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**NURSERY DISEASES OF BLACK PEPPER
(*Piper nigrum* L.) IN KERALA WITH SPECIAL
REFERENCE TO THE MANAGEMENT OF
Phytophthora capsici Leonian, emend. Alizadeh and Tsao**

**By
K. P. MAMMOOTTY**

THESIS

**Submitted in partial fulfilment of the
requirement for the degree of**

Doctor of Philosophy in Agriculture

**Faculty of Agriculture
Kerala Agricultural University**

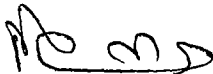
**Department of Plant Pathology
COLLEGE OF HORTICULTURE
VELLANIKKARA, THRISSUR - 680 656
KERALA, INDIA**

2003

DECLARATION

I hereby declare that this thesis entitled "Nursery diseases of black pepper (*Piper nigrum* L.) in Kerala with special reference to the management of *Phytophthora capsici* Leonian, emend. Alizadeh and Tsao" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

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K.P. Mammotty

CERTIFICATE

Certified that this thesis, entitled "Nursery diseases of black pepper (*Piper nigrum* L.) in Kerala with special reference to the management of *Phytophthora capsici* Leonian, emend. Alizadeh and Tsao" is a record of research work done independently by Mr.K.P. Mammootty under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

Vellanikkara

21/8/2003



Dr. Koshy Abraham
Chairman of Advisory Committee
Associate Professor and Head
Department of Plant Pathology
College of Horticulture
Vellanikkara

CERTIFICATE

We, the undersigned members of the Advisory Committee of Mr.K.P. Mammooty, a candidate for the degree of Doctor of Philosophy in Agriculture, agree that this thesis entitled "Nursery diseases of black pepper (*Piper nigrum* L.) in Kerala with special reference to the management of *Phytophthora capsici* Leonian, emend. Alizadeh and Tsao" may be submitted by Mr.K.P. Mammooty, in partial fulfilment of the requirement for the degree.



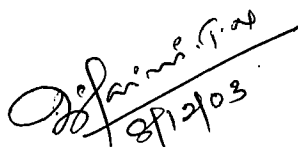
Dr. Koshy Abraham
(Major Advisor)
Associate Professor and Head
Department of Plant Pathology
College of Horticulture
Vellanikkara



Dr. A. Sukumara Varma
Associate Dean (Rtd.)
College of Horticulture
Vellanikkara
(Member)



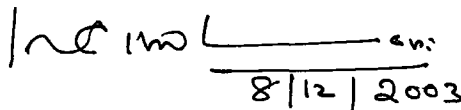
Dr. M.V. Rajendran Pillai
Associate Professor
Department of Plant Pathology
College of Horticulture
Vellanikkara
(Member)



Dr. T.N. Vilasini
Associate Professor
Onattukara Regional Agricultural
Research Station, Kayamkulam
(Member)



Dr. E.V. Nylke
Associate Professor and Head
Department of Plantation Crops & Spices
College of Horticulture
Vellanikkara
(Member)



EXTERNAL EXAMINER

Dr. R. Chandra Mohanan
M.Sc; Ph.D; F.P.S.I.
Principal Scientist (Plant Pathology)
Central Plantation Crops Research Institute (I.C.A.R.)
Regional Station, Kayamkulam.
KRISHNAPURAM- 690 533

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Dedicated to

*Dr. J. Premanathan &
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Introduction

INTRODUCTION

Black pepper (*Piper nigrum* L.), renowned as 'King of Spices' is one of the most important export oriented spice crops of India with a substantial share in foreign exchange earning. Kerala accounts for more than 90 per cent of the area under black pepper in India. In spite of conducive agroclimatic situations prevailing in Kerala, it is paradoxical that the productivity of the crop in the state is no way near to the world average. Many reasons are attributed for this peculiar situation. One of the major reasons is the high incidence of diseases especially the dreadful *Phytophthora* disease.

Black pepper is propagated through rooted cuttings raised in nurseries. Every year several thousands of rooted cuttings are being produced by government and non-governmental agencies. The conditions provided and the practices followed in black pepper nurseries are ideal not only for better growth and establishment of cuttings but also for the massive build up of diseases. As a result, heavy casualties do occur in pepper nurseries every year. Sarma *et al.* (1991) reported that black pepper is affected by about 17 diseases. Among these, the occurrence of diseases incited by *Phytophthora capsici*, *Pythium* sp., *Rhizoctonia solani*, *Sclerotium rolfsii* and *Colletotrichum gloeosporioides* were reported in nurseries by Mammooty and Pillai (1981) and Sarma *et al.* (1987). Among the reported nursery diseases, *Phytophthora* rot causes extensive damage to the nursery during South West monsoon period.

Though, the exact data on extent of losses caused by the nursery diseases are lacking, there are instances of complete damage of pepper cuttings in nurseries due to *Phytophthora* rot. It is estimated that on a global scale, crop loss due to *Phytophthora* foot rot accounts for about 4.5-7.5 million US dollars (Rajan *et al.*, 2002) and a loss of about 30 per cent was reported from Kerala (Samraj and Jose, 1966 and Nambiar and Sarma, 1977).

Since diseases affecting nurseries drastically reduce the production of quality rooted cuttings, concerted efforts are warranted to contain the incidence of such diseases. Further, there is every possibility that new diseases which were not

reported earlier may also occur in the nurseries. Thus, detailed investigations are necessary for better understanding of the diseases so that appropriate remedial measures could be adopted. Another matter of great concern is that many of the nursery diseases will be carried to the main field if cuttings from infected nurseries are used for planting in the main field which, under favourable climatic conditions, may bring out widespread occurrence of the diseases.

One of the practical ways of managing diseases is the identification and use of resistant / tolerant genotypes against diseases. Eventhough, studies conducted on the reaction of pepper genotypes against *Phytophthora* rot failed to identify a resistant type, there are reports indicating variation in response of the genotypes against the disease.

Successful control of *Phytophthora* rot in black pepper nurseries using chemicals especially Bordeaux mixture has been reported (Sasikumaran *et al.*, 1981 and Ramachandran *et al.*, 1991). However, deleterious effects on the ecosystem due to constant and continuous use of chemical fungicides elucidate the need for eco-friendly disease management practices. This was found good especially in the case of *Phytophthora* rot disease. Research works conducted during the past so many years had helped to evolve an eco-friendly disease management strategy involving the beneficial effects of solarization, antagonistic organisms alone and also in combination with fungicides. However, at times these integrated management strategies also may not give the desired effect. The reasons attributed for this failure are selection of efficient antagonistic organisms suitable for particular locality, competition with indigenous microflora, inadequate and untimely cultural practices and incorporation of fungicides incompatible with the biocontrol agents.

Considering the above facts, the present study was carried out with the following objectives.

- Survey on the occurrence of various diseases in black pepper nurseries of northern districts of Kerala.

- Symptomatology of the disease and identification of pathogens associated with the diseases.
- To study the effect of various nursery practices on the incidence of diseases.
- Screening of genotypes of black pepper for host resistance/tolerance against nursery diseases.
- To study the biochemical bases of disease resistance / susceptibility.
- Isolation and selection of promising antagonists.
- To evolve an integrated management strategy against *Phytophthora* rot in black pepper nursery.

Review of Literature

2. REVIEW OF LITERATURE

Black pepper (*Piper nigrum* L.) is the most important dollar earning spice crop of India occupying an area of 1,77,360 ha with a production of 70,000 mt during 2000-2001 (Kumar, 2001). However in productivity, India occupies the last position among the leading pepper producing countries in the world (Alagappan and Manoharan, 2001). The average productivity of pepper in the major producing countries was worked out as 971 kg ha⁻¹ whereas, it is only 322 kg ha⁻¹ in India i.e., 67 per cent behind the world average productivity. The presence of large number of senile unproductive vines, poor genetic stock and incidence of pests and diseases are some of the reasons for low productivity of pepper in India (KAU, 1996a). A massive replanting with elite types is an urgent need to boost up pepper production in the country. It was estimated that about 123 million rooted cuttings are required to replant and gap fill 50 per cent of the total area under pepper in India (Sarma *et al.*, 1987).

Eventhough, there is no precise data on loss in black pepper nursery due to diseases; there are several reports on economic loss due to the infection of *Phytophthora capsici* in the field. In India, upto 20 per cent loss was reported by Samraj and Jose (1966). About 25 to 30 per cent loss has been reported in Kerala (Nambiar and Sarma, 1977). It was reported that nursery diseases alone account for about 10 to 15 per cent loss in black pepper nursery (PRS, 1980). Balakrishnan *et al.* (1986) and Anandaraj *et al.* (1989) reported death of vines upto 9.4 per cent and 3.70 per cent amounting to an annual loss of 905 and 119 mt of black pepper in Kannur and Kozhikode districts of Kerala respectively. Sitepu and Mustika (2000) reported about 10 to 15 per cent crop loss due to *Phytophthora* rot in Indonesia.

Extent of damage caused by *Colletotrichum gloeosporioides* was estimated to be 0.5-13 per cent (PRS, 1996). In Sarawak, 90 per cent loss was reported (Anon, 1978).

Rotting of pepper vines in the nursery by *Rhizoctonia solani* was reported by Mammooty *et al.* (1980) and no report on extent of loss due to *Rhizoctonia* infection

in Black pepper. Choudhary (1943) reported a crop loss of pepper about 76 per cent due to infection of *Sclerotium rolfsii*.

2.1 MORPHOLOGICAL CHARACTERS OF PATHOGENS

2.1.1 *Phytophthora capsici*

Although *Phytophthora* in black pepper was recorded during 1929 (Venkatarao, 1929), the first authentic record of wilt of black pepper due to *Phytophthora* in India was made by Samraj and Jose (1966).

Muller (1936) was the first to identify the pathogen of foot rot of black pepper as *P. palmivora* var. *piperis*. Later Goot (1937), Holliday and Mowat (1963), Turner (1969) and Alconero *et al.* (1972) also proved that foot rot was caused by *P. palmivora*. Turner (1971) compared a large number of isolates from different geographic locations and hosts. From the studies he concluded that all *Phytophthora* isolates from *Piper* in South East Asia belong to the same species and referred as typical strain of *P. palmivora* (Butler) Butler.

Controversy and confusion existed regarding the identity and nomenclature of *Phytophthora* isolates of black pepper. Taxonomy of this pathogen received greater attention by considering morphological characters such as sporangial ontogeny, pedicel length, caducity of sporangia and chromosomal type (Tsao, 1977; Tsao and Tumekate, 1977). Sarma *et al.* (1988) noticed umbellate sporangial ontogeny in all the isolates. The sporangial shapes varied from ovoid to obovoid and pyriform with a tapering base or fusiform. The average L/B ratio ranged from 1.7-2.8 and pedicel length ranged from 6.7-125.7 μm . The mean spore diameter ranged from 20.7-79.9 μm . The organism grows luxuriantly on carrot agar medium.

Santhakumari (1987) isolated *Phytophthora* from black pepper and found that the sporangia were ellipsoid to spherical, papillate, caducous with a size of 27-54 μm . It was found that profuse sporulation occurred in solid cultures when exposed to light and it was sparse in dark. Sarma *et al.* (1991) reported that, the colony

characters of *Phytophthora* isolates of pepper were predominantly petaloid type but they also observed isolates with fluffy growth.

Based on morphological and physiological studies, it was proposed to merge both *P. palmivora* MF4 and *P. capsici* into a single group (Alizadeh, 1983; Alizadeh and Tsao, 1983). Careful examination of a large number of *Phytophthora* isolates from black pepper world wide revealed that a great majority of these isolates produced long pedicellate, caducous sporangia and were identified as *Phytophthora capsici* Leonian emend. A. Alizadeh and P.H. Tsao. *P. capsici* sensulato encompasses all isolates formerly called as *P. palmivora* 'MF4' and should henceforth, be used for naming all isolates of this type from black pepper and other tropical hosts around the world (Tsao, 1991).

2.1.2 *Colletotrichum gloeosporioides*

Rot disease caused by *C. gloeosporioides* (Penz.) Penz. Sacc., the imperfect stage of *Glomerella cingulata*, is one of the major diseases of black pepper. Association of *C. gloeosporioides* on hollow, light, malformed berries of pepper was reported by Nambiar *et al.* (1978).

Arx (1957) combined all straight spored *Gloeosporium* and *Colletotrichum* spp. under one species as *Colletotrichum gloeosporioides*. Hence correct name of the pathogen causing anthracnose disease was *C. gloeosporioides*, the imperfect stage of *Glomerella cingulata*.

The conidia of *C. gloeosporioides* may be oblong or cylindrical with rounded ends (Prasad and Singh, 1960). The length of conidia varied from 7 to 28 μm (Prasad and Verma, 1966; Lele and Asharam, 1969). Mordue (1971) enumerated the morphological characters of *C. gloeosporioides*. The acervuli were setose to glabrous, rounded, elongated or irregular in shape and may attain 500 μm in diameter. Setae varying in length, rarely more than 200 μm long, 4 to 8 μm wide, 1-4 septate tapered towards apex. Conidia hyaline, cylindrical, uninucleate,

9-24 x 3-6 μm formed on unicellular hyaline or faintly brown cylindrical, phialidic conidiophore. Santhakumari (1980) and Varma (1991) described the morphological variation of *Colletotrichum* spp. in ornamental and medicinal plants respectively.

2.1.3 *Rhizoctonia solani*

R. solani Kühn is another pathogen causing stem and leaf rot disease in pepper nursery. The grouping of *R. solani* on the basis of hyphal anastomosis between different strains had gained much importance in the study of this plant pathogen. Parmeter *et al.* (1969) reported that each anastomosis group had its general tendency in host range and pathogenicity. *R. solani* exhibited variations in their characteristics (Flentje *et al.*, 1970). Capacity of hyphal anastomosis between different isolates provides an indication of relationship within groups of isolates.

Generally, *R. solani* is identified mainly based on characteristics of mycelial growth. It was colourless when young and became yellowish brown when old (Hashioka, 1970). Ou (1972) reported that mycelium of *R. solani* causing sheath rot of rice was 6-10 μm width, branching at an acute angle with slight constriction and septum was found at a short distance from the point of constriction. Size of the sclerotia varied from 0.2-1.3 x 0.05 mm. Cordoso *et al.* (1982) reported that nine isolates of *R. solani* from different hosts did not differ in mycelial growth, but the isolates differed in their pathogenicity and the capacity to produce sclerotia. The isolates from perennial soybean were highly pathogenic to cowpea, while cowpea isolates attack cowpea only. Rubber and black pepper isolates did not induce symptoms on cowpea. Sclerotial production was maximum in isolates from black pepper. Vijayan (1986) examined 41 isolates of *R. solani* from different hosts. He found that in all the isolates, young hyphal branches inclined in the direction of growth and constricted at the point of origin from the main hyphae. Branching was always from the distal septum and a prominent septal pore was present in all isolates.

Singh *et al.* (2002) characterized 46 isolates of *R. solani* obtained from diseased rice plant. It has been found that all 46 isolates shared typical characteristics with *R. solani* like right angle branching near the distal septum of cell in young

hyphae and formation of dolopore septum in branches near the point of origin. Sunder *et al.* (2003) compared 112 isolates of *R. solani* from different locations in Haryana and found considerable variations in their cultural, morphological characters, growth and virulence.

2.1.4 *Sclerotium rolfsii*

The fungus has a very wide host range, infecting plants of nearly 100 families (Aycock, 1966). According to Ou (1972), the fungus has many strains and variable morphology and grows luxuriantly on culture media, producing white aerial mycelium and abundant sclerotia.

Although, not much studies have been carried out on this fungus in black pepper, it has been extensively investigated in other crops. Wu (1968) noted that pigmentation of sclerotia occurred in the light and in dark, but sclerotia turned brown under anaerobic conditions.

Ou (1972) reported that mycelium of *S. rolfsii* causing seedling blight of rice has numerous clamp connections but the frequency of these varied within strains or biotypes. Sclerotia were spherical to ellipsoidal about 0.5 to 0.8 mm in diameter. In some cases, it had reached to 3 x 5 mm diameter and may vary according to the strain, nutritional and environmental conditions. Radwan *et al.* (1987) observed variation in mycelial colour and sclerotial production in different isolates collected from different field. Ansari and Agnihotri (2000) isolated 44 isolates of *S. rolfsii*, causing collar rot of soyabean. On the basis of morphological, cultural, oxalic acid production characteristics and pathogenicity, they were grouped into 12 races and one race was more dominant than others. They also reported the variation in sclerotial size from 750 µm to 1200 µm.

2.2 NURSERY DISEASES

A perusal of the literature revealed that only few reports are available on the occurrence of nursery diseases in black pepper. Albuquerque and Duarte (1979)

reported the incidence of *Pythium splendons* in black pepper nurseries from Brazil. The outbreak of the disease in nursery due to *Sclerotium rolfsii* was noticed by Chowdhury (1943) from Assam and Brahma *et al.* (1980) from Kerala. They reported 76 per cent mortality of cuttings in nurseries of Kerala and Assam. Mammooty and Pillai (1981) reported considerable loss in black pepper nursery due to rotting caused by *Pythium* sp. and *Colletotrichum* sp. The occurrence of various diseases in pepper nursery like *Phytophthora* rot by *P. capsici*, basal wilt by *S. rolfsii* and *Rhizoctonia* rot by *R. solani* were reported by Sarma *et al.* (1987). Anandaraj and Sarma (1995) noticed the incidence of *P. capsici*, *C. gloeosporioides*, *R. solani* and *S. rolfsii* in nurseries as well as in the main field. Anandaraj (2000) opined that leaf rots and leaf blights caused by *Rhizoctonia* sp. and *Colletotrichum* sp. basal wilt by *S. rolfsii* and *Phytophthora* rot by *P. capsici* were the main constraints in the production of healthy cuttings in black pepper nursery.

2.2.1 Symptomatology

2.2.1.1 *Phytophthora* rot

The symptomatology of *Phytophthora* rot disease in black pepper was studied by many workers (Holliday and Mowat, 1963; Nambiar and Sarma, 1977; Mammooty, 1978; Ramachandran *et al.*, 1986). Sarma *et al.* (1992) and Anandaraj *et al.*, (1994 and 1996) reported that the infection developed on leaves, stem and roots. On leaves, the symptoms developed as greyish to dark brown spots with fimbriate margin and such leaves got blightened and defoliated within a short time. Occasionally, zonation in the infected portions was also observed. On stem, the symptoms developed as watersoaked lesions which turned dark brown resulting in withering of the entire cutting. On roots, the initial symptom developed as brownish discolouration. In severe cases, decaying of feeder roots occurred which resulted in yellowing of aerial parts. Root infection sometimes reaches the collar region resulting in foot rot symptom.

Nambiar and Sarma (1977) reported that the disease was severe under low temperature and high relative humidity and during such conditions, the lesions developed on the entire leaf lamina. The role of toxic metabolites in the causation of

symptoms like discolouration of vascular tissues beyond the site of infection was elucidated by Lee (1973) and Vilasini (1982).

2.2.1.2 *Colletotrichum* rot

Thomas and Menon (1939) described the symptoms of *Colletotrichum* infection in black pepper as circular to irregular grey spots on leaves on which acervuli appeared. Menon (1949) found that severe incidence lead to merging together of lesions resulting in large necrotic areas. He further observed infection of young stem leading to vine death. From Malaysia, Sitepu and Kasim (1976) reported twig rot, leaf spot and flower rot by *C. gloeosporioides* in black pepper. Sebastian (1982) observed more abundance of acervuli on upper surface of infected leaves. He also noticed the infection of the pathogen even on the pedicel. Mammooty *et al.* (1980 and 1992) and Mammooty and Pillai (1981) reported that spot caused by *Colletotrichum* sp. on black pepper was characterized by yellowish halo surrounding the necrotic spot. Anandaraj and Sarma (1995) also reported similar type of symptoms. They observed that in severe cases young shoots got dried up.

2.2.1.3 *Rhizoctonia* rot

Deighton (1937), Menon (1949) and Vanderweyen (1957) had noticed the presence of *Rhizoctonia* on pepper vines. They also reported that the initial symptoms developed as oval to irregular straw coloured lesions on leaf and stem. Mammooty *et al.* (1980) reported that fungal growth was noticed within 48 h and disease symptoms developed within three to four days after inoculation. They also reported blackening of the bark and brownish exudation near collar region, drooping and drying of leaves 10-12 days after inoculation. The entire vine got dried up within a period of 13-21 days. However, the roots of the affected plants remained apparently healthy. Sarma *et al.* (1987) reported that infection due to *R. solani* started as dark grey patches and mycelium (fungal threads) from these patches often grew rapidly. They stated that heavy shade and high frequency of irrigation in pepper nurseries were favourable for infection by *R. solani*.

2.2.1.4 *Sclerotium* rot

Chowdhury (1943) first reported the incidence of *Sclerotium* rot in black pepper. Brahma *et al.* (1980) reported the outbreak of this disease from different pepper nurseries of Kerala. They found that infection started at the collar region as water soaked region. The leaves of infected plant become flaccid, turned yellow and dropped. The infected plant succumbed to infection within two to three days. They also proved pathogenicity and found that inoculated plants collapsed within five days. Sarma *et al.* (1987) observed the presence of whitish fast growing mycelium on the stem or leaf. On leaf, the pathogen caused leaf rot with round to irregular necrotic spots with concentric zonations. On stem, rotting of infected portion with whitish mycelial growth, later turned to cream coloured and produced grey coloured sclerotia. Anandaraj (2000) reported the occurrence of the greyish spots with whitish mycelium along with sclerotia, at the advanced stage of lesion in black pepper.

2.2.2 Effect of nursery practices on the incidence of diseases

2.2.2.1 Effect of nursery structure

Black pepper nurseries are being raised by various agencies in the state. The methods adopted for producing rooted cuttings varied with different nurseries.

Studies of Steiner (1973) on coffee berry disease caused by *Colletotrichum coffeanum* had clearly showed that incidence of above disease was severe at low light intensity. Sharma and Mohan (1992) reported that shading of nursery of *Eucalyptus grandis* seedlings contributed high disease incidence.

After conducting studies at Pepper Research Station, Panniyur during 1978 and 1979, Mammootty and Pillai (1981) reported that situations inside the pepper nursery were ideal for disease incidence. When the intensity of shade was high, the disease incidence was also high and they recommended regulation of shade inside the nursery for managing the nursery diseases. Heavy shade and high frequency of irrigation in pepper nurseries, ensured high humidity essential for rotting of black pepper. Incidentally, the warm and humid conditions created due to above practices

were congenial for infection by *R. solani* and *S. rolfsii* (Sarma *et al.*, 1987). Mammootty *et al.* (1992) reported that disease incidence in pepper nursery was maximum under high shade condition. However, they noticed poor germination of pepper cuttings when shade intensities were reduced. When intensity of shade in pepper nursery increased, disease incidence was also more (KAU, 2001).

2.2.2.2 *Effect of potting mixture*

Nursery mixture had influenced the disease incidence in the nursery. Richards *et al.* (1964) stressed the need for ideal media for propagating and growing nursery plants. Proportion of soil, sand and cowdung in the ratio of 1:1:1 was the ideal potting mixture which provides better growth and reduced the disease incidence. A reduction in quantity of sand increased the chances of water stagnation in pepper nursery and resulted in the incidence of various diseases (Pillai and Sasikumaran, 1987). Yufdy and Hayani (1991) found that potting mixture composed of sand, soil and farm yard manure at the ratio of 1:1:1 gave better rooting.

2.2.2.3 *Effect of place of collection*

Protection of planting materials in the mainfield as well as in the nursery is important for checking the entry of disease in the new gardens. So collection of planting materials from infected field should be avoided (Sarma *et al.*, 1991 and Mammootty *et al.*, 1992).

2.2.2.4 *Effect of pepper varieties*

In Kerala all popular cultivars of black pepper are susceptible to nursery diseases. At present there is no cultivar available, resistant to *P. capsici*. However, some of the cultivars viz., Narayakudy, Kalluvally and Balankotta showed some degree of tolerance to *Phytophthora* (Sarma *et al.*, 1982 and Sarma and Anandaraj, 1997). They also reported that even popular genotypes viz., Karimunda and Panniyur 1 were susceptible to *P. capsici*.

2.2.2.5 *Effect of processing of runner vines*

In India, runner vines are generally used for propagation of black pepper. Runners depending on the availability were made into cuttings of two to three nodes and were planted in the nursery.

Duarte and Albuquerque (1980) found that dipping of stem cuttings of black pepper in benomyl (0.18 per cent) and carbendazim (0.06 per cent) gave the best control of various diseases in nursery. To get disease free runner shoots, they should be tied back to the main bush or pruned off before the onset of monsoon (Sarma *et al.*, 1988). The technique of rapid multiplication programme not only reduces disease incidence but also helps to increase black pepper production. Well developed root system, better field establishment, more vigorous growth are some of the advantages of this method (Sarma *et al.*, 1992).

Creeping of runner vines into the soil may harbour the pathogen and get transmitted to main field (PRS, 1980). Anandaraj *et al.* (1991) observed that soil containing infected plant debris or apparently healthy nursery stock with incipient root infection or runner shoots collected from infected gardens may also act as source of inoculum and play a major role in spreading the disease. Further, the infected runner shoots are responsible for the secondary spread of the pathogen. Ramachandran *et al.* (1991) recommended dipping of cuttings in fungicides before planting in nursery was found to be effective to ensure proper protection against nursery disease.

2.2.2.6 *Effect of treatment of potting mixture*

It is well known that disease free rooted cuttings reduce the possible entry of the pathogen into the fresh plantation and hence nurseries should be raised in good quality potting mixture. Ramachandran *et al.* (1991) reported that use of fumigated soil will avoid introduction of pathogens to other uninfected gardens. Sarma *et al.* (1988) found that raising of rooted cuttings in methyl bromide fumigated nursery mixture will minimize nematode population in soil.

Soil solarization in its present form involves hydrothermal processes (Stapleton and Devay, 1985). Efficacy of soil solarization in suppressing soil borne plant pathogens is well established (Katan and Devay, 1991). Simultaneously this causes many changes in the biotic and abiotic components of the soil during and after solarization which may finally lead to change in disease, plant growth and yield or both. Sarma *et al.* (1994) reported that soil temperature of solarized bed rose to as high as 50°C which was about 10 to 12°C higher than non solarized soil. Sarma *et al.* (1996) reported that solarization of potting mixture was effective in controlling *P. capsici* infecting black pepper nursery. Significant effect of solarization was observed in controlling pre and post emergence rotting caused by *Pythium aphanidermatum* in ginger (Vilasini, 1996). Binimol (2000) found that solarization of potting mixture for 30 days and application of biocontrol agent and copper oxychloride reduced *Phytophthora* rot in black pepper nursery.

2.2.2.7 *Effect of time of planting*

Pepper nurseries are generally raised during February to May. It has been found that time of planting has some influence on disease incidence. Mittal (1997) reported that incidence of disease in lentil was declined when sowing date was changed. He found that sowing of lentil in the month of October was most effective in reducing the disease caused by *R. solani* and increased the yield. Studies at RARS, Ambalavayal indicated that March was ideal for raising pepper nursery (KAU, 2001).

2.2.2.8 *Effect of frequency of irrigation*

Water stagnation is the single most important factor as far as *Phytophthora* and many of the diseases are concerned. High soil moisture are refined to activate survival activities of *Phytophthora*. Poor internal drainage and excessive water were associated with *P. cinnamomi* infection on avocado (Zentmeyer and Richards, 1952) and foot rot of betle vine (Singh and Chand, 1973). Ristaino *et al.* (1992) found that population density of *P. capsici* causing root rot in *Capsicum annum* was high when frequency of drip irrigation was more.

Satheesan *et al.* (1997) found that irrigation at IW/CPE ratio of 0.25 significantly increased pepper production, while the incidence of *Phytophthora* rot was maximum at above mentioned irrigation level.

Maiti *et al.* (2000) reported highest yield of sugar beet when crop was irrigated at cumulative pan evaporation ratio of 0.45 and 0.60. Root rot incidence caused by *S. rolfii* was also high due to the saturated soil moisture condition.

2.2.2.9 Chemical control

Phytophthora foot rot control both in nursery and main field with various fungicides has been reported by many workers.

Mammootty and Pillai (1981) reported that fortnightly spraying with 0.1 per cent difoltan and one per cent Bordeaux mixture was effective in managing nursery diseases of black pepper. Drenching and spraying with Validacin 0.2 per cent, spraying and drenching with one per cent Bordeaux mixture and 0.2 per cent Akomin at fortnightly intervals were found effective in managing nursery diseases (PRS, 1982). Systemic fungicides like Ridomil MZ and Akomin were found effective in checking the disease (Ramachandran and Sarma, 1985). They also reported that nursery diseases caused by *R. solani*, *Pythium* species, *Colletotrichum gloeosporioides* and *S. rolfii* could be controlled by timely application of Bordeaux mixture.

Sarma *et al.* (1987) reported that application of Bordeaux mixture (one per cent) or copper oxychloride (0.2 per cent) or spraying with Ridomil MZ at monthly intervals gave good control of *Phytophthora*, *Rhizoctonia* and *Sclerotium* rots in pepper nursery. The efficacy of metalaxyl and fosetyl-Al both *in vitro* and *in vivo* in reducing *Phytophthora* infection was established and found superior to Bordeaux mixture (Ramachandran and Sarma, 1990). Melebennur *et al.* (1991) found that foot rot incidence in black pepper treated with Bordeaux mixture - copper oxychloride or Bordeaux mixture - metalaxyl or Bordeaux mixture Captafol reduced considerably. Nair and Sasikumaran (1991); Mammootty *et al.* (1992) and Sarma *et al.* (1994)

reported that copper fungicides like Bordeaux mixture and copper oxychloride were the best for managing fruit rot in black pepper. Recent studies indicated the efficacy of potassium phosphonate both as foliar spray and soil drench in checking *Phytophthora* infection (IISR, 1995). Ali *et al.* (1996) suggested a treatment schedule for managing *Phytophthora* foot rot of black pepper i.e., spraying and drenching of Bordeaux mixture, Ridomil (0.1 per cent) and Akomin (0.2 per cent). Mammooty *et al.* (2003) reported the efficacy of metalaxyl gold and Akomin in managing the *Phytophthora* rot in black pepper.

2.2.3 Screening for resistance / tolerance

2.2.3.1 *Phytophthora capsici*

Identifying the sources of resistance becomes imperative for the effective and long term control of diseases. Earlier workers reported some resistant types of black pepper. Muller (1936) found an Indonesian cultivar Belantung and Diambi and one Indian cultivar, Uthirankotta resistant to *P. palmivora*. *P. colubrinum*, *P. obliquum* and cultivar Balankotta were found to be resistant (Turner, 1973). Nambiar and Sarma (1977) reported that *P. colubrinum*, *P. obliquum* and *P. quinense* were resistant to *Phytophthora* foot rot. Sarma *et al.* (1982) screened 48 cultivars of black pepper and 73 wild *Piper* sp. against *Phytophthora palmivora* by adopting dip inoculation technique. They found that none of the cultivars and wild species showed any reasonable degree of resistance and Narayakodi, Kalluvally, Uthirankotta, Balankotta showed low per cent of incidence compared to others. Vilasini (1982) reported that 17 types of *P. nigrum* tested were highly susceptible to root infection. Dutta (1984) conducted screening of black pepper against *Phytophthora* and found that none of them were resistant. Sitepu and Kasim (1991) did not notice resistance in pepper cultivars screened against *Phytophthora* sp. However, low susceptibility of certain cultivars like Kalluvally, Palaulauta, Belantung and Bangka have been identified in Indonesia.

In Malaysia, Kueh and Sim (1991) observed less susceptibility of Cheriyanakadan and Balankotta to *Phytophthora*. Sarma and Anandaraj (1992)

identified a few tolerant types of black pepper like P24, P339, P1534 and HP780 and cultivars ACC1047, ACC 1095 and ACC347 against *P. capsici* and at Sirsi, after five years of evaluation, they observed P24 and P1352 as field tolerant to *P. capsici*. Radhakrishnan and Mammooty (1993) observed no black pepper cultivars were resistant / tolerant to *Phytophthora*. However, they observed variation in the extent of incidence among the cultivars. Sarma *et al.* (1996) noticed some *Phytophthora* tolerant lines of black pepper. Sarma and Anandaraj (1997) reported that Narayakodi, Kalluvally, Balankotta, Neelamundi, and Cholamundi as tolerant. Rajagopal *et al.* (1998) evaluated seven cultivars and five promising black pepper cultures at Pepper Research Station, Panniyur for 12 years and found that foot rot was the maximum in Kalluvally followed by Neelamundi and the least incidence in culture 54, an OP progeny of Kuthiravally.

Shylaja *et al.* (1996) screened five black pepper cultivars against *P. capsici* and found that none of the regenerated calliclones were completely resistant to the disease. However, some of them derived from unscreened calli exhibited a higher degree of tolerance to the disease, revealing the possibility of exploiting somaclonal variation for *Phytophthora* foot rot disease management. The calliclones of cultivar Kalluvally and Cheriyaaniakadan recorded comparatively high degree of tolerance to the disease in comparison with these susceptible cultivars, Karimunda and Panniyur-1.

There are only few reports of screening of pepper varieties against *Phytophthora* disease using toxic metabolites from culture filtrate. Lee (1973) tested five cultivars of *P. nigrum*, *P. colubrinum* and *P. sarmentosum* and found that *P. colubrinum* and *P. sarmentosum* were resistant and five cultures of *P. nigrum* susceptible. Vilasini (1982) also screened 17 cultures/cultivars of *Piper nigrum* against *P. palmivora* and none of them were found tolerant or resistant.

2.2.3.2 *Colletotrichum gloeosporioides*

A perusal of the literature revealed no systematic work on the screening of black pepper varieties/cultivars against *C. gloeosporioides*.

However, Kueh *et al.* (1981) reported that kuching was highly susceptible to *C. gloeosporioides* and *C. piperis*, whereas, cultivar Uthirankotta and Djambi were less susceptible. Rodrigues *et al.* (1987) reported that black pepper cultivar Guajarina was least susceptible to *C. gloeosporioides* under natural conditions while Djambi and Belatung showed minimum infection.

2.2.3.3 *Rhizoctonia solani*

R. solani has been reported to be a pathogen of 305 host species in tropical and subtropical countries (Ghaffar *et al.*, 1964). The pathogen caused seedling blight, root rot, charcoal rot of stem, foliage blight, tuber decay, dry rot etc. in several crops in different parts of the world. Though, there are no reports on the screening of pepper cultivars against this pathogen, many workers tried to screen germplasm of other crops against *R. solani*.

Allen (1997) mentioned about the differences in varietal susceptibility between cultivars of soybean, cowpea, lima bean and common bean to *R. solani* causing root rot and web blight. Reddy (2000) screened 375 germplasm of rice against *R. solani* and found thirteen accessions resistant. Vidyashekaran *et al.* (2000) could not detect any resistance in rice varieties to *R. solani*. They screened several hundreds of plant genera, but they could identify only a single resistant plant, coconut (*Cocos nucifera*).

2.2.3.4 *Sclerotium rolfsii*

Rao *et al.* (1995) screened 350 groundnut accessions for resistance to *S. rolfsii* and found that eleven genotypes showed less than 25 per cent stem rot incidence. Gorbet and Shokes (1997) found significant difference among 300 genotypes of groundnut evaluated under field screening studies and also suggested that this pathogen caused diseases in more than 500 species of plants. Ambedkar *et al.* (2003) reported that groundnut, sunflower, chilli and soyabean were highly susceptible to *S. rolfsii*, while black gram, green gram, pigeon pea and cotton were moderately susceptible whereas sorghum and pearl millet were less susceptible.

2.2.4 Biochemical basis of disease resistance / tolerance

Disease results whenever any vital function of plants are disrupted by a biotic stimulus and often changes take place in the primary metabolism of the affected cells (Swain, 1977). Further, interactions between host and pathogen determine biochemical dynamics of parasitism and pathogenesis. Plants cope up with pathogen attack by using mechanism of resistance that may rely both on performed protective defenses and inducible defenses.

2.2.4.1 Phenols

Phenolic compounds had been correlated with the resistance of plant to the infective agents (Vidyashekar, 1974; Link, 1983; Sokolova *et al.*, 1988). Phenolics act in different ways to different pathogens. Toxicity of phenols to spore germination, growth of fungi, inhibition of production of enzymes, inactivation of enzymes produced by pathogens and suppression of toxins produced by pathogens were explained as the mechanisms by which the phenols act (Vidyashekhar, 1988).

Increase in levels of total phenols was associated with resistance response to *Phytophthora* blight in Pigeonpea (Kaur and Mehrotra, 1990), *Capsicum* to *P. capsici* (Jeun and Hawang, 1991), cocoa to *P. megakarya* (Ndoumou *et al.*, 1996). Sidhan *et al.* (1996) reported higher levels of total phenols in flag smut resistant wheat varieties as compared to susceptible ones.

Dagde (1999) reported that *Piper colubrinum* and *P. nigrum* (Panniyur-1 and Kalluvally) differed significantly to their total phenol and OD phenol contents.

Among the different phenolics ortho dihydroxy phenols (OD phenols) are known to be highly fungitoxic. Johnson and Schaal (1957) reported a potato tuber resistant to scab. Vidyashekar (1973) reported that grape vine resistant to *Gloeosporium ampelophagum* had higher level of OD phenols. Abraham (1986) noticed an increase of OD phenol, total phenols and leucoanthocyanin in resistant *P. betle* to bacterial leaf spot pathogen. Similar increase in the content of OD phenols was also reported in resistant varieties of chilli by Markose (1996) and tomato by Paul (1998).

2.2.4.2 Carbohydrates, starch, reducing sugars

Sugars may play an important role in the inhibition of pectinolytic and cellulolytic enzymes which are essential for pathogenesis. Sugar and carbohydrates are the precursors of phenolics (Vidyashekar and Kandasamy, 1971). Parashar *et al.* (1990) reported that chickpea cultivar, G-25 was resistant to dry root rot and exuded less amount of sugars as compared to susceptible cultivar C235. Mehtha *et al.* (1992) reported that total sugars were more in highly susceptible cowpea, followed by susceptible and moderately susceptible ones. Singh *et al.* (1992) found less amount of carbohydrates in sesamum infected by *Macrophomina phaseolina*.

Jeun and Hwang (1991) reported that resistance of capsicum plants to *P. capsici* increased with plant age. Resistant cultivar contained lower levels of fructose, glucose and sucrose. The fructose and sucrose contents of susceptible capsicum increased in between two stages. Aveling (1999) could not find any difference in percentage of starch between infected and healthy avocado root infected by *P. cinnamomi*. Sangam and Misirli (2000) found that starch content of susceptible apricot was higher than the resistant ones to *Sclerotinia laxa*.

It was observed that in sorghum variety having a high quantity of reducing sugars was susceptible to bacteria wilt than moderately susceptible ones. Reddy and Sridhar (1975) reported higher levels of reducing and non-reducing sugars in leaves of bacterial leaf blight susceptible rice variety than tolerant one. Bhardwaj *et al.* (1986) found significant decrease in levels of sugars and total phenols in fruits and leaves of capsicum plants susceptible to *P. nicotiana* var *nicotianae*. Abraham (1986) found higher sugar content in betle vine resistant to bacterial wilt. Sidhan *et al.* (1996) mentioned about the higher of quantities of total and reducing sugars in flag smut resistant varieties of wheat as compared to susceptible ones. Paul (1998) found high sugar content in susceptible tomato susceptible to bacterial wilt than resistant variety. While, it was high in resistant chilli than moderately susceptible ones. Dagde (1999) analysed the biochemical constituents of *Piper colubrinum* and *Piper nigrum*. He found that *P. colubrinum* contain high reducing sugar when compared to *P. nigrum*.

Kalluvally, a tolerant cultivar to *P. capsici* had higher content over susceptible variety, Panniyur-1. He also suggested that higher sugar content in *P. colubrinum* determines their immunity/tolerance to disease infection.

2.2.4.3 Enzymes

Enzymes are large protein molecules, which catalyse all the inter-related reactions in living cells. Peroxidase and polyphenol oxidase were reported to be capable of catalyzing the oxidation of phenols to quinones (Chattopadhyay and Bera, 1980; Iwata *et al.*, 1982; Mansfield, 1983) and quinones were associated with disease resistance in plants.

Coulomb and Coulomb (1984) reported increased peroxidase activity in resistant capsicum cultivars than susceptible one when inoculated with *P. capsici*. Rahayuningsih (1990) studied peroxidase activity of five *Piper nigrum* and one *P. hirsutum* genotypes and found that peroxidase activity of six genotypes were different. *P. hirsutum* had a high peroxidase and was highly resistant to *Phytophthora palmivora* infection and *P. nigrum* has the lowest peroxidase and was susceptible to *P. palmivora*. Peroxidase in plants grown under shade was more than those grown under open conditions. Dagde (1999) observed higher activity of peroxidase activity in *P. colubrinum* than Panniyur-1 and Kalluvally.

Kumar (2001) studied the enzyme and protein activities of a tolerant (P24) and two susceptible (Panniyur-1 and Subhakara) pepper genotypes to *P. capsici* and found that tolerant type expressed higher content of defence related enzymes like phenylalanine ammonialase and PR-proteins.

The catalase activities in apple were positively correlated with scab resistant varieties than susceptible ones (Tsakadze and Tsereteli, 1971). Montalbini and Marte (1972) reported that catalase activity in resistant varieties of bean was generally increased and it was comparatively less in susceptible varieties, whereas, Sathiyananthan and Vidyashekar (1981) reported that catalase activity was higher in susceptible rice plant to *Helminthosporium oryzae* than resistant ones. Lizzi

and Coulomb (1991) evaluated the peroxidase and catalase activities in the leaves of *Capsicum annuum* infected with *P. capsici* and Tobacco Mosaic Virus (TMV). They observed higher enzyme activities in resistant varieties. Infection with *P. capsici* induced catalase activity and infection with TMV reduced its activity. Following infection, peroxidase was found increased and catalase activity reduced in the intercellular spaces and their higher concentration led to the reduction of the pathogen.

Gupta *et al.* (1995) reported the changes in the levels of catalase activities in healthy and diseased leaves of *Brassica* species susceptible to *Alternaria* leaf blight. It was found that catalase activity was considerably higher at the initial stages of plant growth in all the species listed which dropped markedly at later stage.

The acid phosphatase has a major role in host/pathogen compatibility reactions (Palilova and Loseva, 1991). They found that wheat susceptible to *Puccinia recondita* had higher acid phosphatase activity than resistant ones. Borua and Das (2000) reported that the increase in activity of acid phosphatase in susceptible capsicum varieties reflected the response of the host to check the attack of *Colletotrichum capsici*.

Xia *et al.* (1994) reported that level of esterase isozyme was slightly higher in cotton resistant to *Verticillium dahliae* than in susceptible ones. Kim *et al.* (2001) suggested that esterase activity in ripe capsicum fruit can inhibit the appressorium formation of *Colletotrichum gloeosporioides* and hence protect the fruits against the fungus.

2.2.4.4 Total free amino acids

Amino acids are the building blocks of protein and during diseased condition the free amino acid composition in plants exhibit changes.

Chile and Vyas (1983) reported a decrease in amino acid content in less susceptible cultivar of betle vine due to infection by *Phytophthora* leaf rot pathogen. Marginal differences among susceptible and resistant varieties for amino acid content in *Phytophthora capsici* infected pepper plants had been reported by Jeun and Hawang

(1991). Sarma and Kaul (1996) found that amount of amino acid content was comparatively higher in resistant apple cultivar to *Venturia inaequalis* than susceptible one. In brinjal, the resistant genotypes recorded higher content of amino acids under healthy condition and its level decreased under diseased environment of bacterial wilt pathogen (Paul, 1998). Dagde (1999) found a significant variation in amino acid content in *P. colubrinum* and *P. nigrum*. Maximum content was observed in *P. colubrinum* and Kalluvally, whereas, minimum in Panniyur-1.

2.3 ISOLATION OF NATIVE ANTAGONISTS AGAINST *P. capsici*

Baker and Cook (1974) stated that antagonistic potential resides in every soil microorganism and any random soil sample should yield antagonists to some microorganisms. Metabolites are secreted and one of these could certainly prove inhibitory to some microorganisms.

The possibility of controlling pathogenic fungi with antagonistic microorganisms has long been considered and studied. Several fungal and bacterial antagonists like *Trichoderma* species, *Gliocladium* spp., *Bacillus subtilis* and fluorescent *Pseudomonas* have been found effective in checking the diseases (Elad *et al.*, 1982). Actinomycetes like *Streptomyces* species have been found antagonistic against several soil borne plant pathogens (Lee *et al.*, 1990).

Antagonism is a phenomenon employed in biological control and it means a relation between organisms, in which one organism creates adverse circumstances to other for its growth. Park (1961) categorized antagonism as antibiosis, competition or exploitation. Papavizas and Lumsden (1982) and Cook and Baker (1983) suggested mode of action of antagonists as lysis, competition, mycoparasitism and competition. Sarma *et al.* (1991) emphasised the need for biological control by manipulating the microbial status of soil suppressive to pathogen.

2.3.1 Fungal antagonists of plant pathogens

The most exhaustively studied microorganism as a biocontrol agent is *Trichoderma* species. The antagonistic potential of this fungus was first demonstrated

by Weindling (1932). He observed that *T. viride* parasitised the mycelia of *Pythium* species and *Phytophthora parasitica*. Several studies revealed potential use of *Trichoderma* as an effective biocontrol agent against *Phytophthora*. Cristinzio (1987) reported the antagonistic property of *Trichoderma* and *Chaetomium* spp. against *P. capsici* under *in vitro* conditions.

Anandaraj and Sarma (1994) opined that *Trichoderma* species and *Gliocladium virens* were the best among several isolates of antagonistic fungi tried against *Phytophthora capsici* in black pepper nursery.

Isolation and identification of microorganisms, antagonistic/ hypersensitive to *Phytophthora capsici* in black pepper plantations of Kerala and Karnataka showed predominance of *T. viride*, *T. harzianum*, *T. hamatum* and *Gliocladium virens* (Sarma *et al.*, 1996). Robert (1998) found four fungal isolates were more effective against *Phytophthora* rot in black pepper.

The combination of *T. harzianum* and *G. virens* and *Verticillium tenerum* was studied by Rajan and Sarma (2000) and indicated the effectiveness in reducing the *Phytophthora capsici* infection in black pepper.

Genesan *et al.* (2000) found that the application of *Trichoderma* significantly increased the dry weight of roots in pepper cuttings when compared with untreated control and suggested that high beneficial effect was due to enhanced nutrient uptake by inoculated plants. Binimol (2000) reported that *T. harzianum* and *T. viride* were effective in managing *Phytophthora* rot in black pepper nursery.

Anith and Das (2001) reported that combined application of *T. harzianum* and *Alcaligenes* species was effective in reducing the incidence of *P. capsici*. They also found that these treatments enhanced plant growth. Abraham *et al.* (2003) reported that *T. harzianum* had an effect in checking the disease incidence in pepper nursery. The maximum mean sprouting percentage was noticed with treatment of soil

solarization and *T. harzianum* and minimum disease incidence with *T. harzianum* alone.

Similar results were also reported in other crops such as cardamom and betle vine. Bhai *et al.* (2000) observed significant reduction of seedling mortality due to *P. meadii* in cardamom. Further, they noticed that application of *T. harzianum* multiplied in coffee husk and farmyard manure reduced the capsule rot of cardamom caused by the same pathogen. However, Mohanty *et al.* (2000) observed that the biological control of foot rot of betle vine caused by *Phytophthora parasitica* var. *piperina* with *T. harzianum* was not effective as that of chemical control in reducing the disease.

Santhakumari and Sanker (2002) reported that two isolates of *T. harzianum* and two isolates of *Aspergillus niger* from rhizosphere, rhizoplane and phyllosphere of black pepper was antagonistic against anthracnose disease (*Colletotrichum gloeosporioides*) of black pepper. *S. rolfsii* in groundnut was minimized by addition of antagonists like *Penicillium* spp. (Geethalakshmi *et al.*, 2003).

2.3.2 Bacterial antagonists of plant pathogens

Plant growth promoting rhizobacteria (PGPR), a unique group which are predominantly rhizosphere inhabitants, can suppress many plant diseases due to their general biological activities including competition for space and nutrients, production of antibiotics, volatile and antimicrobial substances and compounds such as iron chelating siderophores and HCN (Rosales *et al.*, 1995; Anith *et al.*, 1999 and Mondel *et al.*, 2000).

