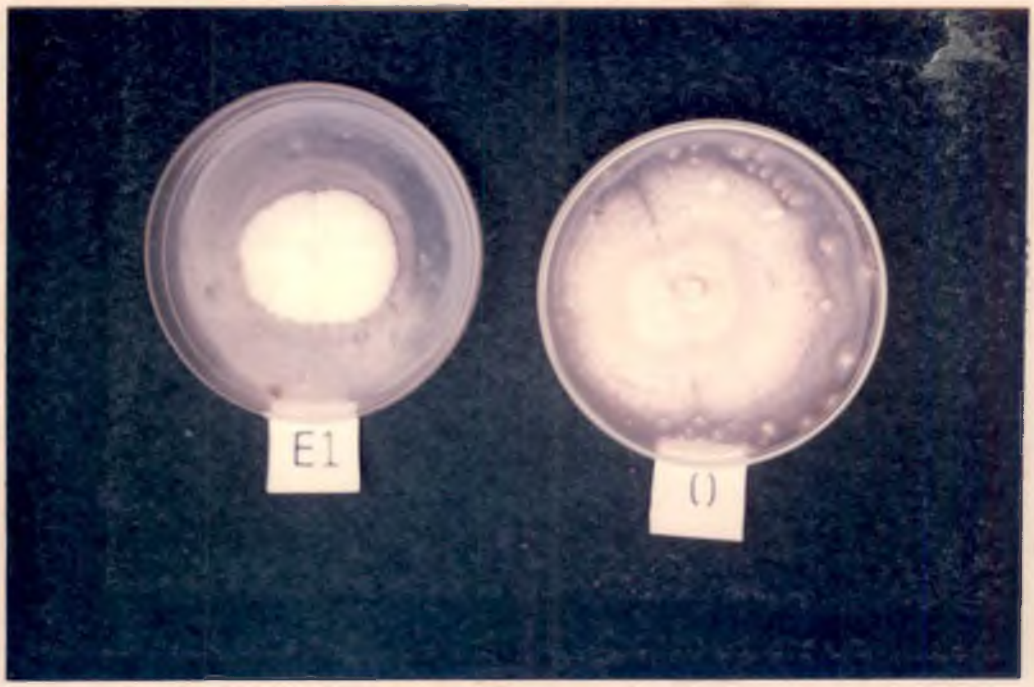
Effect of plant extracts on the mycelial weight of *S.oryzae*

0 - Control

E1 - *Allium sativum*

E2 - *Ocimum sanctum*

E3 - *Azadirachta indica*


E1
0


0
E1
E2
E3

Table 5 Effect of plant extracts on the radial growth of *S. oryzae*

Sl. No.	Treatment	Radial growth after 30 days (cm)	Inhibition over control (%)
1.	Control	8.65 (2.94)	-
2.	Garlic (*Allium sativum*)	2.70 (1.64)	68.79
3.	Tulsi (*Ocimum sanctum*)	1.90 (1.38)	78.03
4.	Neem (*Azadirachta indica*)	4.45 (2.11)	48.56

( ) - Values after $\sqrt{x}$ transformation
CD - 0.0831
F(2,8) - 4.46

Effect on mycelial weight

The effect of the different extracts tried on mycelial weight of *S. oryzae* showed that the extracts differed significantly over control (1.62 g) (Table 6, Fig 1). The effect of the extract of *A. sativum* and *O. sanctum* on mycelial weight was on par with a value of 0.91 g. The least effective extract in inhibiting mycelial growth was that of *Azadirachta indica* (1.05 g) (Plate 8).

Table 6 Effect of plant extracts on the mycelial weight of *S. oryzae*

Sl. No.	Extract used	Mycelial weight (g)	Inhibition over control (%)
1.	Garlic (*Allium sativum*)	0.83 (0.91)	68.32
2.	Tulsi (*Ocimum sanctum*)	0.84 (0.91)	67.94
3.	Neem (*Azadirachta indica*)	2.00 (1.05)	23.66
4.	Control	2.62 (1.62)	-

F(2,8) - 4.46 (not significant)
F(1,8) - 5.32 (significant)
CD - 0.1676
( ) - Values after $\sqrt{x}$ transformation

Effect of fungicides on *S. oryzae in vitro*

Effect on radial growth

Statistical analysis of data revealed that all the treatments were significantly different from control (8.52 cm) (Table 7, Fig. 2). The highest radial growth (1.9 cm) was observed with the fungicide Ediphenphos at 0.05 per cent concentration (Plate 9). This showed that it was least effective in inhibiting the radial growth of *S. oryzae*. The radial growth of *S. oryzae* in media incorporated with Ediphenphos at 0.075 per cent and 0.1 per cent and with Carbendazim at 0.01 per cent were significantly different from each other and

Fig 2 Effect of fungicides on the growth of *S. oryzae*

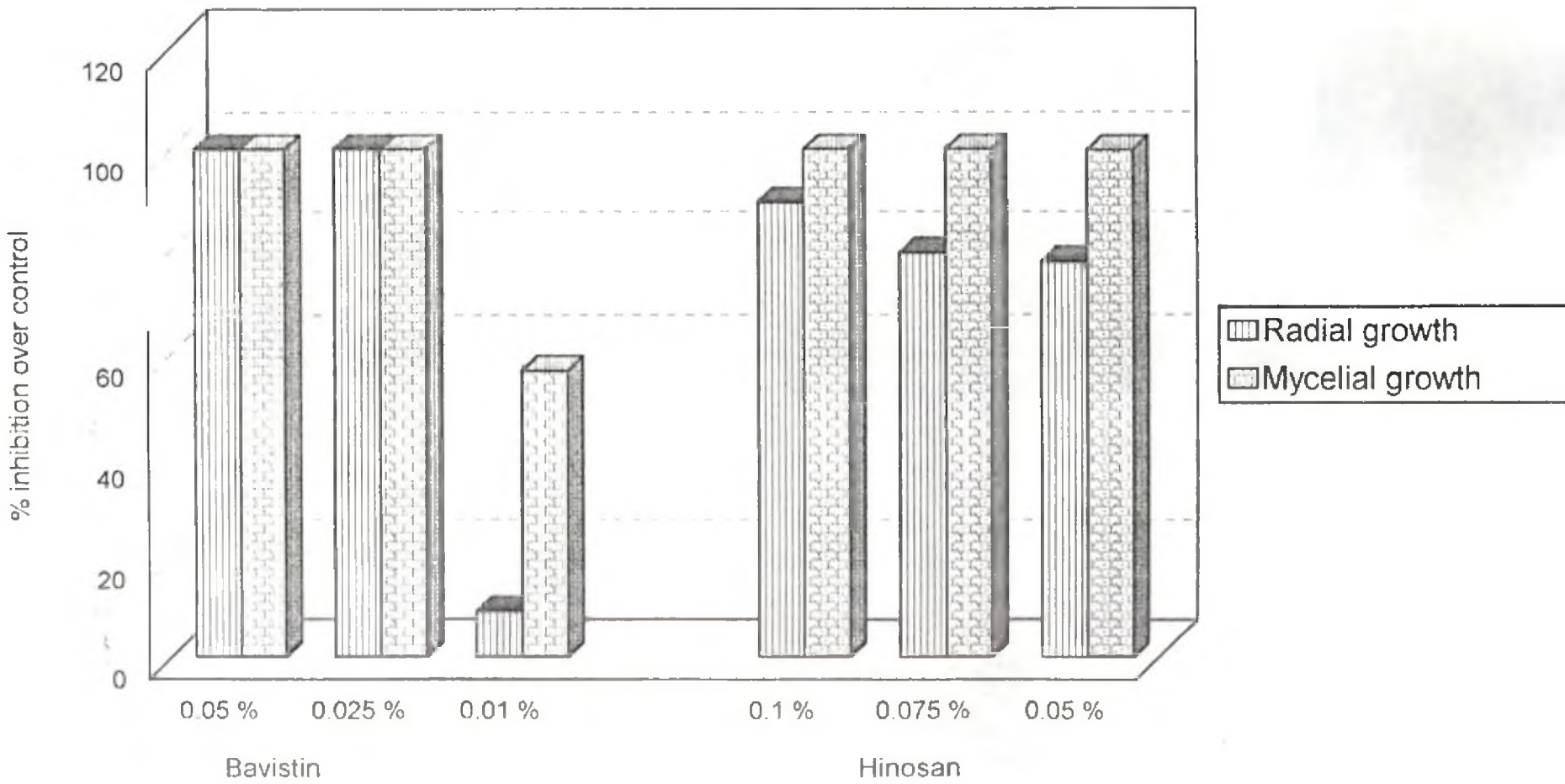


Plate 9.

Effect of Carbendazim on the radial growth of *S. oryzae*

0 - Control

C1 - 0.025 per cent

C2 - 0.01 per cent

Plate 10.

