ETIOLOGY AND MANAGEMENT OF DAMPING - OFF OF SOLANACEOUS VEGETABLES

By

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THESIS

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DECLARATION

I hereby declare that the thesis entitled "**Etiology and management of damping-off of solanaceous vegetables**" 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, fellowship, associateship or other similar title of any other university or society.

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ABBREVIATIONS

PDA	-	Potato Dextrose Agar
m	-	metre
cm	-	centimetre
mm	-	milli metre
μm	-	micro metre
%	-	per cent
g	-	gram
kg	-	kilogram

Introduction

INTRODUCTION

Vegetables are rich sources of minerals, carbohydrates, proteins, vitamins and roughages besides having medicinal values. According to the recent FAO reports, vegetables are grown in India in an area of 6.2 million hectares with the production of 66.5 million tonnes per annum. This area is around 2.8 per cent of the total cropped area in the country. India is the second largest producer of vegetables in the world, next to China. Eventhough the production and productivity has markedly increased in the recent past, the per capita availability of vegetables is much below the minimum nutritional requirements. Besides the problems of soil and water management and socio-economic constraints, the attack of pests and diseases also play an important role in reducing the productivity. Vegetables are easily vulnerable to the attack of pests and diseases because of their succulent and dense growth. Among the vegetables, solanaceous vegetables like chilli (*Capsicum annum* L.) brinjal (*Solanum melongena* L.) and tomato (*Lycopersicon esculentum* Mill.) are most popular and commonly cultivated in India.

Damping-off is a seedling disease common to many of the vegetables. In tropical and subtropical countries, this disease causes very serious problem in raising seedlings. Loss of seedlings during rainy season is very high, sometimes to the extent of 100 per cent. This disease occurs in two phases. Pre-emergence damping-off causes rotting of seedlings before emerging out of the soil surface, where as in post-emergence damping-off, due to invasion of pathogen on the basal cortical region, constriction and shrinking of the base occur which results in the toppling of seedlings on ground.

Different soil-borne fungi such as *Pythium, Phytophthora, Rhizoctonia, Sclerotium, Sclerotinia, Thielavia, Phoma, Glomerella, Fusarium, Botrytis, Ozonium* etc. were reported to be associated with the disease. Among them *Pythium* is more common. High moisture, poor aeration and high planting density lengthen the juvenile stage of the plants and pre-dispose them to damping-off disease.

In Kerala, damping-off is a major problem for raising seedlings in nursery especially during monsoon period. A search on literature revealed that work on damping-off disease has been inadequate and information on many aspects are lacking. Investigations were hence carried out to study certain aspects of damping-off of solanaceous vegetables like chilli, brinjal and tomato with particular emphasis on etiology and disease management and the details are presented here with.

Review of Literature

REVIEW OF LITERATURE

Damping-off of seedling is a very common disease occurring throughout the world. The terminology damping-off is used for disease affecting the prothallia of vascular cryptogams. The disease is most noticeable in nursery beds, green house flats and row crops because symptoms develop suddenly; killing large number of seedlings in local areas. In tropical and subtropical countries, the disease causes a serious problem in raising seedlings. In spite of several measures, the disease is uncontrollable and it is rather very strenuous to raise an early crop. The loss of seedling sometimes reaches up to 100 per cent.

2.1 Causal organisms

Different fungi have been reported to be associated with this disease by various workers. Hesse (1874), a German botanist for the first time, unquestionably demonstrated that damping-off of different crop plant was caused by fungi particularly by *Pythium debaryanum*.

Berkley (1925), Weber and Ramsey (1926) and Person and Chilton (1931) attributed *Pythium debaryanum* and Alexander *et al.* (1931) considered *P. ultimum* as the causal agent of damping-off of tomato.

Middleton (1943) has reported ten different species of Pythium - *P. adhaerens, P. aphanidermatum, P. artotragus, P. debaryanum, P. megalacanthum, P. myriotylum, P. perniciosum, P. salpingophorum, P. spinosum* and *P. ultimum* parasitizing tomatoes in different countries.

According to Gattani and Kaul (1951) *P. aphanidermatum* to be the major causal organism of pre-emergence and post-emergence damping-off of tomato seedlings. Singh and Srivastava (1953) isolated *P. indicum, P. aphanidermatum, Phytophthora parasitica, Rhizoctonia solani, Corticium solani, Sclerotium rolfsii, Phoma betae, Fusarium* sp., *Acrothecium* sp., *Alternaria* sp. and *Helminthosporium* sp. from tomato seedlings affected by damping-off.

Pythium spp. and *Rhizoctonia* sp. were isolated from damping-off infected tomato seedlings by Govindappa and Grewal (1965) and from chilli seedlings by Sahni *et al.* (1967).

Georgieva *et al.* (1970) observed that *R. solani* attacked almost every vegetable. Raicu and Stan (1973) found that *P. parasitica* attacked tomato roots, stem and fruits. Sharma *et al.* (1976) noticed that abundant oospores were produced by *P. nicotianae* var. *parasitica* when it caused damping-off in tomato.

According to Patel and Patel (1976), among different fungi causing damping-off of tomato seedlings only species of *Pythium* were pathogenic and in that *P. aphanidermatum* was found pre-dominant.

Sharma and Sharma (1987) observed that *P. nicotianae* var. *parasitica* isolates from aubergine fruit, *Capsicum annum* leaf, tomato root and tomato fruit showed significant variations of morphological, nutritional and pathogenic behaviour.

Damping-off occurs from 15 to 35°C (Hemmi, 1923), a range to which the growth of most plants was also well adapted. It is most severe in ill aerated, ill drained soils. Such conditions are common in heavy and compact soils. According to

Kadow and Anderson (1937) the chief variables affecting the pre-emergence damping-off were soil moisture and temperature where as high humidity and temperature were the main factors during post-emergence, though soil moisture was also important.

The type of nitrogenous fertilizer also has influenced the incidence of the disease (Mostafa and Sharkas, 1964). Abu-Elamayen *et al.* (1978) observed that in nematode and fungus infected area the incidence was more than in the fungus infected area alone.

2.2 Symptomatology

Singh and Srivastava (1953), Ramakrishnan *et al.* (1973), Agnihotri and Sinha (1986) had described the symptomatology of this disease in detail. The symptoms described by all these workers were almost the same. Damping-off appears in two phases, first as pre-emergence and later as post-emergence. The symptom of pre-emergence stage was rotting of the seeds and seedlings before actual emergence from the soil and post-emergence stage was characterised by sudden collapsing of the seedlings.

2.3 Mycoflora associated with vegetable seeds

Many seed-borne fungi of vegetables are known to cause considerable damage either directly to seeds that carry them or to the crops that are raised from contaminated seeds.

Walker (1952) reported that beans usually attacked by *Rhizoctonia* spp. and *Sclerotinia sclerotiorum* were internally seed borne.

According to Suryanarayana and Bhombe (1961) species of *Alternaria, Aspergillus* and *Fusarium* were fairly common on surface of vegetable seeds and important genera like *Helminthosporium, Colletotrichum* and *Phomopsis* were internally seed borne. All these fungi cause pre and post-emergence death of vegetable seedlings.

Das and Narain (1982) isolated *Aspergillus* spp., *Macrophomina phaseolina, Chaetomium* spp., *Curvularia lunata, Fusarium semitectum, Fulvia fulvum, Geotrichum candidum, Penicillium chrysogenum, Alternaria alternata* and *Phoma multistroata* from the seeds of bitter gourd, ridge gourd, pea, tomato and okra.

The survey of the seed mycoflora of vegetables conducted by Naseema *et al.* (1983) revealed that storage fungi such as *A. flavus, A. niger* and *Rhizopus stolonifer* were externally as well as internally seed-borne in most of the seeds studied including aubergine and tomato. Seedling rotting was caused by *Fusarium equisetii* on amaranthus, *A. niger* on amaranthus and *Hibiscus esculentus, Drechslera rostrata* on cowpea and *Rhizopus stolonifer* on tomato.

The most commonly occurring seed-borne fungi on chilli were *Colleto-trichum, Cladosporium, Alternaria, Drechslera* and *Curvularia* spp. and these fungi affected root elongation more adversely than shoot elongation (Adiver *et al.*, 1987).

Kononkov and Dudina (1987) isolated *A. glaucus, A. versicolor, A. condidus* and *Penicillium* sp. from non-sterilized seeds of tomato, carrot, radish and cucumber.

George (1990) observed that the predominating externally seed borne fungi of cucurbitaceous seeds were *Aspergillus* sp., *Penicillium* sp. and *Rhizopus* sp. while among the internally seed borne fungi the predominant ones were *Fusarium solani, A. flavus* and *Rhizopus stolonifer* and these seed borne fungi were found to cause pre and post-germination rotting.

Maximum reduction in germination of seeds was caused by *Fusarium solani* in bhindi, *A. flavus, A. fumigatus* and *A. niger* in cowpea and *Botryodiplodia* sp. in dolichos bean (Ambika, 1991).

2.4 Management of damping-off

A lot of work has been carried out on the management aspects of damping-off which include physical, chemical, biological, resistant and cultural methods.

2.4.1 Chemical control

A number of fungicides have been tested against damping-off disease by various workers.

Humbert (1918) reported the effect of Bordeaux mixture in controlling post-emergence damping-off of tomato. Brien and Chamberlain (1936) suggested soil sterilization by steam for the control of damping-off of tomato. According to Gattani and Kaul (1951) soil disinfestation with formaldehyde reduced the incidence of damping-off by 57 per cent and a combination of soil treatment with formaldehyde and seed treatment with 10 per cent copper sulphate solution for one hour reduced the incidence by 63 per cent in tomato.

Seed treatment with fungicides not only controls seed-borne pathogens but also controls soil-borne pathogens by forming inhibition zone around it. Jacks (1951) got 100 per cent germination of lettuce seeds treated with Thiram 0.2 per cent when inoculated with one of the following fungi, viz., *Alternaria solani, Rhizoctonia solani* and *Botrytis cinerea*.

According to Strong (1954) seed treatment as well as soil drenching with Cuprocide 50 per cent, Aresan 50 per cent, Thiram, Crag 658, Captan or Crag 54 gave good control of damping-off of tomato seedlings.

Sanchez (1956) found that captan at the rate of 2 g/kg seed was the best for the control of damping-off and seed decay in pea and bean. Effectiveness of this fungicide against *Pythium* sp. and *Fusarium* sp. in peas was reported by Harper (1964). Govindappa and Grewal (1965) observed that seed treatment with Aresan, Agrosan GN and Flit 406 was effective against pre-emergence infection by *P. aphanidermatum* while soil drenching with Flit 406 and Fytolan protected against post-emergence attack in tomato.

Seed treatment and soil drenching with Captan gave good control of damping-off of cabbage caused by *P. aphanidermatum, R. solani* and *R. bataticola* (Grewal and Singh, 1965).

Georgieva *et al.* (1970) reported that the best control of damping-off caused by *R. solani* was obtained with 0.01-0.02 per cent Quinosol, 0.3 per cent thiram and 0.3 per cent maneb. Grover and Dutt (1972) observed good control of pre-emergence damping-off by seed treatment with Ceresan wet or copper oxychloride and post-emergence damping-off by drenching the soil with copper oxychloride, Carboxin, Captan, Agrosan GN, Oxycarboxin, Dithane M-45 or Brassicol in tomato caused by *P. aphanidermatum*.

Effective control of *Phytophthora (nicotianae) parasitica* in tomato was obtained with Dithane M-45, Basamid, Vapam and Ditrapex (Raicu and Stan, 1973).

Ramakrishna *et al.* (1973) reported the efficacy of soil drenching with Thiram in controlling pre-emergence damping-off of tomato and brinjal caused by *P. aphanidermatum*.

Sen and Kapoor (1975) observed that Bavistin, Dithane M-45, BAS-305 F, Benlate, Captan and RH-893 were effective against *R. solani* even at 100 ppm in *in vitro* condition. Vir (1976) obtained good control of damping-off of chilli caused by *Rhizoctonia bataticola* by seed treatment (0.25%) or soil drenching (0.1% aqueous solution) of Bavistin.

Peethambaran (1977) studied the effects of 12 fungicides on the *P. aphanidermatum* population in soil and the results indicated that Benlate, Captan, Duter, Dithane M-45, Copper sulphate and Vitavax were effective even after a period of 22 days, in reducing the growth of the fungus in soil.

Seed treatment with Thiram gave best control of *Helminthosporium* sp. on egg plant seeds (Sorade and Kadam, 1977). Jharia *et al.* (1977) found seed treatment with Thiram and Captan was highly effective in checking the pre and post-emergence losses and mortality at adult stage in chillies.

On trials against damping-off of capsicum caused by *Fusarium* spp., *Pythium* spp. and *Rhizoctonia* sp. Zengni (1978) got 53.3 per cent control using 1 per cent Bordeaux mixture.

Effectiveness of systemic fungicides like Bavistin as seed treatment in controlling *Rhizoctonia bataticola* on Frenchbean, egg plant and tomato was reported by Vyas *et al.* (1981).

Dwivedi and Shukla (1983) found that *Drechslera halodes* was sensitive to Thiram, Cuman L, Ferbam, Zineb, Captan and Aureofungin in *in vitro*.

Using Thiride as seed treatment Naseema *et al.* (1983) effectively controlled seed-borne pathogens like *Penicillium* sp. *A. flavus, R. stolonifer, D. rostrata* and *Curvularia lunata* in different vegetables.

In *in vitro* studies metalaxyl showed good control of *P. (nicotianae) parasitica* causing root and crown rot of tomato (Ioannou and Grogan, 1984) and also completely inhibited the growth of *P. aphanidermatum* (Jain *et al.*, 1984).

Patel *et al.* (1987) observed that soil drenching of Metalaxyl and Carbendazim was as effective as that achieved with Bordeaux mixture against *P. aphanidermatum* and *Cercospora nicotianae* in tobacco.

According to Satija and Indra Hooda (1987a) Brassicol followed by Topsin M were the most effective in controlling damping-off of tomato due to *R. solani* where as Dithane M-45 and thiram were the best treatment for chilli seeds. In another experiment they found that the best control of *F. solani* and *P. aphanidermatum* together was given by seed treatment with MEMC (Methoxy ethyl - mercury chloride) and Captan in tomato and capsicum respectively (Satija and Indra Hooda, 1987b).

Vir and Hooda (1989) found that 2-methoxy ethyl mercury chloride @. 1 g/kg seed or in combination with copper oxychloride (1 + 1 g/kg seed) was the best fungicide in controlling damping-off of tomato and chilli caused by *Rhizoctonia bataticola, Fusarium* sp. and *P. aphanidermatum*.

In onion, best control of pre-emergence and post-emergence damping-off caused by *Fusarium oxysporum, F. moniliforme* and *Rhizoctonia solani* was obtained with Bavistin and Benlate (Abd-Elrazik *et al.*, 1990).

Sharma (1992) got effective control of damping-off of *Citrus jambhiri* caused by *Rhizoctonia solani* by seed treatment with TBZ (tebuconazole) Bavistin, Brassicol Vitavax and Thiride.

Copper oxychloride minimises the pre-emergence damping-off of chilli caused by *Pythium aphanidermatum* (Theradi Mani and Marimuthu, 1994).

Shahda *et al.* (1995) reported the use of Etridiazole, Carbendazin and Thiophonate methyl as seed treatment for the control of damping-off of melon and marrows.

2.4.2 Biological control

Weindling (1938) showed that *Trichoderma viride*, a common saprophytic fungus, was able to parasitize the mycelia of other fungi. Later, he showed that the lethal action of *T. viride* was due to the secretion of an antibiotic substance which he called 'gliotoxin'. Brian and Mc Gowan (1945) [illegible] antibiotic substance from *T. viride* which they named 'viridin'.

T. viride controlled or reduced diseases caused by *Pythium debaryanum* (Gregory *et al.*, 1952). Wright (1956) found that gliotoxin producing strains of *T. viride* were more effective than the viridin producing strain in controlling seedling diseases caused by *Pythium* sp.

Vyas *et al.* (1981) observed that culture filtrates of *T. viride*, *Aspergillus niger* and *A. flavus* suppressed sporangia formation in *Phytophthora* parasitica var. *piperina* from *Piper betle*.

T. viride reduced severity of symptoms due to *Fusarium oxysporum*, f.sp. *lycopersici*, *Verticillium dahliae* and *Rhizoctonia solani* making early flowering and harvesting in tomato (Sporteli *et al.*, 1983).

Krishnamoorthy and Bhaskaran (1990) got good control of *Pythium indicum* causing damping-off of tomato by soil inoculation with *T. viride*, *T. harzianum* and *Laetisavia arvalis*.

In vitro studies conducted by Marchetti *et al.* (1992) revealed that *Rhizoctonia solani*, *Pythium ultimum* and *Chalara elegans* were strongly inhibited by the antagonistic activity of *Trichoderma viride*, *T. harzianum* and *T. pseudokoningii*.

2.4.3 Varietal resistance

The use of disease resistant varieties for controlling plant diseases is a painless method because it doesn't cost the farmers anything. In an under developed country like India, it is all the more important since we can't pay for the heavy costs of spraying and dusting crops on a large scale. Resistant crop varieties reduces pollution resulting from the use of poisonous chemicals there by eliminating the hazard to human health and wild life. Resistant crop varieties check epidemics of pathogens and pests and thus help to maintain the biological balance in the environment. A perusal of literature revealed that no work has been conducted to evaluate the reactions of chilli, brinjal and tomato varieties against damping-off pathogens so far. Bolkman (1985) reported that tomato varieties LA 1312, CX 8303 and CX 8201 were moderately resistant of root rot caused by *Phytophthora parasitica*.