Utkhede (1987) got good control of *P. cactorum* in apple trees by bacterial antagonists *Enterobacter aerogenes*. Sarma *et al.* (1996), found that rhizosphere bacteria, especially fluorescent *Pseudomonas* was effective in checking the growth of *P. capsici*. Jubina and Girija (1998) reported that three bacterial isolates obtained from black pepper rhizosphere could control foot rot of black pepper caused by

Phytophthora capsici. The three isolates provided prolonged protection and reduced mortality upto 90 days after application and they claimed the superiority of these bacteria to *T. harzianum* in controlling the disease. Isolate B13 was identified as the most promising in reducing plant mortality and isolate B7 had a dual function of disease suppression and growth promotion.

2.3.3 *Actinomycetes - antagonists of plant pathogens*

Several actinomycetes have been found as antagonists to many soil borne plant pathogens. Thresiamma *et al.* (1988) found actinomycetes antagonistic to *P. meadii* causing fruit rot of rubber. Lee *et al.* (1990) isolated 4087 actinomycetes from soil and found that *Streptomyces purvullus* was antagonistic to *P. capsici* and *P. parasitica*. Chung and Hong (1991) studied the action of two *Streptomyces* spp. on *P. nicotianae* var. *parasitica* and found that culture filtrates of actinomycetes lysed the mycelia and inhibited spore germination. Chung and Ser (1992) identified that *Streptomyces bikiniensis* and *S. echinosuber* as antagonists to *P. capsici* in capsicum.

2.3.4 *Taxonomy of the genus Trichoderma*

The identity of genus *Trichoderma* have been studied by Rifai (1969), Domsch *et al.* (1980), Papavizas (1985) and Mazundar (1993).

2.3.4.1 *Mechanism of antagonism*

Hyphal contact of *T. hamatum* and parasitic fungi was accomplished by coiling of hyphae (Dennis and Webster, 1971). Reeves (1975) reported that hyphae of *P. cinnamomi* were lysed and oospore production was induced by *T. viride*. A number of parasite fungi capable of penetrating thick walls of resting spore of *Phytophthora* spp. have been identified (Snahe *et al.*, 1977). The mechanisms by which *Trichoderma* spp. control disease include competition, antibiotic production, direct parasitism and lysis (Ayers and Adams, 1981 and Bell, 1982). Mycoparasitism, antibiosis and predation were attributed to antagonistic activity. Lysis of hyphae of pathogens through the production of β -(1-3) glucanase, chitinase, cellulase and protease has been reported by Elad *et al.* (1983).

Species description of *Trichoderma* by Rifai (1969)

Sl. No.	<i>Trichoderma</i> spp.	Colony	Pigmentation	Hyphal diameter in μ	Chlamydo spore	Conidiophore	Phialide	Spore
1	<i>T. piluliferum</i> Webster and Rifai	Slow growing, smooth, pure white	No pigments	2.0-10	Formed frequently, sub-globose	In compact tufts	Short and plump, flask shaped. 4.6-6.5 x 2.8-3.5 μ	Globose, smooth walled colourless 2.5-3.5 μ
2	<i>T. polysporum</i> Link ex pers. Rifai	Slow growing, smooth, pure white	No pigments	1.8-10	Formed infrequently, Sub-globose	In compact tufts	Short and plump, 4.6-6.5 x 3.0-3.5 μ whole like arrangements	Ellipsoid, Colourless, 2.8-3.7 and 1.8-2.0 μ
3	<i>T. hamatum</i> (Bon.) Bain	Slow growing, smooth, whitish to greyish green	No pigments	2.0-9.0	Formed frequently	Highly remifice, form compact tufts	4.0-6.5 x 3.0-4.0 μ	Smooth walled, 3.8-6.0 x 2.2-2.8
4	<i>T. koningii</i> Oud	Rapid growth, smooth surfaced which turns hairy latter, dull dark green	No pigments	2.0-10	Inter calary chlamydo-spores	Much branched, in ring like forms	Fine, pin shaped, 7.5-12.0 x 2.5-3.5 μ in false verticles	Obvoid, smooth walled. 3.0-4.8 x 1.9-2.8 μ
5	<i>T. aureo viride</i> Rifai	Very slow growth, smooth surface	No pigments	1.5-8.0	Scarce	Indistinct, compact tufts	Long and slender, 7-14 x 2.2.5 μ	Obvoid, smooth walled. 3.0-4.3 x 2.0-3.0 μ
6	<i>T. harzianum</i>	Rapid growth, smooth surfaced, which turns hairy later, dull green	No pigments	1.5-12.0	Inter calary or terminal	Much branched, dendroid and form loose tufts	In verticles, short sickle shaped, 5.0-7.0 x 3.0-3.5 μ	Sub-globose, smooth walled. 2.8-3.2 x 2.5-2.8 μ
7	<i>T. longibrachiatum</i> Rifai	Rapid growth, smooth at first which turn fluccose, olive green	Yellowish green pigment, Secreted in some isolates	2.0-10	Numerous, terminal and inter calary	Tufted and arise in circular zone, simple branching.	Bottle shaped abruptly attenuate towards the apex. 6-14 x 2.5-3.0	Elliptical, smooth walled. 3.4-4.6 x 2.0-2.25
8	<i>T. Pseudokoningii</i> Rifai	Rapid growth, smooth, greenish to bright	Yellowish pigments secreted	1.0-10	Infrequently	Formed in different zones	In false whorls skittle shaped, 5.5-8.0 x 2.7-3.5	Sub cylindrical or oblong, smooth walled, 3.4-4.6 x 2.0-2.25 μ
9	<i>T. viride</i> Pers. ExSF Grey	Rapid growth, smooth at first which turn hairy later	No pigments	1.5-12	Formed often	Compact to loose tufts, from continuous or brockening	In false whorls 8.0-14 x 2.4-3.0 μ	Globose or obvoid, 3.6-4.5 x 2.2-3.0 μ

In vitro efficacy of *T. harzianum* and *T. viride* was reported by D'Ercole *et al.* (1993). They found that, the antagonists produced volatile compounds like caprilic, caprinic, capronic acid, ethylene and formaldehyde. Harman *et al.* (1993) purified the chitinolytic enzymes produced by *T. harzianum*. Harman (2000) found that *Trichoderma* spp. exhibited two types of mechanisms like rhizosphere competence, which is the ability of the microorganism to grow and function in the developing rhizosphere and induce systemic acquired resistance (SAR) which give long term protection at substantial distance from the infection site. Saju *et al.* (2002) reported that *Trichoderma* spp. were able to inhibit *P. capsici* infecting black pepper by overgrowth and lysis of mycelia to varying degrees. They also found that percentage inhibition of foot rot pathogen by *Trichoderma* spp. varied from 20 to 81 per cent.

Cook and Baker (1983) found that hyphae of antagonists parasitized on the hyphae of pathogens brought about several morphological changes viz., coiling, disintegration of host cell contents and penetration of host cells. *T. harzianum* readily parasitised the hyphae of *R. solani* leading to coiling and penetration followed by disintegration and death of mycohost (Gokulapalan, 1989). Singh and Singh (2000) studied the antagonistic effect of *T. harzianum* against *S. rolfsii* in brinjal and found that the antagonists attacked and lysed the mycelium and sclerotium of the pathogen. Bunker and Mathur (2001) demonstrated that the hyphae of *T. aureoviride* Rifai coiled over the hyphae of *R. solani* in dual culture, thus resulting in emptying of the contents of hyphae of the latter.

Lenne and Brown (1991) suggested that antibiotics produced by bacterial antagonists were chiefly responsible for the inhibition of *Colletotrichum gloeosporioides*.

2.3.5 *Compatibility of fungicide with antagonists*

The integrated management of diseases is a combination of various control measures. Among these, role of biocontrol agents are important. According to Papavizas (1985) integrated approach can be successful only if the antagonists are

compatible with fungicides. So an idea on the fungicide tolerant strain of *Trichoderma* spp. is essential for success of integrated disease management.

Compatibility of potassium phosphonate with *Trichoderma* spp. was reported by many workers. Moity *et al.* (1982) found that potassium phosphonate was compatible with *Trichoderma* spp. Rajan and Sarma (1997) reported that Akomin and antifungal compound was compatible with *Trichoderma* spp. even at 1200 ppm. They also found that all the *Trichoderma* spp. tested were compatible with Akomin and effectively used for managing *Phytophthora* foot rot of black pepper.

Papavizas (1981) demonstrated the compatibility of metalaxyl with *T. harzianum*. Metalaxyl stimulates lytic capacity of soil microorganisms antagonistic to *P. cinnamomi*. Malajezuk *et al.* (1983) found that metalaxyl was non-toxic to *T. harzianum* in contrast to benzimidazole fungicides. Sharma and Mishra (1995) opined that fungicides like metalaxyl and Captafal showed little inhibition to *T. harzianum*. May and Kimati (2000) reported that among several contact and systemic fungicides tested, metalaxyl at all tested rates did not affect the growth of *Trichoderma*. Akbari and Parakhia (2001) suggested that metalaxyl MZ and fosetyl-Al were found non-inhibitory to *T. harzianum*, *T. viride* and *G. virens* at all concentrations. Jayakumar *et al.* (2003) noticed that *Trichoderma* sp. was competent with metalaxyl MZ even at 1000 µg/ml and showed good control of damping off chilli.

Shanmugham (1996) reported that Bordeaux mixture completely inhibited the growth of *T. viride*. Sarma and Anandaraj (1997) found that copper fungicides were toxic to *Trichoderma* spp. and *Gliocladium virens*. Peciulyte *et al.* (2000) tested sensitivity of thirteen fungi to copper sulphate and copper oxychloride and found that both fungicides were active against fungi. Antagonistic fungi, *Trichoderma* species was more sensitive to copper oxychloride than copper sulphate. Vijayaraghavan and Abraham (2003) reported that Bordeaux mixture at all concentrations completely inhibited the growth of *T. harzianum*, *T. viride* and *T. longibrachiatum* while Ridomil

MZ, Akomin-40, Indofil M-45 and Anthracol at different concentrations showed varying degree of inhibition.

2.4 TIME OF PLANTING

Studies at Pepper Research Station, Panniyur indicated that February to March was the ideal time for raising pepper nursery (PRS, 1998), while, at Ambalavayl it was March (KAU, 2001). During this period, maximum germination, root production and maximum establishment of plants were noticed. However, there was no report about the effect of time of planting on the incidence of *Phytophthora* rot in black pepper nursery. Work done on other crops showed that time of planting had impact on incidence of diseases. Hoshika (1950), Okomoto *et al.* (1951) reported that, by early sowing of rice crop, the plants were able to escape infection as they would have become older by the time the favourable environmental conditions for the disease sets in. Singh *et al.* (1987) showed that potato crop planted in and around 20th October developed minimum disease of *Alternaria alternata* and *Phoma* spp. and gave higher yield. Singh (2002) reported that sowing date of sunflower significantly affected the disease severity (leaf blight) caused by *Alternaria helianthi*. Disease severity was less in crop sown on August 26th than that recorded in crops sown on July 22nd, August 14th and August 2nd. He also observed that optimum temperature and dense canopy of crop which prevailed during rainy season might have affected and favoured the rapid sporulation and development.

2.5 SOLARIZATION

The search for new effective, simple inexpensive and non-hazardous methods for managing soil borne plant pathogens is a continuous task as none of the existing methods can be used in all instances. Some treatments are expensive and economically restricted to certain crops and seasons, whereas others can never be widely used owing to the environmental and economic consideration.

Soil solarization is a method of hydrothermal disinfestation accomplished by covering moist soil with polythene sheets during summer months (Katan, 1981). In

addition to reducing soil fungi, bacteria, nematodes and weeds, soil solarization often results in increased plant growth response (Devay, 1991).

Negative side effects such as phytotoxicity due to release of manganese or other toxic products and rapid soil infestation due to the creation of a biological vacuum were also reported (Baker, 1962; Dawson *et al.*, 1965; Olsen and Baker, 1968).

Effectiveness of solarization in controlling *Phytophthora* diseases in various crops was reported. Solarization was effective in controlling *Phytophthora* disease in tomato and capsicum (Satour *et al.*, 1991). Kurian (1992) and Vilasini (1996) reported the reduction of fungal, bacterial and actinomycetes population in soil. Chellemi *et al.* (1997) recorded the significant reduction in population density of *P. nicotianae* var. *parasitica* in soil by solarization. *P. cinnamomi* activity was not detected at 30 cm depth in infected soil solarized for two weeks. Lopez-Herrera *et al.* (1997) could not observe *P. cinnamomi* at 30, 45 and 60 cm depths after 4-8 weeks of solarization. Sarma *et al.* (1994) reported that soil temperature of solarized bed rose to as high as 50°C which was 10-12°C higher than non solarized bed. They also found a reduction of *Phytophthora* rot in black pepper nursery by soil solarization.

Kurian (1992) found the difference in maximum and minimum soil temperature in solarized and non solarized soil, ranged from 6-11.5°C. She also reported that, solarization was very effective in reducing the disease incidence and increasing the growth of chilli plant. Vilasini (1996) reported an increase in soil temperature in solarized soil over non solarized at 5 and 10 cm depths. It was found that mean maximum temperature was 58.8°C and 53.3°C in solarized soil at 5 and 10 cm depth while it was 46.7°C and 40.6°C in non solarized soil. She also found the effectiveness of soil solarization for reduction in soft rot of ginger.

Sarma *et al.* (1996) reported that solarization of potting mixture was effective in reducing the *P. capsici* of black pepper nursery. Studies at different stations of Kerala Agricultural University revealed that solarization of potting mixture

reduced the pre-sprouting mortality and mortality of rooted cuttings by *P. capsici*. Forty five days solarization with incorporation of *Trichoderma viride* plus Fytolan drenching showed 100 per cent control of nursery diseases. Forty five days solarization plus *Trichoderma viride* was highly effective and recorded 97.22 per cent disease control. Reduction in *Phytophthora* population of potting mixture ranged from 94.41 to 97.35 per cent immediately after solarization. Maximum population of *Trichoderma* spp. was observed in solarized soil incorporated with *Trichoderma* spp. All growth parameters like height of plants, number of leaves, length and breadth of leaves and development of root system were influenced by solarization (KAU, 2001).

2.6 INTEGRATED DISEASE MANAGEMENT (IDM)

Soil is the inhabitant of many microorganisms including plant pathogens, whose activities are influenced by many physical, chemical and biological interactions on it. Many of the serious plant diseases are soil borne, including *Phytophthora* which results in huge economic losses.

Since any single method would be of little effect to contain the disease, an integrated approach would be an ideal strategy to tackle the complex and serious soil borne plant pathogens in many of the economically important crops like black pepper (*Piper nigrum* L.). Nursery hygiene, phytosanitation and other cultural practices, chemical and biocontrol measures coupled with host resistance are important components of IDM, that would reduce the cost, pesticide/fungicide load to the environment.

Hawang and Kim (1995) suggested that *Phytophthora* blight caused by *P. capsici* of *Capsicum annuum* could manage by adopting chemical, biological, cultural (providing better drainage) and plant tolerant varieties. Patel *et al.* (1996) reported that soil solarization of two months during the hot summer and two sprays of metalaxyl + application of *T. harzianum* in tobacco nursery reduced damping off caused by *Pythium aphanidermatum* and yielded maximum number of transplantable seedlings.

There are many reports of integrated management of *Phytophthora* infection in black pepper. Influence of selection of disease free planting material for the *Phytophthora* rot of black pepper was emphasised by Mammooty *et al.* (1980); Sarma *et al.*, (1987) and Sarma *et al.* (1991).

It is very difficult to control *Phytophthora* species once it gains entry into the garden. Therefore use of disease free planting materials is the first step towards the establishment of healthy garden (Sarma *et al.*, 1988 and Mammooty *et al.*, 1992).

Sarma *et al.* (1987) and Ramachandran *et al.* (1991) stressed the need for selection of disease free planting materials, using resistant cultivars, cultural practices and timely use of fungicides for reducing the *Phytophthora* infection in black pepper. Anandaraj and Sarma (1995, 1998) suggested spraying of Bordeaux mixture one per cent, and drenching with copper oxychloride 0.2 per cent and foliar spray of Ridomil MZ/Akomin-40 (0.3 per cent) and application of biocontrol agents to prevent the build up of *P. capsici* in black pepper.

Solarization of potting mixture with addition of neem cake and timely application of fungicides under shaded condition (50 per cent shade) reduced the incidence of nursery diseases of black pepper (PRS, 1993). Sarma *et al.* (1994) recommended cultural practices, chemical control of drenching with copper oxychloride and spraying with Bordeaux mixture alternated with Ridomil against *P. capsici*. Application of neem cake at 1 kg/vine increased in population of microbial antagonists and addition of AMF propagules boosts plant growth and suppressed root infection by *P. capsici*. Nair *et al.* (1993) reported that addition of neem cake @ 2 kg/vine and lime @ 1 kg/vine coupled with Bordeaux mixture spray, drench and pasting reduced the foot rot incidence and increased the yield of black pepper.

Lokesh and Gangadharappa (1995) reported that *Phytophthora* foot rot and nematode diseases of *P. nigrum* were effectively managed by cultural practices, neem cake and phorate application in soil drenching and pasting of Bordeaux mixture before

the onset of monsoon and Akomin (0.04 per cent), Ridomil MZ (100 ppm) as a spray and drench during the second week of July and September in Karnataka. Hegde and Anahosur (1998) reported that success of integrated management of foot rot of black pepper by application of organic amendment and fungicidal application. The reduction in *Phytophthora* rot of black pepper by combined application of Ridomil MZ and biocontrol agents like *Trichoderma* spp. was reported by Sodsa *et al.* (1999). Binimol (2000) reported that 30 days solarized, *T. viride* incorporated, Fytolan drenched treatments were highly effective in managing the *Phytophthora* rot in black pepper. Mammootty *et al.* (2003) reported that spraying and drenching of metalaxyl gold MZ (2.5 g/l) and soil application of *Trichoderma* species registered more than 75 per cent control of *Phytophthora* foot rot in black pepper. Abraham *et al.* (2003) conducted a trial for managing *Phytophthora* rot in black pepper nursery at six pepper growing tracts of southern districts of Kerala and found that percentage of sprouting of pepper cuttings and disease incidence varied with locations. *T. harzianum* had an effect on decreasing disease incidence. The maximum mean sprouting percentage was noticed in treatment of soil solarization for 30 days + *T. harzianum* alone followed by the treatment as per Package of Practices of Kerala Agricultural University.

Materials and Methods

3. MATERIALS AND METHODS

The present investigations on "Nursery diseases of black pepper (*Piper nigrum* L.) in Kerala with special reference to the management of *Phytophthora capsici* Leonian, emend. Alizadeh and Tsao" was conducted at College of Horticulture, Vellanikkara and Regional Agricultural Research Station (RARS), Pilicode during the period 1998 to 2002.

3.1 SURVEY ON THE OCCURRENCE OF NURSERY DISEASES OF BLACK PEPPER

A survey on the occurrence of various diseases in black pepper nurseries raised in the major pepper growing areas of Kasargode, Kannur, Kozhikode and Wynad districts of Kerala was carried out during four nursery seasons of 1998 to 2001. For this, 30 pepper nurseries were selected randomly by stratified random technique which included two from Kerala Agricultural University (KAU), eight from Department of Agriculture, Kerala and twenty from Government approved private nurseries (Appendix-I). Details regarding, the location of nursery, type of nursery structure, type of potting mixture, place of collection of planting materials, varieties/cultivars planted, method of processing of planting materials before planting, method of treatment of potting mixture, time of planting, frequency of irrigation, plant protection methods adopted, incidence of various diseases in the nursery, symptoms of diseases and causal organisms associated with the diseases in the nurseries were collected using a proforma developed for this purpose (Appendix-II). Observations were taken at monthly intervals from February to July from Kasargode, Kannur and Kozhikode districts and from March to August from Wynad district, where raising of nursery was delayed for one month. For recording the incidence of diseases, one square metre area was marked at different points of nursery depending upon its size. From each marked area, the total number of plants and the number diseased were recorded and the percentage incidence of each disease was worked out. Further, the effects of nursery structure, potting mixture, place of collection of planting materials, varieties/cultivars, processing of runner vines, treatment of potting mixture, time of

planting, frequency of irrigation and plant protection measures on the incidence of various diseases were worked out.

3.2 ISOLATION AND IDENTIFICATION OF PATHOGENS

The pathogens causing diseases in black pepper nurseries were isolated from naturally infected pepper cuttings collected from different locations by standard techniques and the Koch's postulates established. The organisms were purified by hyphal tip method and they were identified based on morphological and cultural characters. Ten isolates of each pathogen causing *Phytophthora* rot, *Colletotrichum* rot, *Rhizoctonia* rot and *Sclerotium* rot were collected. The isolates were maintained by periodic sub-culturing in Potato Dextrose Agar (PDA) medium (Appendix-III).

3.3 SYMPTOMATOLOGY

Symptoms of nursery diseases under natural conditions were recorded during the survey of 30 pepper nurseries. Symptoms produced by each pathogen on artificial inoculation of pepper plants were also recorded.

For studying the symptomatology of the diseases under artificial conditions, the pathogens causing rot diseases of pepper cuttings were inoculated as per standard procedure. The inoculum consisted of zoospore/conidial suspension or culture discs of actively growing mycelia with sporangia/conidia/sclerotia of the respective causal organisms. Inoculation was done on leaves, stem and roots depending upon the disease from which the pathogens were isolated.

3.4 SCREENING OF BLACK PEPPER VARIETIES/CULTIVARS AGAINST NURSERY DISEASES

Seven pepper varieties released from Kerala Agricultural University (KAU), four from Indian Institute of Spices Research (IISR), Kozhikode and 39 cultivars/ cultures maintained at the germplasm bank of Pepper Research Station (PRS), Panniyur were evaluated for their resistance/tolerance against rot diseases due

to *Phytophthora capsici*, *Colletotrichum gloeosporioides*, *Rhizoctonia solani* and *Sclerotium rolfsii* (Appendix-IV). The experiment was laid out in CRD. The details of the experiment is as follow:

Design	: CRD
Number of varieties/cultivars	: 50
Replications	: 3
Number of bags/replication	: 50
Number of plants/bag	: 5

The planting materials of the varieties/cultivars were collected from PRS, Panniyur and multiplied at RARS, Pilicode using Rapid Multiplication Techniques (RMT). The vines from RMT were later planted in polyethylene bags (8 x 15 cm) filled with potting mixture containing sand, soil and cowdung at the ratio of 1:1:1, during first week of March 1999. Four months old cuttings were used for screening in July 1999. Inoculation with different pathogens were done by standard techniques. Observations on the incidence of leaf infection and mortality were recorded at regular intervals and the mean percentages worked out.

3.5 BIOCHEMICAL ANALYSIS

Biochemical analysis was carried out for assessing the biochemical bases of tolerance/susceptibility of three pepper genotypes showing susceptible (Panniyur-1), moderately susceptible (Panniyur-5) and tolerant (Kalluvally-II) reactions against *P. capsici*. These genotypes were selected based on the results obtained from screening of pepper varieties/cultivars as given under 3.4.

The biochemical parameters like total phenol, OD phenol, total carbohydrates, starch, reducing sugars, peroxidase, catalase, acid phosphatase, esterase and total free amino acids were estimated from the second leaves of four month old rooted cuttings of above genotypes by maintaining adequate replications. The methodology followed for the estimation of the above biochemical parameters are as follows:

Sl.No.	Parameters	References
1	Total phenol	Sadasivam and Manickam (1992)
2	OD Phenol	Sadasivam and Manickam (1992)
3	Total carbohydrates	Sadasivam and Manickam (1992)
4	Starch	Sadasivam and Manickam (1992)
5	Reducing sugars	Sadasivam and Manickam (1992)
6	Peroxidase	Kar and Misra (1976)
7	Catalase	Kar and Misra (1976)
8	Acid phosphatase	Fiske and Row (1925)
9	Esterase	Asperen (1962)
10	Total free amino acids	Yapinlla and Takahashi (1966)

3.6 ISOLATION OF NATIVE MICROFLORA FROM THE RHIZOSPHERE SOIL

The native rhizosphere microflora from all the 30 pepper nurseries selected for the survey were estimated during July 1998. The quantitative estimation of microflora was done by serial dilution plate technique (Johnson and Curl, 1972). Martins rose Bengal Streptomycin agar, soil extract agar and Kenknights agar (Appendix-III) were used for estimating fungi, bacteria and actinomycetes at a dilution of 10^3 , 10^6 and 10^6 respectively. After purification of the selected isolates of microflora, they were maintained in appropriate media viz., PDA for fungi, nutrient agar for bacteria and Kenknight's agar for actinomycetes. The isolates were maintained by periodic subculturing for further studies.

3.6.1 Evaluation of rhizosphere microflora against *P. capsici*

3.6.1.1 *In vitro* evaluation

The antagonistic property of the micro-organisms isolated from rhizosphere soil against *P. capsici* was studied and compared with two established antagonists, viz., *Trichoderma viride* and *Trichoderma harzianum* by employing dual culture technique (Skidmore and Dickinson, 1976).

3.6.1.2 *Fungi*

Forty eight fungal isolates (F1 to F48) and two established antagonists viz., *T. viride* and *T. harzianum* were tested for their antagonistic effect against *P. capsici*.

Mycelial disc of 8 mm diameter of the pathogen from four days old culture grown in PDA was inoculated at one side of the nine cm Petridish containing PDA and incubated for 48 h. After this, 8 mm mycelial disc of the test isolate was placed 3.5 cm away from the pathogen in the same Petridish and incubated. Three replications were maintained for each antagonist. The pathogen and test organisms grown in monoculture served as control. The growth measurements were taken after 24 h of inoculation of antagonists for four days. The per cent inhibition (I) was calculated using the formula suggested by Vincent (1927).

$$I = \frac{C - T}{C} \times 100$$

where C - Growth of the pathogen in control
T - Growth of the pathogen in dual culture

3.6.1.3 Bacteria

Twenty one bacterial isolates (B1 to B21) from the rhizosphere soil of pepper cuttings were tested for their antagonism against *P. capsici* by the technique of Utkhde (1984). The bacterial isolates were streaked 3.5 cm apart in nine cm Petridish containing PDA two days after the inoculation of the pathogen and incubated for five days. The pathogen and test organisms grown in monoculture served as control. The growth measurements were taken after 24 h of inoculation of test organisms and percentage of inhibition was worked out as given under 3.5.1.2.

3.6.1.4 Actinomycetes

The method for testing *in vitro* antagonism of fourteen actinomycetes (A₁ to A₁₄) against *P. capsici* was done using gross streak assay method (Ahamed and Ahamed, 1963). For this, the pathogen was inoculated 3.5 cm apart from actinomycetes two days after the inoculation of the actinomycetes and incubated up to seven days. Observations were recorded and the percentage of inhibition was calculated as given under 3.5.1.2.

3.6.2 *In vivo* evaluation

All the isolates of fungi, bacteria and actinomycetes studied under *in vitro* conditions were used for evaluating their efficiency in reducing the incidence of *Phytophthora* root rot of pepper cuttings grown in polyethylene bags. The experiment was conducted at RARS, Pilicode during 1999 as per the details given below.

Design	: CRD
Replication	: 3
Number of bags/replication	: 10
Number of plants/bag	: 5
Variety	: Panniyur-1

3.6.2.1 *Mass multiplication of P. capsici*

P. capsici was mass multiplied in sand oats medium. It was prepared by mixing sieved and washed white sand with oat meal in the ratio 19:1. This mixture was taken in 500 ml conical flasks moistened with water and sterilized by autoclaving. The medium was inoculated with 10 mm mycelial disc of *P. capsici* and incubated for two weeks before incorporating in the potting mixture.

3.6.2.2 *Mass multiplication of antagonistic fungi*

For mass multiplication, 10 mm disc of seven day old culture of 50 antagonistic fungi grown on PDA was inoculated in sterilized rice bran filled in polypropylene cover and incubated for 20 days so as to get a population of 10^6 cfu g⁻¹ of the substrate.

3.6.2.3 *Mass multiplication of bacteria*

Bacterial isolates were streaked on nutrient agar in Petridishes and incubated for 72 h for mass multiplication. To each Petridish, ten ml of sterile water was added and the bacterial growth was scraped and added to the beaker. It was then diluted with sterile water to get a bacterial suspension containing 10^{-8} cfu ml⁻¹.

3.6.2.4 *Mass multiplication of actinomycetes*

The growth of the actinomycetes from Petridishes was transferred to 250 ml conical flasks with 100 ml of sterile water and mixed thoroughly in a shaker for ten minutes. Ten ml of this suspension was inoculated to the polyethylene bags containing one kg of 1:1:1 potting mixture.

3.6.2.5 *Inoculation*

The isolates of fungi, bacteria and actinomycetes multiplied as mentioned above were tested against *P. capsici*. For this, antagonists (@ 3 g kg⁻¹ for fungi, 10 ml kg⁻¹ for bacteria and actinomycetes) were mixed with potting mixture in polyethylene bags of size of 8 x 15 cm, just before planting of pepper cuttings. The mass multiplied pathogen was inoculated @ 5 gm kg⁻¹ soil near the base of rooted cuttings 25 days after planting, by removing the top layer of soil and later refilled. After two months of inoculation of *P. capsici*, the cuttings were carefully uprooted, washed thoroughly and observations on the number of roots infected and fresh and dry weights of roots were recorded. The cuttings inoculated with *P. capsici* alone served as control.

3.6.3 *Identification of antagonists*

An attempt was made to identify the two selected most efficient native antagonists, based on the previous studies. The morphological characters were studied by slide culture techniques (Riddel, 1950). Observations were taken on the branching pattern of conidiophore, length and breadth of phialide and shape, size and colour of spore.

To study the mechanism of antagonism of two selected fungal antagonists on *P. capsici*, the dual culture technique of Dennis and Webster (1971) was used.

3.7 COMPATIBILITY OF ANTAGONISTS TO FUNGICIDES

In vitro compatibility of two native fungal antagonists and two established cultures of *T. viride* and *T. harzianum* to four commonly used fungicides in black

pepper nursery were tested by poison food technique (Riker and Riker, 1936). The details of fungicides tested and concentrations are given below:

Trade name	Chemical name	Concentration (per cent)
Akomin-40	Potassium phosphonate	0.05, 0.10, 0.20
Ridomil MZ	Metalaxyl + Mancozeb	0.05, 0.10, 0.20
Bordeaux mixture	Copper sulphate + lime + water	0.5, 1.0, 2.0
Fytolan	Copper oxychloride	0.05, 0.10, 0.20

The required quantity of fungicides were added to 100 ml of sterilized molten PDA medium to get the desired concentrations, mixed well and poured into sterilized Petridishes @ 15 ml plate⁻¹. After solidification of the medium, 8 mm diameter disc of actively growing antagonists were placed at the centre of each Petridish. Five replications were maintained for each concentrations of fungicides. Observations on the growth of antagonists were recorded when they attained full growth in control and the percentage inhibition over control was worked out.

3.8 EFFECT OF TIME OF PLANTING ON THE INCIDENCE OF *Phytophthora* rot

Studies were conducted during 1998 and 1999 nursery seasons at RARS, Pilicode to find out the effect of time of planting on the growth of cuttings and on the incidence of *Phytophthora* rot in black pepper nursery. The experiment was conducted in CRD with ten treatments and three replications. Each replication consisted of 50 bags with five cuttings each. Cuttings of pepper variety Panniyur-1 were planted at fortnightly intervals in polyethylene bags filled with potting mixture starting from the first fortnight of January to the second fortnight of May. Observations on sprouting percentage was recorded one month after planting. Observations on height of plants, number of leaves, number of roots, wet and dry weights of roots and per cent disease incidence were recorded during the last week of July.

3.9 EFFECT OF SOLARIZATION OF POTTING MIXTURE ON THE INCIDENCE OF *Phytophthora* rot

The effect of solarization of potting mixture for 15, 30 and 45 days on the incidence of *Phytophthora* rot in black pepper nursery was studied at RARS, Pilicode during 1998 nursery season. The potting mixture with sand, soil and cowdung at the ratio 1:1:1 was made into a raised bed of 25 cm height and size of 2 x 1 m. The bed was levelled and moistened sufficiently with water. The potting mixture was then mulched with 150 gauge transparent polyethylene sheet. The sides of the sheet were covered with soil to keep the sheets tight in position. The sheets were removed after the required periods of solarization. Potting mixture without solarization served as control. Observations on soil temperature of solarized and non-solarized potting mixture at a depths of five and ten cm were recorded daily at 7.25 am and 2.25 pm in addition to the maximum and minimum atmospheric temperature. The microbial load was estimated just before and after solarization.

For evaluating the efficacy of solarization of potting mixture, an experiment was conducted at RARS, Pilicode as per the details mentioned below.

Design	: CRD
Replication	: 5
Treatments	: 5
Number of bags/replication:	50
Number of plants/bag	: 5
Variety	: Panniyur-1

The effect of duration of solarization of potting mixture on sprouting of cuttings, height of the plant, number of leaves, number of roots, length of roots, wet and dry weight of roots and incidence of *Phytophthora* rot were recorded four months after planting.

3.10 INTEGRATED DISEASE MANAGEMENT (IDM)

The experiments on the integrated management of *Phytophthora* rot in black pepper nursery was conducted at RARS, Pilicode during 2001 and 2002 nursery seasons. The treatments which were found effective in reducing the incidence of *P. capsici* from the previous experiments were included in this trial.

Three separate experiments were conducted using three pepper genotypes viz., Panniyur-1, Panniyur-5 and Kalluvally-II which showed susceptible, moderately susceptible and tolerant reaction respectively to *P. capsici* in both the season. The details of experiment are as follows:

Design	: CRD
Replication	: 3
Treatments	: 30
No. of bags/replication	: 50
No. of pepper cuttings/bag	: 5

Treatment details

Sl. No.	Treatments
1	T ₁ - Solarization of potting mixture for 30 days
2	T ₂ - T ₁ + <i>Trichoderma viride</i>
3	T ₃ - T ₁ + <i>Trichoderma harzianum</i>
4	T ₄ - T ₁ + <i>Trichoderma viride</i> - F48
5	T ₅ - T ₁ + <i>Trichoderma harzianum</i> - F14
6	T ₆ - Non-solarization + <i>T. viride</i>
7	T ₇ - Non-solarization + <i>T. harzianum</i>
8	T ₈ - Non-solarization + <i>Trichoderma viride</i> - F48
9	T ₉ - Non-solarization + <i>Trichoderma harzianum</i> - F14
10	T ₁₀ - T ₁ + spraying and drenching with Akomin-40 - 0.2 per cent
11	T ₁₁ - T ₁ + spraying and drenching with Ridomil MZ - 0.1 per cent
12	T ₁₂ - T ₁ + spraying and drenching with Bordeaux mixture - 1 per cent
13	T ₁₃ - T ₁ + spraying and drenching with Fytolan - 0.2 per cent
14	T ₁₄ - T ₂ + spraying and drenching with Akomin-40 - 0.2 per cent
15	T ₁₅ - T ₂ + spraying and drenching with Ridomil MZ - 0.1 per cent
16	T ₁₆ - T ₃ + spraying and drenching with Akomin-40 - 0.2 per cent
17	T ₁₇ - T ₃ + spraying and drenching with Ridomil MZ - 0.1 per cent
18	T ₁₈ - T ₄ + spraying and drenching with Akomin-40 - 0.2 per cent
19	T ₁₉ - T ₄ + spraying and drenching with Ridomil MZ - 0.1 per cent

20	T ₂₀ - T ₅ + spraying and drenching with Akomin-40 - 0.2 per cent
21	T ₂₁ - T ₅ + spraying and drenching with Ridomil MZ - 0.1 per cent
22	T ₂₂ - T ₆ + spraying and drenching with Akomin-40 - 0.2 per cent
23	T ₂₃ - T ₆ + spraying and drenching with Ridomil MZ - 0.1 per cent
24	T ₂₄ - T ₇ + spraying and drenching with Akomin-40 - 0.2 per cent
25	T ₂₅ - T ₇ + spraying and drenching with Ridomil MZ - 0.1 per cent
26	T ₂₆ - T ₈ + spraying and drenching with Akomin-40 - 0.2 per cent
27	T ₂₇ - T ₈ + spraying and drenching with Ridomil MZ - 0.1 per cent
28	T ₂₈ - T ₉ + spraying and drenching with Akomin-40 - 0.2 per cent
29	T ₂₉ - T ₉ + spraying and drenching with Ridomil MZ - 0.1 per cent
30	T ₃₀ - Absolute control

The potting mixture in the proportion of 1:1:1 (sand:soil:cowdung) was solarized for 30 days as per the details given in 3.9. The cuttings were planted in solarized and non-solarized soil filled in polyethylene bags of size 8 x 15 cm during the first fortnight of March and kept in nursery shed covered with shade net of 50 per cent light infiltration. Two established antagonists viz., *T. viride*, *T. harzianum*, and two native antagonists *T. viride* - F48 and *T. harzianum* - F14 and *P. capsici* were mass multiplied as per the details given in 3.5.2.1 and 3.5.2.2 and inoculated as per the details mentioned in 3.5.2.5. The application of fungicides was started two months after planting. For treatments T₁₀ to T₁₃, the fungicides were applied at fortnightly intervals and for treatments T₁₄ to T₂₉ fungicides were given at monthly intervals.

Observations on disease incidence due to *P. capsici* were recorded at regular intervals up to the last week of July. Per cent disease incidence and per cent efficacy of treatments over control were worked out.

3.11 STATISTICAL ANALYSIS

Statistical analysis was carried out with respect to various experiments using the package MSTAT-C (Freed, 1986). Multiple comparison among treatment means was done using DMRT.

Results

4. RESULTS

4.1 SURVEY ON THE OCCURRENCE OF NURSERY DISEASES OF BLACK PEPPER

A survey on the occurrence of various nursery diseases of black pepper was carried out at four northern districts of Kerala viz., Kasargode, Kannur, Kozhikode and Wynad during 1998 to 2001 nursery seasons.

During the survey, it was observed that black pepper cuttings in nurseries were infected by *Phytophthora* rot, *Colletotrichum* leaf rot, *Rhizoctonia* and *Sclerotium* leaf and collar rots.

4.1.1 Isolation and identification of pathogens

The causal organisms involved in the above four nursery diseases were isolated and Koch's postulates were established. Ten isolates of each pathogen were isolated from different nurseries spread over the four districts surveyed. The cultural and morphological characters of the isolates were studied. Based on the characters and their pathogenicity, the isolates were identified.

4.1.1.1 *Phytophthora* sp.

Phytophthora isolates grown in carrot agar medium produced petalloid uniformly dense cotton wool like aerial mycelium, rarely stellate or radiating. The growth was more dense in the central portion. Hyphae were hyaline, non-septate and smooth. Sporangia were produced on sporangiophore in an umbellate pattern with long caducous sporangia (Plate 1). Sporangia were obovoid to pyriform and ellipsoid, base usually tapered towards the stalk end. Length of sporangia ranged from 20.50 to 92.30 μm and breadth from 19.60 to 56.20 μm . L/B ratio varied from 1.05 to 2.95. The pedicel length varied from 15.8 to 104.0 μm (Table 1). Based on these characters, the ten isolates of *Phytophthora* were identified as *Phytophthora capsici* Leonian emend A. Alizadeh and P.H. Tsao.

4.1.1.2 *Colletotrichum* sp.

The colony colour of the isolates varied from light to dark grey in PDA. However, some isolates exhibited uniformly dark grey growth. The mycelial width ranged from 1.25 to 4.00 μm (Table 2). The colour of spore mass of all the isolates except the one from Vengad was salmon pink while the spore mass from Vengad was pale pink. The length and breadth of conidia of the isolates ranged from 13.45 to 16.45 μm and 3.86 to 5.36 μm respectively (Plate 2). The conidia of the pathogen isolated from Rajapuram were the largest (16.45 x 5.36 μm) while the one from Vengad was the smallest (13.45 x 3.05 μm). Based on the above characters, the pathogen was identified as *Colletotrichum gloeosporioides* (Penz.) Penz. and Sacc. (Plate 2).

4.1.1.3 *Rhizoctonia* sp.

The mycelia were colourless and sub-aerial during the initial stages, later gradually turned dark brown (Plate 3). Mycelium was septate, measured 5.80 to 11.30 μm in thickness (Table 3). Sclerotial formation was scanty and they were unevenly distributed. The sclerotia were rough globose, sub-globose and round to irregular. Sclerotial size varied from 1.00 to 2.80 mm. Based on these characters, the pathogen was identified as *Rhizoctonia solani* Kühn.

4.1.1.4 *Sclerotium* sp.

The mycelial mat of the pathogen grown in PDA was whitish and they were septate and width ranged from 1.80 to 3.90 μm . It produced large number of sclerotia individually or in clusters (Plate 4). The shape of sclerotia was round to irregular and measured 1.22 to 1.87 mm in size (Table 4). Based on these characters, the fungus was identified as *Sclerotium rolfsii* Sacc.

4.2 SYMPTOMATOLOGY

4.2.1 *Phytophthora* rot

All parts of black pepper cuttings were affected by the pathogen. Generally, three types of symptoms were noticed in the nursery i.e., leaf rot, stem/collar rot and root rot.



Plate 1. Mycelium with sporangia of *Phytophthora capsici*



Plate 2. Conidia of *Colletotrichum gloeosporioides*



Plate 3. Culture of *Rhizoctonia solani*



Plate 4. Culture of *Sclerotium rolfsii*

Table 1. Morphological characters of *Phytophthora* isolates from different pepper nurseries

Sl. No.	Location	*Sporangia		*L/B ratio	*Pedicel length (μm)
		Length (μm)	Breadth (μm)		
1	Padmandeme	20.80-33.30	19.60-28.80	1.53-1.89	54.00-79.00
2	Karinthalam	20.50-34.00	19.30-26.80	1.06-1.27	37.30-94.00
3	Rajapuram	24.50-40.60	23.33-54.00	1.05-1.19	15.80-51.20
4	Panniyur	23.90-33.40	20.80-28.80	1.15-1.16	24.90-62.50
5	Vengad	20.80-62.40	19.60-56.20	1.06-1.16	29.12-87.40
6	Koodalipuram	30.10-67.40	24.50-40.50	1.23-1.66	42.31-78.50
7	Koothali	20.30-89.60	19.60-56.20	1.06-1.54	37.40-104.00
8	Moncombu kunnu	41.60-54.00	26.60-33.30	1.56-1.62	24.90-68.44
9	Neerchal	37.40-53.60	25.30-34.40	1.48-1.56	20.80-58.80
10	Kenchira	33.30-92.30	24.60-51.30	1.35-2.95	16.60-73.00

* Mean of 100 observations

Table 2. Morphological characters of *Colletotrichum* isolates from different pepper nurseries

Sl.No.	Location	Width of mycelium (μm)	*Size of conidia	
			Length (μm)	Breadth (μm)
1	Padmandeme	1.25-2.00	15.85	4.49
2	Karinthalam	1.25-3.00	14.75	4.03
3	Rajapuram	1.25-3.50	16.45	5.36
4	Pullur	1.25-3.50	14.71	3.86
5	Kubaneer	1.25-3.50	15.43	5.08
6	Panniyur	1.25-2.50	13.45	3.05
7	Vengad	1.25-4.00	15.40	4.43
8	Karimbam	1.25-2.00	14.39	4.36
9	Neerchaal	1.25-3.50	15.83	4.49
10	Moncombukunnu	1.25-3.00	14.15	4.76

* Mean of 100 observations

Table 3. Morphological characters of *Rhizoctonia* isolates from different pepper nurseries

Sl.No.	Location	*Width of mycelium (μm)	*Sclerotial characters	
			Shape	Size (mm)
1	Padmandeme	6.30-9.20	Globose-subglobose	2.00-2.70
2	Karinthalam	7.10-11.30	Globose-subglobose	1.60-2.80
3	Rajapuram	6.30-9.20	Globose-subglobose	1.30-2.80
4	Pollur	6.70-8.90	Globose-subglobose	1.80-3.00
5	Kubaneer	6.30-9.20	Globose-subglobose	1.70-2.50
6	Kaimbam	5.80-8.40	Globose-subglobose	1.30-1.60
7	Panniyur	6.30-9.20	Globose	1.70-2.60
8	Vengad	5.80-8.40	Globose	1.00-2.00
9	Perumunna	6.30-9.80	Round	1.00-1.80
10	Koodalpuram	6.70-10.30	Globose-subglobose	1.70-2.30

*Mean of 100 observations

Table 4. Morphological characters of *Sclerotium* isolates from different pepper nurseries

Sl.No.	Location	*Width of mycelium (μm)	*Sclerotial characters	
			Shape	Size (mm)
1	Padmandeme	2.10-3.81	Round	1.26-1.77
2	Karinthalam	1.80-3.90	Round	1.40-1.77
3	Rajapuram	2.50-3.74	Irregular	1.45-1.86
4	Kubaneer	2.50-3.46	Round	1.36-1.77
5	Karimbam	2.10-3.90	Round	1.49-1.80
6	Panniyur	2.25-3.80	Irregular	1.22-1.87
7	Vengad	2.00-3.50	Irregular	1.31-1.77
8	Mancombukunnu	2.25-3.85	Round	1.49-1.86
9	Neerchal	1.90-2.90	Round	1.40-1.82
10	Kenchira	2.25-3.86	Round	2.00-1.80

*Mean of 100 observations

The initial symptoms on leaves appeared as small, irregular, water soaked brown lesions with smooth or fimbriate margins, which advanced later rapidly (Plate 5a). An yellow halo was noticed surrounding a fully developed lesion which had a necrotic centre. Generally, the leaf infection initially occurred on the lower leaves and later spread to upper leaves. It was observed that immature leaves were severely affected compared to mature ones. In certain cases, greyish brown lesions with concentric zonations were also observed near the tip as well as on other portions of infected leaves (Plate 5b).

Stem/collar rot resulted in fatal infection with complete death of the vine. Initially a dark brown to black linear lesions appeared on the stem, which later turned wet and slimy to touch. Foliar yellowing, defoliation and breaking off of the stem at the nodal region were the general aerial symptoms noticed in the affected pepper cuttings. Discolouration and rotting of cuttings were also seen at the collar region. During advanced stages of infection, complete decaying and disintegration of the internal tissues were observed. Generally, the rotting at the collar region advances upward and downward. Internal discolouration was also noticed at the site of infection. Death of cuttings was observed within 10-15 days after the appearance of the first symptom.

In the case of root infection, dark brown discolouration appeared on fine roots, which gradually spread to the major roots and then underground portion. The aerial symptom due to root rot was similar to that of collar infection. In addition to this, the leaves turned yellow due to root infection (Plate 5c).

On artificial inoculation on leaves, the pathogen produced water soaked lesions within 24-48 h and the development of symptoms was similar to that observed under natural condition. On stem, the pathogen produced the initial symptom within 48 h and full development of symptoms occurred within 6 to 8 days. The pathogen initiated the disease symptoms on roots within 48 h of inoculation and consequent aerial symptoms appeared within 5 to 10 days and complete death of vine occurred



Plate 5. Symptoms of *Phytophthora* rot in black pepper nursery

a) Leaf rot

b) Leaf rot with concentric zonations

c) Collar and root rot

within 10 to 15 days. Further, much variation was not observed in the symptom expression upon inoculation with different isolates of *P. capsici*.

4.2.2 *Colletotrichum* rot

Colletotrichum mainly infected the leaves of cuttings in the nursery and rarely the stem. Initial symptom on leaves was the development of a chlorotic speck, which turned dark brown in colour within a few days (Plate 6a). Subsequently, this spot enlarged in an irregular circular fashion with a definite yellow margin. The infected area was slightly depressed and colour turned grey to papery white. The acervuli of the pathogen were seen on the infected portions. Under the humid moist condition prevailed in the nursery, the lesions enlarged quickly and attained 25-50 mm in diameter within about seven to eight days. Fructification of the pathogen was more under humid conditions. Defoliation occurred within 10-15 days depending upon the stages of leaves infected, size of spots and climatic conditions.

On artificial inoculation, the initial symptom on leaves appeared within five to ten days. Not much variation in symptom development was observed when cuttings were inoculated with different isolates of the pathogen. The symptoms produced on artificial inoculation was similar to that observed under natural conditions, except for the initiation of numerous minute specks upon inoculation.

Stem infection due to the pathogen was very rare. The symptom usually developed near the nodal region of the newly formed tender shoots. The lesions developed as dark brown areas without any definite margin. Sometimes such lesions were confined to a small area enlarged longitudinally. Severe infection resulted in yellowing of newly formed leaves which later defoliated and such infected stem may sometimes get detached at the nodal region (Plate 6b). The development of symptom on stem after artificial inoculation was similar to that observed under natural conditions.

4.2.3 *Rhizoctonia* rot

The pathogen produced symptoms both on leaves and stem. Infection on leaves started as small brownish lesions, which later spread and turned to either greyish or dark brown patches. Fully developed lesions were brittle and grey in colour. Immediate defoliation was not observed (Plate 7a). Under favourable conditions nearby leaves got infected and such infected leaves were seen webbed together.