Effect of Carbendazim on the mycelial weight of *S. oryzae*

0 - Control

C1 - 0.025 per cent

C2 - 0.01 per cent


O
C2
C1

gave a growth of 1.75 cm, 0.92 cm and 0.62 cm respectively. The effect of Carbendazim at 0.1 per cent, 0.075 per cent, 0.05 per cent, 0.025 per cent and Ediphenphos at 0.25 per cent gave cent per cent inhibition and was on par with each other. Therefore, Carbendazim at 0.025 per cent and Ediphenphos at 0.25 per cent can be considered as the most effective lowest dose in inhibiting the radial growth of *S. oryzae in vitro*.

Table 7 Effect of fungicides on the radial growth of *S. oryzae*

Sl.No.	Chemical	Concentration (%)	Radial growth (cm)	Inhibition (%)
1.	Carbendazim	0.1	0 (1)	100
		0.075	0 (1)	100
		0.05	0 (1)	100
		0.025	0 (1)	100
		0.01	0.62 (1.27)	9.27
2.	Ediphenphos	0.25	0 (1)	100
		0.1	0.92 (1.38)	89.20
		0.075	1.75 (1.66)	79.46
		0.05	1.9 (1.7)	77.70
3.	Control	-	8.51 (3.08)	-

CD - 0.034
F(8,20) - 2.45 (Significant)
( ) - Values after $\sqrt{x+1}$ transformation

Effect on mycelial weight

On statistical analysis of the mycelial weight of the fungus on different fungicide incorporated media it was seen that even though the treatments differed significantly over control (2.68 g), they had no significant difference among themselves (Table 8). This showed that the fungicides under the tested concentration did not permit much mycelial weight of the fungus. There was no mycelial growth obtained with Carbendazim at concentra-tions 0.1, 0.075, 0.05 and 0.025 percentages (Plate 10) and with Ediphenphos at 0.1 and 0.075 per cent concentrations (Plate 11). Only a very little dry weight of 0.016 g was obtained with Carbendazim 0.01 per cent and with Ediphenphos 0.05 per cent a dry weight of 0.005 g was obtained.

Table 8 Effect of fungicides on mycelial weight of *S. oryzae*

Sl.No.	Chemical	Concentration (%)	Mycelial weight (g)	Inhibition over control (%)
1.	Carbendazim	0.1	0 (1)	100
		0.075	0 (1)	100
		0.05	0 (1)	100
		0.025	0 (1)	100
		0.01	1.163 (1.0081)	56.6
2.	Ediphenphos	0.1	0 (1)	100
		0.075	0 (1)	100
		0.05	0.0052 (1.0026)	99.8
3.	Control	-	2.68 (1.92)	-

F(7,18) - 2.58 (not significant)
Treatment vs. control F(1,18) - 4.41 (Significant)
CD - 0.013
( ) - Values after transformation ($\sqrt{x+1}$)

Plate 11.

Effect of Ediphenphos on the radial weight of *S. oryzae*

0 - Control

H1 - 0.1 per cent

H2 - 0.075 per cent

H3 - 0.05 per cent

Plate 12.

Mass multiplication of antagonists on rice bran:sand (1:3)

0 - Control

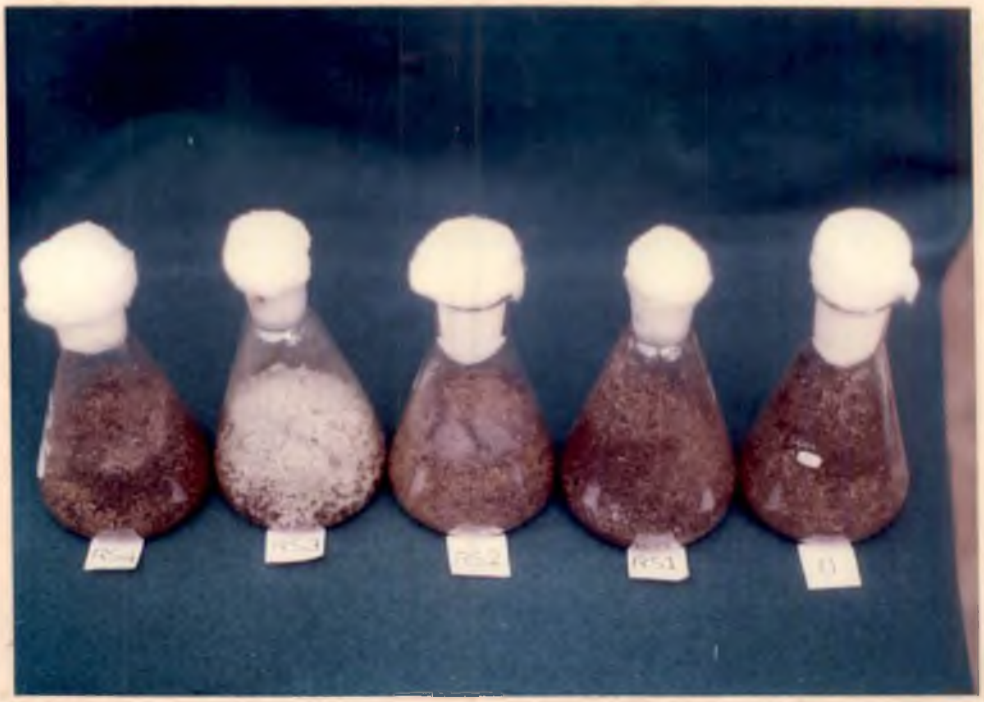
RS1 - *Pestalotiopsis* sp.

RS2 - *Penicillium* sp.

RS3 - *Trichoderma* sp.

RS4 - *Aspergillus* sp.


0
H3
H2
H1



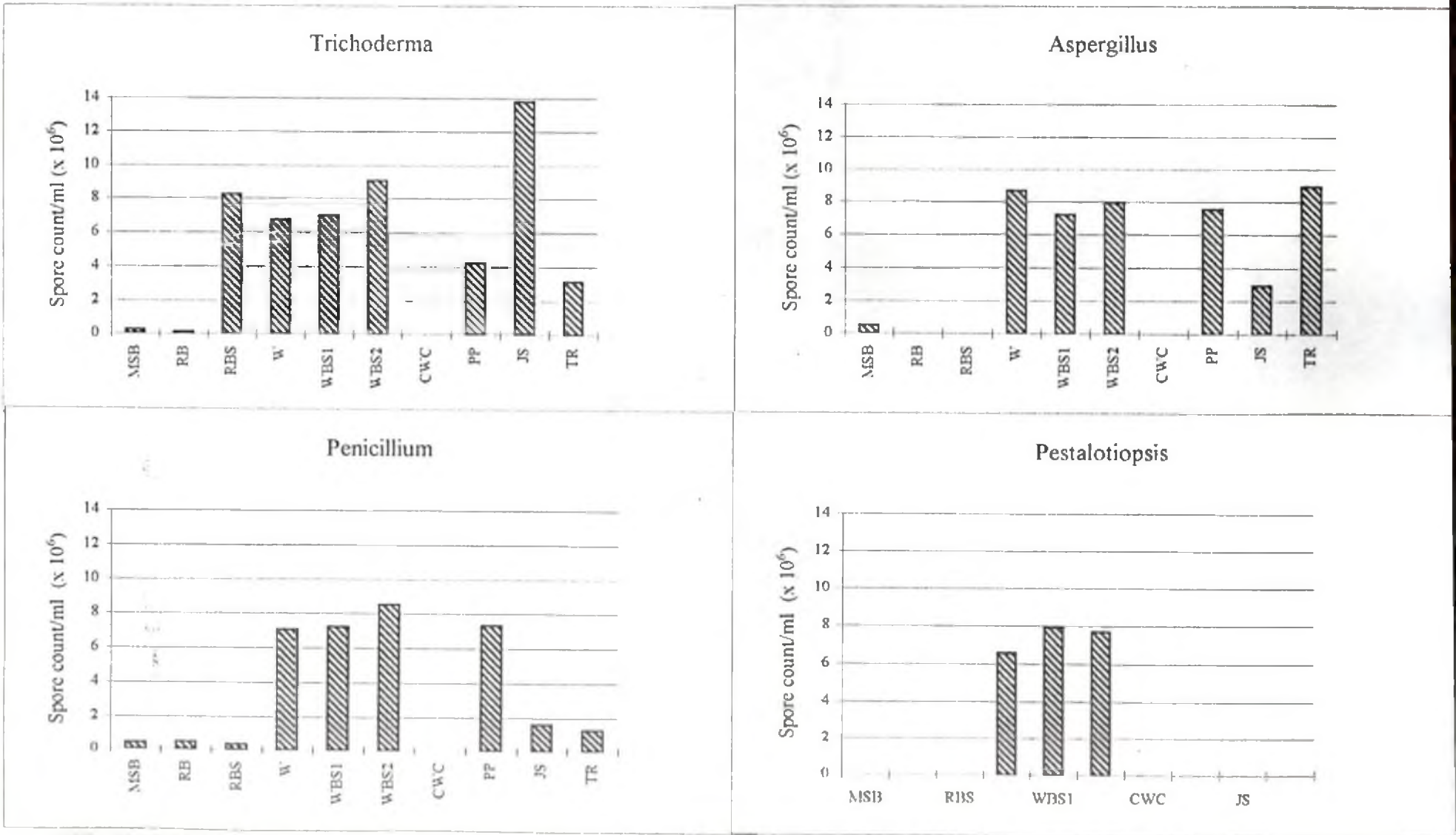
Mass multiplication of antagonists

The potent antagonists against *Sarocladium oryzae*, viz., *Trichoderma* sp., *Aspergillus* sp., *Penicillium* sp. and *Pestalotiopsis* sp. were mass multiplied on different substrates (Plates 12 to 17) and the spore counts recorded.