2.4.4 Mycorrhizal control

It was Frank in 1885 who gave the name mycorrhiza to permanent association of roots with hyphal fungi. Since then a lot of work has been carried out on mycorrhiza but only few reports are available on the successful use of mycorrhiza in disease management.

Daft and Okusanya (1973) observed that in tomato xylem lignification was greater in mycorrhiza infected plants. According to Dehne and Schonbeck (1979) the lower degree of damage by *Fusarium oxysporum* f.sp. *lycopersici* on mycorrhizal (*Glomus mosseae*) plants was mainly due to a reduced rate of spread of the pathogen. They also noticed that infection by mycorrhiza enhanced lignification in cell walls of the endodermis and stele of tomato plants.

Hegde and Rai (1984) got reduction in damping-off due to *P. aphanidermatum* and increased plant height and shoot and root weights in tomato by inoculating *Glomus fasciculatum*.

2.4.5 Organic amendments

The role of organic amendments in the suppression of soil-borne plant pathogens have been emphasized by Papavizas and Devey (1960), Stover (1962), Huber and Watson (1970) and Linderman (1970).

Kannaiya and Prasad (1981) suggested that seedling infection of *Rhizoctonia solani* was reduced by organic amendments such as rice chaff, neem cake, saw dust and manure.

Dwivedi and Chaube (1985) observed good reduction in the number of recoverable propagules of *Macrophomina phaseolina* using Margosa (*Azadirachta indica*) and cotton cakes.

Pandey and Dubey (1994) reported the strong fungi toxicity of essential oils from the leaves of *Hyptis suaveolens*, *Murraya koenigi* and *Ocimum canum* against *Pythium aphanidermatum* and *P. debaryanum* and soil amendment of these fungitoxic plants increased saprophytic fungal community.

Theradi Mani and Marimuthu (1994) obtained good control of post-emergence damping-off of chilli by the application of decomposed coir pith and was comparable with the control obtained by *Trichoderma hamatum* and *T. viride* 2.

2.4.6 Soil solarization

Soil solarization is a method for controlling soil-borne plant pathogens, insect pests and weeds by heating the soil using solar energy. It is a hydrothermal disinfestation process accomplished by covering moist soil with transparent poly-ethylene sheets during the hottest period of the year.

Solarization was found to be effective against soil-borne plant pathogens like *Pythium*, *Phytophthora*, *Rhizoctonia*, *Fusarium*, *Verticillium*, *Plasmodiophora*, *Sclerotium* etc. by various workers (Chen and Katan, 1980; Elad *et al.*, 1980; Katan *et al.*, 1980; Pullman *et al.*, 1981).

Control of sugarcane rot associated with *Pythium arrhaenomanes* and *P. graminicola* in Australia (Chen and Katan, 1980) was the first report of successful control of disease caused by *Pythium* spp. by solarization. Elad *et al.* (1980) found that solarization increased antagonistic population (*Trichoderma harzianum*) and the incidence of disease caused by *R. solani* remained low throughout the season. Effective control of *Rhizoctonia solani* in soil was also reported by Katan *et al.* (1980).

Pullman *et al.* (1981) reported great reduction or complete elimination of *Verticillium dahliae, Pythium* spp. *R. solani* and *Thielaviopsis basicola* in soil covered for 14 - 66 days.

Significant reduction in damping-off fungi *Pythium* spp. and *Fusarium* spp. were obtained when solarization for a period of 55 days done at the Colorado State Forest Nursery (Hildebrand, 1985).

Al-samaria *et al.* (1988) and Hasan (1989) reported effective control of *P. aphanidermatum* by solar heating.

Bourbos and Skoudridakis (1991) observed that soil solarization reduced the number of pathogen propagules (*Colletotrichum coccodes, Fusarium oxysporum* f.sp. *radicis-lycopersici, F. solani, Pyrenochaeta lycopersici, Pythium debaryanum* and *Rhizoctonia lycopersici*) in the soil by 83.5-100 per cent compared with control in green house tomatoes.

In field experiments conducted by Satour *et al.* (1991) good control of *Sclerotium cepivorum* on onions and *P. (nicotianae* var) *parasitica*, *Pyrenochaeta lycopersici*, *Pythium* spp. and *Rhizoctonia solani* on tomatoes were obtained by solarization.

Kurian (1992) found that solarization effectively reduced pre and post-emergence damping-off of chilli in the nursery and in main field but neem cake amendment did not improve the disease control even with solarization.

Materials and Methods

MATERIALS AND METHODS

Investigations on etiology and management of damping-off disease was carried out in summer and rainy seasons in the vegetable plot of Department of Olericulture, College of Horticulture, Vellanikkara. The soil of the experimental plot was of laterite type. Summer crop was raised in the month of February and March 1995 when the atmospheric temperature ranged from 23 to 37°C with a relative humidity of 57-60 per cent. Soil temperature during this period varied from 36 to 40°C.

Rainy season crop was raised in the months of late May and June 1995 with the onset of monsoon. The atmospheric temperature during this period was 23-31°C and the relative humidity ranged from 78 to 86 per cent. Soil temperature during this period varied from 28-33°C.

To study the damping-off disease of solanaceous vegetables; bacterial wilt resistant varieties of chilli (Ujjwala), brinjal (Surya) and tomato (Sakthi) were used in all experiments unless otherwise mentioned.

3.1 Germination percentage of solanaceous vegetable seeds

The germination percentage of different solanaceous crops was recorded by blotter method (ISTA, 1966).

Thirty seeds each of chilli, brinjal and tomato were placed in sterilized petridishes lined with sterilized moistened filter papers. Three replications were maintained for each crop. These petriplates were incubated at room temperature (28 $\pm$ 2°C). Observations on the germination was taken daily for a period of 10 days. Ungerminated seeds were taken out and placed on potato dextrose agar (PDA) medium (Appendix-I) in sterilized petridishes and incubated at room temperature (28 $\pm$ 2°C) and examined daily for the growth of the fungi. Fungi developed were isolated, purified by hyphal tip method and identified (Riker and Riker, 1936). Similarly seeds treated with Thiram @ 2 g/kg seed were also kept to find out the per cent inhibition in germination due to mycoflora.

Seeds were also treated with different fungicides as mentioned in Table 1 to find out the effect of chemicals on germination of solanaceous seeds.

3.2 Isolation and identification of fungi associated with pre-emergence damping-off

3.2.1 Pot culture studies

Thirty seeds each of chilli, brinjal and tomato were sown in pots containing soil collected from a sick field during summer and rainy season. Pots with sterilized soil served as control. Three replications were maintained for each crop. Soil was moistened as and when required. Observations on the number of seeds germinated were recorded daily for a period of ten days.

Ungerminated and rotten seeds were collected, washed thoroughly with tap water, surface sterilized with 0.1 per cent mercuric chloride for 15 seconds and passed through three changes of sterile water. The seeds were then plated on potato dextrose agar medium. Fungi developed were isolated, purified and identified.

3.2.2 Field studies

Hundred seeds each of chilli, brinjal and tomato were sown in nursery beds during summer and rainy seasons. Ungerminated seeds were collected, washed thoroughly with tap water, surface sterilized with 0.1 per cent mercuric chloride for 15 second followed by repeated washing in sterilized water. It was transferred aseptically to potato dextrose agar medium for the isolation of the pathogen. The fungi thus obtained were identified based on morphological characters.

Similarly seeds sown in nursery beds treated with formalin solution (1:50) served as control. Number of seeds germinated in sterilized and unsterilized beds were recorded.

3.3 Isolation and identification of fungi associated with post-emergence damping-off

3.3.1 Pot culture studies

Seeds of chilli, brinjal and tomato were sown in pots as mentioned in 3.1.2. The seedlings which showed typical damping-off symptoms, were collected and small bits (5 mm) of stem were taken, surface sterilized with 0.1 per cent mercuric chloride for 15 seconds, and washed with three changes of sterile water. The bits were then transferred aseptically to potato dextrose agar medium in sterile petridishes and incubated under laboratory conditions. The isolates were purified by repeated hyphal tip planting and purified cultures were maintained for further studies.

3.3.2 Field studies

Solanaceous plants (chilli, brinjal and tomato) which showed typical damping-off symptom were collected from the field during summer and rainy seasons. Stem bits of size 5 mm were cut through advancing edge of the rot and pathogen was isolated as mentioned in 3.2.1. The isolated organisms were maintained on potato dextrose agar medium by periodical subculturing.

3.4 Pathogenicity of the fungi associated with damping-off disease

The pathogenicity of the fungi associated with pre-emergence and post-emergence damping-off was studied in pot culture by artificial inoculation.

3.4.1 Pre-emergence damping-off

Seeds of chilli, brinjal and tomato were sown in small thermocol cups containing sterilized soil inoculated with isolated fungi. Fifteen surface sterilized seeds were sown in each pot. The fungi from ungerminated seeds were reisolated on potato dextrose agar medium and compared with original culture. Seeds sown in uninoculated sterilized soil served as control.

3.4.2 Post-emergence damping-off

Seeds of chilli, brinjal and tomato were sown as mentioned in 3.3.1 but fungi were applied to the soil just after the emergence of seedings. Pots without inoculum served as control. Fungi were reisolated from the infected portions and compared with original culture.

3.5 Morphological characters of the pathogen causing damping-off

The identity of the fungi associated with damping-off disease was established by studying their morphological characters.

3.6 Symptomatology

Symptomatology of pre-emergence and post-emergence damping-off in all three solanaceous crops were also recorded.

3.7 Reactions of different genotypes of chilli, brinjal and tomato to damping-off pathogens

Different varieties/genotypes of chilli, brinjal and tomato were collected from Department of Olericulture and were sown in field during summer and rainy seasons. Observations on the incidence of disease were recorded in both seasons.

Percentage of disease incidence was calculated by the following formula.

$$\text{Percentage of disease incidence} = \frac{\text{No. of plants infected}}{\text{Total number of plants}} \times 100$$

Based on the percentage of disease incidence, varieties were grouped into four categories as mentioned below.

Percentage of disease incidence	Category	
0 - 20	Resistant	- R
>20-40	Moderately Resistant	- MR
>40-60	Moderately Susceptible	- MS
> 60	Susceptible	- S

3.8 Management of damping-off disease

3.8.1 *In vitro* evaluation of plant protection chemicals against damping-off pathogens

For the *in vitro* evaluation experiment, only contact fungicides were used. Efficacy of different contact fungicides against various damping-off pathogens such as *Pythium, Phytophthora, Rhizoctonia* and *Drechslera* were studied by the poisoned food technique (Zentmyer,1955). The fungicides tested were thiram (0.2%), mancozeb (0.2%), captan (0.2%), chlorothalonil (0.2%), copper oxychloride (0.3%) and Bordeaux mixture (1%).

100 ml of PDA was taken in 250 ml conical flask and sterilized at 15 lbs pressure for 20 minutes.

The chemicals were mixed with potato dextrose agar medium in suitable proportion to get the desired concentrations and poured into sterilized petridishes @ 20 ml per plate. Mycelial discs of 7 mm diameter were cut out from actively growing cultures of the different fungi and each of them was placed in the centre of each petridish containing poisoned medium. Three replications of each pathogen were maintained. Checks were maintained without the addition of fungicide. Mean radial growth of the fungal colony was recorded when the growth in the control plates fully covered the medium.

The percentage inhibition of growth was calculated by the formula suggested by Vincent (1927).

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

where

C = radial growth in control

T = radial growth in treatment

3.8.2 *In vitro* evaluation of fungal antagonist *Trichoderma viride* against damping-off pathogens

The antagonistic activity of *T. viride* against damping-off pathogen was done by the dual culture method (Johnson and Curl, 1972). Twenty ml potato dextrose agar medium was transferred into each sterilized petridish. After solidification of the medium, mycelial discs of 10 mm diameter was cut out from actively growing culture of the fungal antagonist *T. viride* and transferred to one end of the petridish. Mycelial disc of 10 mm diameter of each test fungus was similarly transferred from another plate and placed at the opposite end, towards the periphery.

The growth measurements were taken at intervals of 24 hours upto 10 days. The type of antagonism exhibited was recorded. Three replications were maintained for each pathogen. The pathogen and *T. viride* grown in monocultures served as control.

3.8.3 Management of damping-off under field conditions

Field experiments on the management of damping-off of chilli, brinjal and tomato were conducted during summer (February-March 1995) and rainy (late May-June 1995) seasons in the sick plots of Department of Olericulture College of

Horticulture, Vellanikkara. The experiment was laid out in randomized block design with three replications.

Preparation of nursery beds

Nursery beds were prepared in open and well drained areas. The land was dug, levelled and pebbles were removed. Raised nursery beds of size 50 cm x 50 cm were taken. The soil was mixed properly with well dried and powdered cowdung. Fine sand was spread over the nursery beds, seeds were sown in lines and covered with thin layer of sand. To prevent ants BHC 50% WP was dusted around the beds. The nursery was irrigated twice a day during summer months where as in rainy season, irrigation was given as and when required and adequate drainage was also provided.

The fungicides and the concentrations used for the study are presented in Table 1.

The fungicides were applied as seed treatment as well as soil drench. Soil drenching was done twice - immediately after germination and 20 days after germination.

Mycorrhiza, fungal antagonist *Trichoderma viride* and neem cake were applied one week before sowing. Mycorrhiza culture @ 100 g/m^2, *T. viride* @ 10 plate inoculum/m^2 and neemcake @ 250 g/m^2 were applied.

Table 1. Details of the fungicides used for the management of damping-off disease

Generic name	Trade name	Dose	
		Seed tratment	Soil drenching
Thiram	Thiride 75 WS	2 g/kg seed	0.2%
Metalaxyl	Apron 35 WS Ridomil 72 WP	2 g/kg seed -	- 0.05%
Mancozeb	Indofil M-45 75 WP	2 g/kg seed	0.2%
Captan	Captaf 50 WDP	2 g/kg seed	0.2%
Chlorothalonil	Kavach 75 WP	2 g/kg seed	0.2%
Carbendazim	Bavistin 50 WP	1 g/kg seed	0.1%
Copper oxychloride	Fytolan 50 WP	3 g/kg seed	0.3%
Potassium phosphonate	Akomin 40	0.3%	0.3%
Bordeaux Mixture		1%	1%

3.8.4 Summer season crop

The details of the treatments for the summer crop were as follows:

T_1 Thiram - seed treatment

T_2 Metalaxyl - seed treatment

T_3 Mancozeb - seed treatment

T_4 Captan - seed treatment

T_5 Chlorothalonil - seed treatment

T_6 Carbendazim - seed treatment

T_7 Copper oxychloride - seed treatment

T_8 Bordeaux mixture - seed treatment

T_9 Potassium phosphonate - seed treatment

T_{10} Thiram - seed treatment + soil drenching

T_{11} Metalaxyl - seed treatment + soil drenching

T_{12} Mancozeb - seed treatment + soil drenching

T_{13} Captan - seed treatment + soil drenching

T_{14} Chlorothalonil - seed treatment + soil drenching

T_{15} Carbendazim - seed treatment + soil drenching

T_{16} Copperoxychloride - seed treatment + soil drenching

T_{17} Potassium phosphonate - seed treatment + soil drenching

T_{18} Bordeaux mixture - seed treatment + soil drenching

T_{19} Soil inoculation with mycorrhiza before sowing

T_{20} Soil treatment with neemcake before sowing

T_{21} Soil inoculation with antagonist *Trichoderma viride* before sowing

T_{22} Control

3.8.5 Rainy season crop

In addition to the treatments used in summer, two more were added during rainy season. Soil solarization (T_{22}) and soil solarization + soil inoculation with antagonist - *Trichoderma viride* (T_{23}). There were 24 treatments including control (T_{24}) in rainy season crop.

Soil solarization

For the solarization, well prepared raised nursery beds of size 50 cm x 50 cm were taken in April 1995. The beds were irrigated @ 5 l/m² and covered with white polyethylene sheets of 150 gauge thickness without air pockets. To keep the sheets in position the sides of the sheets were covered with soil. The sheets were removed after 45 days and seeds were sown on these beds. In case of the treatment T_{23} (solarization + soil inoculation with antagonist) the antagonist was applied after solarization and the seeds were sown after one week.

Observations on seedling stand were taken immediately after germination and ten days after second fungicidal drenching. The percentage of pre-emergence damping-off was calculated on the basis of the total number of seedlings emerged in sterilized and unsterilized beds (Gattani and Kaul, 1951).

Post-emergence damping-off was calculated based on total germination and mortality of seedlings in different treatments (Govindappa and Grewal, 1964).

3.8.6 Other nursery diseases

Disease incidence and intensity of other diseases observed in the nursery were recorded in both the seasons.

Disease intensity was scored using 0-5 scale as mentioned below:

Disease ratings	Percentage of the leaf area infected
0	No infection
1	< 10
2	11-25
3	26-50
4	51-75
5	> 75

Percentage disease incidence was calculated by the formula mentioned in 3.7 and percentage disease intensity was calculated by the formula suggested by Wheeler (1969).