Dark brown lesions were initially noticed on the stem, especially on collar region, which later spread both upwards and downwards. Reddish brown ooze was occasionally noticed on the infected region. Later, dark brown to black linear lesions developed on internodal region of the infected vines. Cracking and splitting of the nodal and internodal portions were noticed. Such severe infection, resulted in drooping and drying up of leaves and finally the entire plants died within 10 to 25 days (Plate 7b).

Usually, roots of the affected plant remained apparently healthy even after the collapse and death of the vine. Disintegration and rotting of root system were also noticed occasionally. Such infected plants could be easily pulled out. Sclerotia of the pathogen were seen adhered on the infected portion.

On artificial inoculation, the fungus induced the initial symptoms on leaves within five to eight days and on stem within five to twelve days. Marked variation in the symptom development among the different isolates was not noticed. Further, development of symptoms was same as that observed under field condition.

4.2.4 *Sclerotium* rot

In nursery, *Sclerotium rolfsii* was found to infect both leaves and stem of pepper cuttings. On stem, infection was more at the collar region. The main detectable sign of this disease was the appearance of whitish mycelial growth on infected portion. On leaves, initial symptom was the development of water soaked lesion. Later, the

lesion enlarged and the centre of the lesion became grey surrounded by water soaked or yellow areas (Plate 8a). In severe cases, blighting of entire leaves followed by defoliation were observed.

On artificial inoculation, symptoms were developed within four to seven days. Further, development of symptoms was very slow. The infected leaves defoliated within one to two weeks (Plate 8b). The infected portion became dark brown, which spread both upwards and downwards. Such infection resulted in drooping and final defoliation. Severe infection resulted in the collapse and death of vine. Oozing of gummy exudates was invariably noticed on the infected site. Further, it was found that lower portion of infected area remained healthy for one or two weeks and later dried up. Typical sclerotia of the fungus were observed on the infected portion under humid condition. There was not much variation in the symptom development due to different isolates of *S. rolfsii* on artificial inoculation. The infection initiated within five to seven days of inoculation and the death of the vine took place within one to two weeks.

4.3 INCIDENCE OF DISEASES IN DIFFERENT NURSERIES

During the course of the survey, per cent incidence of the four diseases in 30 pepper nurseries were recorded at monthly intervals from February to August during 1998 to 2001 and the results are presented below (Table 5, Fig. 1).

4.3.1 *Phytophthora* rot

Among the diseases in black pepper nurseries, the maximum incidence was due to *Phytophthora* rot. Out of 30 nurseries surveyed, the disease was recorded in 29 nurseries. However, the nursery of Regional Agricultural Research Station, Ambalavayal, Wynad district, was free from the disease as the cuttings were raised under high density polyethylene sheet (HDPE sheet), which permitted 50 per cent light infiltration.

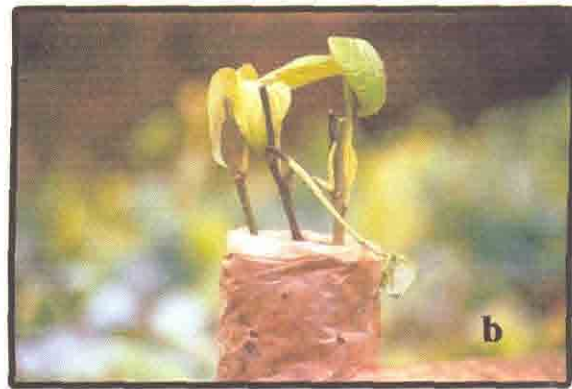


Plate 6. Symptoms of *Colletotrichum* rot

a) Leaf rot

b) Stem rot



Plate 7. Symptoms of *Rhizoctonia* rot

a) Leaf rot

b) Collar rot



Plate 8. Symptoms of *Sclerotium* rot

a) Leaf rot

b) Collar rot

During 1998, the disease was not recorded at Edaneer and Gundiaduka of Kasargode district, Perumpadavu of Kannur district and at RARS, Ambalavayal, Wynad district. At three locations, viz., Padmandame, Thirumeni and Neerchal the incidence was more than 40 per cent. Twenty five to forty per cent incidence was recorded in four nurseries, 10-25 per cent incidence in 13 and below ten per cent in six nurseries. The mean disease incidence during 1998 was 15.37 per cent with highest incidence of 45.51 per cent at Neerchal and lowest of 3.00 per cent at Kuttikkol.

During 1999 season, out of 30 nurseries surveyed, those located at Pilicode and Rajapuram in Kasargode district, RARS, Ambalavayal and Sulthan's Battery in Wynad district did not show any incidence of *Phytophthora* rot. The maximum incidence of disease (40.05 per cent) was recorded at Neerchal. Twenty five to forty per cent incidence in six nurseries, 10 to 25 in 13 nurseries and less than ten per cent in six nurseries were recorded during the season. The mean incidence during 1999 was 14.74 per cent.

Data on disease incidence during 2000 revealed that, pepper cuttings raised at RARS, Ambalavayal were only free from disease. Further, none of the nurseries recorded more than 40 per cent incidence. The incidence ranged from 20 to 35 per cent in 15 nurseries, 10 to 20 per cent in 12 nurseries and in two nurseries it was less than ten per cent. The mean incidence for the year 2000 was 16.92 per cent.

During 2001 nursery season there was no disease incidence at RARS, Ambalavayal and State Seed Farm, Vengad. As was noticed in the previous seasons, the maximum incidence (30.30 per cent) was recorded at Neerchal and the minimum incidence (4.41 per cent) at State Seed Farm, Kankole. Twenty to thirty per cent incidence was noticed in six, 10-20 per cent in 10 and less than 10 per cent in 11 nurseries. It was evident from the data that compared to the other three previous seasons, the mean disease incidence was less during 2001 season.

4.3.2 *Colletotrichum* rot

The pathogen, *C. gloeosporioides* causing leaf rot in pepper was noticed only in certain nurseries. The survey revealed that the disease was noticed in eight nurseries during 1998, nine during 1999, seven during 2000 and eight during 2001. Maximum incidence of 20.15 per cent was noticed in nursery at Rajapuram of Kasargode district and the incidence ranged from nil to 20.15 per cent during 1998. This disease was noticed only in one nursery in Kannur district and one in Wynad district. No incidence was observed in Kozhikode district throughout the survey period. However, in Kasargode district six out of 12 nurseries recorded the disease incidence with a mean of 2.47 per cent during 1998.

During 1999 season, the trend was almost same as that of 1998. The maximum incidence of *Colletotrichum* rot (23.11 per cent) was recorded in Padmandame in Kasargode district and no incidence in 21 locations and in rest of the locations it was less than 11.00 per cent. The mean incidence during 1999 was 2.03 per cent.

Disease incidence during 2000 was maximum (20.12 per cent) at District Agricultural Farm, Karimbam and there was no incidence in 23 locations spread over four districts. The incidence in other nurseries ranged from 4.81 to 10.31 per cent.

During 2001 nursery season, disease incidence was less than eight per cent in all the locations. Though, the disease was absent in 22 locations, the highest 7.42 per cent incidence in Mancombukunnu of Wynad and minimum at Kubaneer.

In general, the mean disease incidence varied during the four seasons of study. It was highest during 1998 and the lowest was recorded during 2001.

4.3.3 *Rhizoctonia* rot

The survey during 1998 revealed that there was no incidence of *Rhizoctonia* rot in Kozhikode and Wynad districts, while, 19.82 per cent incidence was noticed at Kuttikol, Kasargode district and minimum of 1.98 per cent at

Rajapuram. No incidence was recorded in 16 nurseries. The mean incidence during 1998 was 3.29 per cent.

During 1999, 21 out of 30 nurseries were free from incidence of *Rhizoctonia* rot. Maximum incidence was noticed at Karinthalam and the minimum at Madikai of Kasargode district. A mean of 2.42 per cent incidence was noticed during 1999.

During 2000, trend was almost same as that of 1998 and 1999. *Rhizoctonia* rot was not noticed in 20 nurseries. Maximum of 10.13 per cent incidence was noticed at Kubaneer of Kasargode district and minimum of 4.98 per cent at DAF, Karimbam of Kannur district. *R. solani* infection was not noticed in Kozhikode and Wynad districts, while in remaining nurseries it was less than ten per cent.

During 2001, the disease incidence was noticed only in four nurseries, with maximum of 5.03 per cent at Padmandame in Kasargode district and two to five per cent in other nurseries. Incidence was not recorded in any of the nurseries of Kozhikode and Wynad districts. The mean disease incidence was 0.57 per cent during 2001 nursery season.

4.3.4 *Sclerotium* rot

Data on mean incidence of *Sclerotium* rot as shown in Table 5 indicated that incidence was less than four per cent during the survey period. It was 1.44, 0.93, 3.54 and 1.97 per cent during 1998, 1999, 2000 and 2001 respectively. No infection was recorded from pepper nurseries in Kozhikode district during the survey period.

Range of incidence during 1998 was nil to 10.31 per cent. There was no incidence in 23 nurseries. Minimum incidence of 2.95 per cent was noticed at Kenichira, while maximum of 10.31 per cent at Gundiaduka.

Table 5. Occurrence of different diseases in black pepper nurseries during 1998 - 2001

Location	Per cent disease incidence													
	Phytophthora rot				Colletotrichum rot				Rhizoctonia rot				Sclerotium rot	
	1998	1999	2000	2001	1998	1999	2000	2001	1998	1999	2000	2001	1998	2000
KASARGODE DISTRICT														
Pullur	12.36	22.31	26.41	11.28	6.44	0	6.04	0	5.00	0	0	0	0	2.34
Padmandame	40.05	18.12	20.39	10.33	15.21	23.11	0	0	0	0	5.03	5.03	0	0.10
Edaneer	0	23.27	20.41	10.25	0	0	0	5.15	0	5.00	10.10	0	0	10.31
Gundiaduka	0	10.0	20.43	5.50	0	3.0	0	0	8.22	0	5.30	0	10.31	0
Kubaneer	5.04	6.41	20.32	10.46	5.25	2.40	0	2.00	4.01	6.00	10.13	2.00	0	5.06
Pilicode	5.12	0	15.07	5.04	0	0	10.31	2.42	5.00	10.00	0	0	0	1.99
Karinthalam	14.97	10.18	25.32	10.41	0	5.00	0	0	5.00	15.90	9.89	0	5.11	0
Kodakkadu	15.09	15.41	10.38	9.87	5.34	8.88	5.04	2.10	5.00	0	0	0	4.90	0
Kuttikkol	3.00	8.34	10.46	20.14	0	2.15	4.81	0	19.82	8.0	5.01	0	0	5.00
Rojapuram	22.33	0	24.98	10.42	20.15	0	0	0	1.98	0	5.00	4.98	5.00	5.00
Madikai	10.14	29.86	15.16	4.99	0	10.00	0	0	15.00	4.80	0	0	0	0
Pullur (west)	15.33	30.34	20.0	15.21	5.35	0	5.03	5.16	0	10.0	13.0	0	0	9.98
KANNUR DISTRICT														
Karimbam	15.20	10.38	10.31	15.14	6.01	0	20.12	5.41	0	0	4.98	5.00	0	10.00
Vengad	10.20	10.18	10.25	0	0	2.00	0	0	4.95	5.00	0	0	0	0
Kankole	18.05	4.07	11.36	4.41	0	0	0	0	0	0	0	0	5	0
Chalode	15.43	17.45	16.02	7.31	0	0	0	0	5.00	8.0	8.00	0	0	0
Panniyur	9.39	11.26	11.15	23.06	0	0	6.35	3.00	0	0	0	0	0	8.00
Perumunna	13.45	25.19	16.42	6.15	0	0	0	0	5.00	0	0	0	0	0
Thirumeni	45.13	38.44	7.44	8.06	0	0	0	0	0	0	0	0	0	0
Kuthuparamba	15.48	19.16	30.00	7.00	0	0	0	0	9.90	0	0	0	0	0
Koodalipuram	15.32	25.26	28.26	7.43	0	0	0	0	4.90	0	0	0	0	3.00
Perumpadavu	0	23.40	25.27	11.34	0	0	0	0	0	0	0	0	0	19.80
KOZHIKODE DISTRICT														
Thikodi	40.00	7.44	2.25	29.07	0	0	0	0	0	0	0	0	0	0
Koothali	25.28	2.00	19.09	4.46	0	0	0	0	0	0	0	0	0	0
WYNAD DISTRICT														
Ambalavayal	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Neerchal	45.51	40.05	30.46	30.33	10.41	0	0	0	0	0	0	0	0	4.88
Mancombukunnu	9.00	28.30	7.41	20.41	0	7.31	0	7.42	0	0	0	0	0	5.00
Sultans Battery	7.43	0	20.20	25.00	0	0	0	0	0	0	0	0	0	0
Kenichira	7.38	15.0	20.26	15.40	0	0	0	0	0	0	0	0	2.95	0
Cheengeri	25.34	0.25	22.00	27.25	0	0	0	0	0	0	0	0	10.00	0
Mean	15.37	14.74	16.92	12.27	2.47	2.03	1.92	1.09	3.29	2.42	2.54	0.57	1.44	3.54

The disease incidence was comparatively less (0.93 per cent) during 1999. Incidence was noticed in six nurseries ranging from 3.00 to 5.03 per cent.

During 2000, incidence of *Sclerotium* rot was not recorded from Kozhikode and Wynad districts while eight nurseries in Kasargode district had the disease (Table 5). An average of 3.54 per cent incidence was noticed during 2000.

During 2001 season, a mean incidence of 1.90 per cent was recorded. Eleven nurseries were found infected by the pathogen. Incidence ranged from nil to 10.00 per cent with highest at DAF, Karimbam and least at Karinthalam.

In order to get a proper understanding of the disease incidence in various nurseries, the data for the four seasons were pooled together. From the data, it was evident that the maximum incidence of *Phytophthora* rot was at Neerchal of Wynad district followed by Thirumeni of Kannur district (Table 6). It was further observed that 12 nurseries had 15 to 21 per cent incidence and remaining had below 15 per cent. The mean per cent incidence of *Phytophthora* rot in all nurseries during survey period was 14.82 per cent (Fig. 2).

Maximum mean per cent incidence of *Colletotrichum* rot was at Padmandame of Kasargode district (Table 6). In 13 nurseries, there was no incidence of the disease. A mean incidence of 1.88 per cent was recorded from different locations during the survey period.

The highest mean incidence of *Rhizoctonia* rot was recorded at Rajapuram. No incidence of the disease was noticed in Kozhikode and Wynad districts. Mean incidence of *Rhizoctonia* rot during survey period was 2.21 per cent (Table 6).

Survey of four seasons showed 1.97 per cent mean incidence of *Sclerotium* rot in different pepper nurseries with the maximum of 5.50 per cent incidence at District Agricultural Farm, Karimbam (Table 6). No incidence was recorded in eight

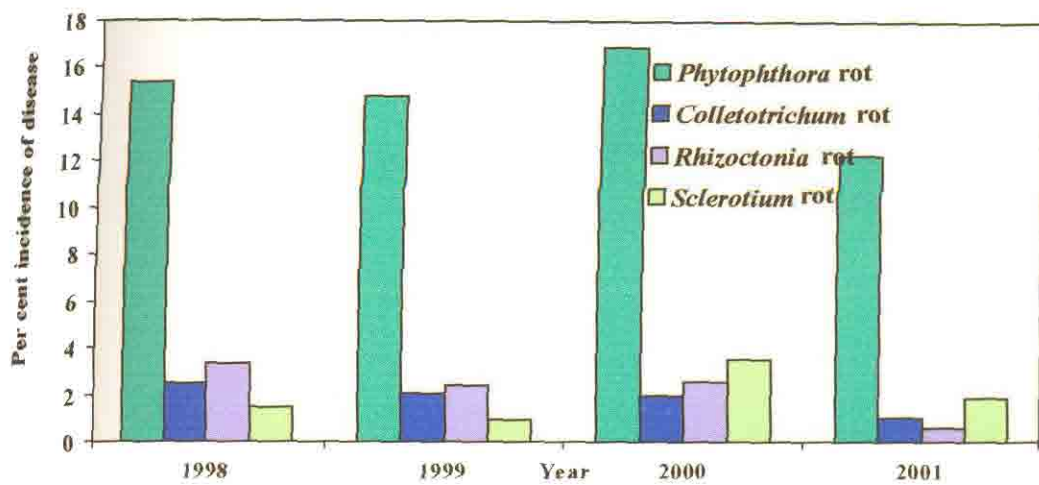


Fig. 1. Mean incidence of different diseases (1998-2001)

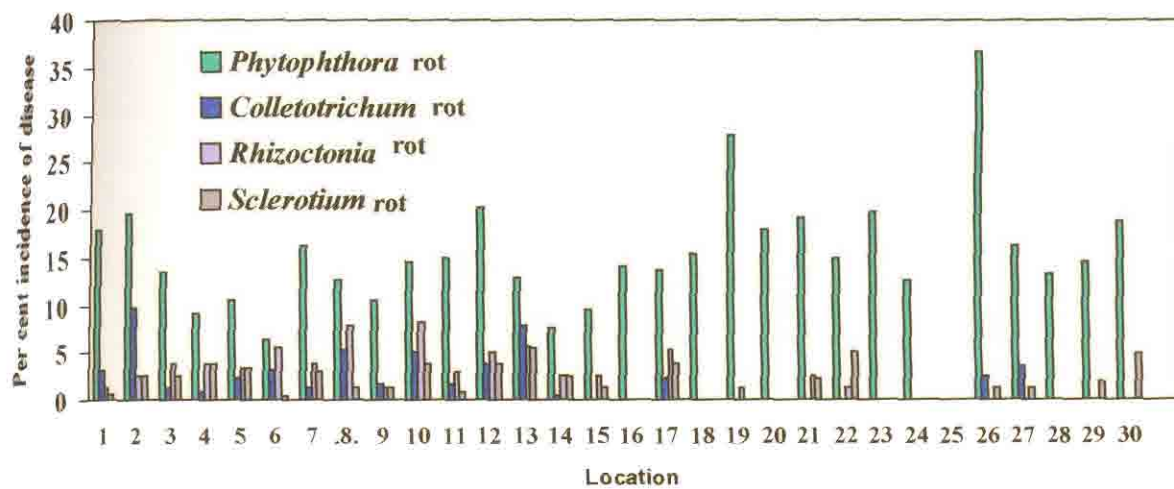


Fig. 2. Mean incidence of diseases in different locations (1998-2001)

Table 6. Mean incidence of diseases in pepper nurseries during 1998-2001

Locations	Per cent disease incidence			
	<i>Phytophthora</i> rot	<i>Colletotrichum</i> rot	<i>Rhizoctonia</i> rot	<i>Sclerotium</i> rot
Pullur	18.00	3.12	1.25	0.59
Padmandame	19.63	9.58	2.52	2.53
Edaneer	13.48	1.29	3.78	2.58
Gundiaduka	8.98	0.75	3.78	3.84
Kubaneer	10.56	2.41	3.38	3.36
Pilicode	6.31	3.18	5.54	0.50
Karinthalam	16.22	1.25	3.75	2.99
Kodakkadu	12.69	5.34	7.70	1.23
Kuttikkol	10.48	1.74	1.25	1.25
Rojapuram	14.43	5.04	8.21	3.71
Madikai	15.04	1.75	2.99	0.75
Pullur (west)	20.22	3.89	4.95	3.75
Karimbam	12.76	7.88	5.75	5.50
Vengad	7.66	0.50	2.50	2.49
Kankole	9.47	0	2.49	1.25
Chalode	14.05	0	0	0
Panniyur	13.72	2.34	5.25	3.73
Perumunna	15.30	0	0	0
Thirumeni	27.77	0	1.25	0
Kuthuparamba	17.91	0	0	0
Koodalipuram	19.07	0	2.48	2.25
Perumpadavu	15.00	0	1.22	4.95
Thikodi	19.69	0	0	0
Koothali	12.71	0	0	0
Ambalavayal	0	0	0	0
Neerchal	36.59	2.60	0	1.22
Mancombukunnu	16.28	3.68	0	1.25
Sultans Battery	13.16	0	0	0.0
Kenichira	14.51	0	0	2.00
Cheengeri	18.71	0	0	4.92
Mean	14.82	1.88	2.21	1.97

nurseries during the course of the survey. In other nurseries, the incidence of *Sclerotium* rot was less than five per cent.

4.3.5 Effect of nursery structure on disease incidence

During the survey, it was found that pepper nurseries were raised under four different types of nursery structures viz., high density polyethylene sheet (HDPE sheet), shade nets, ordinary pandal with thatched coconut leaves and shade trees. Out of the four structures, ordinary pandal was the most popular followed by shade net and shade trees. Nurseries under shade trees were noticed only during 2000 and 2001 seasons. HDPE sheet was used only at RARS, Ambalavayal, where there was no incidence of any diseases during the course of survey.

During 1998, the percentage incidence of *Phytophthora* rot (19.47 per cent), *Colletotrichum* rot (3.7 per cent) and *Sclerotium* rot (2.11 per cent) was more in nurseries raised under ordinary pandal (Table 7). However, incidence of *Rhizoctonia* rot (3.74 per cent) was more in nurseries under shade net compared to ordinary pandal and no disease incidence under HDPE sheet.

Table 7. Effect of nursery structure on the incidence of diseases during 1998

Nursery structure	Per cent incidence			
	<i>Phytophthora</i> rot	<i>Colletotrichum</i> rot	<i>Rhizoctonia</i> rot	<i>Sclerotium</i> rot
Ordinary pandal	19.47	3.47	2.84	2.11
Shade net	11.26	1.47	3.74	0.78
High density polyethylene sheet	0	0	0	0
χ^2	NS			

There was no significant difference among the nursery structures on the incidence of diseases during 1999 (Table 8) and the trend was almost same as that of 1998. The incidence of *Sclerotium* rot was less under ordinary pandal. Here also, no disease incidence was recorded under HDPE sheet.

Table 8. Effect of nursery structure on the incidence of diseases during 1999

Nursery structure	Per cent incidence			
	<i>Phytophthora</i> rot	<i>Colletotrichum</i> rot	<i>Rhizoctonia</i> rot	<i>Sclerotium</i> rot
Ordinary pandal	15.60	2.67	2.65	0.32
Shade net	13.87	1.39	2.20	1.54
High density polyethylene sheet	0	0	0	0
χ^2	NS			

Data on the incidence of nursery diseases during 2000 revealed that plants raised under shade trees and ordinary pandal recorded the higher incidence of *Phytophthora* rot. Incidence of *Colletotrichum* rot and *Rhizoctonia* rot was maximum in ordinary pandal, while that of *Sclerotium* rot was in plants under shade net. None of the plants raised under shade trees recorded the incidence of above three diseases and cuttings grown under HDPE sheet was free from all diseases (Table 9).

Table 9. Effect of nursery structure on the incidence of diseases during 2000

Nursery structure	Per cent incidence			
	<i>Phytophthora</i> rot	<i>Colletotrichum</i> rot	<i>Rhizoctonia</i> rot	<i>Sclerotium</i> rot
Ordinary pandal	20.00	2.85	4.75	4.31
Shade net	10.39	2.92	2.88	6.32
High density polyethylene sheet	0	0	0	0
Shade trees	20.39	0	0	0
χ^2	NS			

During 2001 season, the minimum incidence of *Phytophthora* rot was noticed in cuttings under shade net and the maximum under shade trees. In this case also, incidences of other three diseases were not recorded under shade trees, while cuttings under HDPE sheet were not infected by any pathogen (Table 10).

Table 10. Effect of nursery structure on the incidence of diseases during 2001

Nursery structure	Per cent incidence			
	<i>Phytophthora</i> rot	<i>Colletotrichum</i> rot	<i>Rhizoctonia</i> rot	<i>Sclerotium</i> rot
Ordinary pandal	10.88	1.01	0.95	2.75
Shade net	8.42	2.25	0.75	3.15
High density polyethylene sheet	0	0	0	0
Shade trees	17.50	0	0	0
χ^2	NS			

In general, incidence of *Phytophthora* rot was more when nurseries were raised under shade trees and ordinary pandal with the maximum in the former (Table 11 and Fig. 3). For other diseases, there was not much variation in the percentage of incidence in the above nursery structures. However, it was observed that cuttings raised under HDPE sheet were free from all four diseases throughout the survey period.

Table 11. Effect of nursery structure on the incidence of diseases during 1998-2001

Nursery structure	Per cent incidence			
	<i>Phytophthora</i> rot	<i>Colletotrichum</i> rot	<i>Rhizoctonia</i> rot	<i>Sclerotium</i> rot
Ordinary pandal	16.49	2.50	2.80	2.37
Shade net	11.98	2.01	2.39	2.95
High density polyethylene sheet	0	0	0	0
Shade trees	18.94	0	0	0
χ^2	NS			

4.3.6 Effect of potting mixture on disease incidence

Four types of potting mixtures were used in nurseries with different ratio of sand, soil and cowdung, viz., 1:1:1, 1:2:1 and 1:3:1 while, in some of the nurseries unspecified quantity of above ingredients (others) were used for preparing potting mixture.

Quality of potting mixture had an impact on the incidence of diseases in the pepper nurseries. During 1998, highest incidence of *Phytophthora* rot was noticed in cuttings planted in 1:3:1 potting mixture and the lowest in 1:1:1 potting mixture. While in 1:2:1 and unspecified mixtures (others), *Phytophthora* rot was almost same (Table 12). *Colletotrichum* and *Rhizoctonia* rots were high when cuttings were planted in unspecified potting mixture. While *Sclerotium* rot was high in cuttings raised in 1:2:1 potting mixture.

Table 12. Effect of potting mixture on the incidence of diseases during 1998

Potting mixture	Per cent incidence			
	<i>Phytophthora</i> rot	<i>Colletotrichum</i> rot	<i>Rhizoctonia</i> rot	<i>Sclerotium</i> rot
1:1:1	8.75	2.75	3.25	2.50
1:2:1	15.56	1.57	2.14	3.57
1:3:1	21.89	2.70	1.40	0.39
Others	15.28	2.86	5.21	0.36
χ^2	NS			

During 1999, 29.20 per cent incidence of *Phytophthora* rot was observed in cuttings raised in 1:3:1 potting mixture followed by unspecified potting mixture (others) and minimum infection in 1:1:1 potting mixture (Table 13). Infection by *C. gloeosporioides* was not recorded in cuttings planted in 1:1:1 potting mixture, while in 1:2:1 potting mixture it was 2.29 per cent. Incidence of *Rhizoctonia* rot was also high in vines planted in 1:2:1 potting mixture. No incidence was noted in 1:1:1 and 1:3:1 potting mixtures. *Sclerotium* rot was more in vines grown in unspecified potting mixture and no incidence in 1:3:1 potting mixture.

Table 13. Effect of potting mixture on the incidence of diseases during 1999

Potting mixture	Per cent incidence			
	<i>Phytophthora</i> rot	<i>Colletotrichum</i> rot	<i>Rhizoctonia</i> rot	<i>Sclerotium</i> rot
1:1:1	5.00	0	0	1.00
1:2:1	8.32	2.29	4.20	0.83
1:3:1	29.20	0.78	0	0
Others	14.39	2.03	3.02	1.67
χ^2	NS			

In 2000 season, incidence of *Phytophthora* rot was maximum in pepper cuttings raised in unspecified potting mixture (others) and minimum in 1:1:1 potting mixture (Table 14). The highest incidence of *Colletotrichum* and *Sclerotium* rots was in pepper cuttings raised in 1:1:1 potting mixture and it was minimum in 1:2:1 mixture. *Rhizoctonia* rot was high in pepper cuttings raised in unspecified potting mixture followed by 1:1:1 mixture.

Table 14. Effect of potting mixture on the incidence of diseases during 2000

Potting mixture	Per cent incidence			
	<i>Phytophthora</i> rot	<i>Colletotrichum</i> rot	<i>Rhizoctonia</i> rot	<i>Sclerotium</i> rot
1:1:1	12.50	4.88	2.50	4.88
1:2:1	12.57	0.71	1.43	1.43
1:3:1	19.69	1.00	1.64	3.73
Others	22.93	1.10	4.61	4.50
χ^2	NS			

During 2001, incidence of *Phytophthora* rot was maximum in unspecified potting mixture and that of *Colletotrichum* and *Sclerotium* rots were high in vines grown in 1:1:1 potting mixture, while that of *Rhizoctonia* rot in unspecified one (Table 15). *Phytophthora* rot was minimum in vines grown in 1:3:1 potting mixture followed by 1:2:1. Minimum incidence of *Colletotrichum* rot was in vines grown in 1:2:1 potting mixture, and no *Rhizoctonia* rot was observed in vines grown in 1:1:1 and 1:2:1 potting mixtures. *Sclerotium* rot was minimum in 1:3:1 potting mixture followed by unspecified (others) potting mixture.

Table 15. Effect of potting mixture on the incidence of diseases during 2001

Potting mixture	Per cent incidence			
	<i>Phytophthora</i> rot	<i>Colletotrichum</i> rot	<i>Rhizoctonia</i> rot	<i>Sclerotium</i> rot
1:1:1	10.00	1.81	0	4.00
1:2:1	9.17	0.33	0	1.67
1:3:1	8.85	0.54	0.77	0.92
Others	21.06	1.67	1.50	1.27
χ^2	NS			

Pooled data for four years (1998-2001) indicated that maximum and minimum incidence of *Phytophthora* rot was noticed in vines grown in 1:3:1 and 1:1:1 potting mixture respectively (Table 16 and Fig. 4). Incidence of *Colletotrichum* and *Sclerotium* rot was maximum when cuttings were grown in 1:1:1 potting mixture. While, *Rhizoctonia* rot was in cuttings raised in unspecified potting mixture.

Table 16. Effect of potting mixture on the incidence of diseases during 1998-2001

Potting mixture	Per cent incidence			
	<i>Phytophthora</i> rot	<i>Colletotrichum</i> rot	<i>Rhizoctonia</i> rot	<i>Sclerotium</i> rot
1:1:1	9.06	2.36	1.44	3.10
1:2:1	11.98	1.23	1.94	1.88
1:3:1	20.49	1.12	0.85	1.26
Others	18.41	1.92	3.59	1.95
χ^2	NS			

4.3.7 Effect of place of collection of planting materials on disease incidence

There was only two sources for the collection of planting material for vegetative propagation of pepper cuttings, viz., government farms and private farms. Private sector nurseries were raised by runner shoots collected from private farms only, whereas, in the case of Government farms, it was collected from both agencies.

During 1998, incidence of *Phytophthora* rot was more in nurseries, where planting material was collected from government farms, while incidence of *Colletotrichum*, *Rhizoctonia* and *Sclerotium* rots was high in those collected from private farms (Table 17).

Table 17. Effect of place of collection of planting materials on the incidence of diseases during 1998

Place of collection	Per cent incidence			
	<i>Phytophthora</i> rot	<i>Colletotrichum</i> rot	<i>Rhizoctonia</i> rot	<i>Sclerotium</i> rot
Govt. Farm	16.54	2.09	2.44	1.08
Private Farm	14.19	2.86	4.14	1.81
χ^2	NS			

Incidence of *Phytophthora*, *Rhizoctonia* and *Sclerotium* rots were maximum in cuttings raised from planting material collected from private farms during 1999, while, *Colletotrichum* rot was more in runner vines collected from government farms (Table 18).

Table 18. Effect of place collection of planting materials on the incidence of diseases during 1999

Place of collection	Per cent incidence			
	<i>Phytophthora</i> rot	<i>Colletotrichum</i> rot	<i>Rhizoctonia</i> rot	<i>Sclerotium</i> rot
Govt. Farm	12.81	2.36	1.19	0.71
Private Farm	16.66	1.70	2.34	1.15
χ^2	NS			

Similarly, incidence of all nursery diseases was more in nurseries where planting material was collected from private farms as compared with those in government farms during 2000 (Table 19).

Table 19. Effect of place of collection of planting materials on the incidence of diseases during 2000

Place of collection	Per cent incidence			
	<i>Phytophthora</i> rot	<i>Colletotrichum</i> rot	<i>Rhizoctonia</i> rot	<i>Sclerotium</i> rot
Govt. Farm	12.14	1.71	1.14	2.94
Private Farm	21.71	2.41	3.94	4.17
χ^2	NS			

During 2001, a similar trend as that of 2000 was noticed (Table 20). Maximum incidence of the four rotting diseases was recorded in nurseries where runner vines were collected from private farms. There was no incidence of *Rhizoctonia* rot on cultivars raised from planting material obtained from government farms.

Table 20. Effect of place of planting materials on the incidence of diseases during 2001

Place of collection	Per cent incidence			
	<i>Phytophthora</i> rot	<i>Colletotrichum</i> rot	<i>Rhizoctonia</i> rot	<i>Sclerotium</i> rot
Govt. Farm	11.14	0.96	0	1.43
Private Farm	13.04	1.22	1.13	2.50
χ^2	NS			

Data for four years indicated that highest incidence of all the four diseases were in cuttings raised in planting material collected from private farms (Table 21 and Fig. 5).

Table 21. Effect of place of collection of planting materials on the incidence of diseases during 1998-2001

Place of collection	Per cent incidence			
	<i>Phytophthora</i> rot	<i>Colletotrichum</i> rot	<i>Rhizoctonia</i> rot	<i>Sclerotium</i> rot
Govt. Farm	13.16	1.78	1.20	1.53
Private Farm	16.40	2.05	2.89	2.41
χ^2	NS			

4.3.8 Effect of pepper varieties/cultivars on disease incidence

Panniyur-1 and Karimunda were the two widely used popular pepper genotypes raised in the nurseries. Newly released varieties like Panniyur-2, 3, 4 and 5 were also grown in some nurseries in small scale.

Incidence of all the diseases was noticed in all the varieties planted during different seasons except during 1999. During this season, *Colletotrichum* rot was not noticed in varieties other than Panniyur-1 and Karimunda (Table 22-25). The difference in the incidence of *Phytophthora* rot in Panniyur-1 and Karimunda during survey period (1998-2001) was less than three per cent and this was not significant. The incidence of this disease ranged from 14.41 to 19.69 per cent. Except during

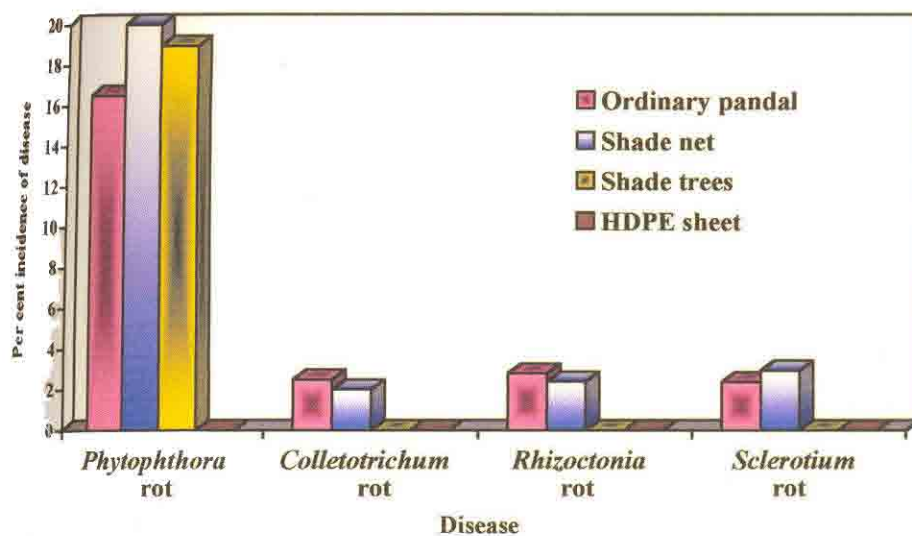


Fig. 3. Effect of nursery structure on the incidence of diseases (1998-2001)

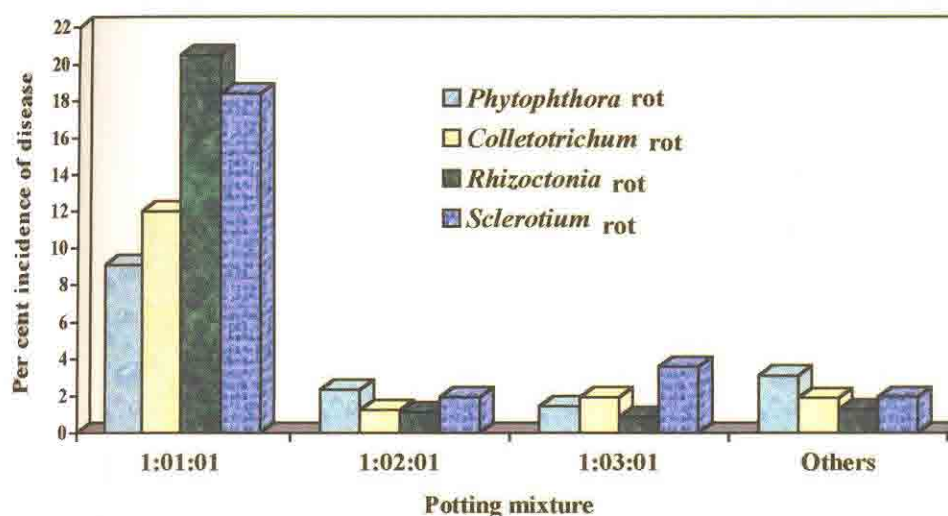


Fig. 4. Effect of potting mixtures on the incidence of diseases (1998-2001)

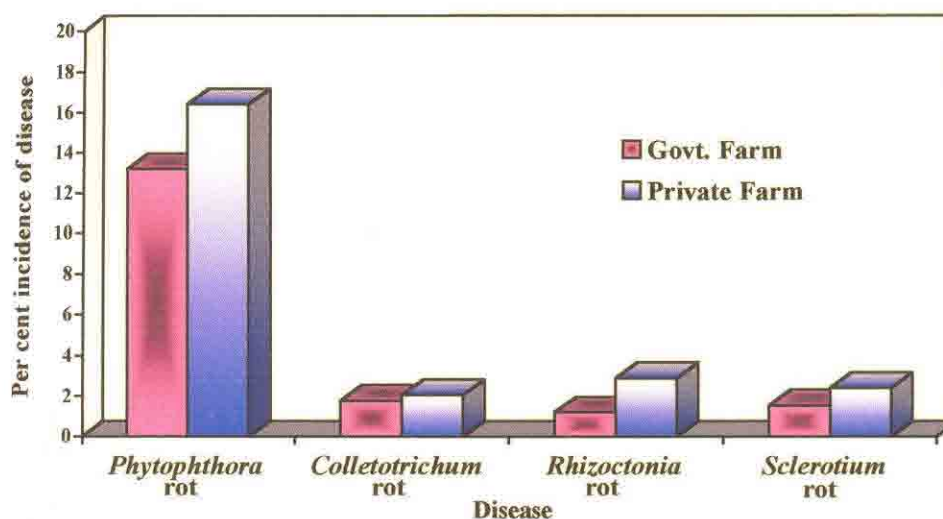


Fig. 5. Effect of place of collection of planting materials on the incidence of diseases (1998-2001)

1998, the other varieties showed comparatively low incidence of this disease. During 1998, other varieties recorded an incidence of 15.97 per cent (Table 22). *Colletotrichum* rot incidence in pepper nursery was less than four per cent during survey period. Incidence of *Rhizoctonia* and *Sclerotium* rot was less than five per cent. Maximum incidence of *Rhizoctonia* rot was recorded in Karimunda during 1998 and in Panniyur-1 (3.23 per cent) during 2000.

Table 22. Effect of pepper varieties/cultivars on the incidence of diseases during 1998

Variety/cultivar	Per cent incidence			
	<i>Phytophthora</i> rot	<i>Colletotrichum</i> rot	<i>Rhizoctonia</i> rot	<i>Sclerotium</i> rot
Panniyur-1	14.41	1.89	2.72	1.07
Karimunda	15.72	2.12	4.89	0.56
Others	15.97	3.41	2.27	2.70
χ^2	NS			

Table 23. Effect of pepper varieties/cultivars on the incidence of diseases during 1999

Variety/cultivar	Per cent incidence			
	<i>Phytophthora</i> rot	<i>Colletotrichum</i> rot	<i>Rhizoctonia</i> rot	<i>Sclerotium</i> rot
Panniyur-1	16.80	3.46	3.39	1.68
Karimunda	18.17	2.62	2.69	0.24
Others	9.24	0	1.18	0.87
χ^2	NS			

Table 24. Effect of pepper varieties/cultivars on the incidence of diseases during 2000

Variety/cultivar	Per cent incidence			
	<i>Phytophthora</i> rot	<i>Colletotrichum</i> rot	<i>Rhizoctonia</i> rot	<i>Sclerotium</i> rot
Panniyur-1	18.33	1.47	3.23	3.90
Karimunda	19.69	0.76	2.96	3.59
Others	12.75	2.67	1.43	3.14
χ^2	NS			

Table 25. Effect of pepper varieties/cultivars on the incidence of diseases during 2001

Variety/cultivar	Per cent incidence			
	<i>Phytophthora</i> rot	<i>Colletotrichum</i> rot	<i>Rhizoctonia</i> rot	<i>Sclerotium</i> rot
Panniyur-1	16.07	1.27	1.13	1.43
Karimunda	15.24	1.45	0.41	1.59
Others	5.49	0.55	0.15	1.88
χ^2	NS			

The data for four years indicated that Karimunda had more infection of *P. capsici* than Panniyur-1 (Table 26 and Fig. 6). Incidence of the disease in other varieties was less compared to Panniyur-1 and Karimunda. Incidence of other three diseases in different varieties during different seasons was less than three per cent.

Table 26. Effect of pepper varieties/cultivars on the incidence of diseases during 1998-2001

Variety/cultivar	Per cent incidence			
	<i>Phytophthora</i> rot	<i>Colletotrichum</i> rot	<i>Rhizoctonia</i> rot	<i>Sclerotium</i> rot
Panniyur-1	16.41	2.02	2.62	2.02
Karimunda	17.21	1.74	2.74	1.50
Others	10.86	1.66	1.26	2.15
χ^2	NS			

4.3.9 Effect of method of processing of runner vines on disease incidence

In Kerala, runner vines (geotrophs) are generally used for vegetative propagation of black pepper. Four types of processing of runner vines were practiced for production of rooted cuttings, viz., coiling of vines on wooden planks (Coiling), allowing vines to creep in the soil (Creeping), coiling and rapid multiplication technique (Coiling + RMT) and coiling and creeping.

During 1998, the highest *Phytophthora* rot incidence of 16.85 per cent was observed in runner vines selected from coiling + creeping method of processing. The

minimum incidence was in nurseries when vines were processed by coiling (Table 27). Incidence of *Colletotrichum* rot was also more in coiling + creeping technique, whereas, incidence of *Rhizoctonia* and *Sclerotium* rots was high in cuttings collected from creeping vines.

Table 27. Effect of processing of runner vines on the incidence of diseases during 1998

Method of processing	Per cent incidence			
	<i>Phytophthora</i> rot	<i>Colletotrichum</i> rot	<i>Rhizoctonia</i> rot	<i>Sclerotium</i> rot
Coiling	13.50	0.99	1.25	0.60
Creeping	15.66	2.92	4.25	2.50
Coiling + RMT	15.44	1.78	3.33	1.11
Coiling + Creeping	16.85	4.20	4.08	1.56
χ^2	NS			

In 1999, *Phytophthora* rot incidence was high when vines were allowed to creep in the soil (creeping). The minimum incidence was in vines collected from coiling + RMT method followed by coiling of vines on wooden planks. High incidence of *Colletotrichum* and *Rhizoctonia* rots was recorded in cuttings obtained from creeping vines, whereas, incidence of *Sclerotium* rot was more in coiling + RMT of vines. Further, it was also observed that there was no incidence of *Sclerotium* rot in vines collected from coiling and coiling + creeping vines (Table 28).

Table 28. Effect of processing of runner vines on the incidence of diseases during 1999

Method of processing	Per cent incidence			
	<i>Phytophthora</i> rot	<i>Colletotrichum</i> rot	<i>Rhizoctonia</i> rot	<i>Sclerotium</i> rot
Coiling	13.80	0.79	1.00	0
Creeping	16.57	5.92	5.46	1.23
Coiling + RMT	12.17	0.71	0.71	2.49
Coiling + Creeping	16.40	0.69	2.52	0
χ^2	NS			

During 2000, the maximum incidence of *Phytophthora* rot was in cuttings produced from creeping of runner vines and minimum from coiling + RMT (Table 29). The percentage incidence of other diseases varied with different methods of processing and it was less than five per cent.

Table 29. Effect of processing of runner vines on the incidence of diseases during 2000

Method of processing	Per cent incidence			
	<i>Phytophthora</i> rot	<i>Colletotrichum</i> rot	<i>Rhizoctonia</i> rot	<i>Sclerotium</i> rot
Coiling	15.70	0	3.00	3.00
Creeping	20.31	1.25	2.92	3.46
Coiling + RMT	12.86	3.24	1.43	4.06
Coiling + Creeping	18.76	3.20	3.29	3.20
χ^2	NS			

Highest incidence of *Phytophthora* rot and *Colletotrichum* rot was observed in nurseries, where runner vines were collected as such in soil (creeping) and minimum in coiling + RMT processing during 2001. *Rhizoctonia* rot and *Sclerotium* rot incidence was also minimum in this case (Table 30).

Table 30. Effect of processing of runner vines on the incidence of diseases during 2001

Method of processing	Per cent incidence			
	<i>Phytophthora</i> rot	<i>Colletotrichum</i> rot	<i>Rhizoctonia</i> rot	<i>Sclerotium</i> rot
Coiling	11.72	0	1.17	0.29
Creeping	17.01	3.55	0.39	2.22
Coiling + RMT	8.33	1.00	0.71	2.86
Coiling + Creeping	12.00	0	0	2.50
χ^2	NS			

Pooled data for four years showed that, there was not much variation among the different methods of processing of runner vines on the incidence of *Phytophthora* rot. The maximum incidence was in cuttings collected from creeping of runner vines, while the incidence of other diseases was below four per cent in cuttings processed by all the different methods (Table 31 and Fig. 7).

Table 31. Effect of processing of runner vines on the incidence of diseases during 1998-2001

Method of processing	Per cent incidence			
	<i>Phytophthora</i> rot	<i>Colletotrichum</i> rot	<i>Rhizoctonia</i> rot	<i>Sclerotium</i> rot
Coiling	13.70	0.45	1.60	0.97
Creeping	17.39	3.36	3.26	2.35
Coiling + RMT	12.20	1.68	1.55	2.63
Coiling + Creeping	16.00	2.02	2.47	1.82
χ^2	NS			

4.3.10 Effect of treatment of potting mixture on disease incidence

During the survey, it was observed that different methods of disinfection of potting mixture like soil solarization, drenching with agrochemical (Bordeaux mixture - 1%) and burning the soil with dry leaves (others) were practiced. In some nurseries disinfection of potting mixture was not followed.

During 1998, the incidence of disease due to *P. capsici* was maximum in cuttings raised in disinfected potting mixture while the minimum was noticed in that treated with agrochemicals (Table 32). The incidence of *Colletotrichum* rot was minimum in cuttings planted in potting mixture treated with burning of soil with dry leaves, while that of *Rhizoctonia* rot was in plants raised in potting mixture treated with chemicals. Further, plants raised in chemical drenched potting mixture did not show any *Sclerotium* rot incidence.

Table 32. Effect of treatment of potting mixture on the incidence of diseases during 1998

Treatment	Per cent incidence			
	<i>Phytophthora</i> rot	<i>Colletotrichum</i> rot	<i>Rhizoctonia</i> rot	<i>Sclerotium</i> rot
Solarization	13.05	2.40	3.00	1.88
Chemical	9.16	2.52	2.53	0
Others	15.36	1.25	3.80	1.56
No treatment	23.91	3.71	6.43	2.33
χ^2	NS			

The data collected during 1999 indicated that, all the nursery diseases except that caused by *R. solani* were more in plants raised in non-disinfected potting mixture. Chemical disinfection of potting mixture had a positive effect in reducing the incidence of *Phytophthora* rot. There was no incidence of *Sclerotium* rot in potting mixtures treated with fungicides (Table 33).

Table 33. Effect of treatment of potting mixture on the incidence of diseases during 1999

Treatment	Per cent incidence			
	<i>Phytophthora</i> rot	<i>Colletotrichum</i> rot	<i>Rhizoctonia</i> rot	<i>Sclerotium</i> rot
Solarization	9.70	0.33	1.7	1.17
Chemical	4.12	1.00	1.00	0
Others	17.15	0	4.18	0.53
No treatment	27.99	6.77	3.33	2.02
χ^2	NS			

Observations recorded during 2000 also revealed that, treatment of potting mixture had a positive effect in reducing nursery diseases of pepper. The data presented in Table 34 revealed that, maximum incidence of all the four nursery diseases were in cuttings raised in non disinfected potting mixture. Minimum incidence of *Phytophthora* rot was recorded in nurseries raised with solarized mixture. Incidence of *Colletotrichum* rot was not observed in cuttings planted in chemical treated potting mixture. Incidence of *Rhizoctonia* and *Sclerotium* rot was minimum in unspecified and maximum in cuttings raised in potting mixture without treatment.

