MANAGEMENT OF RHIZOME ROT OF GINGER

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CERTIFICATE

This is to certify that the work recorded in this thesis entitled **"MANAGEMENT OF RHIZOME ROT OF GINGER"** submitted in partial fulfilment of the requirements for the Degree of **DOCTOR OF PHILOSOPHY IN AGRICULTURE (PLANT PATHOLOGY)** of the Faculty of Post-Graduate Studies, Birsa Agricultural University, Ranchi (Jharkhand) is the record of the bonafide research work carried out by ***SAVITA EKKA*** under my guidance and supervision. No part of the thesis has been submitted for any degree or diploma.

It is further certified that such helps or information received during the course of this investigation and preparation of the thesis have been duly acknowledged.

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ABSTRACT

Rhizome rot disease of ginger was found to be prevalent in all the localities surveyed. The disease incidence varied from 15% to 30.37% in different locations during *Kharif,* 2003-04 and 2004-05 crop seasons. The disease normally appeared during last week of June or 1st week of July. Maximum number of infected plants were recorded during the month of August. The initial symptoms of rhizome rot were recorded on the above ground parts in the form of slight paleness at the tip of terminal leaves followed by yellowing of leaves. The infected leaves ultimately withered. The infected rhizomes became discoloured and later showed rooting.

Laboratory *in vitro* evaluations showed efficacies of fungicides viz., Carbendazim, Mancozeb, Metalaxyl MZ, Copper oxychloride, Carbendazim 12% + Mancozeb 63% (Companian), Benomyl, the bio-agent, *Trichoderma harzianum* and the oil cake, *Pongamia glabra* and these were selected for field trials. The variety, Maran with disease incidence of 8.89% and 11.11% during the two years of trial showed Resistant (R) reaction.

Soil solarization for a period of six weeks recorded 16.40% pre-emergence and 9.38% post-emergence rhizome rot as compared to 40.88% and 19.51% pre and post-emergence rhizome rot, respectively, in non-solarized plots. Soil amendment with *P. glabra* oil cake @ 20q/ha recorded 77.50% germination and 23.75% incidence of rhizome rot. The *P. glabra* cake recorded disease control of 54.4%, fresh rhizome yield of 90.83 q/ha and recorded 20.94% yield increase over control. Soil application of *T. harzianum* @ 5kg/ha was recorded to be the most effective biocontrol agent with 77.50% germination and 27.50% rhizome rot incidence. *T. harzianum* provided 50.74% disease control and recorded fresh rhizome yield of 101.00 g/plant.

Soil drenching of the fungicide, Metalaxyl MZ applied @ 0.02% recorded highest germination (76.04%). Metalaxyl MZ recorded 28.13% rhizome rot incidence with 47.05% disease control and fresh rhizome yield of 428.33 g/3 m row length. Mulching with *Eucalyptus citriodora* leaves @2.5kg/m^2 recorded pre-emergence and post-emergence rhizome rot of 7.50% and 8.19%, respectively. Mulching with *E. citriodora* recorded fresh rhizome yield of 2.81 kg/sq. m.

Among fungicides, Metalaxyl MZ (0.15%) and copper oxychloride (0.3%) were recorded to be effective chemicals for seed rhizome treatment. Metalaxyl MZ (0.15%) affoarded 39.63% disease control with 76.67% germination and 27.92% rhizome rot incidence at maturity. Seed rhizome treatment with Metalaxyl MZ (0.15%) recorded fresh rhizome yield of 83.49 q/ha with cost benefit ratio of 1:16.26. Copper oxychloride (0.3%) affoarded 30.64% disease control with germination of 75.42% and rhizome rot incidence of 32.08% at maturity. Although seed rhizome treatment with copper oxychloride (0.3%) recorded a lower fresh rhizome yield of 74.31 q/ha, the cost benefit ratio was more favourable i.e. 1:18.05 in view of lower cost of the fungicide. Rhizome pelleting with *T. harzianum* recorded 75.82% germination, 35.83% rhizome rot incidence and recorded 31.75% disease control. Rhizome pelleting with *T. harzianum* recorded fresh rhizome yield of 81.38 g/plant.

Mulching with *Eucalyptus citriodora* leaves @2.5kg/m^2 recorded pre-emergence and post-emergence rhizome rot of 7.50% and 8.19%, respectively. Mulching with *E. citriodora* recorded fresh rhizome yield of 2.81 kg/sq. m.

Integration of soil application of the bio-agent, *T. harzianum* @ 5 kg/ha, rhizome dip treatment with the fungicide, Copper oxychloride @ 0.3% followed by two soil drenchings with Metalaxyl MZ solution @ 0.02% recorded 73.87% germination and 23.34% rhizome rot incidence. The above treatment set affoarded 46.82% disease control, recorded fresh rhizome yield of 90.36 q/ha. The cost benefit ratio worked out in the package was 1:7.54.

Rhizome treatment with *T. harzianum* @ 6g/L+ soil amendment with *P. glabra* oil cake @ 20 q/ha + mulching with *E. citriodora* leaves @ 2.5 kg/m^2 which recorded 80.00% germination, 23.33 % disease incidence and affoarded 43.89 % disease control. This package recorded highest fresh rhizome yield of 97.26 /ha with cost benefit ratio of 1:10.44.

The ginger variety, Maran, pre-sowing rhizome treatment with Metalaxyl MZ @ 0.15%, recorded maximum germination of 84.02%, minimum disease incidence of 6.25% and highest fresh rhizome yield of 117.17 q/ha.

Rhizome dip treatment with Metalaxyl MZ @ 0.15 % + two drenchings with Copper oxychloride @ 0.3% + soil application of the bioagent *T. harzianum* @ 5 kg/ha recorded 10.84% incidence and highest fresh rhizome yield of 110.34 q/ha. The above package was followed by treatments including rhizome dip treatment with Copper oxychloride @ 0.3% + two drenchings with Metalaxyl MZ@ 0.02% + soil application of *T. harzianum* @ 5 kg/ha. The package recorded 14.17% rhizome rot incidence and fresh rhizome yield of 105.57 q/ha. Considering the cost benefit ratio in solarized fields, the package, rhizome dip treatment with Metalaxyl MZ @ 0.15% + soil application of bleaching powder @ 15 kg/ha recorded highest cost benefit ratio of 1:3.03 followed by the package rhizome dip treatment with Copper oxychloride @ 0.3% + soil application of bleaching powder @ 15 kg/ha which recorded cost benefit ratio of 1:2.96. In case of non-solarized fields the package, rhizome dip treatment with Copper oxychloride @ 0.3% + soil application of bleaching powder @ 15kg/ha recorded highest cost benefit ratio of 1:14.07, followed by the package including rhizome dip treatment with Metalaxyl MZ @ 0.15 % + soil application of bleaching powder @ 15kg/ha which recorded cost benefit ratio of 1:8.80. The unfavourable cost benefit ratio in the package, rhizome dip treatment with Metalaxyl MZ @ 0.15 % + two drenchings with Copper oxychloride @ 0.3 % + soil application of *T. harzianum* @ 5kg/ha apparently was due to the cost of Copper oxychloride used.

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CHAPTER-1

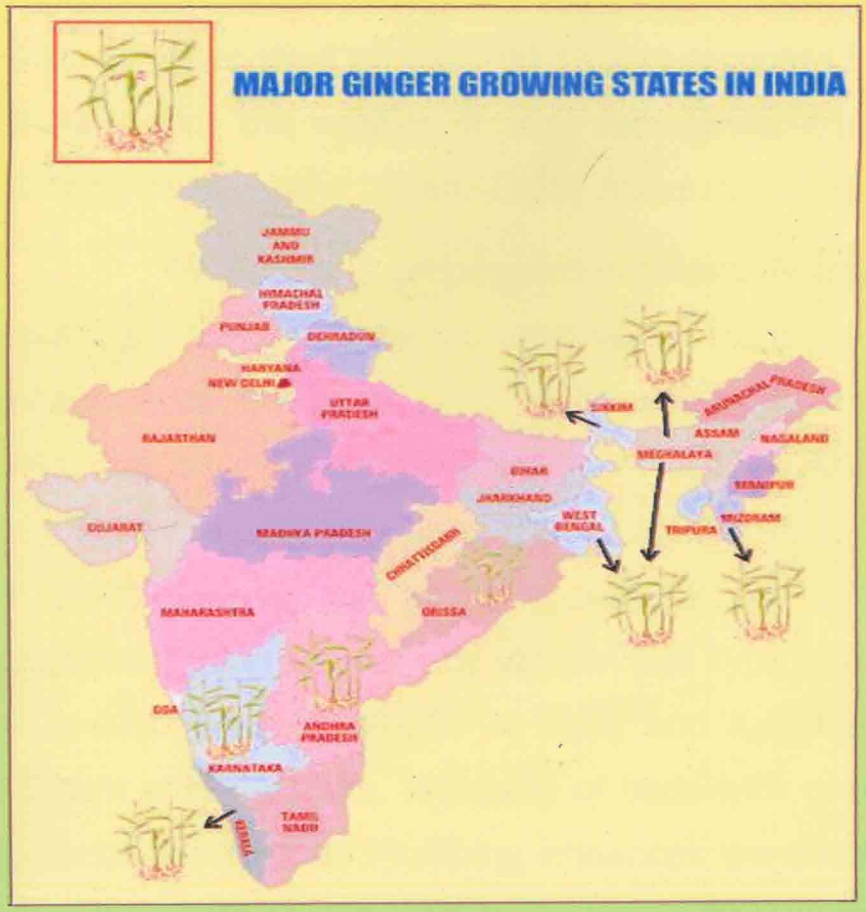
INTRODUCTION

Ginger (*Zingiber officinale* Rosc.) is one of the important spices grown in India. It plays a prominent role in national economy. Among the spices, it ranks third with regard to foreign exchange earning next to black pepper and cardamom. Ginger is native of South Asia. It cultivated in several parts of world, the most important region being India, Jamaica, Sierra Leone, Taiwan, Nigeria, China etc. India is the largest producer and exporter of ginger in the world. The major buyer of Indian ginger are the middle east countries, USA and West European countries. In India, it is cultivated in almost all the states. Kerala is the major ginger growing state contributing one-third of ginger production. Meghalaya is the second leading state followed by Orissa, West Bengal, Andhra Pradesh, Assam, Sikkim, Mizoram, Madhya Pradesh etc. (Plate 1). The cultivated area and production of ginger in India is 58,100 ha and 18,89,400 tonnes, respectively (Directorate of Cocoa Arecanut and Spices Development, Kalikut, 1996).

Ginger is a perennial herbaceous monocotyledon usually grown as annual and is known to human generation as a medicinal and spice crop. It belongs to the family, Zingiberaceae. It grow well in tropical and subtropical climate. The base temperature requirement is 13°C and upper limit 32°C/27°C (day/night) [Hackett and Carolane, 1982). A temperature in excess of 32°C can cause sunburn (Whiely, 1974) and low temperature induce dormancy. The crop requires short or long day length for its growth (Hackett and Carolane, 1982). Brilliant sunshines, heavy rainfall and high relative humidity are necessary for good yield (Ridley, 1912). Ginger is cultivated under rainfed and irrigated conditions. In areas receiving less rainfall, the crop needs regular irrigation. The crop is sensitive to water logging, frost, salinity and tolerant to wind and drought (Hackett and

Plate 1

Major Ginger Growing States in India



- Kerala
- Meghalaya
- Orissa
- West Bengal
- A.P.
- Assam
- Sikkim
- Mizoram

Carolane, 1982). The crop prefers light shade for good growth but shade is not an absolutely necessity.

Ginger has wider adoptability for different soil type and for higher yield the soil should be loose and friable. The most favourable soil pH is 6.0-6.5 (Whiley, 1974). In India, ginger is grown on a wide variety of soil such as sandy loam, clay loam, black rich clay soil and laterite soil. It performs best on medium loam with a good supply of humus (John, 1988).

In India, ginger is planted with commencement of South West monsoon. In areas where the monsoon is late planting is done in June or later. A higher yield of 100-200 % was recorded by planting during 1st week of April with the receipt of summer shower then the general practice of planting in May-June (Khan, 1959; Aiyadurai, 1966).

Ginger is propagated vegetatively from cutting of rhizomes and length and weight of pieces used varies from place to place and variety to variety. A seed rate of 1250 kg/ha was optimum with each seed rhizome weighting 30 g (Randhawa and Nandpuri, 1970). It is an exhaustive crop and requires heavy manuring. Well rotten cattle dung or compost at the rate of 25-30 tonnes per ha is applied at the time of planting. Fertilizer recommendation varies with variety, soil type and climate. A fertilizer dose of 36-225: 20-115: 48-200 N, P_2O_5 and K_2O kg/ha has been adopted in different state in India, mulching of beds with green leaves is an important operation for ginger. Mulching enhances germination, prevent washing of soil due to heavy rain and surface run off, increase infiltration, conserves moisture, regulates temperature, decrease evaporation, suppress weed growth, enhance microbial activity and improve soil fertility. Two mulchings are given first immediately after planting and second about 45 days after planting. Time of harvest depends on the product for which the rhizomes are to be used. If the rhizome are used for vegetable purpose or for preparation of ginger preserves, candy, soft drink, pickles and alcoholic breverages harvest should be done 4-5 months after planting. If it is used for dried ginger and preparation of value added products like ginger oil, oleoresin,

dehydrated and bleached ginger, harvesting is to be done between 8-10 months.

The dried rhizome of ginger is used as spice and hence, it contains moisture 6.9 g/100 gm, protein – 8.6 gm/100 gm, fat – 6.4 gm/100 gm, fibre – 5.9 gm/100 gm, potassium – 0.4 gm/100 gm, phosphorus – 0.15 gm/100 gm, iron – 0.009 g/100 gm, sodium – 0.3 gm/100 gm, vitamin A – 175 IU, vitamin B – 0.85 mg/100 gm, vitamin B_2 – 0.13 mg/100 gm, niacin – 1.9 mg/100 gm, vitamin C – 12.0 mg/100 gm and 380 calories food energy (Pruthi, 1979).

Due to its pleasant pungent and spicy aroma, ginger is used in the manufacture of a number of food products like ginger bread, confectionery, gingerole, curry powder, table sauces, in pickling and in manufacturing of soft drinks, like cordials, ginger cocktail, carbonated drinks etc. The ginger oil obtained from dry ginger powder is primarily used as a flavouring agent in confectionery, preservation and for soft drink. Dry ginger or ginger powder is used in manufacturing of ginger brandy, wine and beer in many western countries. Ginger has basic antiseptic properties and used as carminative and stimulant. It is also used in veterinary medicine.

One of the major obstacles in the way of increasing ginger production are diseases. The target of production can achieved only if the crop is protected from pernicious diseases like Rhizome rot, Bacterial wilt, yellows and leaf spot. Among these, rhizome rot is the complex disease of ginger and has been reported to be caused by different species of *Pythium, Fusarium* and *Ralstonia.*

The disease reduces the potential yield to a greater extent in the field, storage and market. No detailed systemic information is available on this devastating disease of ginger in the region.

Keeping in view, the damage and widespread occurrence of rhizome rot in ginger it was proposed to undertake investigations on management of this disease with the following objectives :

1. To isolate, identify and purify different pathogens associated with rhizome rot and their severity in the region.
2. To evaluate fungicides/biocontrol agent as rhizome treatment against the disease.
3. To evaluate soil treatment/amendment for management of disease.
4. To evaluate pesticides (Fungicide/ Bactericide/ Nematicide) for management of disease.

CHAPTER-2

REVIEW OF LITERATURE

The rhizome rot of ginger (*Zingiber officinale* Rosc.) is a major problem in all the ginger growing states including Jharkhand. The ginger crop suffers from this disease in the field involving fungi and bacteria which ultimately lead to rhizome rot. Although many species of *Pythium* are reported to be associated with the disease, *Pythium aphanidermatum* (Edison) Filzp is the most pre-dominant (Subramanian, 1919; Thomas, 1938; Kannan and Nair, 1965; Sarma *et al.* 1979; Dohroo *et al.,* 1984). Other pathogens reported to cause rhizome rot are *Fusarium oxysporum* Schlecht *f.sp. zingiberi* Trujillo (Haware and Joshi, 1973). *Fusarium solani* Mart. Sacc.(Kumar, 1977) and *Pseudomonas solanacearum* E.F. Smith (Sarma *et al.*, 1978; Mathew *et al.,* 1979).

2.1 HISTORY

Soft rot of ginger is a serious menace to the cultivation of ginger and is reported from all parts of the country. The disease was first reported by Butler (1907) from Surat, Gujarat, Subramanian (1919) described it from Pusa (Bihar) and the pathogen was identified as a strain of *Pythium aphanidermatum* deBary (Mitra and Subramanian, 1928). *P. myriotylum* Drechsler was also reported causing soft rot of ginger from Gujarat (Uppal, 1940). This fungus was also reported to be responsible for the soft rot disease in Ceylon, particularly in plants raised from seed rhizomes received from Surat (Park, 1941). *P. vexans* deBary was also found to cause the same disease in Wynad (Tamil Nadu) at an elevation of 100 m and above (Ramakrishnan, 1949).

In the former state of Madhya Pradesh, ginger cultivation was taken up during 1932. The crop was mainly grown in the district of Chindwara, Bhandara and Nagpur. Rhizome rot disease in the state was first

observed during the year, 1949 as reported by Shahare and Asthana (1962). Different species of *Pythium* viz., *P. myriotylum, P. aphanidermatum, P. monospermum* were isolated from infected rhizomes. Two *Pythium* spp. viz., *P. aphanidermatum* and *P. myriotylum* was found to be pathogenic on ginger. The occurrence of *F. oxysporum f.sp. zingiberi* on ginger was reported from Madhya Pradesh (Haware and Joshi, 1973). Subsequently, two species of *Fusarium,* namely, *F. solani* (Mart.) Sacc. and *F. moniliforme* Sheldon were also reported to be associated with the disease. The above two spp. were reported to be the major cause being responsible for upto 48.6 % of rotting (Rath *et al.*, 1978).

Wilt of ginger caused by *Pseudomonas solanacearum* was first described by Veitch (1946) from Buderim and Eumundi. Subsequently, there were number of reports from different workers such as Ishii and Aragaki (1963), Quinon *et al.* (1964), Aragaki and Quinon (1965), Hayward *et al.* (1967), Zehr (1969), Lee (1974) from Japan, Hawaii, Queensland, Philippines and Malayasia, respectively. The disease, however, was first reported in India from Kerala state.

2.2 SURVEY AND SURVEILLANCE

In a survey conducted in the fields of Bongdong, Korea Republic during 1987 rhizome rot incidence of up to 54.3% was recorded. In the Seosan-Taeahn area of Choongnam Province of Korea Republic, an average rhizome rot incidence of 18.1% was recorded while in the Wanzoo area of Chunbuk Province the disease was three fold more severe. The disease normally started during early July in Season-Taeahn and spread rapidly during the rainy season in the hot summer of late July and August until the cool weather begins in early or mid September (Yang *et al.,* 1988; Kim *et al.,* 1996).

A survey of 15 farmers on the distribution of rhizome rot disease and production constraints in ginger cultivation in Syanga, Palpa, Gumi and Arghakanchi district in Nepal was conducted. Average holding of Bari land was 11.5 Ropani, with an average of 3.3 Ropani cultivated with

ginger. Most household were affected by rhizome rot disease (20 Ropani = 1 ha) (Nepali *et al.,* 2000).

In India, during the survey for incidence of rhizome rot a total of 288 diseased samples were collected from 195 ginger fields spread all over Kerala state during 1984-1985. Survey were carried out from September to November 1984 and from September to December 1985 and included 195 gardens in 12 districts. The disease incidence in the samples collected were between 8.84% to 29.61% (Dake and Edison, 1988; 1989).

Dohroo (1992) recorded the occurrence of wilt disease of ginger caused by *Pseudomonas solanacearum* in Sirmaur district of Himachal Pradesh during surveys conducted in 1989 and 1990 crop seasons.

Widespread occurrence of wilt disease of ginger caused by *Pseudomonas solanacearum* with 27% wilting has been reported from plateau region of Chotanagpur (Singh *et al.*, 1992).

Srivastava (1992) reported rhizome rot incidence of ginger ranging from 15 to 35% from Sikkim. The author recorded losses upto 40-50 % in poorly managed and ill-drained fields. The disease normally started during last week of June or first week of July and continued till September.

Das *et al.* (1997) conducted an extensive survey on ginger growing areas of Assam and reported occurrence of rhizome rot in all the district surveyed. An incidence of 45-50% was recorded in heavily infested areas. The prevalence of rhizome rot disease has also been reported from Karnataka. Kulkarni *et al.* (2006) reported maximum incidence of 23.7% in Shimoga district followed by Kodagu (22.90%), Uttar Kannada (20.24%), Chickmagalur (18.99%), Hassan (15.79%), Mysore (15.42%) and Bidar (13.81%). Havari district recorded a very low incidence (5.23%). The maximum incidence of (47.28%) was recorded in Korlakotta village, which belongs to Sirsi taluk of Uttar Kannada district.

2.3 SYMPTOMATOLOGY

According to Sahare and Asthana (1962) the presence of rhizome rot disease of ginger is indicated by leaves assuming yellow colour. These leaves ultimately wither and die. As the disease progresses the whole shoot is affected and foot of the plant becomes watery and soft. The rhizomes are discoloured and gradually decomposed forming a watery mass of putrefying tissues enclosed by the tough rind. The wounds of infected plants also rot and subsequent rhizome formation ceases.

Haware and Joshi (1973) from Madhya Pradesh recorded the symptoms similar to those of nutritional deficiencies. Initial symptom of the disease appeared in the form of slight paleness of the tip of the terminal leaves. Yellowing of leaves gradually spread down the leaf sheath along the margin. Finally the entire foliage turned yellow followed by drying and withering of the leaves and eventual death of the plant. The dead leaves drooped and hung along the stem. The basal portion of the affected plant showed pale, translucent brown colour and became water soaked, soft and later shrivelled. The disease extended from the collar region to the rhizomes. The infected rhizomes became discoloured and gradually decomposed in the soil. The roots also got infected, became discoloured and later showed rotting. The whole shoot could be easily pulled out from the point of attachment to the rhizomes.

Sarma *et al.* (1978) from Calicut, Kerala state described the symptoms of bacterial wilt of ginger as water soaked, linear streak/ patches on the collar region of the pseudostem. The margin of the lower most leaves showed yellow to bronze coloured margins. Later, the leaves became flaccid with intense yellowish bronze coloured margin and drooped down exhibiting typical wilt symptoms. The ligules and leaf sheath of the infected plants appeared yellowish to dull green in colour. The leaves rolled and the whole plant dried up. Pseudostems came off easily with a gentle pull, which is a feature common to rhizome rot infection caused by *Pythium spp.* The affected pseudostems and rhizomes at advanced stages of infection were

slimy to touch with varying degree of tissue disintegration and exuded milky bacterial exudate when pressed gently. The affected pseudostem when cut open longitudinally showed dark streaks. Rhizomes in early stages of infection showed moderate translucent water soaked lesions enlarging gradually. Later, the lesions spread deep into the rhizome and showed varying degrees of coalescence, thus involving major part of the rhizomes. When small pieces of infected rhizome was placed in water it released turbid bacterial ooze.

Dake and Edison (1989) recorded curling of leaf margin with drooping 5 days after inoculation. In plants inoculated with *Pseudomonas solanacearum,* yellowing symptoms started in the lower most leaves and progressed upwards until all the leaves assumed golden yellow colour. Milky exudate of bacterium was seen on infected pseudostems and rhizomes. Ginger plants artificially inoculated with *Pythium spp.* showed yellowing of leaf tips. The infection spread along the leaf margins. The pseudostem became soft, pale brown near the collar region. Ginger plants inoculated with *Fusarium* spp. showed yellowing of leaves followed by drooping and subsequently drying of the plant. The discolouration was also noticed as the hypacotyl portion of pseudostem.

According to Ramchandran *et al.* (1989) the infection occurred at the collar region of young sprout and the pseudostem resulting in complete rotting of rhizomes. Srivastava (1992) reported yellowing of leaves, pseudostem and eventual wilting of infected plants to be the main aboveground symptoms.

Dohroo (1992) made symptomatological observations and reported water soaked lesions on scales of affected rhizomes. The rhizome tissues disintegrated to form pulpy mass.

Symptomatological studies were also made by Bora and Das (2002) from Assam state. According to the authors wilted ginger plants first showed loss of turgidity which was followed by rolling and wilting of leaves. The leaves became orange yellow in colour at the margins with green

bands on either sides of midribs. The yellowing was first observed on the lower leaves which later extended upward invading all the remaining leaves. In advanced stages, the leaf yellowing progressed, the stem became water soaked and got detached readily from rhizome. The collar region of the stem showed water soaked areas subsequently assuming black colour and longitudinal splitting of the stem, vascular bundles showed brown discolouration. The infected rhizomes became darker in colour, showed water soaked areas and exuded milky fluid. The wilted plants were finally killed within 15-20 days of disease initiation. When the cut ends of the stem was inserted in a tube filled with distilled water, cloudy, mass of bacterial ooze could be seen easily.

Rajan *et al.* (2002) reported foliar yellowing and wilting to be more conspicuous at harvesting time. The infected and partially rotten rhizomes considerably reduced the market value and rendered unfit for seed purposes.

2.4 PATHOGENS ASSOCIATED WITH RHIZOME ROT DISEASE

Shahare and Asthana (1962) from Madhya Pradesh isolated *Pythium myriotylum, P. aphanidermatum, P. monospermum* and *P. gracile* from the diseased plant parts. However, pathogenicity was established with only two *Pythium* species viz., *P. myriotylum* and *P. aphanidermatum.*

Kothari (1966) from Dungarpur district of Rajasthan reported the occurrence of *Fusarium oxysporum, Pythium butleri, P. vexans, P. myriotylum, P. graminicolum* and *Sclerotium rolfsii. Fusarium* spp. was isolated from affected rhizomes showing soft rot symptoms.

During the course of investigation, Haware and Joshi (1973) from Madhya Pradesh recorded association of three different organisms viz., *Sclerotium rolfsii, Fusarium oxysporum* and *Pythium deliense. S. rolfsii* was found to be the incitant of the basal rot, *F. oxysporum* caused yellows disease and soft rot was found to be due to *Pythium* Spp.

Sarma *et al.* (1978) reported association of *Pythium aphanidermatum, P. myriotylum* and *Pseudomonas solanacearum* with the Malady.

According to Mathur *et al.* (1984), *Pythium aphanidermatum* and *Fusarium solani* were recorded to be the two major pathogens responsible for rhizome rot, both in field and in storage in Rajasthan.

Dohroo *et al.* (1987) from Himachal Pradesh isolated fungal pathogens viz., *Pythium pleroticum, P. aphanidermatum, Fusarium equiseti* and *F. solani* from rotten rhizomes samples. Ginger plants with wilt and rhizome rot complex were also infested by rhizome fly (*Mimegralla coeruleifroms*) or infected by the nematodes viz., *Meloidogyne incognita* and *Pratylenchus coffeae.*

Doshi and Mathur (1987) recorded three different types of symptoms caused either by single infection with *Fusarium solani* or *Pythium aphanidermatum* or combined infection with both the above mentioned pathogens. Maximum rotting occurred when *P. aphanidermatum* was artificially inoculated first and was followed by inoculation with *F. solani.* No interaction occurred between the root knot nematode, *M. incognita* and *P. aphanidermatum.*

Rathaiah (1987) reported different species of *Pythium especially P. myriotylum* to be responsible for ginger soft rot.

Bhardwaj *et al.* (1988) reported the association of five pathogens. *P. aphanidermatum* caused wet rot and was able to attack both uninjured and injured rhizomes. The other fungi viz., *F. equiseti, F. solani, Cladosporium cladosporiodes* and *Mucor hiemalis* only cause dry rot symptoms on injured rhizomes.

Yang *et al.* (1988) made 87 isolations from diseased seed ginger plants. Of these 62.8% were *Fusarium* spp. and 11.8% were *Pythium* spp. In regard to 190 isolations made from diseased plants 65.8% were *Pythium* spp. and 31.2% were *Fusarium* spp. The Fusarium isolates were

identified as *F. oxysporum* and *F. solani* while *Pythium* isolate was identified as *P. zingiberis.* The characteristics symptoms of rhizome rot were produced following inoculation of growing plant with *F. oxysporum f.sp. zingiberi* and *P. zingiberis.*

Dake and Edison (1989) collected 288 samples from 195 fields in Kerala state. Among the cultures identified from the above samples 19.8 % were *P. aphanidermatum* and *P. myriotylum,* 6.6% were *F. oxysporum f.sp. zingiberi* and *F. solani* and 26.7% were *Pseudomonas solanacearum.* None of the samples yielded more than one.

Ramchandran *et al.* (1989) from Kerala state reported *Pythium* spp. to be associated with the disease and that *P. aphanidermatum* was found to be the predominant spp.