Percentage Disease Intensity (PDI) =

$$\frac{\text{Sum of all numerical ratings}}{\text{Total number of leaves assessed}} \times \frac{100}{\text{Maximum disease category}}$$

Statistical analysis

Data relating to different experiments were analysed statistically as suggested by Panse and Sukhatme (1978).

Results

RESULTS

The investigations on the etiology and management of damping-off of solanaceous vegetables like chilli, brinjal and tomato were carried out and the results are presented below:

4.1 Germination percentage of solanaceous vegetable seeds

The germination percentage of different solanaceous crops and fungi associated with the ungerminated seeds by blotter method are given in Table 2.

The data revealed that *Aspergillus niger, A. flavus, Rhizopus stolonifer* and *Penicillium* sp. were the important fungi associated with the seeds of all the three crops. Apart from these fungi, *Curvularia lunata, Drechslera rostrata* and *Alternaria* sp. were isolated from chilli, brinjal and tomato seeds respectively.

With regard to the germination percentage of seeds 70, 87 and 90 per cent germination was observed in chilli, brinjal and tomato respectively. Maximum inhibition of germination (13%) was observed in brinjal where as chilli and tomato showed only 8 and 6 per cent inhibition of germination due to mycoflora.

Effect of fungicidal seed treatment on germination presented in Table 3 showed that seed treatment with different fungicides had no deleterious effect on germination of solanaceous seeds except potassium phosphonate (0.3%) and Bordeaux mixture (1%). Among the three crops, tomato seeds were found to be most sensitive to these chemicals and gave only 30 and 36 per cent germination against 84 per cent in control.

Table 2. Percentage of germination and fungi associated with solanaceous seeds by blotter method

Crop	*Mean germination percentage		Percent inhibition of germination due to mycoflora	Fungi associated
	Treated	Untreated		
Chilli	70	62	8	*Aspergillus niger* Van. Tiegh., *A. flavus* Link ex. Fr., *Rhizopus stolonifer* (Fr.) Lind, *Penicillium* sp. Link ex. Fr., *Curvularia lunata* (Wakker) Boedijn
Brinjal	87	74	13	*Aspergillus niger*, *A. flavus*, *Rhizopus stolonifer*, *Penicillium* sp., *Drechslera rostrata* (Drechsler) Shoemaker.
Tomato	90	84	6	*Aspergillus niger*, *A. flavus*, *Rhizopus stolonifer*, *Penicillium* sp., *Alternaria* sp. Nees ex Waller.

* Mean of 3 replications

Table 3. Effect of fungicidal seed treatment on the germination of solanaceous seeds (Blotter method)

Treatments	Dose	*Mean germination percentage		
		Chilli	Brinjal	Tomato
Thiram	2 g/kg seed	70	87	90
Metalaxyl	,,	67	83	83
Mancozeb	,,	66	77	86
Captan	,,	70	80	80
Chlorothalonil	,,	80	83	90
Carbendazim	1 g/kg seed	66	80	86
Copper oxychloride	3 g/kg seed	68	90	90
Potassium phosphonate	0.3%	50	68	36
Bordeaux mixture	1%	60	80	36
Control		62	74	84

* Mean of 3 replications

4.2 Isolation and identification of fungi associated with pre-emergence damping-off

The germination percentage of different solanaceous seeds and the fungi associated with pre-emergence damping-off were recorded by pot culture and field experiments.

4.2.1 Pot culture studies

In summer, the fungus found associated with the disease was *Rhizoctonia solani* where as in the rainy season *Pythium aphanidermatum* and *Phytophthora parasitica* were associated with pre-emergence damping-off (Table 4).

During summer season, 48, 58 and 65 per cent germination was observed in chilli, brinjal and tomato respectively and the per cent inhibition in germination due to pathogen was 5 per cent in chilli, 15 per cent in brinjal and 21 per cent in tomato. In rainy season, germination percentage was comparatively lower than that in summer season (26, 42 and 50 per cent in chilli, brinjal and tomato respectively). The incidence of pre-emergence damping-off was found to be high 27, 31 and 36 per cent in chilli, brinjal and tomato respectively during rainy season.

4.2.2 Field studies

In field studies also percentage germination was high during summer season compared to rainy season.

Maximum incidence of pre-emergence damping-off was recorded in rainy season. *Rhizoctonia solani* seem to be responsible for pre-emergence

Table 4. Germination percentage of solanaceous seeds and fungi associated with pre-emergence damping-off in pot culture experiment

Crop	*Mean percentage germination				Percentage pre-emergence damping-off		Fungi isolated	
	Summer season		Rainy season		Summer season	Rainy season	Summer season	Rainy season
	Unsterilized soil	Sterilized soil	Unsterilized soil	Sterilized soil				
Chilli	48	53	26	53	5	27	*Rhizoctonia solani* Kühn	*Pythium aphanidermatum* (Edson) Fitzpatrick *Phytophthora parasitica* (Dastur) Waterh.
Brinjal	58	73	42	73	15	31	*Rhizoctonia solani*	*P. aphanidermatum* *P. parasitica*
Tomato	65	86	50	86	21	36	*Rhizoctonia solani*	*P. aphanidermatum* *P. parasitica*

* Mean of 3 replications

damping-off during summer season, where as *Pythium aphanidermatum* and *Phytophthora parasitica* were isolated during rainy season (Table 5).

4.3 Isolation and identification of fungi associated with post-emergence damping-off

4.3.1 Pot culture studies

From the experiment to find out the fungi associated with post-emergence damping-off during summer and rainy seasons it was found that *Rhizoctonia solani* was responsible for the post-emergence damping-off disease during summer season, where as fungi like *Pythium aphanidermatum*, *Phytophthora parasitica* and *Drechslera rostrata* were responsible in the rainy season (Table 6).

From the data on percentage of post-emergence damping-off presented in Table 6, it was evident that incidence of post-emergence damping-off was low in summer as compared to rainy season. Maximum incidence of the disease was observed in tomato in both the seasons.

4.3.2 Field studies

Experimental findings on incidence of damping-off and fungi associated with the disease are presented in Table 7.

From the data, it was obvious that post-emergence damping-off was very meagre in summer season, where as in rainy season, disease incidence was high. Maximum incidence of damping-off was noticed in tomato.

Table 5. Germination percentage of solanaceous seeds and fungi associates with pre-emergence damping-off in field experiment

Crop	*Mean percentage germination				Percentage pre-emergence damping-off		Fungi isolated	
	Summer season		Rainy season					
	Unsterilized soil	Sterilized soil	Unsterilized soil	Sterilized soil	Summer season	Rainy season	Summer seaso	Rainy season
Chilli	24	51	10	51	27	41	*Rhizoctonia solani*	*Pythium aphanidermatum* *Phytophthora parasitica*
Brinjal	45	76	28	76	51	48	*Rhizoctonia solani*	*P. aphanidermatum* *P. parasitica*
Tomato	35	75	22	75	40	53	*Rhizoctonia solani*	*P. aphanidermatum* *P. parasitica*

* Mean of 3 replications

Table 6. Percentage of post-emergence damping-off and fungi associated in pot culture experiment

Crop	*Mean percentage of damping-off		Fungi identified	
	Summer season	Rainy season	Summer season	Rainy season
Chilli	11	39	*Rhizoctonia solani*	*Phytophthora parasitica* *Pythium aphanidermatum* *Drechslera rostrata*
Brinjal	12	38	*Rhizoctonia solani*	*Pythium aphanidermatum* *Phytophthora parasitica* *Drechslera rostrata*
Tomato	14	42	*Rhizoctonia solani*	*Pythium aphanidermatum* *Phytophthora parasitica* *Drechslera rostrata*

* Mean of 3 replications

Table 7. Percentage of post-emergence damping-off and fungi associated in field experiment

Crop	*Mean percentage damping off		Fungi identified	
	Summer season	Rainy season	Summer season	Rainy season
Chilli	22.23	49.24	*Rhizoctonia solani*	*Pythium aphanidermatum* *Phytophthora parasitica* *Curvularia lunata* *Drechslera rostrata*
Brinjal	24.67	49.01	*Rhizoctonia solani*	*Pythium aphanidermatum* *Phytophthora parasitica* *Drechslera rostrata*
Tomato	20.00	77.02	*Rhizoctonia solani*	*Pythium aphanidermatum* *Phytophthora parasitica* *Drechslera rostrata*

* Mean of 3 replications

During summer season, *R. solani* was found to be associated with the disease and during rainy season *P. aphanidermatum, P. parasitica*, and *Drechslera rostrata* were isolated from all the three crops and *Curvularia lunata* only from chilli.

4.4 Pathogenicity of the fungi associated with damping-off disease

Pathogenicity of the fungi isolated from different crops from the field was proved according to Koch postulates. Post-emergence damping-off occurred 3-4 days after inoculation.

Pathogenicity test indicated that *Pythium aphanidermatum* and *Phytophthora parasitica* were highly pathogenic on all the three crops as compared to other (Table 8). These two fungi caused pre-emergence damping-off varying from 46.6 to 86.67 per cent and post-emergence damping-off varying from 60 to 81.8 per cent. It was also observed that for both fungi maximum damping-off incidence was observed in tomato.

In the case of *Rhizoctonia solani* also maximum infection was observed in tomato. As far as pre-emergence and post-emergence damping-off were concerned, *Drechslera rostrata* was found to be more pathogenic to brinjal and chilli was least affected. *Curvularia lunata* was isolated only from chilli seedlings and on pathogenicity test, only chilli showed infection.

4.5 Morphological characters of the pathogen causing damping-off

The pathogens associated with damping-off disease were identified based

Table 8. Pathogenicity of isolated fungi in causing damping-off of chilli, brinjal and tomato

Fungus	Crop	Percentage of pre-emergence damping-off	Percentage of post-emergence damping-off
Phythium aphanidermatum	Chilli	46.6	71.4
	Binjal	73.3	70.0
	Tomato	80.0	81.8
Phytophthora parasitica	Chilli	50.0	71.4
	Brinjal	73.3	60.0
	Tomato	86.67	75.0
Rhizoctonia solani	Chilli	33.3	42.9
	Brinjal	33.3	44.02
	Tomato	36.0	61.5
Drechslera rostrata	Chilli	3.33	42.9
	Brinjal	46.67	40.0
	Tomato	23.33	60.0
Curvularia lunata	Chilli	3.33	27.2
	Brinjal	-	-
	Tomato	-	-
Control	Chilli	0	0
	Brinjal	0	0
	Tomato	0	0

on the morphological characters. It was further confirmed by ITCC, IARI, New Delhi. The morphological characters of the organisms observed were as follows.

Pythium aphanidermatum (Edson) Fitzpatrick

The mycelium was hyaline, coenocytic with an average width of 3.4 μm. The growth of the fungus was rapid on potato dextrose agar (PDA) medium with cottony white mycelium which covered 90 mm petri dish within 48 h.

Sporangia were filamentous in the initial stages, swelled later and produced lobulate branches. The size, shape and number of lobes of sporangia varied widely. Sporangia measured 30.6-85 μm x 10.2-57.8 μm and number of lobes varied from one to twelve (Fig.1).

The oogonia were smooth, spherical and size varied from 20.4 to 27.2 μm. Antheridia were stalked, mostly terminal, rarely intercalary, barrel shaped or broadly clavate of 6.8-10.2 μm x 3.4-10.2 μm size. Oospore were spherical, smooth and measured 13.6 to 27.2 μm in diameter (ITCC No.2182.95).

Phytophthora parasitica (Dastur) Waterh.

The mycelium was hyaline, coenocytic with an average width of 3.4 μm. The white fluffy growth of the fungus was rapid on potato dextrose agar medium which covered 90 mm petri dishes within 48 h.

Sporangia were ovoid to spherical not noticeably narrowed at the apex, with an average diameter of 30.6 x 23.8 μm (ITCC No.2043.95, 2044.95, 2045.95, 2046.95) (Fig.2).