Table 34. Effect of treatment of potting mixture on the incidence of diseases during 2000

Treatment	Per cent incidence			
	<i>Phytophthora</i> rot	<i>Colletotrichum</i> rot	<i>Rhizoctonia</i> rot	<i>Sclerotium</i> rot
Solarization	8.56	2.64	2.00	3.00
Chemical	11.26	0	1.76	2.50
Others	18.43	1.69	1.67	1.90
No treatment	29.41	3.33	3.05	7.01
χ^2	NS			

During 2001 season, diseases due to *P. capsici*, *R. solani* and *S. rolfsii* were maximum in cutting, raised in non disinfected potting mixture (Table 35), while that due to *Colletotrichum* rot was maximum in others. There was no incidence of *Rhizoctonia* and *Sclerotium* rot in cuttings planted in solarized and fungicide treated potting mixtures.

Table 35. Effect of treatment of potting mixture on the incidence of diseases during 2001

Treatment	Per cent incidence			
	<i>Phytophthora</i> rot	<i>Colletotrichum</i> rot	<i>Rhizoctonia</i> rot	<i>Sclerotium</i> rot
Solarization	9.61	1.04	0	0
Chemical	3.91	0.32	0	0
Others	14.78	1.67	0.42	3.90
No treatment	20.76	1.31	1.85	3.98
χ^2	NS			

Data for four years showed high incidence of all the four diseases in vines raised in non disinfected potting mixture (Table 36 and Fig. 8). The lowest incidence of *Phytophthora* rot, *Colletotrichum* rot and *Sclerotium* rot was in fungicide treated potting mixture and *Rhizoctonia* rot in cuttings raised in solarized soil.

Table 36. Effect of treatment of potting mixture on the incidence of diseases during 1998-2001

Treatment	Per cent incidence			
	<i>Phytophthora</i> rot	<i>Colletotrichum</i> rot	<i>Rhizoctonia</i> rot	<i>Sclerotium</i> rot
Solarization	10.23	1.60	0.79	1.51
Chemical	7.11	0.96	1.43	0.63
Others	16.43	1.15	2.52	1.97
No treatment	25.52	3.78	3.67	3.84
χ^2	NS			

4.3.11 Effect of time of planting on disease incidence

Planting of pepper cuttings in nurseries was done at different times. It generally started from the first week of February and completed by the end of May. Hence, an attempt was made to elucidate the effect of time of planting on the incidence of various diseases in black pepper nursery.

Data on the effect of time of planting on the incidence of various diseases during 1998 indicated that time of planting had an effect on nursery diseases as revealed by the results of χ^2 analysis (Table 37). In general, as the time of planting got delayed there was higher incidence of diseases. Maximum incidence of *Phytophthora* rot was in cuttings planted during the third week of April and May, followed by those planted during first week of May 1998. The minimum incidence of *Phytophthora* rot was observed, when cuttings were planted during fourth week of March, followed by those planted during first and third week of February.

Variation in the incidence of *Colletotrichum* rot was observed in cuttings planted during different periods. It was maximum in those planted during third week of May. There was no incidence of this disease in cuttings planted during the first week of February, third and fourth week of March and April and first week of May. *Rhizoctonia* rot was maximum in cuttings raised during third followed by fourth week of April. No incidence of diseases was noticed in those planted during the first and third week of February and third week of March and May. *Sclerotium* rot was noticed mainly in cuttings planted during different intervals of March and April, with the maximum in cuttings planted during fourth week of March.

In 1999, it was found that, in some of the nurseries planting of cuttings was done during first and third week of February, third week of April and in the month of May. In general, there was comparatively more incidence of *Phytophthora* rot in cuttings planted during the month of April which ranged from 18.42 to 22.00 per cent (Table 38). However, the maximum value of 23 per cent was noticed in cuttings raised during fourth week of February and the minimum in those planted during third week

Table 37. Effect of time of planting on the incidence of diseases during 1998

Time of planting	Per cent incidence			
	<i>Phytophthora</i> rot	<i>Colletotrichum</i> rot	<i>Rhizoctonia</i> rot	<i>Sclerotium</i> rot
February				
First week	9.00	0	0	2.50
Second week	-	-	-	-
Third week	9.33	3.67	1.50	0
Fourth week	-	-	-	-
March				
First week	10.00	1.67	1.67	0
Second week	12.80	1.00	2.20	1.00
Third week	10.44	0.00	0	2.50
Fourth week	8.56	0.00	8.00	7.78
April				
First week	14.44	7.50	2.50	2.50
Second week	14.83	0.83	1.67	1.33
Third week	30.00	0	10.30	0
Fourth week	15.00	0	10.00	0
May				
First week	20.00	0	1.67	0
Second week	-	-	-	-
Third week	30.00	15.00	0	0
Fourth week	-	-	-	-
χ^2 value - 117	Significant			

- No planting

of March. Varying percentage of incidence of other three diseases was noticed in cuttings planted at different periods. Maximum incidence of *Colletotrichum* rot was in cuttings planted during fourth week of April, while, that of *Rhizoctonia* rot and *Sclerotium* rot were in cuttings raised during second week of April.

During 2000, cuttings were planted only at eight different intervals. Observations recorded from cuttings raised during those intervals also indicated a marked influence of time of planting on the incidence of diseases (Table 39). During this period also, more incidence of *Phytophthora* rot was noticed in cuttings planted during April and May with the maximum in those planted during the first week of May. Maximum incidence of *Colletotrichum* rot was in cuttings planted during first week of May. During the first four intervals, there was no incidence of this disease. Cuttings planted during the first week of April recorded the maximum *Rhizoctonia* rot incidence. There was no incidence of this pathogen in cuttings raised during second week of February, second week of April and first week of May. Comparatively, higher percentage incidence of *Sclerotium* rot was noticed in cuttings raised during first week of May and first week of April with the maximum in the former. Cuttings planted during second week of February and April did not show any incidence of other diseases.

Results of survey conducted during 2001 also indicated the dominance of *Phytophthora* rot in cuttings raised at different intervals (Table 40). Here also, comparatively higher incidence of this disease was observed in cuttings planted during the month of April and May with the maximum in those planted during the second week of April. *Colletotrichum* rot was maximum in cuttings planted during the first week of May, while there was no incidence of this disease in cuttings planted at other five intervals. Incidence of *Rhizoctonia* rot was observed in cuttings planted only at three intervals with the maximum in those planted during last week of March. *Sclerotium* rot was noticed when cuttings were planted during first week of May, third week of March and third week of April.

Results of the analysis of the four years data on the incidence of various nursery diseases indicated that, irrespective of time of planting of cuttings,

Table 38. Effect of time of planting on the incidence of diseases during 1999

Time of planting	Per cent incidence			
	<i>Phytophthora</i> rot	<i>Colletotrichum</i> rot	<i>Rhizoctonia</i> rot	<i>Sclerotium</i> rot
February				
First week	-	-	-	-
Second week	11.00	1.00	0	0
Third week	-	-	-	-
Fourth week	23.00	0	5.00	0
March				
First week	11.50	0	0	0
Second week	8.00	1.00	3.14	1.14
Third week	2.20	0.67	1.67	1.67
Fourth week	16.00	0	0	0.67
April				
First week	20.50	0	0	0
Second week	18.42	2.80	6.90	2.90
Third week	-	-	-	-
Fourth week	22.00	12.80	5.20	2.00
May				
First week	-	-	-	-
Second week	-	-	-	-
Third week	-	-	-	-
Fourth week	-	-	-	-
χ^2	NS			

- No planting

Table 39. Effect of time of planting on the incidence of diseases during 2000

Time of planting	Per cent incidence			
	<i>Phytophthora</i> rot	<i>Colletotrichum</i> rot	<i>Rhizoctonia</i> rot	<i>Sclerotium</i> rot
February				
First week	-	-	-	-
Second week	8.16	0	0	0.00
Third week	-	-	-	-
Fourth week	12.93	0	3.25	1.25
March				
First week	12.18	0	3.27	5.00
Second week	-	-	-	-
Third week	-	-	-	-
Fourth week	11.88	0.00	3.25	3.75
April				
First week	18.41	2.750	7.00	7.50
Second week	16.25	2.000	0	0
Third week	26.27	5.00	3.57	2.86
Fourth week	-	-	-	-
May				
First week	29.47	5.634	0	7.99
Second week	-	-	-	-
Third week	-	-	-	-
Fourth week	-	-	-	-
χ^2	NS			

- No planting

Table 40. Effect of time of planting on the incidence of diseases during 2001

Time of planting	Per cent incidence			
	<i>Phytophthora</i> rot	<i>Colletotrichum</i> rot	<i>Rhizoctonia</i> rot	<i>Sclerotium</i> rot
February				
First week	-	-	-	-
Second week	6.00	0	0	1.50
Third week	7.50	0.86	0	0
Fourth week	3.67	0.44	0.56	0.44
March				
First week	9.32	0	0	0
Second week	10.00	1.67	0	0.67
Third week	13.60	2.00	1.40	5.60
Fourth week	4.00	0	4.28	0
April				
First week	19.00	0	0	0
Second week	21.00	0	0	2.50
Third week	20.84	0	0	5.00
Fourth week	-	-	-	-
May				
First week	20.00	7.00	0	5.92
Second week	-	-	-	-
Third week	-	-	-	-
Fourth week	-	-	-	-
χ^2 value - 113	Significant			

- No planting

Table 41. Effect of time of planting on the incidence of diseases during 1998-2001

Time of planting	Per cent incidence			
	<i>Phytophthora</i> rot	<i>Colletotrichum</i> rot	<i>Rhizoctonia</i> rot	<i>Sclerotium</i> rot
February				
First week	9.00	0	0	2.50
Second week	9.33	0.25	0	0.50
Third week	8.42	2.26	0.75	0
Fourth week	13.32	0.15	2.94	0.56
March				
First week	10.83	0.42	1.23	1.25
Second week	10.26	1.22	1.78	0.94
Third week	8.75	0.88	1.02	3.26
Fourth week	10.19	0	3.88	3.05
April				
First week	18.55	2.56	2.38	2.50
Second week	17.15	1.29	2.14	1.68
Third week	22.32	1.67	6.29	2.62
Fourth week	18.50	6.40	7.60	2.00
May				
First week	22.25	4.21	0.56	4.63
Second week	-	-	-	-
Third week	30.00	15.00	0	0
Fourth week	-	-	-	-
χ^2 value - 114	Significant			

- No planting

Phytophthora rot was very common with varying degrees (Table 41). However, in cuttings planted during April and May, the maximum incidence of the disease ranged from 17.5 to 30.0 per cent. Same trend was also noticed with respect to *Colletotrichum* rot. However, *Rhizoctonia* rot was more in cuttings planted during the fourth week of April. The incidence of *Sclerotium* rot was more in cuttings raised at different time intervals from second week of March to the first week of May.

4.3.12 Effect of frequency of irrigation on disease incidence

During the survey, an attempt was made to study the effect of frequency of irrigation on the incidence of nursery diseases of black pepper. It was observed that for raising pepper nursery, generally four types of irrigation schedule viz., irrigation daily once, daily twice, once in two days and once in three days were practiced. Analysis of the data revealed that frequency of irrigation had significant effect on the incidence of nursery diseases.

During 1998, the maximum incidence of various diseases was in nurseries irrigated twice daily (Table 42), except for *Colletotrichum* rot where it was maximum in nurseries irrigated once in three days. The minimum incidence of *Phytophthora* rot was in cuttings irrigated once in three days, while that caused by *C. gloeosporioides*, *R. solani* and *S. rolfsii* were on plants irrigated daily once, once in three days and once daily respectively.

Table 42. Effect of frequency of irrigation on the incidence of diseases during 1998

Frequency of irrigation	Per cent incidence			
	<i>Phytophthora</i> rot	<i>Colletotrichum</i> rot	<i>Rhizoctonia</i> rot	<i>Sclerotium</i> rot
Daily once	13.31	1.23	3.62	0.39
Daily twice	22.00	2.55	6.90	2.00
Once in two days	15.56	1.78	1.94	1.72
Once in three days	10.60	4.33	0.67	1.67
χ^2	NS			

From the data it was evident that during 1999, more than 10 per cent incidence of *Phytophthora* rot was in pepper cuttings under different frequency of irrigation with the maximum in plants irrigated twice daily and the minimum in those irrigated once in two days (Table 43). Similar results were observed in the case *Colletotrichum* rot. The maximum and minimum *Rhizoctonia* rot incidence was in cuttings irrigated daily twice and daily once respectively. Though, the cuttings were irrigated twice daily, there was no incidence of *Sclerotium* rot. Here the maximum incidence of two per cent was noticed in plants irrigated once in three days.

Table 43. Effect of frequency of irrigation on the incidence of diseases during 1999

Frequency of irrigation	Per cent incidence			
	<i>Phytophthora</i> rot	<i>Colletotrichum</i> rot	<i>Rhizoctonia</i> rot	<i>Sclerotium</i> rot
Daily once	13.77	1.12	1.35	0.73
Daily twice	22.33	4.39	3.53	0
Once in two days	10.20	2.20	2.80	1.00
Once in three days	12.65	0.40	2.00	2.00
χ^2 value - 21.24	Significant			

In 2000 also, comparatively higher percentage incidence of *Phytophthora* rot was noticed in cuttings irrigated at different frequencies. However, the maximum incidence was in cuttings irrigated twice in a day and the minimum in those irrigated once in two days. Rotting due to *C. gloeosporioides* was more in cuttings irrigated once in three days, while that due to *R. solani* was in cuttings irrigated daily twice (Table 44). *Sclerotium* rot was maximum in plants irrigated once in two days followed by those irrigated daily twice.

Table 44. Effect of frequency of irrigation on the incidence of diseases during 2000

Frequency of irrigation	Per cent incidence			
	<i>Phytophthora</i> rot	<i>Colletotrichum</i> rot	<i>Rhizoctonia</i> rot	<i>Sclerotium</i> rot
Daily once	14.17	1.33	2.00	1.75
Daily twice	25.50	1.76	5.00	4.06
Once in two days	12.50	2.08	2.92	5.83
Once in three days	15.50	2.50	0.25	2.50
χ^2	NS			

During 2001, the incidence of nursery diseases were comparatively less than the previous years. Here also, the maximum incidence of *Phytophthora* rot was noticed in cuttings irrigated daily twice and the minimum in plants irrigated once in three days. *C. gloeosporioides* infection was maximum in plants irrigated once in three days and minimum in plants irrigated once in two days. *Rhizoctonia* rot infection was noticed only in plants irrigated once in two days (Table 45). Incidence of *Sclerotium* rot was not observed in plants irrigated once in three days and the maximum value was in plants irrigated daily twice.

Table 45. Effect of frequency of irrigation on the incidence of disease during 2001

Frequency of irrigation	Per cent incidence			
	<i>Phytophthora</i> rot	<i>Colletotrichum</i> rot	<i>Rhizoctonia</i> rot	<i>Sclerotium</i> rot
Daily once	11.31	1.08	0	1.92
Daily twice	15.50	1.13	0	3.44
Once in two days	11.96	0.44	2.29	2.50
Once in three days	10.33	1.67	0	0
χ^2	NS			

Data for four years on the effect of frequency of irrigation in general, revealed that the incidence of *Phytophthora*, *Colletotrichum* and *Rhizoctonia* rots were more in cuttings which received more irrigation (daily twice) while, that of *Sclerotium* rot was with plants which received irrigation once in two days (Table 46 and Fig. 9).

Table 46. Effect of frequency of irrigation on the incidence of diseases during 1998-2001

Frequency of irrigation	Per cent incidence			
	<i>Phytophthora</i> rot	<i>Colletotrichum</i> rot	<i>Rhizoctonia</i> rot	<i>Sclerotium</i> rot
Daily once	13.14	1.19	1.74	1.20
Daily twice	21.33	2.46	3.86	2.36
Once in two days	12.56	1.63	2.49	2.76
Once in three days	12.27	2.23	0.73	1.54
χ^2	NS			

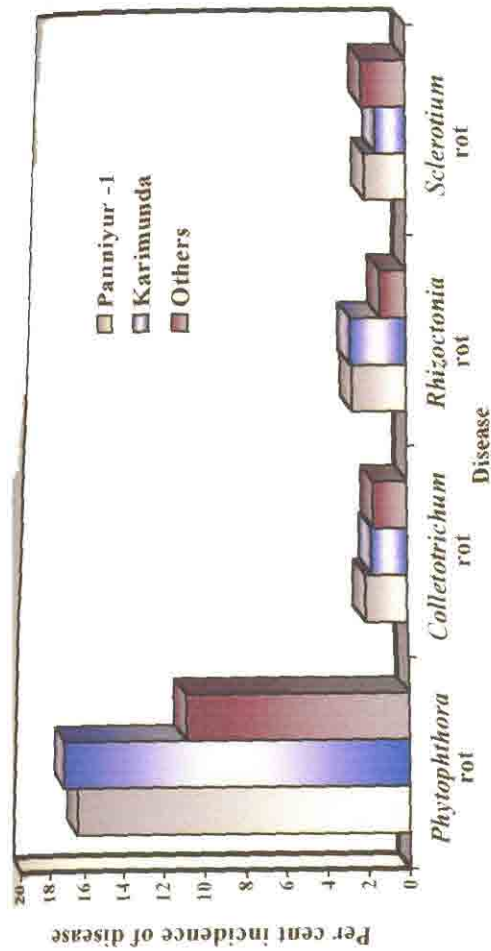


Fig. 6. Effect of varieties/cultivars on the incidence of diseases (1998-2001)

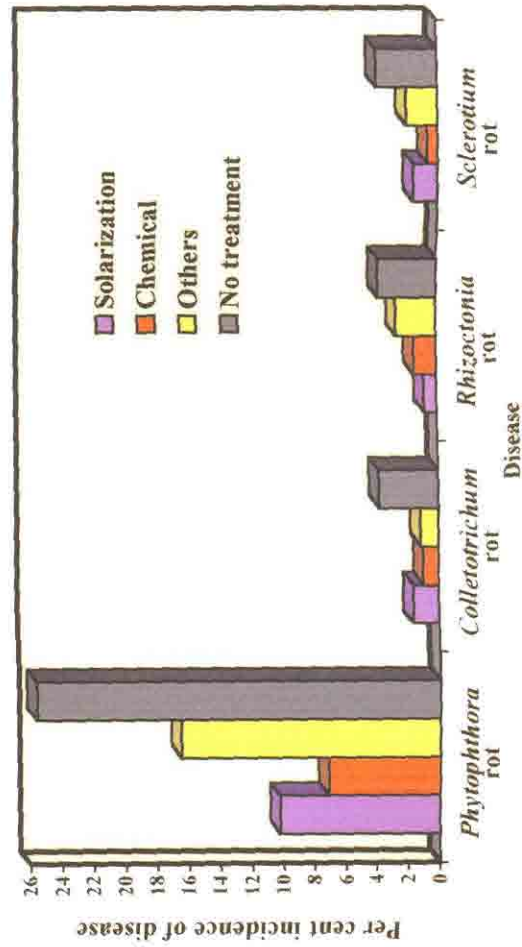


Fig. 8. Effect of treatment of potting mixture on the incidence of diseases (1998-2001)

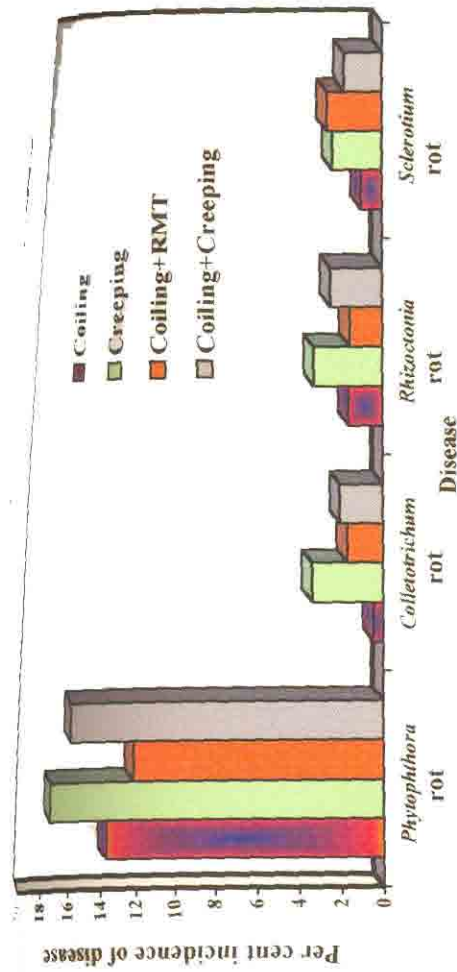


Fig. 7. Effect of processing of runner vines on the incidence of diseases (1998-2001)

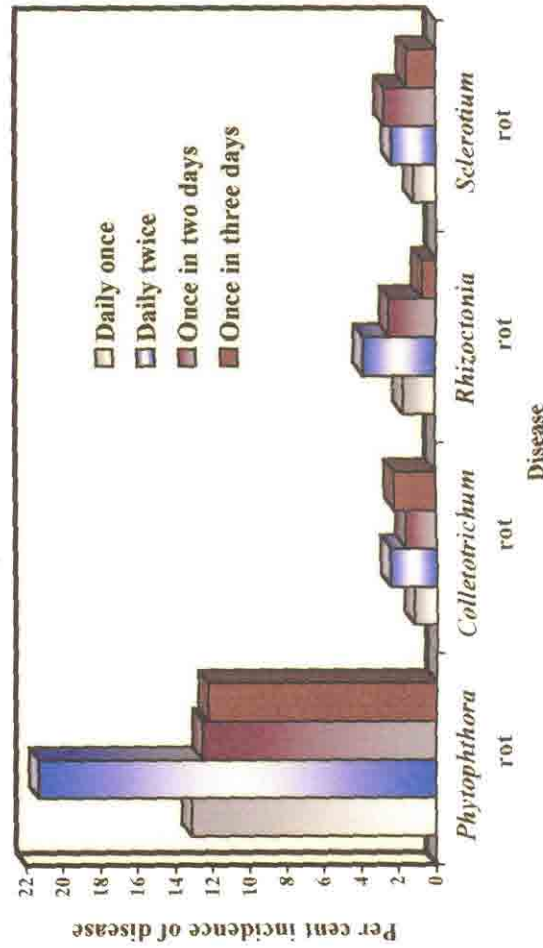


Fig. 9. Effect of frequency of irrigation on the incidence of diseases (1998-2001)

4.3.13 Effect of application of fungicides on disease incidence

As nursery plants are highly prone to incidence of various diseases, appropriate control measures including application of fungicides are inevitable. During the course of survey, it was noticed that fungicides like Bordeaux mixture, copper oxychloride and Akomin were commonly used by different agencies for managing nursery diseases and some of them did not adopted any control measures. The method and schedule of application of these fungicides varied in nurseries during different seasons and as such there was variations in the incidence of diseases at different periods of observations.

Data on the effect of fungicides on the incidence of nursery diseases collected during 1998 indicated that the incidence of *Phytophthora* rot was more compared to other three pathogens (Table 47). Highest incidence was observed in cuttings which did not receive any fungicidal application followed by those received one per cent Bordeaux mixture spray four times in a season. The minimum incidence was in cuttings sprayed with Bordeaux mixture three times and one spray of Akomin and the cuttings sprayed with Bordeaux mixture twice in a season.

The incidence of other three diseases varied with fungicidal treatments. No incidence of *Colletotrichum* rot was noticed in plants sprayed with Bordeaux mixture twice, thrice, five and six times in a season and also in cuttings treated with Bordeaux mixture twice + Akomin once. Maximum incidence was in those cuttings, which were not sprayed with any fungicides.

Rhizoctonia rot was more in cuttings which were not applied with any fungicides followed by those received one per cent Bordeaux mixture spray once in a season. However, no incidence of this disease was noticed in nurseries sprayed with Bordeaux mixture four and six times and spraying Bordeaux mixture once + drenching copper oxychloride thrice and spraying of Bordeaux mixture twice + Akomin once in a season.

Table 47. Effect of chemical treatments on the incidence of diseases during 1998

Sl. No.	Treatments	Per cent incidence			
		<i>Phytophthora</i> rot	<i>Colletotrichum</i> rot	<i>Rhizoctonia</i> rot	<i>Sclerotium</i> rot
1	Spraying Bordeaux mixture - 1% once in a season	18.50	5.00	7.27	2.07
2	Spraying Bordeaux mixture twice in a season	7.33	0	4.33	2.00
3	Spraying Bordeaux mixture thrice in a season	15.00	0	2.50	0
4	Spraying Bordeaux mixture four times in a season	22.38	5.00	0	0
5	Spraying Bordeaux mixture five times in a season	18.50	0	1.00	2.50
6	Spraying Bordeaux mixture six times in a season	13.33	0	0	3.33
7	Spraying Bordeaux mixture once + drenching copper oxychloride once	-	-	-	-
8	Spraying Bordeaux mixture once + drenching copper oxychloride twice	9.00	1.50	2.80	0
9	Spraying Bordeaux mixture once + drenching copper oxychloride thrice	19.60	1.00	0	1.00
10	Spraying Bordeaux mixture once + Akomin once	-	-	-	-
11	Spraying Bordeaux mixture twice + Akomin once	10.00	0	0	0
12	Spraying Bordeaux mixture thrice + Akomin once	7.00	1.27	2.50	0
13	No treatments (Control)	28.33	13.00	15.00	5.00
	χ^2	NS			

- Not adopted

Higher incidence of *Sclerotium* rot was noticed in cuttings that received no fungicidal application and in vines which received other treatments, incidence was less than four per cent.

During 1999, incidence of rots due to *Phytophthora*, *Colletotrichum* and *Rhizoctonia* were more in plants which received no fungicidal treatment. Whereas, *Sclerotium* rot was high in vines sprayed with Bordeaux mixture once. The lowest incidence of *Phytophthora* rot was noticed in cuttings sprayed with Bordeaux mixture two rounds and Akomin one round and there was no incidence of *Colletotrichum*, *Rhizoctonia* and *Sclerotium* rots (Table 48). There was no incidence of these three diseases when nursery was treated with Bordeaux mixture and copper oxychloride once and twice.

During 2000, fungicidal treatments were resorted to all nurseries. During this period, the maximum incidence of *Phytophthora* rot was recorded in plants sprayed with three rounds of Bordeaux mixture and minimum incidence was observed in cuttings sprayed with four rounds of Bordeaux mixture. *Colletotrichum* rot was not recorded in cuttings in three treatments (Table 49). Highest incidence of *R. solani* was observed in vines sprayed with two rounds of Bordeaux mixture followed by three rounds of the same fungicide. Maximum infection due to *S. rolfsii* was recorded in pepper cuttings received one Bordeaux mixture spray followed by spraying of Bordeaux mixture twice in a season, while no incidence was recorded in pepper cuttings treated with Bordeaux mixture for four times.

During 2001, incidence of all the four diseases were more in vines which were not receiving any fungicidal treatment (Table 50). Minimum incidence of *Phytophthora* rot was observed in cuttings that received combined treatments with one Bordeaux mixture spray and three copper oxychloride drenching and there was no incidence of other diseases in cuttings treated with above fungicidal combinations.

Data for 1998-2001 showed that the combined treatment with three spraying of Bordeaux mixture and one spraying of Akomin showed minimum incidence of *Phytophthora* rot followed by two sprayings of Bordeaux mixture and

Table 48. Effect of chemical treatments on the incidence of diseases during 1999

Sl. No.	Treatments	Per cent incidence			
		<i>Phytophthora</i> rot	<i>Colletotrichum</i> rot	<i>Rhizoctonia</i> rot	<i>Sclerotium</i> rot
1	Spraying Bordeaux mixture - 1% once in a season	3.42	3.90	0	5.00
2	Spraying Bordeaux mixture twice in a season	14.50	1.75	6.50	1.25
3	Spraying Bordeaux mixture thrice in a season	7.50	1.00	4.00	0
4	Spraying Bordeaux mixture four times in a season	11.38	3.50	0	0
5	Spraying Bordeaux mixture five times in a season	8.00	1.33	2.00	1.00
6	Spraying Bordeaux mixture six times in a season	10.00	2.00	5.00	0
7	Spraying Bordeaux mixture once + drenching copper oxychloride once	17.00	0	0	0
8	Spraying Bordeaux mixture once + drenching copper oxychloride twice	25.00	0	0	0
9	Spraying Bordeaux mixture once + drenching copper oxychloride thrice	18.50	1.50	1.33	0
10	Spraying Bordeaux mixture once + Akomin once	30.00	1.00	5.00	0
11	Spraying Bordeaux mixture twice + Akomin once	2.00	0	0	0
12	Spraying Bordeaux mixture thrice + Akomin once	6.25	0	0	1.75
13	No treatments (Control)	38.00	7.00	8.00	3.00
	χ^2	NS			

- Not adopted

Table 49. Effect of chemical treatments on the incidence of diseases during 2000

Sl. No.	Treatments	Per cent incidence			
		<i>Phytophthora</i> rot	<i>Colletotrichum</i> rot	<i>Rhizoctonia</i> rot	<i>Sclerotium</i> rot
1	Spraying Bordeaux mixture - 1% once in a season	18.63	6.33	4.33	5.94
2	Spraying Bordeaux mixture twice in a season	21.25	1.25	7.75	5.75
3	Spraying Bordeaux mixture thrice in a season	25.00	0	5.00	5.00
4	Spraying Bordeaux mixture four times in a season	7.00	0	2.79	0
5	Spraying Bordeaux mixture five times in a season	-	-	-	-
6	Spraying Bordeaux mixture six times in a season	11.75	3.33	0	1.67
7	Spraying Bordeaux mixture once + drenching copper oxychloride once	-	-	-	-
8	Spraying Bordeaux mixture once + drenching copper oxychloride twice	19.50	1.25	3.75	5.25
9	Spraying Bordeaux mixture once + drenching copper oxychloride thrice	18.33	1.00	0	3.33
10	Spraying Bordeaux mixture once + Akomin once	-	-	-	-
11	Spraying Bordeaux mixture twice + Akomin once	17.50	0	4.00	1.50
12	Spraying Bordeaux mixture thrice + Akomin once	13.33	4.33	0.83	3.33
13	No treatments (Control)*	-	-	-	-
	χ^2	NS			

- Not adopted

* No control plots

Table 50. Effect of chemical treatments on the incidence of diseases during 2001

Sl. No.	Treatments	Per cent incidence			
		<i>Phytophthora</i> rot	<i>Colletotrichum</i> rot	<i>Rhizoctonia</i> rot	<i>Sclerotium</i> rot
1	Spraying Bordeaux mixture - 1% once in a season	19.50	0	0.19	0
2	Spraying Bordeaux mixture twice in a season	14.17	2.50	0	0
3	Spraying Bordeaux mixture thrice in a season	10.00	0	0	5.00
4	Spraying Bordeaux mixture four times in a season	10.00	0	0	5.00
5	Spraying Bordeaux mixture five times in a season	10.06	0.32	0	3.30
6	Spraying Bordeaux mixture six times in a season	14.33	0.55	0	0
7	Spraying Bordeaux mixture once + drenching copper oxychloride once	15.00	0	0	0
8	Spraying Bordeaux mixture once + drenching copper oxychloride twice	7.20	3.50	1.00	1.0
9	Spraying Bordeaux mixture once + drenching copper oxychloride thrice	4.00	0	0	0
10	Spraying Bordeaux mixture once + Akomin once	11.00	0	0	1.50
11	Spraying Bordeaux mixture twice + Akomin once	8.00	0	1.25	0.50
12	Spraying Bordeaux mixture thrice + Akomin once	8.25	0.75	0	4.00
13	No treatments (Control)	28.00	6.54	5.00	5.00
	χ^2	NS			

one spraying of Akomin (Table 51). Maximum incidence of all the four diseases was observed in cuttings without any fungicidal treatments. Wide variation in the incidence of *Phytophthora* rot was noticed among the treatments. Rots caused by *C. gloeosporioides*, *R. solani* and *S. rolfsii* was not observed in vines treated with one spraying of Bordeaux mixture and drenching of copper oxychloride. Incidence of *Colletotrichum* rot was also not observed in cuttings received two sprayings of Bordeaux mixture and one Akomin spray.

4.4 SCREENING OF BLACK PEPPER VARIETIES/CULTIVARS AGAINST NURSERY DISEASES

Black pepper varieties released from Kerala Agricultural University (KAU) and Indian Institute of Spices Research (IISR), Kozhikode and the black pepper genotypes from the germplasm bank of Pepper Research Station, Panniyur were evaluated for their resistance/ tolerance reaction against the diseases in pepper nursery caused by *P. capsici*, *C. gloeosporioides*, *R. solani* and *S. rolfsii*. Altogether 50 varieties / cultivars were screened against these pathogens.

4.4.1 *Phytophthora* rot

Four month old nursery plants were artificially inoculated using zoospore suspension of *P. capsici* on leaves and roots and the percentage of incidence/ mortality was recorded. Results of the study indicated that none of the 50 varieties/cultivars showed any immunity to the disease. However, there was significant difference among the varieties/cultivars against the disease. The minimum percentage of incidence was noticed in Kalluvally-II, Kalluvally-IV and Panniyur-5, which exhibited less than 60 per cent leaf infection and they were on par with Balankotta, Panniyur-2, Cheriakaniakadan and Shimoga (Table 52). Maximum leaf infection was observed in Perumunda which showed an infection of 98 per cent. Apart from Perumunda, 20 other varieties/cultivars also recorded an infection of more than 90 per cent.

Among the 11 released varieties from KAU and IISR, none of them showed any absolute degree of resistance against the pathogen. Out of the seven varieties released from KAU, Panniyur-5 showed the minimum percentage of leaf

Table 51. Effect of chemical treatments on the incidence of diseases during 1998-2001

Sl. No.	Treatments	Per cent incidence			
		<i>Phytophthora</i> rot	<i>Colletotrichum</i> rot	<i>Rhizoctonia</i> rot	<i>Sclerotium</i> rot
1	Spraying Bordeaux mixture - 1% once in a season	15.01	3.18	2.93	3.25
2	Spraying Bordeaux mixture twice in a season	14.31	2.63	4.65	2.25
3	Spraying Bordeaux mixture thrice in a season	14.38	0.25	2.88	2.50
4	Spraying Bordeaux mixture four times in a season	12.67	2.13	0.70	1.25
5	Spraying Bordeaux mixture five times in a season	12.18	6.44	1.67	1.88
6	Spraying Bordeaux mixture six times in a season	12.35	2.00	1.39	1.25
7	Spraying Bordeaux mixture once + drenching copper oxychloride once	16.00	0	0	0
8	Spraying Bordeaux mixture once + drenching copper oxychloride twice	15.18	1.56	1.25	1.56
9	Spraying Bordeaux mixture once + drenching copper oxychloride thrice	15.10	0.88	0.33	1.08
10	Spraying Bordeaux mixture once + Akomin once	20.50	0.50	2.50	0.76
11	Spraying Bordeaux mixture twice + Akomin once	9.37	0	1.00	0.50
12	Spraying Bordeaux mixture thrice + Akomin once	8.71	1.27	0.83	2.27
13	No treatments (Control)	31.44	8.85	9.33	4.33
	χ^2	NS			

Table 52. Screening of black pepper varieties/cultivars against *P. capsici* - leaf infection

Sl. No.	Varieties/cultivars	Per cent leaf infection*	Sl. No.	Varieties/cultivars	Per cent leaf infection*
1	Kalluvally-II	54.00(0.835) ^g	26	TMB-VIII	90.00(1.286) ^{abcd}
2	Angamali	95.33(1.361) ^{ab}	27	TMB-IX	85.33(1.287) ^{abcdef}
3	Thevarmundi	91.33(1.275) ^{abcd}	28	Munda	90.00(1.256) ^{abcd}
4	Panniyur-4	95.33(1.396) ^{ab}	29	Padarpan	88.00(1.219) ^{abcdef}
5	TMB-I	87.33(1.208) ^{abcde}	30	Perumunda	98.00(1.456) ^a
6	Panniyur-5	55.00(0.836) ^g	31	Vellanamban-I	83.33(1.154) ^{bcdef}
7	Aimperian	91.33(1.278) ^{abcd}	32	Kuthiravally	95.33(1.354) ^{abc}
8	Poonjarmunda	95.33(1.396) ^{ab}	33	Nilgiris	96.00(1.381) ^{ab}
9	Panniyur-1	88.67(1.239) ^{qbcde}	34	Karimkotta	86.67(1.205) ^{abcdef}
10	Karimunda-I	89.33(1.254) ^{abcd}	35	Thevarmundi	86.00(1.189) ^{abcdef}
11	Uthirankotta-I	88.00(1.229) ^{abcdef}	36	Mundi	85.00(1.179) ^{bcdef}
12	Panniyur-3	90.00(1.268) ^{abcd}	37	Kottanadan	81.33(1.134) ^{bcdef}
13	Balankotta	70.67(1.042) ^{defg}	38	Kaniyakadan	87.33(1.208) ^{abcdef}
14	Panniyur-2	68.00(0.972) ^{efg}	39	Panniyur-6	90.67(1.262) ^{abcd}
15	Sreekara	86.00(1.191) ^{abcdef}	40	Culture-6391	94.00(1.323) ^{abc}
16	Subhakara	93.33(1.310) ^{abcd}	41	Kottaram	86.67(1.209) ^{abcdef}
17	Panchami	85.33(1.179) ^{bcdef}	42	Vellanamban-II	84.67(1.172) ^{bcdef}
18	Pournami	85.33(1.187) ^{bcdef}	43	Ceylon	92.00(1.293) ^{abcd}
19	Neelamundi	92.00(1.288) ^{abcd}	44	Karimunda-II	90.00(1.250) ^{abcd}
20	Cheriyakaniakadan	74.00(1.081) ^{cdefg}	45	Culture-1558	92.67(1.297) ^{abcde}
21	Perumkodi	64.00(0.966) ^{fg}	46	Panniyur-7	85.33(1.178) ^{bcdef}
22	Karuvilanchi	90.00(1.252) ^{abcd}	47	Uthirankotta-II	94.00(1.338) ^{abcd}
23	Shimoga	76.67(1.081) ^{cdef}	48	Malligesara	92.67(1.297) ^{abcde}
24	Thulakodi	97.33(1.409) ^{ab}	49	Arakulam munda	87.33(1.211) ^{abcdef}
25	Kalluvally-IV	56.00(0.846) ^g	50	Culture-406	86.00(1.188) ^{abcdef}

* Mean of three replications

Arc-sine transformed values are given in parenthesis

For each column figures followed by same letter do not differ significantly

infection (55 per cent) followed by Panniyur-2 (67.5 per cent). Rest of the Panniyur varieties like Panniyur-1, 3, 4, 6 and 7 recorded an infection ranging from 85.00 to 95.33 per cent with the maximum in variety Panniyur-4.

The varieties released from IISR also showed higher degree of susceptibility. Out of the four varieties of IISR, the highest incidence was recorded in Subhakara followed by Panchami, Pournami and Sreekara with an infection ranging from 85.33 to 86.00 per cent. The two cultivars of Karimunda screened against the pathogen, showed more than 89 per cent leaf infection.

Data on the percentage mortality of pepper varieties/cultivars on root inoculation revealed that Kalluvally-II recorded 26.67 per cent mortality and was on par with six others, viz., Panniyur-5, Balankotta, Kalluvally-IV, Sreekara, TMB-IX and Kaniyakadan. The highest infection of 82.40 per cent was observed in Aimperian which was on par with 43 other cultivar/varieties (Table 53).

Among the released varieties from KAU, Panniyur-5 recorded the minimum mortality of 31.30 per cent and the maximum was with Panniyur-4 (73.73 per cent). Apart from these, five other KAU varieties showed mortality ranging from 59.33 to 67.73 per cent. Varieties released from IISR showed the mortality ranging from 53.73 to 75.87 per cent. The minimum percentage of mortality was with Sreekara and the maximum in Panchami. The popular local cultivars Karimunda-I and Karimunda-II recorded an infection of 73.73 and 62.22 per cent respectively.

4.4.2 *Colletotrichum* rot

Among the 50 cultivars screened against *C. gloeosporioides*, Vellanamban-II, a local cultivar from Idukki district was free from infection when inoculated with the pathogen, while rest of the cultivars were infected to varying degrees ranging from 1.55 to 15.54 per cent. Maximum infection was observed with Pournami and Cheriyaaniyakadan (Table 54).

Table 53. Screening of black pepper varieties/cultivars against *P. capsici* - mortality

Sl. No.	Varieties/cultivars	Per cent mortality	Sl. No.	Varieties/cultivars	Per cent mortality
1	Kalluvally-II	26.67(0.535) ^f	26	TMB-VIII	67.06(0.961) ^{abcd}
2	Angamali	68.80(0.983) ^{abcd}	27	TMB-IX	48.93(0.774) ^{cdef}
3	Thevarmundi	79.98(1.111) ^{ab}	28	Munda	72.13(1.030) ^{abc}
4	Panniyur-4	73.73(1.035) ^{abc}	29	Padarpan	68.00(0.976) ^{abcd}
5	TMB-I	58.67(0.887) ^{abcd}	30	Perumunda	71.10(1.011) ^{abc}
6	Panniyur-5	31.20(0.587) ^{ef}	31	Vellanamban-I	57.86(0.866) ^{abcde}
7	Aimperian	82.40(1.139) ^a	32	Kuthiravally	80.26(1.120) ^{ab}
8	Poonjarmunda	77.73(1.081) ^{abc}	33	Nilgiris	73.32(1.030) ^{abc}
9	Panniyur-1	67.20(0.965) ^{abcd}	34	Karimkotta	62.00(0.910) ^{abcd}
10	Karimunda-I	73.73(1.035) ^{abc}	35	Thevarmundi	72.67(1.025) ^{abc}
11	Uthirankotta-I	64.40(0.940) ^{abcd}	36	Mundi	64.40(0.933) ^{abcd}
12	Panniyur-3	67.29(0.961) ^{abcd}	37	Kottanadan	62.00(0.914) ^{abcd}
13	Balankotta	40.00(0.682) ^{def}	38	Kaniyakadan	53.33(0.819) ^{bcdef}
14	Panniyur-2	67.78(0.974) ^{abcd}	39	Panniyur-6	60.00(0.893) ^{abcd}
15	Sreekara	53.73(0.824) ^{abcdef}	40	Culture-6391	69.33(0.996) ^{abcd}
16	Subhakara	66.67(0.960) ^{abcd}	41	Kottaram	53.33(0.819) ^{bcdef}
17	Panchami	75.87(1.077) ^{abc}	42	Vellanamban-II	69.51(0.915) ^{abcd}
18	Pournami	64.40(0.937) ^{abcd}	43	Ceylon	62.12(0.910) ^{abcd}
19	Neelamundi	68.93(0.985) ^{abcd}	44	Karimunda-II	62.22(0.915) ^{abcd}
20	Cheriyakaniakadan	66.67(0.960) ^{abcd}	45	Culture-1558	69.33(0.988) ^{abcd}
21	Perumkodi	55.60(0.848) ^{abcde}	46	Panniyur-7	59.33(0.886) ^{abcd}
22	Karuvilanchi	72.00(1.015) ^{abc}	47	Uthirankotta-II	63.86(0.886) ^{abcd}
23	Shimoga	82.26(1.137) ^{ab}	48	Malligesara	66.80(0.975) ^{abcd}
24	Thulakodi	69.00(0.984) ^{abcd}	49	Arakulam munda	69.20(0.983) ^{abcd}
25	Kalluvally-IV	41.07(0.693) ^{def}	50	Culture-406	62.22(0.915) ^{abcd}

* Mean of three replications

Arc-sine transformed values are given in parenthesis

For each column figures followed by same letter do not differ significantly

Table 54. Screening of black pepper varieties/cultivars against *C. gloeosporioides*

Sl. No.	Varieties/cultivars	Per cent leaf infection*	Sl. No.	Varieties/cultivars	Per cent leaf infection*
1	Kalluvally-II	1.55(0.104) ^{bcd}	26	TMB-VIII	4.45(0.175) ^{abcd}
2	Angamali	5.09(0.186) ^{abcd}	27	TMB-IX	3.55(0.157) ^{abcd}
3	Thevarmundi	10.37(0.322) ^{abc}	28	Munda	3.54(0.185) ^{abcd}
4	Panniyur-4	4.33(0.165) ^{abcd}	29	Padarpan	1.88(0.114) ^{abcd}
5	TMB-I	9.32(0.301) ^{abc}	30	Perumunda	6.96(0.222) ^{abcd}
6	Panniyur-5	1.78(0.082) ^{cd}	31	Vellanamban-I	5.30(0.190) ^{abcd}
7	Aimperian	8.39(0.283) ^{abcd}	32	Kuthiravally	1.89(0.085) ^{abcd}
8	Poonjarmunda	1.84(0.084) ^{cd}	33	Nilgiris	14.50(0.389) ^{cd}
9	Panniyur-1	13.53(0.376) ^{ab}	34	Karimkotta	3.24(0.178) ^{ab}
10	Karimunda-I	2.51(0.352) ^{abcd}	35	Thevarmundi	5.32(0.191) ^{abcd}
11	Uthirankotta-I	12.10(0.352) ^{abc}	36	Mundi	5.44(0.235) ^{abcd}
12	Panniyur-3	2.67(0.133) ^{abcd}	37	Kottanadan	7.67(0.268) ^{abcd}
13	Balankotta	6.36(0.255) ^{abcd}	38	Kaniyakadan	5.33(0.191) ^{abcd}
14	Panniyur-2	5.37(0.234) ^{abcd}	39	Panniyur-6	7.13(0.267) ^{abcd}
15	Sreekara	7.05(0.265) ^{abcd}	40	Culture-6391	5.18(0.228) ^{abcd}
16	Subhakara	11.87(0.340) ^{abc}	41	Kottaram	3.72(0.161) ^{abcd}
17	Panchami	4.29(0.164) ^{abcd}	42	Vellanamban-II	0.00 (0.007) ^d
18	Pournami	15.54(0.397) ^a	43	Ceylon	13.53(0.314) ^{abc}
19	Neelamundi	6.30(0.245) ^{abcd}	44	Karimunda-II	6.98(0.222) ^{abcd}
20	Cheriyakaniakadan	15.43(0.383) ^{ab}	45	Culture-1558	10.00(0.198) ^{abcd}
21	Perumkodi	8.79(0.292) ^{abc}	46	Panniyur-7	10.77(0.321) ^{abc}
22	Karuvilanchi	6.89(0.162) ^{abcd}	47	Uthirankotta-II	3.50(0.156) ^{abcd}
23	Shimoga	1.78(0.082) ^{cd}	48	Malligesara	2.38(0.155) ^{abcd}
24	Thulakodi	3.48(0.114) ^{abcd}	49	Arakulam munda	3.45(0.184) ^{abcd}
25	Kalluvally-IV	6.32(0.198) ^{abcd}	50	Culture-406	7.00(0.217) ^{abcd}

* Mean of three replications

Arc-sine transformed values are given in parenthesis

For each column figures followed by same letter do not differ significantly

It was also found that the infection varied with the varieties released from KAU and IISR. Among these varieties, Pournami recorded maximum infection.

4.4.3 *Rhizoctonia* rot

R. solani was found to infect leaves and collar region of pepper cuttings. It was observed that collar infection was more pronounced than leaf infection. Data on the percentage of leaf infection indicated that Panniyur-2 recorded the least infection followed by Kalluvally-II and Perumkodi and these were on par with 39 other genotypes (Table 55). The cultivar Malligesara recorded the maximum leaf infection. Further, nine other cultivars showed a percentage leaf infection of more than 80. All the varieties released from KAU recorded more than 50 per cent leaf infection with Panniyur-2 showing the lowest value and Panniyur-4, the highest. The percentage of leaf infection in the case of the varieties released from IISR ranged from 70.33 (Subhakara) to 78.17 (Pournami). The two Karimunda cultivars viz., Karimunda-I and Karimunda-II recorded percentage infection of 64.83 and 78.50 respectively.

There was significant difference among the varieties/cultivars with regard to collar infection caused by *R. solani* (Table 56). It was found that Kalluvally-II exhibited the minimum mortality and was on par with Balankotta, Panniyur-5 and Kalluvally-IV. The maximum percentage mortality of pepper cuttings due to collar rot was exhibited by Padarpan. In Poonjarmunda, Aimperian and Kuthiravally the mortality percentage was more than 70.