According to Rana and Arya (1991), *F. oxysporum f.sp. zingiberi* was the associated pathogen with ginger yellows and rhizome rot disease.

In southern Rajasthan, *P. myriotylum, F. solani* and the root knot nematode, *Meloidogyne javanica* and *M. indica* have been reported to be associated with rhizome rot disease. (Lodha *et al.,* 1994).

Mathur *et al.* (1992) and Ram *et al.* (1999) from Karnataka found the association of *P. myriotylum* and *F. solani* with the disease.

Sheela *et al.* (1995). Reported occurrence of nematode species viz., *M. incognita, Radopholus similis, Rotylenchus reniformis, Helicotylenchus multicinctus, Pratylenchus spp. Tylenchorhynchus spp., Hoplolaimus indicus, Cricoremoides spp.* and *Xiphinema spp.* in the rhizosphere of ginger.

From Assam, Das *et al.* (2001) identified *P. aphanidermatum* as the cause of rhizome rot.

Under field conditions the rhizome rot disease was found to be associated with *Ralstonia solanacearum, Pythium spp., F. oxysporum, Pratylenchus coffeae* (Rajan *et al.,* 2002).

Kumar and Sarma (2004) isolated *R. solanacearum* from wilted ginger plants collected from different locations of Kerala, Assam and West Bengal.

Kulkarni *et al.* (2006) isolated *P. aphanidermatum, F. solani, Sclerotium rolfsii* and *M. arenaria* from samples collected from southern parts of Karnataka state.

2.5 MANAGEMENT

2.5.1 *In vitro* tests

2.5.1.1 *In vitro* fungicidal tests

Seed rhizome treatments, soil application of organics, fungicides, bioagents and mulching alone or in combinations have been tested and found to be effective in reducing rhizome rot and increasing the yield of rhizomes.

Abbaiah and Subbayya (1975) conducted bioassay of fungicides and antibiotics against *P. aphanidermatum.* Five best of ten fungicides tested *in vitro* were further tested by soil vial technique and reported wettable ceresan (Methoxyethyl-mercury chloride) to be the most effective. EI-Khadem *et al.* (1977) reported that aldicarb, fensulfothion and phenamiphos at concentration of 125 ppm completely inhibited the growth of *Ps. solanacerum in vitro* experiments. Sharma and Joshi (1979) reported inhibition of most of the seed borne fungi of ginger by mancozeb, carbendazim, benomyl and kitazin (IBP).

According to Mathur *et al.* (1984) from Rajasthan, Ridomil and Fenaminosulf checked 100% growth of *Pythium* even at 1 ppm in sequence testing. These fungicides were not found effective against *Fusarium.* However, only Difolatan could check the growth of both the pathogens. While evaluating the efficacies of systemic fungicides on *in vitro* growth of *P. aphanidermatum.* Ramchandran *et al.* (1989) reported etridiazole to be the most effective with the lowest ED_{50} and ED_{90} values.

Chahal *et al.* (1990) reported complete inhibition of growth of *P. aphanidermatum* and *Phytopthora infestans* even at a low concentration

of 5 µ/ml under *in vitro* conditions. Sharma and Dohroo (1991) from Himachal Pradesh reported carbendazim alone and carbendazim plus mancozeb to completely inhibit the growth of *F. oxysporum f.sp. zingiberi* in *in vitro* test. Kurecheue *et al.* (1992) conducted *in vitro* test with twelve fungicides for their efficacy against *P. aphanidermatum*. A minimum concentration of 500 ppm of agallol and 2000 ppm each of thiride and cheshunt compound were required for complete inhibition of the fungus. Agallol plus thiride recorded complete inhibition of the fungus at 100 ppm concentration each.

Choi *et al.* (1996) conducted pot experiments to determine responses of variant isolates to fungicides viz., Metalaxyl, Metalaxyl + Copper oxychloride, Echlomezol (etridiazole) and propamocarb hydrochloride. Mycelial growth was almost completely inhibited by Metalaxyl + Copper oxychloride and Metalaxyl at the concentration of 50 mg/l and 100 mg/L, respectively. Three isolates were not affected by Echlomezol (etridiazole) even at the concentration of 100 mg/L. In the case of propamocarb hydrochloride, the oospore formation also varied depending on the isolates tested, regardless of sensitive and tolerant isolates to the fungicides. Disease development in preinoculated and naturally infected rhizomes of ginger was significantly inhibited by metalaxyl, metalaxyl + copper oxychloride and echlomazole but not propamocarb hydrochloride.

Park *et al.* (1998) tested a total of 68 isolates of *P. zingiberum* for their tolerance of metalaxyl. Nine isolates were tolerant and showed mycelial growth on PDA containing 100 ppm of metalaxyl. At 500-1000 ppm, metalaxyl tolerant isolates grew their mycelia and formed oospore while metalaxyl susceptible isolates could not grow at >10 ppm. Metalaxyl tolerant isolates were completely inhibited by metalaxyl with carbendazim and with copper oxychloride at 100 ppm. Singh *et al.* (2000) reported superiority of streptomycin and streptopencillin at concentrations of 500 and 1000 ppm over other antibiotics *in vitro* and *in vivo* tests against bacterial wilt of ginger caused by *Ps. solanacearum*.

2.5.1.2 *In vitro* tests with biocontrol agents

Bhardwaj and Gupta (1987) reported inhibition of *P. aphanidermatum, F. equiseti, F. solani* and other pathogens by *T. viride, T. harzianum* and *T. hamatum* in *in vitro* tests. Similarly growth inhibition of (73-78%) of *F. oxysporum f.sp. zingiberi* in *in vitro* test by *T. harzianum* and *Gliocladium virens* has been reported by Sharma and Dohroo (1991). Pandey *et al.* (1992) tested several antagonists for the biological control of rhizome rot of ginger caused by *F. oxysporum. Agave americana* extract was found to be very effective in controlling the disease under laboratory and field conditions, followed closely by culture filterate/extracts of *Bacillus subtilis, Cannabis sativa, Lyonia ovalifolia* and *Aspergillus niger.* The percent reduction of infection over control were 75.9, 69.4, 58.5, 54.7 and 52.0, respectively.

According to Rathore *et al.* (1992) *T. viride* produced non volatile substances which inhibited the growth of ginger rhizome rot pathogen *P. myriotylum* and *F. solani* by 70 and 10%, respectively, when these organisms were grown on media plates previously used for *T. viride.* Production of *P. myriotylum* oogonia was also inhibited. Volatile substance produced by *T. viride* completely inhibited growth of *P. myriotylum* but reduced the colony diameter of *F. solani* by only 3.4%. Balakrishnan *et al.* (1997) reported that suppression of *P. aphanidermatum* caused rhizome rot of ginger by *Aspergillus niger, A. terreus, Penicillium spp.* and *Absidia cylindrospora.* The former three fungi inhibited *P. aphanidermatum* by upto 100% by producing fungitoxic non volatile metabolites. *A. cylindrospora* expressed mild inhibition (7.03%), *A. cylindrospora* and *P. aphanidermatum* also exhibited mutual overgrowth in dual culture. *A. niger* showed good protection against rhizome rot. The severity of rhizome rot infection was low when infected soil was tested with *A. terreus, Penicillium* spp. and *A. cylindrospora.* The highest yield was recorded with *A. niger.*

Usman *et al.* (1997) tested twelve isolates belonging to eight species of *Trichoderma* and also isolates of *G. virens* for their bio-control

efficacies and mode of action on *P. aphanidermatum*, the causal organism of rhizome rot of ginger. Considerable variations were noticed among these isolates and only *T. hamatum* (ISO2) showed typical inhibition of the pathogenic fungus in dual culture tests.

Shanmugam *et al.* (1999) made attempts to isolate the native micro-organism antagonistic to *P. aphanidermatum*, the cause of rhizome rot of ginger and screen their efficacies against the pathogen under *in vitro* conditions and in pot culture. The study of the rhizosphere microflora revealed the presence of *Rhizopus sp., Aspergillus carneus, A. niger, A. flavus, Eupenicillium javanicum, T. viride, T. harzianum and Bacillus spp.* Dual culture of these organism with *P. aphanidermatum* indicated that only *T. harzianum* and *T. viride* were potential antagonists.

Shanmugam and Varma (1999) isolated native microorganisms from the rhizosphere of healthy ginger plants in the rhizome rot affected field and screened *in vitro* experiments for their antagonistic effects against the pathogen *P. aphanidermatum* by dual culture and cell free culture filtrate. *Aspergillus niger, A. fumigants, A. flavus* and *T. viride* were found to be potential antagonists.

2.5.1.3 *In vitro test with* organic amendment

Kaushal and Siddiqui (2003) evaluated *in vitro* efficacies of water soluble extracts of oil cakes of groundnut (*Arachis hypogaea*), Margosa (*Azadirachta indica*), Mahua (*Madhuca indica*) and Castor (*Ricinus communis*) at 1.25, 2.50, 5.0 and 10% (w/v) against the rhizome rot of ginger caused by *F. oxysporum f.sp. zingiberi*. The extract of oil cakes of castor was most effective in all concentration followed by groundnut oil cake extract at 10%. The extract of Mahua cake was least effective.

2.5.2 VARIETAL SCREENING

Limited reports on varietal resistance against rhizome rot of ginger is available in literature. Resistance of the ginger variety, Maran against *P. aphanidermatum* has been reported from Kerala state (Indrasenan and Paily, 1974).

Indrasenan *et al.* (1982) reported susceptibility of almost all the ginger varieties against the bacterial wilt pathogen, *Ps. solanacearum.* Ali *et al.* (1995) screened the available genotypes against *Pythium spp.* (*P. aphanidermatum, P. deliense* and *P. myriotylum*). The cultivar, SG 600 was recorded to be resistant with only 8% mortality as compared to 42.92% mortality in the local cultivar.

Setty *et al.* (1995) from Kernataka state screened the total of 18 cultivars/ varieties under field conditions for resistance against rhizome rot caused by *Pythium spp.* The varieties, Suprabha and Himachal Pradesh recorded least (< 3%) disease incidence.

2.5.3 Soil Solarization

Ai *et al.* (2001) studied the effect of coloured plastic film mulches on the growth and yield of ginger and the results indicated that the mulches reduced the soil temperature and preserved the moisture. Compared with control, the soil temperature under black and gray film mulch were not markedly different, whereas the soil moisture content were enhanced by 3.57% - 5.02% and 3.28% - 4.68%, respectively. Mathur *et al.* (2002) studied integration of soil solarization and pesticides for management of rhizome rot of ginger in non-solarized fields. Seed treatment with Ridomil MZ @ 6.25 g/L and soil application of Phorate @ 10 g/sq.m plus Ridomil MZ @ 10 L/plot drench significantly reduced the 3.7% rotting. In the solarized field, Ridomil MZ seed dressing plus drench, and Ridomil MZ seed dressing plus Phorate application and Ridomil MZ drench resulted in less disease (2.6-4.2%) and higher yield (1.6 – 1.36 kg) over untreated control.

Mohan *et al.* (2004) attempted solarization of soil by mulching with 100 micro meter thick polythene sheet. The mulching increased the soil temperature by 6.0-12.7°C more as compared to non-mulched soil. This heating of soil was found to be effective in controlling the disease due to greater reduction in soil propagules of *F. oxysporum f.sp. zingiberi.* In solarized plots, there was a considerable increase in seed germination, plant

height and yield and greater reduction in disease incidence (88.18%) over solarized plot.

2.5.4 *In vivo* tests

2.5.4.1 Rhizome treatment with fungicides

Sarma *et al.* (1978) made field assessment of systemic and contact fungicides in the control of rhizome rot pathogen, *P. aphanidermatum* and recorded all the nine fungicides tested to increase rhizome yields, the best being Dithane Z-78 (zineb), followed by captan and difolatan (captafol).

Sharma and Dohroo (1982) reported control of rhizome rot caused by *P. pleroticum* and *F. equiseti* through rhizome dip treatment in 0.2% solution of Dithane M-45 (mancozeb) or Daconil (chlorothalonil) under field conditions. Dohroo *et al.* (1984) conducted field trials during *kharif,* 1981 and 1982. The fungicides used were zineb (Dithane Z-78), zinopropylene bis dithiocarbamate (Antracol), mancozeb (mancozeb) (BPM), copper oxychloride (fycop) (Rallis India), 5-ethyl N-(dimethy-amino propyl), thio carbamate hydrochloride (previcur 70) and metalaxyl (Ridomil 5 G) Ridomil 5G was recorded to be the most effective fungitoxicant in controlling the disease as well as in increasing rhizome yield during both the years.

According to Mathur *et al.* (1984) rotting caused by *P. aphanidermatum* and *F. solani* was best reduced by Bayletan (triadimefon) followed by fenaminosulf, Difolatan (captafol), syllit (dodine) and Ridomil (metalaxyl). All the test compounds reduced germination when rhizomes were dipped for 4-24 hours but increased it after only 2 hour with the exception of Blitox 50 (copper oxychloride). Dohroo and Sharma (1985 a) reported efficacies of chemicals such as, Antracol (propineb 0.25%), Fycop and Blitox 50 (copper oxychloride 0.3%) against rhizome rot when used as 30 minutes dip treatment for rhizomes.

Ojha *et al.* (1986) obtained complete control of bacterial wilt caused by *Pseudomonas solanacearum* by rhizome treatment with Emisan 6 + Plantomycin for 30 minutes followed by 3 sprayings, the first 30 days after

planting and thereafter at intervals of 15 days. While working on soft rot disease of ginger Abraham *et al.* (1988) from Andhra Pradesh obtained maximum germination and lowest incidence of pre-emergence rhizome rot following seed rhizome treatment with captafol.

Thakore *et al.* (1988) spray inoculated seed rhizomes of ginger with *P. aphanidermatum* and treated with six nonsystemic and four systemic fungicides prior to sowing. Dithane M-45 (mancozeb), Difolatan (captafol), ziride, captan and metalaxyl reduced infection, increased germination and also increased yield. Panoctin (guazatine) reduced rotting but also reduced seed germination. Dohroo (1989) evaluated seed rhizome treatments and recommended pre sowing dip of seed rhizomes in Bavistin @ 0.1% for 60 minutes for the management of ginger yellows caused by *F. oxysporum f.sp. zingiberi*. Das *et al.* (1990) evaluated efficacies of fungicides for seed treatment against pre emergence rhizome rot of ginger. Seed rhizome treatment with captan 0.2%, captafol 0.2% and Dithane M-45 0.3% were at par with each other in respect of germination percentage and incidence of pre emergence rhizome rot. However, seed treatment with captan 0.2% for 30 minutes recorded a numerically higher percent germination (93.35%) and lower incidence of pre emergence rhizome rot (6.65%). Continuing the work further, Das *et al.* (2001) showed that Ridomil MZ-72 @ 0.1% effectively reduced the disease with only 18.63% disease incidence. Ridomil MZ-72 treated rhizome showed maximum germination as well as the highest yield.

Raj *et al.* (2004) tested six antibiotics and three fungicides for the management of bacterial wilt of ginger in hilly areas of Darjeeling where the disease was most prevalent. Among the six antibiotics tested as seed protectant, terramycin @ 500 ppm gave good result in term of percent plant mortality (11.11%) and yield (175 q/ha) followed by streptocycline and chloramphenicol @ 500 ppm. Griseofulvin, Ledermycin and Penicillin also reduced plant mortality but the efficacy was less than terramycin and streptocycline. Singh *et al.* (2004) reported highest seed germination

(96.50%), rhizome yield (250.25 q/ha) and lowest disease incidence (5%) following spray application of Ridomil MZ (0.3%) under field conditions.

2.5.4.2 Rhizome treatment with biocontrol agents

According to Dohroo and Sharma (1985 b) pre storage dipping or steeping rhizomes in *T. hamatum* suspension or smearing of rhizomes with *T. viride* proved effective against *F. equiseti*. They also observed treatment of rhizomes with *T. viride* to give 80% control of rhizome rot caused by *P. pleroticum* and *F. equiseti*. Bhardwaj *et al.* (1988) reported control of rhizome rot of ginger caused by *P. aphanidermatum* during storage by three *Trichoderma spp.* to varying degrees. Of the various treatments tried, steeping inoculated rhizomes in a spore suspension of *T. viride* or smearing with *T. hamatum* was quite effective against *P. aphanidermatum* on seed rhizome. Good control of *F. equiseti* rot was given either by pre storage steeping of inoculated rhizomes in *T. harzianum* suspension or by smearing with *T. viride*.

Shaktawat (1987) and Ram (1988) reported significant suppression of rhizome rot of ginger by either pelleting the rhizome seed with *T. viride* or soil amendment of this bio agent just before sowing. Ram *et al.* (1997) tested two BCAs viz., *T. harzianum* and Fluorescent pseudomonad for the biological control of rhizome rot caused by *F. solani* and *P. myriotylum*. The BCAs were introduced into the soil when the ginger was planted and control was assessed 100 days later. Both agents multiplied in the soil and rhizosphere and inhibited the growth of pathogens. Soil application of bio control agents was more effective than treatment of the planting materials.

2.5.5 Soil application

2.5.5.1 Manuring

Rai *et al.* (2002) evaluated the effect of nitrogen dosages on rhizome rot disease caused by *P. aphanidermatum* in a field trial. The minimum disease incidence of 15% and maximum yield of rhizomes i.e. 261.25 q/ha was recorded at the nitrogen dose of 75 kg/ha. Singh *et al.*

(2004) investigated the effects of rhizomes size and nitrogen dosage on incidence of rhizome rot caused by *P. aphanidermatum*. The highest disease severity (5%) and minimum yield of rhizomes (81.60 q/ha) were recorded when fingers (5-10 g) were used as planting stock. Planting of full rhizomes (50-60 g) resulted in minimum disease severity (3%) and maximum yield (130.32 q/ha). The number of tillers per plant (12), disease incidence (28.25%) and yield (265 q/ha) were maximum with 70 kg N/ha. Rao *et al.* (2004) tested nine different combinations of nitrogen and potash fertilizer and three different spacings on incidence of rhizome rot caused by *P. aphanidermatum*. Rhizome rot incidence was significantly greater (26.1%) on plant grown in plot treated with nitrogen and potash (N_{100} kg K_{100} kg/ha) applied as urea and muriate of potash, respectively, than other N, K combinations irrespective of different plant spacing with increasing level of N upto 150 kg/ha and lower level of K @ 100 kg/ha reduced the disease incidence significantly (10.8 to 10.2%) irrespective of plant spacing. N and K interactions showed higher spacings of 25 cm row to row and 20 cm plant to plant, medium nitrogen level 150 kg/ha and lower K (100 kg/ha) reduced the disease incidence significantly than other treatments. Combination in lower spacings 20 cm row to row and 15 cm plant to plant, higher N (200 kg/ha) and lower K (100 kg/ha) produced maximum yield (14.82 t/ha).

2.5.5.2 Organic amendments

Singh and Pandey (1966) studied the effect of soil amendment with plant residues and compost on population of *P. aphanidermatum* in the laboratory. Amendment with dry straw of wheat (C:N = 58:1) and dry maize cob maize powder (C:N = 131:1) as well as green leaves of neem (*Azadirachta indica*), bhang (*Cannabis sativa*) and bakaian (*Melia azadirachta*) @ 5% (w/w) suppressed development of *Pythium* in soil. Sadanandan and Iyer (1986) studied the effect of organic amendments on rhizome rot of ginger and recorded lowered disease incidence and increased yield of rhizomes following amendments with Neem cake. The authors also determined the effect of amendments of FYM on soil nutrient status.

Thakore *et al.* (1987) reported reduction of rhizome rot caused by *P. aphanidermatum* and *F. solani* following soil amendment of cake made from *Azadirachta indica , Calophylum inophyllum* or *Pongamia glabra* (*P. pinnata*). The maximum yield increase was given by cakes made from *P. glabra* followed by *Hibiuscus sabdariffa* and *Brassica campestris.* For integrated management of root knot Nematode (*M. incognita*) infecting ginger, soil amendment with poultry manure and saw dust (24, 26.48 t/ha) with urea 0.1800 kg N/ha, Neem cake @ 2.5 t/ha before planting, Carbofuran @ 1.0 kg before planting has been reported by Steriling (1989) and Mohanty *et al.* (1992).

Dohroo *et al.* (1994) reported minimum incidence of rhizome rot in soil treated with Pinus needle and neem cake powder. The population of root knot Nematode (*Meloidogyne* spp.) was reduced to 74%. The population of bio-agents viz., *Trichoderma* spp. and *Gliocladium* spp. were maximum in soil treated with neem cake and Pinus needle. Dohroo and Gupta (1995) reported reduction in the incidence of damping off, wilt, blight and rots of cotton, soybean, coconut and ginger. Increased population of biological control agents were found during decomposition of oil cakes by the release of acids and other chemicals.

Mohanty *et al.* (1995) reported suppression of the root-knot nematode (*M. incognita*), disease intensity and increased yield of ginger following pre-planting application of neem cake (1 t/ha) followed by post-planting application of Carbofuran (1 kg ai/ha) 45 days after planting. According to Vadhera *et al.* (1998) amending the soil with different oil cakes was effective in reducing soil population of *M. incognita* as well as for reducing root gall formation in ginger grown in Madhya Pradesh, India. The highest yield and maximum reduction in soil population was recorded in neem cake treated plot. Denematization of ginger rhizome at 45°C for three hours + summer ploughing and covering the soil with polythene in May (15-30) gave high yield and reduced nematode population.

Vudhivanich and Sasitorn (2002) studied the effect of soil amendment with urea and calcium oxide on the survival of *R. solanacearum,*

the causal agent of bacterial wilt or rhizome rot of ginger. Population of *R. solanacearum* in the soil amended with urea and calcium oxide decreased from 0.88 x 10^7 Cfu/ml to 0.15 x 10^5 Cfu/ml in week one, 0.1 10^4 Cfu/ml in week 2 and 0 Cfu/ml in week 3. The control treatment still contained high population levels of 0.26 x 10^7 Cfu/ml in week one, 0.13 x 10^6 Cfu/ml in week 2 to 3 and 0.11 x 10^6 Cfu/ml in week 4. This population level could cause typical wilt of tested gingers. Amaresh *et al.* (2004) reported lowest incidence (22.92%) of rhizome rot caused by *P. aphanidermatum* following soil amendment with Neem cake @ 2 t/ha. The above treatment also recorded highest rhizome yield (32.91 q/ha).

2.5.5.3 Fungicides

Soil application of Bordeaux mixture (2:2:50) has been reported to be quite effective against rhizome rot caused by *P. myriotylum* and *P. aphanidermatum,* respectively (Bhagwat 1960; Shahare and Asthana, 1962). Ichitani (1980) recorded comparatively lower incidence of rhizome rot caused by *P. zingiberi* in the field fumigated with methyl bromide.

Sharma *et al.* (1980) obtained highest germination of rhizomes inoculated with *P. aphanidermatum* after drenching the soil with Dithane Z-78 and Difolatan, while evaluating the efficacies of soil applied fungitoxicant against wet and dry rot of ginger caused by *P. pleroticum* and *F. equiseti.* Dohroo *et al.* (1984) from Himachal Pradesh reported Ridomil 5G to be most effective in controlling the disease as well as in increasing the yield of rhizomes.

Doshi and Mathur (1987) reported significant increase in the germination of seed rhizomes following soil drenching with Aliette (Fosetyl Al). Pre and post-drenching rotting was minimum following treatment with Aliette, Bordeaux mixture, Dithane M-45 (Mancozeb) and Difolatan (Captafol). These fungicides also increased yield of fresh rhizomes significantly. Srivastava (1992) from Sikkim reported efficacies of combined treatment of soil drenching with Zineb or Mancozeb, rhizome treatment with Carbendazim and incorporation of Thiodan (Endosulfan dust) into the soil

against rhizome rot caused by *P. aphanidermatum*. Jacob *et al.* (2002) reported reduced incidence of rhizome rot following combined soil application of Phorate (1.25 g/m^2) and Triademefon or Benomyl or Bitertanol 1 g/L each or copper oxychloride 3 g/L.

2.5.5.4 Biocontrol agents

Ram *et al.* (1997) tested two biocontrol agents viz., *T. harzianum* and *Pseudomonas fluorescens* for the biological control of rhizome rot of ginger caused by *F. solani* and *P. myriotylum*. The BCAs were introduced into the soil when the ginger was planted and control was assessed 100 days later. Both agents multiplied in the soil and rhizosphere and inhibited growth of pathogens. Soil application of BCAs was more effective than treatment of planting materials.

Rajan *et al.* (2002) reported *T. harzianum* isolated from Sikkim to be effective in the control of rhizome rot substantially. *T. harzianum* was incorporated into the soil @ 50 g/pot at the time of planting.

2.5.5.5 Mulching

Mishra and Mishra (1982) reported suppression of early weed growth, increased crop emergence, improved growth and higher yield following mulching of ginger plots with dried leaves or straw. Pre-emergence application of 2,4-D at 1 kg a.i./ha or Atrazine at 1 kg/ha was as effective as four hand weedings, 2,4-D or Atrazine with mulching recorded highest yield and highest net return. Das (1999) from Orissa used green leaves of Mahaneem (*Melia azadirach*), Karanj (*Pongamia glabra*), Acacia (*Acacia arabica*), Eucalyptus (*Eucalyptus citriodora*) and mango (*Mangifera indica*) @ 2.5 kg m^2 or paddy straw and paddy husk @ 2 kg m^2 in three split dosages of 6:2:2 as mulching once immediately after sowing and two other after first and second intercultural operation and top dressing at 45 and 90 days, respectively. Among the treated plots highest germination percentage and maximum tillers per individual clump were observed in paddy straw mulching but lesser rhizome yield and greater number of root galls along with final nematode population than the plots treated with mango leaves.

Karanj leaves and Mahaneem leaves indicated the possible nematicidal properties of these plants. Among the green leaf mulched plot, the Mahaneem leaf was found to be having significantly more nematicidal potentiality over other with reduced number of root galls and nematode multiplication rate. That was the only treatment where the final soil nematode population was much below the initial level and the plot was absolutely free from rhizome rot incidence.

Senapati *et al.* (2006) evaluated combined efficacies of three (Neem, Karanj and Niger oil cakes) and four (Mahaneem, Neem, Acacia and Eucalyptus) leaf mulches against rhizome rot disease complex of ginger using the susceptible variety, PGS-19 at Potangi, Orissa. Three years pooled mean indicated that Karanj cake + Mahaneem leaf mulch was the most effective treatment with minimum disease intensity (8.33%) and maximum rhizome yield (13.36 t/ha). Rhizome emergence was highest (96%) in Mahaneem mulch treatment.

2.5.6 Integration

2.5.6.1 Seed treatment plus soil application of fungicides

Ichitani (1980) reported reduction in the incidence of rhizome rot caused by *P. zingiberum* by pre-treating seed rhizomes with echlomezol (etridiazole) and by methyl bromide soil treatment. The spread of disease was prevented with a soil drench of echlomezol around source of primary infection. Sharma *et al.* (1980) reported highest germination of ginger rhizomes artificially inoculated with *P. aphanidermatum* by soil drenching with Dithane Z-78 and Difolatan and highest yield with Blitane (Zineb + Copper oxychloride), Dithane Z-78 and Difolatan when used as drenches or drenches plus seed treatment.

Rathiah (1987) observed that dipping or wetting of seed pieces one day before planting and soil drenching with a mixture of Ridomil + Captafol three months after planting controlled rhizome rot and increased the yield of ginger.

Kumar *et al.* (1989) reported best control of rhizome rot disease caused by *F. oxysporum* following soil treatment with 4% Formaldehyde combined with treatment of seed rhizomes with Topsin M-70 (thiophonate methyl) at 0.1%. Ramchandran *et al.* (1989) tested five systemic fungicides, namely Fosetyl Al, Metalaxyl, Oxadixyl, Propanocarb and ethazole were evaluated against rhizome rot disease of ginger caused by *P. aphanidermatum*. The fungicides were tested as soil and seed treatment and by raising the plant in fungus infested soil. Of the fungicides tested Metalaxyl formulation, namely Ridomil 5G granules and Apron 35 WS gave the best control of disease.

Srivastava (1994) managed soft rot caused by *P. aphanidermatum* in Sikkim effectively by drenching the soil with Zineb or Mancozeb following rhizome treatment with Carbendazim and incorporating thiodan dust into soil to control insect invasion.

Das *et al.* (1997) evaluated two antibiotics viz., Gentamycin and Streptocycline, Bordeaux mixture and cowdung slurry for the management of bacterial wilt of ginger caused by *Ps. solanacearum* in a sick plot using infested seed rhizomes for three consecutive seasons. Drenching the beds with 1% Bordeaux mixture four times at monthly intervals commencing from significantly reduced wilt incidence to 36.63% and increased the yield of rhizome.