Mass multiplication of *Trichoderma* sp.

The effect of different substrates on the growth and sporulation of *Trichoderma* sp. is shown in Table 9 (Fig.4). A good mycelial growth with an excellent sporulation of 1.38 x 10^7 spores/ml was noticed with bits of jack seed as substrate. The spore count differed significantly from that of the other substrates. The spore count on wheat bran : sand (1:10) w/w) media and on rice bran : sand (1:3 w/w) was found to be on par. Both had a good mycelial growth of *Trichoderma* sp. Good mycelial growth was also observed with wheat bran : sand (1:3 w/w) media and wheat grains. The spore count/ml for both these were on par coming to 6.97×10^6 for the former and 6.7 x 10^6 for the later. The spore count on tapioca rind and papaya fruit pulp was on par and the mycelial growth was good. The mycelial growth on rice bran medium was moderate. On mushroom spent bed the mycelial growth was poor and no growth was seen with cowdung : $CaCO_3$ (100:1 w/w). However the spore count/ml on these three media was found to be on par.

Fig 4 Effect of different substrates on antogonistic fungi



MSB - Mushroom spent bed RB - Rice bran RBS - Rice bran : sand (1:3) W - Wheat WBS1 - Wheat bran : sand (1:3)
WBS2 - Wheat bran : sand (1:10) CWC - Cowdung : CaCO3 (100:1) PP - Papaya pulp JS - Jack seeds TR - Taploca rind

Table 9 Effect of substrates on *Trichoderma*. sp.

Sl. No.	Substrate	Spore count/ml ($x10^6$)	Growth seen
1.	Mushroom spent bed	0.22	S+
2.	Rice bran	0.12	S++
3.	Rice bran : sand (1:3)	8.23	S+++
4.	Wheat	6.7	S+++
5.	Wheat bran : sand (1:3)	6.97	S+++
6.	Wheat bran : sand (1:10)	9.07	S+++
7.	Cowdung : $CaCO_3$ (100:1)	0	N
8.	Papaya pulp	4.23	S+++
9.	Jack seeds	13.8	S+++
10.	Tapioca rind	3.13	S+++

CD - 0.136
S - Sporulation
M - Mycelial growth
N - No growth

\+ - Poor mycelial growth
++ - Moderate mycelial growth
+++ - Good mycelial growth

Mass multiplication of *Aspergillus* sp.

Good mycelial growth of this fungus was seen on wheat and tapioca rind with a sporulation of $8.67x10^6$ spores/ml and $8.93x10^6$, spores/ml respectively. The effect of these substrates on sporulation was on par and significantly different from that of other substrates (Table 10). Good mycelial growth was also seen with wheat bran : sand (1:10 w/w), papaya, wheat bran : sand (1:3 w/w) and jack seed. Poor mycelial growth and a spore count

of $0.47x10^6$ spores/ml was seen with mushroom spent bed. No growth was observed with rice bran : sand (1:3 w/w) and cowdung : $CaCO_3$ (100:1 w/w)

Table 10 Effect of substrates on *Aspergillus* sp.

Sl. No.	Substrate	Spore count/ml ($x10^6$)	Growth seen
1.	Mushroom spent bed	0.47	S+
2.	Rice bran	0	N
3.	Rice bran : sand (1:3)	0	N
4.	Wheat	86.7	S+++
5.	Wheat bran : sand (1:3)	7.2	S+++
6.	Wheat bran : sand (1:10)	7.93	S+++
7.	Cowdung : $CaCO_3$ (100:1)	0	N
8.	Papaya pulp	7.53	S+++
9.	Jack seeds	2.93	S+++
10.	Tapioca rind	8.93	S+++

CD - 0.102
S - Sporulation
N - No growth
\+ - Poor mycelial growth
+++ - Good mycelial growth

Mass multiplication of *Penicillum* sp.

Wheat bran : sand (1:10 w/w) was found to be a good substrate for *Penicillium* sp. It gave good mycelial growth and a spore count of 8.5×10^6 spores/ml which is significantly higher from other values (Table 11). The mycelial growth and

sporulation on papaya, wheat bran : sand (1:3 w/w) and wheat was found to be good. Moderate mycelial growth was noticed with jack seed, tapioca rind, rice bran and rice bran : sand (1:3 w/w). No growth was obtained with cowdung : $CaCO_3$ (100:1 w/w). Lowest spore count of 3.4×10^5 spores/ml was noticed on rice bran : sand (1:3 w/w).

Table 11 Effect of substrates on *Penicillium* sp.

Sl. No.	Substrate	Spore count/ml ($x10^6$)	Growth seen
1.	Mushroom spent bed	0.43	S+
2.	Rice bran	0.47	S++
3.	Rice bran : sand (1:3)	0.34	S++
4.	Wheat	7.03	S+++
5.	Wheat bran : sand (1:3)	7.20	S+++
6.	Wheat bran : sand (1:10)	8.50	S+++
7.	Cowdung : $CaCO_3$ (100:1)	0	N
8.	Papaya pulp	7.33	S+++
9.	Jack seeds	1.6	S++
10.	Tapioca rind	1.27	S++

CD - 0.077
S - Sporulation
N - No growth

\+ - Poor mycelial growth
++ - Moderate mycelial growth
+++ - Good mycelial growth

Mass multiplication of *Pestalotiopsis* sp.

The mycelial growth of *Pestalotiopsis* sp. was found to be good and the spore count/ml, wheat bran : sand (1:3 w/w) and wheat bran : sand (1:10 w/w) were on par (Table 12). Good mycelial growth and a spore count of 6.57×10^6 spores/ml was observed on wheat. Moderate mycelial growth was noticed on papaya, poor growth on mushroom spent bed and no mycelial growth was seen on rice bran, rice bran : sand (1:3 w/w), cowdung : $CaCO_3$ (100:1 w/w), jack seed and tapioca rind. There was no sporulation at all on these substrates.

Table 12 Effect of substrates on *Pestalotiopsis* sp.

Sl. No.	Substrate	Spore count/ml ($\times 10^6$)	Growth seen
1.	Mushroom spent bed	0	M+
2.	Rice bran	0	N
3.	Rice bran : sand (1:3)	0	N
4.	Wheat	6.57	S+++
5.	Wheat bran : sand (1:3)	7.9	S+++
6.	Wheat bran : sand (1:10)	7.7	S+++
7.	Cowdung : $CaCO_3$ (100:1)	0	N
8.	Papaya pulp	0	M++
9.	Jack seeds	0	N
10.	Tapioca rind	0	N

CD - 0.013

S - Sporulation
M - Mycelial growth
N - No growth

\+ - Poor mycelial growth
++ - Moderate mycelial growth
+++ - Good mycelial growth

Plate 13.

Mass multiplication of antagonists on wheat bran:sand (1:10)

0 - Control

WS1 - *Pestalotiopsis* sp.

WS2 - *Penicillium* sp.

WS3 - *Trichoderma* sp.

WS4 - *Aspergillus* sp.

Plate 14.

Mass multiplication of antagonists on wheat grains

0 - Control

W1 - *Pestalotiopsis* sp.

W2 - *Penicillium* sp.

W3 - *Trichoderma* sp.

W4 - *Aspergillus* sp.


WS1
2
WS3

Plate 15.