Among the seven KAU varieties, four of them viz., Panniyur-1, 2, 4 and 6 showed mortality percentage of more than 50. All the IISR varieties recorded more than 40 per cent mortality with the maximum in Pournami.

4.4.4 *Sclerotium* rot

There was significant difference among the varieties on the percentage of leaf infection by *S. rolfsii* and it ranged from 54.83 to 90.83. The minimum percentage

Table 55. Screening of black pepper varieties/cultivars against *R. solani* - leaf infection

Sl. No.	Varieties/cultivars	Per cent leaf infection*	Sl. No.	Varieties/cultivars	Per cent leaf infection*
1	Kalluvally-II	54.83(0.841) ^{ef}	26	TMB-VIII	72.17(1.037) ^{abcdef}
2	Angamali	62.17(0.940) ^{cde}	27	TMB-IX	80.83(1.122) ^{abcde}
3	Thevarmundi	79.13(1.100) ^{abcdef}	28	Munda	61.83(0.906) ^{cdef}
4	Panniyur-4	80.50(1.313) ^{abcde}	29	Padarpan	73.83(1.040) ^{abcdef}
5	TMB-I	60.83(0.917) ^{bcdelf}	30	Perumunda	75.83(1.070) ^{abcdef}
6	Panniyur-5	56.83(0.851) ^{def}	31	Vellanamban-I	79.17(1.099) ^{abcdef}
7	Aimperian	62.00(0.909) ^{cdef}	32	Kuthiravally	82.50(1.152) ^{abcd}
8	Poonjarmunda	71.77(1.019) ^{abcdef}	33	Nilgiris	82.67(1.143) ^{abcde}
9	Panniyur-1	72.17(1.017) ^{abcdef}	34	Karimkotta	76.00(1.059) ^{abcdef}
10	Karimunda-I	64.83(0.947) ^{abcdef}	35	Thevarmundi	65.83(0.947) ^{abcdef}
11	Uthirankotta-I	78.67(1.093) ^{abcdef}	36	Mundi	74.00(1.047) ^{abcdef}
12	Panniyur-3	74.67(1.047) ^{abcdef}	37	Kottanadan	82.50(1.142) ^{abcde}
13	Balankotta	62.67(0.916) ^{cdef}	38	Kaniyakadan	86.17(1.197) ^{abc}
14	Panniyur-2	51.50(0.800) ^f	39	Panniyur-6	76.50(1.088) ^{abcdef}
15	Sreekara	73.33(1.031) ^{abcdef}	40	Culture-6391	71.67(1.011) ^{abcdef}
16	Subhakara	70.33(1.000) ^{abcdef}	41	Kottaram	81.00(1.122) ^{abcdef}
17	Panchami	72.50(1.022) ^{abcdef}	42	Vellanamban-II	76.33(1.070) ^{abcdef}
18	Pournami	78.17(1.091) ^{abcdef}	43	Ceylon	87.00(1.222) ^{ab}
19	Neelamundi	68.83(0.984) ^{abcdef}	44	Karimunda-II	78.50(1.096) ^{abcde}
20	Cheriyakaniakadan	71.50(1.009) ^{abcdef}	45	Culture-1558	67.83(0.076) ^{abcdef}
21	Perumkodi	55.00(0.838) ^{ef}	46	Panniyur-7	76.17(1.093) ^{abcdef}
22	Karuvilanchi	69.00(0.983) ^{abcdef}	47	Uthirankotta-II	76.50(1.075) ^{abcdef}
23	Shimoga	72.00(1.021) ^{abcdef}	48	Malligesara	89.17(1.236) ^a
24	Thulakodi	72.17(1.025) ^{abcdef}	49	Arakulam munda	80.33(1.153) ^{abcd}
25	Kalluvally-IV	64.83(0.941) ^{abcdef}	50	Culture-406	79.50(1.112) ^{abcde}

* Mean of three replication

Arc-sine transformed values are given in parenthesis

For each column figures followed by same letter do not differ significantly

Table 56. Screening of black pepper varieties/cultivars against *R. solani* - mortality

Sl. No.	Varieties/cultivars	Per cent mortality	Sl. No.	Varieties/cultivars	Per cent mortality
1	Kalluvally-II	16.13(0.412) ^k	26	TMB-VIII	51.06(0.797) ^{cdefghi}
2	Angamali	56.00(0.846) ^{bcddefgh}	27	TMB-IX	68.66(0.977) ^{abcdef}
3	Thevarmundi	56.67(0.852) ^{bcddefghi}	28	Munda	62.13(0.912) ^{abcddefgh}
4	Panniyur-4	57.60(0.864) ^{bcddefghij}	29	Padarpan	81.10(1.135) ^a
5	TMB-I	53.87(0.825) ^{cdefghi}	30	Perumunda	47.73(0.763) ^{defghi}
6	Panniyur-5	32.27(0.597) ^{ijk}	31	Vellanamban-I	59.33(0.880) ^{abcddefgh}
7	Aimperian	76.00(0.060) ^{abc}	32	Kuthiravally	73.06(1.027) ^{abcd}
8	Poonjarmunda	77.33(0.104) ^{ab}	33	Nilgiris	60.66(0.899) ^{abcddefgh}
9	Panniyur-1	50.93(0.795) ^{cdefghi}	34	Karimkotta	57.73(0.866) ^{bcddefghi}
10	Karimunda-I	41.86(0.702) ^{fghi}	35	Thevarmundi	57.33(0.861) ^{bcddefghi}
11	Uthirankotta-I	44.53(0.729) ^{efghi}	36	Mundi	59.60(0.882) ^{abcddefgh}
12	Panniyur-3	39.87(0.683) ^{ghij}	37	Kottanadan	45.33(0.738) ^{efghi}
13	Balankotta	22.13(0.475) ^{jk}	38	Kaniyakadan	50.67(0.792) ^{cdefghi}
14	Panniyur-2	58.53(0.872) ^{abcddefgh}	39	Panniyur-6	53.06(0.818) ^{cdefghi}
15	Sreekara	48.00(0.764) ^{defghi}	40	Culture-6391	45.33(0.736) ^{defghi}
16	Subhakara	43.47(0.715) ^{efghij}	41	Kottaram	61.60(0.906) ^{abcddefgh}
17	Panchami	55.73(0.844) ^{bcddefghi}	42	Vellanamban-II	49.47(0.780) ^{defghi}
18	Pournami	59.33(0.880) ^{abcddefgh}	43	Ceylon	46.40(0.747) ^{efghi}
19	Neelamundi	68.80(0.981) ^{abcde}	44	Karimunda-II	45.20(0.737) ^{efghi}
20	Cheriyakaniakadan	58.93(0.875) ^{abcddefgh}	45	Culture-1558	50.66(0.791) ^{cdefghi}
21	Perumkodi	42.93(0.712) ^{efghij}	46	Panniyur-7	42.80(0.709) ^{defghi}
22	Karuvilanchi	59.46(0.880) ^{abcddefgh}	47	Uthirankotta-II	65.60(0.946) ^{abcddefgh}
23	Shimoga	62.67(0.916) ^{abcddefgh}	48	Malligesara	59.73(0.883) ^{abcddefgh}
24	Thulakodi	54.27(0.828) ^{cdefghi}	49	Arakulam munda	45.60(0.737) ^{eghi}
25	Kalluvally-IV	38.67(0.660) ^{kij}	50	Culture-406	61.07(0.898) ^{abcddefgh}

* Mean of three replication

Arc-sine transformed values are given in parenthesis

For each column figures followed by same letter do not differ significantly

of leaf infection was in Panniyur-2 followed by Kuthiravally and Kalluvally-IV and these were on par with 38 others (Table 57). Maximum leaf infection of 92.17 per cent was observed in Thevarmundi which was closely followed by TMB-VIII, Panniyur-1, Karimunda-II, Arakulamunda and Culture 6391. The varieties released from KAU showed a percentage leaf infection ranging from 54.83 to 90.83. The percentage of leaf infection in IISR varieties varied from 77.17 to 86.00 per cent.

Maximum mortality of 74.43 per cent was recorded in Poonjarmunda followed by Kuthiravally and Angamali. The least mortality of 17.87 per cent was observed in the cultivar Balankotta which was followed by Kalluvally-II (20.80 per cent) and Panniyur-5 (25.73 per cent) (Table 58). Among the KAU varieties, the least mortality was observed in Panniyur-5. Among the varieties released from IISR, maximum mortality was in the variety Panchami and the least in Subhakara.

4.5 BIOCHEMICAL ANALYSIS

Since different cultivars/varieties of black pepper showed varying degrees of tolerance/susceptibility towards *P. capsici*, investigations were carried out to elucidate the biochemical parameters that contributed to differential performance. Leaf samples of three pepper genotypes, belonging to tolerant Kalluvally-II, moderately susceptible Panniyur-5 and susceptible Panniyur-1 were subjected to biochemical analysis.

4.5.1 Phenolics

4.5.1.1 Total phenols

The total phenol content in three black pepper genotypes differed significantly (Table 59 and Fig. 10). The highest total phenol content was recorded in tolerant cultivar Kalluvally-II which was significantly higher than that of Panniyur-5 and Panniyur-1 whereas in Panniyur-1 and Panniyur-5, it was on par.

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Table 57. Screening of black pepper varieties/cultivars against *S. rolfsii* - leaf infection

Sl. No.	Varieties/cultivars	Per cent leaf infection*	Sl. No.	Varieties/cultivars	Per cent leaf infection*
1	Kalluvally-II	56.83(0.854) ^c	26	TMB-VIII	91.00(1.323) ^{ab}
2	Angamali	80.33(1.197) ^{abc}	27	TMB-IX	84.33(1.164) ^{abc}
3	Thevarmundi	92.17(1.342) ^{ab}	28	Munda	68.50(0.975) ^{abc}
4	Panniyur-4	70.67(0.999) ^{abc}	29	Padarpan	75.17(1.050) ^{abc}
5	TMB-I	77.00(1.089) ^{abc}	30	Perumunda	80.33(1.113) ^{abc}
6	Panniyur-5	64.17(0.929) ^{bc}	31	Vellanamban-I	78.67(1.094) ^{abc}
7	Aimperian	81.83(1.150) ^{abc}	32	Kuthiravally	89.17(1.297) ^{ab}
8	Poonjarmunda	78.83(1.049) ^{abc}	33	Nilgiris	84.00(1.174) ^{abc}
9	Panniyur-1	90.83(1.387) ^a	34	Karimkotta	82.50(1.141) ^{abc}
10	Karimunda-I	83.83(1.157) ^{abc}	35	Thevarmundi	81.17(1.131) ^{abc}
11	Uthirankotta-I	83.60(1.151) ^{abc}	36	Mundi	84.67(1.195) ^{abc}
12	Panniyur-3	86.33(1.204) ^{abc}	37	Kottanadan	80.67(1.120) ^{abc}
13	Balankotta	83.17(1.239) ^{abc}	38	Kaniyakadan	78.17(1.098) ^{abc}
14	Panniyur-2	54.83(0.836) ^c	39	Panniyur-6	72.33(1.032) ^{abc}
15	Sreekara	77.17(1.101) ^{abc}	40	Culture-6391	90.17(1.318) ^{ab}
16	Subhakara	77.50(1.142) ^{abc}	41	Kottaram	73.67(1.038) ^{abc}
17	Panchami	81.50(1.291) ^{ab}	42	Vellanamban-II	76.50(1.072) ^{abc}
18	Pournami	86.00(1.189) ^{abc}	43	Ceylon	87.50(1.216) ^{abc}
19	Neelamundi	69.83(1.017) ^{abc}	44	Karimunda-II	90.83(1.318) ^{ab}
20	Cheriyakaniakadan	77.50(1.095) ^{abc}	45	Culture-1558	77.17(1.117) ^{abc}
21	Perumkodi	75.67(1.067) ^{abc}	46	Panniyur-7	83.17(1.175) ^{abc}
22	Karuvilanchi	67.83(0.976) ^{abc}	47	Uthirankotta-II	79.17(1.123) ^{abc}
23	Shimoga	82.67(1.161) ^{abc}	48	Malligesara	87.67(1.281) ^{ab}
24	Thulakodi	81.17(1.143) ^{abc}	49	Arakulam munda	90.83(1.287) ^{ab}
25	Kalluvally-IV	57.00(0.858) ^c	50	Culture-406	74.00(1.055) ^{abc}

* Mean of three replication

Arc-sine transformed values are given in parenthesis

For each column figures followed by same letter do not differ significantly

Table 58. Screening of black pepper varieties/cultivars against *S. rolfsii* - mortality

Sl. No.	Varieties/cultivars	Per cent mortality	Sl. No.	Varieties/cultivars	Per cent mortality
1	Kalluvally-II	20.80(0.472) ^{ef}	26	TMB-VIII	58.00(0.866) ^{abc}
2	Angamali	66.67(0.961) ^{ab}	27	TMB-IX	45.33(0.737) ^{bcde}
3	Thevarmundi	61.87(0.920) ^{abc}	28	Munda	60.67(0.894) ^{abc}
4	Panniyur-4	50.30(0.789) ^{abcd}	29	Padarpan	57.73(0.865) ^{abc}
5	TMB-I	50.83(0.793) ^{abcd}	30	Perumunda	54.93(0.836) ^{abcd}
6	Panniyur-5	25.73(0.530) ^{def}	31	Vellanamban-I	53.33(0.819) ^{abcd}
7	Aimperian	65.10(0.942) ^{abc}	32	Kuthiravally	67.86(0.968) ^{ab}
8	Poonjarmunda	74.13(1.058) ^a	33	Nilgiris	48.67(0.773) ^{abcde}
9	Panniyur-1	53.87(0.823) ^{abcd}	34	Karimkotta	37.33(0.642) ^{cdef}
10	Karimunda-I	40.00(0.683) ^{bcdef}	35	Thevarmundi	54.67(0.832) ^{abcd}
11	Uthirankotta-I	41.33(0.694) ^{bcdef}	36	Mundi	47.33(0.759) ^{abcde}
12	Panniyur-3	42.13(0.704) ^{bcdef}	37	Kottanadan	64.44(0.933) ^{abc}
13	Balankotta	17.87(0.430) ^f	38	Kaniyakadan	42.13(0.706) ^{bcdef}
14	Panniyur-2	52.67(0.813) ^{abcd}	39	Panniyur-6	60.00(0.893) ^{abc}
15	Sreekara	45.54(0.740) ^{bcde}	40	Culture-6391	62.13(0.911) ^{abc}
16	Subhakara	35.10(0.633) ^{bcdef}	41	Kottaram	58.00(0.873) ^{abc}
17	Panchami	48.00(0.764) ^{abcde}	42	Vellanamban-II	63.33(0.928) ^{abc}
18	Pournami	38.67(0.666) ^{bcdef}	43	Ceylon	48.67(0.770) ^{abcde}
19	Neelamundi	46.00(0.745) ^{bcde}	44	Karimunda-II	53.33(0.819) ^{abcd}
20	Cheriyakaniakadan	60.00(0.889) ^{abc}	45	Culture-1558	62.13(0.911) ^{abc}
21	Perumkodi	35.33(0.636) ^{cdef}	46	Panniyur-7	43.20(0.716) ^{bcdef}
22	Karuvilanchi	40.53(0.688) ^{bcdef}	47	Uthirankotta-II	56.13(0.848) ^{abc}
23	Shimoga	59.67(0.901) ^{abc}	48	Malligesara	53.33(0.819) ^{abcd}
24	Thulakodi	43.88(0.722) ^{bcdef}	49	Arakulam munda	62.40(0.914) ^{abc}
25	Kalluvally-IV	50.80(0.792) ^{abcd}	50	Culture-406	56.13(0.850) ^{abc}

* Mean of three replication

Arc-sine transformed values are given in parenthesis

For each column figures followed by same letter do not differ significantly

4.5.1.2 *Ortho-dihydric phenol (OD Phenol)*

A similar trend as in the case of total phenol was observed with respect to OD phenol content (Table 59 and Fig. 10). Significantly higher OD phenol content was recorded in tolerant cultivar Kalluvally-II which was significantly higher than moderately susceptible variety, Panniyur-5 and susceptible variety, Panniyur-1.

Table 59. Total and OD phenols contents in black pepper genotypes

Genotypes	Content (mg g ⁻¹)	
	Total phenol	OD phenol
Panniyur-1	4.39	3.27
Panniyur-5	4.51	3.38
Kalluvally-II	5.15	3.88
CD(0.05)	0.19	0.14

4.5.2 *Total carbohydrates*

The total carbohydrate contents in the leaves of three genotypes of *Piper nigrum* varied significantly. The leaves of Panniyur-1 contained significantly higher amount of carbohydrate compared to other two genotypes. The total carbohydrate contents in Kalluvally-II and Panniyur-5 were 21.06 and 23.73 per cent less than that in Panniyur-1 (Table 60 and Fig. 11).

4.5.2.1 *Starch*

The genotypes of black pepper differed significantly with respect to starch content. A similar trend as that noticed in total carbohydrate was observed in this case also. The highest starch content was recorded in Panniyur-1, the susceptible variety and the least in moderately susceptible variety, Panniyur-5, which was on par with tolerant cultivar Kalluvally-II (Table 60 and Fig. 11). It was also noted that tolerant cultivar Kalluvally-II contained 25.08 per cent less starch as compared to the susceptible variety, Panniyur-1.

4.5.2.2 Reducing sugars

Analysis of data on reducing sugars revealed a significant difference among the pepper genotypes (Table 60 and Fig. 11). The highest content of reducing sugars was noticed in moderately susceptible variety Panniyur-5 followed by the tolerant cultivars, Kalluvally-II. In the susceptible variety Panniyur-1, it was significantly less than Panniyur-5 and Kalluvally-II.

Table 60. Total carbohydrates, starch and reducing sugar contents in black pepper genotypes

Genotypes	Content (mg g ⁻¹)		
	Total carbohydrates	Starch	Reducing sugar
Panniyur-1	20.79	12.42	2.80
Panniyur-5	15.86	8.15	4.05
Kalluvally-II	16.42	9.31	3.37
CD(0.05)	1.41	0.60	0.01

4.5.3 Enzymes

4.5.3.1 Peroxidase

Significant difference could be observed among black pepper genotypes with respect peroxidase activity (Table 61 and Fig. 12). The tolerant cultivar, Kalluvally-II exhibited significantly higher peroxidase activity and was on par with moderately susceptible Panniyur-5. The susceptible variety Panniyur-1 showed lowest peroxidase activity.

4.5.3.2 Catalase

Catalase activity of three pepper genotypes tested differed significantly (Table 61 and Fig. 12). The highest activity of this enzyme was observed in tolerant Kalluvally-II followed by susceptible Panniyur-1 and least in moderately susceptible Panniyur-5.

4.5.3.3 Acid phosphatase

Significant differences in acid phosphatase activity was observed among different pepper genotypes studied. The activity of this enzyme was high in susceptible variety Panniyur-1 which was significantly superior compared to Panniyur-5 and Kalluvally-II. The acid phosphatase activity in Panniyur-5 was significantly higher than that in Kalluvally-II (Table 61 and Fig. 12).

4.5.3.4 Esterase

Activity of esterase in the leaves of the susceptible variety Panniyur-1 was significantly higher than that of the tolerant Kalluvally-II and moderately susceptible Panniyur-5 which showed an intermediary value between susceptible and tolerant genotypes (Table 61 and Fig. 12).

Table 61. Enzyme activities in black pepper genotypes

Genotypes	Peroxidase (mg g ⁻¹)	Catalase (mg g ⁻¹ x 10 ⁻²)	Acid phosphatase (mg g ⁻¹ x 10 ⁻⁴)	Estarase (mg g ⁻¹ x 10 ⁻³)
Panniyur-1	3.47	68.41	5.09	11.49
Panniyur-5	4.76	37.55	1.96	5.57
Kalluvally-II	4.97	89.93	1.33	5.85
CD(0.05)	1.23	10.45	0.29	0.29

4.5.4 Total free amino acids

The total free amino acid content was significantly higher in tolerant cultivar Kalluvally-II followed by moderately susceptible variety Panniyur-5 and susceptible variety Panniyur-1 and they were significantly different from each other (Table 62 and Fig. 13).

Table 62. Total free amino acids content in black pepper genotypes

Genotype	Total amino acids (μ g ⁻¹)
Panniyur-1	3.32
Panniyur-5	4.34
Kalluvally-II	8.44
CD(0.05)	0.23

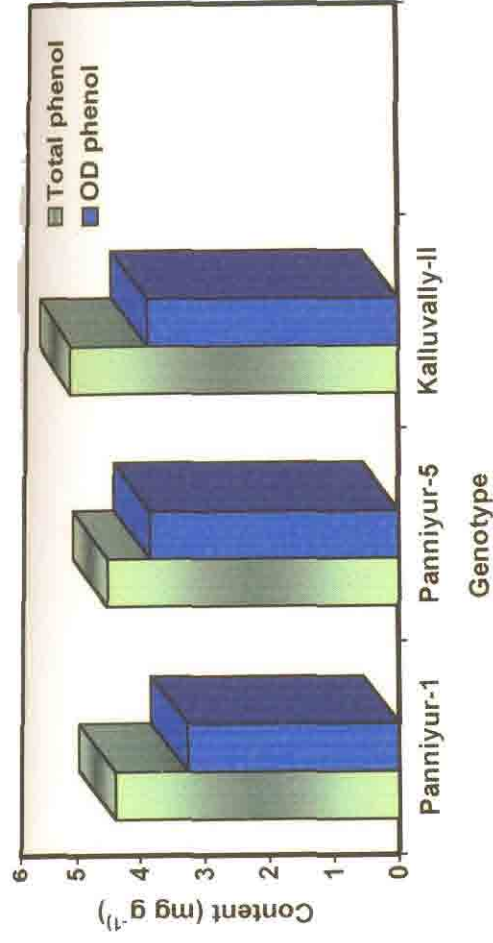


Fig. 10. Total and OD phenol contents in black pepper genotypes

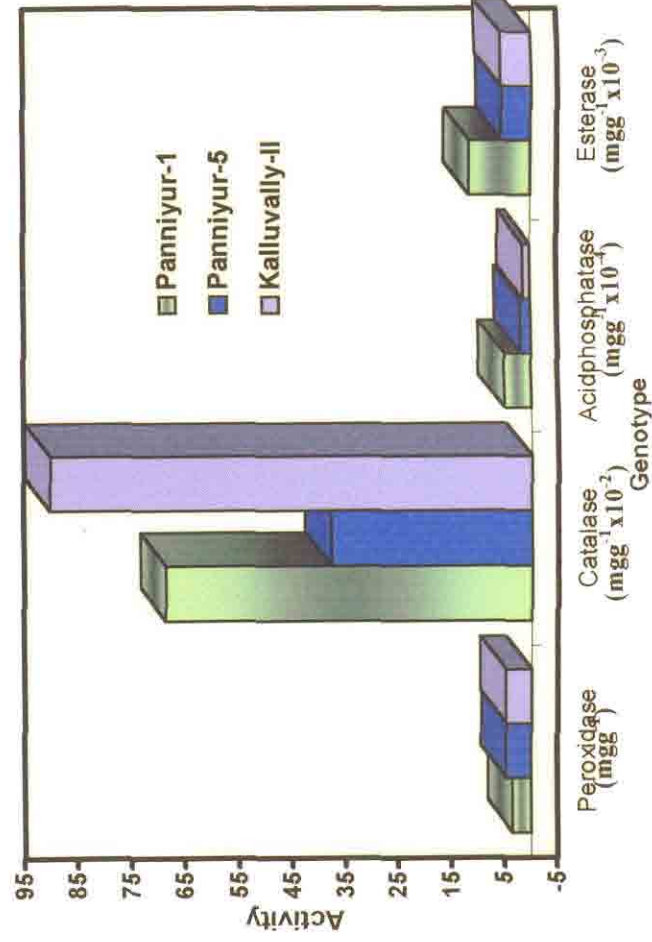


Fig. 12. Enzyme activities in black pepper genotypes

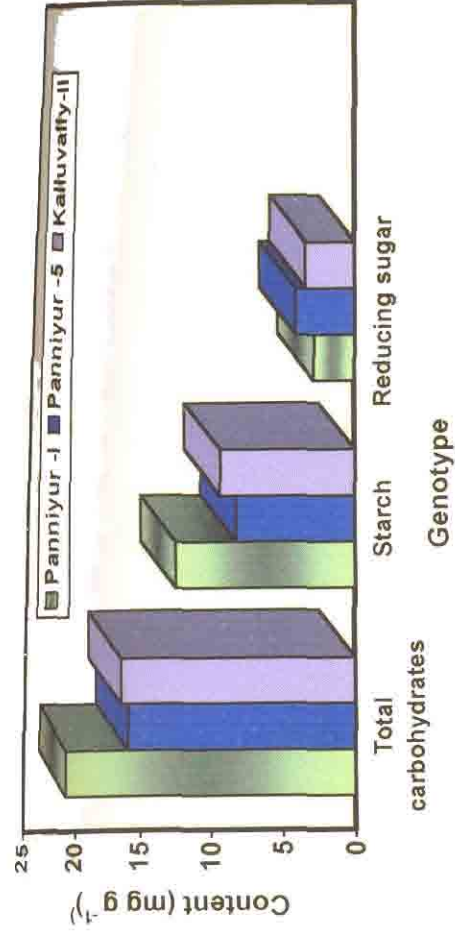


Fig. 11. Total carbohydrates, starch, reducing sugar contents in black pepper genotypes

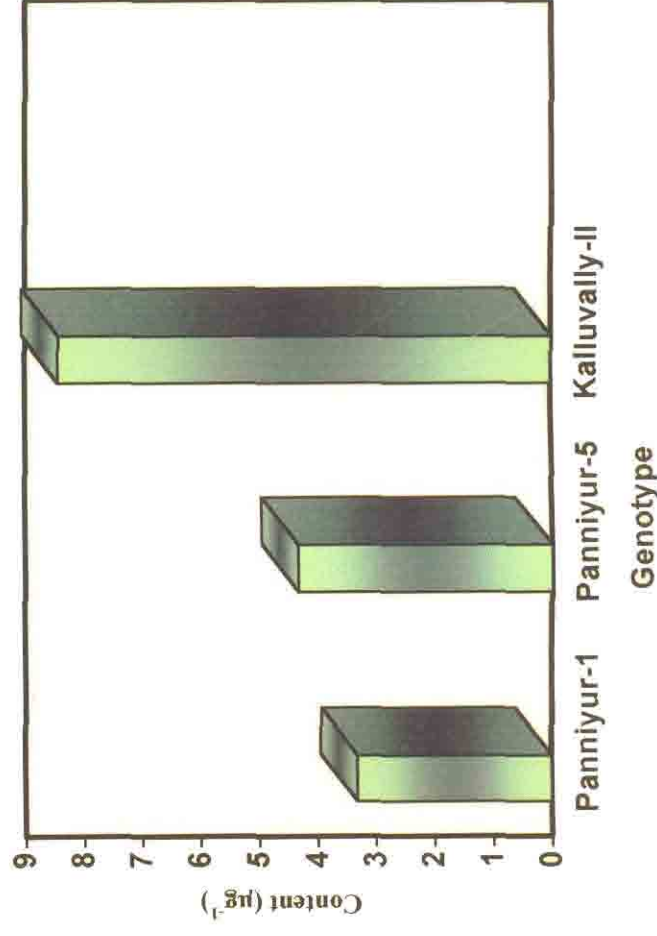


Fig. 13. Total free amino acid contents in black pepper genotypes

4.6 ISOLATION OF NATIVE MICROFLORA FROM THE RHIZOSPHERE SOIL

Soil samples were collected from 30 pepper nurseries of different locations of Kasargode, Knnur, Kozhikode and Wynad districts of Kerala. The samples were collected from the rhizosphere of pepper cuttings. Soil microbes, viz., fungi, bacteria and actinomycetes were isolated from these samples by serial dilution plate technique and the results are presented in Table 63.

4.6.1 Fungi

Significant variation in the population of fungi were noticed in soil samples collected from different locations. Highest fungal count of soil was noticed in samples collected from Regional Agricultural Research Station, Ambalavayal (RARS) followed by those from District Agricultural Farm, Koothali, Kozhikode district and these were on par with those collected from 10 different locations (Table 63).

The minimum population of fungi was observed in samples from nursery at Thikkodi and this was closely followed by samples collected from nurseries at Kodakadu and Karinthalam areas.

4.6.2 Bacteria

Though not significant, the bacterial count was found to vary with different locations (Table 63). Maximum population was recorded from the rhizosphere soil collected from Sulthan's Battery of Wynad district and the least was in soils of Karinthalam of Kasargode district. In other locations the population of bacteria ranged from 1.67 to 4.67×10^6 cfu g^{-1} soil.

4.6.3 Actinomycetes

There was no significant difference among the locations on the population of actinomycetes (Table 63). The population of actinomycetes varied in different locations with a maximum in soil samples collected from Kuthupuramba and RARS, Ambalavayal. The least count was observed in Kuttikol.

Table 63. Rhizosphere soil microorganisms from different pepper nurseries

Sl. No	Location	Fungi ($\times 10^3$ cfu g ⁻¹ soil)	Bacteria ($\times 10^6$ cfu g ⁻¹ soil)	Actinomy cetes ($\times 10^6$ cfu g ⁻¹ soil)	Predominant fungal isolate
KASARGODE DISTRICT					
1	Pullur	18.00	1.67	3.67	<i>Rhizopus, Trichoderma</i>
2	Padomane	22.67	4.33	4.33	<i>Penicillium, Trichoderma</i>
3	Edaneer	28.33	3.00	2.00	<i>Trichoderma, Rhizopus</i>
4	Gundiauka	18.67	4.67	3.00	<i>Trichoderma, Rhizopus</i>
5	Kubaneer	11.00	3.00	3.67	<i>Trichoderma, Rhizopus</i>
6	Pilicode	16.33	2.33	2.33	<i>Trichoderma, Rhizopus</i>
7	Karinthlam	9.33	1.33	2.00	<i>Trichoderma, Rhizopus</i>
8	Kodakadu	8.67	4.67	2.67	<i>Trichoderma, Rhizopus</i>
9	Kutikkol	17.67	2.00	1.00	<i>Trichoderma, Rhizopus</i>
10	Rajapuram	11.33	3.00	3.67	<i>Penicillium, Rhizopus</i>
11	Madikai	10.00	2.00	3.67	<i>Trichoderma, Penicillium</i>
12	Pullur-II	17.33	3.67	4.33	<i>Penicillium, Aspergillus</i>
KANNUR DISTRICT					
13	Karimbam	29.67	4.00	2.67	<i>Trichoderma, Rhizopus, Aspergillus</i>
14	Vengad	30.00	4.33	3.00	<i>Rhizopus, Penicillium, Trichoderma</i>
15	Kankole	22.33	4.00	1.33	<i>Rhizopus, Penicillium, Trichoderma</i>
16	Chalode	30.67	3.33	3.67	<i>Aspergillus, Rhizopus, Trichoderma</i>
17	Panniyur	29.67	3.67	4.33	<i>Aspergillus, Trichoderma</i>
18	Perumunna	23.67	3.67	4.00	<i>Aspergillus, Trichoderma</i>
19	Thirumeni	13.33	2.33	1.33	<i>Aspergillus, Rhizopus</i>
20	Kuthuparama	28.67	4.00	4.67	<i>Aspergillus, Trichoderma</i>
21	Koodalipuram	18.67	4.33	1.33	<i>Aspergillus, Trichoderma</i>
22	Perumpadavu	23.00	3.33	4.33	<i>Aspergillus, Trichoderma</i>
KOZHIKODE DISTRICT					
23	Thikkodi	08.00	2.67	3.00	<i>Rhizopus, Aspergillus</i>
24	Koothali	31.67	4.67	2.33	<i>Trichoderma, Penicillium</i>
WYNAD DISTRICT					
25	Ambalavayal	34.33	3.67	4.67	<i>Aspergillus, Penicillium, Trichoderma</i>
26	Neerchal	17.00	2.00	2.00	<i>Aspergillus, Penicillium</i>
27	Mancombukunnu	19.33	3.33	2.33	<i>Trichoderma, Aspergillus, Penicillium</i>
28	Sulthan Battery	25.67	5.33	2.69	<i>Trichoderma, Rhizopus</i>
29	Kenichira	20.00	4.67	2.69	<i>Trichoderma, Rhizopus</i>
30	Cheengeri	31.00	4.33	1.33	<i>Trichoderma, Aspergillus</i>
CD (0.05)		13.42	NS	NS	

All the rhizosphere microbes isolated were subcultured and used for further studies. Based on the cultural and morphological characters, 48 fungi, 21 bacteria and 14 actinomycetes were selected. Among the different fungal isolates, majority of them belonged to the genus *Trichoderma* and *Rhizopus* followed by *Aspergillus* and *Penicillium*.

4.6.4 *In vitro* evaluation of native and established microbes against *P. capsici*

4.6.4.1 *Fungi*

Fourty eight fungal isolates and the two established antagonists viz., *T. viride* and *T. harzianum* were evaluated for their antagonistic effect against *P. capsici* under *in vitro* conditions by dual culture technique and the percentage inhibition of the pathogen was worked out.

It was evident from the data given in Table 64, that all the fungal isolates tested, showed antagonistic action against pathogen. It was observed that F14 (Plate 9a) exerted the maximum inhibition of 68.00 per cent closely followed by F47 and F48 (Plate 9b). The inhibition percentage in established antagonists viz., *T. viride* and *T. harzianum* were 59.52 and 57.14 respectively and they were on par with F22, F31 and F18. The least inhibition percentage was exhibited by the F46, which was on par with F38 and other isolates showed an inhibition ranging from 39.04 to 53.33 per cent.

4.6.4.2 *Bacteria*

Among the 21 bacterial isolate selected, all of them showed inhibition against *P. capsici* (Table 65). The extent of inhibition recorded with the isolates ranged from 17.78 to 38.89 per cent with the maximum by B5. However the inhibitory effect shown by B5 was on par with that of B12, B19 and B20. The minimum inhibition was observed with B14 and it was on par with B1, B2 and B6.

4.6.4.3 *Actinomycetes*

The different isolates of actinomycetes isolated from different nurseries were screened against *P. capsici*. The study revealed that, compared to fungal and

Table 64. *In vitro* efficacy of fungal isolates against *P. capsisi*

Fungal isolates	Per cent inhibition*	Fungal isolate	Per cent inhibition*
F1	39.04 ^p	F26	51.43 ^{defg}
F2	40.00 ^{op}	F27	53.33 ^{cde}
F3	40.95 ^{nop}	F28	46.67 ^{ghijklm}
F4	45.71 ^{hijklm}	F29	49.52 ^{efghij}
F5	50.48 ^{efgh}	F30	50.00 ^{efghi}
F6	48.55 ^{efghijk}	F31	58.57 ^b
F7	46.66 ^{ghijklm}	F32	51.43 ^{efg}
F8	40.00 ^{op}	F33	52.86 ^{cde}
F9	46.67 ^{efghij}	F34	47.14 ^{ghijkl}
F10	46.19 ^{hijklm}	F35	42.85 ^{lmnop}
F11	49.52 ^{efghij}	F36	52.38 ^{def}
F12	49.52 ^{efghi}	F37	46.18 ^{hijklm}
F13	44.76 ^{jklmn}	F38	34.76 ^q
F14	68.00 ^a	F39	47.62 ^{efghijkl}
F15	43.80 ^{klmno}	F40	47.14 ^{ghijkl}
F16	46.17 ^{hijklm}	F41	45.24 ^{ijklmn}
F17	49.54 ^{efghij}	F42	52.38 ^{def}
F18	56.19 ^{bcd}	F43	46.19 ^{hijklm}
F19	48.57 ^{efghijk}	F44	51.43 ^{defg}
F20	47.14 ^{ghijkl}	F45	50.00 ^{efghi}
F21	53.33 ^{cde}	F46	30.95 ^q
F22	58.93 ^b	F47	65.71 ^a
F23	49.53 ^{efghij}	F48	64.57 ^a
F24	49.04 ^{efghij}	<i>T. viride</i>	59.52 ^b
F25	41.90 ^{mnp}	<i>T. harzianum</i>	57.14 ^{bc}

* Mean of three replications

In each column figures followed by same letter do not differ significantly according to DMRT

Table 65. *In vitro* efficacy of bacterial isolates against *P. capsici*

Bacterial isolates	Per cent inhibition*
B1	20.74 ⁱ
B2	20.00 ⁱ
B3	27.04 ^{gh}
B4	30.74 ^{defgh}
B5	38.89 ^a
B6	21.48 ⁱ
B7	17.78 ⁱ
B8	28.46 ^{efgh}
B9	26.75 ^h
B10	33.33 ^{bcde}
B11	32.20 ^{cdefg}
B12	34.82 ^{abcd}
B13	29.87 ^{defgh}
B14	27.78 ^{fgh}
B15	32.95 ^{bcdef}
B16	33.33 ^{bcde}
B17	32.22 ^{cdefgh}
B18	31.85 ^{cdefgh}
B19	37.41 ^{ab}
B20	36.29 ^{abc}
B21	33.33 ^{bcde}

* Mean of three replications

In each column figures followed by same letter do not differ significantly according to DMRT

bacterial isolates, majority of the isolates showed less inhibitory action against the pathogen (Table 66). Although there was no significant difference among the isolates, the maximum inhibition was observed with A1 and this was followed by A2 and A4. The least inhibition of 11.11 per cent was exhibited by A13.

Table 66. *In vitro* efficacy of Actinomycetes isolates against *P. capsici*

Actinomycetes isolates	*Per cent inhibition
A1	29.62
A2	28.52
A3	19.26
A4	27.78
A5	21.48
A6	22.22
A7	18.89
A8	14.82
A9	14.81
A10	18.32
A11	19.26
A12	22.22
A13	11.11
A14	14.82
	NS

* Mean of three replications

4.6.5 *In vivo* evaluation of native and established antagonists against *P. capsici*

An experiment was laid out using Panniyur-1 variety grown in polythene bags. The antagonistic ability of fungi, bacteria and actinomycetes isolated from pepper nurseries and established antagonists against *P. capsici* were tested under *in vivo* conditions.

4.6.5.1 *Fungi*

Fifty fungal isolates including 48 isolates obtained from different nurseries and two established antagonists (*T. viride*) and (*T. harzianum*) were evaluated for their effect against *P. capsici* on rooted pepper cuttings grown in polythene bags (Table 67).

The percentage of root infection and fresh and dry weights of roots were taken four months after planting of cuttings. Results of the study revealed that the antagonistic fungi had a significant effect on the incidence of root rot infection. The minimum root rot infection was recorded in cuttings inoculated with F14 (*Trichoderma* sp.) which was on par with F48 (*Trichoderma* sp.), *T. viride* and *T. harzianum* respectively. The maximum root rot infection of 99.30 per cent was in vines treated with F16 followed by control (92.67 per cent).

Data on the fresh weight of roots showed that, the maximum weight was noticed in plants treated with F14 (*Trichoderma* sp.) followed by *T. harzianum*, F48 (*Trichoderma* sp.) and *T. viride* (Table 67). The minimum fresh root weight of 0.17 g was recorded in plants inoculated with F16. A similar trend as in the case of fresh weight of roots was observed in the dry weight of roots also with the maximum value in F48 and the minimum in F16.

4.6.5.2 *Bacteria*

A significant difference was noticed among the 21 bacterial isolates (Table 68). It was observed that the mean incidence of root rot varied from 49.33 per cent (isolate B3) to 100 per cent (isolate B13). Though, there was no significant difference among the isolates on fresh weight and dry weight, a maximum fresh weight was observed in bacterial isolate B11 followed by B6 and the least was observed in isolate B13. Regarding dry weight, the maximum was observed in B19 followed by isolates B11 and B12.

4.6.5.3 *Actinomycetes*

Fourteen actinomycetes isolated from different pepper nurseries were evaluated against *P. capsici* and it was noticed that although a significant difference was observed among the isolates. The per cent of root rot infection was maximum in control and this was on par with A7. The least percentage of root rot infection was observed in A2. The maximum fresh weight of roots was obtained when vines were treated with A4 and the least was observed in control. The same trend was noticed

Table 67. *In vivo* evaluation of fungal isolates against *P. capsici*

Isolate	Incidence of root rot*	Fresh weight of roots (g)*	Dry weight of roots (g)*
1	2	3	4
F1	49.33 ^{opq}	8.40 ^{abcde fgh}	1.75 ^{efghijk}
F3	14.67 ^t	7.93 ^{abcde fgh}	2.96 ^{cde fgh}
F3	63.00 ^{fghijk}	5.80 ^{cde fgh}	1.95 ^e
F4	15.67 ^t	7.13 ^{bcde fgh}	2.21 ^{efghijk}
F5	62.67 ^{fghijk}	4.53 ^{de fgh}	0.95 ^{hijk}
F6	63.33 ^{fghij}	6.50 ^{bcde fgh}	2.51 ^{de fghij}
F7	58.33 ^{ijklm}	10.10 ^{abcde f}	3.63 ^{bcde}
F8	68.67 ^t	6.62 ^{bcde fgh}	2.42 ^{de fghij}
F9	85.00 ^{cd}	5.71 ^{cde fgh}	1.35 ^{fghijk}
F10	88.67 ^{bc}	2.45 ^{fgh}	0.85 ^{hijk}
F11	60.33 ^{ghijkl}	6.92 ^{bcde fgh}	2.11 ^{efghijk}
F12	54.17 ^{lmno}	6.54 ^{bcde fgh}	1.91 ^{efghijk}
F13	59.10 ^{hijklm}	6.67 ^{bcde fgh}	1.43 ^{efghijk}
F14	3.33 ^u	15.77 ^a	5.25 ^b
F15	92.17 ^b	0.78 ^h	0.28 ^{jk}
F16	99.30 ^a	0.17 ^h	0.02 ^k
F17	63.83 ^{fghij}	7.27 ^{abcde fgh}	1.98 ^{efghijk}
F18	49.67 ^{nopq}	7.95 ^{abcde fgh}	1.85 ^{efghijk}
F19	55.33 ^{klmno}	8.00 ^{abcde fgh}	1.93 ^{efghijk}
F20	64.00 ^{fghij}	7.30 ^{bcde fgh}	1.65 ^{efghijk}
F21	49.17 ^{opq}	9.62 ^{abcde f}	2.45 ^{de fghij}
F22	37.67 ^r	10.50 ^{abcde f}	3.43 ^{bcde f}
F23	66.30 ^{fgh}	7.51 ^{bcde fgh}	1.35 ^{fghijk}
F24	43.00 ^{qr}	11.78 ^{abcde}	3.59 ^{bcde f}
F25	80.17 ^{de}	3.83 ^{efgh}	0.35 ^{fghijk}
F26	63.00 ^{fghijk}	5.25 ^{cde fgh}	1.15 ^{ghijk}
F27	48.67 ^{opq}	10.22 ^{abcde f}	3.59 ^{de fgh}
F28	52.67 ^{lmnop}	9.00 ^{abcde f}	2.00 ^{efghijk}
F29	60.33 ^{ghijkl}	9.50 ^{abcde f}	1.88 ^{efghijk}
F30	43.67 ^{qr}	9.33 ^{abcde f}	2.51 ^{de fghijk}
F31	62.67 ^{fghijk}	7.80 ^{abcde fgh}	1.62 ^{efghijk}
F32	57.33 ^{jklmn}	7.28 ^{bcde fgh}	2.01 ^{efghijk}
F33	49.33 ^{opq}	7.05 ^{bcde fgh}	1.92 ^{efghijk}
F34	63.33 ^{fghij}	6.01 ^{cde fgh}	1.23 ^{fghijk}
F35	66.00 ^{fghi}	8.55 ^{abcde fgh}	1.45 ^{efghijk}
F36	49.33 ^{opq}	10.22 ^{abcde f}	3.25 ^{bcde f}
F37	57.33 ^{jklmn}	10.73 ^{abcde}	3.45 ^{bcde f}
F38	89.33 ^{bc}	1.42 ^{gh}	0.35 ^{ijk}

Contd.

Table 67. Continued

1	2	3	4
F39	81.00 ^{de}	4.54 ^{defgh}	1.96 ^{efghijk}
F40	46.33 ^{pq}	8.89 ^{abcdefgh}	1.17 ^{ghijk}
F41	67.33 ^{fg}	5.97 ^{cdefgh}	1.95 ^{efghijk}
F42	49.67 ^{opq}	8.47 ^{abcdefgh}	3.35 ^{abcdefg}
F43	83.33 ^{cd}	4.13 ^{efgh}	1.23 ^{efghijk}
F44	51.67 ^{mnop}	7.55 ^{bcdefgh}	2.57 ^{defghi}
F45	68.66 ^f	8.20 ^{abcdef}	1.33 ^{fghijk}
F46	76.00 ^e	8.70 ^{bcdefgh}	2.41 ^{defghijk}
F47	13.33 ^t	7.57 ^{bcdefgh}	4.78 ^{bc}
F48	3.33 ^u	13.27 ^{abc}	7.79 ^a
<i>T. viride</i>	4.00 ^u	12.50 ^{abcd}	6.96 ^a
<i>T. harzianum</i>	5.37 ^s	14.20 ^{ab}	6.44 ^a
Control	92.67 ^b	0.72 ^h	0.11 ^k

* Mean of three replications

In each column figures followed by same letter do not differ significantly according to DMRT

Table 68. *In vivo* evaluation of bacterial isolates against *P. capsici*

Isolate	Per cent incidence of root rot*	Fresh weight of roots (g)*	Dry weight of roots (g)*
B1	71.87 ^g	5.10	2.02
B2	61.33 ^j	4.86	1.43
B3	49.33 ⁱ	7.17	2.34
B4	67.33 ^h	5.97	1.57
B5	76.00 ^{ef}	5.68	2.13
B6	64.00 ^{ij}	8.07	3.12
B7	67.33 ^h	4.66	1.26
B8	88.67 ^b	2.45	0.68
B9	98.87 ^a	0.17	0.01
B10	64.67 ^{hi}	7.37	2.31
B11	57.00 ⁱ	8.25	3.05
B12	63.33 ^{ij}	7.83	3.04
B13	100.00 ^a	0	0
B14	82.33 ^d	3.43	1.13
B15	85.37 ^{cd}	3.09	1.03
B16	84.00 ^{cd}	5.60	1.85
B17	75.33 ^f	5.69	1.99
B18	84.33 ^{cd}	2.74	0.96
B19	86.67 ^{bc}	8.31	3.33
B20	82.33 ^d	6.35	1.98
B21	83.00 ^d	6.52	1.83
Control	78.67 ^e	4.48	0.51

* Mean of three replications

In each column figures followed by same letter do not differ significantly according to DMRT

when observations were taken for dry weight of roots. The least dry weight of 0.36 g was observed in control and it was on par with all the isolates (Table 69).

Table 69. *In vivo* evaluation of actinomycetes isolates against *P. capsici*

Isolate	Per cent incidence of root rot*	Fresh weight of roots (g)*	Dry weight of roots (g)*
A1	72.67 ^g	7.02	2.36
A1	64.67 ⁱ	5.38	1.79
A3	81.98 ^{de}	3.44	1.28
A4	71.83 ^g	7.85	2.84
A5	68.93 ^h	4.85	1.44
A6	75.77 ^f	5.52	1.60
A7	87.67 ^{ab}	3.94	1.16
A8	86.67 ^{bc}	3.54	1.11
A9	76.90 ^f	3.54	1.11
A10	82.67 ^{de}	2.04	0.66
A11	84.11 ^{cd}	3.59	0.96
A12	79.93 ^e	2.14	0.57
A13	76.67 ^f	4.35	1.51
A14	72.13 ^g	5.56	1.96
Control	90.07 ^a	1.28	0.36

* Mean of three replications

In each column figures followed by same letter do not differ significantly according to DMRT

4.6.5.4 Identification of efficient antagonists

The two fungal isolates (F14 and F48) that showed better antagonistic ability both under *in vitro* and *in vivo* were identified based on the cultural and morphological characters.

4.6.5.4.1 Isolate F14

The colour of the colonies was whitish green, grow rapidly and form smooth surfaced, watery white sparse aerial mycelium radiating from the centre of mycelial disc. The conidial areas were whitish green and changed from bright green to rather dull green. The mycelium was septate, branched, smooth walled, hyaline with thickness of 2.0 to 11.0 μm . Conidiophores were much branched and borne singly or in groups, especially in lower ones (Plate 10a). The phialides were borne singly and

irregularly along in sides of the main and small branches. The phialides $4.5 - 7.5 \times 2.5 - 3.0 \mu\text{m}$, short, skittle shaped, narrower at the base than middle, than attenuated towards the neck. The phialospores produced singly and accumulate at the tip of each phialides. They measure about $2.5 - 3.5 \times 2.3 - 2.5 \mu\text{m}$. Globose or obvoid smooth walled with a broad base and pale green in colour. Based on the above characters, this isolates was identified as *Trichoderma harzianum* Rifai (Rifai, 1964).