Sharma *et al.* (1980) tested nine fungicides viz., Dithane Z-78, Difolatan, Captan, Tafasan, Blitox-50, Bavistin, Kitazin and Demosan in field for 3 years. The fungicide were applied as seed treatment, soil drench and seed treatment + soil drenching. The germination increased in all the treatment except in Blitox 50 in which it was lower than the check. The highest germination was found when rhizomes were treated with Benlate, Dithane Z-78 and Tafasan. Germination was also above 85% when soil drenching was done with Difolatan, Demosan, Dithane Z-78 and Captan. Minimum rotting was observed in Blitane when it was used as seed treatment, seed treatment plus soil drenching and soil drenching alone

followed by Difolatan, Captan and Dithane Z-78 when used as seed treatment plus soil drenching and as soil drenching only.

Mathur *et al.* (2002) studied integration of soil solarization and pesticides for management of rhizome rot of ginger. In non-solarized field, seed treatment with Ridomil MZ @ 6.5 g/L and soil application of Phorate @ 10 g/sq. m plus Ridomil MZ @ 10 L/pot drench significantly reduced the disease recording only 3.7% rotting. In the solarized field, Ridomil MZ seed dressing plus drench and Ridomil MZ seed dressing plus Phorate application and Ridomil MZ drench resulted in less disease (2.6 – 4.6%) and higher yield (1.6 – 1.36 kg) over untreated control.

2.5.6.2 Bioagent plus Fungicide

While working on integrated management of ginger yellows, Dahroo (1995) reported reduction in disease incidence and increased yield of rhizomes following seed treatment in a solution of Mancozeb 0.25% and Carbendazim 0.1% for 60 minutes. The affect of seed treatment with fungicides as above further increased when BCAs were used either alone or in combination at the time seed bed preparation. The author found that fungicidal seed treatment and BCAs i.e., *T. harzianum* and *T. hamatum* each at 350/3m^2 decreased the incidence of yellows and increased the yield significantly. Ram *et al.* (1999) evaluated the efficacy of *Pseudomonas* species alone or in combination with *T. harzianum* and also with fungicidal rhizome treatment. Combination of both BCAs resulted in better germination and plant stand, reduced disease incidence and increased yield. Soil application of BCAs was found to be more effective as compared to seed treatment. Integration of soil application of BCAs with fungicidal rhizome treatment [Bavistin + Ridomil MZ (Metalaxyl + Mancozeb] increased the efficiency of disease control as compared with their individual treatments. Soil application of *T. harzianum* and rhizome treatment with Pseudomonas species and fungicide was most effective among all the tested treatment.

Beena and Sarma (2000) reported seed treatment with Metalaxyl (Ridomil MZ) and soil application of *T. harzianum* to be effective in the

suppression of rhizome rot. Das *et al.* (2001) studied the effect of different varieties and fungicides against rhizome rot. The authors examined six varieties of ginger along with five fungicidal treatments. They observed that 'Maran' variety yielded 114.08 q/ha which was followed by Rio de-Janeiro (106.47 q/ha). Percent disease incidence recorded was less in these two varieties which showed highest germination. Effect of different fungicides on disease incidence showed that Ridomil MZ-72 @ 0.2% effectively reduced the infection with only 18.63% disease. Ridomil MZ-72 treated rhizome showed maximum germination as well as the highest yield. The above treatment was followed by Copper oxychloride @ 0.3% Bordeaux mixture @ 1%, Mancozeb (Indofil M-45) @ 0.25% and Captan @ 0.25%. Dohroo (2001) recorded best management of rhizome rot by integrated practices of rhizome treatment with fungicide (Dithane M-45 and Bavistin) and the bio-agent *T. harzianum.*

Jayasekhar *et al.* (2000) evaluated fungicidal seed ginger treatment as well as BCAs (*T. harzianum* + neem cake or *T. viride* + neem cake) which were incorporated in FYM and applied to the soil prior to sowing. All the tested fungicides and BCAs exhibited effectiveness against rhizome rot caused by *P. aphanidermatum* and increased rhizome yield. Metalaxyl MZ @ 0.1% recorded lowest disease incidence (4.23%). Cost benefit ratio was highest (1:2.85) with *T. harzianum* + neem cake application followed by 0.1% Metalaxyl (1:2.71). Meena and Mathur (2003) used three BCAs i.e., *T. viride, G. virens, Ps. fluorescens* and an effective fungicidal mixture of Ridomil MZ (Metalaxyl) 6.25 g and Bavistin (Carbendazim 50 WP) 2 g/L for treating seed rhizomes and soil individually and in combination for the suppression of rhizome rot caused by *F. solani* and *P. myriotylum.* Crop and disease parameters such as crop stand, rhizome yield, rotting percentage and pathogen suppression in the rhizosphere were determined. Pelleting of seed rhizomes with BCAs was not found effective. Pelleting either with fungicidal mixture or BCAs combined with soil application of BCAs were effective in suppressing the disease and increasing the yield. In the

rhizosphere pot study, integrated approach resulted in reduction of inoculum density of *F. solani* and increased in the BCAs population. Rhizome seed treatment with fungicidal mixture followed by soil application of *G. virens* was the most effective treatment and superior to all other treatments.

Kulkarni *et al.* (2006) recorded minimum rhizome rot incidence of 6.85% and maximum fresh rhizome yield of 10150 kg/ha following rhizome treatment with Metalaxyl MZ (0.6%) plus soil application of talc based *T. harzianum* (10 kg powder mixed with FYM/ha) plus soil application of *Eupatorium* as green manure and soil drenching with Copper oxychloride (0.3%).

CHAPTER-3

MATERIALS AND METHODS

All the investigations on rhizome rot of ginger (*Zingiber officinale* Rosc.) occurring in the Chotanagpur region of Jharkhand state were carried out in the laboratory, glasshouse of the Department of Plant Pathology and Research Farm of Birsa Agricultural University (BAU), Ranchi. Field trials were conducted during Kharif, 2003-2004 and 2004-2005 crop seasons.

Geographically BAU Ranchi is located between 27°17′ north latitude and 85°19′ east longitude in the Chotanagpur region of Jharkhand state at an altitude of 625 meter above the mean sea level.

3.1 SURVEY AND SURVEILLANCE

Surveys were undertaken during Kharif, 2003-04 & 2004-05 crop seasons in ginger growing areas adjoining Kanke in order to record incidence of rhizome rot disease and also for collection of both plant and soil samples for further laboratory examination work for identification of causal pathogen(s).

For survey work, one farmer each in eight localities viz., Kanke, Boreya, Sukurhuttu, Pithoria, Ratu, Itki, Namkom and Ormanjhi were identified. The identification of farmers was made on the basis of total area under ginger cultivation. Survey visits during both the crop seasons were made by the end of June, July, August and September months. Visits during the month of June was made to record the total number of plants in 3m x 3m area in ginger plots. Further visits were made to record the number of infected plants showing characteristic above ground symptoms. Percentage incidence of rhizome rot disease was calculated on the basis of total number of plants infected by the end of September each year.

3.2 SYMPTOMATOLOGY

Experimental plots of ginger were visited frequently to record the initiation and further development of symptoms on above ground plant parts. The expression of symptoms during different growth stages were recorded and described.

Symptoms on rhizomes were recorded after harvest of the crop. The rhizomes were washed in running tap water and examined for disease symptoms.

Symptoms on rhizomes were also recorded from samples drawn from the market and those stored in warehouses. Infected plant parts of ginger showing prominent symptoms were photographed.

3.3 COLLECTION OF DISEASED SAMPLES

Diseased plants with early but well established symptoms were selected from several sites of farmers fields. The infected plant samples were packed in paper bags and labeled including the place and date of collection and other useful informations and brought back to laboratory for microscopic examination, isolation of causal pathogen and other laboratory studies.

3.4 LABORATORY STUDIES

The diseased samples were first washed with running tap water to remove any adhering inert materials. This was followed by washing with 3-4 changes of sterilized distilled water. Small pieces of infected plant parts together with adjoining healthy portion were disinfected with 0.1 percent Mercuric chloride for one minutes and washed thoroughly in sterilized distilled water. Some pieces were placed in humid chamber for development of fructifications/sporulation and afterwards were examined with the help of binocular compound microscope for the micro-organism(s) associated with diseased samples. Preliminary examinations were carried out with water mount of scrappings from infected tissues. The same materials were examined by mounting in a drop of glycerol on glass slides.

3.5 CULTURAL METHODOLOGIES

3.5.1 Sterilization of glasswares

Glasswares required for various experiments such as Petri-dishes, Conical flask, Pipettes, Test tubes, thistle funnels etc. were first washed with a cleaning powder in tap water. After that these glasswares were treated with strong cleaning solution prepared in the ratio of 20 gm $K_2Cr_2O_7$: 1000 ml water : 160 ml concentrated H_2SO_4. Again the glasswares were washed thoroughly first in running tap water and finally with sterilized water as described by Ricker and Ricker (1936) and Tuite (1969).

Inoculation needle was sterilized by dipping in spirit and heating over flame of spirit lamp until red. To ensure proper sterilization the same process was repeated two to three times. The inoculation transfers were carried out within laminar flow. It was first cleaned with cotton dipped in formalin solution. Then it was subjected to ultraviolet light for five minutes by closing the door of the chamber.

Forceps were also sterilized in the above manner and used to transfer the specimen from one place to another. Cork borer was also sterilized in the above manner and exclusively used for cutting the disc of desired diameter (generally 3 mm disc) of the inoculum to be inoculated on media wherever required.

3.5.2 Sterilization of earthen pots

The earthen pots were washed thoroughly with water rinsed with two percent Formalin and dried in the sunlight before use. The earthen pots containing soil was sterilized for three consecutive days in an autoclave at 15 lbs/sq. inch pressure for 30 minutes. Sterilized pots were filled up with the sterilized soil and covered with sterilized polythene sheets in order to prevent aerial contaminations.

3.5.3 Composition of media stains and method of preparation

Potato Dextrose Agar (PDA) :

Potato	:	200 g
Dextrose	:	20 g
Agar-Agar	:	20 g
Distilled water	:	1000 ml

For preparation of PDA, peeled potatoes (200 g) were cut into thin slices and boiled in 500 ml of distilled water for 15 minutes. It was then filtered through Muslin cloth and the filtrate was taken in the flask. In another flask 500 ml of distilled water was taken. Twenty gm of Agar-Agar powder and 20 g of Dextrose was added and boiled. Potato extract filtrate and boiled Agar-Agar and Dextrose were mixed thoroughly and distilled waster was added to complete final volume of 1000 ml. The flask was plugged with non-absorbent cotton and then sterilized with the help of Autoclave at 15 lbs/sq. inch pressure for 15 minutes. The medium was then cooled down to 45°C and about 5-8 ml poured into each test tube of 10 ml capacity and 20 ml to each Petri-plates of 90 mm diameter. The test tube were sterilized in an autoclave following routine procedure (Tuite, 1969).

Malt extract liquid medium :

Malt extract	:	20 g
Water	:	1 lit

Heat 20 g extract in 1 lit. of water until dissolved.

***Trichoderma* selective medium** I

Glucose : 3 g

$NH_4 NO_3$: 1 g

KCI : 0.15 g

$K_2H PO_4$: 0.9 g

$Mg SO_4 7 H_2O$: 0.2 g

Agar : 15 g

Water : 1 lit

After autoclaving add 250 mg chloramphenicol, 300 mg fenaminosulf, 200 mg quintozene and 150 mg Rose Bengal.

Nutrient Agar Media (for cultivation of bacteria) :

Glucose	:	2.5 gm
Peptone	:	5.0 gm
Beef extract	:	3.0 gm
Agar-Agar	:	15 gm
Distilled water	:	1000 ml

Weighed quantities of Peptone, Beef extracts and Agar-Agar were thoroughly mixed in distilled water, boiled for half an hour and then sterilized in an autoclave as above.

Tetrazolium Chloride Agar (TZCA)

Peptone	:	10 g
Cosein hydrolysate	:	1 g
Glucose	:	5 g
Agar	:	15 g

2,3-5-triphenyl tetrazolium chloride – 0.05 g

Gram Staining

Hucker's ammonium oxalate crystal violet strain

Solution-A

Crystal violet	:	2 g
Alcohol (95 %)	:	20 ml

Solution-B

Ammonium oxalate	:	0.8 g
Distilled water	:	80.0 ml

Mixed solution A and B

Grams iodine solution

Iodine	:	1 g
Potassium iodide	:	2 g
Distilled water	:	300 ml

Dissolved weighed quantity of Iodide and potassium iodide in water.

Gram staining Procedure

The smears were fixed by passing the slide over the flame for two or three times. The slides were covered with Gentian violet for 1 to 2 minutes and washed with Lugols iodine. Decolorized the slide with alcohol and immediately washed with water. Counter stained with 0.5 % aqueous Safranin solution or dilute Carbol fuchsin (1:20) for 1 to 2 minute and finally washed the Smear, allowed to dry in air.

Preparation of Smear

For preparation of Smears, sterile distilled water was slowly poured on to the culture tube without disturbing the bacterial growth and allowed the culture tube to stand undisturbed for 2-3 minute. In a clean sterilized Pipette, sucked small amount of bacterial suspension was sucked and put a drop of suspension on upper end of slide in slanting position. Allowed the drop to near down and air-dried at room temperature. As the smear dried the Smeared area with a pencil on opposite surface of the slide.

Safranine Solution

Safranine	:	0.5 g
Distilled water	:	100 ml

Flagella staining procedure

The principle involved in staining flagella is to get a heavily distribution of stain on these with the help of mordants like Tannic acid, potassium aluminium sulphate and Mercuric chloride. To prepare bacterial smears, the slide should be absolutely greeze free. Twelve to eighteen hrs growth on slant on a nutrient agar medium is used for preparation of smear. To prepare a smear, sterile distilled water is poured slowly into the culture tube without disturbing the bacterial growth. A clean sterilized pipette was lowered slowly into the bacterial suspension to allow a small amount of the suspension to be sucked in automatically. A drop of suspension is allow to run down and the slide is air dried at room temperature.

Staining Solution (Gray's method)

Solution-A

Mercuric chloride	:	2.0 ml
Tannic acid	:	2.0 ml
Aluminum potassium sulphate	:	5.0 ml

Solution-B

Basic fuchsin	:	0.4 ml

Ziehl Nelson's Carbol Fuchsin Stain

Basic fuchsin	:	0.3 g
Alcohol	:	70.0 ml
Phenol crystal	:	5.0 g
Distilled water	:	95.0 ml

Staining schedule

1. Smear was prepare on clean slide as described above.
2. Modrant solution was filtered and smear was covered with the solution and allow to act for 8-10 minutes.
3. The slide was washed with distilled water.
4. Smear on the slide was covered with filtered Ziehl Nelson's carbol Fuchsin Stain and allowed for 5 minutes.
5. The slide was washed in tap water, air dried and examined under oil emersion objective.

3.5.4 Isolation of Pathogens

From infected plant tissues

Routine isolation of fungal pathogens were made on PDA. Infected plant parts viz., Rhizomes, leaves, pseudostem of ginger showing characteristic symptoms of the disease were used. The infected parts were first washed by passing it through running tap water. Diseased part of 2-5 mm size just touching the healthy portion were chosen and cut into small pieces with a sterilized knife. These pieces were washed thoroughly in sterilized water to remove surface contaminants, if any. These tissues were surface sterilized with 1 percent Mercuric chloride for 45 second. After

sterilization these pieces were washed in three to four changes of sterile water to remove Mercuric chloride residues. Excess moisture was removed by keeping the pieces suppressed between two folds of sterilized blotting paper. The pieces were planted on PDA slant with the help of sterilized inoculating needle and incubated at 28±1°C for growth pathogen(s). As soon as the mycelium growth was visible around the planted pieces, hyphal tips were transferred to sterilized medium previously poured into sterilized petri-plates. After isolation, the petri-plates were left for ten days for sporulation. Pure culture of pathogens were maintained by regular transfer for further studies.

Bacterial pathogens were isolated following Streak plate method on Nutrient Agar media. Infected pseudostem were cut into 3.4 cm long pieces and surface sterilized with 1 percent Mercuric chloride solution for 30 seconds. The pieces were washed in sterile distilled water and dried on sterile blotting paper. The individual pseudostem were placed in a test tube/conical flask containing sterile distilled waster. Bacterial Ooze emerged and from cut ends which was visible to the necked eye. After 3-5 minutes, a loopful of suspension from the Ooze was taken and streaked on to Nutrient Agar medium in petri-plates. The streaking was done in two more plates without recharging the wire loop with bacterial suspension. Incubated the petri-plates in an inverted position at 25°C and examined daily.

From rhizosphere soil

Previously sterilized molten Agar-Agar was poured in sterilized petri-plates, allowed to dry in a cool and dark place for 48 hrs. Small quantity of soil collected from rhizosphere of infected ginger plants were scattered over agar surface. Petri-plates were incubated for a few days. As soon as mycelium of the fungal pathogens were seen under low power microscope, the developing colony was transferred aseptically to PDA slants with the help of sterilized inoculating needle and plugged tightly with non-absorbent cotton to obtain pure culture.

3.5.5 Maintenance and Preservation of Culture

Pure culture of pathogen(s) was obtained by single spore inoculation technique (Keitt, 1915). Single spore of pathogen observed under binocular microscope were picked up individually and transferred on sterilized PDA slant. The marginal mycelial growth developed subsequently was picked up aseptically for subculturing and preserved at low temperature (5±1°C) in refrigerator.

Single bacterial colony was obtained from second or third plates. After selection of right colony, transferred to nutrient agar slant by touching wire loop of the inoculating needle. The purity of culture was checked by making dilute suspension of culture in water and streaked on to nutrient agar plates.

For preservation of the bacterial pathogen, suspension of bacterial culture was taken in three test tubes filled with sterile distilled water and incubated at room temperature.

3.5.6 Morphological Studies of Pathogen(s)

In order to determine and ascertain identity of pathogen(s) morphological features were studied. In case of fungal pathogens, temporary mounts were prepared using Lactophenol and cotton blue. Characteristic feature of vegetative and reproductive structures viz, Sporangiophore, Sporangia, Antheridium, Oogonium, Macro and Micro-conidia etc. were examined under binocular compound microscope calibrated with stage and ocular micrometer (Pathak, 1974; Ricker and Ricker, 1936).

Smears prepared from bacterial culture were fixed, stained and examined under oil-immersion. The pathogens were photographed under Stereoscopic Zoom Microscope.

3.5.7 Calibration

For calibration, the ocular micrometer was first placed inside the eye pieces of 10X magnification and objective lens of 40X magnification. The stage micrometer was brought into clear focus under objective and ocular division in ocular micrometer was coincided and calculation were made for one division of ocular.

Calibration of microscope

At 10X one division of ocular = 0.01 mm (10 μm)

AT 40X one division of ocular = 0.025 mm (2.5 μm)

AT 100X one division of ocular = 0.001 mm (1.0 μm)

3.6 Association of pathogens with rhizome rot of ginger

In order to determine the association of pathogens and their relative dominance, laboratory trials were undertaken. For isolations infected rhizomes, Pseudostem and rhizosphere soil obtained from heavily infected field were used. The infected samples were collected from five locations viz., Kanke, Chutia, Ratu, Namkom and Pithoria villages where ginger is grown on a commercial scale. Five rhizomes/pseudostem were taken from each locations. Further, four pieces each of (1-15 cm^2) were made from each samples and mixed for isolation purpose. These pieces after surface sterilization were placed on PDA in Petri-plates. Pathogens isolated were identified on the basis of colony characters/ morphotaxonomic features as detailed below.

3.7 MANAGEMENT

3.7.1 *In vitro* evaluation of fungicides against *P. aphanidermatum* and *F. oxysporum f.sp. zingiberi*

For assessing efficacies of different fungitoxicants *in vitro P. aphanidermatum* and *F. oxysporum f.sp. zingiberi,* seven fungicides viz., Metalaxyl MZ (Ridomil MZ), Mancozeb (Indofil M-45), Thiophanate methyl (Topsin-M), Carbendazim (Bavistin), Copper oxychloride (Blitox 50), Benomyl (Benlate) and combination of Carbendazim 12% + Mancozeb 63% (Companion) were bioassayed at 250, 500 and 1000 ppm by usual poisoned food technique (Schmitz, 1930). *P. aphanidermatum* and *F. oxysporum f.sp. zingiberi* were grown on PDA medium by adding required quantity of fungicides to obtain the desired concentration on the basis of the active ingredients. Poisoned medium (20 ml) was poured in each of the sterilized petri-plate (90 mm) while suitable checks were maintained without fungicides. The mycelial disc (5 mm dia) taken from 7 days old culture was placed in the

centre of the petri-plate containing poisoned medium and incubated at 25 ± °C. Data on linear growth of the fungus were recorded till the control plates were fully covered with mycelium of the fungus. The percent inhibition of the growth was calculated by the formula of Vincent (1927).

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

Where, I = Inhibition of mycelial growth

C = Growth in control

T = Growth in treatment

3.7.2 *In vitro* evaluation of *Trichoderma* species on radial growth of *P. aphanidermatum* and *F. oxysporum f.sp. zingiberi*

To study the biocontrol potential of antagonistic fungi against *P. aphanidermatum* and *F. oxysporum f.sp. zingiberi*, four species of *Trichoderma* viz., *T. harzianum, T. viride, T. hamatum* and *T. virens* obtained from Indian type culture collection unit, Division of Plant Pathology, IARI, New Delhi were tested for their efficacies on PDA in dual culture. The mycelial disc of 7 mm diameter from the margin of three days old culture of each *Trichoderma* spp. and the pathogen were placed opposite each other on PDA plates. Dual plates were incubated at 28± 2°C in BOD incubator and the radial growth of pathogen and the test species was recorded in each case. Pathogen alone inoculated on PDA plates served as control. Percent inhibition of pathogen was calculated based on the growth in control and dual culture plates (Vincent, 1927).

3.7.3 *In vitro* evaluation of oil cake(s) against *P. aphanidermatum* and *F. oxysporum f.sp. zingiberi*

To evaluate the *in vitro* efficacy of oil cakes against *P.aphanidermatum* and *F. oxysporum f.sp. zingiberi* five oil cakes viz., *Arachis hypogaea, Azadirachta indica, Brassica campestris, Pongamia glabra* and *Sesamum indicum* were tested by poisoned food technique. The powdered cakes were autoclaved at 15 lb pressure for 30 minutes. Measured quantities of cakes

Trade, common and chemical names, active ingradients doses and source of fungicides/bactricide

Trade and common name of fungicides/ bactricide	Chemical name	Active ingradients	Dose	Sources
Ridomil MZ (Metalaxyl MZ)	Methyl DL-N (2-6-dimethyl phenyl)-N- (2-methoxy acetyl)- alaninate	25 WP	0.1 %	Syngenta India Ltd., 14, J. Tata Road Mumbai- 400020
Blitox-50 (Copper oxychloride)	50 % copper oxychloride	50 WP	0.2 %	Rallis India Ltd., 21, D Suklhadvale Marg, Mumbai- 1
Indofil M-45 (Mancozeb)	Zinc iron and magenese ethylene bisdithio carbonate	75 WP	0.2 %	Indofil Chemicals Company, Nirlon House, Dr. Annie Besant Road, Mumbai-2
Bavistin (Carbendazim)	Methyl-2-benzimidaxzole carbonate	50 WP	0.05 %	BASF India Ltd., Agro-chemical Division Maybaker House, S.K. Ahir Marg, P.O. Box No. 19108, Mumbai-25
Benlate (Benomyl)	Methyl-1- (butyl carbamoyl)-2-benzimidazole carbonate	50 WP	0.05 %	E.I. Dupont India Ltd., 4, Community Centre Panchohed Park, New Delhi-15
Companion (Carbendazim 12 % + Mancozeb 63 %)	Carbendazim 12 % Mancozeb 63 %, sodium salt of acetyl napthyl Sulforate 2.0 %, Kaolin	75 WP	0.1 %	United Phosphorus Limited 167, Dr.A.B. Road, Mumbai-18
Topsin-M (Thiophanate methyl)	Dimethyl 4, 4'-0- Phenylene is (3-thiollaophanate)	75 WP	0.05 %	Motilal Pesticides India Pvt. Ltd.; 305, Manjusha 57,New Delhi- 110019

under evaluation i.e. 10 to 20 and 30 g each were mixed with 90, 80 and 70 ml of sterilized, cooled (40°C), unsolidified PDA medium, respectively. Final concentration of 10, 20 and 30 percent were thus obtained. Twenty ml amended medium of each concentration was poured into separate sterilized petri-plates in three replications. After solidification, inoculations in plates were made centrally with 7 mm agar block of 3 days old culture(s) of *P. aphanidermatum* and *F. oxysporum f.sp. zingiberi*. One control plates without any amendment was maintained side by side. All the plates were incubated at 25±2°C. The radial growth of colony was measured after 10 days of incubation and the percent inhibition was calculated by the formula given by Vincent (1927).

3.7.4 Varietal Screening

Pot trials were laid out in Completely Randomized Design (CRD) during *Kharif,* 2003-04 and 2004-05 crop seasons to screen ginger varieties for resistance against rhizome rot under artificial epiphytotics. Seed rhizome of seven varieties were procured from the Department of Horticulture, BAU, Kanke (Nadia), HARP, Plandu (Suruchi & Suprabha), IGAU, Raipur (Maran, Wynad), Local market of Pune and Ranchi (Local Pune, Ranchi). Rhizomes of each variety were planted in 30 cm dia pot filled with sterilized soil (3 rhizome/pot) in three replications. The recommended doses of fertilizer and routine cultural practices were followed. Sixty days old plants were inoculated with mycelial suspension of *P. aphanidermatum* and *F. oxysporum f.sp. zingiberi* and bacterial suspension of *R. solanacearum.* Disease incidence was recorded by direct counting method for each replication by using 0-5 scale (Das, 1999) given as follows :

Rating scale	Disease percentage range	Reaction	Symbol assigned
0	No infection	Immune	I
1	1-20	Resistant	R
2	21-40	Moderately Resistant	MR
3	41-60	Moderately Susceptible	MS
4	61-80	Susceptible	S
5	80-100	Highly Susceptible	HS

3.8 FIELD EVALUATIONS

3.8.1 Effect of soil solarization on pre-emergence and post-emergence rhizome rot

Field trial(s) were undertaken during 2003-04 and 2004-05 crop seasons to record effect of soil solarization on pre-emergence and post-emergence rhizome rot and yield of ginger. The trial(s) were laid out in RBD with four replications. Ten days prior to soil solarization field were infested with 80 g each of *P. aphanidermatum* and *F. oxysporum f.sp. zingiberi* grown on PDA medium and *R. solanacearum* grown on nutrient agar medium. For solarization, the plot were covered with 22 gauge thick transparent polythene sheets by spreading the sheet from all sides, burying and sealing along the edge with top soil in 20 cm deep furrow. Solarization was done for 0, 3 and 6 weeks during the month of May-June at the ambient day temperature ranges of 35-45°C. After completion of solarization period the polysheets were removed from plots. Pieces of seed rhizome(s) of the local ginger variety was planted in 2m x 1m sized plots with 25cm x 15cm spacings. Data on pre-emergence and post-emergence rhizome rot were recorded 60 days after planting and at maturity stages, respectively.

3.8.2 Field evaluation of oil cake(s) on rhizome rot of ginger

For field evaluation of soil amendments, trials were undertaken during *Kharif,* 2003-2004 and 2004-2005 crop seasons in sick plots developed in the glasshouse compound of the Department of Plant Pathology. The trials including seven treatments were laid out in RBD with three replications. Rhizome pieces of local ginger cultivar (20-25 cm dia with 2-3 sprouts) were planted in 3 X 1m sized plots at spacing of 20 X 15 cm. The treatments included oil cakes of *Arachis hypogaea, Azadirachta indica, Brassica campestris, Pongamia glabra* and *Sesamum indicum.* Plots applied with inorganic fertilizers i.e. N:P:K @ 75:50:50 and also plots without inorganic fertilizers and oil cakes were maintained as controls.

Oil cakes @ 20 q/ha were incorporated into the soil 30 days before planting the rhizome pieces. The percent germination of rhizomes was recorded at 60 days after planting. The percent rot and fresh rhizome yield(s) were recorded at maturity of the crop. The data are presented in the Table 9a, b.