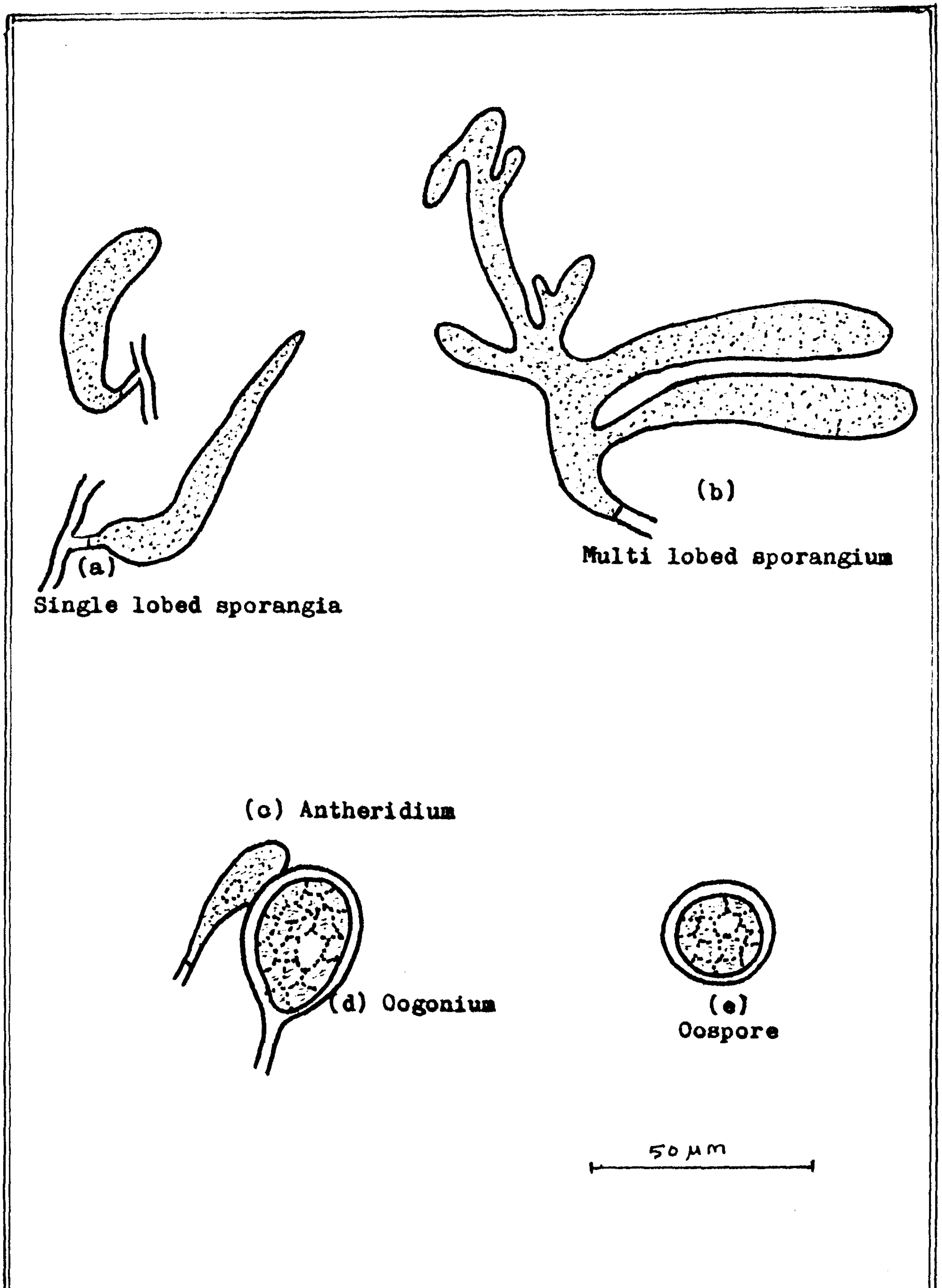


Fig. I

Reproductive structures of *Pythium aphanidermatum*

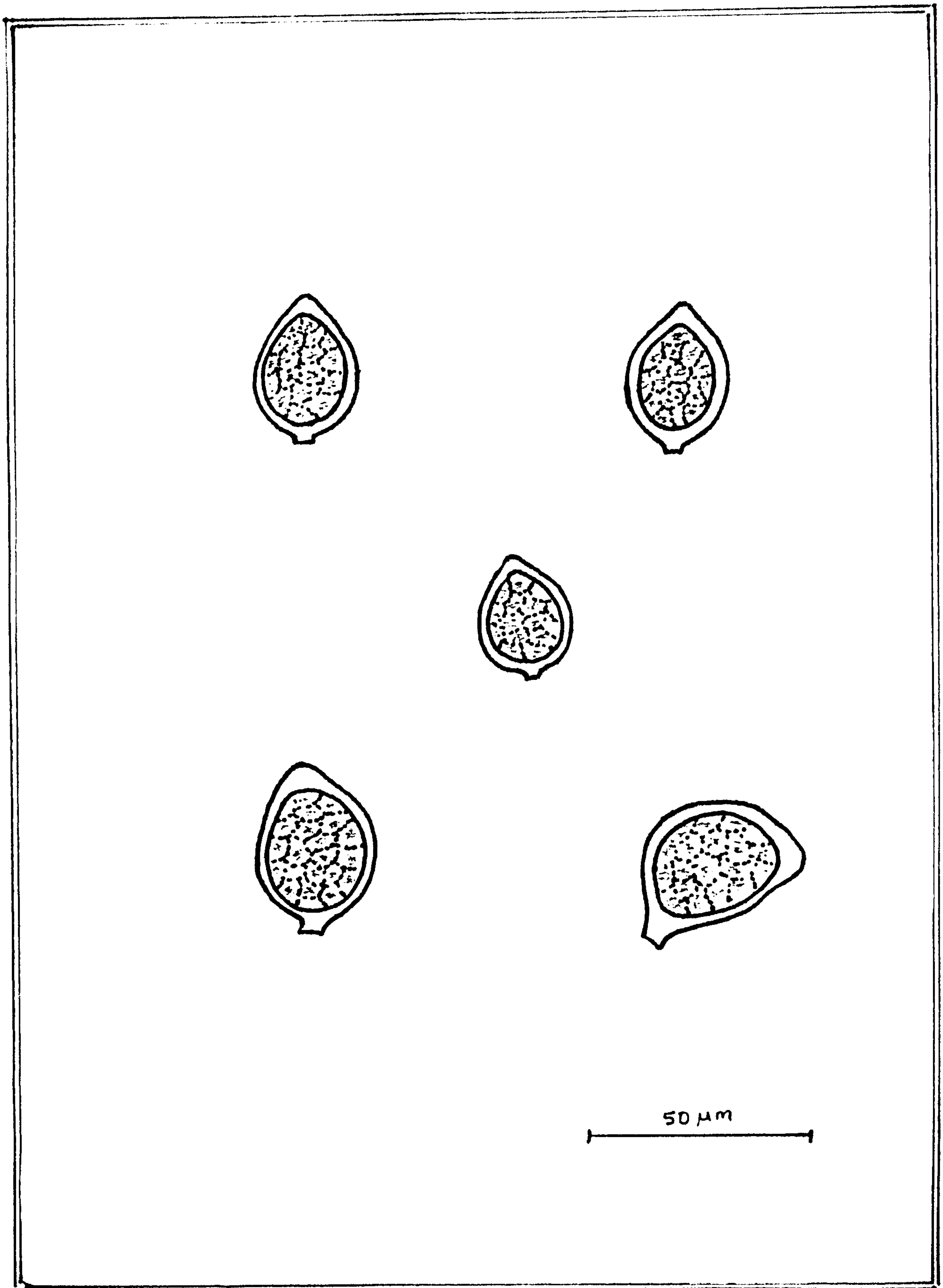


Fig.2

Sporangia of *Phytophthora parasitica*

Rhizoctonia solani Kühn

Septate mycelium composed of colourless hyphae later turning yellowish and then deep brown in colour. Cells of hyphae at advancing edge of the colony has 6.8 μm wide and upto 150 μm long. The mycelium covered 90 mm petri dish within 48 h. The hyphal branches developed at right angles (Fig.3).

The sclerotial initials were white and loose textured. Mature sclerotia appeared brown in colour. The sclerotium was irregular in size and shape. Sclerotia developed as a crust radiating out from the point of inoculation or as separate entities scattered over colony surface (ITCC No.2048.95).

Drechslera rostrata (Drechsler) Shoemaker

The growth was rather slow on potato dextrose agar medium and covered 90 mm petri dish within 7 days. Thick, black, velvetty growth was noticed with septate hyphae of 3.4-6.8 μm width. The conidia varied in shape and size fusiform to long elliptical, 3-9 septate and dark brown in colour. The average size of conidia was 37.4 μm x 13.5 μm (ITCC No.2047.95) (Fig.4).

Curvularia lunata (Wakker) Boedijn

The mycelium was septate, profusely branched and light brown. Hyphae 2-4 μm wide. Conidiophore dark brown and unbranched. Conidia boat shaped, brown, 3 septate and 3rd cell from the base conspicuously larger, broader and darker than others. Rounded apical cell and a sub hyaline, some what obconical basal cell which bears a scar indicating point of attachment to the conidiophore. Average size of conidia was 20.4 μm x 11.9 μm (ITCC No.2049.95) (Fig.5).

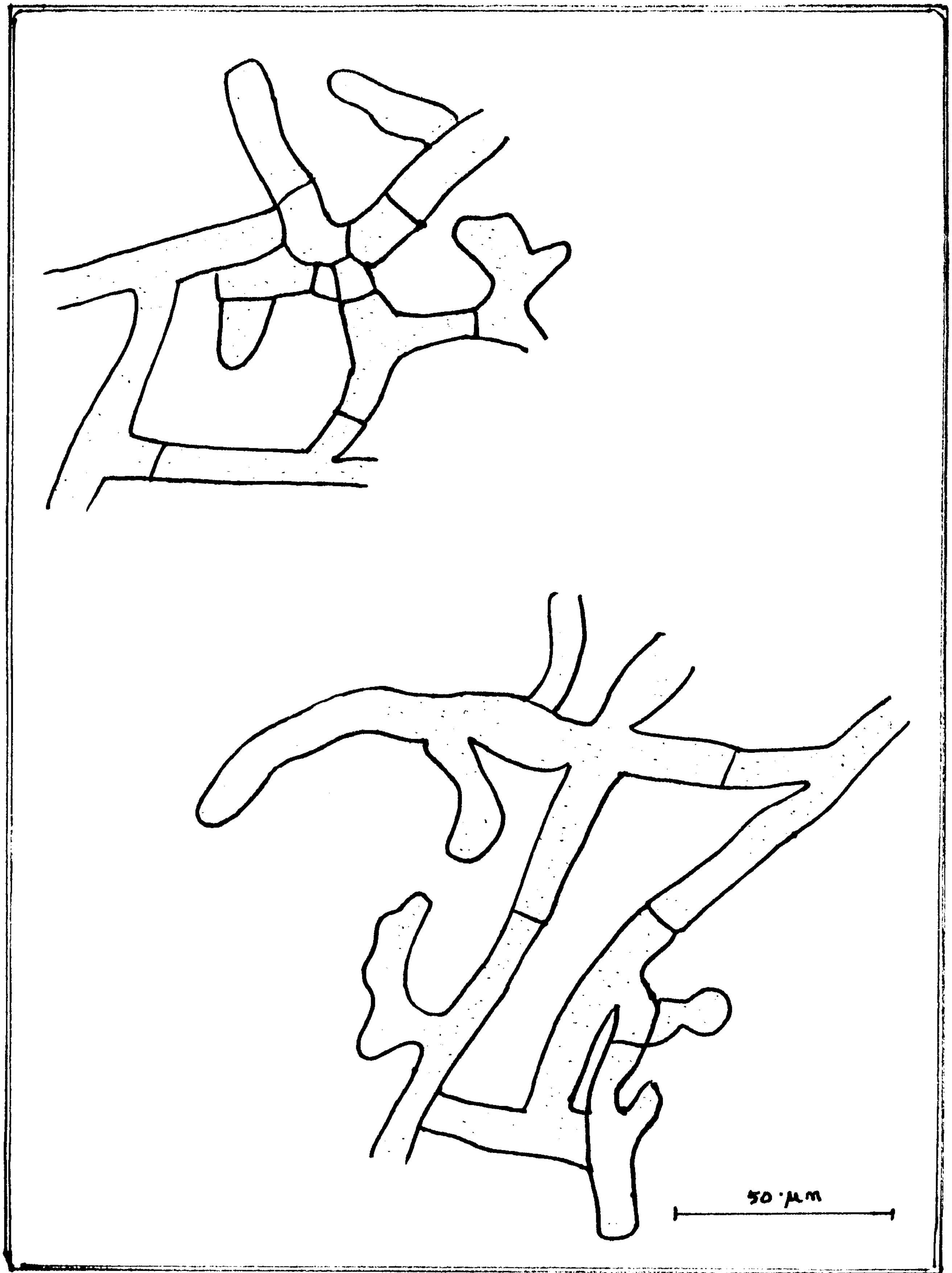


Fig.3

Mycelia of <u>Rhizoctonia</u> <u>solani</u>

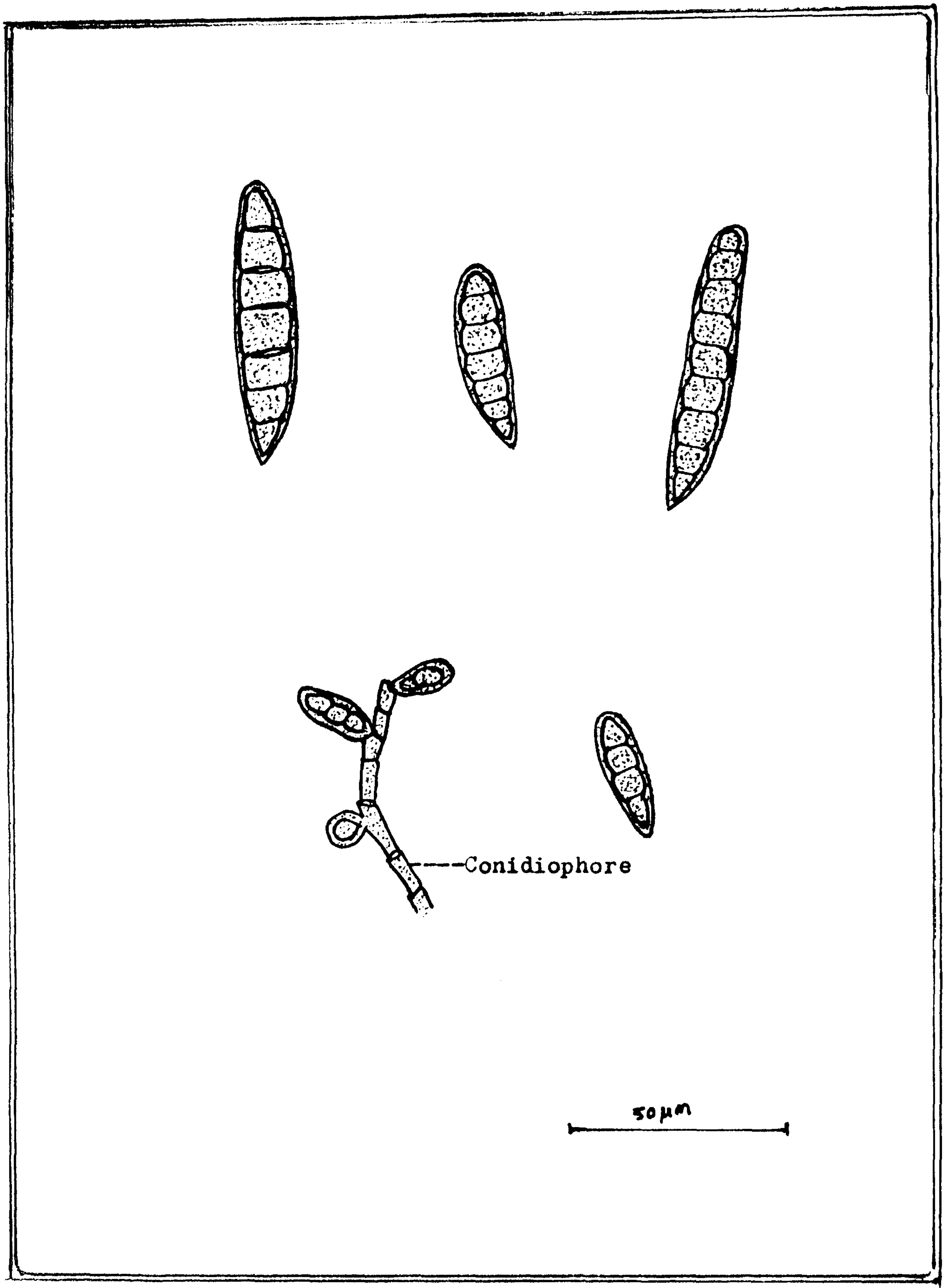


Fig.4

Conidia of Drechslera rostrata

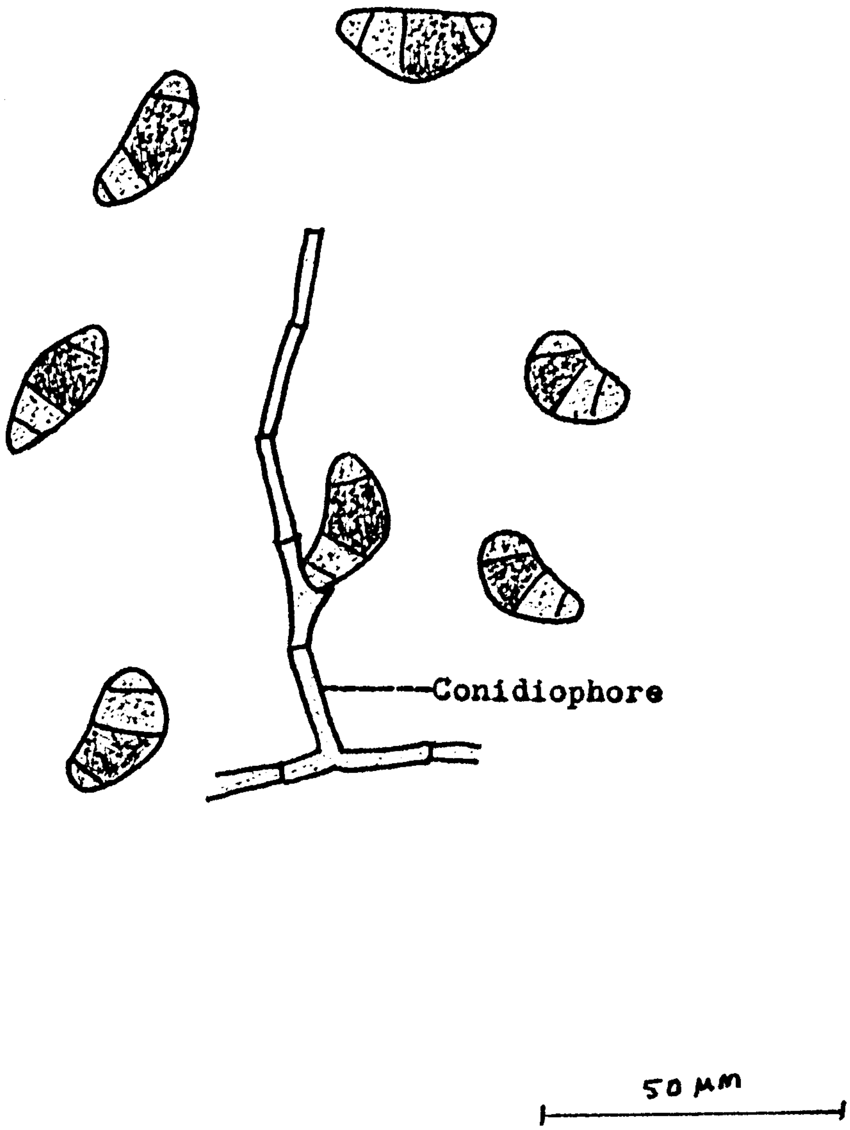


Fig.5

Conidia of Curvularia lunata

4.6 Symptomatology

The pre-emergence and post-emergence damping-off symptoms were similar in all the three crops. In the pre-emergence phase, the seeds were completely rotted before they emerge out. The post-emergence phase was characterised by infection of the young, juvenile tissue of the collar region at the ground level. The infected tissues became soft and water soaked. As the disease advanced, the stem became constricted at the base and the seedlings toppled over or collapsed. Slight variations in symptoms were observed with different pathogens. In *P. aphanidermatum*, infected tissues appeared soft and water soaked but as the disease advanced, the stem became constricted at the base and plants collapsed. In *P. parasitica*, rotting of the stem and leaves were observed in addition to collar rot. *R. solani, Drechslera rostrata* and *C. lunata* caused brown necrosis of the collar region (Plate I to IV).

4.7 Reactions of different genotypes of chilli, brinjal and tomato to damping-off pathogens

The varieties/genotypes obtained from Department of Olericulture were screened against damping-off disease under field condition during rainy and summer seasons. Data of the experiment are furnished in Table 9 and 10.

From Table 9, it could be noticed that out of eleven chilli accessions evaluated during summer, Surakta and LCA-304 were found to be resistant to damping-off with 10.6 and 18.2 per cent infection respectively. RHRC clustering (pendent) showed maximum infection of 59.6 per cent.