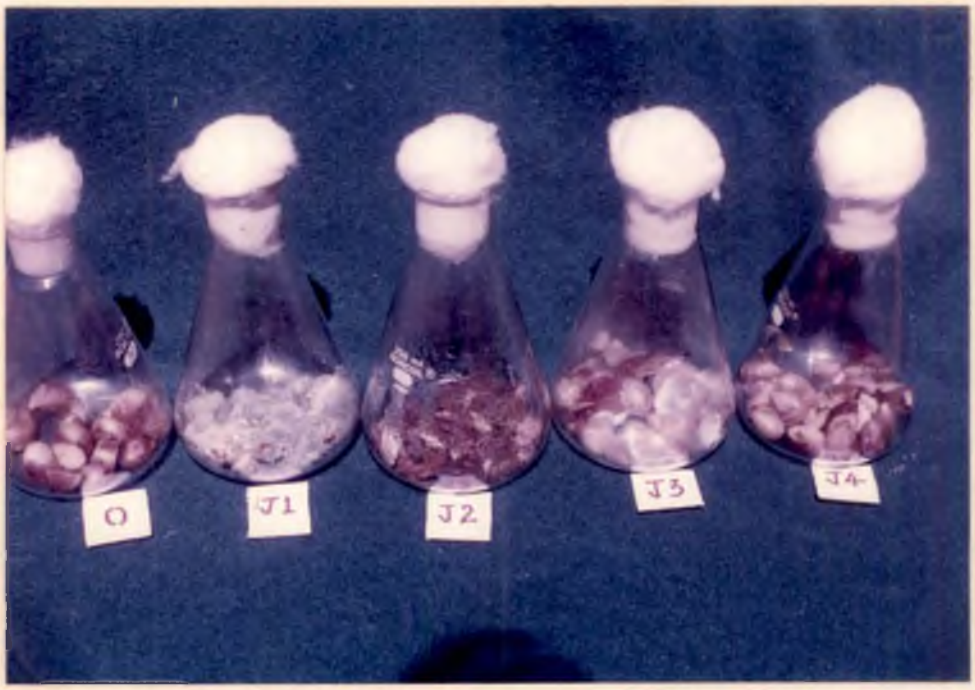
Mass multiplication of antagonists on bits of jack seeds

0 - Control
J1 - *Trichoderma* sp.
J2 - *Aspergillus* sp.
J3 - *Penicillium* sp.
J4 - *Pestalotiopsis* sp.

Plate 16.

Mass multiplication of antagonists on tapioca rind

0 - Control
T1 - *Trichoderma* sp.
T2 - *Aspergillus* sp.
T3 - *Penicillium* sp.
T4 - *Pestalotiopsis* sp.


O
J1
J2
J3
J4

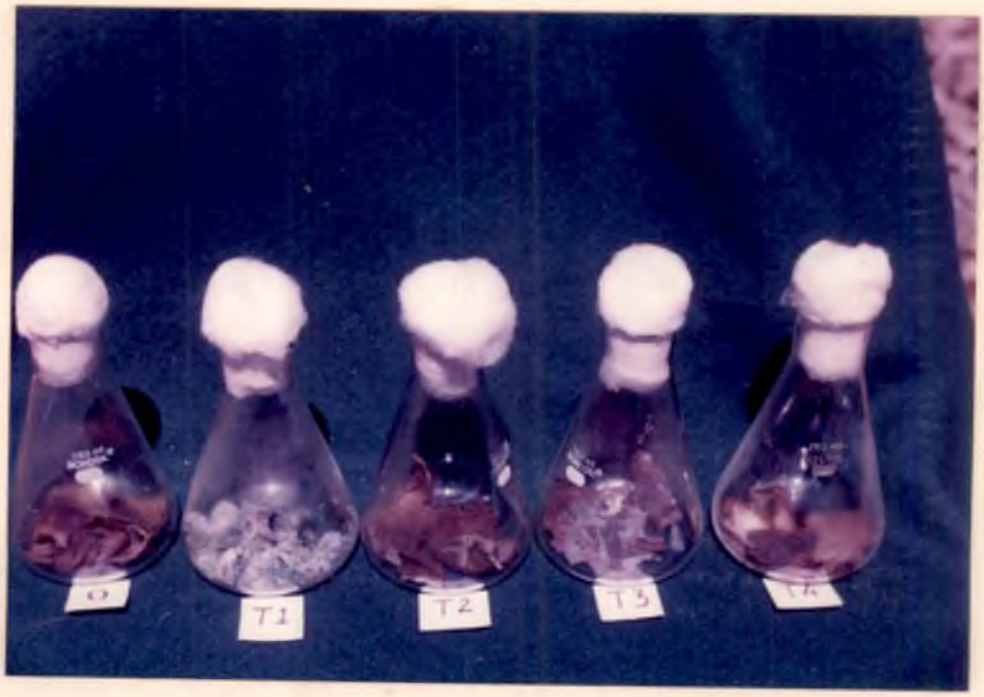

T1
T2
T3

Plate 17.

Mass multiplication of antagonists on papaya pulp

0 - Control

P1 - *Pestalotiopsis* sp.

P2 - *Trichoderma* sp.

P3 - *Aspergillus* sp.

P4 - *Penicillium* sp.

Plate 18.

Integrated management of sheath rot under pot culture trial


P4
P3
P2
P1
0

Effect of integrated management on disease intensity of sheath rot of rice

Statistical analysis on the individual effect of the various factors used in the integrated management strategy revealed that the best method of application was seed treatment (Tables 13, 14). The least effective method was foliar application of the different antagonists (5.12). Among the different antagonists, the most effective was *Trichoderma* sp. (3.51). It differed significantly from the next best treatment, viz, *Aspergillus* sp. (4.00). The least effective was found to be *Penicillium* sp. (4.57). The effect of the fungicide Carbendazim (3.7) was found to be significant over Ediphenphos (4.34) in controlling sheath rot. Among the different plant extracts tried, the effect of *Azadirachta indica* (4.5) and *Allium sativum* (4.32) were on par with each other, but significantly different from that of *Ocimum sanctum*. Hence *O. sanctum* was found to be the best.

Eventhough the effect of different antagonists under different methods of application did not vary significantly with each other, it was noted that *Trichoderma* sp. when applied as seed treatment had the lowest disease intensity of 2.5 and was the most effective, while foliar application of *Penicillium* sp had the maximum disease intensity of 5.55 and was the least effective.

The seed treatment method of different antagonists combined with the fungicide Carbendazim gave significant control of sheath rot while the most ineffective combination was that of Carbendazim and Ediphenphos with foliar application of antagonists.

The best combination of antagonist and fungicide was found to be that of *Trichoderma* sp. with Carbendazim (3.39) and the least effective being *Penicillium* sp. with Ediphenphos (5.12). However, the combinations had no significant difference.

The seed treatment method along with the extract of *O. sanctum* gave the lowest disease incidence (2.25). The foliar application along with the extract of *Allium sativum* gave the highest significant score of 5.7. The next significant score was that of foliar application method along with *Azadirachta indica* extract.

The interaction effect of the different antagonists, extracts and fungicides extracts were not significant. Among the combination of antagonist with extract, the best was *Trichoderma* sp. along with extract of *O. sanctum*. *Penicillium* sp. together with the extract of *Allium sativum* was the least effective. Among fungicides + extracts, Carbendazim + extract of *O. sanctum* was found to be the most effective, while the least effective was Ediphenphos + *Azadirachta indica* extract.

The combination of Carbendazim with *Trichoderma* sp. as seed treatment gave the lowest disease incidence. Along with *Penicillium* sp. applied as foliar spray, the disease incidence was the highest (5.74). However, the effects of these combinations had no significant difference. There was significant difference between the interaction effect of methods of application of different antagonists and extracts. Lowest disease incidence was noticed when antagonists were applied as seed treatment along with extracts. The effect of application of *Aspergillus* sp. and *O. sanctum* extract was on par with *Trichoderma* sp. applied with *Azadirachta indica* extract. Most effective treatment combination was seed treatment of *Trichoderma* sp. with *O. sanctum* extract (1.58).

Among the best combination of method of application of antagonists with fungicides and extracts, seed treatment with Carbendazim and *Ocimum sanctum* (1.76) was the best. Lowest disease intensity was obtained with foliar application of Carbendazim and the extract of *Allium sativum* (5.73). However, the treatments did not vary significantly.

Among the antagonist, fungicide and extract combination, no significant effect could be noticed. The most effective combination was with *Aspergillus* sp., *Carbendazim* and extract of *O. sanctum* (2.79). The least effective was the combination of *Penicillium* with Ediphenphos and extract of *Azadirachta indica* (5.75).

On statistical analysis of all the four factors tested in pot culture trial (Plate 18), viz, methods of application (seed treatment, seedling root dip and foliar spray), antagonists, (*Trichoderma* sp., *Aspergillus* sp., and *Penicillium* sp.), fungicides (Carbendazim and Ediphenphos) and plant extracts (*O. sanctum*, *Allium sativum* and *Azadirachta* indica) did not differ significantly under integration. However, the best combination was that of *Trichoderma* sp. applied as seed treatment along with Ediphenphos and extract of *O. sanctum* (1.4). The least effective combination was that of *Penicillium* sp. as foliar spray along with Ediphenphos and extract of *Allium sativum* (6.59).