3.8.3 Effect of soil application of *Trichoderma* species on management of rhizome rot of ginger

To evaluate the efficacy of soil applied *Trichoderma* species on incidence of rhizome rot of ginger pot trial were undertaken in glasshouse of the Department of Plant Pathology. Thirty five earthen pots of twenty five cm diameter were filled with sterile soil. For soil application, spore suspension of *Trichoderma* species viz., *T. harzianum, T. viride, T. hamatum* and *T. virens* were prepared in sterilized water and filtered through muslin cloth. Moistened broken wheat grains were filled in polypropylene bags (8x12") @ 250 g/bag and were sterilized at 121°C and 15 lb pressure for one hr. The sterilized wheat grains were inoculated with spore suspension of *Trichoderma* species @ 5 ml/bag with the help of hypodermic syringe. Inoculated bags were incubated at room temperature for 15 days. The biocontrol agent inocula were incorporated the soil at the time of planting @ 50 g/pot. Two seed rhizomes of 20-25 cm size were sown in seven pots for each treatment. The pathogens were incorporated into the soil two months after planting. Before application of pathogens, upper layer of soil (around the collar region) was removed. For fungal pathogens, the mycelial suspension (Cfu = $23x10^4$ ml) for *Pythium* and $28x10^4$ ml for *Fusarium oxysporum f.sp. zingiberi* was applied @ 100 ml/ row at the collar region of plant. For *Ralstonia solanacearum* bacterial suspension (Cfu = $1.3x10^8$ ml) was applied @ 80 ml/row at collar region. For comparison control plots without BCAs were maintained side by side. After 60 days of sowing germination percentage and percent incidence were recorded. Yield of fresh ginger rhizomes was recorded after harvesting.

3.8.4 Efficacies of soil application (drenching/application as granules) of chemical toxicants against rhizome rot of ginger

Field trial(s) were conducted during 2003-2004 and 2004-2005 crop seasons. The trials were laid out in RBD with three replications and seven treatments to evaluate efficacies of soil applied fungi-toxicants/ bactericide/ nematicide against rhizome rot disease. The toxicants used were carbendazim 12% + mancozeb 63%, copper oxychloride, metalaxyl MZ (fungicides), carbofuran (granular insecticide with nematicidal properties), plantomycin and bleaching powder (bactericides). Control plots without soil application of toxicants mentioned above were also maintained. Seed rhizomes of the local ginger cultivar measuring 20-25 cm in dia with 2-3 sprouts were planted in rows of 3 m length with spacings of 40 cm x 15 cm during first week of June. The plots were artificially inoculated with *P. aphanidermatum, Fusarium oxysporum f.sp. zingiberi* and *R. solanacearum,* ten days before planting. The inoculum was derived from 10 days old culture of the pathogen grown in 500 ml conical flasks on PDA. Two drenching(s) of toxicants as above were given during mid August and mid September at 20 days intervals @ 10 litres of solution per 25 sq.meter. Carbofuran 3G was applied as granules @ 3 g/sq.m. The data on percent germination, disease incidence and yield of rhizomes was recorded at maturity of the crop.

3.8.5 Efficacies of seed rhizome treatment with fungicides/ bactericide on incidence of rhizome rot of ginger

To evaluate efficacies of selected fungicides/bactericide on germination of rhizome, incidence of rhizome rot and yield of ginger, field trials were conducted during *Kharif* , 2003-04 and 2004-05 crop seasons under natural epiphytotics. The experiment was laid out in RBD with three replications. One kg of local ginger variety was planted in 1.5 x 1.2 m sized plots with 25 x 15 cm spacings. Seed rhizomes were treated by dipping in specified dosage of fungicidal/ bactericidal solution for 30 minutes, dried under shade and planted. Untreated control was also maintained. Percent incidence was recorded in all treatments by counting number of infected clumps. Fresh rhizome yield per

plots was also recorded. Cost benefit ratio for each treatment was worked out as follows.

$$\text{Cost Benefit Ratio} = \frac{\text{Value of additional yield} - \text{Cost of inputs}}{\text{Cost of inputs}}$$

The details of treatments were as follows :

T_1 = Rhizome dip in Metalaxyl MZ (Ridomil MZ) @ 0.15%

T_2 = Rhizome dip in Copper oxychloride (Blitox-50) @ 0.3%

T_3 = Rhizome dip in Mancozeb (Indofil M-45) @ 0.25%

T_4 = Rhizome dip in Carbendazim (Bavistin) @ 0.1%

T_5 = Rhizome dip in Carbendazim 12% + Mancozeb 63% (Companion) @ 0.2%

T_6 = Rhizome dip in Benomyl (Benlate) @ 0.1%

T_7 = Rhizome dip in Streptocycline @ 100 ppm

3.8.6 Effect of rhizome pelleting treatment with *Trichoderma* species in the management of rhizome rot

In order to study the biocontrol potential of *Trichoderma* species against rhizome rot disease laboratory pot culture trials were undertaken. Autoclaved potting mixture of soil plus farm yard manure (FYM) in the ratio of 2:1 was filled in earthen pots of 20 cm dia @ 3 kg soil-FYM mixture per pot. The soil was made sick by soil inoculation with associated pathogens viz., *P. aphanidermatum, F. oxysporum f.sp. zingiberi* two week before ginger planting. The above mentioned pathogens were grown separately on corn meal sand mixture of flask at 28°C for 7 days. Soil inoculation was done by mixing corn meal sand mixture grown pathogens in equal volume of soil. Twenty gram of mixture of *P. aphanidermatum* and *F. oxysporum f.sp. zingiberi* was evenly spread on the surface of each pot and mixed well upto 10 cm depth of soil. The pots were watered immediately after inoculation to provide moisture required for growth and establishment of pathogens in soil. Cultures of

Trichoderma species viz., *T. harzianum, T. viride, T. hamatum* and *T. virens* were grown separately on 2 percent malt extract liquid medium in conical flasks for 7 days at 25°C. The mycelial mats/ spores of *Trichoderma* species were separated by filtering through Whatman filter paper No. 49 and air dried at 25°C for 2 days. Thirty gram culture of each species was mixed with 30 g sterilized fine clay and finally mixed with 15 ml sterilized distilled water to make a slurry. Initial inoculum density of each species was determined by plating 1 ml @ 1:1000 dilution on *Trichoderma* Selective medium I. The above slurry was uniformly coated on ginger rhizome pieces (5 cm, 15 cm size, 20 g in weight with 2-3 buds) by single dip. The pelleting treatment was done before sowing in pots in the sick soil. Surface sterilized rhizomes sown in pots served as controls. Fifteen rhizome pieces were pelleted for each treatment and sown in separate pots which served as replication for individual treatments. A constant watch was made on healthy and diseased sprouts and at 150 days after sowing.

3.8.7 Effect of organic mulching on incidence of rhizome rot and yield of ginger

Field trials were undertaken to study the effect of organic mulching of green leaves/straw of locally available plant species on incidence of rhizome rot disease and yield of rhizomes. The trials were laid out in RBD with six treatments and three replications and planted in rows in 1m x 1m plots. Seed rhizome pieces of local ginger variety with 2-3 buds were planted with 25 cm x 20 cm spacings. Green leaves of karanj (*Pongamia glabra*), Eucalyptus (*Eucalyptus citriodora*), Mango (*Mangifera indica*), Forest fire (*Butea monosperma*) @ 2.5 kg/m^2 and paddy (*Oryza sativa*) straw @ 2 kg /m^2 were used as organic mulches in the trial. First mulching was done immediately after planting which was followed by 2^{nd} and 3^{rd} mulching at 45 and 90 days after planting. Control plots without mulching were also maintained. Pre-emergence rhizome rot due either to infected seed rhizomes pieces or soil infection immediately before emergence were recorded 30 days after planting. Post-emergence rhizome rot and rhizome yield(s) were recorded at maturity of the crop.

3.9 INTEGRATED MANAGEMENT

3.9.1 Integrated management of rhizome rot of ginger with fungicides, bioagents and oil cakes

Field trials were conducted during *Kharif,* 2005-2006 and 2006-2007 crop seasons under natural epiphytotics to study combined efficacy of fungicide(s) viz. Metalaxyl MZ + copper oxychloride, bioagent *T. harzianum* and oilcake *Pongamia glabra* on incidence of rhizome rot and yield of ginger. The experimental trial(s) were laid out in RBD with three replications and seven treatments. Seed rhizomes of local ginger variety (20-25 cm dia with 2-3 sprouts) were dipped in fungicidal solution for 30 minutes, dried in shade and planted 1.5 x 1m sized plot with 15x25 cm spacing. Drenching of fungicide @ 10 L/25 sq.m was done 60 days after planting while soil application of *Pongamia glabra* oilcake @ 20 q/ha and commercial formulation of *T. harzianum* @ 5 kg/ha were given before planting of seed rhizomes. Control plots were maintained without rhizome treatment, without soil application/ drenching of fungicides. Per cent disease incidence was recorded in all treatment by counting the number of infected clumps. The wet rhizome yield/ plots was also recorded. The details of treatments were as follows :

T_1 - Soil application of *Pongamia glabra* oilcake @ 20 q/ha + rhizome dip in metalaxyl MZ @ 0.15%

T_2 - Soil application of commercial formation of *T. harzianum* @ 5 kg/ha + rhizome dip in metalaxyl MZ @ 0.15% + soil drenching with copper oxychloride @ 0.3%

T_3 - Soil application of commercial formulation of *T. harzianum* @ 5 kg/ha and *Pongamia glabra* oilcake @ 20 q/ha + rhizome dip in metalaxyl MZ @ 0.15% + soil drenching with copper oxychloride @ 0.3%

T_4 - Soil application of *Pongamia glabra* @ 20 q/ha + rhizome dip in copper oxychloride 0.3%

T_5 - Soil application of commercial formulation of *T. harzianum* @ 5 kg/ha + rhizome dip in copper oxychloride @ 0.3% + soil drenching with metalaxyl MZ @ 0.02%

T_6 - Soil application of commercial formulation of *T. harzianum* @ 5 kg/ha and *Pongamia glabra* oilcake @ 20 q/ha + rhizome dip in copper oxychloride @ 0.3% + soil drenching with metalaxyl MZ 0.02%

T_7 - Control

3.9.2 Biological management of rhizome rot of ginger involving bioagent, oilcake and mulching

In order to study the biological management strategy against rhizome rot of ginger, trials were conducted during *Kharif* 2005-06 and 2006-07 crop seasons in sick plot. The seed rhizome of local ginger variety (20-25 dia) was pelleted with *T. harzianum* @ 6 g/L and sown on 1 x 1m plots with 15 x 20 cm spacings. Soil application of *Pongamia glabra* oilcake @ 20 q/ha was given before planting of rhizome. Green leaves of *Eucalyptus citriodora* @ 2.5 kg/m^2 in three split doses (6:2:2) were used as mulching once immediately after sowing and two other after first and second intercultural operations at 45 and 90 days respectively. One plot was kept untreated as control. Observations on germination percentage and incidence of rhizome rot was recorded by counting number of infected clumps. The wet rhizome yield per plot was also estimated and analyzed statistically. The details are as follows :

T_1 - Rhizome treatment with *T. harzianum* @ 6 g/L

T_2 - Soil amendment with *Pongamia glabra* oilcake @ 20 q/ha

T_3 - Mulching with *Eucalyptus citriodora* leaves @ 2.5 kg/m^2

T_4 - Rhizome treatment with *T. harzianum* @ 6 g/L + soil amendment with *Pongamia glabra* oilcake @ 20 q/ha

T_5 - Rhizome treatment with *T. harzianum* @ 6 g/L + mulching with *Eucalyptus citriodora* leaves @ 2.5 kg/m^2

T_6 - Soil amendment with *Pongamia glabra* oilcake @ 20 q/ha + mulching with *Eucalyptus citriodora* leaves @ 2.5 kg/m^2

T_7 - Rhizome treatment with *T. harzianum* @ 6 g/L + soil amendment with *Pongamia glabra* oilcake @ 20 q/ha + mulching with *Eucalyptus citriodera* leaves @ 2.5 kg/m^2

T_8 - Control

3.9.3 Combined effect(s) of ginger varieties pre-sowing rhizome treatment and fungicidal sprays against rhizome rot

Field trials were conducted during 2005-06 and 2006-07 crop seasons to determine combined effect(s) of ginger varieties, pre-sowing rhizome treatment and sprays with fungicides in the management of rhizome rot disease and for realization of highest yield potential. Five varieties of ginger viz., Maran, Nadia, Suruchi, Suprabha, Wynad, Pune (Local) and Ranchi (Local) were included in the trial. The above mentioned ginger varieties were obtained from HARP, Palandu (Suruchi, Suprabha), Department of Horticulture, BAU (Nadia), Indira Gandhi Agricultural University, Raipur (Maran, Wynad), local market of Pune and Ranchi (Pune Local, Ranchi Local) respectively. Three fungicides viz., copper oxychloride (0.3%), Metalaxyl MZ (0.15%), Carbendazim 12% + Mancozeb 63% (0.2%) were used for pre-sowing treatment of rhizome pieces. The trial was laid out in RBD with three replications. For fungicidal dip treatment, the rhizome pieces (20-25 cm with 2-3 sprouts) were immersed in fungicidal solutions of the required concentration for a period of 30 minutes. The treated rhizome were planted in 2m x 1m sized plot at 40x15 cm spacings. NPK @ 75:50:50 were applied before sowing. Two fungicidal sprays were given first at the initial appearance of the disease (characterized by leaf yellowing) and the second spraying was followed after 15 days interval. Data on pre-emergence rhizome rot was recorded after 60 DAS while the observations on post-emergence rhizome rot and fresh rhizome yield were recorded at maturity.

3.9.4 Integration of soil solarization with fungicides/ bactericide and bioagent

Field trial(s) were undertaken during 2005-06 and 2006-07 crop seasons to evaluate integration of soil solarization with fungicides/ bactericide and bioagent for management of rhizome rot disease. The trial(s) were laid out in Split plot design with solarized and non-solarized plots as main treatment and nine treatment as sub-plots. Seed treatment and soil drenching with fungicides viz., metalaxyl MZ and copper oxychloride. Soil application of bleaching powder

@ 15 kg/ha and the bioagent *T. harzianum* and combination thereof. The plots (1m x 1m) were infested with *P. aphanidermatum, F. oxysporum f.sp. zingiberi* grown on PDA and *R. solanacearum* grown on nutrient agar by adding 100 g inoculum per plot. Soil solarization was done by covering the plot with 300 guage transparent polythene sheet for 6 weeks. Necessary care was taken to avoid formation of air packets while sealing the plot with polythene sheets. After 6 weeks the polythene sheets were removed. Seed rhizomes of local ginger variety (20-25 cm dia with 2-3 sprout) were dipped in solutions of metalaxyl MZ (Ridomil MZ @ 1.5 g/L), copper oxychloride (Blitox 50 @ 3 g/L) for 30 minutes dried in shade and planted at 15 x 25 cm spacings. Two drenching of fungicide wee given during mid August – mid September at 10 day interval @ 10 litres of mixture per 25 sq. meters. While soil application of commercial formation of *T. harzianum* @ 5 kg/ha and bleaching powder @ 15 g/ha was done before planting of seed rhizomes. Control plots were maintained without treatment of seed rhizome without soil application/ drenching of fungicides/ bioagent. Observation on disease incidence and fresh yield of ginger was recorded at the maturity of crop. The treatment details are as follows :

T_1 - Rhizome dip in metalaxyl MZ @ 0.15% + one drenching with metalaxyl MZ @ 0.02%.

T_2 - Rhizome dip in metalaxyl MZ @ 0.15% + two drench with metalaxyl MZ @ 0.02% + soil application of *T. harzianum* @ 5 kg/ha.

T_3 - Rhizome dip in copper oxychloride @ 0.3% + one drenching with copper oxychloride @ 0.3%.

T_4 - Rhizome dip in copper oxychloride @ 0.3% + two drenchings with copper oxychloride @ 0.3% + soil application of *T. harzianum* @ 5 kg/ha.

T_5 - Rhizome dip in copper oxychloride @ 0.3% + two drenchings with metalaxyl MZ @ 0.02% + soil application of *T. harzianum* @ 5 kg/ha.

T_6 - Rhizome dip in copper oxychloride @ 0.3% + soil application of bleaching powder @ 15 kg/ha.

T_7 - Rhizome dip in metalaxyl MZ @ 0.15% + two drenchings with copper oxychloride @ 0.3% + soil application of *T. harzianum* @ 5 kg/ha.

T_8 - Rhizome dip in metalaxyl MZ @ 0.15% + soil application of bleaching powder @ 15 kg/ha.

T_9 - Control

CHAPTER-4

EXPERIMENTAL FINDINGS

4.1 SURVEY AND SURVEILLANCE

Surveys were undertaken on three convenient routes. The Route-1. included Boreya, Kanke, Sukurhuttu and Pithoria villages. The Route-2 included Ratu and Itki villages and under the Route-3, Ormanjhi and Namkum areas were covered. The ginger plots of identified contact farmer were visited to record total number of plants infected (with current and cumulative figures) for calculation of percent disease incidence. The details are given in Table 1a, b. The disease incidence varied from 15 – 30.37% during 2003-04 and 2004-05 crop seasons. The highest incidence (30.37%) was recorded at Ratu. Progress of rhizome rot of ginger in farmers' field at different locations at Ranchi including current and cumulative figures for the year 2003-04 and 2004-05 have been graphically represented in Plate Nos. 2, 3, 4 & 5. The current infection during 28-30th July probably represented initial seed rhizome infection. Maximum current infection was recorded during the period 28-30th August, which was followed by a decline of further spread. In regard to cumulative figures again the infection recorded during 28-30th July represented seed rhizome borne infection, those recorded during 28-30th September being the total infection at maturity.

4.2 SYMPTOMATOLOGY

The symptoms on the above ground parts appeared in the form of slight paleness of the tip of the terminal leaves followed by yellowing of the leaves. The infected leaves ultimately withered. The infection gradually spread down the leaf sheath, the dead leaves drooped and hung along the stem. The pseudostem became watery and soft. The disease extended further down from the collar region to the rhizomes. The infected rhizomes became discoloured and alter showed rotting. The infected shoot could be easily pulled out on the point of attachment to the rhizome leaving the rotten and decomposed rhizome in the soil (Plate(s) 6, 7, 8, 9 & 10).

Table 1a . Survey for occurrence of rhizome rot of ginger (2003-04)

Sl. No.	Location, contact farmer/ farm	Total no. of plants 28th – 30th June	No. of plant infected					Disease incidence (%)
			28th – 30th July	28th – 30th August		28th – 30 September		
			Current	Current	Cumulative	Current	Cumulative	
Route-1								
1.	Boreya Sri Dhaneswar Mahto	115	5	11	18	8	26	22.61
2.	Kanke Spice Block, Deptt. Of Horticulture	118	6	12	18	7	25	21.19
3.	Sukurhuttu Sri Dayanand Ram	102	10	7	17	6	23	23.55
4.	Pithoria Sri Ganpat Mahli	100	2	9	11	4	15	15.00
Route-2								
5.	Ratu Sri Harinath Bhagat	126	11	10	21	3	24	19.05
6.	Itki Sri Sukra Oraon	112	8	9	17	11	28	25.00
Route-3								
7.	Ormanjhi Sri Eqbal Ansari	95	2	13	15	7	22	23.16
8.	Namkom Sri Jodhan Munda	120	4	16	20	11	31	25.83

Date of sowing/harvesting :

1. 15 May/ 10 Jan.
2. 30 May/30 Jan.
3. 25 May/20 Jan.
4. 02 June/5 Feb
5. 10 May/02 Jan.
6. 18 May/05 Feb.
7. 05 June/ 05 Feb.
8. 10 May/15 Jan.

Table 1b . Survey for occurrence of rhizome rot of ginger (2004-05)

Routes	Location, contact farmer/ farm	Total no. of plants 28th – 30th June	No. of plant infected					Disease incidence (%)
			28th – 30th July	28th – 30th August		28th – 30 September		
			Current	Current	Cumulative	Current	Cumulative	
Route-1								
1.	Boreya Sri Dhaneswar Mahto	126	8	12	20	7	27	21.42
2.	Kanke Spice Block, Deptt. Of Horticulture	126	11	11	22	7	29	23.06
3.	Sukurhuttu Sri Dayanand Ram	110	10	9	19	4	23	20.90
4.	Pithoria Sri Ganpat Mahli	123	6	9	15	10	25	20.33
Route-2								
5.	Ratu Sri Harinath Bhagat	135	12	16	28	13	41	30.37
6.	Itki Sri Sukra Oraon	120	9	10	19	9	28	23.33
Route-3								
7.	Ormanjhi Sri Eqbal Ansari	105	5	9	14	7	21	20.00
8.	Namkom Sri Jodhan Munda	115	11	13	24	6	30	26.09

Date of sowing/harvesting :

1. 18 May/ 03 Feb.
2. 28 May/26 Jan.
3. 01 June/15 Feb.
4. 25 May/20 Jan.
5. 05 June/18 Feb.
6. 17 May/02 Feb.
7. 05 June/ 28 Feb.
8. 30 May/17 Feb.

Plate 2

Progress of Rhizome Rot of Ginger in Farmer's field at different locations of Ranchi (Current:2003-04)

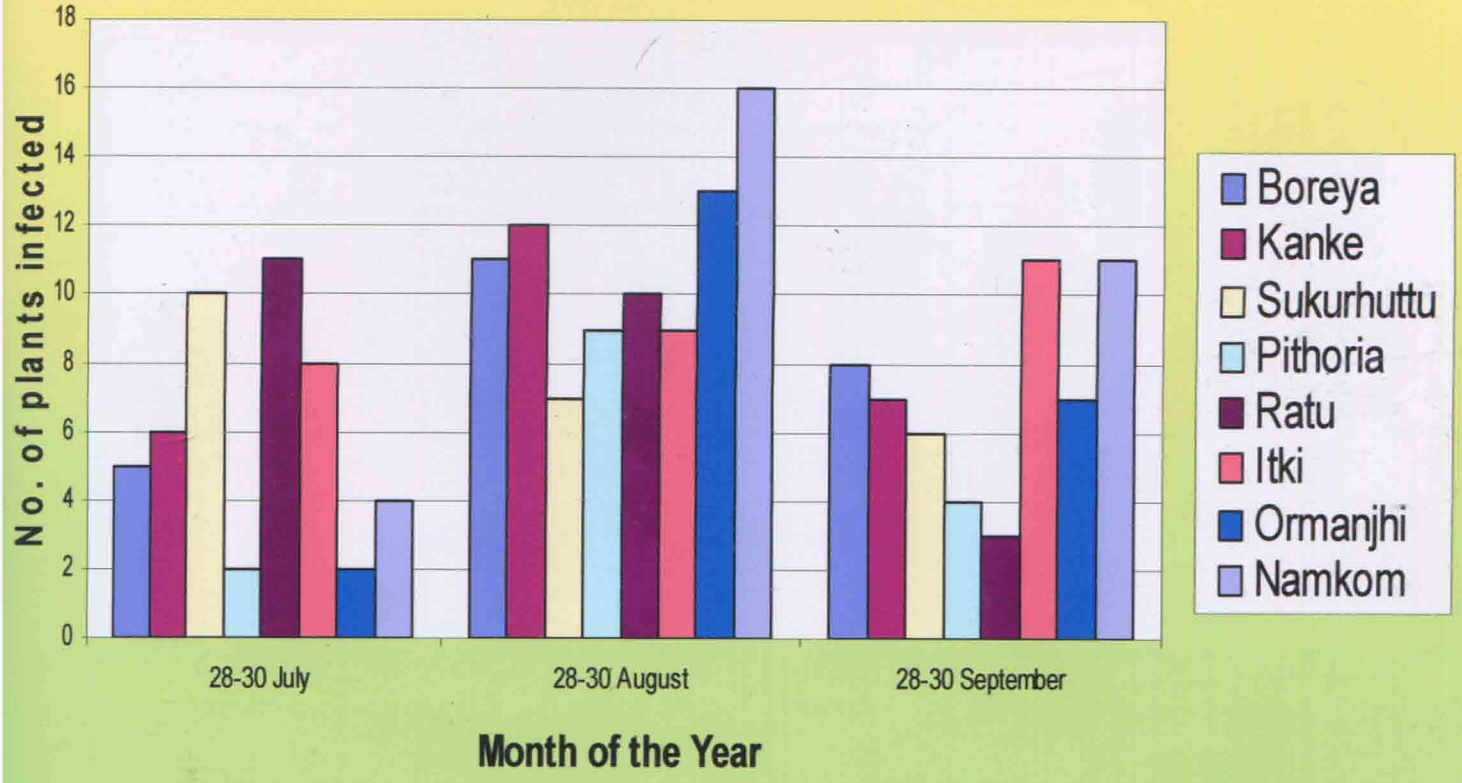


Plate 3

Progress of Rhizome Rot of Ginger in Farmer's field at different locations of Ranchi (Cumulative:2003-04)

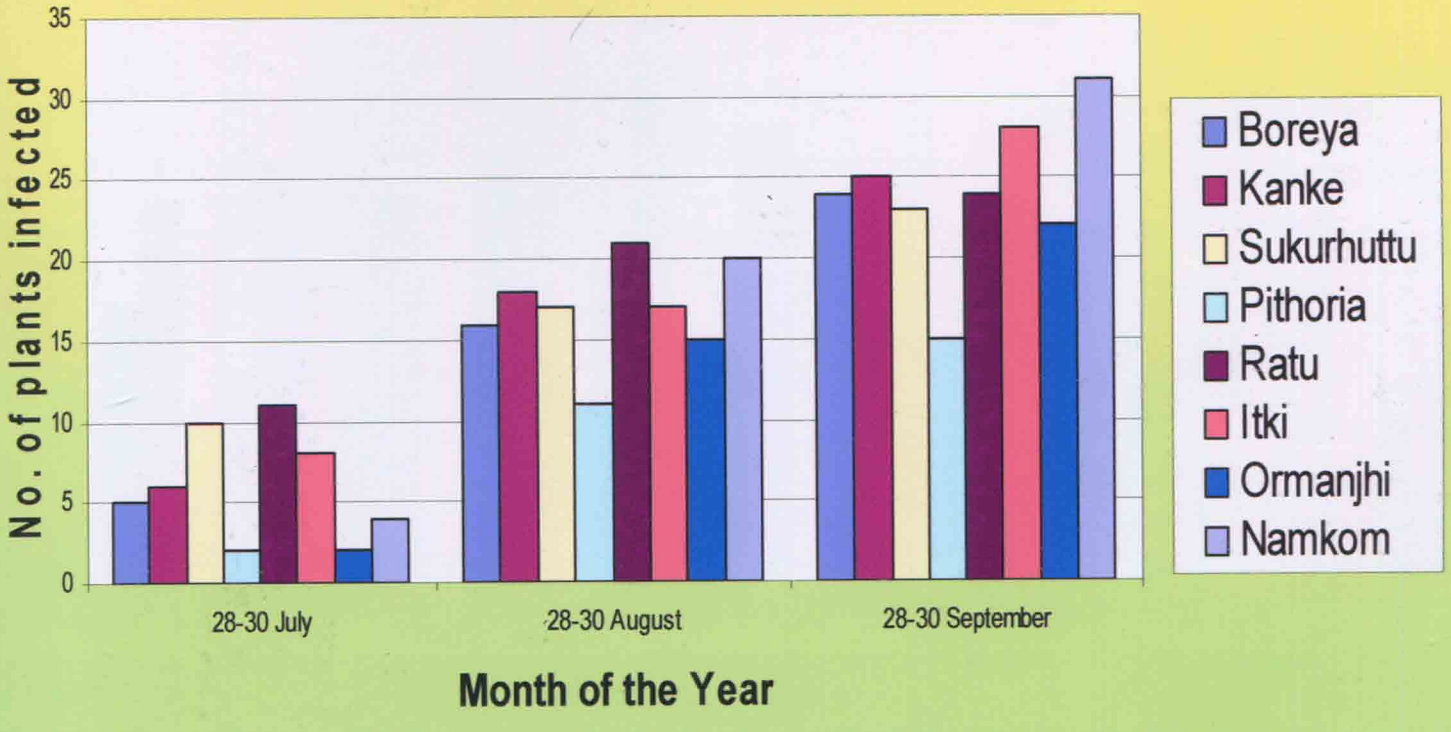
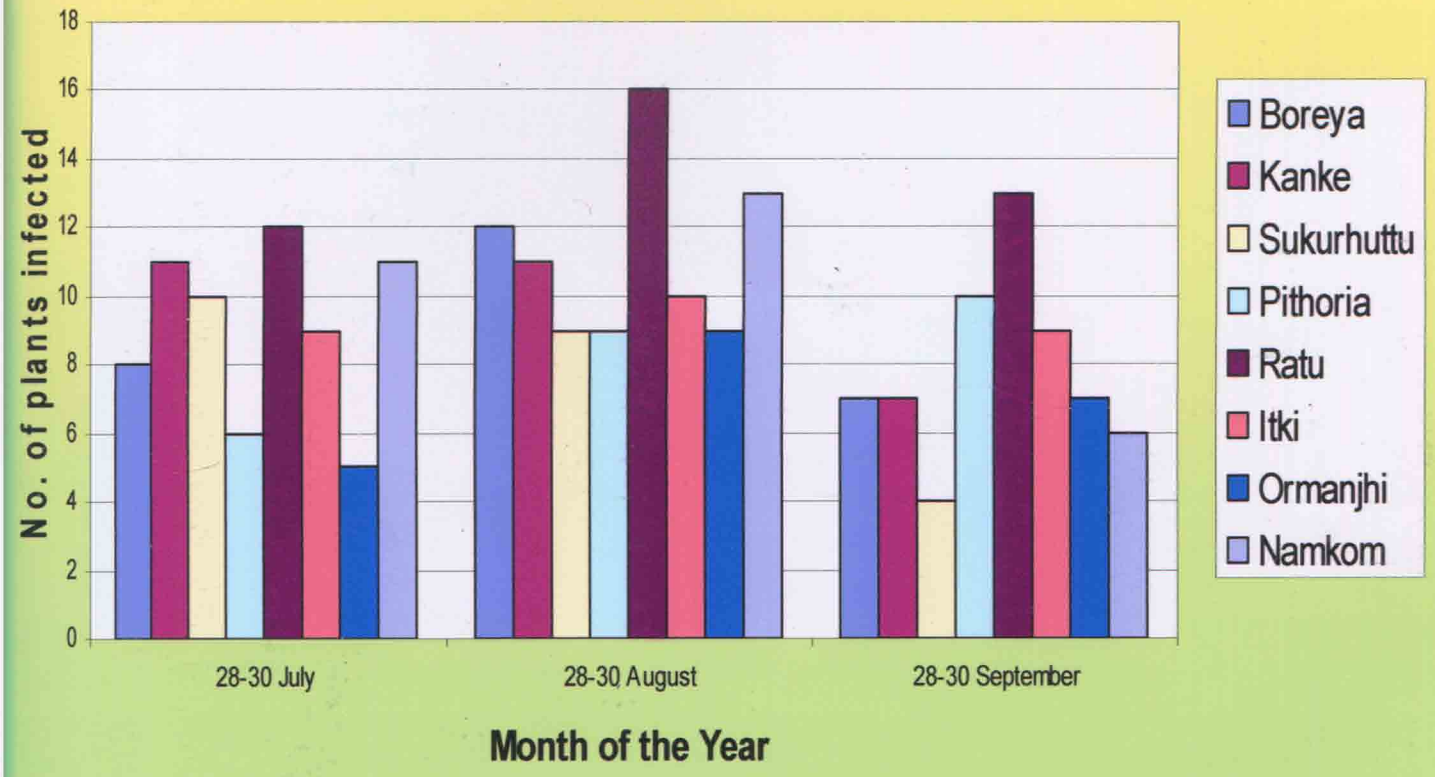