Plate I. Chilli seedlings showing damping-off

Left - Diseased seedlings
Right - Healthy seedlings

Plate II. Brinjal seedlings showing damping-off

Left - Diseased seedlings
Right - Healthy seedlings

Plate III. Tomato seedlings showing damping-off

Left - Diseased seedlings
Right - Healthy seedlings

Plate IV. Damping-off incidence in nursery bed

Table 9. Reactions of different genotypes of chilli, brinjal and tomato to damping-off pathogens during summer season

Chilli			Brinjal			Tomato		
Variaties/ genotypes	Percentage disease incidence	Category	Varieties/ genotypes	Percentage disease incidence	Category	Varieties/ genotypes	Percentage disease incidence	Category
BC 14-2	26.5	MR	Arka Keshav	10	R	BR-10	21.1	MR
BC-24	21	MR	BB-44	27.9	MR	BT-18	42	MS
Ujjwala	24	MR	BB-13-1	67.0	S	Sakthi	37.66	MR
			CHES-249	4.29	MS			
BC21-2	46	MS	CHES-243	22.7	MR	BT-1	10.1	R
LCA-304	18.2	R	HDE-444	33.8	MR	LE-79-5	9.8	R
Surakta	10.6	R	BB-7	31	MR			
LCA-305	37.8	MR	CHES-309	28.1	MR			
LCA-301	20.3	MR	SM-6-6	26.4	MR			
RHRC clustering (Pendent)	59.6	MS	Swarnasree	37.6	MR			
			Surya	21.58	MR			
Chilli Guehhendar	39.1	MR	BB-1	24.3	MR			
Punjab Surkh	23.07	MR	BB-60 C	13.5	R			

R - Resistant
MR - Moderately Resistant
MS - Moderately Susceptible
S - Susceptible

Table 10. Reactions of different genotypes of chilli, brinjal and tomato to damping-off pathogens during rainy season

Chilli			Brinjal			Tomato		
Varieties/ genotypes	Percentage disease incidence	Category	Varieties/ genotypes	Percentage disease incidence	Category	Varieties/ genotypes	Percentage disease incidence	Category
Chilli Guehhendar	57	MS	Arka Keshav	39.4	MR	BT-10	28.6	MR
BC-14-2	10.4	R	BB-13-1	28.9	MR	BT-18	38.6	MR
Ujjwala	44	MS	CHES-249	55.3	MS	BT-1	30.2	MR
BC-21-2	21.05	MR	CHES-243	38.5	MR	BT-21	30	MR
Pusa Sukra	36	MR	BB-44	44.5	MS	Sakthi	44.5	MS
K. Kirthi	17.6	R	HOE-444	25.6	MR	BRH-1	25	MR
Surakta	22	MR	BB-7	56.5	MS	BRH-2	27	MR
LCA 305	22.6	MR	BWR-12	45.6	MS	Pusa Ruby	36.6	MR
LCA-301	15.1	R	BB-60 C	16.5	R	LE-79-5	11.6	R
KDCS 810	7.8	R	SM-6-6	34	MR			
Arka Lohit	8.9	R	Sorya	42.9	MS			
RHRC Clustering (Pendent)	9.1	R						
JCA 283	9.6	R						
LCA 304	8.1	R						
Phule-5	8.3	R						
Punjab Surkh	48.6	MS						

R - Resistant
MR - Moderately Resistant
MS - Moderately susceptible
S - Susceptible

In brinjal genotypes, Arka Keshav and BB-60-C showed only 10 and 13.5 per cent infection whereas maximum infection of 67 per cent was observed in BB-13-1.

Among the tomato lines tested, LE 79-5 and BT-1 showed lowest infection of 9.8 per cent and 10.1 per cent respectively while BT-18 was found to be moderately susceptible to the disease.

From Table 10, it was observed that out of 17 genotypes of chilli screened during rainy season, 9 genotypes such as BC 14-2, K-Kirthi, LCA-301, KDCS-810, Arka Lohit, RHRC clustering (pendent), JCA-283, LCA 324 and Phule 5 were resistant to the disease having less than 20 per cent infection. Maximum infection was observed in Punjab Surkh (48.6%) and chilli Guchhendar (57%).

In case of brinjal, lowest disease incidence of 16.5 per cent was observed in BB-60-C and highest incidence of 56.5 per cent in BB-7.

Out of ten tomato lines tested, LE-79-5 showed minimum disease incidence (11.6%) and maximum infection was observed in Sakthi (44.5%).

4.8 Management of damping-off disease

4.8.1 *In vitro* evaluation of plant protection chemicals against damping-off pathogens

In order to find out the most effective fungicide against damping-off pathogens viz., *P. aphanidermatum, P. parasitica, R. solani* and *D. rostrata*, a bioassay with different fungicides was carried out using poison food technique (Zentmyer, 1955).

The results of the experiments are given in Tables 11 to 14.

From the data presented in Table 11 and 12 it was observed that, the evaluation of fungicides against *P. aphanidermatum* and *P. parasitica* gave almost similar results. It was found that in both cases, 1 per cent Bordeaux mixture and 0.3 per cent copper oxychloride gave 100 per cent inhibition of the organisms (Plate V). Captan 0.2 per cent and Thiram 0.2 per cent gave 81·11 to 87·8 per cent inhibition over the control. Chlorothalonil 0.2 per cent was found to be least effective against these organisms.

In the case of *R. solani* and *D. rostrata* also maximum inhibition was observed in 1 per cent Boardeaux mixture (Table 13 and 14). All other treatments were found equally effective, giving 75 to 87 per cent inhibition of pathogens over control (Fig.6).

4.8.2 *In vitro* evaluation of fungal antagonist *Trichoderma viride* against damping-off pathogens

The antagonistic activity of *T. viride* against *P. aphanidermatum, P. parasitica, R. solani* and *D. rostrata* was studied and results are presented in Table 15. The antagonist and test organisms were inoculated on the same day in dual culture.

The initial growth rate of *P. aphanidermatum, P. parasitica* and *R. solani* were same in both mono and dual culture. On second day, when the mycelium of the antagonist and test organisms came in contact, die-back and disintegration of the test organism was noted resulting in an inhibition band. Slowly

Table 11. *In vitro* sensitivity of *Pythium aphanidermatum* to selected fungicides

Sl. No.	Treatments	*Mean colony diameter (cm)	Per cent inhibition over control
1	Bordeaux mixture 1%	0	100
2	Captan 0.2%	1.1	87.78
3	Chlorothalonil 0.2%	4.73	47.4
4	Copper oxychloride 0.3%	0	100
5	Mancozeb 0.2%	3.83	57.44
6	Thiram 0.2%	1.6	82.22
7	Control	9.0	0

Table 12. *In vitro* sensitivity of *Phytophthora parasitica* to selected fungicides

Sl. No.	Treatments	*Mean colony diameter (cm)	Percent inhibition over control
1	Bordeaux mixture 1%	0	100
2	Captan 0.2%	1.23	86.33
3	Chlorothalonil 0.2%	5.3	41.11
4	Copper oxychloride 0.3%	0	100
5	Mancozeb 0.2%	3.52	60.89
6	Thiram 0.2%	1.7	81.11
7	Control	9.0	0

* Mean of 3 replications

Table 13. *In vitro* sensitivity of *Rhizoctonia solani* to selected fungicides

Sl. No.	Treatments	*Mean colony diameter (cm)	Per cent inhibition over control
1	Bordeaux mixture 1%	1	88.89
2	Catan 0.2%	1.67	81.44
3	Chlorothalonil 0.2%	2.23	75.22
4	Copper oxychloride 0.3%	1.23	86.33
5	Mancozeb 0.2%	1.17	87.00
6	Thiram 0.2%	1.5	83.33
7	Control	9.0	0

Table 14. *In vitro* sensitivity of *Drechslera rostrata* to selected fungicides

Sl. No.	Treatments	*Mean colony diameter (cm)	Per cent inhibition over control
1	Bordeaux mixture 1%	1	88.89
2	Captan 0.2%	1.13	87.44
3	Chlorothalonil 0.2%	1.63	81.89
4	Copper oxychloride 0.3%	2.03	77.44
5	Mancozeb 0.2%	1.9	78.89
6	Thiram 0.2%	1.17	87.00
7	Control	9.0	0

* Mean of 3 replications

Fig.6 *In vitro* evaluation of fungicides against damping-off pathogens

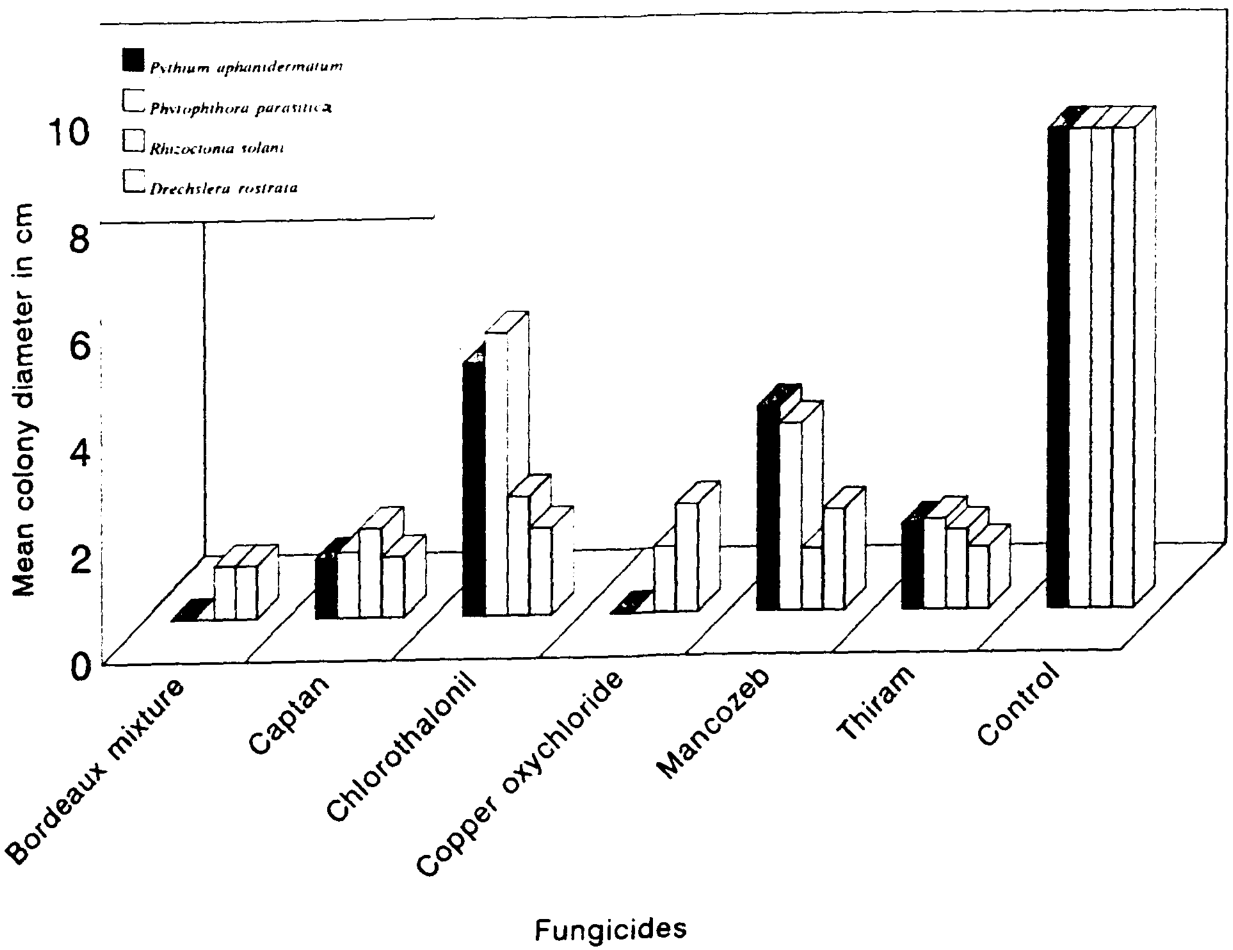


Table 15. Growth of the pathogen and antagonist in mono and dual culture (in cm)

Test organism		Days after incubation																	
		1		2		3		4		5		6		7		8		9	
		A	T	A	T	A	T	A	T	A	T	A	T	A	T	A	T	A	T
Pythium aphanidermatum																			
	D	1.5	4.5	2.8	6.2	3.6	5.0	5.0	4.0	7.0	2.0	8.5	0.5	9	-	9.0	-		
	M	1.5	4.0	2.8	7.5	3.6	9.0	5.0	9.0	7.5	9.0	9.0	9.0	9	9.0	9.0	9.0		
Phytophthora parasitica																			
	D	1.5	4.9	2.5	6.5	3.3	5.7	4.2	4.8	6.5	2.5	8.0	1.0	9	-	9.0	-		
	M	1.5	5.0	2.8	7.5	3.6	9.0	5.0	9.0	7.5	9.0	9.0	9.0	9	9.0	9.0	9.0		
Rhizoctonia solani																			
	D	1.5	2.7	2.8	5.6	3.5	5.5	4.5	4.5	6.0	3.0	7.5	1.5	8	1.0	9.0	9.0		
	M	1.5	2.6	2.8	5.5	3.6	9.0	5.0	9.0	7.5	9.0	9.0	9.0	9	1.0	9.0	9.0		
Drechslera rostrata																			
	D	1.5	1.1	2.8	1.9	3.6	2.7	5.0	3.1	5.5	3.5	7.5	1.5	8	1.0	8.5	0.5	9	-
	M	1.5	1.1	2.8	1.9	3.6	2.7	5.0	3.1	7.5	3.7	9.0	4.5	9	7.5	9.0	9.0	9	9

A - Antagonist　　D - Dual culture
T - Test organism　　M - Mono culture

the antagonist over grew the pathogen causing complete disintegration of the pathogens (Plate VI and VII).

In the case of *Drechslera rostrata*, the growth rate in mono and dual culture was same up to 4th day. There after, no further growth of pathogen was observed in dual culture. Antagonist completely over grew the test organism resulting in disintegration of pathogen (Plate VIII).

4.8.3 Management of damping-off under field condition

In order to find out the effective measures to reduce the incidence of damping-off disease in solanaceous crops under natural conditions, field experiments were conducted during summer and rainy seasons in a sick plot.

4.8.4 Summer season crop

During summer season, incidence of pre-emergence damping-off was comparatively less in all three crops. The experimental findings are furnished in Table 16 to 18.

It was found that in case of chilli, seed treatment with chlorothalonil (T_5) gave maximum (38.67%) germination. The lowest germination (8.67%) was noticed in case of Bordeaux mixture (T_8). Neem cake (T_{20}) and potassium phosphonate (T_9) were found to be on par with Bordeaux mixture in germination (Table 16).

With regard to pre-emergence damping-off significant difference was noticed among the treatments. Lowest incidence (12%) was observed in chlorothalonil (T_5) treatment followed by thiram (T_1) and Bordeaux mixture (T_8). Soil application of neem cake (T_{20}), mycorrhiza (T_{19}) and seed treatment with

Plate V. Effect of fungicides in potato dextrose agar medium on the growth of *Pythium aphanidermatum*

a. Bordeaux mixture
b. Copper oxychloride
c. Thiram
d. Control

Plate VI. *Trichoderma viride* against *Pythium aphanidermatum* in dual culture

A. Antagonist (mono culture)
D. Dual culture
P. Pathogen (mono culture)


a
b
c
d

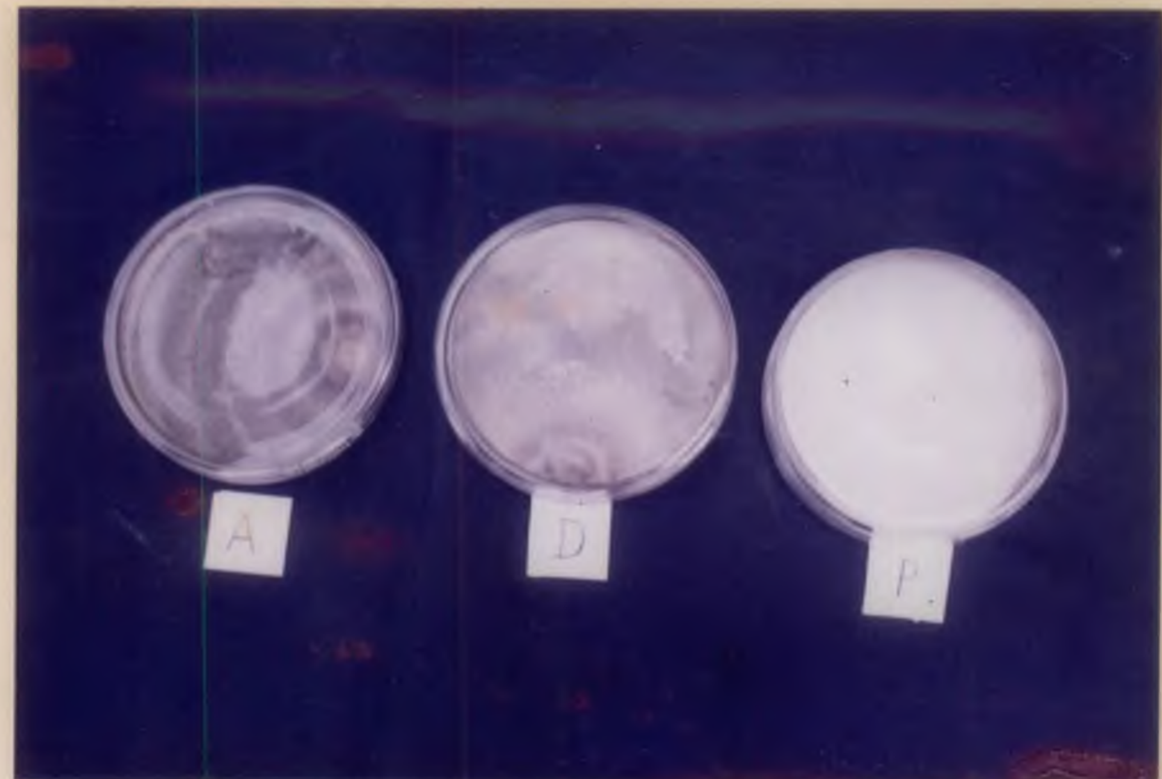
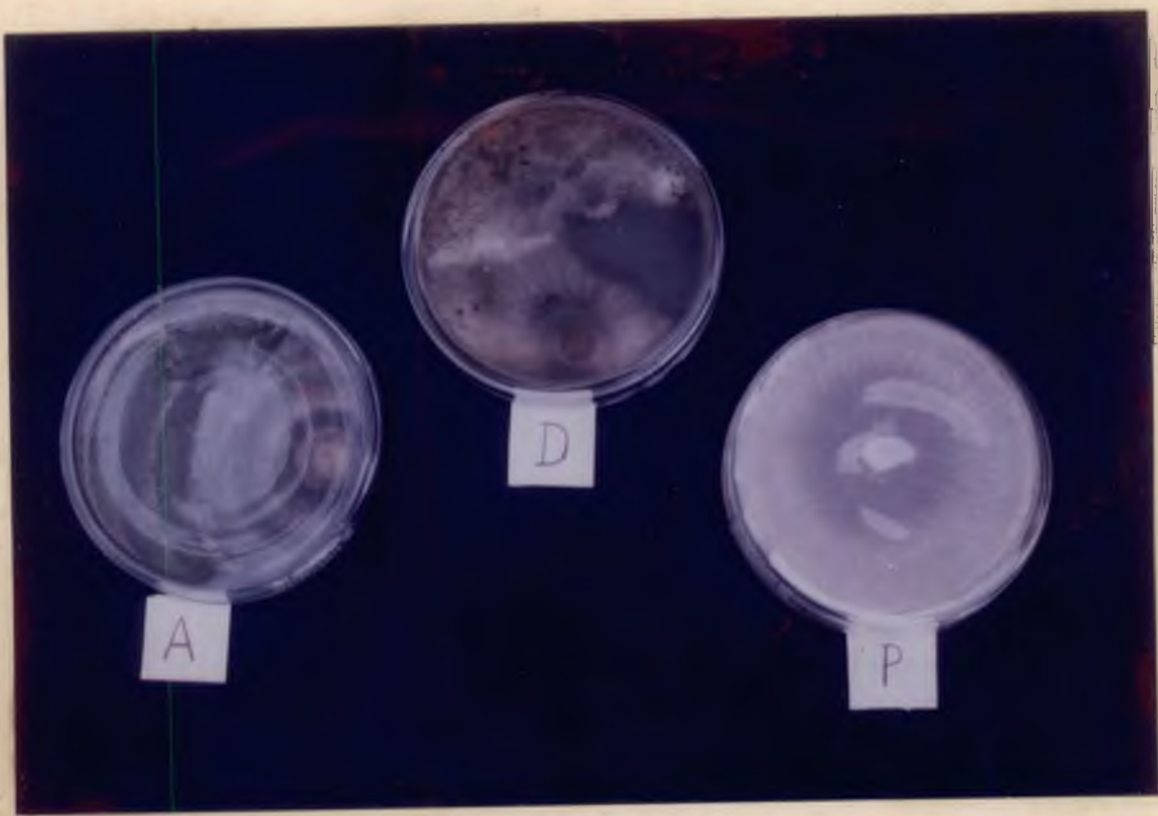