Effect of integrated management on the yield of rice plants affected by sheath rot disease

The various methods of application of antagonists had a significant difference between each other (Table 13, 15). The seed treatment method was found to be significantly better than the other methods giving an yield/pot of 40.03g. The effect of root dip method and foliar application of antagonists on yield was found to be on par (28.17 g and 27.67 g respectively). All the antagonists tried had significant effect on the yield. The most suited antagonist was *Trichoderma* which gave an yield/pot of 35.53. The least effective was *Aspergillus* (27.53 g/pot) as far as yield was considered. All the extracts used had significant

effect on yield. Garlic extract gave the highest yield of 35.19 g/pot and was on par with the extract of tulsi (*Ocimum sanctum*). The least effective was that of neem (*Azadirachta indica*). The effect of fungicides on yield was insignificant.

Table 13 Effect of integrated management on disease intensity and yield of sheath rot of rice

Sl. No.	Treatment	Mean disease score	Yield/ pot (g)
1.	Seed treatment + *Trichoderma* + Carbendazim + Garlic	3.50 (1.87)	52.5
2.	Seed treatment + *Trichoderma* + Carbendazim + Tulsi	1.77 (1.33)	42.5
3.	Seed treatment + *Trichoderma* + Carbendazim + Neem	2.24 (1.50)	36.5
4.	Seed treatment + *Trichoderma* + Ediphenphos + Garlic	3.45 (1.86)	47.5
5.	Seed treatment + *Trichoderma* + Ediphenphos + Tulsi	1.40 (1.18)	47.5
6.	Seed treatment + *Trichoderma* + Ediphenphos + Neem	3.08 (1.75)	38.5
7.	Seed treatment + *Aspergillus* + Carbendazim + Garlic	3.20 (1.79)	43.5
8.	Seed treatment + *Aspergillus* + Carbendazim + Tulsi	1.45 (1.20)	45.0
9.	Seed treatment + *Aspergillus* + Carbendazim + Neem	3.85 (1.96)	22.5
10.	Seed treatment + *Aspergillus* + Ediphenphos + Garlic	3.75 (1.94)	48.0
11.	Seed treatment + *Aspergillus* + Ediphenphos + Tulsi	3.24 (1.80)	25.0

Sl. No.	Treatment	Mean disease score	Yield/ pot (g)
12.	Seed treatment + *Aspergillus* + Ediphenphos + Neem	3.93 (1.98)	30.0
13	Seed treatment + *Penicillium* + Carbendazim + Garlic	3.71 (1.93)	36.5
14	Seed treatment + *Penicillium* + Carbendazim + Tulsi	2.10 (1.45)	45.0
15.	Seed treatment + *Penicillium* + Carbendazim + Neem	4.25 (2.06)	40.0
16.	Seed treatment + *Penicillium* + Ediphenphos + Garlic	4.49 (2.12)	42.5
17.	Seed treatment + *Penicillium* + Ediphenphos + Tulsi	4.16 (2.04)	48.5
18.	Seed treatment + *Penicillium* + Ediphenphos + Neem	5.90 (2.43)	29.0
19.	Root dip + *Trichoderma* + Carbendazim + Garlic	2.50 (1.58)	42.0
20.	Root dip + *Trichoderma* + Carbendazim + Tulsi	3.06 (1.75)	30.0
21.	Root dip + *Trichoderma* + Carbendazim + Neem	4.10 (2.02)	26.0
22.	Root dip + *Trichoderma* + Ediphenphos + Garlic	3.35 (1.83)	28.5
23.	Root dip + *Trichoderma* + Ediphenphos + Tulsi	3.50 (1.87)	32.5
24.	Root dip + *Trichoderma* + Ediphenphos + Neem	5.00 (2.24)	44.0
25.	Root dip + *Aspergillus* + Carbendazim + Garlic	3.64 (1.91)	25.5
26.	Root dip + *Aspergillus* + Carbendazim + Tulsi	3.33 (1.82)	19.0

Sl. No.	Treatment	Mean disease score	Yield/ pot (g)
42.	Foliar application + *Trichoderma* + Ediphenphos + Neem	4.55 (2.13)	22.5
43.	Foliar application + *Aspergillus* + Carbendazim + Garlic	5.67 (2.38)	27.5
44.	Foliar application + *Aspergillus* + Carbendazim + Tulsi	3.93 (1.98)	32.5
45.	Foliar application + *Aspergillus* + Carbendazim + Neem	5.91 (2.43)	20.5
46.	Foliar application + *Aspergillus* + Ediphenphos + Garlic	5.50 (2.35)	36.5
47.	Foliar application + *Aspergillus* + Ediphenphos + Tulsi	4.16 (2.04)	17.5
48.	Foliar application + *Aspergillus* + Ediphenphos + Neem	6.15 (2.48)	21.0
49.	Foliar application + *Penicillium* + Carbendazim + Garlic	6.32 (2.51)	34.0
50.	Foliar application + *Penicillium* + Carbendazim + Tulsi	4.31 (2.08)	11.5
51.	Foliar application + *Penicillium* + Carbendazim + Neem	5.56 (2.36)	25.0
52.	Foliar application + *Penicillium* + Ediphenphos + Garlic	6.59 (2.57)	23.0
53.	Foliar application + *Penicillium* + Ediphenphos + Tulsi	4.55 (2.13)	27.0
54.	Foliar application + *Penicillium* + Ediphenphos + Neem	6.20 (2.49)	50.0
55.	Control	5.75 (2.40)	39.5

( ) values after $\sqrt{x}$ transformation

Sl. No.	Treatment	Mean disease score	Yield/ pot (g)
27.	Root dip + *Aspergillus* + Carbendazim + Neem	3.20 (1.79)	16.5
28.	Root dip + *Aspergillus* + Ediphenphos + Garlic	4.79 (2.18)	16.5
29.	Root dip + *Aspergillus* + Ediphenphos + Tulsi	3.93 (1.98)	26.0
30.	Root dip + *Aspergillus* + Ediphenphos + Neem	3.90 (1.97)	22.5
31.	Root dip + *Penicillium* + Carbendazim + Neem	2.74 (1.66)	37.0
32.	Root dip + *Penicillium* + Carbendazim + Tulsi	4.24 (2.06)	22.5
33.	Root dip + *Penicillium* + Carbendazim + Neem	4.11 (2.03)	28.5
34.	Root dip + *Penicillium* + Ediphenphos + Garlic	5.83 (2.42)	28.5
35.	Root dip + *Penicillium* + Ediphenphos + Tulsi	3.57 (1.89)	32.5
36.	Root dip + *Penicillium* + Ediphenphos + Neem	5.16 (2.27)	30.0
37.	Foliar application + *Trichoderma* + Carbendazim + Garlic	5.25 (2.29)	39.5
38.	Foliar application + *Trichoderma* + Carbendazim + Tulsi	3.75 (1.94)	25.0
39.	Foliar application + *Trichoderma* + Carbendazim + Neem	5.25 (2.29)	20.0
40.	Foliar application + *Trichoderma* + Ediphenphos + Garlic	5.00 (2.24)	24.5
41.	Foliar application + *Trichoderma* + Ediphenphos + Tulsi	4.25 (2.06)	40.0

Table 14 Effect of integrated management on disease intensity of sheath rot of rice

Sl. No.	Factors of integration	Table values of F	Significance	CD
1.	Method	F(2,54)-3.17	+	0.09
2.	Method	F(2,54)-3.17	+	0.09
3.	Method + Antagonist	F(4,54)-2.54	-	0.15
4.	Fungicide	F(1,54)-4.02	+	0.01
5.	Method + Fungicides	F(2,54)-3.17	+	0.12
6.	Antagonist + Fungicides	F(2,54)-3.17	-	0.12
7.	Method + Antagonist + Fungicide	F(4,54)-2.54	-	0.21
8.	Extracts	F(4,54)-3.17	-	0.09
9.	Mehtod + Extracts	F(4,54)-2.54	-	0.15
10.	Antagonists + Extract	F(4,54)-2.54	-	0.15
11.	Method + Antagonist + Extract	F(4,54)-2.54	+	0.26
12.	Fungicide + Extract	F(4,54)-3.17	-	0.12
13.	Method + Fungicide+ Extract	F(4,54)-2.54	-	0.21
14.	Antagonist + Fungicide + Extract	F(4,54)-2.54	-	0.21
15.	Method + Antagonist + Fungicide + Extract	F(8,54)-2.12	-	0.36

+ - Significant
- - Non significant

Table 15 Effect of integrated management on yield of sheath rot affected plants

Sl. No.	Factors of integration	Table values of F	Significance	CD
1.	Method	F(2,55)-3.17	+	3.89
2.	Antagonists	F(2,55)-3.17	+	3.89
3.	Method + Antagonist	F(4,55)-2.54	-	6.74
4.	Fungicide	F(1,55)-4.02	-	3.18
5.	Method + Fungicides	F(2,55)-3.17	-	5.51
6.	Antagonist + Fungicides	F(2,55)-3.17	-	5.51
7.	Method + Antagonist + Fungicide	F(4,55)-2.54	-	9.54
8.	Extracts	F(2,55)-3.17	+	3.89
9.	Mehtod + Extracts	F(4,55)-2.54	-	6.74
10.	Antagonists + Extract	F(4,55)-2.54	-	6.74
11.	Method + Antagonist + Extract	F(8,55)-2.12	-	11.68
12.	Fungicide + Extract	F(2,55)-3.17	-	5.51
13.	Method + Fungicide+ Extract	F(4,55)-2.54	-	9.54
14.	Antagonist + Fungicide + Extract	F(4,55)-2.54	+	9.54
15.	Method + Antagonist + Fungicide + Extracts	F(8,55)-2.12	-	11.52

\+ - Significant
\- - Non significant

The interaction effect of method of application of antagonists and different antagonists tried had no significant effect on yield. However the highest yield (44.17 g/pot) was

noticed with the application of *Trichoderma* sp as seed treatment. Lowest yield (21.00 g/pot) was with *Aspergillus* sp. applied as root dip of seedlings.