Plate 4

Progress of Rhizome Rot of Ginger in Farmer's field at different locations of Ranchi (Current:2004-05)



Plate(s) - 6, 7, 8, 9 & 10

Symptoms of Rhizome rot on different parts of the ginger plant

Plate 6

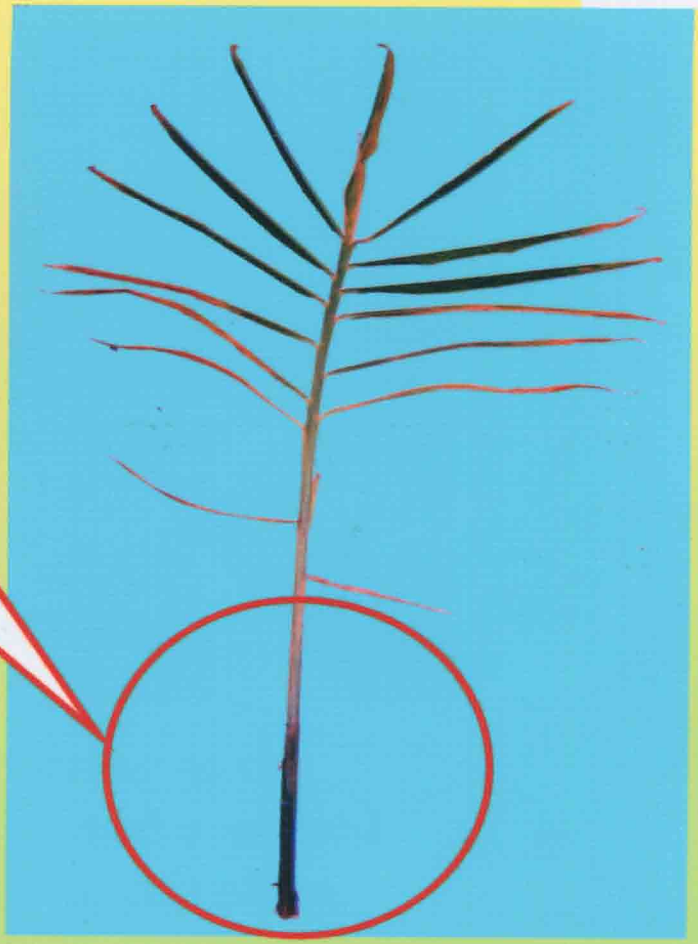
Paleness (chlorosis) of the tip of the terminal leaves

Translucent brown coloration of basal portion

Plate 7

Foliage turning yellow followed by gradual drying of the leaves

Plate 8

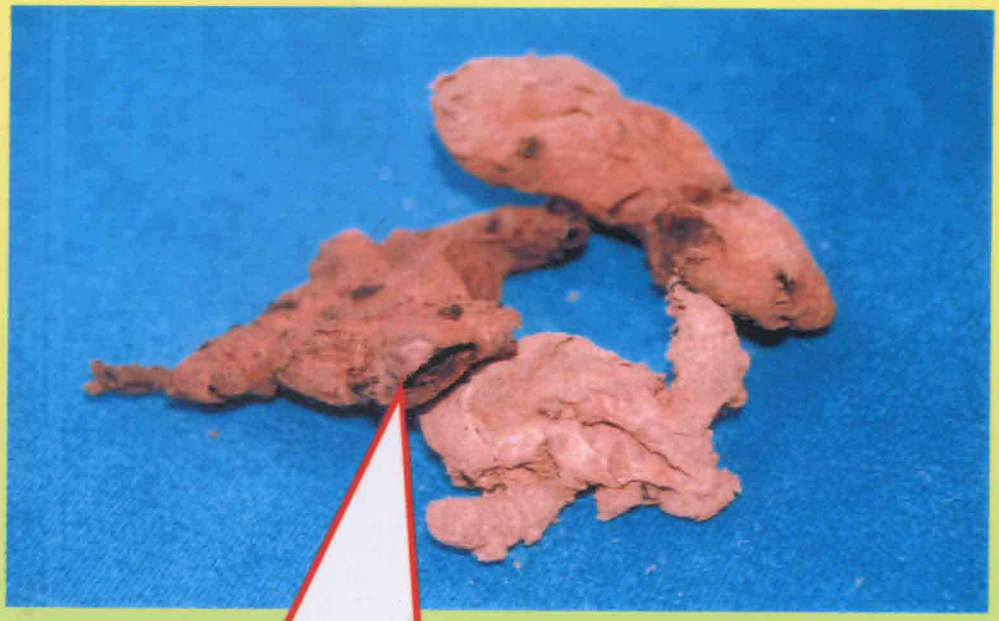


Blackening of the collar region and extension of the disease towards rhizomes

Plate 9

Withering of the leaves and eventual death of the plant

Plate 10



Rhizomes becoming water soaked, soft, shrivelled and rotten

4.3 ASSOCIATION OF PATHOGENS

Samples of infected rhizomes, pseudostem and sick soil of ginger growing field were brought to the laboratory for making pure culture isolations of associated pathogens. In isolations made from infected rhizomes out of total of 160 isolations, 67 samples yielded *Pythium spp.* 33 yield *Fusarium spp.* and the remaining 35 yielded *Ralstonia solanacearum* cultures. In case of pseudostem 55 samples yielded *Pythium spp.*, 22 *Fusarium spp.* and remaining 24 yielded culture of *Ralstonia*. While isolations made from sick soil 47 samples yielded *Pythium spp.*, 13 *Fusarium spp.* and 11 samples yielded *Ralstonia*. The results of the above isolations have been presented in Table 2; Plate(s) 11, 12 & 13.

Table 2. Association of pathogens with rhizome rot of ginger

Source	Location	Infected sample/ pieces	Isolated pathogen(s)			Total
			Pythium spp.	*Fusarium spp.*	*Ralstonia spp.*	
Rhizome	Boreya	5 x 4	10	4	4	14
	Kanke	5 x 4	9	6	3	18
	Sukurhuttu	5 x 4	6	3	5	18
	Pithoria	5 x 4	14	2	5	20
	Ratu	5 x 4	8	5	2	20
	Itki	5 x 4	8	6	5	15
	Ormanjhi	5 x 4	4	2	4	10
	Namkum	5 x 4	8	5	7	19
	Total		67	33	35	134
Pseudostem	Boreya	5 x 4	5	3	0	8
	Kanke	5 x 4	10	7	3	20
	Sukurhuttu	5 x 4	12	0	5	17
	Pithoria	5 x 4	0	4	3	7
	Ratu	5 x 4	10	2	7	19
	Itki	5 x 4	0	0	4	4
	Ormanjhi	5 x 4	4	2	2	8
	Namkum	5 x 4	14	4	0	18
	Total		55	22	24	101
Rhizome Soil	Boreya	5 x 4	5	1	0	6
	Kanke	5 x 4	4	0	2	6
	Sukurhuttu	5 x 4	7	2	1	10
	Pithoria	5 x 4	6	3	3	12
	Ratu	5 x 4	4	0	1	5
	Itki	5 x 4	9	2	0	11
	Ormanjhi	5 x 4	5	3	2	10
	Namkum	5 x 4	7	2	2	11
	Total		47	13	11	71

Contaminated plates excluded.

Plate 11

Association of pathogens with Rhizome rot of Ginger (Rhizome samples)

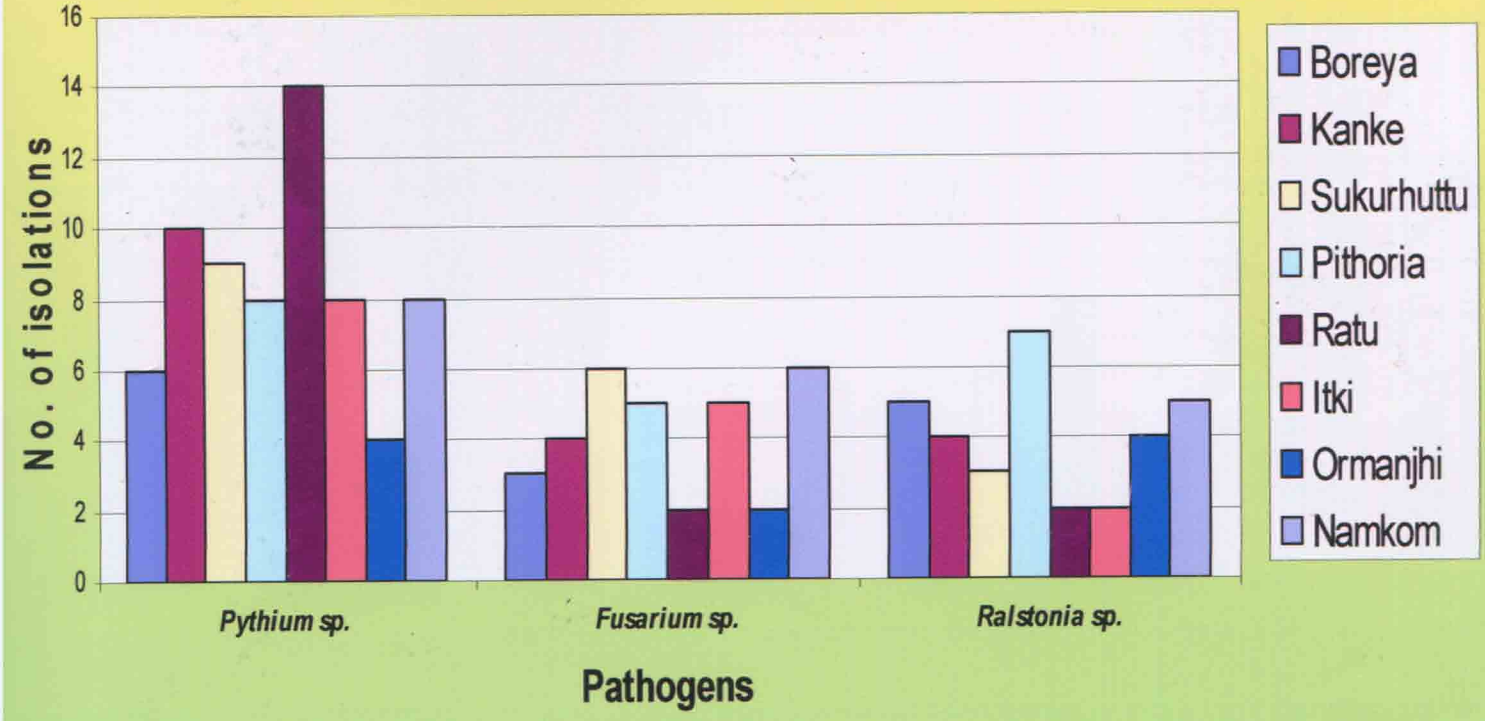


Plate 12

Association of pathogens with Rhizome rot of Ginger (Pseudostem samples)

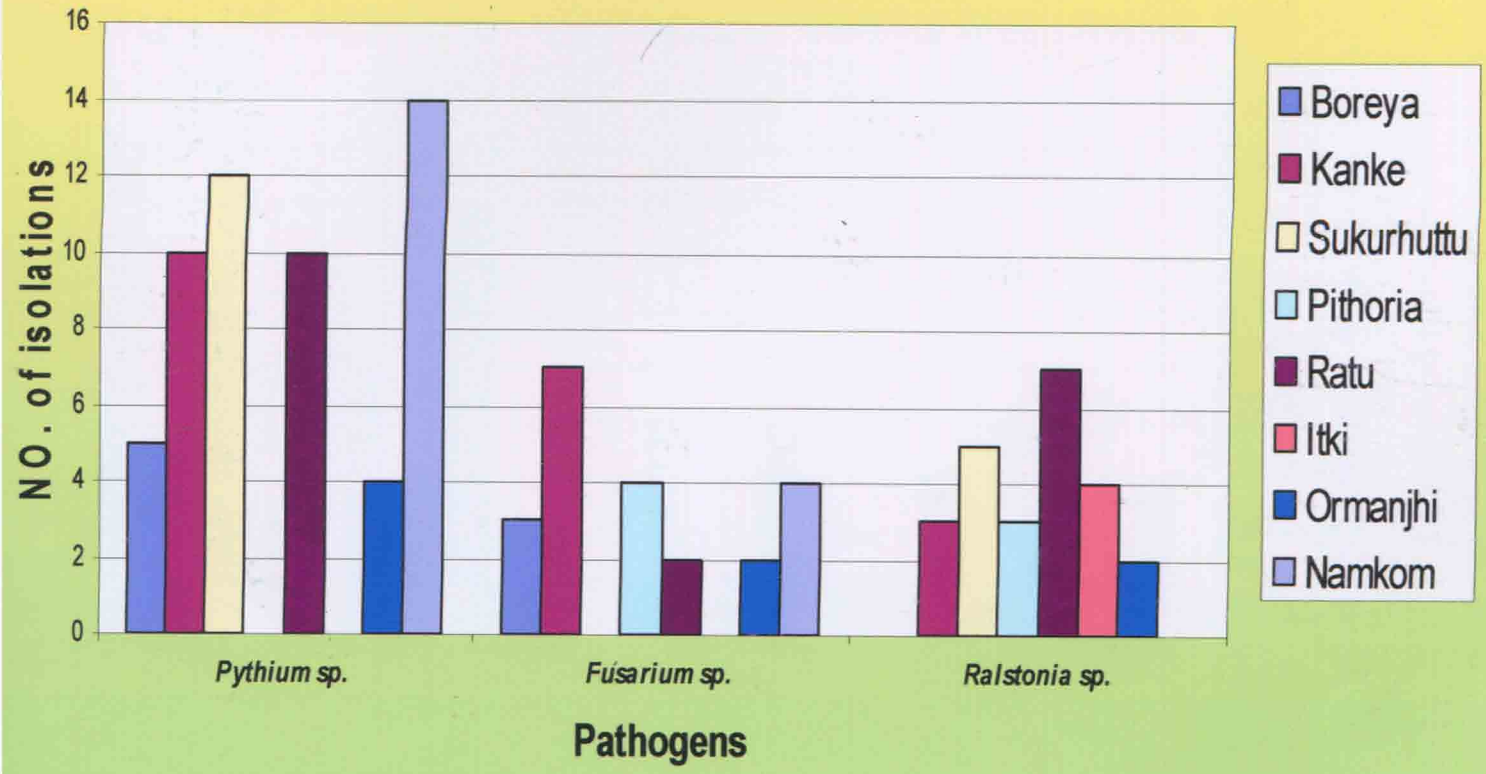
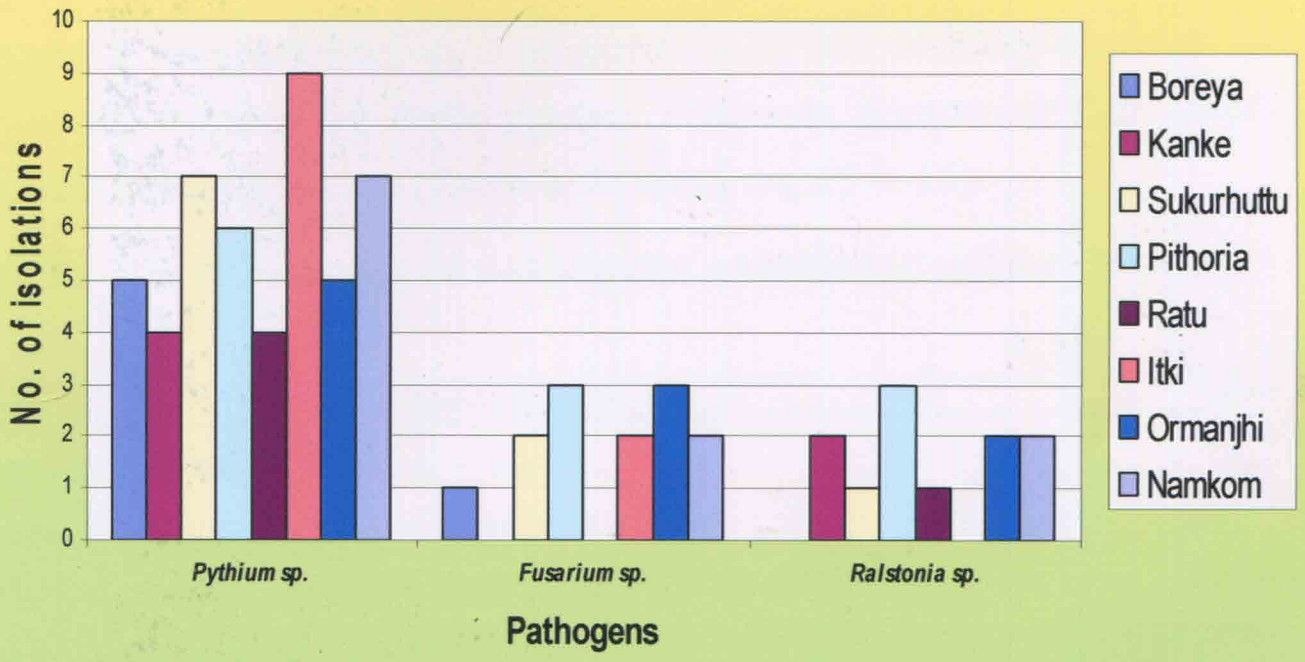


Plate 13

Association of pathogens with Rhizome rot of Ginger
(Rhizosphere soil samples)



4.4 IDENTIFICATION OF PATHOGENS

For identification of pathogens associated with rhizome rot, the morphotaxonomic features were studied. Slides prepared from isolated cultures and stained preparations were examined under binocular compound microscope. Dimensions of various fructifications viz., hyphae, sprangia, oogonia, antheridia, oospore and conidia were measured. Details regarding morphotoxonomic features are given in Table 3.

The isolated pathogens were tentatively identified as *Pythium spp., Fusarium spp.* and *Ralstonia spp.* The pure cultures of all the above isolated pathogens wee submitted to ITCC, Division of Plant Pathology, IARI, New Delhi-110012 for identification. The identities of the above pathogens were confirmed as *Pythium aphanidermatum, Fusarium oxysporum f.sp. zingiberi* and *Ralstonia solanacearum* (Table 3; Plate(s) 14, 15 & 16).

Table 3 . Identification of pathogens associated with rhizome rot of ginger.

Morpho-taxonomic features	Pathogens*
Hyphae – branched hyline 3.5 – 8 μ Sporangia – Swollen bud like upto 500 μ long Oogonia – Spherical, smooth, thin walled 19-27 μ Antheridia – Clavate terminal 15-23 μ Oospore – Thick walled 15-25 μ	*Pythium aphanidermatum*
Hyphae – hyline 3.9 – 6.7 μm Micro-conidia – 0-1 Septate, Ovate, 4.8 – 11.7 x 2.9 –3.9 μm Macro-conidia – 3-4 Septate, Sickle Shaped, 15.5 – 31.2 X 3.9 – 4.8 μm Pigmentation – Violet to black	*Fusarium oxysporum f.sp. zingiberi*
Simple staining test – Short rod shaped with rounded end Gram's staining test – Red stain of Safranin (gram-ve) Flagella staining – Polar	*Ralstonia solanacearum*

*Identification confirmed at Indian Type Culture Collection (ITCC), Division of Plant Pathology, IARI, New Delhi- 110012.

Plate - 14

Pathogen (s) isolated from ginger tissues

Fig 1. Culture of *Pythium aphanidermatum*

Fig 2. Mycelium with swelling sporangia

Fig 3. Oospores

Plate 14

Pathogen(s) isolated from infected ginger tissues

1. *Pythium aphanidermatum*

Fig 1

Fig 2

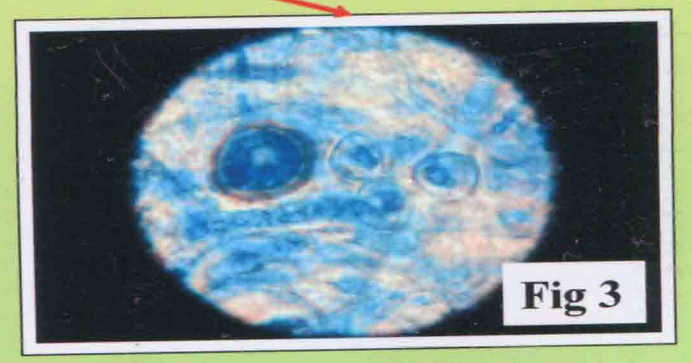


Fig 3

Plate - 15

Pathogen (s) isolated from ginger tissues

Fig 1. Culture of *Fusarium oxysporum f.sp. zingiberi*

Fig 2. Micro and Macroconidia

Plate 15

Pathogen(s) isolated from infected ginger tissues

2. *Fusarium oxysporum f.sp. zingiberi*

Fig 1

Fig 2

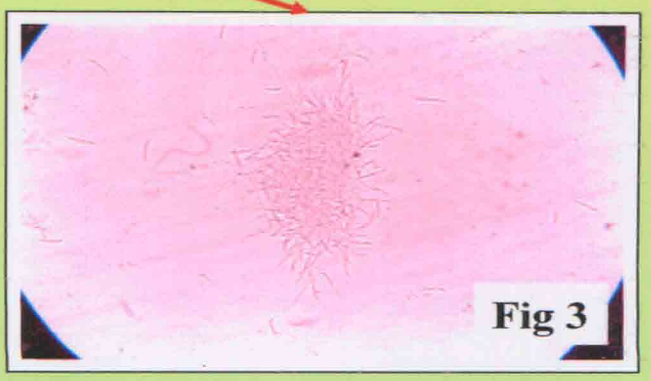


Fig 3

Plate - 16

Pathogen (s) isolated from ginger tissues

Left - Culture of *Ralstonia solanacearum*

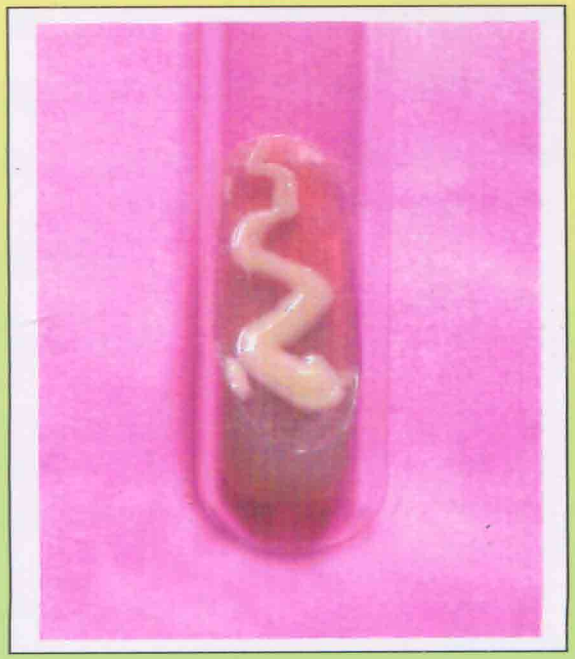
Right - Single cell (upper)

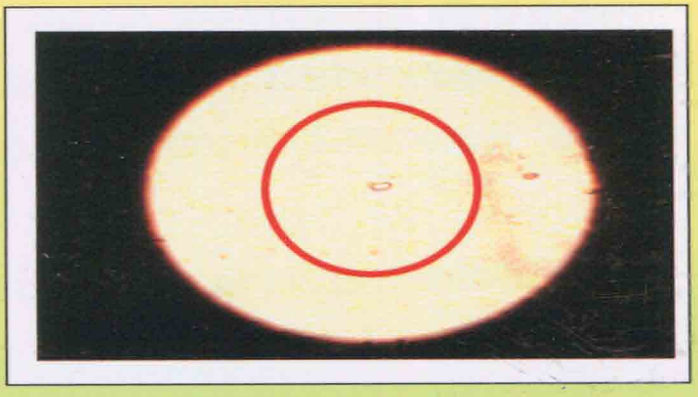
Single cell with polar Flagella (lower)

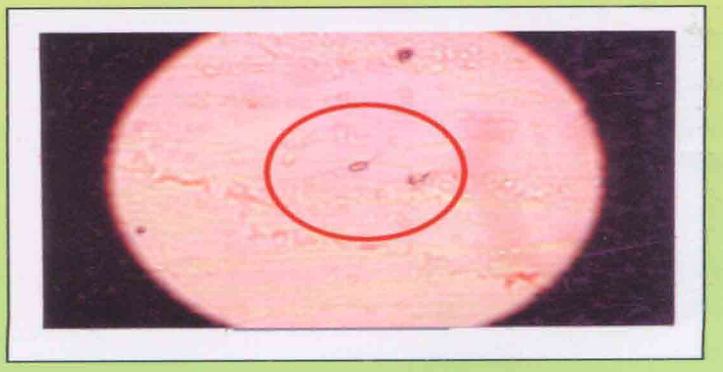
Plate 16

Pathogen(s) isolated from infected ginger tissues

3. *Ralstonia solanacearum*







4.5 MANAGEMENT

4.5.1 *In vitro* evaluation of fungicides

In *in vitro* tests to determine efficacies of different fungicides against *P. aphanidermatum* Metalaxyl MZ (Ridomil MZ), Carbendazim 12% + Mancozeb 63% (companion), Mancozeb (Indofil M 45) and Copper oxychloride (Blitox 50) recorded complete inhibition of the pathogen at 500 + 1000 ppm concentrations, while at 250 ppm concentration Metalaxyl MZ (Ridomil MZ), Carbendazim 12% + Mancozeb 63% (companion), Mancozeb (Indofil M 45) recorded complete inhibition with Copper oxychloride recording 86.82% inhibition (Table 4a).

In *in vitro* test with fungicides on growth inhibition of *F. oxysporum f.sp. zingiberi* 100% inhibition was recorded with Carbendazim 12% + Mancozeb 63% (companion), Carbendazim (Bavistin) and Benomyl (Benlate) at 250 ppm concentration(Table 4b).

Table 4a. *In vitro* evaluation of fungicides on growth inhibition of *P. aphanidermatum*

Treatments	Mean inhibitin (%)			Mean
	250 ppm	500 ppm	1000 ppm	
Metalaxyl MZ (Ridomil MZ)	100.00	100.00	100.00	100.00
	(90.00)	(90.00)	(90.00)	(90.00)
Carbendazim 12 % + Mancozeb 63 % (Companian)	100.00	100.00	100.00	100.00
	(90.00)	(90.00)	(90.00)	(90.00)
Mancozeb (Indofil M-45)	100.00	100.00	100.00	100.00
	(90.00)	(90.00)	(90.00)	(90.00)
Copper oxychloride (Blitox 50)	86.82	100.00	100.00	95.61
	(68.70)	(90.00)	(90.00)	(77.89)
Carbendazim (Bavistin)	1.54	11.17	22.86	11.85
	(5.69)	(19.55)	(28.56)	(20.18)
Thiophanate methyl (Topsin M)	12.97	25.26	65.11	34.45
	(21.12)	(31.46)	(53.79)	(35.97)
Benomyl (Benlate)	1.42	9.02	21.32	10.59
	(6.64)	(17.45)	(27.51)	(19.00)
Mean	25.69	36.36	52.32	38.13
	(30.46)	(37.11)	(46.32)	(38.12)

CD at 5 % :
Fungicide = 1.24
Concentration = 1.07
Fungicide x concentration = 2.15
CV = 1.10
*Figures in parenthesis are arcsine transformed prior to analysis.