A
D
P

Plate VII. *Trichoderma viride* against *Rhizoctonia solani* in dual culture

A. Antagonist (mono culture)
D. Dual culture
P. Pathogen (mono culture)

Plate VIII. *Trichoderma viride* against *Drechslera rostrata* in dual culture

A. Antagonist (mono culture)
D. Dual culture
P. Pathogen (mono culture)


D
A
P

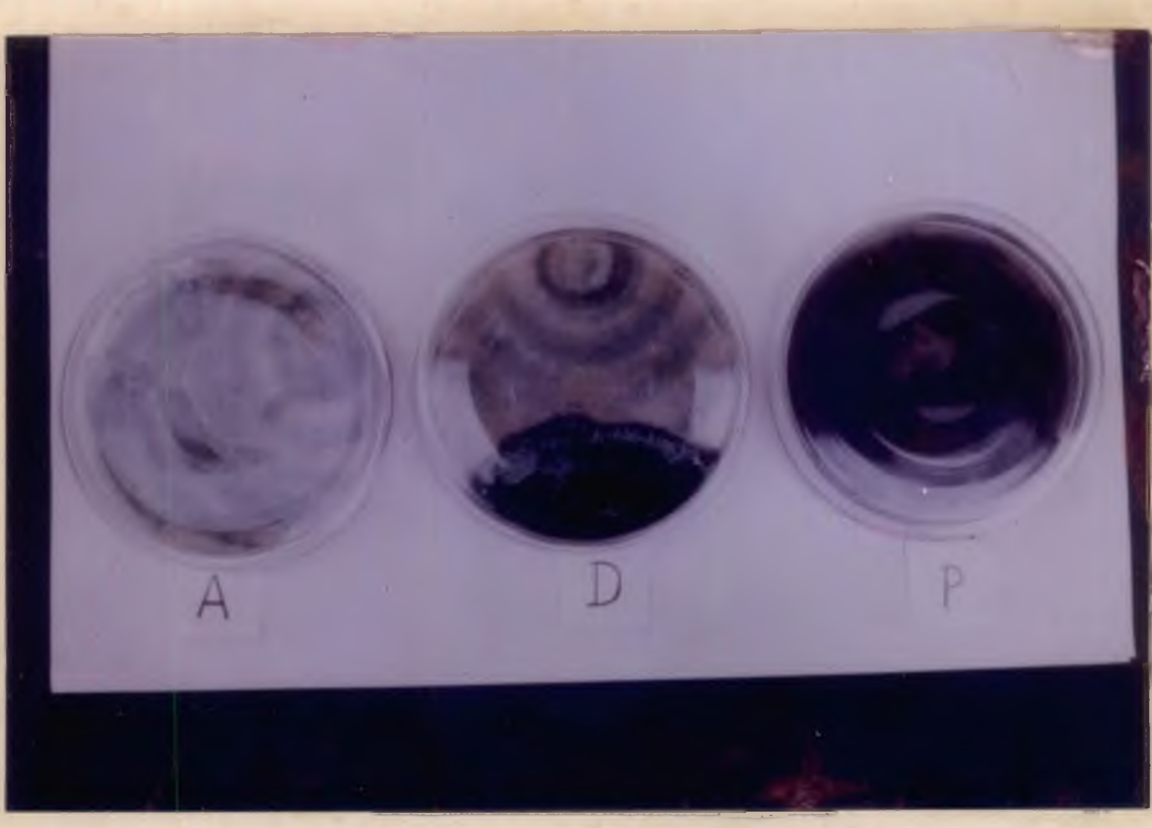

A
D
P

Table 16. Effect of different treatments on the germination and pre-emergence damping-off in chilli during summer season

Treatment	Percentage germination	Percentage pre-emergence damping-off
T_1	*34.67 (0.626) abc	*16.000 (0.3838) ab
T_2	30.00 (0.578) abc	20.667 (0.4666) abc
T_3	28.00 (0.555) abcd	22.667 (0.4864) abc
T_4	26.67 (0.542) abcd	24.000 (0.5097) abc
T_5	38.67 (0.669) a	12.000 (0.3488) 9
T_6	26.00 (0.534) abcde	24.667 (0.5197) bc
T_7	28.67 (0.563) abcd	22.000 (0.4845) abc
T_8	8.67 (0.292) g	21.333 (0.4776) abc
T_9	14.67 (0.390) efg	26.000 (0.5341) bc
T_{10}	35.33 (0.636) ab	15.333 (0.3969) ab
T_{11}	26.67 (0.541) abcd	24.000 (0.5118) abc
T_{12}	28.67 (0.564) abcd	22.000 (0.4854) abc
T_{13}	25.33 (0.526) abcde	25.333 (0.5225) bc
T_{14}	38.67 (0.670) a	12.006 (0.3511) a
T_{15}	28.00 (0.555) abcd	22.667 (0.4955) abc
T_{16}	26.67 (0.540) abcd	24.000 (0.5074) abc
T_{17}	14.67 (0.392) efg	29.333 (0.5719) c
T_{18}	11.33 (0.338) fg	19.333 (0.4551) abc
T_{19}	21.33 (0.479) cdef	29.333 (0.5706) c
T_{20}	17.33 (0.421) defg	33.333 (0.6133) c
T_{21}	26.00 (0.533) abcde	24.667 (0.5174) bc
T_{22}	24.00 (0.510) bcde	26.667 (0.5364) bc

*Mean of 3 replication
Figures in parentheses are transformed values

In each column figures followed by same letter do not differ significantly ($p=0.5$) according to DMRT

Table 17. Effect of different treatments on the germination and pre-emergence damping-off in brinjal during summer season

Treatment	Percentage germination	Percentage pre-emergence damping-off
T_1	*49.334 (0.779) bcd	*26.667 (0.5417) cde
T_2	46.000 (0.645) cde	30.000 (0.5788) cde
T_3	50.664 (0.792) abcd	25.333 (0.5229) bcde
T_4	58.000 (0.868) abcd	19.333 (0.4511) abcd
T_5	64.666 (0.935) ab	11.333 (0.3382) ab
T_6	48.666 (0.772) bcd	27.333 (0.5444) abc
T_7	51.334 (0.799) abcd	24.667 (0.5190) bcde
T_8	42.000 (0.704) de	24.000 (0.4986) bcde
T_9	32.666 (0.603) e	33.333 (0.6082) cde
T_{10}	50.000 (0.785) abcd	26.000 (0.5331) cde
T_{11}	49.334 (0.779) abcd	39.667 (0.6803) e
T_{12}	50.666 (0.792) abcd	25.333 (0.5271) bcde
T_{13}	60.000 (0.886) abc	16.000 (0.4114) abc
T_{14}	65.334 (0.942) a	10.667 (0.3006) a
T_{15}	50.000 (0.785) abcd	26.000 (0.5349) cde
T_{16}	53.334 (0.819) abcd	22.667 (0.4955) bcde
T_{17}	32.000 (0.597) abcd	34.000 (0.6193) de
T_{18}	44.000 (0.725) e	22.000 (0.4829) abcd
T_{19}	45.334 (0.718) cde	30.667 (0.5845) cde
T_{20}	43.334 (0.718) de	32.667 (0.6072) cde
T_{21}	45.334 (0.738) cde	30.664 (0.5802) cde
T_2	44.666 (0.731) cde	31.333 (0.5900) cde

*Mean of 3 replications
Figures in parentheses are transformed values

In each column figures followed by same letter donot differ significantly ($p=0.05$) according to DMRT

Table 18. Effect of different treatments on the germination and pre-emergence damping-off in tomato during summer season

Treatment	Percentage germination	Percentage pre-emergence damping-off
T_1	*40.666 (0.691) abc	*34.000 (0.6222) abcdef
T_2	43.334 (0.718) abc	31.333 (0.5900) abcde
T_3	42.666 (0.711) abc	32.000 (0.6009) abcde
T_4	44.666 (0.732) abc	30.000 (0.5786) abcd
T_5	50.666 (0.792) a	24.000 (0.5069) a
T_6	36.666 (0.649) bcd	38.000 (0.6624) bcdef
T_7	36.000 (0.643) bcd	38.667 (0.6710) cdef
T_8	14.000 (0.380) e	35.667 (0.6398) abcdef
T_9	16.666 (0.413) e	43.000 (0.7144) def
T_{10}	43.334 (0.718) abc	31.333 (0.5917) abcde
T_{11}	46.000 (0.745) abc	28.667 (0.5627) abc
T_{12}	44.666 (0.732) abc	30.000 (0.5786) abcd
T_{13}	49.334 (0.779) ab	25.333 (0.5263) ab
T_{14}	49.334 (0.779) ab	25.333 (0.5259) ab
T_{15}	38.000 (0.663) abcd	36.667 (0.6484) bcdef
T_{16}	38.000 (0.663) abcd	36.667 (0.6497) bcdef
T_{17}	16.000 (0.410) e	43.667 (0.7215) ef
T_{18}	10.666 (0.327) e	38.000 (0.6642) bcdef
T_{19}	28.000 (0.556) d	46.667 (0.7517) ef
T_{20}	18.000 (0.435) e	56.667 (0.8524) f
T_{21}	34.000 (0.621) cd	40.667 (0.6905) cdef
T_{22}	35.334 (0.636) cd	39.333 (0.6710) cdef

*Mean of 3 replications
Figures in parenthesis are transformed values

In each column figures followed by same letter donot differ significantly (p 0.05) according to DMRT potassium phosphonate (T_9) were found to be not effective in reducing disease incidence.

Data shown in Table 17 indicated maximum germination (65.33%) of brinjal seeds treated with in chlorothalonil (T_{14}) and minimum germination percentage of 32.00 (T_{17}) in potassium phosphonate treatments. With regard to control of pre-emergence damping-off, chlorothalonil (T_{14}) treatment was found to be most effective followed by Captan (T_{13}) and Bordeaux mixture (T_{18}). Maximum disease incidence was observed in treatments with metalaxyl (T_{11}), potassium phosphonate (T_{17}) and neem cake (T_{20}).

In tomato also the germination percentage was found to be high (50.67) when chlorothalonil (T_5) was applied (Table 18). Bordeaux mixture (T_8), potassium phosphonate (T_9) and neem cake (T_{20}) had low percentage germination to the tune of 14, 16.67 and 18 per cent respectively. Seed treatment with chlorothalonil (T_5) has showed the lowest pre-emergence damping-off (24%) followed by captan (T_{13}) (25%). The highest incidence (56%) was observed when neem cake (T_{20}) was used.

In case of post-emergence damping-off also disease incidence was comparatively low in summer season (Table 19). Statistically no significant difference between the treatments was noticed in the case of chilli, brinjal and tomato. Minimum damping-off was noticed in the case of seed and soil treatment with carbendazim (T_{15}) with regard to chilli (5.08%) and brinjal (5.33%) where it was mancozeb (5.67%) in case of tomato. Seed and soil treatment with carbendazim was also equally effective in tomato as it recorded only six per cent incidence. Apart from this fungicide, soil drenching with Bordeaux mixture and copper oxychloride were also found effective in all the three crops.

Table 19. Effect of different treatments on the management of post-emergence damping-off in solanaceous crops during summer

Treatment	Percentage post-emergence damping-off		
	Chilli	Brinjal	Tomato
T_1	*21.67 (0.419)	*17.00 (0.379)	*15.33 (0.304)
T_2	22.00 (0.43)	21.67 (0.432)	11.33 (0.316)
T_3	18.20 (0.424)	17.50 (0.383)	7.00 (0.232)
T_4	13.96 (0.378)	15.33 (0.361)	17.00 (0.375)
T_5	18.00 (0.441)	16.83 (0.366)	14.67 (0.326)
T_6	13.00 (0.327)	12.27 (0.317)	7.67 (0.220)
T_7	13.00 (0.363)	10.67 (0.279)	7.00 (0.240)
T_8	20.67 (0.410)	9.33 (0.283)	6.33 (0.233)
T_9	20.50 (0.462)	21.90 (0.417)	55.00 (0.839)
T_{10}	11.67 (0.316)	9.67 (0.277)	9.33 (0.235)
T_{11}	13.33 (0.334)	13.67 (0.340)	7.37 (0.254)
T_{12}	7.00 (0.248)	7.93 (0.255)	5.67 (0.193)
T_{13}	7.00 (0.246)	6.33 (0.231)	10.00 (0.251)
T_{14}	16.00 (0.369)	13.00 (0.333)	12.27 (0.309)
T_{15}	5.08 (0.214)	5.33 (0.197)	6.00 (0.231)
T_{16}	5.67 (0.222)	6.00 (0.226)	6.87 (0.246)
T_{17}	12.83 (0.330)	11.33 (0.304)	43.33 (0.527)
T_{18}	5.67 (0.230)	5.33 (0.218)	6.83 (0.240)
T_{19}	16.00 (0.411)	10.33 (0.298)	8.67 (0.272)
T_{20}	15.00 (0.333)	11.67 (0.310)	19.33 (0.404)
T_{21}	5.33 (0.218)	10.00 (0.290)	5.80 (0.225)
T_{22}	22.23 (0.486)	24.67 (0.502)	20.00 (0.422)
	NS	NS	NS

NS - Not significant
*Mean of 3 replication
Figures in paretheses are transformed values

4.8.5 Rainy season crop

During the rainy season, in all the three crops maximum percentage germination and minimum percentage damping-off were noticed in the treatments of solarization alone (T_{22}) and soil solarization + soil inoculation with antagonist (T_{23}). Among the fungicides, seed treatment with thiram (T_{10}) as well as chlorothalonil (T_5) gave good germination, while thiram (T_{10}) and Bordeaux mixture (T_{18}) gave better control of pre-emergence damping-off in all three crops (Table 20 to 22).

In chilli, lowest germination (10%) and highest pre-emergence damping-off (40.67%) was noticed when neem cake (T_{20}) used where as in brinjal metalaxyl (T_2) gave lowest germination (24%) and highest pre-emergence (52%) damping-off. In case of tomato lowest germination (4%) and highest pre-emergence damping-off was noticed when potassium phosphonate (56%) was used.

Effect of different treatments on post-emergence damping-off presented in Table 23, showed that soil drenching with Bordeaux mixture (T_{18}) was most effective which recorded only 11.67, 12.33 and 14 per cent incidence for chilli, brinjal and tomato respectively. Soil solarization + soil inoculation with antagonist (T_{23}) and soil drenching with fungicide such as captan (T_{13}), copper oxychloride (T_{16}), mancozeb (T_{12}), thiram (T_{10}), chlorothalonil (T_{14}) were also found to be statistically on par with Bordeaux mixture as regards the control of damping-off of all the three crops.