4.6.5.4.2 Isolate F48

The colonies grow fast and attained full growth in 9 cm Petridish in about 3-4 days. Colonies were smooth surfaced, watery white and sparse mycelial mat, which later may become hairy from the formation of loose scandy aerial hyphae which make them somewhat whitish. Mature colonies were dark green or dark bluish in colour. Fully matured culture emitted a typical 'coconut odour'. Mycelium hyaline, smooth walled, septate and much branched measuring 1.5 to 11.5 μm thickness. The main branches of conidiophores produce side branches either singly or in groups. Phialides arise in false or irregular whorls, with adequate distance from each other (Plate 10b). They measured about $9.0 - 14.5 \times 2.5 - 3.2 \mu\text{m}$ in size. Phialospores are sub-globose or obvoid with minutely rough wall measured about $3.5 - 6.5 \mu\text{m}$ and green in colour. So this isolate was identified as *Trichoderma viride* Pers. ex S.F.Grey (Webster, 1964).

The selected native antagonist *Trichoderma harzianum*-F14 and *Trichoderma viride*-F48 and the standard culture of *T. harzianum* were found efficient antagonist to *P. capsici*. The antagonists overgrow the pathogen within a short period of time and interactions like hyphal coiling, penetration and disintegration of the host hyphae was observed which ultimately lead to death of the pathogen.

4.7 COMPATIBILITY OF ANTAGONISTS TO FUNGICIDES

Fungicides commonly used in pepper gardens for the control of *P. capsici* were evaluated at various concentrations to know their compatibility with standard cultures *T. viride* and *T. harzianum*, the selected native antagonists *Trichoderma harzianum* (F14) and *Trichoderma viride* (F48) are given below.



Plate 9. *Trichoderma* spp. and *P. capsici* in dual culture

a) *T. harzianum* (F 14)

b) *T. viride* (F 48)



Plate 10. Photomicrographs of selected fungal antagonists

a) *T. harzianum* (F 14)

b) *T. viride* (F 48)

Among the fungicides tested for the compatibility to biocontrol agents, Bordeaux mixture showed high inhibition of growth of antagonist followed by Fytolan (Table 70). Akomin-40 and Ridomil MZ. In general, it was noticed that as the concentration increased, there was increased inhibition of antagonists.

Results showed that the response of *T. viride* to four fungicides tested at various concentrations differed significantly. The fungus showed no inhibition of growth with 0.05 per cent Ridomil-MZ. Akomin-40 (0.05 per cent) and Ridomil MZ (0.10 per cent) showed the least inhibition and they were on par with that of 0.10 per cent and 0.20 per cent Akomin-40 and Ridomil MZ respectively. However, at 0.20 per cent, Akomin-40 showed an inhibition percentage of 24.44. Bordeaux mixture at two higher concentrations (one and two per cent) and Fytolan - 0.20 per cent did not support any growth of *T. viride*. But only slight growth was noticed in Bordeaux mixture (0.50 per cent) and in Fytolan (0.05 and 0.10 per cent).

The response of *T. harzianum* to different fungicides was similar to that noticed in *T. viride*. Two per cent Bordeaux mixture did not support any growth of this antagonist. However, the lowest concentration of Bordeaux mixture and Fytolan exhibited 83.33 and 84.44 per cent inhibition of the fungus respectively and it was on par with the inhibitory effect of other concentrations of these fungicides. Akomin-40 and Ridomil-MZ incorporated media supported good growth of the fungus indicating the compatibility of these fungicides with this antagonist. Maximum growth (8.90 cm) of the fungus was noticed with the lowest concentration of Akomin-40 and Ridomil-MZ and was on par with their two higher concentrations.

Significant difference in the inhibitory effect on the growth of *T. harzianum* (F14) was noticed with the fungicides tested.

Fytolan at all concentrations tested and the higher two concentrations of Bordeaux mixture completely inhibited the growth of the fungus. Only slight growth was observed with 0.5 per cent Bordeaux mixture. Akomin-40 and Ridomil-MZ incorporated media supported comparatively good growth of this fungus. There was

Table 70. Compatibility of biocontrol agents with fungicides

Sl. No.	Fungicides	Concentration (Per cent)	<i>T. viride</i>		<i>T. harzianum</i>		<i>T. harzianum</i> - F14		<i>T. viride</i> - F48	
			Mean diameter of colony* (cm)	Per cent inhibition over control	Mean diameter of colony* (cm)	Per cent inhibition over control	Mean diameter of colony* (cm)	Per cent inhibition over control	Mean diameter of colony* (cm)	Per cent inhibition over control
1	Akomin-40	0.05	8.80 ^a	2.22	8.90 ^a	1.11	8.50 ^a	5.56	8.80 ^a	2.22
		0.10	8.40 ^a	6.66	8.10 ^a	10.00	8.00 ^a	11.11	8.60 ^a	4.44
		0.20	6.80 ^b	24.44	8.00 ^a	11.11	7.40 ^a	17.78	8.20 ^a	8.89
2	Ridomil-MZ	0.05	9.00 ^a	0.00	8.90 ^a	1.11	9.00 ^a	0	8.60 ^a	4.44
		0.10	8.80 ^a	2.22	8.60 ^a	6.30	8.20 ^a	8.89	8.20 ^a	8.89
		0.20	8.60 ^a	4.44	8.20 ^a	9.89	7.20 ^a	20.00	8.00 ^a	11.11
3	Bordeaux mixture	0.50	0.30 ^c	96.0	1.50 ^b	83.33	1.00 ^b	88.89	0.76 ^c	71.11
		1.00	0 ^c	100.0	0.30 ^b	96.67	0 ^b	100.00	0.36 ^d	83.40
		2.00	0 ^c	100.0	0 ^b	100.00	0 ^b	100.00	1.10 ^c	88.89
4	Fytolan	0.05	1.0 ^c	87.77	1.40 ^b	84.44	0 ^b	100	2.6 ^b	71.11
		0.10	0.20 ^c	97.78	0.60 ^b	93.33	0 ^b	100	1.5 ^{bc}	83.40
		0.20	0 ^c	100.00	0.25 ^b	94.44	0 ^b	100	1.0 ^{bc}	88.89
5	Control		9.0 ^a		9.0 ^a		9.0 ^a		9.0 ^a	

* Mean of five replications

In each column figures followed by same letter do not differ significantly according to DMRT

no inhibition of growth with 0.05 per cent Ridomil-MZ. All concentration of Akomin-40 and Ridomil-MZ at 0.1 and 0.2 per cent showed hundred per cent inhibition of growth of the fungus.

The response of *Trichoderma viride* (F48) also varied significantly to different fungicides. None of the fungicides tested did show complete inhibition of the fungus. The minimum percentage inhibition was noticed with 0.05 per cent Akomin-40 followed by that of Akomin (0.1 per cent) and Ridomil-MZ (0.05 per cent) and they were on par with other concentrations of these fungicides.

The different concentrations of Bordeaux mixture exerted more than 90 per cent inhibition and were on par with two higher concentrations of Fytolan. However, only 71.11 per cent inhibition was noticed with 0.5 per cent Fytolan indicating the non-compatibility of copper fungicides with *Trichoderma* sp.

4.8 EFFECT OF TIME OF PLANTING ON THE INCIDENCE OF *P. capsici*

An experiment was laid out to find out the influence of time of planting of pepper cuttings on the incidence of *P. capsici*. Cuttings of Panniyur-1 variety were planted at fortnightly intervals for two seasons (1998, 1999) starting from January to end of May. Observations on sprouting percentage of cuttings, incidence of *P. capsici* and other biometric characters were recorded.

4.8.1 Sprouting of cuttings

Data presented in Table 71 revealed that time of planting had a significant effect on sprouting percentage. The sprouting percentage ranged from 65.2 to 94.0 per cent during 1998 and 67.33 to 92.0 per cent during 1999. During 1998 the maximum sprouting of 94.00 per cent was noticed when the cuttings were planted on the sixth fortnight and was on par with that recorded at all intervals except the ninth and tenth fortnight. During 1999, more than 90 per cent sprouting was noticed during fifth, sixth and seventh fortnights with maximum in cuttings planted on the fifth fortnight and it was on par with sprouting recorded from first to eighth fortnights. Here also pepper cutting planted during the last two fortnights showed comparatively less sprouting percentage with minimum in those planted during the tenth fortnight.

Table 71. Effect of time of planting on sprouting of pepper cuttings

Sl.No.	Time of planting	*Per cent sprouting	
		1998	1999
1	First fortnight (January)	83.61	80.27
2	Second fortnight (January)	81.86	82.53
3	Third fortnight (February)	85.86	80.26
4	Fourth fortnight (February)	90.80	89.60
5	Fifth fortnight (March)	89.33	92.00
6	Sixth fortnight (March)	94.00	91.20
7	Seventh fortnight (April)	83.20	91.73
8	Eighth fortnight (April)	83.07	80.67
9	Ninth fortnight (May)	69.33	71.47
10	Tenth fortnight (May)	65.20	67.33
	CD (0.05)	13.29	11.80

* Mean of three replications

4.8.2 Number of leaves

Observation on the number of leaves presented in Table 72 showed that time of planting had an effect on the production of leaves. The cuttings planted on the fourth fortnight of 1998 recorded the maximum number of leaves followed by those planted on fifth fortnight. The cuttings planted during the last two fortnight supported comparatively lesser number of leaves.

Table 72. Effect of time of planting on number of leaves

Sl.No.	Time of planting	*Number of leaves	
		1998	1999
1	First fortnight (January)	5.00	4.33
2	Second fortnight (January)	6.33	5.67
3	Third fortnight (February)	6.00	7.00
4	Fourth fortnight (February)	8.00	7.67
5	Fifth fortnight (March)	7.67	6.67
6	Sixth fortnight (March)	6.33	6.67
7	Seventh fortnight (April)	3.33	4.33
8	Eighth fortnight (April)	5.00	4.33
9	Ninth fortnight (May)	2.67	7.33
10	Tenth fortnight (May)	2.33	5.67
	CD (0.05)	1.95	2.76

* Mean of three replications

In 1999 also, there was significant variation on the number of leaves with planting intervals. Here cuttings planted during the fourth fortnight produced the maximum number of leaves, followed by those planted on the ninth and third fortnights. Contrary to the results obtained during 1998, the minimum number of leaves was observed on cutting planted on the first, seventh and eighth fortnights of 1999.

4.8.3 Height of plant

Time of planting had a significant effect on height of pepper cuttings (Table 73). Observations recorded during 1998 indicated that cuttings planted during the first fortnight had the maximum height. The minimum height was recorded with cuttings planted on seventh fortnight followed by tenth fortnight. During 1999, the maximum and minimum heights were observed with cuttings planted on third and eighth fortnights respectively.

Table 73. Effect of time of planting on height of plant

Sl.No.	Time of planting	*Height of plant (cm)	
		1998	1999
1	First fortnight (January)	12.00	8.30
2	Second fortnight (January)	8.67	8.70
3	Third fortnight (February)	9.67	9.85
4	Fourth fortnight (February)	8.15	9.75
5	Fifth fortnight (March)	7.70	9.70
6	Sixth fortnight (March)	6.30	8.75
7	Seventh fortnight (April)	5.61	5.51
8	Eighth fortnight (April)	7.83	5.49
9	Ninth fortnight (May)	8.87	8.37
10	Tenth fortnight (May)	5.92	7.45
	CD (0.05)	4.67	3.03

* Mean of three replications

4.8.4 Number of roots

Data presented in Table 74 indicated that time of planting significantly influenced the production of roots. During 1998, the maximum and minimum number of roots were produced in cuttings planted on the fourth fortnight and on the last two

fortnights respectively. However, in 1999 season, the maximum number of roots was observed with cuttings planted on the third fortnight. While the minimum in cuttings planted during the last fortnight.

Table 74. Effect of time of planting on number of roots

Sl.No.	Time of planting	*Number of roots	
		1998	1999
1	First fortnight (January)	5.00	5.67
2	Second fortnight (January)	8.00	5.67
3	Third fortnight (February)	5.67	10.00
4	Fourth fortnight (February)	8.33	9.67
5	Fifth fortnight (March)	7.67	8.33
6	Sixth fortnight (March)	6.33	7.67
7	Seventh fortnight (April)	3.33	6.00
8	Eighth fortnight (April)	5.00	5.67
9	Ninth fortnight (May)	2.33	7.67
10	Tenth fortnight (May)	2.33	5.00
	CD (0.05)	2.16	3.86

* Mean of three replications

4.8.5 Length of roots

Time of planting had significant effect on the length of roots (Table 75). Data collected during 1998 showed that cuttings planted during the third, fourth, fifth and sixth i.e., during February to March 1998 had more than 26 cm long roots, with the maximum in cuttings planted during third fortnight. Comparatively less root length was noticed in cuttings planted during the last three fortnights. In 1999 also similar trend was observed. During this season, more than 24 cm long roots were noticed in cuttings planted during the third, fourth, fifth and sixth fortnights with maximum in the former. However, length of roots was less than 10 cm in cuttings planted during the last four intervals.

Table 75. Effect of time of planting on length of roots

Sl.No.	Time of planting	*Length of roots (cm)	
		1998	1999
1	First fortnight (January)	17.50	14.76
2	Second fortnight (January)	12.84	16.97
3	Third fortnight (February)	26.84	26.67
4	Fourth fortnight (February)	26.00	26.65
5	Fifth fortnight (March)	26.07	24.35
6	Sixth fortnight (March)	26.57	26.63
7	Seventh fortnight (April)	10.98	9.98
8	Eighth fortnight (April)	8.00	8.76
9	Ninth fortnight (May)	9.26	7.49
10	Tenth fortnight (May)	9.17	8.85
	CD (0.05)	11.16	4.89

* Mean of three replications

4.8.6 Wet weight of roots

Data presented in Table 76, revealed that in general, time planting had an influence on the wet weight of roots with the cuttings planted during the early five fortnight, having more wet weight than the last five ones. During 1999, there was no significant variation between time of planting and wet weight of roots. Here also, wet weight was reduced when time of planting was delayed.

Table 76. Effect of time of planting on wet weight of roots

Sl.No.	Time of planting	*Wet weight of roots (g)	
		1998	1999
1	First fortnight (January)	10.00	7.35
2	Second fortnight (January)	10.47	9.16
3	Third fortnight (February)	11.58	10.65
4	Fourth fortnight (February)	11.52	11.88
5	Fifth fortnight (March)	11.15	9.21
6	Sixth fortnight (March)	9.16	10.35
7	Seventh fortnight (April)	8.89	9.37
8	Eighth fortnight (April)	6.36	9.83
9	Ninth fortnight (May)	6.47	6.53
10	Tenth fortnight (May)	8.38	6.90
	CD (0.05)	4.67	NS

* Mean of three replications

4.8.7 Dry weight of roots

During 1998, comparatively more dry weight of roots was noticed in early planted cuttings, i.e., on third, fourth, fifth and sixth fortnights with the maximum in these planted during the fourth fortnight (Table 77). The minimum in cuttings planted during the last fortnight. There was significant variation in dry weight of roots during 1999. The maximum dry weight of roots was recorded in cuttings planted during the fourth fortnight, which was on par with third, first, fifth and sixth fortnights. While minimum dry weight was in cuttings planted during ninth fortnight, which was on par with tenth, second, seventh and eighth fortnights.

Table 77. Effect of time of planting on dry weight of roots

Sl.No.	Time of planting	*Dry weight of roots (g)	
		1998	1999
1	First fortnight (January)	0.93	1.64
2	Second fortnight (January)	1.02	1.05
3	Third fortnight (February)	1.17	1.86
4	Fourth fortnight (February)	2.17	1.97
5	Fifth fortnight (March)	2.26	1.33
6	Sixth fortnight (March)	1.45	1.78
7	Seventh fortnight (April)	0.80	0.87
8	Eighth fortnight (April)	0.76	0.82
9	Ninth fortnight (May)	0.81	0.42
10	Tenth fortnight (May)	0.60	0.54
	CD (0.05)	1.13	0.66

* Mean of three replications

4.8.8 Disease incidence

From the data presented in Table 78 it is evident that time of planting of cutting had a significant effect on the incidence of *Phytophthora* rot. In general, in early or late planted cuttings there was more incidence of *Phytophthora* rot compared to those planted during February and March. During 1998, significantly higher percentage of incidence of the disease was recorded in cuttings planted during the last three fortnights with the maximum of 26.80 per cent in these planted during the eighth fortnight. The minimum incidence was observed in cutting planted during sixth fortnight followed by cuttings planted during fifth fortnight and these were on par with the incidence of *P. capsici* planted from first to fourth fortnights.

Table 78. Effect of time of planting on disease incidence

Sl.No.	Time of planting	*Per cent disease incidence	
		1998	1999
1	First fortnight (January)	11.00	13.47
2	Second fortnight (January)	12.40	12.40
3	Third fortnight (February)	10.27	8.53
4	Fourth fortnight (February)	6.00	8.00
5	Fifth fortnight (March)	5.33	6.53
6	Sixth fortnight (March)	5.20	6.27
7	Seventh fortnight (April)	16.27	14.67
8	Eighth fortnight (April)	26.80	18.40
9	Ninth fortnight (May)	21.87	15.33
10	Tenth fortnight (May)	26.27	17.47
	CD (0.05)	10.44	8.31

* Mean of three replications

In 1999 also similar trend was observed as that of 1998. But the percentage of incidence of disease was comparatively less than that recorded during 1998. The maximum and minimum incidence due to *P. capsici* was noticed in cuttings planted during the eighth and sixth fortnights respectively.

4.9 EFFECT OF SOLARIZATION OF POTTING MIXTURE ON THE INCIDENCE OF *Phytophthora* rot

A nursery experiment was carried out during 1998 season to find out the effect of solarization of potting mixture on the incidence of *Phytophthora* rot in black pepper nursery. Observations on temperature in solarized and non-solarized potting mixture, atmospheric temperature, population of soil microbes and plant growth were recorded.

4.9.1 Temperature¹

Temperature of the solarized and non-solarized potting mixture was recorded daily during the entire 45 days of solarization at 5 cm and 10 cm depth at

7.25 am and 2.25 pm and weekly mean of temperature was calculated. Further, the weekly mean of minimum and maximum atmospheric temperature was also recorded (Table 79).

From the data given in Table 84, it is evident that the soil temperature in the solarized potting mixture was always higher than that of non-solarized soil. During the solarization period, the weekly mean temperature ranged from 33.87°C to 38.78°C at 5 cm depth in solarized potting mixture at 7.25 am compared to 30.64°C to 32.33°C in non solarized soil. At 2.25 pm, the corresponding soil temperature at 5 cm ranged from 51.09°C to 59.56°C and 42.64°C to 46.26°C in solarized and non-solarized potting mixtures respectively.

The maximum weekly mean soil temperature in solarized soil at 10 cm depth in the morning (7.25 am) was 39.59°C and the minimum temperature was 34.17°C with a aggregate mean of 37.27°C. In non-solarized potting mixture at the same depth maximum and minimum temperature recorded were 31.63°C and 32.77°C respectively. Temperature observed in the afternoon (2.25 pm) in solarized soil ranged from 44.80°C to 54.13°C with a total mean of 51.77°C. While in non-solarized potting mixture it was 39.59°C to 42.47°C.

During solarization period the mean maximum and minimum atmospheric temperature were 32.53 and 21.93°C respectively.

4.9.2 Population of soil microorganisms

Effect of duration of solarization on soil microbes viz., fungi, bacteria and actinomycetes was assessed. Observations recorded after 15, 30 and 45 days of solarization showed a general reduction in the population of soil microorganisms.

4.9.2.1 Soil fungi

Population of soil fungi just before solarization was 31.39×10^3 cfu g⁻¹ soil. After 15 days of solarization, the fungal count was reduced to 23.0×10^3 cfu g⁻¹ soil which amounted to 26.73 per cent reduction from the original count (Table 80). Enumeration after 30 days of solarization showed a very drastic reduction of the count

Table 79. Weekly mean atmospheric and soil temperature during solarization (1-2-98 to 17-3-98)

Week	Soil temperature °C										Atmospheric temperature °C	
	Solarized potting mixture					Non-solarized potting mixture						
	5 cm depth		10 cm depth		53.42	5 cm depth		10 cm depth				
	7.25 am	2.25 pm	7.25 am	2.25 pm		7.25 am	2.25 pm	7.25 am	2.25 pm			
1	37.46	51.09	34.17	53.42		31.50	46.26	32.00	40.90		33.20	20.96
2	38.00	58.58	38.40	44.80		30.64	45.21	31.63	40.23		32.77	21.27
3	33.87	57.67	36.33	52.14		31.71	46.93	32.09	42.47		32.06	20.70
4	37.63	59.46	39.13	53.76		32.33	44.86	32.43	40.57		32.24	23.57
5	38.87	59.56	35.97	52.37		32.00	42.64	32.77	39.59		32.47	22.69
6	38.78	59.45	39.59	54.13		31.15	44.87	31.88	41.21		32.40	22.36
Average	37.44	57.47	37.27	51.77		31.56	45.13	32.13	40.82		32.53	21.93

of soil fungi (2.95×10^3 cfu g⁻¹ soil) from the initial population. After 45 days of solarization the population of fungi was 1.89×10^3 cfu g⁻¹ soil. This indicating that there was 94.00 per cent reduction in the population of fungi due to solarization.

4.9.2.2 *Bacteria*

The initial population of bacteria before solarization was 5.72×10^6 cfu g⁻¹ soil and their population was reduced to 4.61×10^6 cfu g⁻¹ soil after 15 days of solarization (Table 80). The percentage reduction after 15 days of solarization was 19.41. After 30 days of solarization, the population was 1.22×10^6 cfu g⁻¹ of soil which amounted to 78.67 per cent reduction compared to the initial count. However, the bacterial population (1.23×10^6 cfu g⁻¹ soil) recorded after 45 days of solarization did not show much variation compared to those taken during 30 days of solarization.

4.9.2.3 *Actinomycetes*

Actinomycetes population also showed reduction with the increase in the duration of solarization. Intial count of actinomycetes was 4.06×10^6 cfu g⁻¹ soil and after 15 days of solarization it was reduced to 3.61×10^6 cfu g⁻¹ soil, a reduction of 11.08 per cent (Table 80). The population after 30 days of solarization was 2.11×10^6 cfu g⁻¹ soil a decrease of 48.03 per cent. Further drastic reduction of population of 87.69 per cent was noticed after 45 days of solarization (0.5×10^6 cfu g⁻¹ soil) compared to the initial population.

Table 80. Effect of solarization on the population of soil microbes

Treatments	Population of soil microorganisms		
	Fungi ($\times 10^3$ cfu g ⁻¹ soil)	Bacteria ($\times 10^6$ cfu g ⁻¹ soil)	Actinomycetes ($\times 10^6$ cfu g ⁻¹ soil)
Before solarization	31.39	5.72	4.06
15 DAS	23.00	4.61	3.61
T value	14.97**	7.99**	2.68
30 DAS	2.95	1.22	2.11
T value	20.27**	7.99**	5.13**
45 DAS	1.89	1.23	0.50
T value	35.59**	7.33**	6.11**

Note: T value - Before solarization vs. 15, 30 and 45 DAS

DAS - Days after solarization

** Significant

4.9.3 Growth parameter and disease incidence

4.9.3.1 *Sprouting percentage*

Though not significant, more sprouting percentage was noticed when the cuttings were planted in solarized potting mixture. More than 90 per cent germination was observed in cuttings planted in soil solarized for various periods (Table 81).

4.9.3.2 *Height of plants*

Solarization resulted in increasing the height of plants. Maximum height of cuttings (13.19 cm) were observed in potting mixture solarized for 45 days followed by those in 30 days. The minimum value (7.20 cm) was in cutting raised in non-solarized potting mixture (Table 81).

4.9.3.4 *Number of leaves*

Solarization had no significant effect on production of leaves (Table 81). However, comparatively higher number of leaves were noticed in cuttings raised in potting mixture solarized for 45 days followed by those in 30 days of solarization (5.33 Nos). The minimum number of leaves (4.33) were observed in cuttings grown in potting mixture solarized for 15 days.

4.9.3.5 *Number of roots*

Solarization of potting mixture did not show any significant difference on the number of roots (Table 81). Here also the maximum number (10.67) of roots were observed in plants grown in potting mixture solarized for 45 days followed by cuttings raised in soil solarized for 30 days. The minimum number of roots (5.33) was noticed in cuttings grown in non-solarized potting mixture.

4.9.3.6 *Length of roots*

Significant difference on the length of roots of cuttings raised in non-solarized and solarized potting mixture was not recorded. But comparatively more length of roots was observed in cuttings grown in 45 days solarized potting mixture

Table 81. Effect of solarization on plant growth and disease incidence

Sl. No.	Treatments	Sprouting percentage*	Height of plants (cm)*	Number of leaves*	Number of roots*	Length of roots (cm)*	Wet weight of roots (g)*	Dry weight of roots (g)*	Per cent disease incidence*
1	Non-solarization	84.86	7.20	4.66	5.33	16.13	8.68	0.79	15.73
2	Solarization of 15 days	94.28	9.38	4.33	7.00	15.14	8.92	1.14	14.53
3	Solarization for 30 days	96.65	10.99	5.33	9.33	17.15	17.75	2.43	6.53
4	Solarization for 45-days	96.85	13.19	5.67	10.67	17.66	22.01	2.86	7.60
CD (0.05)		NS	2.12	NS	NS	NS	7.39	NS	3.33

* Mean of five replications

followed by those in 30 days. The minimum length of roots was in plants grown in potting mixture solarized for 15 days (Table 81).

4.9.3.7 *Wet weight of roots*

Significant difference in wet weight of roots was noticed with different periods of solarization. The maximum wet weight (22.01 g) was in plants grown in potting mixture solarized for 45 days and was on par with those raised in 30 days solarization. The minimum wet weight of 8.68 g was recorded in cuttings planted in non-solarized potting mixture and was in par with the wet weight of rooted cuttings raised in 15 days solarized soil (Table 81).

4.9.3.8 *Dry weight of roots*

Though not significant the maximum dry weight of roots was observed in cuttings raised in 45 days solarized potting mixture and the minimum in cuttings from non-solarized potting mixture (Table 81).

4.9.3.9 *Disease incidence*

Data on the percentage of incidence of *P. capsici* on cuttings raised in solarized and non-solarized potting mixture showed significant difference. The minimum percentage of disease incidence was noticed in cuttings raised in potting mixture solarized for 30 days and was on par with that of cuttings raised in 45 days solarized potting mixture (Table 81). Here more than 14.00 per cent disease incidence was observed in cuttings grown in 15 days solarized and non-solarized potting mixtures.

4.10 INTEGRATED DISEASE MANAGEMENT (IDM)

To find out the efficacy of solarization of potting mixture, application of biocontrol agents and fungicides on the management of *Phytophthora* rot in black pepper nursery, an experiment was conducted during 2001 and 2002 seasons at RARS, Pilicode (Plate 11). Three pepper genotypes viz., Panniyur-I, Panniyur-5 and



Plate 11. View of the nursery experiment

Kalluvally-II which showed varying degrees of susceptibility/tolerance were used in the trial.

4.10.1 IDM in Panniyur-1

Data on the percentage incidence of *Phytophthora* rot during 2001 are presented in Table 82. It is evident from the table that all treatments were significantly superior to control in reducing the incidence of *Phytophthora* rot. The maximum incidence of disease was in control (T₃₀) which was four times more than that in T₁₄ (Solarization + application of *T. viride* + spraying and drenching of Akomin-40). This treatment was followed by T₁₆ (Solarization + *T. harzianum* + Akomin-40), T₂₀ (Solarization + *T. harzianum* - F14 + Akomin-40) and T₄ (Solarization + *T. viride* - F48). They were significantly superior to seven other treatments. The treatments T₁₄, T₆, T₂₀ and T₄ showed more than 70 per cent efficiency over control in reducing the disease incidence with maximum efficiency by T₁₄.

Phytophthora rot in plants grown in solarized potting mixture (T₁) was 20.40 per cent. However, with the incorporation of *Trichoderma* sp. into solarized soil, the disease incidence got reduced. In these treatments, the disease incidence ranged from 10.54 per cent in T₄ to 14.27 per cent in T₃ (Solarization + *T. harzianum*). When *Trichoderma* was incorporated in non-solarized potting mixture, there was a reduction in disease incidence. Here the incidence ranged from 14.13 to 21.33 per cent. Further, it was noticed that in treatments where biocontrol agents were incorporated in solarized soil, the incidence was comparatively less than as compared to treatment wherein biocontrol agent was incorporated in non-solarized potting mixture.

Comparison of the effect of fungicidal application in pepper cuttings raised in solarized soil on the incidence of *Phytophthora* rot showed that the treatment. T₁₂ (Solarization + spraying and drenching Bordeaux mixture) had a significant effect in reducing the disease but it did not differ significantly with other fungicidal treatments (T₁₀, T₁₁ and T₁₃).

Table 82. Integrated management of *Phytophthora* rot in Panniyur-1 (2001)

Treatments	Per cent disease incidence	Per cent efficiency of the treatment over control
T ₁ - Solarization of potting mixture for 30 days	20.40 ^{bcdef}	46.12
T ₂ - T ₁ + <i>Trichoderma viride</i>	13.60 ^{cdefg}	64.08
T ₃ - T ₁ + <i>Trichoderma harzianum</i>	14.27 ^{cdefg}	62.31
T ₄ - T ₁ + <i>Trichoderma viride</i> - F48	10.54 ^{efg}	72.16
T ₅ - T ₁ + <i>Trichoderma harzianum</i> - F14	14.13 ^{cdefg}	62.76
T ₆ - Non-solarization + <i>T. viride</i>	20.93 ^{bcdef}	44.72
T ₇ - Non-solarization + <i>T. harzianum</i>	21.33 ^{bcde}	43.74
T ₈ - Non-solarization + <i>Trichoderma viride</i> - F48	14.13 ^{cdefg}	62.68
T ₉ - Non-solarization + <i>Trichoderma harzianum</i> - F14	15.73 ^{bcdefg}	58.45
T ₁₀ - T ₁ + spraying and drenching with Akomin-40 - 0.2 per cent	20.70 ^{bcdef}	45.32
T ₁₁ - T ₁ + spraying and drenching with Ridomil MZ - 0.1 per cent	23.33 ^{bcd}	38.46
T ₁₂ - T ₁ + spraying and drenching with Bordeaux mixture - 1 per cent	18.67 ^{bcdefg}	50.69
T ₁₃ - T ₁ + spraying and drenching with Fytolan - 0.2 per cent	22.40 ^{bcd}	40.57
T ₁₄ - T ₂ + spraying and drenching with Akomin-40 - 0.2 per cent	8.30 ^g	78.34
T ₁₅ - T ₂ + spraying and drenching with Ridomil MZ - 0.1 per cent	16.27 ^{bcdefg}	57.05
T ₁₆ - T ₃ + spraying and drenching with Akomin-40 - 0.2 per cent	9.22 ^g	75.65
T ₁₇ - T ₃ + spraying and drenching with Ridomil MZ - 0.1 per cent	12.27 ^{defg}	67.62
T ₁₈ - T ₄ + spraying and drenching with Akomin-40 - 0.2 per cent	18.30 ^{bcdefg}	51.66
T ₁₉ - T ₄ + spraying and drenching with Ridomil MZ - 0.1 per cent	14.93 ^{bcdefg}	60.57
T ₂₀ - T ₅ + spraying and drenching with Akomin-40 - 0.2 per cent	10.27 ^{fg}	72.87
T ₂₁ - T ₅ + spraying and drenching with Ridomil MZ - 0.1 per cent	22.93 ^{bcd}	39.43
T ₂₂ - T ₆ + spraying and drenching with Akomin-40 - 0.2 per cent	20.00 ^{bcdef}	47.17
T ₂₃ - T ₆ + spraying and drenching with Ridomil MZ - 0.1 per cent	25.33 ^b	33.17
T ₂₄ - T ₇ + spraying and drenching with Akomin-40 - 0.2 per cent	18.93 ^{bcdefg}	50.00
T ₂₅ - T ₇ + spraying and drenching with Ridomil MZ - 0.1 per cent	24.13 ^{bc}	36.27
T ₂₆ - T ₈ + spraying and drenching with Akomin-40 - 0.2 per cent	18.67 ^{bcdefg}	50.71
T ₂₇ - T ₈ + spraying and drenching with Ridomil MZ - 0.1 per cent	18.13 ^{bcdefg}	52.30
T ₂₈ - T ₉ + spraying and drenching with Akomin-40 - 0.2 per cent	15.50 ^{bcdefg}	59.06
T ₂₉ - T ₉ + spraying and drenching with Ridomil MZ - 0.1 per cent	20.67 ^{bcdef}	45.40
T ₃₀ - Absolute control	37.87 ^a	-

In each column figures followed by same letter do not differ significantly according to DMRT

Observation on the incidence of the disease in treatments consisting of application of biocontrol agents and fungicides in solarized or non-solarized soil, revealed that in general, application of antagonists and fungicides to cuttings raised in solarized potting mixture had comparatively less disease incidence. The lowest value was observed in T₁₄, followed by T₁₆ and T₂₀. During 2002 also, all the treatments were significantly superior to control (T₃₀) in reducing the incidence of *Phytophthora* rot (Table 83). The minimum incidence (10.53 per cent) was recorded in T₅ (Solarization + *T. harzianum* - F14) with 68.78 per cent efficiency over control. This was followed by T₁₅ (Solarization + *T. viride* + Akomin-40) and T₁₄ (Solarization + *T. viride* + Akomin-40) and these treatment were more than 60 per cent efficient over control.

In plants raised in solarized potting mixture (T₁) the incidence of *P. capsici* was 19.20 per cent. When the antagonists were incorporated in solarized soil (T₂-T₅), the maximum incidence was recorded in T₂ (Solarization + *T. viride*) and the minimum in T₅. However, when the antagonist (*T. harzianum* - F14) was incorporated with non-solarized potting mixture, the incidence was 16.67 per cent (T₉) an increase of 36.77 per cent over T₅. In general the incidence of *Phytophthora* rot was more in cuttings raised in non-solarized soil mixed with antagonist compared to those raised in solarized soil with antagonist.

The incidence of *Phytophthora* rot in treatments with solarized soils drenched and sprayed with fungicides ranged from 16.27 per cent in T₁₂ (Solarization + Bordeaux mixture) to 20.80 in T₁₃ (Solarization + Fytolan). Comparison of the percentage incidence of *Phytophthora* rot in treatments T₁₄ - T₂₉, showed that the minimum incidence of 12.53 per cent was in T₁₅ followed by T₁₄ and T₁₆. All these treatments showed more than 59 per cent efficiency over control. The maximum incidence was recorded in T₂₉ (*T. harzianum* - F14 + Ridomil MZ).

The percentage incidence of the disease in treatments with antagonists and fungicides in solarized or non-solarized soil revealed that application of antagonists

Table 83. Integrated management of *Phytophthora* rot in Panniyur-1 (2002)

Treatments	Per cent disease incidence	Per cent efficiency of the treatment over control
T ₁ - Solarization of potting mixture for 30 days	19.20 ^{bdef}	43.08
T ₂ - T ₁ + <i>Trichoderma viride</i>	17.60 ^{bdefg}	47.82
T ₃ - T ₁ + <i>Trichoderma harzianum</i>	17.33 ^{bdefg}	48.62
T ₄ - T ₁ + <i>Trichoderma viride</i> - F48	15.73 ^{cdefg}	53.36
T ₅ - T ₁ + <i>Trichoderma harzianum</i> - F14	10.53 ^g	68.78
T ₆ - Non-solarization + <i>T. viride</i>	16.67 ^{bdefg}	50.58
T ₇ - Non-solarization + <i>T. harzianum</i>	17.33 ^{bdefg}	48.62
T ₈ - Non-solarization + <i>Trichoderma viride</i> - F48	18.67 ^{bdef}	44.65
T ₉ - Non-solarization + <i>Trichoderma harzianum</i> - F14	16.67 ^{bdefg}	50.58
T ₁₀ - T ₁ + spraying and drenching with Akomin-40 - 0.2 per cent	20.00 ^{bdef}	40.71
T ₁₁ - T ₁ + spraying and drenching with Ridomil MZ - 0.1 per cent	19.60 ^{bdef}	41.89
T ₁₂ - T ₁ + spraying and drenching with Bordeaux mixture - 1 per cent	16.27 ^{bdefg}	51.76
T ₁₃ - T ₁ + spraying and drenching with Fytolan - 0.2 per cent	20.80 ^{bde}	38.33
T ₁₄ - T ₂ + spraying and drenching with Akomin-40 - 0.2 per cent	13.20 ^{efg}	60.87
T ₁₅ - T ₂ + spraying and drenching with Ridomil MZ - 0.1 per cent	12.53 ^{fg}	62.85
T ₁₆ - T ₃ + spraying and drenching with Akomin-40 - 0.2 per cent	13.60 ^{defg}	59.68
T ₁₇ - T ₃ + spraying and drenching with Ridomil MZ - 0.1 per cent	16.40 ^{bdefg}	51.38
T ₁₈ - T ₄ + spraying and drenching with Akomin-40 - 0.2 per cent	19.60 ^{bdef}	41.89
T ₁₉ - T ₄ + spraying and drenching with Ridomil MZ - 0.1 per cent	14.67 ^{defg}	56.51
T ₂₀ - T ₅ + spraying and drenching with Akomin-40 - 0.2 per cent	16.67 ^{bdefg}	50.58
T ₂₁ - T ₅ + spraying and drenching with Ridomil MZ - 0.1 per cent	18.93 ^{bdef}	43.88
T ₂₂ - T ₆ + spraying and drenching with Akomin-40 - 0.2 per cent	17.73 ^{bdefg}	47.44
T ₂₃ - T ₆ + spraying and drenching with Ridomil MZ - 0.1 per cent	22.67 ^{bc}	32.79
T ₂₄ - T ₇ + spraying and drenching with Akomin-40 - 0.2 per cent	21.20 ^{bcd}	37.15
T ₂₅ - T ₇ + spraying and drenching with Ridomil MZ - 0.1 per cent	22.07 ^{bc}	31.60
T ₂₆ - T ₈ + spraying and drenching with Akomin-40 - 0.2 per cent	20.53 ^{bde}	39.13
T ₂₇ - T ₈ + spraying and drenching with Ridomil MZ - 0.1 per cent	22.67 ^{bc}	32.79
T ₂₈ - T ₉ + spraying and drenching with Akomin-40 - 0.2 per cent	19.20 ^{bdef}	43.08
T ₂₉ - T ₉ + spraying and drenching with Ridomil MZ - 0.1 per cent	23.60 ^b	30.03
T ₃₀ - Absolute control	33.73 ^a	-

In each column figures followed by same letter do not differ significantly according to DMRT

Table 84. Pooled data on integrated management of *Phytophthora* rot in Panniyur-1 (2001-2002)

Treatments	Per cent disease incidence	Per cent efficiency of the treatment over control
T ₁ - Solarization of potting mixture for 30 days	19.80 ^{bcdefgh}	44.69
T ₂ - T ₁ + <i>Trichoderma viride</i>	15.60 ^{efghijk}	56.42
T ₃ - T ₁ + <i>Trichoderma harzianum</i>	15.80 ^{defghijk}	55.87
T ₄ - T ₁ + <i>Trichoderma viride</i> - F48	13.09 ^{ijk}	63.64
T ₅ - T ₁ + <i>Trichoderma harzianum</i> - F14	12.32 ^{jk}	65.59
T ₆ - Non-solarization + <i>T. viride</i>	18.80 ^{bcdefghi}	47.49
T ₇ - Non-solarization + <i>T. harzianum</i>	19.32 ^{bcdefghi}	46.03
T ₈ - Non-solarization + <i>Trichoderma viride</i> - F48	16.40 ^{defghijk}	54.19
T ₉ - Non-solarization + <i>Trichoderma harzianum</i> - F14	16.20 ^{defghijk}	54.75
T ₁₀ - T ₁ + spraying and drenching with Akomin-40 - 0.2 per cent	20.35 ^{bcdefg}	43.16
T ₁₁ - T ₁ + spraying and drenching with Ridomil MZ - 0.1 per cent	21.45 ^{bde}	40.08
T ₁₂ - T ₁ + spraying and drenching with Bordeaux mixture - 1 per cent	17.47 ^{cdefghij}	51.20
T ₁₃ - T ₁ + spraying and drenching with Fytolan - 0.2 per cent	21.65 ^{bcde}	39.53
T ₁₄ - T ₂ + spraying and drenching with Akomin-40 - 0.2 per cent	10.70 ^k	70.11
T ₁₅ - T ₂ + spraying and drenching with Ridomil MZ - 0.1 per cent	14.20 ^{ghijk}	60.34
T ₁₆ - T ₃ + spraying and drenching with Akomin-40 - 0.2 per cent	11.41 ^{jk}	68.43
T ₁₇ - T ₃ + spraying and drenching with Ridomil MZ - 0.1 per cent	14.33 ^{ghijk}	59.97
T ₁₈ - T ₄ + spraying and drenching with Akomin-40 - 0.2 per cent	18.95 ^{bcdefghi}	47.07
T ₁₉ - T ₄ + spraying and drenching with Ridomil MZ - 0.1 per cent	14.80 ^{fghijk}	58.66
T ₂₀ - T ₅ + spraying and drenching with Akomin-40 - 0.2 per cent	13.48 ^{hijk}	62.37
T ₂₁ - T ₅ + spraying and drenching with Ridomil MZ - 0.1 per cent	20.93 ^{bcdef}	40.03
T ₂₂ - T ₆ + spraying and drenching with Akomin-40 - 0.2 per cent	18.87 ^{bcdefghi}	47.29
T ₂₃ - T ₆ + spraying and drenching with Ridomil MZ - 0.1 per cent	23.98 ^b	33.02
T ₂₄ - T ₇ + spraying and drenching with Akomin-40 - 0.2 per cent	20.06 ^{bcdefg}	43.97
T ₂₅ - T ₇ + spraying and drenching with Ridomil MZ - 0.1 per cent	23.60 ^{bc}	34.08
T ₂₆ - T ₈ + spraying and drenching with Akomin-40 - 0.2 per cent	19.57 ^{bcdefg}	45.34
T ₂₇ - T ₈ + spraying and drenching with Ridomil MZ - 0.1 per cent	20.37 ^{bcdefg}	43.10
T ₂₈ - T ₉ + spraying and drenching with Akomin-40 - 0.2 per cent	17.35 ^{cdefghi}	51.54
T ₂₉ - T ₉ + spraying and drenching with Ridomil MZ - 0.1 per cent	22.14 ^{bcd}	38.16
T ₃₀ - Absolute control	35.80 ^a	-

In each column figures followed by same letter do not differ significantly according to DMRT

and fungicides in cuttings in solarized soil was more effective in reducing the disease incidence compared to those in solarized, antagonist and fungicides applied treatments. The minimum disease incidence was observed in T₁₅ (12.53 per cent) and maximum in T₂₉ (23.60 per cent).

Pooled analysis of the data for two seasons, on IDM of *Phytophthora* rot in Panniyur-1 indicated significant difference among the treatments (Table 84). It was noticed that all treatments had reduced the disease incidence compared to control (T₃₀). Percentage efficiency of the treatments over control ranged from 33.02 to 70.11. The data showed that the treatment T₁₄ was superior to all other treatments except eleven other treatments and showed more than 70 per cent efficiency over control.

Maximum disease incidence was observed in control (T₃₀) followed by T₂₃. Further, on comparing the effect of application of four antagonists added in solarized and non-solarized soil in reducing the disease. It was observed that application of *T. harzianum* - F14 (T₅) and *T. viride* - F48 (T₄) in solarized soil was more effective in reducing the disease incidence. Data on the incidence of the disease in cuttings grown in solarized potting mixture and sprayed with fungicide (T₁₀ to T₁₃) showed that spraying Bordeaux mixture (T₁₂) was more effective than other fungicides in reducing the disease.

Application of fungicides and biocontrol agents in plants raised in solarized or non-solarized potting mixture (T₁₄ to T₂₉) showed the efficiency of solarization along with biocontrol agents and fungicides in reducing the disease incidence compared to non-solarized ones. Here the minimum disease incidence of 10.70 per cent was noticed in T₁₄ and was on par with T₁₆, T₁₅, T₁₇ and T₂₀. These treatments showed the higher efficiency over control with the maximum being in T₁₄.

4.10.2 IDM in Panniyur-5

Results of the experiment on IDM of *P. capsici* in Panniyur-5 during 2001 (Table 85). The data on the disease incidence in this experiment was similar to that

Table 85. Integrated management of *Phytophthora* rot in Panniyur-5 (2001)

Treatments	Per cent disease incidence	Per cent efficiency of the treatment over control
T ₁ - Solarization of potting mixture for 30 days	13.33 ^{fgh}	60.17
T ₂ - T ₁ + <i>Trichoderma viride</i>	17.47 ^{bcdefg}	47.80
T ₃ - T ₁ + <i>Trichoderma harzianum</i>	12.53 ^{gh}	62.56
T ₄ - T ₁ + <i>Trichoderma viride</i> - F48	13.60 ^{efgh}	59.37
T ₅ - T ₁ + <i>Trichoderma harzianum</i> - F14	18.40 ^{bcdefg}	45.03
T ₆ - Non-solarization + <i>T. viride</i>	19.90 ^{bdef}	40.54
T ₇ - Non-solarization + <i>T. harzianum</i>	20.30 ^{bcde}	39.35
T ₈ - Non-solarization + <i>Trichoderma viride</i> - F48	14.27 ^{cdefgh}	57.36
T ₉ - Non-solarization + <i>Trichoderma harzianum</i> - F14	15.46 ^{bcdefgh}	53.81
T ₁₀ - T ₁ + spraying and drenching with Akomin-40 - 0.2 per cent	15.60 ^{bcdefgh}	53.39
T ₁₁ - T ₁ + spraying and drenching with Ridomil MZ - 0.1 per cent	16.93 ^{bcdefgh}	49.42
T ₁₂ - T ₁ + spraying and drenching with Bordeaux mixture - 1 per cent	16.26 ^{bcdefgh}	51.42
T ₁₃ - T ₁ + spraying and drenching with Fytolan - 0.2 per cent	15.10 ^{cdefgh}	54.88
T ₁₄ - T ₂ + spraying and drenching with Akomin-40 - 0.2 per cent	10.30 ^h	69.23
T ₁₅ - T ₂ + spraying and drenching with Ridomil MZ - 0.1 per cent	12.80 ^{gh}	61.76
T ₁₆ - T ₃ + spraying and drenching with Akomin-40 - 0.2 per cent	14.13 ^{defgh}	57.78
T ₁₇ - T ₃ + spraying and drenching with Ridomil MZ - 0.1 per cent	15.33 ^{bcdefgh}	54.29
T ₁₈ - T ₄ + spraying and drenching with Akomin-40 - 0.2 per cent	12.26 ^{gh}	63.34
T ₁₉ - T ₄ + spraying and drenching with Ridomil MZ - 0.1 per cent	16.26 ^{bcdefgh}	51.42
T ₂₀ - T ₅ + spraying and drenching with Akomin-40 - 0.2 per cent	12.27 ^{gh}	62.56
T ₂₁ - T ₅ + spraying and drenching with Ridomil MZ - 0.1 per cent	18.40 ^{bcdefg}	45.03
T ₂₂ - T ₆ + spraying and drenching with Akomin-40 - 0.2 per cent	14.53 ^{cdefgh}	56.59
T ₂₃ - T ₆ + spraying and drenching with Ridomil MZ - 0.1 per cent	20.93 ^{bc}	37.47
T ₂₄ - T ₇ + spraying and drenching with Akomin-40 - 0.2 per cent	17.10 ^{bcdefgh}	48.91
T ₂₅ - T ₇ + spraying and drenching with Ridomil MZ - 0.1 per cent	20.80 ^{bcd}	37.85
T ₂₆ - T ₈ + spraying and drenching with Akomin-40 - 0.2 per cent	16.80 ^{bcdefgh}	49.81
T ₂₇ - T ₈ + spraying and drenching with Ridomil MZ - 0.1 per cent	21.87 ^b	34.60
T ₂₈ - T ₉ + spraying and drenching with Akomin-40 - 0.2 per cent	14.00 ^{efgh}	58.17
T ₂₉ - T ₉ + spraying and drenching with Ridomil MZ - 0.1 per cent	15.90 ^{bcdefgh}	52.49
T ₃₀ - Absolute control	33.47 ^a	-

In each column figures followed by same letter do not differ significantly according to DMRT

recorded in Panniyur-1. The highest incidence was noticed in control (T₃₀) and lowest in T₁₄ (Solarization + *T. viride* + Akomin-40). Treatment T₁₄ was followed by T₁₈ (Solarization + *T. viride* - F48 + Akomin-40), T₂₀ (Solarization + *T. harzianum* - F14 + Akomin-40), T₃ (Solarization + *T. harzianum*) and T₁₅ (Solarization + *T. viride* + Ridomil MZ). They were on par with each other and with other treatments except T₂₃ (*T. viride* + Ridomil MZ), T₂₇ (*T. viride* - F48 + Ridomil MZ) and control. More than 61.0 per cent efficiency in reducing the incidence of disease over control was recorded with the treatments T₁₄, T₁₈, T₃, T₂₀ and T₁₅.