The combination of method of application of different antagonists along with fungicides had no significant effect on yield, but seed treatment method along with Carbendazim gave the highest yield of 40.44 g/pot while foliar application of antagonists along with Carbendazim gave the lowest yield of 26.17 g/pot.

Among the interaction of antagonists and fungicides on yield, *Trichoderma* sp. with Ediphenphos had the most favourable effect giving an yield of 36.17 g/pot while *Aspergillus* sp. along with Ediphenphos was most unfavourable with an yield of 27.00 g/pot. The effects were insignificant.

No significant effect could be noticed when a combination of method of application of antagonists and extracts were tried. The highest effect was seed treatment method along with extracts of *Allium sativum* (45.08 g) and lowest for foliar application with extracts of *O. sanctum* (25.67g).

Among the combination of antagonists with extracts, no significant effect on yield could be noticed, but highest yield 39.08 g/pot) was obtained with *Trichoderma* sp. + *Allium sativum* extract and lowest yield (22.17 g/pot) with *Aspergillus* and *Azadirachta indica* extract.

Significant effect on yield could be noticed with the combination of fungicides and extracts. The effect of Carbendazim along with *A. sativum* extract and Ediphenphos along with extracts of *O. sanctum* and *A. sativum* was on par. The highest yield/pot of 37.56 was for Carbendazim combined with *A. sativum*. The lowest yield was for *Carbendazim + A. indica* (20.06g) even though it was on par with Ediphenphos + *A. indica* and Carbendazim + *O. sanctum*.

No significant effect was noticed with the combination of methods of application of antagonists with fungicides and different antagonists. Highest yield (44.5 g/pot) was for seed treatment with *Trichoderma* sp. and Ediphenphos. Lowest yield (20.33 g/pot) was for the combination of *Aspergillus* sp. as seedling root dip with Carbendazim.

The highest yield/pot (50 g) was seen with the combination of seed treatment with *Trichoderma* sp., *A. sativum* extract and lowest yield/pot (19.5 g) was seen for root dip method combined with *Aspergillus* sp and *A. indica* extract. Moreover among the method + antagonist + extract combination no significant effect on yield could be noticed.

The combination of methods of application of antagonists with fungicides and plant extracts had no significant effect on yield. Seed treatment + Ediphenphos + *Allium sativum* extract gave the highest yield (46 g/pot) and foliar application + Carbendazim + *A. indica* extract the lowest (21.83 g/pot).

Significant effect could be noticed on the interaction effect of antagonist + fungicide + extract. Most favourable effect was for *Trichoderma* sp. + Carbendazim + *A. sativum* extract giving an yield of 44.67 g/pot. Least effective combination was *Aspergillus* sp. + Carbendazim + *A. indica* extract (19.83 g/pot).

The integrated management practice involving all the factors of interaction had no significant effect on yield. The combination of *Trichoderma* applied as seed treatment along with the fungicide Carbendazim and the extract of *Allium sativum* gave the highest yield of 52.5 g/pot. Lowest yield of 11.5 g/pot was obtained with the foliar application of *Penicillium* sp. + Carbendazim and the extract of *O. sanctum*.

DISCUSSION

DISCUSSION

Sheath rot disease of rice caused by *Sarocladium oryzae* Gams and Hawksworth (*Acrocylindrium oryzae* Saw.) has emerged as an important disease, causing extensive damage in the various rice growing tracts of Kerala. Rice, being our staple food crop, has to be saved from this disease so that our hungry millions can be fed. In the present investigation, an ecofriendly management strategy, integrating biological and chemical measures has been attempted.

S. oryzae was isolated from naturally infected rice plants from Moncompu, Alappuzha, Kerala. Pathogenicity trials were conducted, the pathogen was reisolated and is being maintained in pure culture. The identity of the above organism as a pathogen has already been established in the past (Sawada, 1992; Tasugi and Ikeda, 1956; Chen, 1957; Ou, 1963 and Jiminez and Panizo, 1977). The fungi associated with the pathogen were isolated from spermosphere, phylloplane and rhizosphere of rice and phylloplane of rice weeds in order to study their antagonistic behaviour on the pathogen. There are indications that different species of *Trichoderma*, *Aspergillus*, *Penicillium* and *Pestalotiopsis* are active antagonists.

Joseph and Philip (1980) observed the antagonistic effect of *T. viride*, *Myrothecium roseum* and *Chaetomium gracile* on

the seed borne pathogens associated with rice. Natarajan and his associates (1987) noticed that *T. viride* is an active antagonist of *S. oryzae*. Similar results were observed by Paneerselvam and Saravanamuthu (1996). They also noticed that *Aspergillus* sp. and *Penicillium* sp. had antagonistic behaviour in relation to *S. oryzae*.

Pot trials were conducted in the present investigation to compare the types of application, viz., seed treatment, foliar as well as root dip method with the effective antagonists, viz. *T. viride*, *A. niger* and *Penicillium* sp. Among the antagonists, *T. viride* was the best and among the types of application, root dip alone was the best treatment, while seed treatment was better than other treatments when used as a part of the integated system. Dry seed treatment with *Trichoderma* sp. gave excellent control of *Macrophomina phaseolina* causing root rot of oil seeds, pulses and sesamum (Jeyarajan and Ramakrishnan, 1995; Sankar and Jeyarajan, 1996).

In general, there was significant increase in pots treated with the antagonists. However, the type of application slightly differed as evidenced by better performance of *A. niger* in root dip method and *T. viride* in seed treatment.

Backman and Rodriguez-Kabana (1975) obtained a similar yield increase when *T. viride* was used as seed treatment against *Sclerotium rolfsii*. Elad *et al*. (1980) also obtained increased

yields of beans, when *T. harzianum* was applied against *S. rolfsii*.

Effect of different plant extracts on the radial growth and mycelial weight of *Sarocladium oryzae* was tested. All the extracts tried, viz, *Allium sativum*, *Azadirachta indica* and *Ocimum sanctum* inhibited the radial growth and dry weight of the fungus. Highest inhibition of radial growth was for *O. sanctum* extract (1.9 cm). The minimum dry weight was seen with the extract of *Allium sativum* and *O. sanctum* (0.83 g and 0.84 g respectively). Naidu and John (1981) found that the radial growth and mycelial weight of *S. oryzae* were reduced by garlic bulb extract. Kanagarajan (1988) reported that neem leaf extract reduced the growth of *S. oryzae*. *Ocimum sanctum* and *Azadirachta indica* inhibited the spore germination of *S. oryzae* (Komala *et al.*, 1988; George, 1995).

The effect of fungicides at different concentrations on the radial growth and mycelial weight of the fungus was studied (Tables 5 and 6). Carbendazim 0.025 per cent had least radial growth and mycelial weight (cent per cent inhibition). Ediphenphos 0.25 per cent had least radial growth while Ediphenphos 0.075 per cent had least mycelial growth (total inhibition). Raghunathan and Vijayaraghavan (1976) found that Ediphenphos 0.05 per cent is effective against *S. oryzae*.

There has been enough literature in the past on the antagonistic properties of various fungi, viz., *Trichoderma* spp. *Aspergillus* spp., *Penicillium* spp. and several others with potentiality to be used for biological control of pathogens like *Rhizoctonia solani*, *S. oryzae* etc. (Henis *et al.*, 1978; Elad *et al.*, 1980; Gokulapalan, 1989; Viswakumar, 1989; George, 1995; Paneerselvam and Saravanamuthu, 1996). However, there has been very little effort on the mass multiplication of the potential antagonists. Therefore, an effort was made in the present investigation to develop a suitable substrate for the mass multiplication of the antagonists found useful in the biological control of *S. oryzae*.