The least effective treatment in the control of post-emergence damping-off was found to be the application of neem cake (T_{20}).

Table 20. Effect of different treatments on the germination and pre-emergence damping-off in chilli during rainy season

Treatment	Percentage germination	Percentage pre-emergence damping-off
T_1	*35.67 (0.6394) bcd	*15.000 (0.3635) bc
T_2	17.66 (0.4326) i	33.000 (0.6104) ghij
T_3	12.00 (0.3511) jk	38.667 (0.6703) hig
T_4	31.00 (0.5901) cdefg	19.667 (0.4509) cde
T_5	31.33 (0.5940) cdefg	19.333 (0.4494) cde
T_6	20.00 (0.4636) hi	30.667 (0.5838) fghi
T_7	25.00 (0.5229) efgh	25.667 (0.5233) defg
T_8	15.67 (0.4064) ijk	30.000 (0.5795) fghi
T_9	27.33 (0.5500) efg	23.333 (0.4992) def
T_{10}	36.00 (0.6432) bc	14.667 (0.3640) bc
T_{11}	19.33 (0.4551) hi	31.333 (0.5914) fghij
T_{12}	11.33 (0.3433) jk	39.333 (0.6767) ij
T_{13}	32.00 (0.6010) cdef	19.000 (0.4379) cde
T_{14}	32.33 (0.6047) bcde	18.333 (0.4297) cd
T_{15}	19.67 (0.4587) hi	31.000 (0.5883) fghij
T_{16}	24.67 (0.5188) fgh	26.000 (0.5267) defg
T_{17}	28.00 (0.5573) defg	22.667 (0.4930) def
T_{18}	16.33 (0.4158) ij	29.333 (0.5714) fgh
T_{19}	25.67 (0.5307) efgh	25.000 (0.5189) defg
T_{20}	10.00 (0.2545) l	40.667 (0.6897) j
T_{21}	24.33 (0.5149) gh	26.333 (0.5365) efg
T_{22}	44.00 (0.7251) a	6.667 (0.2224) a
T_{23}	40.00 (0.6844) ab	10.667 (0.3291) b
T_{24}	10.33 (0.3267) kl	40.333 (0.6872) i

*Mean of 3 replications

Figures in parenthesis are transformed values

In each column figures followed by same letter donot differ significantly ($p = 0.05$) according to DMRT

Table 21. Effect of different treatments on the germination and pre-emergence damping-off in brinjal during rainy season

Treatment	Percentage germination	Percentage pre-emergence damping-off
T_1	*40.00 (0.6846) b	*36.000 (0.6362) bc
T_2	24.00 (0.5112) h	52.000 (0.8045) h
T_3	31.67 (0.5969) def	44.333 (0.7232) defgh
T_4	30.00 (0.5795) efg	46.000 (0.7413) efgh
T_5	32.33 (0.6045) cdef	43.667 (0.7153) cdefg
T_6	31.67 (0.5973) def	44.333 (0.7263) efgh
T_7	32.33 (0.6047) cdef	43.667 (0.7180) cdefgh
T_8	34.67 (0.6291) bcde	36.333 (0.6384) bcd
T_9	30.67 (0.5868) ef	40.333 (0.6842) bcdef
T_{10}	36.67 (0.6501) bcd	39.333 (0.6675) bcde
T_{11}	25.00 (0.5234) gh	51.000 (0.7948) gh
T_{12}	30.67 (0.5868) ef	45.333 (0.7357) efgh
T_{13}	30.67 (0.5868) ef	45.333 (0.7357) efgh
T_{14}	30.00 (0.5795) efg	46.000 (0.7416) efgh
T_{15}	33.00 (0.6117) cdef	43.000 (0.7121) cdefg
T_{16}	32.00 (0.6011) def	44.000 (0.7222) cdefgh
T_{17}	29.67 (0.5737) efg	40.667 (0.6856) bcdef
T_{18}	38.00 (0.6641) bc	33.000 (0.6055) b
T_{91}	31.00 (0.6259) cde	45.000 (0.7336) efgh
T_{20}	28.00 (0.5574) fgh	48.000 (0.7641) fgh
T_{21}	33.33 (0.6145) cdef	42.617 (0.7014) cdef
T_{22}	50.33 (0.7887) a	25.667 (0.5101) a
T_{23}	51.67 (0.8021) a	24.333 (0.4994) a
T_{24}	28.33 (0.5604) fgh	47.667 (0.7592) fgh

*Mean of 3 replications
Figures in parentheses are transformed values
In each column figures followed by same letter donot differ significantly ($p=0.05$) according to DMRT

Table 22. Effect of different treatments on the germination and pre-emergence damping-off in tomato during rainy season

Treatment	Percentage germination	Percentage pre-emergence damping-off
T_1	*27.33 (0.5499) abc	*47.333 (0.7581) abcde
T_2	23.00 (0.4994) cde	51.667 (0.8033) bcdef
T_3	24.67 (0.5186) bcf	50.000 (0.7864) bcdef
T_4	24.67 (0.5196) bcd	50.000 (0.7858) bcdef
T_5	27.00 (0.5448) abc	47.667 (0.7611) abcdef
T_6	25.67 (0.5297) bcd	49.000 (0.7762) abcdef
T_7	22.67 (0.4956) cde	52.000 (0.8064) cdef
T_8	16.67 (0.4203) e	45.000 (0.7345) abcd
T_9	4.00 (0.2014) d	55.667 (0.8437) ef
T_{10}	27.67 (0.5533) abc	47.000 (0.7550) abcde
T_{11}	24.67 (0.5186) bcd	50.000 (0.7864) bcdef
T_{12}	24.33 (0.5155) bcd	50.333 (0.7889) bcdef
T_{13}	24.00 (0.5117) bcd	50.667 (0.7926) bcdef
T_{14}	29.33 (0.5714) abc	45.333 (0.7384) abcd
T_{15}	24.67 (0.5188) bcd	50.000 (0.7863) bcdef
T_{16}	21.67 (0.4840) cde	53.000 (0.8166) def
T_{17}	3.67 (0.1923) f	56.000 (0.8476) f
T_{18}	18.33 (0.4423) de	43.333 (0.7173) abc
T_{19}	29.00 (0.5682) abc	45.667 (0.7408) abcd
T_{20}	23.00 (0.4994) cde	51.667 90.8033) bcdef
T_{21}	28.00 (0.5553) abc	46.667 (0.7517) abcd
T_{22}	31.67 (0.5976) ab	43.000 (0.7143) ab
T_{23}	33.67 (0.6189) a	41.000 (0.6936) a
T_{24}	22.33 (0.4875) cde	52.333 (0.8115) def

*Mean of 3 replications
Figures in parentheses are transformed values
In each column figures followed by same letter donot differ significantly ($p=0.05$) according to DMRT

Table 23. Effect of different treatments on the management of post-emergence damping-off in solanaceous crops during rainy season

Treatment	Percentage post-emergence damping-off		
	Chilli	Brinjal	Tomato
T_1	*31.33 (0.5856) bcd	*29.33 (0.572) abcde	*36.67 (0.6308) abcd
T_2	33.00 (0.5992) bcd	37.33 (0.6524) bcde	36.00 (0.6237) abcd
T_3	44.00 (0.7215) cde	41.33 (0.6973) de	34.33 (0.5993) abcd
T_4	21.00 (0.4712) abc	19.50 (0.4517) abcd	26.07 (0.4600) cd
T_5	29.33 (0.5675) abcd	40.33 (0.6849) cde	32.00 (0.6013) abcd
T_6	26.67 (0.5373) abcd	36.67 (0.6497) bcde	45.33 (0.7383) bcd
T_7	21.33 (0.4797) abcd	19.33 (0.4483) abcd	29.00 (0.5558) abc
T_8	20.67 (0.4682) abc	20.00 (0.4586) abcd	25.00 (0.5165) abc
T_9	43.67 (0.7200) cde	40.33 (0.6857) cde	50.00 (0.7845) cd
T_{10}	18.83 (0.4462) ab	18.83 (0.4354) abcd	24.33 (0.4939) abc
T_{11}	25.33 (0.5021) abcd	26.00 (0.4627) abcd	20.33 (0.4586) ab
T_{12}	23.67 (0.5022) abcd	15.50 (0.3918) abc	20.50 (0.4442) ab
T_{13}	15.17 (0.3944) ab	13.17 (0.3643) ab	17.00 (0.4162) ab
T_{14}	17.33 (0.4183) ab	24.33 (0.5093) abcd	22.00 (0.4854) abc
T_{15}	18.33 (0.4393) ab	20.67 (0.4567) abcd	32.67 (0.5992) abcd
T_{16}	16.33 (0.4088) ab	18.33 (0.4319) abcd	18.00 (0.4310) ab
T_{17}	19.00 (0.4482) ab	21.00 (0.4526) abcd	36.00 (0.6403) abcd
T_{18}	11.67 (0.3223) a	12.33 (0.3241)a	14.00 (0.3583) a
T_{19}	33.33 (0.6137) bcd	33.00 (0.5998) abcde	32.33 (0.6045) abcd
T_{20}	44.33 (0.7269) de	39.67 (0.6790) cde	42.00 (0.6926) bcd
T_{21}	18.00 (0.4369) ab	29.67 (0.5728) abcde	29.67 (0.5723) abcd
T_{22}	20.00 (0.4582) ab	25.00 (0.5003) abcd	28.00 (0.5554) abc
T_{23}	14.33 (0.3827) ab	19.00 (0.4339) abcd	17.83 (0.4332) ab
T_{24}	58.83 (0.8700) e	53.00 (0.8166) e	59.33 (0.8800) d

*Mean of 3 replications
Figures in parentheses are transformed values
In each column figures followed by same letter donot differ significantly (p=0.05) according to DMRT

4.8.6 Other nursery diseases

Other nursery diseases of solanaceous crops were also recorded during both the seasons.

Summer season

Bacterial wilt

0.10 per cent bacterial wilt incidence was observed in tomato where as chilli and brinjal were completely free from wilt incidence.

Leaf spot disease

Cercospora leaf spot caused by *C. capsici* was observed in chilli seedlings. The disease incidence was very meagre (0.25%) and the disease intensity was 9.6 per cent.

In brinjal, leaf spot caused by *Alternaria solani* was observed causing 0.02 per cent incidence and 16 per cent disease intensity.

In tomato, mild disease intensity (6.4%) of early blight caused by *Alternaria solani* was observed in the seedlings and the disease incidence was only 0.02 per cent.

Rainy season

In rainy season, leaf blight disease caused by *Phytophthora parasitica* was severe in all the three crops and the disease incidence was 58, 53 and 59 and disease intensity was 60, 50 and 60 per cent in chilli, brinjal and tomato respectively.

Discussion

DISCUSSION

Among the various diseases of solanaceous vegetables, damping-off causes considerable damage in the nursery. The disease is responsible for the poor germination and seedling stand in nursery beds and often carries the pathogen to the main fields where transplanting is done. In Kerala, the disease is more serious in rainy season and the mortality of seedlings sometimes reach to the extent of 100 per cent during this period. Usually, the disease incidence can be reduced with certain fungicides but complete control of the disease is not yet achieved.

A perusal of literature revealed that work on damping-off of vegetables in Kerala was scanty. There is no information available on the cause of this disease and about the disease management practices except the work of Kurian (1992), regarding the effectiveness of solarization on damping-off of chillies. In view of the above facts, an investigation was carried out to study certain aspects of damping-off disease of solanaceous crops in Kerala, particularly the etiology and management using chemical and biological means.

Bacterial wilt of solanaceous vegetables is a major problem in the acid lateritic, soils of Kerala. Hence, the popular bacterial wilt resistant varieties of chilli, brinjal and tomato viz., Ujjwala, Surya and Sakthi were used for the experiments.

Several fungi found on the seeds of vegetables are known to cause considerable damage either directly to the seeds that carry them or to the crops that are raised from such contaminated seed stock. They may cause reduction or complete inhibition of germination or poor development of seedlings showing various kinds of disease symptoms. So the first attempt of the investigation was to find out the mycoflora responsible for poor germination of seeds.

In blotter experiment, common storage fungi like *Aspergillus niger, A. flavus, Penicillium* sp. and *Rhizopus stolonifer* were found associated with the seeds of chilli, brinjal and tomato. Das and Narain (1982) observed *Penicillium* sp. *Aspergillus* sp. and *Alternaria alternata* associated with tomato seeds and Naseema *et al.* (1983) also observed *A. niger* and *R. stolonifer* on brinjal and tomato seeds. Apart from these storage fungi, pathogenic fungi *Curvularia lunata, Drechslera rostrata* and *Alternaria* sp. were also isolated from chilli, brinjal and tomato respectively. Gupta and Basuchaudhary (1995) observed *Curvularia lunata* on chilli and brinjal and *Drechslera austrgliensis* on brinjal. Naseema *et al.* (1983) isolated *D. rostrata* from cowpea seeds. However, the presence of *D. rostrata* on brinjal seeds was not observed so far.

The germination percentage or the viability of the solanaceous seeds were found to be different in blotter, pot culture and field experiments. The percentage of germination of chilli, brinjal and tomato were 70, 87 and 90 respectively in blotter method where as in pot culture and field experiments germination percentages were 53, 73, 86 and 51, 76, 75 respectively.

The next aspect of the investigation was to find out the pathogens responsible for pre and post-emergence damping-off. The pathogens responsible for damping-off disease were found to vary with the season. During summer season, *Rhizoctonia solani* was found to be predominantly associated with pre and post-emergence damping-off in all the three crops. Singh and Srivastava (1953), and Govindappa and Grewal (1965) have reported the ability of *Rhizoctonia solani* to cause pre and post-emergence damping-off in tomato. Sahni *et al.* (1967) observed this pathogen associated with chilli damping-off.

During rainy season, *Pythium aphanidermatum* and *Phytophthora parasitica* were the main pathogens responsible for pre and post-emergence damping-off. The ability of *Pythium* spp. and *Phytophthora* spp. in causing damping-off had already been reported by several workers (Gattani and Kaul, 1951; Singh and Srivastava, 1953; Sahni *et al.*, 1967; Raicu and Stan, 1973; Patel and Patel, 1976).

In the present study, among the different species of *Pythium* only *Pythium aphanidermatum* was found associated with damping-off disease. Gattani and Kaul (1951) and Patel and Patel (1976) also observed *P. aphanidermatum* as the major causal organism of damping-off. Middleton (1943) reported nine more species of *Pythium* in addition to *P. aphanidermatum* as the cause of damping-off of tomato. However, other species of *Pythium* were not found associated with damping-off in this acid lateritic soil.

Singh and Srivastava (1953) and Raicu and Stan (1973) also observed *Phytophthora parasitica* as the cause of damping-off of tomato.

The Pythiaceous fungi are extremely susceptible to desiccation and water is essential for the sporangial germination of these fungi. So, the disease caused by these fungi are severe during rainy season.

In addition to *Pythium* and *Phytophthora*, *Drechslera rostrata* was also found to cause post-emergence damping-off in all the three crops and *Curvularia lunata* only on chilli. Singh and Srivastava (1953) isolated *Helminthosporium* sp. from tomato seedlings affected by damping-off and reported to be non-pathogenic.

It was also observed that in both seasons, maximum pre and post-emergence damping-off incidence was observed in tomato. This may be due to the more succulent nature of tomato when compared to brinjal and chilli. As the succulence of the plant increases susceptibility to damping-off also increases (Agnihotri and Sinha, 1986).

The morphological characters of the pathogens, *Pythium aphanidermatum* (Waterhouse and Waterston, 1964), *Phytophthora parasitica* (Waterhouse and Waterston, 1964), *Rhizoctonia solani* (Duggar, 1915; Townsend and Willetts, 1954). *Drechslera rostrata* and *Curvularia lunata* (Subramanian, 1971) have been studied in detail by various workers. In the present study also, the morphological characters of these organisms were in line with that described by the above workers.

Development of a disease in the plant is not a sudden effect. A chain of events are responsible for causation of any disease. The symptoms and manifestation of injury to the plant is the last event in this chain of events. In the present study, rotting of the seeds was the symptom observed in pre-emergence damping-off while post-emergence damping-off was characterised by sudden collapsing of the seedling. The symptoms observed in this study were similar to those described by the earlier workers (Singh and Srivastava, 1953; Ramakrishnan *et al.*, 1973; Agnihotri and Sinha, 1986). However, slight variations in the symptoms were observed with different causal organisms. In *P. aphanidermatum*, infected tissues at the collar region appeared water soaked, stem became constricted at the base and plants collapsed, where as in *P. parasitica*, in addition to collar rot, rotting of the entire stem and leaves were observed. Brown necrosis of the collar region was the main symptom observed in case of *D. rostrata*, *R. solani* and *Curvularia lunata*.

Genetic response of the host to the pathogen is an innate plant factor determining success of infection. A genetically susceptible plant is infected readily and rapidly while a resistant plant puts up obstacles in the way of penetration and establishment of pathogen. Moreover, use of resistant varieties for controlling plant disease is a cheap, harmless and ecofriendly method. Thus, an attempt was made to screen available chilli, brinjal and tomato varieties/genotypes against damping-off pathogens under natural condition.