Table 4b. ***In vitro*** **evaluation of fungicides on growth inhibition of** ***Fusarium oxysporum f.sp. zingiberi***

Treatments	Mean inhibitin (%)			Mean
	250 ppm	500 ppm	1000 ppm	
Carbendazim (Bavistin)	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)
Carbendazim 12% + Mancozeb 63% (Companian)	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)
Benomyl (Benlate)	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)
Copper oxychloride (Blitox 50)	2.67 (9.46)	12.77 (20.96)	31.28 (34.02)	15.57 (23.26)
Metalaxyl MZ (Ridomil MZ)	30.61 (33.58)	52.26 (46.38)	83.70 (66.19)	55.56 (48.22)
Thiophonate methyl (Topsin M)	34.96 (36.21)	94.94 (76.95)	95.81 (78.71)	75.24 (60.13)
Mancozeb (Indofil M-45)	69.26 (56.35)	100.00 (90.00)	100.00 (90.00)	89.75 (71.37)
Mean	34.38 (35.91)	65.02 (53.79)	77.70 (61.89)	59.03 (50.24)

CD at 5 % :
Fungicide = 6.05
Concentration = 5.24
Fungicide x concentration = 10.49
CV = 3.91
*Figures in parenthesis are arcsine transformed values.

4.5.2 In *in vitro* evaluation of biocontrol agents

In *in vitro* evaluation of biocontrol agents (BCAs) viz., *T. harzianum, T. viride, T. hamatum, T. virens* on mycelial growth of *P. aphanidermatum* and *F. oxysporum f.sp. zingiberi,* minimum mean radial growth (11.67 mm and 16.17 mm) and maximum mean growth inhibition (78.59% and 71.22%) were recorded in the case of *T. harzianum* in respect of *P. aphanidermatum* and *F. oxysporum f.sp. zingiberi,* respectively. *T. viride* recorded mean radial growth of (14.33 mm and 16.83 mm) and mean growth inhibition (74.10% and 70.03%) in respect of the two pathogens as above, respectively. (Table 5; Plate(s) 17 & 18).

Table 5. ***In* vitro evaluation of BCAs on mycelial growth of *P.* aphanidermatum and *Fusarium oxysporum f.sp. zingiberi***

Treatments	*P. aphanidermatum*		*F. oxysporum f.sp. zingiberi*	
	Mean radial growth (mm)	Mean growth inhibition (%)	Mean radial growth (mm)	Mean growth inhibition (%)
T. harzianum	11.67	78.59 (62.69)	16.17	71.22 (57.55)
T. viride	14.33	74.10 (59.39)	16.83	70.03 (56.82)
T. hamatum	20.17	63.54 (52.88)	19.17	65.86 (54.24)
T. virens	15.33	72.20 (58.25)	21.17	62.25 (52.08)
Control	55.33	-	56.17	-
SEm ±	0.49	0.64	0.61	0.80
CD at 5 %	1.63	2.24	2.02	2.83
CV %	3.64	1.89	4.08	2.52

4.5.3 ~~In~~ *In vitro* evaluation of oilcake(s)

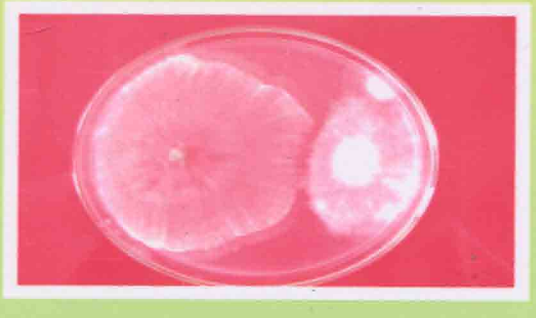
Five oilcake(s) viz., *Azadirachta indica, Arachis hypogaea, Brassica campestris, Pongamia glabra* and *Sesamum indicum* were evaluated against *P. aphanidermatum* and *F. oxysporum f.sp. zingiberi* at 10, 20 and 30% concentrations. In case of *P. aphanidermatum, Pongamia glabra* recorded mean radial growth of 18.33 mm and 13.33 mm at 20 and 30% concentration of cake, respectively. Mean inhibition recorded were 70.49% and 78.22% respectively, at the above concentrations. *A. indica* cake recorded mean radial growth of 22.50 mm and 15.83 mm and mean inhibition of 63.81% and 74.13% respectively of the above pathogen. Similar observations were recorded in the case of *F. oxysporum f.sp. zingiberi* with values of 20.83 mm and 16.33 mm of mean radial growth and 68.59% and 75% mean growth

Plate 17

In vitro evaluation of BCAs on mycelial growth of *Pythium aphanidermatum* in dual cultures

P. aphanidermatum* + *T. harzianum

P. aphanidermatum* + *T. viride



P. aphanidermatum* + *T. hamatum

P. aphanidermatum* + *T. virens

Plate 18

In vitro evaluation of BCAs on mycelial growth of *Fusarium oxysporum f. sp. zingiberi* in dual cultures

F. oxysporum f.sp. zingiberi + T. harzianum

F. oxysporum f.sp. zingiberi + T. viride

F. oxysporum f.sp. zingiberi + T. hamatum

F. oxysporum f.sp. zingiberi + T. virens

inhibition in case of *P. glabra* followed by *A. indica* which recorded 29.17 mm and 19.17 mm mean radial growth and 56.03% and 71.42% mean inhibition at 20 and 30% concentrations, respectively (Table Nos. 6a, b).

Table 6a. *In vitro* evaluation of oilcake(s) on mycelial growth of *P. aphanidermatum*

Oil cake(s)	Concentration (%)					
	10		20		30	
	Mean radial growth (mm)	Mean growth inhibition (%)	Mean radial growth (mm)	Mean growth inhibition (%)	Mean radial growth (mm)	Mean growth inhibition (%)
Arachis hypogaea	50.67	17.16 (24.43)	48.17	22.79 (28.52)	42.67	30.17 (33.31)
Azadirachta indica	35.17	42.48 (40.68)	22.50	63.81 (53.01)	15.83	74.13 (59.43)
Brassica campestris	56.50	7.59 (15.61)	51.83	16.61 (24.05)	45.33	25.88 (30.52)
Pongamia glabra	27.17	55.83 (48.19)	18.33	70.49 (57.09)	13.33	78.22 (62.20)
Sesamum indicum	58.17	4.87 (12.34)	55.50	10.71 (18.97)	50.17	18.24 (25.26)
Control	61.17	-	62.17	0.00	61.17	-
SEm ±	0.56	1.14	0.64	0.93	0.35	0.51
CD at 5 %	1.78	3.79	2.05	3.07	1.13	1.69
CV %	2.00	7.01	2.59	4.42	1.61	2.09

Table 6b. ***In vitro* evaluation of oilcake(s) on mycelial growth of *F. oxysporum f.sp. zingiberi***

Oil cake(s)	Concentration					
	10		20		30	
	Mean radial growth (mm)	Mean growth inhibition (%)	Mean radial growth (mm)	Mean growth inhibition (%)	Mean radial growth (mm)	Mean growth inhibitio (%)
Arachis hypogaea	45.50	31.23 (33.97)	40.33	39.18 (38.76)	35.33	45.92 (42.65)
Azadirachta indica	37.33	45.58 (41.32)	29.17	56.03 (48.46)	19.17	71.42 (57.67)
Brassica campestris	56.33	14.85 (22.63)	55.17	16.84 (24.22)	51.33	21.42 (27.54)
Pongamia glabra	28.17	57.14 (49.28)	20.83	68.59 (55.92)	16.33	75.00 (60.00)
Sesamum indicum	52.17	21.16 (27.39)	50.33	24.11 (29.39)	48.33	26.02 (30.56)
Control	66.17	-	66.33	-	65.33	-
SEm ±	0.65	0.58	0.50	0.48	0.60	0.51
CD at 5 %	2.06	1.93	1.69	1.58	1.90	1.70
CV %	2.35	2.89	2.09	2.09	2.63	2.04

4.5.4 VARIETAL SCREENING

For varietal screening pot trials under artificial epiphytotics were laid out in completely randomized design as described in Chapter 3 (Section 3.7.4). Seven varieties procured from different institution were included in the trial. The variety, Maran with disease incidence of 8.89% and 11.11% during the two years of trial showed Resistant (R) reaction. The varieties, Suruchi, Suprabha and Wynad showed Moderately Resistant (MR) reaction. The varieties, Pune Local and Nadia showed Moderately Susceptible (MS) reaction and the variety, Ranchi local showed susceptible (S) reaction in 0-5 rating scale (Table 7).

Table 7. Screening of ginger varieties against rhizome rot of ginger under artificial epiphytotics

Cultivar/ Variety	Disease incidence* (%)			Reaction	Yield* (g/plant)		
	2003-04	2004-05	Pooled		2003-04	2004-05	Pooled
Suruchi	28.89 (32.49)	26.67 (31.11)	27.78 (31.80)	MR	81.33	83.33	81.83
Suprabha	31.11 (33.86)	35.55 (36.57)	33.33 (35.22)	MR	85.67	84.33	85.00
Nadia	48.89 (45.63)	44.45 (41.82)	46.67 (43.72)	MS	79.00	81.67	80.33
Maran	8.89 (17.13)	11.11 (19.26)	10.00 (18.20)	R	116.67	105.00	110.83
Wynad	20.00 (26.56)	17.78 (24.84)	18.89 (25.70)	MR	90.00	93.33	91.67
Pune (Local)	40.00 (37.90)	37.78 (37.90)	38.89 (38.55)	MS	81.00	85.00	83.00
Ranchi (Local)	62.22 (52.10)	57.78 (49.47)	60.00 (50.79)	S	71.00	75.00	73.50
SEm ±	1.39	1.43	1.52	-	3.45	3.20	3.33
CD at 5%	4.25	4.39	4.42	-	10.57	9.81	9.65
CV %	6.84	7.21	7.57	-	6.92	6.39	6.66

*Mean of three replications

4.6. FIELD EVALUATIONS

4.6.1 Effect of soil solarization on pre-emergence and post-emergence rhizome rot

Field trials were laid out in RBD with four replications during *Kharif* 2003-04 and 2004-05 crop seasons. The fields were infested with 80 g each of *P. aphanidermatum* and *F. oxysporum f.sp. zingiberi* grown in the laboratory on PDA and *R. solanacearum* grown on nutrient agar medium ten days prior to soil solarization. Other details are given in Chapter 3 (Section 3.75).

Pooled data for the two crop seasons revealed that soil solarization for a period of 6 weeks recorded 16.40% pre-emergence and 9.38% post-

emergence rhizome rot as compared to 40.88% and 19.51% pre-emergence and post-emergence rhizome rot, respectively, in non-solarized plots. Yield(s) of fresh rhizomes in plots solarized for 6 weeks and in non-solarized plots recorded were 3.186 kg/plot and 1.812 kg/plot, respectively, indicating significant differences in both rhizome rot incidence and yield(s) of fresh rhizome (Table 8; Plate 19).

Table 8. Effect of soil solarization on pre-emergence and post-emergence rhizome rot of ginger

Week of solarization	*Pre-emergence rhizome rot (%)			*Post-emergence rhizome rot (%)			*Yield of fresh rhizome (kg/plot)		
	2003-04	2004-05	Pooled	2003-04	2004-05	Pooled	2003-04	2004-05	Pooled
0	39.58 (38.95)	42.19 (40.46)	40.88 (39.71)	17.40 (24.55)	21.61 (27.65)	19.51 (26.10)	1.94	1.68	1.81
3	29.19 (32.62)	23.96 (29.21)	26.57 (30.92)	14.85 (22.58)	15.93 (23.42)	15.39 (23.00)	2.29	2.49	2.39
6	15.61 (23.11)	17.19 (24.31)	16.40 (23.71)	8.64 (16.89)	10.13 (18.47)	9.38 (17.68)	3.21	3.16	3.19
SEm ±	1.74	1.49	1.62	1.17	1.36	1.26	0.18	0.10	0.14
CD at 5%	6.13	5.27	5.00	4.12	4.78	3.89	0.63	0.35	0.44
CV %	11.01	9.53	10.31	10.94	11.69	11.62	14.37	8.21	11.50

*Mean of four replications

4.6.2 Field evaluation of oil cake(s) on rhizome rot of ginger

Soil amendment with oil cake(s) were evaluated under field condition during *Kharif,* 2003-04 and 2004-05 crop seasons in sick plots. Oil cake(s) @ 20 q/ha were incorporated into the soil 30 days before planting rhizome pieces of the local ginger cultivar. Methodological details are given in Chapter 3 (Section 3.7.6).

As may be observed in Table Nos. 9a, b; soil amendment with *Pongamia glabra* recorded 77.50% germination and 23.75% incidence of rhizome rot the above treatment recorded disease control 54.4%, fresh rhizome yield of 90.83 q/ha giving 20.94% yield increase over control.

Solarization of Experimental plots

Plate 19

Thickness of polysheet-20 gauze

Duration-3 / 6 weeks

Table9a. Evaluation of oilcake(s) on incidence of rhizome rot and yield of rhizome (2003-04 & 2004-05)

Oil cake(s)	Dose (q/ha)	2003-2004					2004-2005				
		Germination* (%)	Incidence* (%)	Disease control (%)	Yield (q/ha)	Yield increased over control (q/ha)	Germination* (%)	Incidence* (%)	Disease control (%)	Yield (q/ha)	Yield increased over control (q/ha)
Arachis hypogaea	20	66.83 (54.29)	39.17 (38.74)	25.39	80.89	13.11	64.17 (53.28)	40.83 (39.71)	20.98	78.89	6.90
Azadirachta indica	20	75.00 (60.08)	25.83 (30.51)	50.08	90.56	22.78	75.83 (60.60)	26.27 (31.05)	48.38	88.89	16.96
Brassica campestris	20	71.67 (57.90)	35.00 (36.26)	33.33	87.78	20.00	74.16 (59.53)	34.17 (35.73)	33.87	86.11	14.12
Pongamia glabra	20	78.33 (62.42)	21.67 (27.68)	58.72	92.22	24.44	76.67 (61.33)	25.83 (30.47)	50.00	89.44	17.45
Sesamum indicum	20	70.83 (57.37)	36.67 (37.25)	30.15	86.11	18.33	66.67 (54.78)	39.17 (41.64)	24.19	80.00	8.01
Recommended dose of fertilizer (RDF)	75:50:50 kg/ha	64.17 (53.27)	42.50 (52.25)	19.05	78.89	11.11	69.17 (56.27)	41.67 (40.19)	19.35	81.67	9.68
Control	-	62.50 (52.25)	52.50 (46.43)	-	67.78	-	60.83 (51.26)	51.67 (45.67)	-	71.99	-
SEm ±	-	2.10	1.23	-	3.94	-	1.92	1.60	-	3.53	-
CD at 5 %	-	6.53	3.84	-	12.27		5.98	4.99	-	11.01	-
CV %	-	6.39	5.81	-	8.18		5.86	7.33	-	7.42	-

*Mean of three replications

Table 9 b . Evaluation of oilcake(s) on incidence of rhizome rot and yield of rhizome (Pooled data)

Oil cake(s)	Dose (q/ha)	*Germination (%)	*Incidence (%)	Disease control (%)	Yield (q/ha)	Yield increasec over control (q/ha)
Azadirachta indica	20	77.50 (61.88)	23.75 (29.08)	54.40	90.83	20.94
Pongamia glabra	20	75.42 (60.34)	26.25 (30.78)	49.60	89.72	19.83
Arachis hypogaea	20	65.42 (53.78)	40.00 (39.22)	23.19	79.89	10.00
Brassica compestris	20	72.92 (58.72)	34.58 (35.99)	33.60	86.94	17.05
Sesamum indicum	20	68.75 (56.08)	40.42 (39.45)	22.39	83.06	13.17
Recommended dose of fertilizer (RDF)	75:50:50 kg/ha	66.67 (54.77)	42.08 (40.44)	19.20	80.27	10.38
Control	-	61.67 (51.67)	52.08 (46.20)	-	69.89	-
SEm ±	-	2.00	1.43	-	3.74	-
CD at 5 %	-	5.85	4.16	-	10.90	-
CV %	-	6.13	6.64	-	7.81	-

*Mean of three replications

4.6.3 Effect of soil application of *Trichoderma* species on management of rhizome rot of ginger

Soil applied *Trichoderma spp.* viz., *T. harzianum, T. viride, T. hamatum* and *T. virens* were evaluated against rhizome rot in glass house pot trials. The detailed method of application of bio-control agent inocula is given in Chapter 3 (Section 3.8.3).

Trichoderma harzianum was recorded to be the most effective bio-control agent with 77.50 % germination and 27.50 % rhizome rot incidence *T. harzianum* provided 50.74 % disease control and recorded fresh rhizome yield of 101.00 g/plant. The next efficacious bio-control agent, *T. viride* recorded 70.86 % germination, 30.00 % rhizome rot incidence, affoarded 46.27 % disease control and recorded fresh rhizome yield of 95.22 g/plant (Table 10).

Table 10. Effect of soil application of *Trichoderma* spp. on management of rhizome rot of ginger in pot culture

Treatments	Germination* (%)			Incidence* (%)			Disease control* (%)			Yield (g/plant)		
	2003-04	2004-05	Pooled	2003-04	2004-05	Pooled	2003-04	2004-05	Pooled	2003-04	2004-05	Pooled
T.harzianum	78.33 (62.30)	76.67 (62.46)	77.50 (62.38)	25.00 (29.97)	30.00 (33.18)	27.50 (31.57)	57.14	43.75	50.74	104.50	97.50	101.00
T.viride	70.00 (56.83)	71.67 (57.86)	70.86 (57.34)	28.34 (32.14)	31.67 (34.21)	30.00 (33.18)	51.41	40.62	46.27	95.75	94.69	95.22
T.hamatum	68.33 (55.83)	66.67 (54.80)	67.50 (55.31)	35.00 (36.24)	33.33 (35.20)	32.50 (35.72)	39.99	37.50	41.79	89.50	91.25	90.38
T.virens	65.00 (54.83)	65.75 (53.76)	65.38 (54.30)	41.67 (40.20)	43.34 (41.17)	40.83 (40.69)	28.56	18.73	26.87	86.25	84.56	85.40
Control	61.67 (51.77)	63.33 (52.77)	62.50 (52.27)	58.33 (49.80)	53.33 (46.92)	55.83 (48.36)				83.75	78.69	81.22
SEm ±	1.61	1.52	1.56	1.02	1.34	1.19				2.44	2.00	2.23
CD %	4.90	4.61	4.50	3.11	4.67	3.43				7.41	6.08	6.43
CV %	5.73	5.38	5.56	5.43	7.01	6.21				5.30	4.47	4.92

*Mean of four replications

4.6.4 Efficacies of soil application (drenching/ application as granules) of chemical toxicant against rhizome rot of ginger

Six chemical toxicant were evaluated under field conditions during *Kharif* 2003-04 and 2004-05 crop seasons. The toxicants included were fungicides, bactericides and a systemic granular insecticide with nematicidal properties. The plots were artificially inoculated with *P. aphanidermatum* and *F. oxysporum f.sp. zingiberi* and *R.solanacearum* ten days before planting as detailed in Chapter 3 (Section 3.8.4). Soil drenching with copper oxychloride @ 0.30 % recorded 71.88 % germination, 26.04 % rhizome rot incidence and highest disease control of 50.99 %. Drenching with copper oxychloride recorded fresh rhizome yield of 638.33 g/3 m row length. Soil drenching of the fungicide, Metalaxyl MZ applied @ 0.02 % recorded highest germination (76.04 %). Metalaxyl MZ recorded (28.13 %) rhizome rot incidence with 47.05 % disease control and fresh rhizome yield of 428.33 g/ 3m row length (Table 11 a & b).

4.6.5 Efficacies of seed rhizome treatment with fungicides/ bactericide on incidence of rhizome rot of ginger

To Evaluate efficacies of selected fungicides/ bactericide, field trials were conducted during *Kharif,* 2003-04 and 2004-05 under natural epiphytotics. Methodological details of the trials are given in Chapter 3 (Section 3.7.15).

Among fungicides, Metalaxyl MZ (0.15 %) and copper oxychloride (0.30 %) were recorded to be effective chemicals for seed rhizome treatment. Metalaxyl MZ (0.15 %) affoarded 39.63 % disease control with 76.67% germination and 27.92% rhizome rot incidence at maturity. Seed rhizome treatment with Metalaxyl MZ recorded fresh rhizome yield of 83.49 q/ha with cost benefit ratio of 1:16.26. Copper oxychloride 0.30 % affoarded 30.64 % disease control with germination of 75.42 % and rhizome rot incidence of 32.08% at maturity. Although seed rhizome treatment with copper oxychloride 0.3% recorded a lower fresh rhizome yield of 74.31 q/ha. The cost benefit ratio

Table 11a. Effect of soil application of chemical toxicants on incidence of rhizome rot and yield of fresh rhizome

Treatment	Dose	Method or application	2003-2004				2004-2005			
			Germination* (%)	Incidence* (%)	Disease control (%)	Yield/3 m row length (g)	Germination* (%)	Incidence* (%)	Disease control (%)	Yield/3 m row length (g)
Carbendazim 12% + mancozeb 63% (companion)	0.25 %	Drenching	58.33 (49.83)	43.75 (41.40)	22.22	330.40	56.25 (48.62)	39.58 (38.90)	20.84	325.00
Copper oxychloride (Blitox 50)	0.30 %	Drenching	70.83 (57.76)	27.08 (31.34)	51.88	600.00	72.92 (58.87)	25.00 (29.91)	50.00	676.66
Metalaxyl MZ (Ridomil MZ)	0.02 %	Drenching	75.00 (60.14)	29.17 (32.59)	48.14	397.67	77.08 (61.97)	27.08 (31.15)	45.84	460.00
Plantomycin	100 ppm	Drenching	60.42 (51.09)	33.33 (35.27)	40.74	310.00	62.50 (52.30)	37.50 (37.74)	25.00	305.00
Carbofuran	2.5 g/3 m row length	Application of granule	54.17 (47.41)	37.50 (37.74)	33.33	300.00	51.99 (48.58)	35.42 (36.51)	29.16	328.30
Bleaching powder	3.0 g/3m row length	Application of powder	64.58 (63.51)	31.25 (33.93)	44.44	371.67	66.67 (54.89)	29.17 (32.68)	41.66	383.33
Control	-	-	45.65 (42.51)	56.25 (48.25)	-	250.00	49.90 (44.96)	50.00 (45.02)	-	283.33
SEm ±	-	-	2.57	2.17	-	16.82	3.50	1.75		18.60
CD at 5 %	-	-	8.02	6.75	-	52.39	10.89	5.46		57.95
CV %	-	-	8.61	10.07	-	7.97	11.45	8.43		8.17

*Mean of three replications.

Table 11b. Effect of soil application of chemical toxicants on incidence of rhizome rot and yield of fresh rhizomes (Pooled data)

Treatment	Dose	Method or application	Germination* (%)	Incidence* (%)	Disease control (%)	Yield/3 m row length (g)
Carbendazim 12% + mancozeb 63% (companion)	0.25 %	Drenching	57.29 (49.22)	41.67 (40.19)	21.57	327.50
Copper oxychloride (Blitox 50)	0.30 %	Drenching	71.88 (53.21)	26.04 (30.62)	50.99	638.33
Metalaxyl MZ (Ridomil MZ)	0.02 %	Drenching	76.04 (61.06)	28.13 (31.87)	47.05	428.33
Plantomycin	100 ppm	Drenching	61.46 (51.70)	35.42 (36.50)	33.33	307.50
Carbofuran	2.5 g/3 m row length	Application of granule	53.08 (48.00)	36.46 (37.13)	31.38	314.17
Bleaching powder	3.0 g/3m row length	Application of powder	65.63 (54.20)	30.21 (33.31)	43.14	377.50
Control	-	-	48.28 (43.74)	53.13 (46.82)	-	266.67
SEm ±	-	-	3.07	1.97		17.73
CD at 5 %	-	-	8.94	5.74		51.66
CV %	-	-	10.17	9.32		8.08

*Mean of three replications

was more favourable i.e. 1:18.05 in view of lower cost of the fungicide. However, yield differences between the two treatments as above were significant. The bactericide, Streptocycline used for seed treatment at 100 ppm affoarded 9.90 % disease control with 62.08 % germination, 41.67 % disease incidence at maturity and fresh rhizome yield of 70.31q/ha. Seed rhizome treatment with Streptocycline 100 ppm recorded cost benefit ratio 1:1.06 (Table 12a (i) (ii); 12b (i) (ii); & 12c (i) (ii).