Among the various substrates tried, jack seeds cut into pieces was the best as evidenced by fungal growth at the cut ends, in the case of *T. viride* (Fig. 4). In an attempt to control *Aphis craccivora* using the biological agent *Fusarium pallidoroseum*, Hareendranath (1989) used jack seeds effectively.

Tapioca rind and wheat grains were effective in mass multiplication of *Aspergillus niger* (Fig. 4). Kuruvila and Jacob (1981) reported wheat seeds to be useful in the multiplication of *Fusarium oxysporum*, the biological agent of rice brown plant hopper.

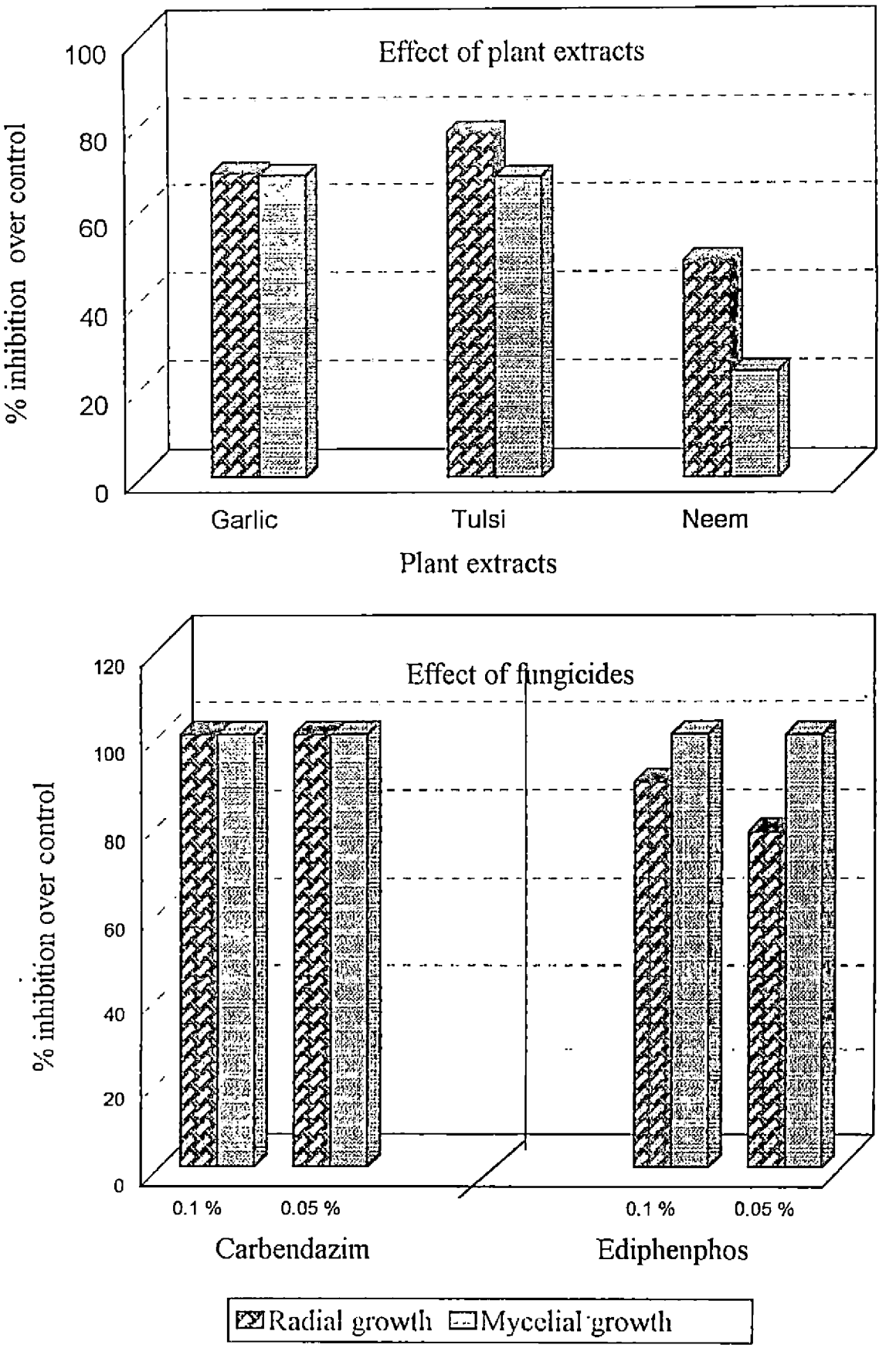
The host medium for the multiplication of *Penicillium* sp. and *Pestalotiopsis* sp. was wheat bran : sand at a proportion

of 1:10 w/w (Fig. 4). Several workers in the past have developed wheat bran as an excellent medium for the multiplication of various antagonists against several fungi (Henis *et al.*, 1978; Lewis and Papavizas, 1987; Gokulapalan, 1989; Viswakumar, 1989; Faizal, 1992; Fravel *et al.*, 1995; Mehta *et al.* 1995; Sharma and Basondrai, 1996). The advantage of mass multiplying *T. viride* in sand - sorghum medium for the control of sugarcane root rot caused by *Pythium graminicolum* has been emphasised by Padmanabhan and Alexander (1987).

The management strategy to be followed under field conditions should be economically viable and environmentally desirable. The above can be achieved only by integrating various methods of disease management, viz., biological, physical as well as chemical. As the above are not mutually exclusive, integration of these was tried in various combinations.

The study indicated that among the antagonists *T. viride* was the best and the ideal application system was seed treatment with respect to reduced disease incidence as well as higher grain yield (Tables 13, 14 and 15). Among the fungicides tried, Carbendazim gave better host yield, while Ediphenphos treated pots had least disease intensity. Among the plant extracts tried, *O. sanctum* and *Allium sativum* were effective as the former reduced disease incidence, while the latter increased grain yield.

Fig 3 Relative performance of plant extracts and fungicides in suppressing *S. oryzae*

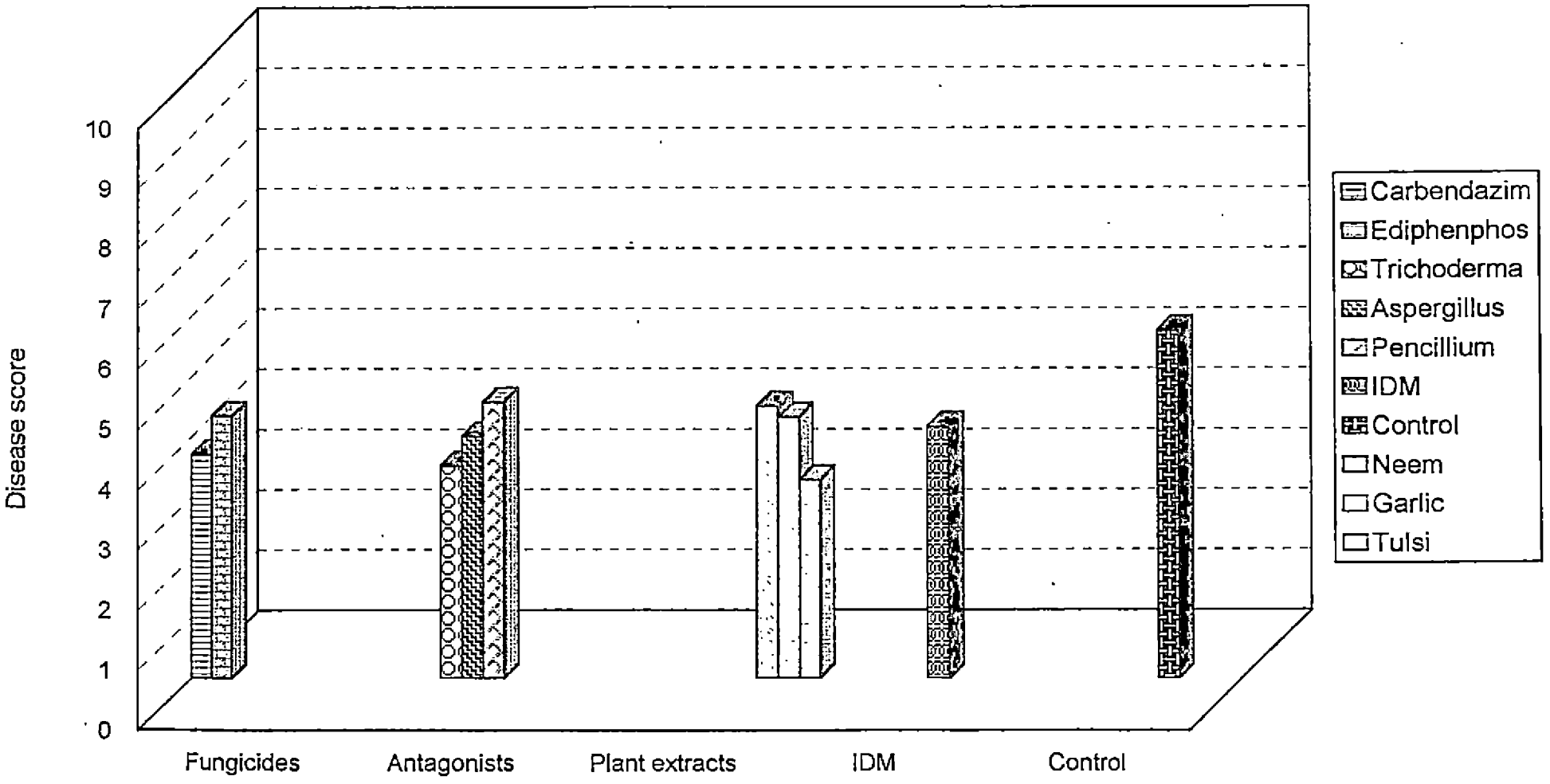


Zacharia (1990) reported significant increase in grains per panicle and yields of grain and straw in plots with integrated management practices using biological and chemical measures against sheath blight of rice.