None of the varieties/genotypes tested under the study was found to be immune to the disease in both seasons. However, certain varieties of chilli, brinjal and tomato were found resistant to damping-off pathogens. Chilli genotypes Surakta and LCA-304 showed disease incidence of only 10.6 and 18.2 percentage and were resistant in summer where as in rainy season Surakta recorded 22 percentage incidence showing moderately resistant reaction. Like wise BC-14-2, LCA-301 which were highly resistant in rainy season were found to be moderately resistant in summer where as RHRC clustering (pendent) showing 9.1 per cent incidence in rainy season recorded 59.6 percentage in summer.

In case of brinjal, Arka Keshav and BB-60-C showed only 10 and 13.5 percentage damping-off in summer whereas in rainy season Arka Keshav was only moderately resistant with 39.4 per cent disease incidence.

Tomato accessions LE-79-5 and BT-1 were found to be resistant during summer with 9.8 and 10.1 per cent infection while BT-1 was moderately resistant in rainy season.

It is quiet evident from the foregoing discussion that, the genotypes found resistant in summer were found to be moderately resistant or moderately susceptible in rainy season or vice versa, indicating that the reactions of genotypes varied with different pathogens associated with damping-off in both seasons. However, certain genotypes like LCA-304 of chilli, BB-60-C of brinjal and LE-79-5 of tomato showed mild incidence in both seasons indicating resistance to all damping-off pathogens associated with the disease.

A search on literature revealed that there is no information about the varietal reactions to damping-off disease of solanaceous vegetables. The earlier reports indicated that damping-off is caused by a number of pathogens (Singh, 1987). So the varieties developed should be resistant to all these pathogens which is quite impossible and cumbersome.

An appropriate approach for disease management will be integration of methods directed against the pathogen, in favour of the host and for modification of the environment. For this, the most effective way is the use of resistant varieties supplemented with cultural, chemical and biological methods and most of these methods were tried against damping-off disease by various workers (Humbert, 1918; Jacks, 1951; Strong, 1954; Wright, 1956; Dwivedi and Chaube, 1985; Satour *et al.*, 1991). However, the report on the management of damping-off disease in Kerala is very meagre except the study of Kurian (1992) on the effect of solarization on damping-off of chillies. So the next point of investigation was to find out the effective management practices against damping-off of solanaceous vegetables.

In bioassay of six fungicides, Bordeaux mixture and copper oxychloride gave hundred per cent inhibition in growth of *P. aphanidermatum* and *P. parasitica* in potato dextrose agar medium. Chlorothalonil was found to be less effective and the inhibition percentage was below 50 percentage. The efficacy of Bordeaux mixture and Fytolan in inhibiting the growth of *P. aphanidermatum* has been established by Shanmugham (1996). Similarly the efficacy of Bordeaux mixture and Fytolan in inhibiting the growth of *Phytophthora* sp. was proved by Mammootty (1978) and Edwin Prem (1995).

In the case of *R. solani* and *D. rostrata* all fungicides tested were found equally effective and maximum inhibition was observed when Bordeaux mixture was used. Sen and Kapoor (1975) observed inhibition of *R. solani* using Captaf and Dithane M-45. In the present study mancozeb and captan were also found to be effective in inhibiting the growth of *R. solani* and *D. rostrata*.

In vitro evaluation of *T. viride* against all the isolated pathogens of damping-off showed strong antagonistic property. The antagonist when contacted the pathogens, parasitized them and slowly caused die-back and disintegration of the pathogens. Thus the present study showed the hyperparastic ability of *T. viride* on *P. aphanidermatum, P. parasitica, R. solani* and *D. rostrata*. The antagonistic property of *T. viride* against *P. aphanidermatum* (Shanmugham, 1996), *P. parasitica* var. *piperina* (Vyas *et al.*, 1981), *R. solani* (Marchetti *et al.*, 1992) and *Drechslera* sp. (Pande, 1985) were reported by various workers under *in vitro* conditions.

Management of soil-borne diseases seems to be much more complex than that of air-borne diseases as in the former, application of chemical is difficult and extremely costly. Hence, successful management of soil-borne diseases can be achieved only through an integration of various methods such as physical, chemical and biological means. With this view, a field experiment was carried out to find out the effect of fungicides, antagonist, organic amendment and solarization on germination and incidence of pre and post-emergence damping-off of solanaceous vegetables in summer and rainy seasons.

Among the different fungicides tested, seed treatment with chlorothalonil and thiram @ 2 g/kg seed gave maximum germination in both seasons. Similar beneficial effects of seed treatment with these chemicals have been noted in a trial conducted at Durgapura (Kalloo *et al.*, 1995).

During the course of present study, it was also observed that seed treatment with 1 per cent Bordeaux mixture and 0.3 per cent potassium phosphonate had affected the germination of solanaceous seeds and drastic reduction in germination was observed in case of tomato. Tomato seeds have delicate seed coat as compared to brinjal and tomato. Sensitivity of tomato seeds to Bordeaux mixture and potassium phosphonate may be due to the alkaline and acidic reactions of these chemicals. Lime is added to Bordeaux mixture to reduce phytotoxicity, but sometimes lime itself may be injurious. Horsfall *et al.* (1938) also reported injury in tomatoes due to Bordeaux mixture. Likewise, acidic reactions of potassium phosphonate may be the reason for low germination in tomato. Choudhury ([illegible]) reported that tomatoes do best in a soil that has a soil reaction from pH 6.0 to 7.0

and is not recommended in soil where pH 5.0 or lower. Thus, from the present study it was found that Bordeaux mixture and Potassium phosphonate can not be recommended for seed dressing because of their deleterious effect on germination of solanaceous vegetable seeds especially in the case of tomato.

Effect of solarization on germination of chilli seeds was reported by Kurian (1992). During the present study also maximum germination of all solanaceous seeds was observed in solarized beds as compared to all other treatments in rainy season.

Solarization not only induced good germination but also gave vigorous and taller seedlings. Chen and Katan (1980) and Kurian (1992) observed significant increase in organic content and available P and K in the solarized plots. This may be the reason for increased vigour of seedlings in the solarized plots.

Application of neem cake to the soil was found to reduce the germination of all solanaceous seeds. Russel (1977) reported that incorporation of organic materials into moist warm soil and resultant development of large volume of anaerobic sites can lead to problems of plant growth reduction because of production of acetic acid, butyric acid, reduced sulfur compounds and other volatile compounds which are injurious to plant roots.

Next point to be discussed is the effectiveness of chemical, cultural and biological methods in reducing pre and post-emergence damping-off in summer and rainy seasons.

In case of pre-emergence damping-off, significant difference was noticed among the treatments in both seasons. In summer, seed treatment with chlorothalonil @ 2 g/kg seed was found to be most effective in reducing pre-emergence damping-off in chilli, brinjal and tomato. Other fungicides such as captan, Bordeaux mixture and thiram also gave good control of pre-emergence damping-off in all the three crops, while soil application of neem cake was found to be not much effective in checking pre-emergence damping-off.

In rainy season, lowest incidence of pre-emergence damping-off was observed in solarized beds. Among the chemicals, thiram and Bordeaux mixture treatments were found effective in reducing pre-emergence damping-off. Reviewing the effect of fungicidal treatments, it was found that seed treatment with chlorothalonil and thiram @ 2 g/kg seed gave not only good germination, but also provided better control of pre-emergence damping-off. In addition to this, 1 per cent Bordeaux mixture was also effective in checking pre-emergence damping-off in both seasons. However, the efficacy of Bordeaux mixture in reducing pre-emergence damping-off was not useful since it cannot be used for seed treatment due to its deleterious effect on germination.

The seed protecting quality of thiram from fungal pathogens like *Pythium*, *Phytophthora* and *Rhizoctonia* was reported by various workers (Georgieva *et al.*, 1970; Sarade and Kadam, 1977; Naseema *et al.*, 1983). Like-wise Grewal and Singh (1965) observed good control of damping-off of cabbage caused by *R. solani* with Captaf seed treatment. So the present study is in line with the findings of earlier workers.

With regard to post-emergence damping-off no appreciable difference could be noticed among the treatments during summer season. Under *in vitro* studies also all fungicides tested were found equally effective against *R. solani*. However, lowest disease incidence of chilli, brinjal and tomato was noticed in nursery beds in which seed treatment and soil drenching of carbendazim (0.1%), copper oxychloride (0.3%) and Bordeaux mixture (1%) were done. Effectiveness of carbendazim, Boardeaux mixture and copper oxychloride against *R. solani* was reported by Sen and Kapoor (1975), Zengni (1978) and Vir and Hooda (1989). Moreover, in the course of present study it was also observed that seedlings in the carbendazim and chlorothalonil treated beds were more vigorous and tall as compared to other treatments in both seasons.

During rainy season, significant difference was noticed among the treatments. Soil drenching with 1 per cent Bordeaux mixture just after germination and 20 days after germination gave maximum control of post-emergence damping-off followed by soil solarization and soil inoculation with *Trichoderma viride*. Successful control of damping-off pathogens by soil drenching with Bordeaux mixture has been reported by various workers (Humbert, 1918; Zengni, 1978; Patel *et al.*, 1987). The effectiveness of solarization for the control of *P. aphanidermatum* causing pre and post-emergence damping-off in chilli and soft rot of ginger has been established by Kurian (1992) and Vilasini (1996). Krishnamoorthy and Bhaskaran (1990) and Theradi Mani and Marimuthu (1994) observed good control of damping-off caused by *P. ultimum* and *P. aphanidermatum* in tomato and chilli respectively with *T. viride* and *T. harzianum*. In the present investigation, the combination of solarization and antagonist gave better control than these treatments alone. However, Vilasini (1996) observed that solarization alone was better than the combination of solarization and antagonist, where the antagonist was applied before solarization in controlling *P. aphanidermatum* causing soft rot of ginger. So the present study revealed that the application of antagonist after solarization is more effective in controlling soil-borne pathogens.

In addition to the above treatments, seed treatment and soil drenching with captan, copper oxychloride, mancozeb, thiram and chlorothalonil were also found effective in reducing post-emergence damping-off. The efficacy of these fungicides in reducing damping-off infection in solanaceous vegetables have been reported by many workers (Grover and Dutt, 1972; Ramakrishnan *et al.*, 1973; Kalloo *et al.*, 1995). So the present findings are in agreement with the findings of earlier workers.

It was also observed that soil application of neem cake was least effective in controlling post-emergence damping-off. Kurian (1992) also observed that application of neem cake amendment did not effectively reduce the damping-off infection even with solarization.

There are reports that seed treatment alone can check the damping-off disease (Sanchez, 1956; Jharia *et al.*, 1977). But in the present study it was observed that combination of seed treatment and soil drenching of fungicides were more effective than seed treatment alone in checking post-emergence damping-off especially during rainy season.

From the overall findings on disease management some notable observations are to be pointed out that solarization of nursery beds was most effective in reducing damping-off disease in rainy season. Among plant protection chemicals, seed treatment with chlorothalonil and thiram induced better germination and also reduced pre-emergence damping-off. Soil drenching with 1 per cent Bordeaux mixture was found most effective in controlling post-emergence damping-off. In addition to Bordeaux mixture, copper oxychloride (in summer season) and captan, copper oxychloride, thiram and chlorothalonil (in rainy season) also gave good control of damping-off disease. Hence, these fungicides can also be utilized for the management of damping-off disease of solanaceous vegetables.

Summary

SUMMARY

Chilli, brinjal and tomato are the most popular and commonly cultivated solanaceous vegetables in Kerala and damping-off disease is a major constraint in raising seedlings of these crops especially during monsoon period. Considering the seriousness of the disease and non-availability of information regarding the cause and management of this disease under Kerala conditions, the present work has been carried out to study the etiology and management of damping-off disease in solanaceous vegetables. Most popular and bacterial wilt resistant varieties of chilli (Ujjwala), brinjal (Surya) and tomato (Sakthi) were used for the experiments.

In blotter method, fungi like *Aspergellus niger, A. flavus, Rhizopus stolonifer* and *Penicillium* sp. were found associated with solanaceous seeds and caused only partial inhibition in germination of seeds. Apart from these fungi, *Curvularia lunata, Drechslera rostrata* and *Alternaria* sp. were isolated from seeds of chilli, brinjal and tomato respectively.

Pathogens such as *Rhizoctonia solani* (in summer season), *Pythium aphanidermatum, Phytophthora parasitica* and *Drechslera rostrata* (in rainy season) were found to be associated with pre and post-emergence damping-off of chilli, brinjal and tomato. *Curvularia lunata* was found associated with only chilli seedlings.

Compared to summer, damping-off incidence was high during rainy season and in both seasons maximum pre and post-emergence damping-off incidence was observed in tomato. In pre-emergence damping-off the young seedlings were

killed before they reach the soil surface while post-emergence phase was characterized by sudden collapsing of seedlings. Slight variation in symptoms were observed with different pathogens.

Reactions of varieties/genotypes of chilli, brinjal and tomato to damping-off pathogens were studied under natural conditions and none of the varieties/genotypes tested under the study was found to be immune to the disease in both seasons. However, chilli genotypes Surakta and LCA-304; brinjal genotypes, Arka Keshav and BB-60-C and tomato accessions LE-75-5 and BT-1 were found to be resistant during summer. Likewise RHRC clustering (pendent) of chilli, BB-60-C of brinjal and BT- 1 of tomato were found to be resistant during rainy season. Genotypes namely LCA-304 of chilli, BB-60-C of brinjal and LE-79-5 of tomato showed resistance to damping-off in both season.

Among six fungicides tested in *in vitro* Bordeaux mixture (1%) and copper oxychloride (0.3%) gave cent per cent inhibition of growth of *Pythium aphanidermatum* and *Phytophthora parasitica*. In case of *Drechslera rostrata* and *Rhizoctonia solani* all the treatments were found equally effective and maximum inhibition was observed in 1% Bordeaux mixture.

In vitro evaluation of *Trichoderma viride* against damping-off pathogens resulted in dieback and disintegration of mycelium of all the pathogens.

In field studies among chemical seed treatments, chlorothalonil and thiram @ 2 g/kg seed gave maximum germination in both seasons, whereas lowest germination was observed in seeds treated with 1 per cent Bordeaux mixture and potassium phosphonate (0.3%).

In summer, chlorothalonil seed treatment was found to be most effective in reducing pre-emergence damping-off followed by treatments with captan, Bordeaux mixture and thiram. During rainy season, maximum seed germination, and minimum pre-emergence damping-off was observed in solarized beds in all the three crops.

With regard to post-emergence damping-off, significant difference among treatments was not noticed in summer season. However, lowest disease incidence of chilli, brinjal and tomato was noticed in nursery beds in which seed and soil were treated with carbendazim, copper oxychloride and Bordeaux mixture.

During rainy season, soil drenching with 1% Bordeaux mixture gave maximum control of post-emergence damping-off. Besides Bordeaux mixture, seed treatment and soil drenching with captan, copper oxychloride, mancozeb, thiram and chlorothalonil were also found to be effective in reducing post-emergence damping-off. The combination of solarization and antagonist gave better control of post-emergence damping-off than application of these treatments individually.

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*Originals not seen

Appendix

APPENDIX-I

Potato dextrose agar medium

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

ETIOLOGY AND MANAGEMENT OF DAMPING - OFF OF SOLANACEOUS VEGETABLES

By

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ABSTRACT OF A THESIS

Submitted in partial fulfilment of the requirement for the degree of

Master of Science in Agriculture

Faculty of Agriculture

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1996

ABSTRACT

The etiology and management studies of damping-off of chilli, brinjal and tomato were carried out at the College of Horticulture, Vellanikkara, Thrissur during 1994-95. Bacterial wilt resistant varieties like Ujjwala of chilli, Surya of brinjal and Sakthi of tomato were used for the study.

Fungi like *Aspergillus niger, A. flavus, Penicillium* sp. and *Rhizopus stolonifer* were found associated with the seeds of chilli, brinjal and tomato. In addition, *Curvularia lunata, Drechslera rostrata* and *Alternaria* sp. were isolated from chilli, brinjal and tomato respectively.

The pathogens responsible for pre and post-emergence damping-off were *Rhizoctonia solani* in summer and *Pythium aphanidermatum, Phytophthora parasitica* and *Drechslera rostrata* in rainy season.

In varietal reaction, none of the varieties/genotypes was found to be immune to the disease. However, certain genotypes like LCA-304 of chilli, BB-60-C of brinjal and LE-79-5 of tomato showed resistance in both seasons.

In *in vitro* studies, Bordeaux mixture (1%) and copper oxychloride (0.3%) completely inhibited the growth of *P. aphanidermatum* and *P. parasitica* where as all six fungicides tested were found equally effective against *R. solani* and *D. rostrata*.

In vitro evaluation of *Trichoderma viride*, against all the isolated organisms of damping-off resulted in die-back and disintegration of the pathogens.

Among the fungicides, seed treatment with chlorothalonil and thiram @ 2 g/kg seed gave maximum germination and minimum incidence of pre-emergence damping-off in both seasons. Bordeaux mixture (1%) and potassium phosphonate (0.3%) have affected the germination of seeds especially in tomato. In rainy season, compared to all other treatments, maximum germination, and minimum pre-emergence damping-off was observed in solarized plots. Carbendazim (0.1%) and Bordeaux mixture (1%) treatments were found to be most effective in controlling post-emergence damping-off during summer and rainy season respectively. Solarization followed by application of antagonist was also equally effective as Bordeaux mixture treatment in rainy season.