Addition of different biocontrol agents in solarized and non-solarized soil potting mixtures reduced the disease incidence compared to control. In general, addition of biocontrol agents in solarized potting mixture reduced the disease compared to treatments consisting of non-solarization and biocontrol agents. The lowest disease incidence was noticed in T₃ and the highest in T₇. The disease incidence of plants in solarized potting mixture (T₁) was 13.33 per cent.

There was not marked variation in per cent of disease incidence when plants raised in solarized, potting mixture incorporated with fungicides (T₁₀ to T₁₃). The disease incidence in these treatments varied from 15.10 to 16.93 per cent.

When pepper cuttings were raised in solarized potting mixture with biocontrol agents and fungicides, the incidence of disease was minimum in T₁₄ followed by T₁₈, T₂₀ and T₁₅. These treatments were on par and showed more than 61.0 per cent efficiency over control. The maximum incidence of *Phytophthora* rot was noticed in T₂₉ (*T. harzianum* - F14 + Ridomil MZ).

During 2002 also, there was significant difference among the treatments on the percentage of disease incidence (Table 86). The minimum incidence was noticed in treatment T₁₄ that showed 67.65 per cent efficiency over control. This was followed by T₁₅ and T₁₆, which showed more than 50 per cent efficiency over control. The maximum incidence was noticed in control.

Table 86. Integrated management of *Phytophthora* rot in Panniyur-5 (2002)

Treatments	Per cent disease incidence	Per cent efficiency of the treatment over control
T ₁ - Solarization of potting mixture for 30 days	24.00 ^{ab}	11.76
T ₂ - T ₁ + <i>Trichoderma viride</i>	22.40 ^{abc}	17.65
T ₃ - T ₁ + <i>Trichoderma harzianum</i>	22.00 ^{abcd}	19.12
T ₄ - T ₁ + <i>Trichoderma viride</i> - F48	18.40 ^{cdef}	32.35
T ₅ - T ₁ + <i>Trichoderma harzianum</i> - F14	17.20 ^{bcdef}	36.76
T ₆ - Non-solarization + <i>T. viride</i>	20.00 ^{bcd}	26.47
T ₇ - Non-solarization + <i>T. harzianum</i>	18.80 ^{bcdef}	30.88
T ₈ - Non-solarization + <i>Trichoderma viride</i> - F48	19.20 ^{bcdef}	29.41
T ₉ - Non-solarization + <i>Trichoderma harzianum</i> - F14	17.20 ^{bcdef}	36.76
T ₁₀ - T ₁ + spraying and drenching with Akomin-40 - 0.2 per cent	16.80 ^{cdef}	38.24
T ₁₁ - T ₁ + spraying and drenching with Ridomil MZ - 0.1 per cent	17.73 ^{bcdef}	34.82
T ₁₂ - T ₁ + spraying and drenching with Bordeaux mixture - 1 per cent	15.60 ^{def}	42.65
T ₁₃ - T ₁ + spraying and drenching with Fytolan - 0.2 per cent	16.67 ^{cdef}	38.71
T ₁₄ - T ₂ + spraying and drenching with Akomin-40 - 0.2 per cent	8.80 ^g	67.65
T ₁₅ - T ₂ + spraying and drenching with Ridomil MZ - 0.1 per cent	11.60 ^{ef}	57.36
T ₁₆ - T ₃ + spraying and drenching with Akomin-40 - 0.2 per cent	13.20 ^{ef}	51.47
T ₁₇ - T ₃ + spraying and drenching with Ridomil MZ - 0.1 per cent	15.33 ^{cdef}	43.64
T ₁₈ - T ₄ + spraying and drenching with Akomin-40 - 0.2 per cent	16.53 ^{cdef}	39.23
T ₁₉ - T ₄ + spraying and drenching with Ridomil MZ - 0.1 per cent	17.60 ^{bcdef}	35.29
T ₂₀ - T ₅ + spraying and drenching with Akomin-40 - 0.2 per cent	15.63 ^{def}	42.54
T ₂₁ - T ₅ + spraying and drenching with Ridomil MZ - 0.1 per cent	21.20 ^{abcde}	22.06
T ₂₂ - T ₆ + spraying and drenching with Akomin-40 - 0.2 per cent	16.53 ^{cdef}	39.23
T ₂₃ - T ₆ + spraying and drenching with Ridomil MZ - 0.1 per cent	15.33 ^{def}	43.64
T ₂₄ - T ₇ + spraying and drenching with Akomin-40 - 0.2 per cent	18.53 ^{bcdef}	31.88
T ₂₅ - T ₇ + spraying and drenching with Ridomil MZ - 0.1 per cent	22.67 ^{abc}	16.65
T ₂₆ - T ₈ + spraying and drenching with Akomin-40 - 0.2 per cent	21.20 ^{abcde}	22.06
T ₂₇ - T ₈ + spraying and drenching with Ridomil MZ - 0.1 per cent	20.00 ^{bcd}	26.47
T ₂₈ - T ₉ + spraying and drenching with Akomin-40 - 0.2 per cent	19.20 ^{bcdef}	29.41
T ₂₉ - T ₉ + spraying and drenching with Ridomil MZ - 0.1 per cent	20.00 ^{bcd}	26.47
T ₃₀ - Absolute control	27.20 ^{bcd}	-

In each column figures followed by same letter do not differ significantly according to DMRT

The effect of application of antagonists with solarized and non-solarized potting mixture on the incidence of *P. capsici* was compared and it was evident from the data that, there was not much variation in the disease incidence in this variety. The minimum disease incidence (17.2 per cent) was noticed in treatments T₅ and T₉ compared to 24 per cent disease recorded in solarized soil (T₁).

Application of different fungicides in plants raised in solarized potting mixture had less disease incidence compared to non-solarized treatment. Here, the minimum incidence of 15.60 per cent was observed in treatment T₁₂ (Solarization + Bordeaux mixture).

Similar to the results obtained during 2001, less incidence of the disease was recorded in treatments where biocontrol agents and fungicides were applied in plants raised in solarized potting mixture. The maximum incidence was noticed in T₂₅ (*T. harzianum* + Ridomil MZ) and minimum in T₁₄ followed by T₁₅ and T₁₆.

Pooled analysis of the data presented in Table 87 showed significant difference among treatments. The treatment T₁₄ showed the least disease incidence of 9.55 per cent and it was on par with T₁₅, T₁₆, T₂₀ and T₁₈. These were significantly superior to all other treatments. The maximum incidence was observed in control (T₃₀). The efficiency of various treatments over control in reducing the disease incidence ranged from 28.44 to 68.52 per cent.

Comparison of the data on the disease incidence of cuttings raised in solarized, non-solarized and antagonists incorporated treatments (T₁ to T₉) showed minimum disease incidence in T₄ and maximum in treatments T₆ and T₂.

Significant variation was not observed in the disease incidence in plants raised in solarized and fungicide treatments (T₁₀ to T₁₃). Here, the plants in treatment T₁₃ (Solarization + Fytolan) and T₁₂ (Solarization + Bordeaux mixture) recorded comparatively less disease incidence with more than 47.0 per cent efficiency over control.

Table 87. Pooled data on integrated management of *Phytophthora* rot in Panniyur-5 (2001-2002)

Treatments	Per cent disease incidence	Per cent efficiency of the treatment over control
T ₁ - Solarization of potting mixture for 30 days	18.67 ^{bcd}	38.46
T ₂ - T ₁ + <i>Trichoderma viride</i>	19.94 ^{bcd}	34.28
T ₃ - T ₁ + <i>Trichoderma harzianum</i>	17.27 ^{bcd}	43.06
T ₄ - T ₁ + <i>Trichoderma viride</i> - F48	16.00 ^{bcd}	47.26
T ₅ - T ₁ + <i>Trichoderma harzianum</i> - F14	17.78 ^{bcd}	41.40
T ₆ - Non-solarization + <i>T. viride</i>	19.95 ^{bcd}	34.25
T ₇ - Non-solarization + <i>T. harzianum</i>	19.55 ^{bcd}	35.56
T ₈ - Non-solarization + <i>Trichoderma viride</i> - F48	16.74 ^{bcd}	45.15
T ₉ - Non-solarization + <i>Trichoderma harzianum</i> - F14	16.33 ^{bcd}	46.18
T ₁₀ - T ₁ + spraying and drenching with Akomin-40 - 0.2 per cent	16.23 ^{bcd}	46.51
T ₁₁ - T ₁ + spraying and drenching with Ridomil MZ - 0.1 per cent	17.34 ^{bcd}	42.85
T ₁₂ - T ₁ + spraying and drenching with Bordeaux mixture - 1 per cent	15.93 ^{bcd}	47.50
T ₁₃ - T ₁ + spraying and drenching with Fytolan - 0.2 per cent	15.86 ^{bcd}	47.73
T ₁₄ - T ₂ + spraying and drenching with Akomin-40 - 0.2 per cent	9.55 ^e	68.52
T ₁₅ - T ₂ + spraying and drenching with Ridomil MZ - 0.1 per cent	12.20 ^{de}	59.79
T ₁₆ - T ₃ + spraying and drenching with Akomin-40 - 0.2 per cent	13.65 ^{de}	55.01
T ₁₇ - T ₃ + spraying and drenching with Ridomil MZ - 0.1 per cent	15.32 ^{bcd}	49.51
T ₁₈ - T ₄ + spraying and drenching with Akomin-40 - 0.2 per cent	14.36 ^{de}	52.67
T ₁₉ - T ₄ + spraying and drenching with Ridomil MZ - 0.1 per cent	16.94 ^{bcd}	44.17
T ₂₀ - T ₅ + spraying and drenching with Akomin-40 - 0.2 per cent	14.08 ^{de}	53.66
T ₂₁ - T ₅ + spraying and drenching with Ridomil MZ - 0.1 per cent	19.80 ^{bcd}	34.74
T ₂₂ - T ₆ + spraying and drenching with Akomin-40 - 0.2 per cent	15.53 ^{bcd}	48.81
T ₂₃ - T ₆ + spraying and drenching with Ridomil MZ - 0.1 per cent	18.07 ^{bcd}	40.44
T ₂₄ - T ₇ + spraying and drenching with Akomin-40 - 0.2 per cent	17.82 ^{bcd}	40.44
T ₂₅ - T ₇ + spraying and drenching with Ridomil MZ - 0.1 per cent	21.71 ^b	28.44
T ₂₆ - T ₈ + spraying and drenching with Akomin-40 - 0.2 per cent	19.01 ^{bcd}	37.34
T ₂₇ - T ₈ + spraying and drenching with Ridomil MZ - 0.1 per cent	20.93 ^{bc}	31.02
T ₂₈ - T ₉ + spraying and drenching with Akomin-40 - 0.2 per cent	16.58 ^{bcd}	45.35
T ₂₉ - T ₉ + spraying and drenching with Ridomil MZ - 0.1 per cent	18.00 ^{bcd}	40.67
T ₃₀ - Absolute control	30.34 ^a	-

In each column figures followed by same letter do not differ significantly according to DMRT

Disease incidence in cuttings raised in solarized soil incorporated with antagonists and fungicides was low compared to those in non-solarized treatments (T₂₂ to T₂₉). The minimum disease incidence was noticed in treatment T₁₄, with 68.52 per cent efficiency over control. More than 50.0 per cent efficiency in reducing the disease incidence was noticed with T₁₅, T₁₆, T₁₈ and T₂₀. The treatment T₂₅ was least efficient in checking the disease incidence.

4.10.3 IDM in Kalluvally-II

In Kalluvally-II, the disease incidence was less when compared with P₁ and P₅ during 2001 (Table 88). In this case also all treatments were significantly superior than control, with minimum disease incidence of 7.07 per cent in T₁₆ (Solarization + *T. harzianum* + Akomin-40) with 72.94 per cent efficiency over control. This was followed by T₁₄ (Solarization + *T. viride* + Akomin-40) with 71.95 per cent efficiency. The treatment T₃ (Solarization + *T. harzianum*) also recorded more than 60 per cent efficiency. The maximum incidence was in control.

Comparison of the percentage of disease incidence in solarized and non-solarized potting mixture supplemented with four biocontrol agents (T₁ to T₉) revealed that application of *T. harzianum* in solarized potting mixture (T₃) reduced the incidence of *Phytophthora* rot compared to all other treatments. In solarized potting mixture (T₁), the incidence was 11.60 per cent. Application of fungicides in cuttings grown in solarized soil also reduced disease incidence compared to control. The minimum and the maximum disease incidence were in treatments T₁₀ (Solarization + Akomin-40) and T₁₃ (Solarization + Fytolan) respectively.

It was evident from the result that application of biocontrol agents and fungicides in plants grown in solarized potting mixture had an effect in reducing disease incidence when compared with treatments T₂₂ to T₂₉, where non-solarized potting mixture was used. The solarized treatments T₁₆ and T₁₄ showed maximum efficiency of more than 70.00 per cent over control, while it was 53.04 per cent in T₂₂ (*T. viride* + Akomin-40).

Table 88. Integrated management of *Phytophthora* rot in Kalluvally-II (2001)

Treatments	Per cent disease incidence	Per cent efficiency of the treatment over control
T ₁ - Solarization of potting mixture for 30 days	11.60 ^{fghi}	55.61
T ₂ - T ₁ + <i>Trichoderma viride</i>	11.20 ^{fghi}	57.14
T ₃ - T ₁ + <i>Trichoderma harzianum</i>	10.27 ^{ghi}	60.70
T ₄ - T ₁ + <i>Trichoderma viride</i> - F48	13.33 ^{cdefgh}	48.99
T ₅ - T ₁ + <i>Trichoderma harzianum</i> - F14	16.40 ^{bdefg}	37.24
T ₆ - Non-solarization + <i>T. viride</i>	19.47 ^{bc}	25.49
T ₇ - Non-solarization + <i>T. harzianum</i>	18.13 ^{bcd}	30.62
T ₈ - Non-solarization + <i>Trichoderma viride</i> - F48	12.93 ^{defghi}	50.52
T ₉ - Non-solarization + <i>Trichoderma harzianum</i> - F14	15.20 ^{bdefg}	41.83
T ₁₀ - T ₁ + spraying and drenching with Akomin-40 - 0.2 per cent	12.53 ^{defghi}	52.05
T ₁₁ - T ₁ + spraying and drenching with Ridomil MZ - 0.1 per cent	16.13 ^{bdefg}	38.27
T ₁₂ - T ₁ + spraying and drenching with Bordeaux mixture - 1 per cent	13.73 ^{bdef}	47.46
T ₁₃ - T ₁ + spraying and drenching with Fytolan - 0.2 per cent	16.40 ^{bdefg}	37.24
T ₁₄ - T ₂ + spraying and drenching with Akomin-40 - 0.2 per cent	7.33 ^{hi}	71.95
T ₁₅ - T ₂ + spraying and drenching with Ridomil MZ - 0.1 per cent	13.60 ^{cdefg}	47.95
T ₁₆ - T ₃ + spraying and drenching with Akomin-40 - 0.2 per cent	7.07 ⁱ	72.94
T ₁₇ - T ₃ + spraying and drenching with Ridomil MZ - 0.1 per cent	14.80 ^{bdefg}	43.36
T ₁₈ - T ₄ + spraying and drenching with Akomin-40 - 0.2 per cent	11.33 ^{fghi}	56.37
T ₁₉ - T ₄ + spraying and drenching with Ridomil MZ - 0.1 per cent	16.27 ^{bdefg}	37.73
T ₂₀ - T ₅ + spraying and drenching with Akomin-40 - 0.2 per cent	11.20 ^{fghi}	57.14
T ₂₁ - T ₅ + spraying and drenching with Ridomil MZ - 0.1 per cent	16.4 ^{bcd}	37.24
T ₂₂ - T ₆ + spraying and drenching with Akomin-40 - 0.2 per cent	12.27 ^{efghi}	53.04
T ₂₃ - T ₆ + spraying and drenching with Ridomil MZ - 0.1 per cent	18.00 ^{bcd}	31.11
T ₂₄ - T ₇ + spraying and drenching with Akomin-40 - 0.2 per cent	16.13 ^{bdefg}	38.27
T ₂₅ - T ₇ + spraying and drenching with Ridomil MZ - 0.1 per cent	18.53 ^{bcd}	29.09
T ₂₆ - T ₈ + spraying and drenching with Akomin-40 - 0.2 per cent	16.67 ^{bcd}	36.20
T ₂₇ - T ₈ + spraying and drenching with Ridomil MZ - 0.1 per cent	20.67 ^b	20.90
T ₂₈ - T ₉ + spraying and drenching with Akomin-40 - 0.2 per cent	14.02 ^{bdefg}	46.35
T ₂₉ - T ₉ + spraying and drenching with Ridomil MZ - 0.1 per cent	15.33 ^{bdefg}	41.33
T ₃₀ - Absolute control	26.13 ^a	-

In each column figures followed by same letter do not differ significantly according to DMRT

Observations on IDM of *Phytophthora* rot in cultivar Kalluvally-II taken during 2002 also showed significant difference among the treatments (Table 89). The minimum incidence was in T₂₀ (Solarization + *T. harzianum* - F14 + Ridomil MZ) followed T₂₁ which was on par with 11 other treatments.

Observations on the disease incidence in T₁ to T₉ showed the minimum incidence of 15.60 per cent in T₅ (Solarization + *T. harzianum* - F14) and the maximum in T₈ (*T. viride* - F48). Here also disease incidence was more in plants raised in non-solarized, antagonist incorporated treatments.

The percentage of disease incidence in cuttings raised in solarized soil with fungicidal treatments ranged from 17.60 per cent in T₁₂ to 22.40 per cent in T₁₁.

In treatments T₁₄ to T₂₉, the incidence of *Phytophthora* rot was comparatively less in cuttings raised in solarized soil and supplemented with biocontrol agents and fungicides. The minimum incidence was in T₂₀ and T₂₁ (12.30 per cent) which showed an efficiency of 61.81 and 57.72 per cent respectively. The maximum incidence of 24.80 per cent was recorded in T₂₈ (*T. harzianum* - F14 + Ridomil MZ).

The perusal of the data on pooled analysis given in Table 90 indicated that all the treatments were significantly superior to control in reducing the disease incidence. The minimum disease incidence was noticed in treatment T₂₀ followed by T₁₆ and T₁₄. All these treatments recorded more than 58 per cent efficiency over control.

Plants in solarized potting mixture (T₁) showed only 15.00 per cent disease incidence followed by plants in treatment T₄. Among the solarized and non-solarized treatments incorporated with biocontrol agents, the maximum incidence was in treatment T₃.

Comparison of the data on the disease incidence of plants in treatments, where fungicides were incorporated in solarized soil revealed that treatment T₁₀

Table 89. Integrated management of *Phytophthora* rot in Kalluvally- II (2002)

Treatments	Per cent disease incidence	Per cent efficiency of the treatment over control
T ₁ - Solarization of potting mixture for 30 days	18.40 ^{cdefgh}	37.27
T ₂ - T ₁ + <i>Trichoderma viride</i>	21.07 ^{bdefg}	28.16
T ₃ - T ₁ + <i>Trichoderma harzianum</i>	17.60 ^{defgh}	39.99
T ₄ - T ₁ + <i>Trichoderma viride</i> - F48	17.20 ^{efgh}	41.35
T ₅ - T ₁ + <i>Trichoderma harzianum</i> - F14	15.60 ^{ghi}	46.81
T ₆ - Non-solarization + <i>T. viride</i>	16.00 ^{fghi}	45.44
T ₇ - Non-solarization + <i>T. harzianum</i>	18.80 ^{bdefg}	35.90
T ₈ - Non-solarization + <i>Trichoderma viride</i> - F48	21.20 ^{bdefg}	27.71
T ₉ - Non-solarization + <i>Trichoderma harzianum</i> - F14	20.00 ^{bdefg}	31.81
T ₁₀ - T ₁ + spraying and drenching with Akomin-40 - 0.2 per cent	18.40 ^{cdefgh}	37.27
T ₁₁ - T ₁ + spraying and drenching with Ridomil MZ - 0.1 per cent	22.40 ^{bcd}	23.63
T ₁₂ - T ₁ + spraying and drenching with Bordeaux mixture - 1 per cent	17.60 ^{cdefgh}	39.99
T ₁₃ - T ₁ + spraying and drenching with Fytolan - 0.2 per cent	22.00 ^{bcd}	24.99
T ₁₄ - T ₂ + spraying and drenching with Akomin-40 - 0.2 per cent	15.60 ^{ghi}	46.81
T ₁₅ - T ₂ + spraying and drenching with Ridomil MZ - 0.1 per cent	16.53 ^{efghi}	43.64
T ₁₆ - T ₃ + spraying and drenching with Akomin-40 - 0.2 per cent	15.60 ^{ghi}	46.81
T ₁₇ - T ₃ + spraying and drenching with Ridomil MZ - 0.1 per cent	17.20 ^{defgh}	41.36
T ₁₈ - T ₄ + spraying and drenching with Akomin-40 - 0.2 per cent	19.21 ^{bdefg}	34.51
T ₁₉ - T ₄ + spraying and drenching with Ridomil MZ - 0.1 per cent	16.67 ^{efghi}	43.16
T ₂₀ - T ₅ + spraying and drenching with Akomin-40 - 0.2 per cent	11.20 ⁱ	61.81
T ₂₁ - T ₅ + spraying and drenching with Ridomil MZ - 0.1 per cent	12.40 ^{hi}	57.72
T ₂₂ - T ₆ + spraying and drenching with Akomin-40 - 0.2 per cent	24.20 ^{abc}	17.49
T ₂₃ - T ₆ + spraying and drenching with Ridomil MZ - 0.1 per cent	21.06 ^{bdefg}	28.20
T ₂₄ - T ₇ + spraying and drenching with Akomin-40 - 0.2 per cent	22.26 ^{bcd}	24.11
T ₂₅ - T ₇ + spraying and drenching with Ridomil MZ - 0.1 per cent	23.60 ^{bcd}	19.54
T ₂₆ - T ₈ + spraying and drenching with Akomin-40 - 0.2 per cent	19.20 ^{bdefg}	34.54
T ₂₇ - T ₈ + spraying and drenching with Ridomil MZ - 0.1 per cent	21.47 ^{bdefg}	26.80
T ₂₈ - T ₉ + spraying and drenching with Akomin-40 - 0.2 per cent	24.80 ^{ab}	15.45
T ₂₉ - T ₉ + spraying and drenching with Ridomil MZ - 0.1 per cent	23.60 ^{bcd}	19.54
T ₃₀ - Absolute control	29.33 ^a	-

In each column figures followed by same letter do not differ significantly according to DMRT

Table 90. Pooled data on integrated management of *Phytophthora* rot in Kalluvally-II (2001-2002)

Treatments	Per cent disease incidence	Per cent efficiency of the treatment over control
T ₁ - Solarization of potting mixture for 30 days	15.00 ^{defgh}	45.91
T ₂ - T ₁ + <i>Trichoderma viride</i>	16.14 ^{bcddefgh}	41.80
T ₃ - T ₁ + <i>Trichoderma harzianum</i>	18.94 ^{fgh}	31.70
T ₄ - T ₁ + <i>Trichoderma viride</i> - F48	15.27 ^{defgh}	44.93
T ₅ - T ₁ + <i>Trichoderma harzianum</i> - F14	16.01 ^{bcddefgh}	42.26
T ₆ - Non-solarization + <i>T. viride</i>	17.74 ^{bcddef}	36.03
T ₇ - Non-solarization + <i>T. harzianum</i>	18.48 ^{bcddef}	33.36
T ₈ - Non-solarization + <i>Trichoderma viride</i> - F48	17.07 ^{bcddef}	38.44
T ₉ - Non-solarization + <i>Trichoderma harzianum</i> - F14	17.600 ^{bcddef}	36.53
T ₁₀ - T ₁ + spraying and drenching with Akomin-40 - 0.2 per cent	14.47 ^{cdefgh}	44.21
T ₁₁ - T ₁ + spraying and drenching with Ridomil MZ - 0.1 per cent	19.25 ^{bcd}	30.58
T ₁₂ - T ₁ + spraying and drenching with Bordeaux mixture - 1 per cent	15.67 ^{cdefgh}	43.49
T ₁₃ - T ₁ + spraying and drenching with Fytolan - 0.2 per cent	19.23 ^{bcddef}	30.65
T ₁₄ - T ₂ + spraying and drenching with Akomin-40 - 0.2 per cent	11.47 ^{gh}	58.64
T ₁₅ - T ₂ + spraying and drenching with Ridomil MZ - 0.1 per cent	15.07 ^{cdefg}	45.65
T ₁₆ - T ₃ + spraying and drenching with Akomin-40 - 0.2 per cent	11.34 ^{gh}	59.11
T ₁₇ - T ₃ + spraying and drenching with Ridomil MZ - 0.1 per cent	16.20 ^{bcddefgh}	41.58
T ₁₈ - T ₄ + spraying and drenching with Akomin-40 - 0.2 per cent	15.27 ^{defgh}	44.93
T ₁₉ - T ₄ + spraying and drenching with Ridomil MZ - 0.1 per cent	16.47 ^{bcddefg}	40.61
T ₂₀ - T ₅ + spraying and drenching with Akomin-40 - 0.2 per cent	11.15 ^h	59.79
T ₂₁ - T ₅ + spraying and drenching with Ridomil MZ - 0.1 per cent	14.48 ^{efgh}	47.78
T ₂₂ - T ₆ + spraying and drenching with Akomin-40 - 0.2 per cent	18.24 ^{bcddef}	34.22
T ₂₃ - T ₆ + spraying and drenching with Ridomil MZ - 0.1 per cent	19.53 ^{bcd}	29.57
T ₂₄ - T ₇ + spraying and drenching with Akomin-40 - 0.2 per cent	19.18 ^{bcddef}	30.83
T ₂₅ - T ₇ + spraying and drenching with Ridomil MZ - 0.1 per cent	21.09 ^b	23.95
T ₂₆ - T ₈ + spraying and drenching with Akomin-40 - 0.2 per cent	17.92 ^{bcddef}	35.38
T ₂₇ - T ₈ + spraying and drenching with Ridomil MZ - 0.1 per cent	21.06 ^{bc}	24.09
T ₂₈ - T ₉ + spraying and drenching with Akomin-40 - 0.2 per cent	19.41 ^{bcd}	30.00
T ₂₉ - T ₉ + spraying and drenching with Ridomil MZ - 0.1 per cent	19.43 ^{bcd}	29.93
T ₃₀ - Absolute control	27.73 ^a	-

In each column figures followed by same letter do not differ significantly according to DMRT

(Solarization + Akomin 40) and T_{12} (Solarization + Bordeaux mixture) were more efficient than the other two.

The treatment T_{20} showed the minimum disease incidence and maximum efficiency of disease control followed by treatments T_{16} and T_{14} .

Discussion

5. DISCUSSION

Nursery diseases act as the major constraint in the production of quality rooted cuttings of black pepper. Among them, *Phytophthora* rot is the most serious one. Further, the conditions provided in the nursery for better growth and establishment of cuttings are ideal for the development of nursery diseases. Another alarming factor is that, if cuttings from infected nurseries are planted in the main field the diseases are also carried to the field resulting in their wide spread occurrence. Thus, it is imperative to take steps for managing the diseases in the nursery itself. Though, integrated management practices are available for managing *Phytophthora* rot in nurseries, in certain situations especially during heavy monsoon periods, the expected level of management is not always achieved. Hence, in view of the serious nature of nursery diseases and the potential threat they possess in the main field, the present study was undertaken to find out the occurrence of various nursery diseases in four northern districts of Kerala and to evolve an integrated disease management strategy against *Phytophthora* rot.

5.1 SURVEY ON THE OCCURRENCE OF NURSERY DISEASES

To find out the occurrence of diseases in black pepper nursery, a detailed survey was conducted in 30 nurseries raised at different locations of Kasargode, Kannur, Kozhikode and Wynad districts of Kerala for four nursery seasons of 1998-2001. During the survey, occurrence of *Phytophthora* rot, *Colletotrichum* rot, *Rhizoctonia* rot and *Sclerotium* rot were observed. The occurrence of *Phytophthora* rot due to *P. capsici* (Sarma *et al.*, 1994 and Anandaraj, 2000), *Colletotrichum* rot due to *Colletotrichum gloeosporioides* (Mammooty and Pillai, 1981), *Rhizoctonia* rot due to *Rhizoctonia solani* (Mammooty *et al.*, 1980 and Sarma *et al.*, 1987) and *Sclerotium* rot due to *Sclerotium rolfsii* (Chowdhury, 1943 and Brahma *et al.*, 1980) were reported earlier. Though, Albuquerque and Duarte (1979) and Mammooty and Pillai (1981) reported *Pythium* rot in black pepper nursery, the incidence of this disease was not observed during the survey.

Ten isolates of each causal organism associated with nursery diseases were brought into pure culture and their pathogenicity established. They were identified based on their cultural and morphological characters.

For identifying the isolates of the pathogen causing *Phytophthora* rot, the sporangial characters like sporangial ontogeny, size, shape, L/B ratio and pedicel length were studied in addition to their cultural characters. The isolates produced uniformly dense cotton wool like aerial mycelium in carrot agar. The mycelium was hyaline, non-septate and smooth. Sporangia papillate, caducous, long stalked, ovoid to pyriform and were produced in umbellate fashion. Length of sporangia varied from 20.30 to 92.30 μm and breadth from 19.60 to 52.20 μm with the L/B ratio of 1.05 to 2.95. The pedicel length varied from 15.8 to 10.4 μm . These characters are in confirmity with those reported by many workers for *P. capsici* (Sarma *et al.*, 1980; Alizadeh, 1983; Sastry and Hegde, 1987 and Tsao and Alizadeh, 1988). Hence, based on above characters and the typical symptoms they produced in black pepper, the isolates were identified as *Phytophthora capsici* Leonian emend A. Alizadeh and P.H. Tsao (Tsao, 1991).

Isolates of *Colletotrichum* sp. produced light to dark grey colonies with pinkish spore mass. The mycelium was septate with a width ranging from 1.25 to 4.00 μm . The length and breadth of conidia of isolates ranged from 13.45 to 16.45 μm and 3.86 to 5.36 μm respectively. These characters are in agreement with that reported for *C. gloeosporioides* (Prasad and Verma, 1966; Mordue, 1971; Santhakumari, 1980 and Varma, 1991). Based on the above characters and pathogenicity the isolates were identified as *Colletotrichum gloeosporioides* (Penz.) Penz. Sacc.

Isolates of *Rhizoctonia* rot pathogen produced mycelia which were colourless in the initial stages and turned dark brown at maturity. Mycelia septate, and measured 5.80 to 11.30 μm in width. The different isolates produced globose to irregular sclerotia of varied size and all isolates produced typical symptoms on pepper plants. Eventhough the occurrence of *Rhizoctonia* rot in black pepper was reported by

Mammootty *et al.* (1980) and Sarma *et al.* (1987), the details of the morphological characters of the pathogen were lacking. However, cultural and morphological characters observed in the present study were almost in conformity with that reported for *R. solani* in other crops (Vijayan, 1986; Singh *et al.*, 2002 and Sunder *et al.*, 2003). Based on these characters and the typical symptoms produced, the isolates were identified as *Rhizoctonia solani* Kuhn.

Isolates of *Sclerotium* sp. had septate mycelia with a width ranging from 1.80 to 3.90 μ m. They produced irregular to round sclerotia of 1.20 to 1.87 mm in size and all of them produced typical symptoms on artificial inoculation. No information was available on the morphological characters of the pathogen causing *Sclerotium* rot in black pepper. However, characters observed in the present study were in agreement with *S. rolfsii*, affecting other crops (Ou, 1972; Radwan *et al.*, 1987 and Ansari and Agnihotri, 2000). Hence isolates of the pathogen were identified as *Sclerotium rolfsii* Sacc.

Symptomatology of the nursery diseases observed during the survey was studied both under natural and artificial conditions in order to have a clear understanding of the diseases. Symptoms of *Phytophthora* rot manifested on leaves, stem and roots. On leaves, infection started as water soaked lesions which later enlarged and became dark brown to black in colour with smooth or fimbriate margins. Concentric zonations were occasionally observed on infected portion. Severe infection resulted in defoliation. On stem, linear dark brown to black lesions appeared near the collar region as well as at any point of the stem which later enlarged resulting in wilting of the cuttings. On the roots, the initial symptom was the development of discolouration on fine roots. Later the lesions spread to main roots resulting in yellowing, defoliation and wilting of the cuttings. On artificial inoculation the pathogens produced similar symptoms as that observed under natural conditions. The symptoms noticed during the study were almost similar to that observed by earlier workers (Mammootty, 1978; Nambiar and Sarma, 1982; Sarma and Anandaraj, 1996 and Anandaraj, 2000). Further, inoculation of isolates of *P. capsici* did not show any variation in symptoms indicating that they did not differ much in their virulence.

C. gloeosporioides mainly infected leaves of pepper cuttings and rarely on stem. The symptoms developed as small dark brown, circular to irregular lesions with yellow halo. Later, the lesion became grey to papery white and slightly depressed. Severe infection leads to defoliation. Same types of symptoms were noticed upon artificial inoculation. The symptoms noticed were similar to those reported by Menon (1949), Sebastian (1982) and Anandaraj and Sarma (1995). They further stated that the symptom expression vary with climatic conditions.

Symptoms of *R. solani* infection were noticed on leaves and collar region. On leaves, the disease appeared as small brownish lesion which later turned to light to dark brown patches. In advanced stages, the infected portions were brittle and grey in colour. When nearby leaves got infected, such leaves were seen webbed together and remained as such for long time. Collar infection started as small linear dark brown lesion which later spread both upwards and downwards. Oozing of reddish brown liquid, cracking and splitting of infected portion were also seen. Severe infection resulted in drooping and drying up of leaves and later the plants succumbed to infection. Menon (1949) and Sarma *et al.* (1987 and 1991) reported similar type of symptoms in black pepper due to *R. solani*. Artificial inoculation of isolates of the pathogen also produced the same symptoms. Mammooty *et al.* (1980) reported that roots of such infected cuttings remained apparently healthy in majority of the cases. However, disintegration and rotting of root system were noticed in the present study.

Like *R. solani*, *S. rolfsii* also infected leaves and stem, especially the collar region. Infection both on leaves and stem initiated as water soaked lesion which later turned grey. Invariably whitish fungal growth was found on the infected portion. Severe infection on leaves resulted in defoliation. Collar region gradually turned dark brown and infection further spread both upwards and downwards and finally resulted in drooping of leaves and wilting of cuttings. Gummy exudates and sclerotia of the fungus were noticed on the infected portion. Further, no variation in the symptom expression was noticed upon inoculation of different isolates of *S. rolfsii*. Almost similar symptoms were reported by Brahma *et al.* (1980); Sarma *et al.* (1987) and Anandaraj (2000). Sarma *et al.* (1987) noticed concentric zonations on the infected

portions of pepper leaves by *S. rolfii*. However, such concentric zonations were not observed in the present study. Further, Brahma *et al.* (1980) reported that *S. rolfii* infected pepper succumb to infection within a short period of two to three days. But in the present study, death of cutting took place one to two weeks after artificial inoculation probably due to the climatic conditions and virulence of the pathogen.

A perusal of the literature revealed that about 17 diseases infect black pepper (Sarma *et al.*, 1991). As the crop is propagated mainly through cuttings raised in nurseries there is every possibility that some of the diseases prevalent in main field may get carried to the nurseries and *vice versa*. Hence, during the survey the percentage incidence of various diseases in 30 nurseries of northern Kerala was worked out. During the survey, an attempt was also made to assess the effect of various nursery practices adopted for raising pepper nursery on the incidence of different diseases.

Occurrence of only four diseases was noticed during the survey. Among them the most wide spread one was *Phytophthora* rot. It occurred in 29 out of 30 nurseries surveyed with varying intensities. The one which was free from this disease was the nursery of Regional Agricultural Research Station (RARS), Ambalavayal. This was raised in a permanent structure with HDPE sheet roofing which prevented rain water falling directly on young pepper vines. The survey also revealed that incidence of the disease varied with seasons and locations. The maximum incidence of the disease was in Neerchal and Thirumeni areas of Wynad and Kannur districts respectively. Thus, the study again confirmed the reports of previous workers that *Phytophthora* rot is the main constraint in the production of quality black pepper cuttings (Mammooty *et al.*, 1980 and Anandaraj *et al.*, 1986).

P. capsici, the incitant of *Phytophthora* rot in nursery is known for its ability to survive for longer periods, if contaminated soil and planting material are used for raising nursery, the pathogen flourishes well under conducive humid conditions prevailing in the nursery. These coupled with presence of large number of succulent host plants may be the reason for the large scale incidence of the disease.

Further, the local climatic conditions or the nursery practices adopted in various locations in different seasons might have contributed for the variations in disease incidence. It is to be noted that there was no incidence of diseases in nursery under protected conditions at RARS, Ambalavayal of Wynad district, while the maximum incidence was noticed in nursery under ordinary nursery structure at Neerchal of the same district, where almost same climatic conditions prevail.

Observations recorded on the incidence of diseases caused by *C. gloeosporioides*, *R. solani* and *S. rolfsii* revealed variations with respect to the locations and seasons. However, no incidence of these disease was noticed at RARS, Ambalavayal and in two nurseries of Kozhikode district. *Rhizoctonia* rot was not observed in any of the nurseries in Wynad district. The occurrence of these diseases in pepper nurseries were reported by many workers (Sarma *et al.*, 1987 and Mammootty *et al.*, 1992).

Incidences of *Colletotrichum* rot and *Rhizoctonia* rot were the highest during 1998, while that of *P. capsici* and *S. rolfsii* was more during 2000. The minimum incidence of *Phytophthora* rot, *Colletotrichum* rot and *Rhizoctonia* rot was during 2001. Further, from the data for four seasons it is evident that out of 30 nurseries surveyed, *Phytophthora* rot, *Colletotrichum* rot, *Rhizoctonia* rot and *Sclerotium* rot were not recorded in first, thirteenth, eleventh and eighth nurseries respectively. The agro-climatic factors prevalent in different locations during the seasons might have influenced the variations on the occurrence of diseases. The absence of diseases at RARS, Ambalavayal may be due to the effect of nursery structure with HDPE roofing and concrete flooring which prevented the water stagnation and continuous wetting of plants due to rain.

5.2 EFFECT OF NURSERY PRACTICES ON DISEASE INCIDENCE

The data collected during the survey were further analysed to find out the effect of different nursery practices on the incidence of nursery diseases. A perusal of literature revealed that not much effort has been made to elucidate the role of nursery practices on disease incidence.

As pepper nurseries are raised during summer months, it has to be protected from direct sunlight. For this adequate shade has to be provided. Apart from this, shaded condition also enhances sprouting and further development of cuttings. Incidentally, the warm humid conditions prevailing under shade are also congenial for fungal infection (Sarma *et al.*, 1987). It was observed that four types of nursery structures were used for raising nurseries. These include ordinary pandal thatched with coconut leaves, synthetic shade net and HDPE sheet, the latter was noticed at RARS, Ambalavayal only. A few nurseries were raised under shade trees during 2000 and 2001 seasons. It was noticed that the disease incidence varied depending upon the shade structures. None of the plants raised under HDPE sheet showed any diseases due to the obvious reasons mentioned earlier.

From the pooled data it was evident that incidence of *Phytophthora* rot was more in nurseries raised under shade trees and ordinary pandal compared to shade net. However, the incidence of other diseases was not recorded in cuttings raised under shade trees. High incidence of *Phytophthora* rot under shade trees might be due to improper shade resulting in the poor development of cuttings and also due to excessive wetting of plants due to raindrops falling from the trees causing local injury. Ordinary pandal with thatched coconut leaves provide high humidity. Further, intensity of shade under thatched nursery varied from nursery to nursery. In many nurseries even all the sides were covered by thatched leaves, restricting the movement of air and light, creating favourable conditions for the development of *Phytophthora* rot. Mammooty *et al.* (1992) and KAU (2001) suggested that nursery diseases of black pepper could be controlled by regulating shade. Further, it was also pointed out that management of light intensity had a positive effect on growth characters of the plant. Comparatively less incidence of *Phytophthora* rot was noticed in plants grown under shade net, as shade net provided uniform light infiltration, air circulation and thereby prevent continuous wetting of plants. This indicates the necessity for selection of shade structure for management of nursery diseases of black pepper.

Quality of potting mixture is an important prerequisite for obtaining good planting materials. During the survey, it was noticed that four types of potting

mixtures were used in nurseries with varying ratios of its ingredients. It was also revealed that type of potting mixture used for raising cuttings had an effect on the incidence of diseases.

From the data for four years, it was evident that the incidence of *Phytophthora* rot was comparatively less in cuttings grown in potting mixture of 1:1:1 ratio of sand, soil and cowdung. The maximum incidence was in those raised in 1:3:1 potting mixture. According to Nambiar and Sarma (1982), water stagnation is the single most important factor as far as *Phytophthora* diseases are concerned as water stagnation increases the activity of the pathogen. Potting mixture with equal quantities of sand, soil and cowdung will be sufficiently porous ensuring better drainage and aeration which enhanced growth of plants and minimise disease incidence (Richards, 1964; Yufdy and Hayani, 1991). Disease incidence was higher in potting mixture with more quantity of soil due to lack of proper drainage and aeration which is conducive for disease development. It was reported that a reduction in the quantity of sand in the potting mixture favour water stagnation and more incidence of various diseases in black pepper nursery (Nambiar *et al.*, 1978).

Collection of disease free planting material is one of the main criteria for raising quality nursery plants. Pepper nurseries are usually raised during the month of February to May depending on local conditions. During this unfavourable period, the incidence of diseases cannot easily be detected. If utmost care is not taken, there are chances of collection of apparently healthy runner vines with fungal infection. During the survey, it was noticed that runner vines were mainly collected from government and private farms. Hence the role of place of collection of planting material on the incidence of nursery diseases was studied. It was found that disease incidence was more in vines collected from private farms where proper management of diseases or adequate precautions for maintenance of runner vines were not scientifically followed. This emphasizes the need for proper maintenance and selection of propagating material (runner vines) to prevent the incidence of diseases. The necessity of using disease free planting material in preventing the entry of pathogens in nurseries and main fields was emphasized by Sarma *et al.* (1991) and Mammooty *et al.* (1992).

The survey revealed that cuttings of Panniyur-1 and Karimunda were used in majority of the pepper nurseries in addition to Panniyur-2, 3, 4 and 5 on small scale basis. The mean data for four years showed the highest incidence of *Phytophthora* rot in Karimunda, followed by Panniyur-1 and the least in other genotypes. While, there was not much variations on the incidence of other diseases.

So far, any high degree of resistance in pepper genotypes against *P. capsici* was not reported. However, there are reports on the variation in the extent of severity caused by *P. capsici* among the cultivars (Radhakrishnan and Mammooty, 1993). Though, Panniyur-1 and Karimunda are high yielding and widely acceptable, these are highly susceptible to *P. capsici*. If they are widely used for large scale planting, there is every chance of severe incidence of the disease under favourable conditions. Hence, the cultivation of mixture of high yielding pepper genotypes as suggested by Sarma and Anandaraj (1992) and Sadanandan (2000), may be resorted to in order to avoid complete wipe out of the plantations. Hence, efforts have to be taken to raise nurseries in this line. A positive indication to this is evident from the fact that there was less incidence of the disease in nurseries raised with mixture of genotypes.

Effect of processing of runner vine on incidence of nursery disease was studied. Mainly four methods of processing of runner vines were adopted by different agencies. Not much variations on disease incidence were observed with the different methods of processing of runner vines. In general, the incidence was comparatively more when vines were allowed to creep in the soil followed by coiling and creeping method. Minimum incidence was noticed in cuttings taken from runner vines from coiling + Rapid Multiplication Technique. High incidence of diseases in cuttings collected from creeping vines may be due to the possibility of tender runner shoots coming in contact with infected soil. Sarma *et al.* (1991) reported that in *Phytophthora* foot rot of black pepper, the runner shoots were first infected and then spreads to other parts of the vine. Coiling of runner vines has prevented the contact of vines with contaminated soil. The cuttings raised by RMT method were robust with profuse root system and less prone to diseases (Anandaraj *et al.*, 1991 and Ramachandran *et al.*, 1991).

As many of the diseases in pepper nurseries are caused by soil-borne pathogens, it is always advantageous to disinfect the potting mixture before planting of cuttings. During the survey, it was observed that the potting mixtures were subjected to solarization, chemical treatments and traditional way of disinfection by burning of soil with dry leaves. Significant effect of pre-planting treatments of potting mixture on the incidence of nursery disease was noticed. This is especially true in the case of *Phytophthora* rot. Disinfection of potting mixture with chemicals had a good effect in reducing the incidence of all the diseases except *Rhizoctonia* rot. Solarization also reduced incidence of *P. capsici*. Hence, disinfection of potting mixture with chemicals or by solarization can be adopted as a regular nursery practice for reducing the incidence of diseases. Usefulness of disinfection of potting mixture by chemicals or by solarization in checking *Phytophthora* rot in black pepper nursery was reported (KAU, 1996b; Malebennur *et al.*, 1991; Sarma *et al.*, 1994; Anandaraj and Sarma, 1995 and Binimol, 2000).

The susceptibility/resistance of plants is influenced to a great extent by the age of cuttings. Survey revealed that pepper nurseries were raised generally from February to May. The study on the effect of time of planting on disease incidence indicated comparatively less incidence of *Phytophthora* rot in cuttings planted at different intervals in February to March. When time of planting got delayed, disease incidence was more. Almost similar trend was noticed with the other diseases also. In Kerala, February/March was recommended as ideal time of planting of cuttings in nursery (KAU, 2001). The vigorous growth of cuttings planted during February - March might have made the cuttings less susceptible to the disease.

Since, pepper nurseries are raised during the summer periods regular irrigation is essential. Scheduling of the frequency of irrigation in different nurseries surveyed were found to vary. Frequency of irrigation had a significant effect on the incidence of nursery diseases. The maximum incidence of diseases was in nurseries which were irrigated twice a day. Though, irrigation help in proper growth and establishment of the crop, excessive irrigation may lead to water stagnation and high humidity in the nurseries which may create congenial condition for the development

of the diseases especially the *Phytophthora* rot. Role of excess water on *Phytophthora* rot incidence was reported by Ramachandran *et al.* (1991) and Satheeshan *et al.* (1997).

It was observed during the survey that for controlling nursery diseases, fungicides were used in different nurseries and the scheduling of fungicidal application varied from season to season. But in certain nurseries, fungicidal application was not even resorted. From the present study, it was evident that timely application of Bordeaux mixture twice or thrice and spraying of Akomin once had an effect in checking the incidence of *Phytophthora* rot. The importance of prophylatic application of Bordeaux mixture in controlling *Phytophthora* rot was reported by Sasikumaran *et al.* (1981) and Ramachandran *et al.* (1991). Thus, proper scheduling of fungicidal treatment has to be resorted to contain the incidence of this disease. But the other three diseases were not observed when spraying of Bordeaux mixture and drenching of copper oxychloride once in a season were resorted. So the study revealed that inclusion of a systemic fungicide like Akomin along with Bordeaux mixture is effective in managing *Phytophthora* rot disease. The study also indicated the necessity for timely adoption of chemical control measures in reducing the incidence of nursery diseases.

Thus, the study on the effect of various nursery practices on disease incidence indicated the necessity for revamping the present practices by utilizing the appropriate methods of nursery practices which had a positive effect in reducing the diseases especially the most dreadful *Phytophthora* rot of black pepper nursery.

5.3 SCREENING OF BLACK PEPPER VARIETIES/CULTIVARS AGAINST NURSERY DISEASES

Identification and utilization of host resistance is one of the most effective and practical ways of reducing the losses due to plant diseases. As some of the nursery diseases of black pepper like *Phytophthora* rot being difficult to control during favourable conditions of disease development, it is imperative to have a search for source of resistance among available genetic resources. With this view an attempt was

made to screen 50 genotypes of black pepper including varieties released from Kerala Agricultural University (KAU) and Indian Institute of Spices Research (IISR), against nursery diseases caused by *P. capsici*, *C. gloeosporioides*, *R. solani* and *S. rolfsii*.