Table 12a (i) : Effect of seed (rhizome) treatment with fungicides/ bactericide on incidence of rhizome rot of ginger (2003-04)

Treatment	Dose	Germination* (%) after 60 days	Incidence* (%) at maturity	Disease control (%)	Yield (q/ha)
Metalaxyl MZ (Ridomil MZ)	0.15 %	78.33 (62.42)	27.50 (31.57)	38.89	81.95
Copper oxychloride (Blitox-50)	0.30 %	74.17 (59.66)	32.50 (34.67)	27.78	73.26
Mancozeb (Indofil M-45)	0.25 %	70.83 (57.40)	38.33 (38.21)	14.82	69.44
Carbendazim (Bavistin)	0.10 %	67.50 (55.28)	40.83 (39.69)	9.27	71.53
Carbendazim 12 % + Mancozeb 63% (Companion)	0.20 %	72.50 (58.68)	35.00 (36.13)	22.22	72.92
Benomyl (Benlate)	0.10 %	65.00 (53.76)	41.67 (40.19)	7.40	70.49
Streptocycline	100 ppm	62.50 (52.30)	42.50 (40.68)	5.56	69.10
Control	-	59.17 (50.30)	45.00 (42.13)	-	68.05
SEm ±	-	2.12	1.92	-	2.59
CD at 5 %	-	6.49	5.89	-	7.94
CV %	-	6.53	8.79	-	6.23

*Mean of three replications

Table 12a (ii) : Cost benefit ratio for management of rhizome rot of ginger through fungicide/bactericide (2003-04)

Treatment	Dose	Additional yield over control (q/ha)	Value of additional yield (Rs.)	Additional cost of application (Rs.)	Net Return	Cost benefit ratio
Metalaxyl MZ (Ridomil MZ)	0.15 %	13.90	69500.00	4425.00	65075.00	1:15.71
Copper oxychloride (Blitox-50)	0.30 %	5.21	26050.00	1443.00	24607.00	1:18.05
Mancozeb (Indofil M-45)	0.25 %	1.39	6950.00	1215.00	5735.00	1:5.72
Carbendazim (Bavistin)	0.10 %	3.48	17400.00	1335.00	16065.00	1:13.03
Carbendazim 12 % + Mancozeb 63% (Companion)	0.20 %	4.87	24350.00	3675.00	20675.00	1:6.61
Benomyl (Benlate)	0.10 %	2.44	12200.00	1475.00	10725.00	1:8.27
Streptocycline	100 ppm	1.05	5250.00	5700.00	-450	1:0.92
Control	-	-	-	-	-	-

Cost of Fungicides (Rs kg^{-1}/L^{-1})

Metalaxyl MZ (Ridomil MZ) – Rs.1450/-, Copper Oxychloride (Blitox-50) – Rs.228/-
Mancozeb (Indofil M-45) – Rs.225/-, Carbendazim (Bavistin) – Rs.630/-,
Carbendazim 12 % + Mancozeb 63 % (Campanion) – Rs.700/-,
Benomyl (Benlate) – Rs.700/-, Streptocycline – Rs.5625/-, Cost of application (Rs.) –
Seed treatment – 1 labour @ 75/-
Sale price of ginger – Rs.50/kg

Table 12b (i) : Effect of seed rhizome treatment with fungicides/ bactericide on incidence of rhizome rot of ginger (2004-05)

Treatment	Dose	Germination* (%) after 60 days	Incidence* (%) at maturity	Disease control (%)	Yield (q/ha)
Metalaxyl MZ (Ridomil MZ)	0.15%	75.00 (60.47)	28.33 (31.83)	40.35	85.04
Copper oxychloride (Blitox-50)	0.3%	76.67 (61.51)	31.67 (34.22)	33.33	75.36
Mancozeb (Indofil M-45)	0.25 %	65.00 (53.76)	37.50 (37.70)	21.05	70.83
Carbendazim (Bavistin)	0.1%	63.33 (52.83)	43.33 (41.15)	8.78	72.22
Carbendazim 12 % + Mancozeb 63% (Companion)	0.2%	70.00 (57.91)	33.33 (35.22)	29.83	74.30
Benomyl (Benlate)	0.1%	60.00 (50.77)	42.50 (40.68)	10.53	71.87
Streptocycline	100 ppm	61.67 (51.82)	40.83 (39.71)	14.04	71.52
Control	-	57.50 (49.34)	47.50 (43.57)	-	70.14
SEm ±	-	2.65	2.16	-	2.80
CD at 5 %	-	8.12	6.62	-	8.56
CV %	-	8.39	9.85	-	6.56

*Mean of three replications

Table 12b (ii). Cost benefit ratio for management of rhizome rot of ginger through fungicide/ bactericide (2004-05)

Treatment	Dose	Additional yield over control (q/ha)	Value of additional yield (Rs.)	Additional cost of application (Rs.)	Net Return	Cost : benefit ratio
Metalaxyl MZ (Ridomil MZ)	0.15 %	14.90	74500.00	4425.00	70075.00	1:16.84
Copper oxychloride (Blitox-50)	0.30 %	5.22	26100.00	1443.00	24657.00	1:18.09
Mancozeb (Indofil M-45)	0.25 %	0.69	3450.00	1215.00	2235.00	1:2.84
Carbendazim (Bavistin)	0.10 %	2.08	10400.00	1335.00	9065.00	1:7.79
Carbendazim 12 % + Mancozeb 63% (Companion)	0.20 %	4.16	20800.00	3675.00	17125.00	1:5.66
Benomyl (Benlate)	0.10 %	1.73	8650.00	1475.00	7175.00	1:5.86
Streptocycline	100 ppm	1.38	6900.00	5700.00	1200.00	1:1.21
Control	-	-	-	-	-	-

Cost of Fungicides (Rs kg^{-1}/L^{-1})

Metalaxyl MZ (Ridomil MZ) – Rs.1450/-, Copper Oxychloride (Blitox-50) – Rs.228/-
Mancozeb (Indofil M-45) – Rs.225/-, Carbendazim (Bavistin) – Rs.630/-,
Carbendazim 12 % + Mancozeb 63 % (Campanion) – Rs.900/-,
Benomyl (Benlate) – Rs.700/-, Streptocycline – Rs.5625/-,
Cost of application (Rs.) – Seed treatment – 1 labour @ 75/-
Sale price of ginger – Rs.50/kg

Table 12c (i). Effect of seed (rhizome) treatment with fungicides/ bactericide on incidence of rhizome rot of ginger (Pooled data)

Treatment	Dose	Germination* (%) after 60 days	Incidence* (%) at maturity	Disease control (%)	Yield (q/ha)
Metalaxyl MZ (Ridomil MZ)	0.15 %	76.67 (61.44)	27.92 (31.70)	39.63	83.49
Copper oxychloride (Blitox-50)	0.30 %	75.42 (60.35)	32.08 (34.45)	30.64	74.31
Mancozeb (Indofil M-45)	0.25 %	67.92 (55.59)	37.92 (37.96)	18.01	70.74
Carbendazim (Bavistin)	0.10 %	65.42 (54.06)	42.08 (40.42)	9.02	71.88
Carbendazim 12 % + Mancozeb 63% (Companion)	0.20 %	71.25 (58.29)	34.17 (35.68)	26.12	73.61
Benomyl (Benlate)	0.10 %	62.50 (52.27)	42.08 (40.44)	9.02	71.08
Streptocycline	100 ppm	62.08 (52.06)	41.67 (40.19)	9.90	70.31
Control	-	58.33 (49.82)	46.25 (42.85)	-	69.10
SEm ±	-	2.40	2.14	-	2.70
CD at 5 %	-	6.93	6.18	-	7.78
CV %	-	7.49	9.77	-	6.40

*Mean of three replications

Table 12c (ii). Cost benefit ratio for management of rhizome rot of ginger through fungicide/ bactericide (Pooled data)

Treatment	Dose	Additional yield over control (q/ha)	Value of additional yield (Rs.)	Additional cost of application (Rs.)	Net Return	Cost : benefit ratio
Metalaxyl MZ (Ridomil MZ)	0.15 %	14.39	71950.00	4425.00	67525.00	1:16.26
Copper oxychloride (Blitox-50)	0.30 %	5.21	26050.00	1443.00	24607.00	1:18.05
Mancozeb (Indofil M-45)	0.25 %	1.04	5200.00	1215.00	3985.00	1:4.28
Carbendazim (Bavistin)	0.10 %	2.78	13900.00	1335.00	12565.00	1:10.41
Carbendazim 12 % + Mancozeb 63% (Companion)	0.20 %	4.51	22550.00	3675.00	18875.00	1:6.14
Benomyl (Benlate)	0.10 %	1.98	9900.00	1475.00	8425.00	1:6.71
Streptocycline	100 ppm	1.21	6050.00	5700.00	350.00	1:1.06
Control	-	-	-	-	-	-

Cost of Fungicides (Rs kg^{-1}/L^{-1})

Metalaxyl MZ (Ridomil MZ) – Rs.1450/-, Copper Oxychloride (Blitox-50) – Rs.228/-
Mancozeb (Indofil M-45) – Rs.225/-, Carbendazim (Bavistin) – Rs.630/-,
Carbendazim 12 % + Mancozeb 63 % (Companion) – Rs.900/-,
Benomyl (Benlate) – Rs.700/-, Streptocycline – Rs.5625/-,
Cost of application (Rs.) – Seed treatment – 1 labour @ 75/-
Sale price of ginger – Rs.50/kg

4.6.6 Effect of rhizome pelleting treatment with *Trichoderma* species in the management of rhizome rot

The effect of rhizome pelleting treatment with *Trichoderma spp.* viz., *T. harzianum, T. viride, T. hamatum* and *T. virens* in the management of rhizome rot disease was studied in laboratory pot culture trials. The methodological details are given under Chapter 3 (Section 3.7.16). The data are presented in Table 13.

Rhizome pelleting with *T. harzianum* recorded 75.82 % germination, 35.83 % rhizome rot incidence and recorded 31.75 disease control. Rhizome pelleting with *T. harzianum* recorded fresh rhizome yield of 81.38 g/plant. Rhizome pelleting with *T. harzianum* recorded fresh rhizome yield of 81.38 g/plant. Rhizome pelleting with *T. viride* recorded 70.00 % germination, 43.33 % incidence and 17.47 % disease control. Pelleting treatment with *T. viride* recorded fresh rhizome yield of 75.88 g/plant being at par with rhizome pelleting treatment with *T. harzianum.*

4.6.7 Effect of organic mulching on incidence of rhizome rot and yield of ginger

For the field trials to study the effect of organic mulching, green leaves of Karanj (*P. glabra*), Eucalyptus (*E. citriodora*), Mango (*M. indica*), Forest fire (*B. monosperma*) @ 2.5 kg/m^2 and Paddy straw (*O. sativa*) @ 2 kg/m^2 were included. First mulching was done immediately after planting which was followed by 2nd and 3rd mulching at 45 and 90 days after planting. Mulching with *E. citriodora* leaves recorded pre-emergence and post-emergence rhizome rot of 7.50 % and 8.19 %, respectively. Mulching with *E. citriodora* recorded fresh rhizome yield of 2.81 kg/sq.m. Organic mulching with leaves of *P. glabra* with pre-emergence, post-emergence rhizome rot and fresh rhizome yield of 13.33 %, 16.39 % and 2.02 kg/sq. m, respectively was the second best treatment (Table14; Plate 20).

Table 13. Effect of soil application of BCAs on germination, incidence and yield of ginger (2003-04, 2004-05 & Pooled)

Treatment(s)	2003-2004				2004-05				Pooled			
	Germination* (%)	Incidence* (%)	Disease control (%)	Yield (g/plant)	Germination* (%)	Incidence* (%)	Disease control (%)	Yield (g/plant)	Germination* (%)	Incidence* (%)	Disease control (%)	Yield (g/plant)
T. harzianum	78.33 (62.30)	25.00 (29.97)	57.14	104.50	76.67 (62.46)	30.00 (33.18)	43.75	97.50	77.50 (62.38)	27.50 (31.57)	50.74	101.00
T. viride	70.00 (56.83)	28.34 (32.14)	51.41	95.75	71.67 (57.86)	31.67 (34.21)	40.62	94.69	70.86 (57.34)	30.00 (33.18)	46.27	95.22
T. hamatum	68.33 (55.83)	35.00 (36.24)	39.99	89.50	66.67 (54.80)	33.33 (35.20)	37.50	91.25	67.50 (55.31)	32.50 (35.72)	41.79	90.38
T. virens	65.00 (54.83)	41.67 (40.20)	28.56	86.25	65.75 (53.76)	43.34 (41.17)	18.73	84.56	65.38 (54.30)	40.83 (40.69)	26.87	85.40
Control	61.67 (51.77)	58.33 (49.80)	-	83.75	63.33 (52.77)	53.33 (46.92)	-	78.69	62.50 (52.27)	55.83 (48.36)	-	81.22
SEm ±	1.61	1.02	-	2.44	1.52	1.34	-	2.00	1.56	1.19	-	2.23
CD 5 %	4.90	3.11	-	7.41	4.61	4.07	-	6.08	4.50	3.43	-	6.43
CV %	5.73	5.43	-	5.30	5.38	7.01	-	4.47	5.56	6.28	-	4.92

Table 14. Effect of organic mulching on pre and post emergence rhizome rot and yield of fresh rhizomes

Treatments	Mulching with	Yield of fresh rhizome (2003-04)			Yield of fresh rhizome (2004-05)			Yield of fresh rhizome (Pooled data)		
		Pre-emergence* rhizome rot (%)	Post-emergence* rhizome rot (%)	Yield/ plot* (kg/sq.m)	Pre-emergence rhizome rot (%)	Post-emergence rhizome rot (%)	Yield/ plot (kg/sq.m)	Pre-emergence rhizome rot (%)	Post-emergence rhizome rot (%)	Yield/ plot (kg/sq.m)
Butea monosperma	Leaves	10.00 (18.44)	18.52 (25.23)	1.64	13.33 (21.15)	19.21 (25.98)	1.50	11.67 (19.79)	18.87 (25.60)	1.58
Eucalyptus citriodora	Leaves	6.67 (14.76)	9.06 (16.91)	2.66	8.33 (16.60)	7.31 (15.49)	2.96	7.50 (15.68)	8.19 (16.15)	2.81
Mangifera indica	Leaves	10.00 (18.44)	20.41 (26.82)	1.36	15.00 (22.79)	21.56 (27.63)	1.30	12.50 (20.42)	20.99 (27.23)	1.33
Oryza sativa	Straw	5.00 (12.92)	24.56 (29.68)	1.45	6.67 (14.76)	23.17 (28.77)	1.49	3.88 (13.84)	23.88 (29.23)	1.47
Pongamia glabra	Leaves	15.00 (22.79)	17.64 (24.63)	1.96	11.67 (19.83)	15.14 (22.82)	2.07	13.33 (21.34)	16.39 (23.73)	2.02
Control	Without mulching	16.67 (24.05)	27.03 (31.29)	1.13	18.33 (25.38)	28.67 (32.35)	1.12	17.50 (24.66)	27.85 (31.82)	1.12
SEm ±		1.43	2.42	0.16	1.86	1.47	0.14	1.43	2.00	0.15
CD %		4.56	7.71	0.52	5.93	4.69	0.46	4.24	5.91	0.44
CV %		13.38	16.24	16.73	16.02	9.98	14.25	14.88	13.51	15.38

*Mean of three replication.

Plate 20

Mulching of Experimental plot with *Eucalyptus citriodora* leaves

1st mulching - at planting of rhizomes

2nd mulching – after 6 weeks

3rd mulching – after 12 weeks

4.7 Integrated management

For integrated management of rhizome rot of ginger under Ranchi conditions, the following Modules with different sets of packages were evaluated during *Kharif,* 2005-06 and 2006-07 crop seasons under natural epiphytotics.

Module packages 1. Integrated management of rhizome rot of ginger with fungicides, bioagents and oil cakes.

Module packages 2. Biological management of rhizome rot involving bio-agent, oil cake and mulching.

Module packages 3. Combined effect(s) of ginger varieties and pre-sowing rhizome treatment with fungicides.

Module packages 4. Integration of fungicides/ bactericide and bio-agent on rhizome rot of ginger in solarized and non-solarized fields.

The details of field trials including treatments, dosages and layout etc. as per above Modules are given in Section 3.8.1, 3.8.2, 3.8.3 and 3.8.4, respectively. Commercial formulation of the bio-agent, *Trichoderma harzianum* (Trichodex) was used in the integrated management trial modules.

4.7.1 Module packages 1. Integrated management of rhizome rot of ginger with fungicides, bioagents and oil cakes.

A perusal of pooled data Table Nos 15a (i) (ii);15 b(i) (ii);15c (i) (ii) integration of soil application of the bio-agent *T. harzianum* @ 5 kg/ha, rhizome dip treatment with the fungicide copper oxychloride @ 0.30 % followed by two soil drenching with Metalaxyl MZ solution @ 0.02 % recorded 73.87 % germination and 23.34 % rhizome rot incidence. The above treatment set affoarded 46.82 % disease control, recorded fresh rhizome yield of 90.36 q/ha.

Table 15a (i). Integrated management of rhizome rot of ginger through fungicides, bioagent and oilcake (2005-2006)

Module package 1			Germinatio* (%)	Incidenc* (%)	Disease control (%)	Yield (q/ha)
Soil application	Rhizome dip	Soil drenching				
Pongamia glabra oilcake @ 20 q/ha	Metalaxyl MZ @ 0.15%	-	75.55 (60.52)	21.11 (27.26)	53.67	100.33
T. harzianum @ 5 kg/ha	Metalaxyl MZ @ 0.15%	Copper oxychloride @ 0.3%	80.00 (59.00)	16.67 (23.81)	63.41	105.95
T. harzianum @ 5 kg/ha + *Pongamia glabra* oilcake @ 20 q/ha	Metalaxyl MZ @ 0.15%	Copper oxychloride @ 0.3%	86.67 (68.68)	8.89 (16.53)	80.49	110.89
Pongamia glabra cake @ 20 q/ha	Copper oxychloride @ 0.3%	-	70.00 (56.88)	27.78 (29.59)	39.03	88.21
T. harzianum @ 5 kg/ha	Copper oxychloride @ 0.3%	Metalaxyl MZ @ 0.02 %	73.33 (59.16)	24.45 (29.48)	46.33	89.59
T. harzianum @ 5 kg/ha + *Pongamia glabra* oilcake @ 20 q/ha	Copper oxychloride @ 0.3%	Metalaxyl MZ @ 0.02 %	77.78 (62.04)	18.89 (25.37)	58.54	98.24
Control	-	-	68.89 (56.23)	45.56 (42.45)	-	80.46
SEm ±			2.33	2.91	-	4.32
CD 5 %			7.27	9.07	-	13.46
CV %			6.70	18.16	-	7.78

* Mean of three replications

Table 15a (ii). Cost benefit ratio of integrated management of rhizome rot of ginger through fungicides, bioagent and oilcake (2005-06)

Module packages - 1			Additional yield over control (q/ha)	Value of additional yield (Rs.)	Additional cost of cultivation (Rs.)	Net return (Rs.)	Cost benefit ratio
Soil application	Rhizome dip	Soil drenching					
Pongamia glabra oilcake @ 20 q/ha	Metalaxyl MZ @ 0.15 %	-	19.84	99200.00	24800.00	74400.00	1:4.00
T. harzianum @ 5 kg/ha	Metalaxyl MZ @ 0.15 %	Copper oxychloride @ 0.3%	25.49	127450.00	74480.00	52970.00	1:1.71
T. harzianum @ 5 kg/ha + *Pongamia glabra* oilcake @ 20 q/ha	Metalaxyl MZ @ 0.15 %	Copper oxychloride @ 0.3%	30.43	152150.00	94480.00	57670.00	1:1.61
Pongamia glabra cake @ 20 q/ha	Copper oxychloride @ 0.3%	-	7.75	38750.00	21818.00	16932.00	1:1.78
T. harzianum @ 5 kg/ha	Copper oxychloride @ 0.3%	Metalaxyl MZ @ 0.02 %	9.13	45650.00	5998.00	39650.00	1:7.61
T. harzianum @ 5 kg/ha + *Pongamia glabra* oilcake @ 20 q/ha	Copper oxychloride @ 0.3%	Metalaxyl MZ @ 0.02 %	17.78	88900.00	22998.00	65902.00	1:3.87
Control	-	-	-	-			-

Cost of Fungicides (Rs kg^{-1}/L^{-1})

Metalaxyl MZ (Ridomil MZ) – Rs.1450/-, Copper Oxychloride (Blitox-50) – Rs.228/-, *Trichoderma harzianum* – 256/-, *P. glabra* cake – 10/-kg

Cost of application (Rs.) – Seed treatment – 1 labour @ 75/-, Soil application – 2 labour @ 75/-,Drenching- 3 labours @ 75/-
Sale price of ginger – Rs.50/kg

Table 15b (i). Integrated management of rhizome rot of ginger through fungicides, bioagent and oilcake (2006-07)

Module packages – 1			Germination* (%)	Incidence* (%)	Disease control (%)	Yield (q/ha)
Soil application	Rhizome dip	Soil drenching				
Pongamia glabra oilcake @ 20 q/ha	Metalaxyl MZ @ 0.15 %	-	72.22 (58.33)	23.33 (28.73)	44.74	98.08
T. harzianum @ 5 kg/ha	Metalaxyl MZ @ 0.15 %	Copper oxychloride @ 0.3%	78.89 (62.95)	15.55 (25.60)	63.17	106.00
T. harzianum @ 5 kg/ha + *Pongamia glabra* oilcake @ 20 q/ha	Metalaxyl MZ @ 0.15 %	Copper oxychloride @ 0.3%	82.22 (65.16)	11.11 (19.42)	73.69	108.20
Pongamia glabra cake @ 20 q/ha	Copper oxychloride @ 0.3%	-	72.22 (58.26)	25.56 (30.29)	39.46	90.00
T. harzianum @ 5 kg/ha	Copper oxychloride @ 0.3%	Metalaxyl MZ @ 0.02 %	74.45 (59.78)	22.22 (27.96)	47.37	91.12
T. harzianum @ 5 kg/ha + *Pongamia glabra* oilcake @ 20 q/ha	Copper oxychloride @ 0.3%	Metalaxyl MZ @ 0.02 %	80.00 (63.76)	20.00 (26.07)	52.63	96.40
Control	-	-	65.55 (54.07)	42.22 (40.52)	-	82.18
SEm ±			2.12	2.60	-	4.44
CD 5 %			6.61	8.10	-	13.89
CV %			6.09	15.87	-	8.01

* Mean of three replications

Table 15b (ii). Cost benefit ratio of integrated management of rhizome rot of ginger through fungicides, bioagent and oilcake (2006-07)

Module packages – 1			Additional yield over control (q/ha)	Value of additional yield (Rs.)	Additional cost of cultivation (Rs.)	Net return (Rs.)	Cost benefit ratio
Soil application	Rhizome dip	Soil drenching					
Pongamia glabra oilcake @ 20 q/ha	Metalaxyl MZ @ 0.15 %	-	15.90	79500.00	24800.00	54700.00	1:3.21
T. harzianum @ 5 kg/ha	Metalaxyl MZ @ 0.15 %	Copper oxychloride @ 0.3%	23.82	119100.00	74480.00	44620.00	1:1.60
T. harzianum @ 5 kg/ha + *Pongamia glabra* oilcake @ 20 q/ha	Metalaxyl MZ @ 0.15 %	Copper oxychloride @ 0.3%	26.02	130100.00	94480.00	35620.00	1:1.38
Pongamia glabra cake @ 20 q/ha	Copper oxychloride @ 0.3%	-	7.82	39100.00	21818.00	17282.00	1:1.78
T. harzianum @ 5 kg/ha	Copper oxychloride @ 0.3%	Metalaxyl MZ @ 0.02 %	8.94	44700.00	5998.00	38702.00	1:7.45
T. harzianum @ 5 kg/ha + *Pongamia glabra* oilcake @ 20 q/ha	Copper oxychloride @ 0.3%	Metalaxyl MZ @ 0.02 %	14.22	7100.00	22998.00	48402.00	1:3.10
Control	-	-	-	-	-	-	-

Cost of Fungicides (Rs kg^{-1}/L^{-1})

Metalaxyl MZ (Ridomil MZ) – Rs.1450/-, Copper Oxychloride (Blitox-50) – Rs.228/-, *Trichoderma harzianum* – 256/-, *Pongamia glabra* – 10/-kg
Cost of application (Rs.) – Seed treatment – 1 labour @ 75/-, Soil application – 2 labour @ 75/-,Drenching- 3 labours @ 75/-
Sale price of ginger – Rs.50/kg

Table 15c (*i*). Integrated management of rhizome rot of ginger through fungicides, bioagent and oilcake (pooled data)

Module packages – 1			Germinatio* (%)	Incidenc* (%)	Disease control (%)	Yield (q/ha)
Soil application	Rhizome dip	Soil drenching				
Pongamia glabra oilcake @ 20 q/ha	Metalaxyl MZ @ 0.15 %	-	73.89 (57.43)	22.22 (28.00)	49.37	99.37
T. harzianum @ 5 kg/ha	Metalaxyl MZ @ 0.15 %	Copper oxychloride @ 0.3%	79.45 (60.97)	16.11 (24.71)	63.29	105.98
T. harzianum @ 5 kg/ha + *Pongamia glabra* oilcake @ 20 q/ha	Metalaxyl MZ @ 0.15 %	Copper oxychloride @ 0.3%	84.45 (66.92)	10.00 (18.44)	77.22	109.40
Pongamia glabra cake @ 20 q/ha	Copper oxychloride @ 0.3%	-	71.11 (57.57)	26.67 (29.94)	39.23	89.11
T. harzianum @ 5 kg/ha	Copper oxychloride @ 0.3%	Metalaxyl MZ @ 0.02%	73.87 (59.47)	23.34 (28.72)	46.82	90.36
T. harzianum @ 5 kg/ha + *Pongamia glabra* oilcake @ 20 q/ha	Copper oxychloride @ 0.3%	Metalaxyl MZ @ 0.02%	78.89 (62.90)	19.45 (25.72)	55.68	97.32
Control	-	-	67.22 (55.15)	43.89 (41.48)	-	81.32
SEm ±			2.23	2.76		4.38
CD 5 %			6.49	8.04		12.76
CV %			6.40	17.03		7.89

* Mean of three replications

Table 15c (ii). Cost benefit r atio of integrated management of rhizome rot of ginger through fungicides, bioagent and oilcake (Pooled data)

Module packages – 1			Additional yield over control (q/ha)	Value of additional yield (Rs.)	Additional cost of cultivation (Rs.)	Net return (Rs.)	Cost benefit ratio
Soil application	Rhizome dip	Soil drenching					
Pongamia glabra oilcake @ 20 q/ha	Metalaxyl MZ @ 0.15%	-	18.05	90250.00	24800.00	65450.00	1:3.64
T. harzianum @ 5 kg/ha	Metalaxyl MZ @ 0.15%	Copper oxychloride @ 0.3%	24.66	123300.00	74480.00	48820.00	1:1.66
T. harzianum @ 5 kg/ha + *Pongamia glabra* oilcake @ 20 q/ha	Metalaxyl MZ @ 0.15%	Copper oxychloride @ 0.3%	28.08	140400.00	94480.00	45920.00	1:1.49
Pongamia glabra cake @ 20 q/ha	Copper oxychloride @ 0.3%	-	7.79	38950.00	21818.00	17132.00	1:1.79
T. harzianum @ 5 kg/ha	Copper oxychloride @ 0.3%	Metalaxyl MZ @ 0.02%	9.04	45200.00	5998.00	39202.00	1:7.54
T. harzianum @ 5 kg/ha + *Pongamia glabra* oilcake @ 20 q/ha	Copper oxychloride @ 0.3%	Metalaxyl MZ @ 0.02%	16.00	80000.00	22998.00	57002.00	1:3.48
Control	-	-	-	-	-	-	-

Cost of Fungicides (Rs kg^{-1}/L^{-1})

Metalaxyl MZ (Ridomil MZ) – Rs.1450/-, Copper Oxychloride (Blitox-50) – Rs.228/-, *Trichoderma harzianum* – 256/-, *Pongamia glabra* – 10/-kg
Cost of application (Rs.) – Seed treatment – 1 labour @ 75/-, Soil application – 2 labour @ 75/-,Drenching- 3 labours @ 75/-
Sale price of ginger – Rs.50/kg

The cost benefit ratio worked out in the package under Module 1 was 1:7.54. The other effective package was soil application of oil cake of *Pongamia glabra* @ 20 q/ha, rhizome dip treatment with Metalaxyl MZ @ 0.15 % for a period of 30 minutes recorded germination (73.89 %), disease incidence (22.22%) and affoarded 49.37 % disease control. This package recorded fresh rhizome yield of 99.37 q/ha. The cost benefit ratio calculated was 1:3.68 in view of the quantity and cost of the *P. glabra* oil cake. The yield differences in the above mentioned packages were at par and the cost benefit ratio in package 5 (without application of *P. glabra* oil cake) was found to be more favourable. Highest fresh rhizome yields were obtained in the package, soil application of *T. harzianum* @5 kg/ha plus oil cake of *P. glabra* @ 20 q/ha, rhizome dip treatment with Metalaxyl MZ @ 0.15% for a period of 30 minutes,two drenching with copper oxychloride @ 0.3% but the cost benefit ratio were less favorable.

4.7.2 Module packages 2. Biological management of rhizome rot involving bio-agent, oil cake and mulching.

In Module packages 2 rhizome treatment with *T. harzianum* @ 6g/L+ soil amendment with *P. glabra* oil cake @ 20 q/ha + mulching with *E. citriodora* leaves @ 2.5 kg/m^2 which recorded 80.00% germination, 23.33 % disease incidence and affoarded 43.89 % disease control. This package recorded highest fresh rhizome yield of 97.26 /ha with cost benefit ratio of 1:10.44. The package including *T. harzianum* @ 6g/L+ soil amendment with *P. glabra* oil cake @ 20 q/ha recorded 75.83 % germination,29.58 % incidence and affoarded 28.86 % disease control.The packagerecorded fresh rhizome yield of 87.41 q/ha and cost benefit ratio of 1:2.99. (Table 16a (i) (ii); 16b(i) (ii); 16c (i) & (ii).

Module packages 3. Combined effect(s) of ginger varieties and pre-sowing rhizome treatment with fungicides.

Field trials to determine combined effect of ginger varieties, pre-sowing rhizome treatment against rhizome rot were conducted during 2005-06 and 2006-07 crop seasons. The details of treatment packages on given under Section 3.8.3

The data are presented in Table 17a (i) (ii); 17b(i) (ii); & 17c (i) (ii) as may be observed pooled data Table 17 C (i) (ii), the treatment package i.e. the ginger variety Maran with pre-sowing rhizome treatment with Metalaxyl MZ @ 0.15 %, recorded maximum germination of 84.02 %, minimum disease incidence of 6.25 % and highest fresh rhizome yield of 117.17 q/ha. The above package was followed by the use of ginger variety Wynad and pre-sowing rhizome treatment with Metalaxyl MZ @ 0.15 % recorded 81.25 % germination, 11.81 % disease incidence and fresh rhizome yield of 84.92 q/ha (Table Nos. 17c (i & ii). In regard to germination the varietal effect (V), fungicidal effect (F), the interaction thereof (V x F) and control versus variety, however, were found to be statistically non-significant. In case of rhizome rot incidence the interaction between the variety and the fungicide (V x F) was also recorded to be statistically non-significant, but the variety, the fungicide and control versus variety recorded significant differences. In regard to combined effects of ginger varieties pre-sowing rhizome treatment with fungicide on yield of fresh ginger, the interaction between the variety and the fungicides was found to be statistically non-significant but the effect of the variety, efficacy of fungicide and control versus variety were recorded to be statistically significant.