From the study it was evident that cheap and locally available substrates like jack seeds, tapioca rind and wheat bran : sand (1:10 w/w) were highly suitable for the mass multiplication of antagonistic fungi. Comparison of the effect of plant extracts and fungicides in suppressing S. *oryzae*, the extract of *Ocimum sanctum* had almost the same inhibition as that of Ediphenphos at 0.05 per cent concentration (Fig. 3). The disease intensity of sheath rot was lower than the control when the integrated management practices were adopted (Fig. 5). It is also better than or equal to the individual effects of fungicides, antagonists and plant extracts. Therefore, integrated management of sheath rot was found ecofriendly and better than the traditional methods of control.

SUMMARY

Fig 5 Effects of fungicides, antagonists, plant extracts and integrated disease management practices on the disease intensity of sheath rot



SUMMARY

SUMMARY

Sheath rot disease, caused by *Sarocladium oryzae* Gams and Hawksworth, is one of the important diseases of rice in Kerala. Chemical control is extensively practised to check this disease. Continuous use of chemicals cause great environmental hazards inspite of having the risk of development of resistance by the pathogen. The present attempt is to work out an efficient, ecofriendly integrated control measure utilising biocontrol agents and plant products in combination with the minimum dose of fungicides against this disease.

Potent antagonists were screened from the mycoflora isolated from spermosphere, phylloplane and rhizosphere of rice and phylloplane of rice weeds by dual culturing. The antagonists so identified and used in *in vitro* studies were *Trichoderma* sp., *Aspergillus* sp., *Penicillium* sp. and *Pestalotiopsis* sp.

The pot culture trials conducted to find the integration of the antagonists *Trichoderma* sp. *Aspergillus* sp. and *Penicillium* sp., under various systems of application, viz. seed treatment, foliar application and root dip method, revealed that no treatment was superior over the others significantly. *Trichoderma* sp proved to be the best antagonist and root dip the most effective method. The lowest disease incidence was seen when *Trichoderma* sp was applied as root dip. Considering the yield, the best treatment was *Aspergillus* sp. and the best method was seed treatment.

In the *in vitro* experiment conducted to find the most effective extract against *S. oryzae*, all the plant extracts tried, viz. *Allium sativum* (bulb extract), *Azadirachta indica* and *Ocimum sanctum* (leaf extracts) inhibited the radial growth and mycelial weight of *Sarocladium oryzae*. Highest inhibition of radial growth was with *O. sanctum* extract. Minimum dry weight was seen with the extract of *A. sativum* and *O. sanctum*.

To find the lowest dose of effective fungicides another *in vitro* trial was conducted. It was found that the radial growth and mycelial weight of *Sarocladium oryzae* was inhibited to 100 per cent by Carbendazim 0.025 per cent. Total inhibition of radial growth and mycelial weight was also achieved with Ediphenphos 0.25 per cent and Ediphenphos 0.075 per cent respectively.

In another experiment, different low cost substrates were estimated to identify the best medium for mass multiplication of the antagonists. Results revealed that jack seeds were the best for *Trichoderma* sp., tapioca rind and wheat grains were good for *Aspergillus* sp. *Penicillium* sp. could be easily multiplied on wheat bran : sand (1:10 w/w) medium and *Pestalotiopsis* sp. on wheat bran : sand (1:3 w/w) and wheat bran sand (1:10 w/w).

A pot culture trial was conducted to compare the time and method of application of antagonists together with spraying

the plant extracts and the lowest dose of the most effective fungicide. Results showed that none of the treatments were superior over the others when, yield and disease intensity were considered. Regarding the individual effects of the factors of integration, highest yield and lowest disease intensity was seen with *Trichoderma* sp. among antagonists and seed treatment among the various methods of application of antagonists tried. Disease intensity was low with Carbendazim among the fungicides and *O. sanctum* among the extracts; but yield was high with Ediphenphos and extracts of *A. sativum* and *O. sanctum*. The best combination for low disease intensity was *Trichoderma* sp. + seed treatment + Ediphenphos + extract of *O. sanctum*. Highest yield was for the combination of *Trichoderma* sp. as seed treatment with Carbendazim and extract of *Allium sativum*.

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* Originals not seen

Appendix - I

Composition of solid media used:

1. **Potato dextrose agar**

Peeled and sliced potato	- 200 g
Dextrose	- 20 g
Agar agar	- 20 g
Distilled water	- 1000 ml

2. **Rosebengal streptomycin agar**

Dextrose	- 10 g
Peptone	- 5 g
Potassium dihydrogen phosphate	- 1 g
Magnesium sulphate	- 0.5 g
Rosebengal	- 1 part in 30,000 parts of the medium
Agar agar	- 20 g
Streptomycin	- 30 mg
Distilled water	- 1000 ml

3. **Potato dextrose broth**

Peeled and sliced potato	- 200 g
Dextrose	- 20 g
Distilled water	- 1000 ml

Appendix - II

Lactophenol - cotton blue

Anhydrous lactophenol	-	67 ml
Distilled water	-	20 ml
Cotton blue	-	0.1 g

Anhydrous lactophenol prepared by dissolving 20 g phenol in 16 ml lactic acid and 31 ml glycerol.

INTEGRATED MANAGEMENT OF SHEATH ROT OF RICE (*Oryza sativa* L.)

By

BLESSY JOSE

Abstract of the Thesis

Submitted in partial fulfilment of the requirement

for the degree

MASTER OF SCIENCE IN AGRICULTURE

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Kerala Agricultural University

COLLEGE OF AGRICULTURE

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ABSTRACT

ABSTRACT

Sheath rot disease of rice, caused by *Sarocladium oryzae* Gams and Hawksworth, is one of the most important diseases of rice in Kerala. The present investigation was to work out an efficient ecofriendly integrated control measure utilising biocontrol agents and plant products in combination with the minimum dose of fungicides against this disease.

The antagonists found effective against *Sarocladium oryzae* are *Trichoderma* sp., *Aspergillus* sp. and *Penicillium* sp. Among these, *Trichoderma* sp. was found to decrease the disease intensity and increase the yield, the most.

Among the various methods of application of antagonists tried, seed treatment and root dip method were found to be the best.

In the pot culture trial conducted to find out the mode of action of antagonists under various systems of application, none of the treatments proved superior to others.

Leaf extract of *Ocimum sanctum* (10 per cent) had maximum inhibition of the radial growth of the fungus. Minimum dry weight was seen with the bulb extract (10 per cent) of *Allium sativum* and extract (10 per cent) of *Ocimum sanctum*.

Carbendazim at 0.025 per cent concentration brought about 100 per cent inhibition of radial growth and mycelial weight of *S. oryzae*. Total inhibition of radial growth of the fungus was achieved by the application of 0.25 per cent Ediphenphos and total inhibition of the mycelial growth was achieved by the application of Ediphenphos at 0.075 per cent concentration.

For mass multiplication of antagonists, bits of jack seeds proved to be the best substrate for *Trichoderma* sp. as evidenced by fungal growth. Tapioca rind and wheat grains was the best suited *Aspergillus* sp. Wheat bran:sand (1:10 W/W) proved to be the best medium for *Penicillium* sp. For *Pestalotiopsis* sp., wheat bran : sand mixture at a proportion of 1:3 and 1:10 were found equally good.

The integrated management practices revealed that none of the treatments were superior over others when yield and disease intensity were considered. However, least disease intensity was noticed with the application of *Trichoderma* sp. as seed treatment, followed by foliar spray of Ediphenphos and leaf extract (10 per cent) of *Ocimum sanctum*. Highest yield was obtained in the treatment combination of *Trichoderma* sp. applied as seed treatment followed by the foliar application of Carbendazim and the bulb extract (10 per cent) of *Allium sativum*.