Screening of genotypes against *P. capsici* was done using the standard leaf and root inoculation methods. The study revealed that none of the genotypes screened were immune to *P. capsici*. However, they showed varying percentages of leaf infection and mortality. It was observed that the cultivar Kalluvally-II, Panniyur-5 and Kalluvally-IV showed less than 60 per cent leaf infection but they were on par with Balankotta, Cheriyanakadan and Shimoga. The minimum percentage of mortality was with Kalluvally-II, but it was on par with six other genotypes including Kalluvally-IV and Panniyur-5. Eventhough, Kalluvally-II, Panniyur-5 and Kalluvally-IV showed almost same intensity of leaf infection (54.0 to 56.0 per cent), the genotype Kalluvally-II had the least percentage of mortality (26.67 per cent) followed by Panniyur-5 (31.30 per cent). Hence, it can be presumed that the genotype Kalluvally-II possessed some degree of tolerance against *P. capsici* while Panniyur-5 exhibited moderately susceptible reaction. Rest of the cultivars was susceptible as they showed higher leaf infection and mortality.

Among the varieties released from KAU and IISR, Panniyur-5 had the minimum of leaf infection and mortality. A perusal of the literature revealed that attempts were made by many workers to screen pepper genotypes against *Phytophthora* rot and reported that none of the genotypes exhibited absolute resistance. It was reported that some of the genotypes like Kalluvally, Balankotta, Narayakodi, Uthirankotta, Cheriyanakadan, Neelamundi and Cholamundi exhibited tolerant reaction against the disease (Turner, 1971; Nambiar and Sarma, 1977; Sitepu and Kasim, 1991; Kueh and Sim, 1991; Shylaja *et al.*, 1996; Sarma *et al.*, 1997). But this was disputed by some other workers (Vilasini, 1982; Dutta, 1984 and Rajagopal *et al.*, 1998).

The tolerant reaction noticed in Kalluvally-II may be due to its anatomical and biochemical configuration. Dagde (1999) noticed difference in the anatomical and

biochemical aspects of tolerant Kalluvally and susceptible Panniyur-1. Ravindran *et al.* (2000) considered Panniyur-5 as tolerant to nursery diseases. But in the present study it exhibited moderately susceptible reaction. Eventhough no source of absolute resistance against *P. capsici* was noticed, the tolerant/moderately susceptible genotypes identified during the study can be utilized for evolving resistant/tolerant ones.

Screening of pepper genotypes against *C. gloeosporioides* revealed that all the cultivars except Vellanamban-II showed varying percentage of disease incidence. Among the cultivars which took up infection Kalluvally-II had the minimum incidence followed by Panniyur-5 and Shimoga. Among the varieties released from KAU and IISR, the minimum incidence was in Panniyur-5 and maximum in Pournami. There are no reports on the reaction of pepper genotypes against *C. gloeosporioides* from India. However, Kueh *et al.* (1981) and Rodrigues *et al.* (1987) recorded variation in the reaction of pepper cultivars to *C. gloeosporioides*. The genotypes Vellanamban-II which did not take up infection may be subjected to further screening using different isolates of the pathogen under different agro-climatic conditions to confirm whether it possesses immunity against the disease.

The reaction of black pepper genotypes against *R. solani* was assessed by inoculating on the leaves and collar region. The study indicated that the genotypes reacted differently to *R. solani*. The least foliar infection was observed with Panniyur-2 followed by Kalluvally-II and Perumkodi, while the minimum mortality was noticed in Kalluvally-II and Balankotta. Other genotypes recorded comparatively higher percentage of disease incidence. Though, there was comparatively less leaf infection of Panniyur-2 and Kalluvally-II, the latter showed lesser mortality than the former indicating tolerance of Kalluvally-II against *R. solani*. The varieties released from KAU and IISR did not show any appreciable level of resistance/tolerance against *R. solani*. There is no information on the reaction of black pepper genotypes against *R. solani*. But the resistance/tolerance reaction of other crop plants against *R. solani* has been elucidated by many workers (Allen, 1997; Reddy, 2000 and Vidyashekaran *et al.*, 2000).

Screening of pepper genotypes against *S. rolfii* revealed significant difference among them. Here also the minimum leaf infection was noticed in Panniyur-2 followed by Kalluvally-II and Kalluvally-IV. The minimum mortality was in Balankotta closely followed by Kalluvally-II and Panniyur-5. Eventhough, Balankotta showed minimum per cent mortality, it showed more than 80 per cent leaf infection. However, Kalluvally-II showed minimum leaf infection and mortality revealing its tolerance to *S. rolfii*. Among the released varieties, Panniyur-2 and Panniyur-5 showed less leaf infection and mortality respectively. The reaction of pepper genotypes against *S. rolfii* has not been reported so far. However, some reports on other crops indicated that they reacted differently to infection by *S. rolfii* (Rao *et al.*, 1995; Gorbet and Shokes, 1997 and Ambedkar *et al.*, 2003).

The screening of 50 genotypes of black pepper against *P. capsici*, *C. gloeosporioides*, *R. solani* and *S. rolfii* revealed that the genotypes reacted differently with the pathogen. The genotype Kalluvally-II exhibited tolerance and Panniyur-5 showed moderately susceptible reactions.

5.4 BIOCHEMICAL ANALYSIS

Screening of black pepper genotypes against nursery diseases revealed that the genotypes reacted differently to the pathogen, showing tolerant, moderately susceptible and susceptible reactions. This type of variation in reaction towards the pathogen is determined mainly by biochemical constituents of the plant. Hence, an attempt was made to elucidate the biochemical factors which impart tolerance/susceptibility in pepper genotypes. For this, the foliar contents of phenolics, sugars, amino acid and enzyme activities were estimated with respect to tolerant Kalluvally-II, moderately susceptible Panniyur-5 and susceptible Panniyur-1.

The results of the present investigations revealed that the phenolic contents of the three genotypes of black pepper varied considerably. The tolerant cultivar Kalluvally-II possessed higher total and OD phenol contents than the moderately susceptible Panniyur-5 and susceptible Panniyur-1. Similar observations were also

made by Dagde (1999) in black pepper. Many workers opined that phenolics have a protective role against the invasion of plant pathogens. They act by inhibiting growth, spore germination, enzyme and toxin production (Vidyashekar, 1975 and Chet *et al.*, 1978). Some phenolics even detoxify the pathogen toxin (Tamari and Kaji, 1955). So higher contents of total and OD phenols in Kalluvally-II might have helped this genotype to express the tolerant reaction while lower contents in Panniyur-5 and Panniyur-1 made them moderately susceptible and susceptible respectively. Abraham (1986) noticed higher contents of total and OD phenols in resistant genotypes of betelvine against bacterial leaf spot pathogen. Similar observation was reported by Paul (1998) in chilli against bacterial wilt.

The level of carbohydrate in the plant tissues influence the incidence and development of disease to a large extent. Sugars are precursors for synthesis of compounds which impart resistance to plants (Vidyashekar, 1990). The present study revealed that, the susceptible variety Panniyur-1 contained more carbohydrates than the moderately susceptible Panniyur-5 and tolerant Kalluvally-II. Similarly, there was significant difference in the starch content. It was more in susceptible genotypes than moderately susceptible ones. The higher content of these compounds may have a role to determine the susceptibility of Panniyur-1, as they act as the preferred nutrients for the pathogens. Dagde (1999) also observed difference in sugar content in tolerant and susceptible genotypes of black pepper. Higher content of reducing sugars was recorded in Panniyur-5 and Kalluvally-II which may have utilized for production of phenolic compounds to determine the moderately susceptible/tolerant reaction of these genotypes. The lowest content in Panniyur-1 makes this genotype susceptible. Results of the present study are in agreement with that of Dagde (1999). He noticed more reducing sugars in tolerant black pepper cultivar than the susceptible one. Abraham (1986) noticed higher content of reducing sugars in bacterial leaf spot resistant betelvine cultivars than susceptible ones. Similar finding was also observed by Sidhan *et al.* (1996) in wheat against flag smut, again implying the role of reducing sugar in resistance reaction.

Kalluvally-II, the tolerant genotype contained higher content of aminoacids than the moderately susceptible Panniyur-5 and susceptible Panniyur-1, thus proving that the content of aminoacids helped to determine the reaction of these genotypes against diseases. According to Vidyashekaran (1990) aminoacids not only play an important role in the synthesis of proteins but also have a pivotal role in the synthesis of phenolics and lignin. Further, amino acids have a capacity to behave as methyl donors and thus change the proportion of cellwall and thus interfere with auxin action (Andel, 1965). Dagde (1999) stated that the content of aminoacids in tolerant and susceptible cultivars of black pepper had a role in their resistant/tolerant reaction to *P. capsici*. Further, high levels of amino acid in the expression of resistance were reported by Chile and Vyas (1983) in betelvine against *Phytophthora* foot rot, Phuken (1994) in potato against late blight and Paul (1998) in brinjal against bacterial wilt disease.

Pathogenic invasion in plants leads to changes in the activity of enzymes which can be correlated with disease resistance/susceptibility. Peroxidase is an important enzyme in the synthesis of lignins and it catalyses the oxidation of phenols into more toxic quinones. In the present study, higher peroxidase activity was noticed in tolerant Kalluvally-II compared to the least activity noticed in Panniyur-1, while Panniyur-5 showed an intermediary activity. Many workers have noticed a close relationship between disease resistance and peroxidase activity. Dagde (1999) noticed higher activity of peroxidase enzyme in the leaves of tolerant genotype of black pepper compared to the susceptible one. Similar findings were reported by Lizzi and Coulomb (1991) in chilli against *P. capsici*, Markose (1996) in chilli against bacterial wilt and Paul (1998) in brinjal against bacterial wilt.

As in the case of peroxidase, catalase activity was high in Kalluvally-II, lowest activity was observed in Panniyur-5 and intermediate activity in Panniyur-1. Positive correlation of more catalase activity in resistance reaction was reported in apple (Tasakadze and Tsereteli (1971) and Montalbini and Mate (1972) in bean and Lizzi and Coloumb (1991) in tobacco.

Acid-phosphatase also plays a major role in host-pathogen compatibility reactions (Palilova and Loseva, 1991). Significant difference was noticed among the different pepper genotypes with respect to this enzyme where its activity was higher in the susceptible variety Panniyur-1 than Panniyur-5 and Kalluvally-II. This is in agreement with the report by Borua and Das (2000). They observed an increase in activity of acid phosphatase in capsicum varieties susceptible to *Colletotrichum capsici*. Hence, it can be presumed that the tolerant and moderately susceptible reactions of Kalluvally-II and Panniyur-5 may be due to less activity of acid phosphatase.

The pepper genotypes differed in their esterase activity. Significantly higher activity of this enzyme was noticed in the susceptible Panniyur-1 and lower in tolerant Kalluvally-II, thus implying the role played by esterase in imparting tolerant/susceptible reaction. Though, the exact role played by this enzyme in disease resistance/susceptibility is not known, it plays a major role in hydrolysing the ester link of different metabolites in plants. Increased activity of esterase in susceptible cultivars of finger millet against blast disease was reported by Muraleedharn *et al.* (1996) while Xia *et al.* (1996) noticed higher activity in resistant cotton varieties against Verticillium wilt.

5.5 ISOLATION OF NATIVE MICROFLORA FROM THE RHIZOSPHERE SOIL

The awareness of deleterious effects of chemical fungicides in the ecosystem have created interest among the scientists for locating biocontrol agents against soil borne diseases. Further, due to the variability existing in the pathogen, it is ideal to select native antagonists which would be more adapted to the soil conditions and having more competitive saprophytic ability than introduced cultures (Papavizas and Lewis, 1981).

Cook and Baker (1983) stated that, the starting point for biological control is often the isolation of potential antagonists from root environment where disease is lacking such as suppressive soil and from healthy plants in diseased fields. Further,

Baker and Cook (1974) opined that antagonists should be sought from the rhizosphere rather than the soil mass as their effective activity will be on the root surface. Hence, in the present study, an attempt was made to select antagonistic microbes prevalent in the rhizosphere of pepper plants in different nurseries from four northern districts of Kerala. For this, soil samples were collected from the rhizosphere of pepper plants and quantitative estimation of soil microbes was carried out. Results of the study revealed the presence of bacteria, actinomycetes and fungi in that order in different nurseries. Variation in the population of these microbes was noticed in soils collected from different nurseries. It may be due to varied soil types and climatic conditions prevailing in different locations. Jeyarajan *et al.* (1994) noticed that in *Phytophthora* suppressive soils, the population of bacteria and actinomycetes was 30 and 35 times more compared to conducive soil. Jubina and Girija (1998) observed the abundance of soil bacteria in rhizosphere soils of black pepper.

From the micro flora isolated from different rhizosphere soils of pepper nurseries, representative cultures of fungi, bacteria and actinomycetes were selected based on cultural characteristics. From these microbes, 48 fungi, 21 bacteria and 14 actinomycetes were selected for further studies. The antagonistic action of these organisms against *P. capsici* was estimated under *in vitro* and *in vivo* conditions. Further, the efficacy of the isolates was compared with that of established antagonists *T. viride* and *T. harzianum*.

In vitro evaluation of fungal antagonists against *P. capsici* revealed significant difference among the isolates in inhibiting the growth of the pathogen. Among various isolates, isolate F14 showed maximum inhibition closely followed by isolate F47 and F48. Similarly, established *Trichoderma* spp. showed good inhibition of *P. capsici*. Antagonistic ability of *Trichoderma* sp. to *Phytophthora* spp. was reported by Reeves and Jackson (1972); Al-Heeti and Sinclair (1988) and Anandaraj and Sarma (1991). Eventhough both bacterial and actinomycetes isolates showed varying percentages of inhibition, their performance was not as effective as that of fungal isolates.

It is a well known fact that performance of microbial isolates may not be same both under *in vitro* and *in vivo* conditions. Hence, all the microbes evaluated under *in vitro* were tested under *in vivo* also for further evaluating their antagonistic ability against *P. capsici*. Out of the 50 fungal isolates including standard *Trichoderma* spp. isolates F14 and F48 showed more than 96 per cent root protection. While the established antagonists (*T. harzianum* and *T. viride*) showed 95-96 per cent root protection against *P. capsici*. Inoculation of these isolates also resulted in maximum wet and dry weight of roots, again indicating their effect in reducing the *Phytophthora* root rot in black pepper nursery. Bacterial and actinomycete isolates failed to protect pepper cuttings against the root rot as effectively as the fungal isolates.

The potential ability of *Trichoderma* sp. as an effective biocontrol agent and their predominance in rhizosphere soil was already established by Mukhopathyay (1995), Harman (2000) and Doraiswamy *et al.* (2003). Less effectiveness of bacteria and actinomycetes against *P. capsici* was reported by Veena (1996) and Jubina and Girija (1998). Thus, it is evident that two native fungal isolates (F14 and F48) and two established *Trichoderma* spp. exhibited promising effect against *P. capsici* both under *in vitro* and *in vivo* conditions.

The two fungal isolates (F14 and F48) were identified at their species level by studying their cultural and morphological characters. The isolate F14 produced whitish green colonies. Mycelium was septate, branched, smooth walled and hyaline. Conidiophores branched, borne singly or sometimes formed in groups. Phialides 4.5 - 7.5 x 2.5 - 3.0 μm , short, narrower at the base than middle. Phialospores produced singly, 2.5 - 3.5 x 2.3 - 2.5 μm , globose, obovoid, smooth walled and pale green in colour. All these characters were almost in conformity with those reported by Rifai (1964) and was thus identified as *Trichoderma harzianum* Rifai.

Isolate F48 also produced smooth surfaced, watery white and sparse mycelial mat. Colonies when mature turned dark green or dark blue in colour. Mycelium hyaline, smooth walled, septate 1.5 - 11.5 μm diameter. Phialides produced

in false or irregular whorls. Phialospores subglobose, obovoid, minutely rough walled, green in colour and measured 3.5 - 6.5 μm . Similar characters were reported by Webster (1964) and thus the isolate was identified as *Trichoderma viride* Pers. ex. S.F. Grey.

The selected and established antagonists overgrew the pathogen and showed interactions like coiling, penetration and disintegration of the host hyphae, which ultimately led to the death of the pathogen. Similar observations were reported by Bell *et al.* (1982); D'Ercole *et al.* (1993) and Harman (2000) in *Trichoderma* sp. on various plant pathogens. Bell *et al.* (1982) reported that the hyphae of *Trichoderma* penetrated the mycelium of pathogens and grew luxuriantly within it and the hyphae of the pathogen were severely ruptured at the point of contact with the hyphae of *Trichoderma* ultimately leading to lysis and disintegration. Cell wall degrading enzymes might have also played a role in this type of antagonistic action. Hence the native and selected *Trichoderma* spp. used in the study is found to have effective action against the pathogen and these fungi could be utilized for the integrated management of *Phytophthora* rot in black pepper nursery.

5.6 COMPATIBILITY OF ANTAGONISTS TO FUNGICIDES

In any integrated disease management programme, its components, must be compatible with each other. Otherwise, the desired output of the programme may not be achieved. This is more pertinent when biocontrol agents are used as one of the components in the integrated disease management strategy. So in the present study, the compatibility of two native (*T. viride* - F48 and *T. harzianum* - F14) and two established fungal antagonists (*T. viride* and *T. harzianum*) with four commonly used fungicides (Bordeaux mixture, Fytolan, Akomin-40 and Ridomil MZ) in pepper gardens were evaluated under *in vitro* conditions. The results indicated that all the four antagonists were compatible with Akomin-40 and Ridomil MZ and incompatible with Bordeaux mixture and Fytolan. These findings are in agreement with those reported by many workers (Sarma *et al.*, 1996; Hegde and Anahosur, 1998; Vijayaraghavan and Abraham, 2003 and Jayakumar *et al.*, 2003).

Variations in the response of the four *Trichoderma* spp. were noticed with copper fungicides. More than 80 per cent inhibition over control was observed with all the antagonists with the two higher concentrations of Bordeaux mixture and Fytolan. The lowest concentration of these fungicides in general permitted slight growth. Fytolan incorporated media did not support any growth of the native isolate of *T. harzianum* (F-14). However, Bordeaux mixture is more toxic than Fytolan to the different *Trichoderma* spp. The incompatibility of *Trichoderma* spp. with copper fungicides has been reported (Shanmugham, 1996 and Sarma *et al.*, 1996). However, Krishnamoorthy and Bhaskaran (1994) noticed normal growth of *T. harzianum* in copper oxychloride incorporated media. While Shanmugham (1996) reported 56.66 per cent inhibition of *T. viride* with Fytolan. Thus, the four antagonists can be safely tried along with Ridomil MZ and Akomin-40 in the integrated management of *P. capsici* in black pepper nursery.

5.7 EFFECT OF TIME OF PLANTING ON THE INCIDENCE OF *Phytophthora* rot

Incidence of many plant diseases can be avoided or reduced by the selection of appropriate time of planting/sowing. Selection of right time of planting will help to avoid the coincidence of susceptible stage of plant growth with the maximum activity of the pathogen. This is true in the case of *Phytophthora* rot in black pepper nursery. During the survey on the occurrence of various nursery diseases of black pepper in different nurseries, it was noticed that various agencies resort to planting of cuttings from February to the end of May. Consequently, higher incidence of *Phytophthora* rot was noticed in late planted cuttings. Hence, a study was undertaken for two seasons to find out the effect of time of planting of cuttings on their growth and on the incidence of *Phytophthora* rot.

The cuttings of Panniyur-1 were planted from January to May at fortnightly intervals. The study revealed that time of planting had influenced the sprouting percentage, incidence of *Phytophthora* rot and growth parameters. In general, cuttings planted at different intervals from January to April showed more than 80 per cent

sprouting with the maximum in those planted during February and March. Those planted during the month of May showed the least sprouting percentage. Further, cuttings planted during February and March showed better growth as evidenced by better morphological growth parameters as compared to the cuttings planted during May. Moreover, the incidence of *P. capsici* was also less in these cuttings. The cuttings planted during January showed more incidence of *P. capsici* but it was less than those planted during April to May. Though, the ideal time recommended for getting maximum stand in black pepper nursery is during February to March (KAU, 2001) there are no reports on the effect of time of planting on the incidence of *Phytophthora* rot. Thus, the present investigations revealed that planting of cuttings in February-March is ideal not only for getting better crop stand but also to reduce the loss caused by *P. capsici*. The vigorous growth of the cuttings collected from the dormant runner vines planted during February to March might have helped in avoiding the attack of *P. capsici* to a greater extent. Also, it may be noticed that late collection of runner vines during April to May after prolonged spell of drought may have weakened the vines and when such weak cuttings were planted they become more prone to infection. Hence, to get robust cuttings, every effort has to be made to raise the nursery during the month of February to March.

5.8 EFFECT OF SOLARIZATION OF POTTING MIXTURE ON THE INCIDENCE OF *Phytophthora* rot

Eventhough, soil borne plant pathogens can be controlled to a certain extent by different management practices including chemical means, satisfactory control is not always possible. This is true in the case of *Phytophthora* rot of black pepper nursery incited by the ubiquitous soil borne pathogen, *P. capsici*. Continuous use of chemical fungicides to combat soil borne pathogens may lead to many ecological problems including development of resistant strains. Hence, it is essential to explore the possibility of utilizing ways by which the pathogen propagules can be eliminated or inactivated. One of the effective ways to achieve this is the use of the enormous potential of solar energy for soil disinfection by means of soil solarization. Soil solarization is an inexpensive and non-hazardous method in managing soilborne

diseases (Stapleton and DeVay, 1986). According to Katan and DeVay (1991) solarization not only reduces the population of soil borne pathogens and weed flora but also improves the emergence, growth and stand of plants. The duration of solarization also has an effect in reducing the pathogen propagules. Hence, a study was undertaken to find out the effect of solarization of potting mixture in reducing the incidence of *Phytophthora* rot in black pepper nursery. The potting mixture was subjected to solarization for different durations using 150 gauge polyethylene sheets as delineated in materials and methods.

Observations on the soil temperature recorded during the experiment revealed a substantial build up of the soil temperature in solarized potting mixture compared to non-solarized one. The maximum temperature build up was seen at 5 cm depth. Further, in solarized soil, temperature at 5 cm depth was above 33°C at 7.25 a.m while at 2.25 p.m it was 51°C at same depth. The build up of soil temperature due to soil solarization was reported by many workers (Katan, 1981; Chandran, 1989; Vilasini, 1996 and Binimol, 2000). According to them, an increase in soil temperature had a deleterious effect on the population of soil microbes, including the pathogen which lead to the reduction in the disease incidence. The result of the estimation of soil micro flora before and after solarization at different intervals are in agreement with above observations of these workers. It was observed that, as the duration of solarization increased there was a general decrease in the microbial population compared to the initial count.

The sprouting of pepper cuttings grown in potting mixture solarized for different periods had more sprouting percentage than those raised in non-solarized one. Further, it was noticed that as the duration of solarization increased there was a favourable effect on the growth of the plants as evidenced by the increase in height of plants, number of leaves and roots, length and wet and dry weight of roots. Such beneficial effects of solarization on the plant growth due to physico-chemical and biological factors in soil, were reported by Kurian (1992); Vilasini (1996) and Binimol (2000).

Observations on the incidence of *Phytophthora* rot in pepper cuttings indicated that solarization had a significant effect. Cuttings grown in potting mixture solarized for 30 days had the minimum incidence of disease was on par with those grown in 45 days solarized mixture. There was not much difference in the disease incidence in cutting raised in 15 days solarized and non-solarized potting mixture. The effectiveness of solarization of potting mixture in reducing *P. capsici* infection in black pepper nursery was noticed by Sarma *et al.* (1996), Binimol (2000) and Abraham *et al.* (2003). The reduction in the incidence of disease observed in cuttings grown in potting mixture solarized for longer periods may be due to the adverse effect of solarization on the pathogen propagules as pointed out by Stapleton and DeVay (1986). They opined that soil disinfestation by solarization become more effective when heating of moist soil was increased. Further, it may be noted that cuttings raised in 30 and 45 days solarized potting mixture was more vigorous and this may have also contributed to the less incidence of the disease.

5.9 INTEGRATED DISEASE MANAGEMENT

Now a days, the strategy of plant disease management has shifted from an absolute and single method to integration of different approaches of disease management at economically acceptable level. Eventhough, integrated approach comprising of cultural, biological and chemical methods individually or in combinations were reported to be effective in containing *Phytophthora* rot in black pepper nursery to a certain extent, many times satisfactory level of control was not always obtained. Many reasons related with climate, pathogen, selection and application of fungicides and biocontrol agent etc. can be attributed for this.

For successful management of any soil borne pathogens efforts have to be made to select promising native antagonists as well as resistant/tolerant genotypes suitable for particular geographical area. Hence, the present study was conducted for two seasons using different genotypes of black pepper possessing tolerant (Kalluvally-II), moderately susceptible (Panniyur-5) and susceptible (Panniyur-1) reaction to *P. capsici* find out the effect of solarization, native and established fungal antagonists individually or in combination with fungicides as delineated in the materials and methods.

Observations on the disease incidence due to *P. capsici* were recorded at fortnightly intervals. Pooled analysis of the data for Panniyur-1 showed that all the treatments had an effect in reducing the disease incidence when compared to control. The minimum disease incidence was noticed in treatment T₁₄ (Solarization of potting mixture + *T. viride* + Akomin-40) followed by treatment T₁₆ (Solarization of potting mixture + *T. harzianum* + Akomin-40) and treatment T₅ (Solarization of potting mixture + *T. harzianum* (F14)). These treatments recorded more than 65 per cent efficiency over control in checking the *Phytophthora* rot. The maximum disease incidence was recorded in control (T₃₀) followed by treatment T₂₃ (*T. viride* + Ridomil MZ). Further, it is evident from the data that incorporation of fungicides, antagonists or antagonist and fungicides in solarized soil was more effective in checking the disease than when these were applied in non-solarized soil.

Observations on the disease incidence in Panniyur-5 indicated significant difference among the treatments. Pooled analysis of the data for two seasons, indicated that the treatment T₁₄ (Solarization of potting mixture + *T. viride* + Akomin-40) was the most promising one in reducing the incidence of the disease with more than 68 per cent efficiency over control. This treatment was on par with T₁₅ (Solarization of potting mixture + *T. viride* + Ridomil MZ), T₁₆ (Solarization of potting mixture + *T. harzianum* + Akomin-40), T₁₈ (Solarization of potting mixture + *T. viride* (F48) + Akomin-40) and T₂₀ (Solarization of potting mixture + *T. harzianum* (F14) + Akomin-40). These treatments showed more than 50 per cent efficiency over control and the maximum incidence was noticed in control. Thus, in general integration of disease management measures like solarization of potting mixture, application of antagonists and fungicides like Akomin-40 and/or Ridomil MZ can be used for checking the incidence of the disease in this genotype. Further, solarization of potting mixture also was helpful for reducing disease incidence when combined with antagonists and fungicides.

Observations on the incidence of *P. capsici* in the tolerant cultivar Kalluvally-II, revealed that all the treatments were superior to control. As in the case of Panniyur-1 and Panniyur-5, solarization of potting mixture had an effect in reducing

the disease incidence. The treatment T₂₀ (Solarization of potting mixture + *T. harzianum* (F.14) + Akomin-40) followed by treatment T₁₆ (Solarization of potting mixture + *T. harzianum* + Akomin-40) and treatment T₁₄ (Solarization + *T. viride* + Akomin-40) were found to be efficient in reducing the disease incidence. These treatments recorded more than 55 per cent efficiency over control with maximum efficiency in treatment T₂₀.

According to Sarma (1994) and Anandaraj and Sarma (1995) integrated management is the only way to combat *Phytophthora* rot in black pepper nursery. The effectiveness of soil solarization, biocontrol agents alone or in combination with fungicides like metalaxyl or potassium phosphonate in managing *Phytophthora* rot of black pepper were reported (Malebennur *et al.*, 1991; Anandaraj and Sarma, 1995; Lokesh and Gangadharappa, 1995; Hegde and Anahosur, 1998 and Binimol, 2000). There are reports on the effectiveness of Bordeaux mixture in reducing the *Phytophthora* rot in black pepper nursery (Sarma *et al.*, 1987; Ramachandran *et al.*, 1991 and Mammooty *et al.*, 1992). But the present study showed that though application of Bordeaux mixture cuttings raised in solarized potting mixture had an effect in checking disease incidence, but it was not as effective as those treatments consisting of soil solarization of potting mixture, application of antagonists and fungicides. This were again emphasises the need for an integrated approach in the management of *Phytophthora* rot in black pepper nursery.

Thus, the study revealed that solarization of potting mixture for 30 days, addition of established as well as native isolates of *Trichoderma* spp. along with Akomin-40 (0.2 per cent) spray and drench at monthly intervals can be effectively followed for managing the incidence of *Phytophthora* rot in black pepper nursery.

Summary

6. SUMMARY

Nursery diseases cause extensive damage in black pepper and thus adversely affect the production of quality planting material. Hence, investigations were carried out to elucidate the occurrence of various diseases in pepper nurseries, the effect of nursery practices on disease incidence and also to evolve an integrated management strategy for containing *Phytophthora* rot disease in black pepper nursery.

Periodic survey on the occurrence of nursery diseases was conducted in 30 pepper nurseries of four northern districts of Kerala during different nursery seasons. Incidence and symptoms of rotting of pepper plants in different nurseries were recorded and causal organisms were identified as *Phytophthora capsici*, *Colletotrichum gloeosporioides*, *Rhizoctonia solani* and *Sclerotium rolfsii*.

Incidence of diseases varied with different locations during different seasons. Among the diseases, *Phytophthora* rot was the most predominant one in all the nurseries surveyed except the one at Regional Agricultural Research Station, Ambalavayal. Nursery at this station was free from incidence of any diseases. *Colletotrichum* rot, *Rhizoctonia* rot and *Sclerotium* rot were comparatively less compared to *Phytophthora* rot.

The maximum incidence of *Phytophthora* rot, *Colletotrichum* rot, *Rhizoctonia* rot and *Sclerotium* rot was at nurseries of Neerchal, Padmandeme, Rajapuram and Karimbam respectively.

Symptoms of nursery diseases were recorded during the survey. *P. capsici* infected all parts of the plant and produced typical symptoms on leaf, stem/collar region and on roots.

Colletotrichum gloeosporioides infected mainly leaves and rarely the stem. Severe leaf infection led to defoliation and rotting of tender stem.

Leaves and collar regions were infected by *R. solani*. Leaf infection leads to either defoliation or webbing together of infected leaves. Collar rot leads to death of the vine.

S. rolfsii also infected leaves and collar region of the plant. Whitish mycelial growth was observed on the infected portion and severe infection resulted in defoliation. Collar infection resulted in drying of leaves and collapse of the vine.

Effect of various nursery practices on the incidence of diseases were evaluated. Shade structure had an influence on the disease incidence. Nursery under HDPE sheet was free from all the diseases. Incidence of *Phytophthora* rot was high in nurseries raised under shade trees and ordinary pandal, while it was low in those under shade net.

Type of potting mixture also affected disease incidence. *Phytophthora* rot was less in cuttings grown in potting mixture containing sand, soil and cowdung at the ratio 1:1:1. While, it was more in cuttings grown in 1:3:1 potting mixture and that of *R. solani* in unspecified potting mixture.

The highest incidence of all the four diseases was noticed in cuttings collected from private farms as compared to government farms.

Pepper genotypes Panniyur-1 and Karimunda were widely used for raising nurseries and both of them showed high incidence of *Phytophthora* rot.

Incidence of diseases was comparatively more in cuttings collected from runner shoots that were allowed to creep in the soil. Minimum incidence was recorded in cuttings processed by coiling + rapid multiplication technique (RMT).

Disinfection of potting mixture reduced the incidence of diseases in nursery. Incidence of *Phytophthora* rot, *Colletotrichum* rot and *Sclerotium* rot was minimum in cuttings raised in potting mixture when treated with chemicals while that of *Rhizoctonia* rot, in cuttings planted in solarized potting mixture.

Time of planting of cuttings had an effect on disease incidence. Incidence of diseases was comparatively less when nurseries were raised during February to March.

Studies on the effect of frequency of irrigation revealed that *Phytophthora*, *Colletotrichum* and *Rhizoctonia* rots were more in nurseries irrigated daily twice, whereas, *Sclerotium* rot was more in nurseries irrigated once in two days.

Nurseries treated with three rounds of Bordeaux mixture and one round of Akomin showed minimum incidence of *Phytophthora* rot. Maximum incidence of all the diseases were observed in unsprayed nurseries.

Screening of 50 black pepper genotypes against the nursery diseases revealed that none of them were immune to *P. capsici*, *R. solani* and *S. rolfsii*. All genotypes showed varying percentages of leaf infection and mortality when inoculated with *P. capsici*. Kalluvally-II followed by Panniyur-5 showed minimum leaf infection and mortality.

Vallanamban-II, a local cultivar from Idukki, did not take up infection of *C. gloeosporioides*, while Kalluvally-II followed by Panniyur-5 showed minimum incidence.

The least leaf infection due to *R. solani* was in Panniyur-2 and Kalluvally-II, while the minimum mortality was in Kalluvally-II and Balankotta.

Panniyur-2 and Kalluvally-II recorded minimum leaf infection due to *S. rolfsii*. The lowest mortality was observed with Balankotta, Kalluvally-II and Panniyur-5. However, Balankotta had more leaf infection.

Biochemical bases of disease reaction of three pepper genotypes which showed tolerant (Kalluvally-II), moderately susceptible (Panniyur-5) and susceptible (Panniyur-1) reactions to *P. capsici* were studied. More contents of total and OD phenols and total free amino acids were noticed in tolerant cultivar Kalluvally-II.

Activities of peroxidase, catalase and esterase were also high in tolerant cultivar. Total carbohydrates, starch and acid phosphatase activities were more in susceptible Panniyur-1. Reducing sugar content was high in moderately susceptible Panniyur-5.

Rhizosphere microflora from pepper plants in different pepper nurseries were isolated. A quantitative estimation of these microbes revealed more abundance of bacteria followed by actinomycetes and fungi.

From the above soil microbes, 48 fungi, 21 bacteria and 11 actinomycetes were studied for their antagonistic effect against *P. capsici* both under *in vitro* and *in vivo* conditions. All soil microbes studied, exhibited antagonistic activity against the pathogen with varying degrees. Among these, the fungal isolates F14, F47 and F48 and standard culture of *T. viride* and *T. harzianum* showed higher percentage of inhibition. Inhibitory effect of isolates of bacteria and actinomycetes were less as compared to fungal isolates.

When these antagonistic microbes were tested under *in vivo*, two native fungal isolates, F14 and F48 and two established antagonists *T. viride* and *T. harzianum* showed maximum root protection upon inoculation with *P. capsici*.

The two promising antagonists, F14 and F48 were identified as *Trichoderma harzianum* and *Trichoderma viride* respectively.

Selected native and established antagonists were compatible with Akomin-40 and Ridomil MZ, but were incompatible with Bordeaux mixture and Fytolan.

Time of planting had a significant effect on the incidence of diseases. Cuttings planted during February-March had better sprouting and growth, in addition to less disease incidence.

Solarization of potting mixture for 30 and 45 days influenced better sprouting and growth of pepper cuttings. Minimum incidence of *Phytophthora* rot was noticed in cuttings raised in potting mixture solarized for 30 days.

Experiment on the integrated management of *Phytophthora* rot of black pepper nursery were conducted using susceptible (Panniyur-1), moderately susceptible (Panniyur-5) and tolerant (Kalluvally-II) genotypes for two seasons.

Results of IDM in Panniyur-1 indicated that all the treatments had an effect in reducing disease incidence when compared to control. The minimum incidence of *Phytophthora* rot was noticed in treatment T₁₄ (Solarization of potting mixture for 30 days + *T. viride* + Akomin-40) followed by T₁₆ (Solarization of potting mixture for 30 days + *T. harzianum* + Akomin-40) and T₅ (Solarization of potting mixture for 30 days + *T. harzianum* F14).

Observations on incidence of *Phytophthora* rot in Panniyur-5 indicated significant difference among treatments. The treatment, T₁₄ was the most promising one in reducing the disease incidence. This treatment was comparable with those treatments consisting of solarization of potting mixture, application of native and established antagonists and Akomin-40.

Mean incidence of *Phytophthora* rot in tolerant cultivar Kalluvally-II indicated that the treatment T₂₀ (Solarization of potting mixture for 30 days + *T. harzianum* - F14 + Akomin-40) was the best in managing the disease incidence followed by T₁₆ and T₁₄.

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*Originals not seen

Appendices

APPENDIX - I
Area selected for survey

Sl. No.	District	Name of the agency/farmer	Place
1	KASARGODE	State Seed Farm, Pullur	Pullur
2		Mr. Narayana, P. Padmandeme	Padmandeme
3		Mr. Bhaskaran, V. Edaneer	Edaneer
4		Mr. Venkitaswara Bhat, Gundiaduka	Gundiaduka
5		Mr. Ashok Kumar Hulla P., Kubaneer	Kubaneer
6		Mrs. P. Padmini, Pilicode	Pilicode
7		Mrs. Susamma George K., Karithalam	Karithalam
8		Mr. Sukumaran, T.M., Kodakkadu	Kodakkadu
9		Mr. Muraleedharan, A.C., Kuttikkol	Kuttikkol
10		Mrs. Eliamma, P.V., Rajapuram	Rajapuram
11		Mrs. Padmanabha Thandri, Madikkai	Madikkai
12		Mr. Benny George, S., Pullur (west)	Pullur (west)
13	KANNUR	District Agricultural Farm, DAF, Karimbam.	Karimbam
14		State Seed Farm (SSF), Vengad	Vengad
15		State Seed Farm (SSF), Kankole	Kankole
16		Demonstration centre, Chalode	Chalode
17		Pepper Research Station (PRS), Panniyur	Panniyur
18		Mr. Thomas, C.K., Perumunna	Perumunna
19		Mr. Gopi, Vazayil, Thirumeni	Thirumeni
20		Mr. Raghavan, Velloth, Kuthuparamba	Kuthuparamba
21		Mr. Balan Nambeeshan, Koodalipuram	Koodalipuram
22		Mr. Simon George, Perumpadavu	Perumpadavu
23	KOZHIKODE	Coconut Nursery (CN), Thikkodi	Thikkodi
24		District Agricultural Farm (DAF), Koothali	Koothali
25	WYNAD	Regional Agrl. Res. Station, (RARS), Ambalavayal	Ambalavayal
26		Mrs. Shobhana Kumari, K.K., Neerchal	Neerchal
27		George, P. Joseph, Mancombukunnu	Mancombukunnu
28		Mr. Thomas George, Sulthan's Bathery	Sulthan's Bathery
29		Sudhanen, E.R., Kenichira	Kenichira
30		Chengeri Extension Centre (CEC), Cheengeri	Cheengeri

APPENDIX - II
Proforma
Survey on the occurrence of nursery diseases of black pepper

1. Name of the agency/farmer :
2. Location :
3. Year of observations :
4. Incidence of disease :
 - 4.1 Casual organism/organisms
 - 4.2 Symptomatology
 - 4.3 Per cent incidence
5. Type of nursery structure
 - 5.1 Ordinary pandal
 - 5.2 Shade net
 - 5.3 Shade trees
 - 5.4 High density polyethylene sheet (HDPE sheet)
6. Type of potting mixture
 - 6.1 1:1:1 (Sand:Soil:Cowdung)
 - 6.2 1:2:1 (Sand:Soil:Cowdung)
 - 6.3 1:3:1 (Sand:Soil:Cowdung)
 - 6.4 Others (Unspecified quantity of ingredients)
7. Place of collection of planting materials
 - 7.1 Government farm
 - 7.2 Private farm
8. Variety/Cultivar planted
 - 8.1 Panniyur-1
 - 8.2 Karimunda
 - 8.3 Others
9. Processing of runner vines
 - 9.1 Coiling
 - 9.2 Creeping
 - 9.3 Coiling + Rapid multiplication technique (RMT)
 - 9.4 Coiling + Creeping

10. Treatment of potting mixture

10.1 Solarization

10.2 Chemicals

10.3 Others

10.4 No treatment

11. Time of planting

February	March	April	May
First week	First week	First week	First week
Second week	Second week	Second week	Second week
Third week	Third week	Third week	Third week
Fourth week	Fourth week	Fourth week	Fourth week

12. Frequency of irrigation

12.1 Daily once

12.2 Daily twice

12.3 Once in two days

12.4 Once in three days

13. Application of fungicides

13.1 Spraying Bordeaux mixture once in a season

13.2 Spraying Bordeaux mixture twice in a season

13.3 Spraying Bordeaux mixture thrice in a season

13.4 Spraying Bordeaux mixture four times in a season

13.5 Spraying Bordeaux mixture five times in a season

13.6 Spraying Bordeaux mixture six times in a season

13.7 Spraying Bordeaux mixture once + drenching copper oxychloride once in a season

13.8 Spraying Bordeaux mixture once + drenching copper oxychloride twice in a season

13.9 Spraying Bordeaux mixture once + drenching copper oxychloride thrice in a season

13.10 Spraying Bordeaux mixture once + akomin once in a season

13.11 Spraying Bordeaux mixture twice + akomin once in a season

13.12 Spraying Bordeaux mixture thrice + akomin once in a season

13.13 No treatment (Control)

APPENDIX - III

MEDIA COMPOSITION

1. Potato Dextrose Agar medium

Potato	:	200.0 g
Dextrose	:	20.0 g
Agar	:	20.0 g
Distilled water	:	1000 ml

2. Nutrient Agar medium

Glucose	:	5.0 g
Peptone	:	5.0 g
Beef extract	:	3.0 g
NaCl	:	5.0 g
Agar	:	20.0 g
Distilled water	:	1000 ml
pH	:	6.5 to 7.5

3. Ken Knight's Agar medium

Dextrose	:	1.0 g
KH ₂ PO ₄	:	0.1 g
NaNO ₃	:	0.1 g
KCl	:	0.1 g
MgSO ₄	:	0.1 g
Agar	:	20.0 g
Distilled water	:	1000 ml
pH	:	7

4. Martin's Rose Bengal Streptomycin Agar medium

Dextrose	:	10.0 g
Peptone	:	5.0 g
KH ₂ PO ₄	:	1.0 g
MgSO ₄	:	0.5 g
Agar	:	20.0 g
Rose Bengal	:	0.03 g
Streptomycin	:	30.0 mg (added aseptically to the sterilized medium)
Distilled water	:	1000 ml

5. Carrot Agar Medium

Carrot	:	200.0 g
Agar	:	20.0 g
Distilled water	:	1000 ml

APPENDIX - IV

Black pepper varieties/cultivars used for screening against nursery diseases

I. Kerala Agricultural University (KAU) varieties

1. Panniyur-1
2. Panniyur-2
3. Panniyur-3
4. Panniyur-4
5. Panniyur-5
6. Panniyur-6
7. Panniyur-7

II. Indian Institute of Spices Research (IISR) varieties

1. Sreekara
2. Subhakara
3. Panchami
4. Pournami

III. Germplasm bank of Pepper Research Station (PRS), Panniyur - culture/cultivar

- | | |
|------------------------|----------------------|
| 1. Kalluvally-II | 20. Padarpan |
| 2. Angamali | 21. Perumunda |
| 3. Thevarmundi | 22. Veluthanamban-II |
| 4. TMB-I | 23. Kuthiravally |
| 5. Aimperian | 24. Nilgiris |
| 6. Poonjarmunda | 25. Karimkotta |
| 7. Karimunda-I | 26. Thevarmundi |
| 8. Uthiramkotta | 27. Mundi |
| 9. Balankotta | 28. Kottanadan |
| 10. Neelamundi | 29. Kaniakadan |
| 11. Cheriya kaniakadan | 30. Culture-6391 |
| 12. Perumkodi | 31. Kottaram |
| 13. Karuvilanchi | 32. Veluthanamban |
| 14. Shimoga | 33. Ceylon |
| 15. Thulakodi | 34. Culture-1558 |
| 16. Kalluvally-IV | 35. Uthirankotta |
| 17. TMB-VII | 36. Mallgesara |
| 18. TMB-IX | 37. Arakulammunda |
| 19. Munda | 38. Culture-406 |

NURSERY DISEASES OF BLACK PEPPER
(*Piper nigrum* L.) IN KERALA WITH SPECIAL
REFERENCE TO THE MANAGEMENT OF
***Phytophthora capsici* Leonian, emend. Alizadeh and Tsao**

By
K. P. MAMMOOTTY

ABSTRACT OF THE THESIS

Submitted in partial fulfilment of the
requirement for the degree of

Doctor of Philosophy in Agriculture

Faculty of Agriculture
Kerala Agricultural University

Department of Plant Pathology
COLLEGE OF HORTICULTURE
VELLANIKKARA, THRISSUR - 680 656
KERALA, INDIA

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ABSTRACT

Nursery diseases are the major limiting factor in the production of quality planting materials of black pepper. Investigations were carried out to study the various diseases occurring in black pepper nurseries of northern districts of Kerala, the effect of nursery practices on the incidence of diseases and to evolve an integrated management strategy against *Phytophthora* rot in black pepper nursery.

Four nursery diseases viz., *Phytophthora* rot, *Colletotrichum* rot, *Rhizoctonia* rot and *Sclerotium* rot were recorded from different nurseries surveyed. The pathogens causing the diseases were isolated and identified as *Phytophthora capsici* Leonian emend A. Alizadeh and P.H.Tsao, *Colletotrichum gloeosporioides* (Penz.) Penz. Sacc., *Rhizoctonia solani* Kühn and *Sclerotium rolfsii* Sacc.

Symptomatology of these diseases were studied. The pathogen *P. capsici* produced symptoms on all parts of the plant, while *C. gloeosporioides* infected mainly on leaves. *R. solani* and *S. rolfsii* infected both leaves and collar regions. The infected plants produced typical symptoms depending upon the pathogen and plant parts affected.

Incidence of nursery diseases varied with locations and nursery seasons. Among the nursery diseases noticed during the survey, *Phytophthora* rot was the most predominant one. Incidence of other three diseases was comparatively less than that of *Phytophthora* rot.

Various nursery practices followed for raising pepper nurseries viz., nursery structures, potting mixture, place of collection of planting materials, variety / cultivar planted, processing of runner vines, treatment of potting mixture, time of planting, frequency of irrigation and application of fungicides had an effect on the incidence of nursery diseases especially *Phytophthora* rot. However, cuttings raised under high density polyethylene sheet did not show any incidence of diseases.

Screening for host resistance indicated tolerant and moderately susceptible reactions of Kalluvally-II and Panniyur-5 respectively against nursery diseases. The

biochemical parameters of these genotypes, which impart this type of reactions, were studied in comparison with susceptible Panniyur-1.

Total phenols, OD phenol and total free amino acid contents and peroxidase, catalase and esterase activities were more in tolerant Kalluvally-II, while total carbohydrates, starch and acid phosphatase activity were maximum in susceptible Panniyur-1. Reducing sugar content was high in moderately susceptible Panniyur-5.

Quantitative estimation of rhizosphere microflora from different pepper nurseries yielded bacteria, actinomycetes and fungi. Fungal antagonists exerted more antagonistic activity against *P. capsici* both under *in vitro* and *in vivo* conditions. Among these two isolates F14 and F48 were selected based on their better antagonistic efficiency against *P. capsici* and they were identified as *Trichoderma harzianum* Rifai and *Trichoderma viride* Pers. ex S.F. Gray aggr. The established antagonists *T. harzianum* and *T. viride* also exerted good antagonistic efficiency against *P. capsici*.

The native and established antagonists were compatible with Akomin-40 and Ridomil MZ, while Bordeaux mixture and Fytolan were not compatible with any of the four fungal antagonists.

Better growth and minimum disease incidence in pepper cuttings were recorded when nurseries were raised during February-March.

Pepper cuttings raised in solarized potting mixture for 30 days showed more sprouting, better plant growth and less incidence of disease.

Integrated management of *Phytophthora* rot in black pepper nursery was carried out using tolerant Kalluvally-II, moderately susceptible Panniyur-5 and susceptible Panniyur-1. In all the three black pepper genotypes, all the treatments had a significant effect in reducing the incidence of *Phytophthora* rot when compared with control. The minimum disease incidence in Panniyur-1 and Panniyur-5 was recorded in cuttings in treatment T₁₄ (Solarization of potting mixture for 30 days + *T. viride* +

Akomin-40), while in Kalluvally-II it was T₂₀ (Solarization of potting mixture for 30 days + *T. harzianum* - F14 + Akomin-40). In general, solarization of potting mixture, application of *Trichoderma* spp. and fungicides like Akomin 40 and / or Ridomil MZ can be used for managing the incidence of *Phytophthora* rot in black pepper nursery.