Table 16a (i). Effect of bioagent, organic amendment and mulching on rhizome rot of ginger (2005-06)

Module packages – 2	Germination* (%)	Incidence* (%)	Disease control (%)	Yield (q/ha)
Rhizome treatment with *T. harzianum* @ 6 g/L	74.17 (59.49)	35.00 (36.24)	17.64	75.33
Soil amendment with *Pongamia glabra* oilcake @ 20 q/ha	71.67 (57.87)	37.50 (37.74)	11.76	72.10
Mulching with *Eucalyptus citriodora* leaves @ 2.5 kg m^{-2}	65.00 (53.76)	40.83 (39.71)	3.93	69.39
Rhizome treatment with *T. harzianum* @ 6 g/L + soil amendment with *Pongamia glabra* oilcake @ 20 q/ha	75.00 (60.08)	30.83 (33.70)	27.46	86.47
Rhizome treatment with *T. harzianum* @ 6 g/L + mulching with *Eucalyptus citriodora* leaves @ 2.5 kg m^{-2}	72.50 (58.43)	32.50 (34.72)	23.53	77.24
Soil amendment with *Pongamia glabra* oilcake @ 20 q/ha + mulching with *Eucalyptus citriodera* leaves @ 2.5 kg m^{-2}	70.83 (57.34)	36.67 (37.50)	13.72	76.08
Rhizome treatment with *T. harzianum* @ 6 g/L + soil amendment with *Pongamia glabra* oilcake @ 20 q/ha + mulching with *Eucalyptus citriodora* leaves @ 2.5 kg m^{-2}	79.17 (62.81)	24.17 (29.27)	43.13	95.70
Control	60.00 (50.79)	42.50 (40.68)	-	67.50
SEm ±	2.67	1.72		3.04
CD 5 %	NS	5.27		9.32
CV %	8.05	8.24		6.81

* Mean of three replications

Table 16a (ii). Cost benefit ratio for biological management of rhizome rot of ginger (2005-06)

Module packages - 2	Additional yield over control (q/ha)	Value of additional yield (Rs.)	Additional cost of application (Rs.)	Net return (Rs.)	Cost benefit ratio
Rhizome treatment with *T. harzianum* @ 6 g/L	7.83	39150.00	9565.00	29585.00	1:4.09
Soil amendment with *Pongamia glabra* oilcake @ 20 q/ha	4.60	23000.00	20150.00	2850.00	1:1.14
Mulching with *Eucalyptus citriodora* leaves @ 2.5 kg m^{-2}	1.89	9450.00	2750.00	6700.00	1:3.44
Rhizome treatment with *T. harzianum* @ 6 g/L + soil amendment with *Pongamia glabra* oilcake @ 20 q/ha	18.97	94850.00	30465.00	64385.00	1:3.11
Rhizome treatment with *T. harzianum* @ 6 g/L + mulching with *Eucalyptus citriodora* leaves @ 2.5 kg m^{-2}	9.74	48700.00	13065.00	35635.00	1:3.73
Soil amendment with *Pongamia glabra* oilcake @ 20 q/ha + mulching with *Eucalyptus citriodora* leaves @ 2.5 kg m^{-2}	8.58	42900.00	22900.00	20000.00	1:1.87
Rhizome treatment with *T. harzianum* @ 6 g/L + soil amendment with *Pongamia glabra* oilcake @ 20 q/ha + mulching with *Eucalyptus citriodora* leaves @ 2.5 kg m^{-2}	28.20	141000.00	13435.00	127565.00	1:10.49
Control	-	-	-	-	-

Cost of bioagent/ oilcake (Rs kg^{-1}/L^{-1})

T. harzianum – Rs.256/-, *Pongamia glabra* cake – Rs.10/-,
Cost of application – 3 mulching @ 2250/- (10 labour hired for mulching),
Rhizome treatment – 1 labour @ 75/-, Soil application- 3 labours/day/ha
Sale price of ginger – Rs.50/kg

Table 16b (*i*). Effect of bioagent, organic amendment and mulching on rhizome rot of ginger (2006-07)

Module packages – 2	Germination* (%)	Incidence* (%)	Disease control (%)	Yield (q/ha)
Rhizome treatment with *T. harzianum* @ 6 g/L	75.83 (60.60)	28.33 (32.03)	37.04	78.02
Soil amendment with *Pongamia glabra* oilcake @ 20 q/ha	70.83 (57.40)	32.50 (34.66)	27.78	76.17
Mulching with *Eucalyptus citriodora* leaves @ 2.5 kg m^{-2}	69.17 (56.34)	41.67 (40.19)	7.40	72.82
Rhizome treatment with *T. harzianum* @ 6 g/L + soil amendment with *Pongamia glabra* oilcake @ 20 q/ha	76.67 (61.25)	20.00 (26.45)	55.56	88.35
Rhizome treatment with *T. harzianum* @ 6 g/L + mulching with *Eucalyptus citriodora* leaves @ 2.5 kg m^{-2}	74.17 (59.49)	26.67 (31.07)	40.73	80.92
Soil amendment with *Pongamia glabra* oilcake @ 20 q/ha + mulching with *Eucalyptus citriodora* leaves @ 2.5 kg m^{-2}	71.67 (57.87)	39.17 (38.71)	12.96	76.39
Rhizome treatment with *T. harzianum* @ 6 g/L + soil amendment with *Pongamia glabra* oilcake @ 20 q/ha + mulching with *Eucalyptus citriodpra* leaves @ 2.5 kg m^{-2}	80.83 (64.11)	17.50 (24.63)	61.11	98.82
Control	65.83 (54.25)	45.00 (42.11)	-	70.90
SEm ±	1.85	1.98	-	3.28
CD 5 %	5.67	6.07	-	10.06
CV %	5.44	9.78	-	7.08

* Mean of three replications

Table 16b (ii). Cost benefit ratio for biological management of rhizome rot of ginger (2006-07)

Module packages – 2	Additional yield over control (q/ha)	Value of additional yield (Rs.)	Additional cost of application (Rs.)	Net return	Cost benefit ratio
Rhizome treatment with *T. harzianum* @ 6 g/L	7.12	35600.00	9565.00	26035.00	1:3.72
Soil amendment with *Pongamia glabra* oilcake @ 20 q/ha	5.27	26350.00	20150.00	6200.00	1:1.31
Mulching with *Eucalyptus citriodora* leaves @ 2.5 kg m^{-2}	1.92	9600.00	2750.00	6850.00	1:3.49
Rhizome treatment with *T. harzianum* @ 6 g/L + soil amendment with *Pongamia glabra* oilcake @ 20 q/ha	17.45	87250.00	30465.00	56785.00	1:2.86
Rhizome treatment with *T. harzianum* @ 6 g/L + mulching with *Eucalyptus citriodora* leaves @ 2.5 kg m^{-2}	10.02	50100.00	13065.00	37035.00	1:3.84
Soil amendment with *Pongamia glabra* oilcake @ 20 q/ha + mulching with *Eucalyptus citriodora* leaves @ 2.5 kg m^{-2}	5.49	27450.00	22900.00	4550.00	1:1.20
Rhizome treatment with *T. harzianum* @ 6 g/L + soil amendment with *Pongamia glabra* oilcake @ 20 q/ha + mulching with *Eucalyptus citriodora* leaves @ 2.5 kg m^{-2}	27.92	139600.00	13435.00	126165.00	1:10.39
Control	-	-	-	-	-

Cost of bioagent/ oilcake (Rs kg^{-1}/L^{-1})

T. harzianum – Rs.256/-, *Pongamia glabra* cake – Rs.10/-,
Cost of application – 3 mulching @ 2250/- (10 labour hired for mulching),
Rhizome treatment – 1 labour @ 75/-, Soil application- 3 labours/day/ha
Sale price of ginger – Rs.50/kg

Table 16c (i). Effect of bioagent, organic amendment and mulching on rhizome rot of ginger(Pooled data)

Module packages – 2	Germination* (%)	Incidence* (%)	Disease control (%)	Yield (q/ha)
Rhizome treatment with *T. harzianum* @ 6 g/L	75.00 (60.05)	33.75 (35.45)	18.83	76.68
Soil amendment with *Pongamia glabra* oilcake @ 20 q/ha	71.25 (57.83)	38.33 (38.22)	7.82	74.40
Mulching with *Eucalyptus citriodora* leaves @ 2.5 kg m^{-2}	67.08 (55.05)	37.92 (37.95)	8.80	71.10
Rhizome treatment with *T. harzianum* @ 6 g/L + soil amendment with *Pongamia glabra* oilcake @ 20 q/ha	75.83 (60.78)	29.58 (32.87)	28.86	87.41
Rhizome treatment with *T. harzianum* @ 6 g/L + mulching with *Eucalyptus citriodora* leaves @ 2.5 kg m^{-2}	73.33 (58.96)	31.25 (33.94)	24.83	79.08
Soil amendment with *Pongamia glabra* oilcake @ 20 q/ha + mulching with *Eucalyptus citriodora* leaves @ 2.5 kg m^{-2}	71.25 (57.64)	37.08 (37.44)	10.82	76.24
Rhizome treatment with *T. harzianum* @ 6 g/L + soil amendment with *Pongamia glabra* oilcake @ 20 q/ha + mulching with *Eucalyptus citriodora* leaves @ 2.5 kg m^{-2}	80.00 (63.47)	23.33 (28.75)	43.89	97.26
Control	62.92 (52.52)	41.58 (40.44)	-	69.20
SEm ±	2.53	1.86	-	3.17
CD 5 %	NS	5.38	-	9.18
CV %	7.52	9.02	-	6.95

* Mean of three replications

Table 16c (ii). Cost benefit ratio for biological management of rhizome rot of ginger (Pooled data)

Treatment	Additional yield over control (q/ha)	Value of additional yield (Rs.)	Additional cost of application	Net return	Cost benefit ratio
Rhizome treatment with *T. harzianum* @ 6 g/L	7.48	37400.00	9565.00	27835.00	1:3.91
Soil amendment with *Pongamia glabra* oilcake @ 20 q/ha	5.20	26000.00	20150.00	5850.00	1:1.29
Mulching with *Eucalyptus citriodora* leaves @ 2.5 kg m^{-2}	1.90	9500.00	2750.00	6750.00	1:3.45
Rhizome treatment with *T. harzianum* @ 6 g/L + soil amendment with *Pongamia glabra* oilcake @ 20 q/ha	18.21	91050.00	30465.00	60585.00	1:2.99
Rhizome treatment with *T. harzianum* @ 6 g/L + mulching with *Eucalyptus citriodora* leaves @ 2.5 kg m^{-2}	9.88	49400.00	13065.00	36335.00	1:3.78
Soil amendment with *Pongamia glabra* oilcake @ 20 q/ha + mulching with *Eucalyptus citriodora* leaves @ 2.5 kg m^{-2}	7.04	35200.00	22900.00	12300.00	1:1.54
Rhizome treatment with *T. harzianum* @ 6 g/L + soil amendment with *Pongamia glabra* oilcake @ 20 q/ha + mulching with *Eucalyptus citriodora* leaves @ 2.5 kg m^{-2}	28.06	140300.00	13435.00	126865.00	1:10.44
Control	-	-	-	-	-

Cost of bioagent/ oilcake (Rs kg^{-1}/L^{-1})

T. harzianum – Rs.256/-, *Pongamia glabra* cake – Rs.10/-,
Cost of application – 3 mulching @ 2750/- (10 labour hired for mulching),
Rhizome treatment – 1 labour @ 75/-, Soil application- 3 labours/day/ha
Sale price of ginger – Rs.50/kg

Table 17 a(i). Combined effect(s) of ginger variety and pre-sowing rhizome treatment with fungicides on germination and incidence of rhizome rot of ginger (2005-06)

Varieties		Fungicides				
		Copper oxychloride (0.3 %)	Metalaxyl MZ (0.15 %)	Carbendazim (12%) + Mancozeb (63%)	Mean	Control
Suruchi	G	75.00 (60.00)	77.78 (61.89)	72.22 (58.18)	75.00 (60.00)	68.06 (55.61)
	I	13.89 (21.89)	12.50 (20.70)	22.22 (28.11)	16.20 (23.73)	29.17 (32.71)
Suprabha	G	70.83 (57.29)	75.00 (60.00)	68.05 (55.61)	71.29 (57.61)	63.89 (53.07)
	I	15.28 (23.03)	16.67 (24.12)	25.00 (30.00)	18.96 (25.77)	30.56 (33.58)
Nadia	G	69.49 (56.48)	76.39 (60.94)	70.83 (57.29)	72.24 (58.18)	65.27 (53.91)
	I	22.22 (28.11)	19.44 (26.43)	28.39 (32.20)	23.35 (28.93)	43.75 (41.44)
Maran	G	80.55 (63.87)	83.33 (65.88)	76.39 (60.94)	80.09 (63.51)	72.22 (58.18)
	I	8.33 (16.71)	5.56 (13.69)	11.11 (19.46)	8.33 (16.71)	12.50 (20.70)
Wynad	G	79.17 (62.87)	81.94 (64.82)	73.61 (59.08)	78.24 (62.17)	69.44 (56.42)
	I	9.72 (18.15)	15.27 (23.03)	19.44 (26.43)	14.81 (22.63)	23.61 (29.06)
Pune Local	G	65.28 (53.91)	73.61 (59.08)	63.89 (53.07)	67.59 (55.30)	61.11 (51.41)
	I	23.68 (29.13)	18.05 (25.18)	27.78 (31.82)	23.17 (28.79)	36.11 (36.93)
Ranchi	G	70.83 (57.29)	72.22 (58.18)	66.67 (54.76)	69.90 (56.73)	62.50 (52.20)
Local	I	20.83 (27.13)	16.67 (24.12)	30.56 (33.58)	22.69 (28.45)	54.17 (47.41)
Mean	G	73.02 (58.69)	77.18 (61.48)	70.24 (56.91)	73.48 (59.02)	69.44 (56.42)
	I	16.23 (23.84)	14.88 (22.71)	23.50 (29.00)	18.22 (25.26)	32.84 (34.94)

Germination	SEm ±	CD (5 %)	Incidence	SEm ±	CD (5 %)	
V	2.10	NS	CV % = 10.83	2.11	5.98	CV % = 23.53
F	1.38	12.62		1.38	3.92	
VxF	3.64	NS		3.66	NS	
Control X var.	1.18	NS		1.19	3.36	

G = Germination
I = Incidence
V = Variety
F = Fungicide

Table 17 a(ii). Combined effect(s) of ginger varieties and pre-sowing rhizome treatment with fungicides on yield of ginger (2005-06)

Varieties/ Fungicides	Yield (Q/h)				
	Copper oxychloride (0.3 %)	Metalaxyl MZ (0.15 %)	Carbendazim (12%) + Mancozeb (63%)	Mean	Control
Suruchi	91.15	81.89	67.54	74.64	57.99
Suprabha	76.80	75.63	65.84	68.33	55.04
Nadia	72.37	74.93	40.26	55.92	36.11
Maran	103.79	120.00	83.96	94.62	70.71
Wynad	94.37	75.23	70.43	77.19	68.73
Pune Local	69.31	71.22	45.59	59.36	51.50
Ranchi Local	62.46	70.56	38.60	50.73	31.30
Mean	81.46	81.35	58.89	68.68	53.05
	SEm ±		CD (5 %)	CV %	
V	3.75		12.99	16.49	
F	2.46		6.95		
VxF	6.50		NS		
Control Vs. variety	2.10		5.96		

V = Variety
F = Fungicide

Table 17 b(i). Combined effect(s) of ginger variety and pre-sowing rhizome treatment with fungicides on germination and incidence of rhizome rot of ginger (2006-07)

Varieties		Fungicides				
		Copper oxychloride (0.3 %)	Metalaxyl MZ (0.15 %)	Carbendazim (12%) + Mancozeb (63%)	Mean	Control
Suruchi	G	70.83 (57.29)	72.22 (58.18)	68.05 (55.61)	70.37 (57.04)	65.28 (53.91)
	I	16.67 (24.12)	13.89 (21.89)	20.83 (27.13)	17.13 (24.43)	33.33 (35.24)
Suprabha	G	69.44 (56.42)	73.61 (59.08)	65.28 (53.91)	69.44 (56.42)	61.11 (51.41)
	I	18.05 (25.18)	15.28 (23.03)	22.22 (28.11)	18.52 (25.48)	31.94 (34.39)
Nadia	G	72.22 (58.18)	77.78 (61.89)	68.05 (55.61)	72.68 (58.50)	66.66 (54.70)
	I	20.83 (27.13)	16.67 (24.12)	27.78 (31.82)	21.76 (27.83)	38.89 (38.59)
Maran	G	81.95 (64.82)	84.72 (66.97)	77.78 (61.89)	81.48 (64.52)	75.00 (60.00)
	I	11.11 (19.46)	6.95 (15.23)	13.89 (21.89)	10.65 (19.09)	15.28 (23.03)
Wynad	G	76.39 (60.94)	80.56 (63.87)	74.99 (59.93)	77.31 (61.55)	72.22 (58.18)
	I	12.50 (20.70)	8.33 (16.71)	20.83 (27.13)	13.89 (21.89)	30.55 (33.58)
Pune Local	G	70.83 (57.29)	72.22 (58.18)	66.66 (54.76)	69.90 (56.73)	62.50 (52.24)
	I	20.83 (27.13)	13.89 (21.89)	26.39 (30.92)	20.37 (26.85)	34.72 (36.09)
Ranchi	G	68.05 (55.61)	70.83 (57.29)	65.28 (53.91)	68.05 (55.61)	63.89 (53.07)
Local	I	25.00 (30.00)	19.44 (26.43)	33.33 (35.24)	25.92 (30.59)	48.61 (44.20)
Mean	G	72.82 (58.56)	75.99 (60.60)	69.44 (56.42)	72.75 (58.50)	66.67 (54.76)
	I	17.86 (25.03)	13.49 (21.56)	23.61 (29.06)	18.32 (25.33)	33.33 (35.24)
Germination	SEm ±	CD (5 %)	Incidence	SEm ±	CD (5 %)	
V	2.57	NS	CV % = 13.21	1.19	5.15	CV % = 20.00
F	1.68	NS		1.82	2.97	
VxF	4.45	NS		3.15	NS	
Control X var.	1.44	NS		1.48	2.19	

G = Germination
I = Incidence
V = Variety
F = Fungicide

Table 17 b(ii). Combined effect(s) of ginger cultivar and pre-sowing rhizome treatment with fungicides on yield of ginger (2006-07)

Varieties/ Fungicides	Yield (Q/h)				
	Copper oxychloride (0.3 %)	Metalaxyl MZ (0.15 %)	Carbendazim (12%) + Mancozeb (63%)	Mean	Control
Suruchi	77.56	82.28	72.22	77.35	55.29
Suprabha	75.24	78.76	68.37	74.12	53.76
Nadia	76.78	81.98	49.34	69.37	46.13
Maran	96.63	114.23	82.82	97.89	68.91
Wynad	88.29	94.61	77.46	86.79	64.92
Pune Local	70.71	76.09	47.99	64.93	42.70
Ranchi Local	60.79	74.12	41.15	58.69	39.66
Mean	78.00	86.01	62.76	75.59	53.05
	SEm ±		CD (5 %)	CV % = 10.45	
V	2.45		8.49		
F	1.60		4.54		
VxF	4.25		NS		
Control Vs. variety	1.38		3.89		

V = Variety
F = Fungicide

Table 17 c(i). Combined effect(s) of ginger variety and pre-sowing rhizome treatment with fungicides on germination and incidence of rhizome rot of ginger (Pooled data)

Varieties		Fungicides				
		Copper oxychloride (0.3 %)	Metalaxyl MZ (0.15 %)	Carbendazim (12%) + Mancozeb (63%)	Mean	Control
Suruchi	G	72.91 (58.63)	75.00 (60.00)	70.14 (56.85)	72.68 (58.50)	66.67 (54.76)
	I	15.27 (23.03)	13.20 (21.30)	21.53 (27.63)	16.67 (24.12)	31.25 (34.02)
Suprabha	G	70.13 (56.85)	74.31 (59.54)	66.67 (54.76)	70.37 (57.04)	62.50 (52.24)
	I	16.67 (24.12)	15.97 (23.50)	23.67 (29.13)	18.77 (25.70)	31.25 (34.02)
Nadia	G	70.83 (57.29)	77.09 (61.41)	69.44 (56.42)	72.45 (58.37)	65.97 (54.27)
	I	21.53 (27.63)	18.06 (25.18)	27.09 (31.37)	22.23 (28.11)	37.50 (37.76)
Maran	G	81.25 (64.38)	84.02 (66.42)	77.08 (61.34)	80.78 (64.01)	73.61 (59.08)
	I	9.72 (18.15)	6.25 (14.51)	12.50 (21.89)	9.49 (17.95)	13.89 (21.89)
Wynad	G	77.78 (61.89)	81.25 (64.38)	74.30 (59.54)	77.78 (61.89)	70.83 (57.29)
	I	11.12 (19.46)	11.81 (20.09)	20.14 (26.64)	14.36 (22.30)	27.08 (31.37)
Pune Local	G	68.06 (55.61)	72.92 (58.63)	65.27 (53.91)	68.74 (55.98)	61.81 (51.83)
	I	22.22 (28.11)	15.97 (23.50)	27.08 (31.37)	21.76 (27.83)	35.42 (36.51)
Ranchi	G	69.40 (56.42)	71.53 (57.73)	65.97 (54.27)	68.97 (56.11)	63.19 (52.65)
Local	I	22.92 (28.59)	18.06 (25.18)	31.95 (34.39)	24.31 (29.53)	51.39 (45.80)
Mean	G	72.91 (58.63)	76.59 (61.07)	69.84 (56.66)	73.11 (58.76)	66.37 (54.51)
	I	17.06 (24.43)	14.19 (22.14)	23.42 (28.93)	18.23 (25.25)	32.54 (34.76)
Germination	SEm ±	CD (5 %)	Incidence	SEm ±	CD (5 %)	
V	2.35	NS	CV % = 11.16	1.23	5.52	CV % = 21.83
F	1.78	NS		1.29	3.62	
VxF	4.07	NS		3.42	NS	
Control X var.	1.31	NS		1.11	3.10	

G = Germination
I = Incidence
V = Variety
F = Fungicide

Table 17 c(ii). Combined effect(s) of ginger cultivar and pre-sowing rhizome treatment with fungicides on yield of ginger (Pooled data)

Varieties/ Fungicides	Yield (Q/h)				
	Copper oxychloride (0.3 %)	Metalaxyl MZ (0.15 %)	Carbendazim (12%) + Mancozeb (63%)	Mean	Contro
Suruchi	78.37	82.08	69.88	76.78	56.63
Suprabha	76.02	77.20	67.11	73.44	54.40
Nadia	74.57	78.45	44.80	65.94	41.12
Maran	100.21	117.17	83.39	100.26	69.81
Wynad	91.33	84.92	73.95	83.40	66.83
Pune Local	70.01	73.65	52.14	65.27	46.79
Ranchi Local	61.63	72.34	39.88	57.95	35.48
Mean	78.78	83.69	61.59	74.72	53.01
	SEm ±		CD (5 %)	CV % = 13.72	
V	3.16		8.87		
F	2.07		5.80		
VxF	5.49		NS		
Control Vs. variety	1.78		4.98		

V = Variety
F = Fungicide

4.7.4 Module packages 4. Integration of fungicides/ bactericide and bio-agent on rhizome rot of ginger in solarized and non-solarized fields.

Among the different packages under Module 4, rhizome dip treatment with Metalaxyl MZ @ 0.15 % + two drenching with copper oxychloride @ 0.30 + soil application of the bioagent *T. harzianum* @ 5 kg/ha (T_7) recorded 10.84 per cent incidence and highest fresh rhizome yield of 110.34 q/ha. The above treatment was followed by the treatment T_5 including rhizome dip treatment with Copper oxychloride @ 0.3 % + two drenching with Metalaxyl MZ@ 0.02% + soil application of *T. harzianum* @ 5kg/ha recorded 14.17 % incidence and fresh rhizome yield of 105.57 q/ha (Pooled data Table Nos 18a,b i & ii). In considering the cost benefit ratio in solarized field the

treatment T_8 (rhizome dip treatment with Metalaxyl MZ @ 0.15 % + soil application of bleaching powder @ 15kg/ha recorded the highest Cost benefit Ratio of 1:3.03 followed by the treatment T_6 (rhizome dip treatment with Copper oxychloride @ 0.3 % + soil application of bleaching powder @ 15kg/ha) which recorded cost benefit ratio of 1:2.96. In case of non-solarized fields the treatment T_6 as mentioned above recorded the highest cost benefit ratio of 1:14.07, followed by the treatment T_8 detailed above which recorded cost benefit ratio of 1:8.80. The unfavorable cost benefit ratio in the case of T_7 (rhizome dip treatment with Metalaxyl MZ @ 0.15 % + two drenching with Copper oxychloride @ 0.3 % + soil application of *T. harzianum* @ 5kg/ha) apparently was due to the cost of Copper oxychloride used in the package. Reduction of the dose of the fungicide would possibly result in a more favarable cost benefit ratio.

Table 18 a. Integration of fungicide/ bactericide and bioagents on rhizome rot of ginger in solarized and non-solarized fields

Treatments	Incidence (%)			Yield (q/ha)		
	2005-06	2006-07	Pooled	2005-06	2006-07	Pooled
S_0	25.68 (30.46)	26.17 (30.79)	25.93	91.83	93.65	92.74
S_1	11.48 (19.82)	10.25 (18.63)	10.87	108.74	111.45	110.09
CD 5 % S	6.32	7.48	4.57	17.96	7.15	8.83
Treatments						
T_1	18.89 (25.77)	19.45 (26.21)	19.17	100.83	100.24	100.54
T_2	16.11 (23.66)	15.00 (22.79)	15.55	103.12	105.03	104.08
T_3	22.78 (28.52)	23.33 (28.86)	23.06	96.11	96.99	96.55
T_4	21.67 (27.76)	18.33 (25.33)	20.00	98.69	103.21	100.95
T_5	14.45 (22.32)	13.89 (21.89)	14.17	105.03	106.11	105.57
T_6	20.56 (26.99)	19.45 (26.21)	20.01	101.62	102.06	101.84
T_7	10.00 (18.44)	11.67 (20.00)	10.84	111.39	109.29	110.34
T_8	15.00 (22.79)	15.00 (22.79)	15.00	105.29	102.78	104.04
T_9	27.78 (31.82)	27.78 (31.82)	27.78	88.67	89.10	88.89
CD 5 % T	4.59	5.56	4.76	8.43	7.23	7.70
CV %	19.27	13.26	16.72	7.14	5.98.	6.58

Table 18 b(i). Cost benefit ratio of integration of fungicides/ bactericide and bioagents on rhizome rot of ginger in non-solarized fields

Treatments	Additional yield over control (q/ha)			Value of additional yield (Rs.)			Additional cost of cultivation (Rs.)	Net return (Rs.)			Cost benefit ratio		
	2005-06	2006-07	Pooled	2005-06	2006-07	Pooled		2005-06	2006-07	Pooled	2005-06	2006-07	Pooled
T_1	7.69	7.89	7.79	38450.00	39450.00	38950.00	7475.00	30975.00	31975.00	31475.00	1:5.14	1:5.28	1:5.21
T_2	13.60	10.64	12.12	68000.00	53200.00	60600.00	11955.00	56045.00	41245.00	48645.00	1:5.69	1:4.45	1:5.07
T_3	4.95	5.92	5.44	24750.00	29600.00	27200.00	69993.00	-45243	-40393	-42793	1:0.35	1:0.42	1:0.39
T_4	11.28	6.96	9.11	56400.00	34800.00	45550.00	139973.00	-83573	-105173	-94423	1:0.40	1:0.25	1:0.32
T_5	12.79	11.03	11.91	63950.00	55150.00	59550.00	8973.00	54977.00	46177.00	50577.00	1:7.13	1:6.15	1:6.64
T_6	7.02	5.68	6.38	35350.00	28400.00	31900.00	2268.00	33082.00	26132.00	29632.00	1:15.59	1:12.52	1:14.07
T_7	18.33	18.02	18.28	91650.00	90100.00	91400.00	142955.00	-51305	-52855	-51555	1:0.64	1:0.63	1:0.64
T_8	8.00	9.41	8.71	40000.00	47050.00	43550.00	4950.00	35050.00	42100.00	38600.00	1:8.08	1:9.51	1:8.80

Cost of Chemicals (Rs kg^{-1}/L^{-1})

Metalaxyl MZ (Ridomil MZ) – Rs.1458/-, Copper Oxychloride (Blitox-50) – Rs.228/-
Bleaching powder – Rs.35/- *T.* harzianum – Rs. 256/-
Cost of application (Rs.) – Seed treatment – 1 labour @ 75/-, Drenching- 2 lobour @ 75/- ,Soil application -2 labour @ 75/-
Sale price of ginger – Rs.50/kg

Table 18 b(ii). Cost benefit ratio of integration of fungicides/ bactericide and bioagents on rhizome rot of ginger in solarized fields

Treatments	Additional yield over control (q/ha)			Value of additional yield (Rs.)			Additional cost of cultivation	Net return			Cost benefit ratio		
	2005-06	2006-07	Pooled	2005-06	2006-07	Pooled		2005-06	2006-07	Pooled	2005-06	2006-07	Pooled
T_1	16.43	14.58	15.51	82150.00	72900.00	77550.00	38225.00	43925.00	34675.00	39325.00	1:2.15	1:1.91	1:2.03
T_2	18.25	18.27	18.26	91250.00	91350.00	91300.00	42705.00	48545.00	48645.00	48595.00	1:2.14	1:2.14	1:2.14
T_3	8.95	10.82	9.89	44750.00	54100.00	49450.00	100743.00	-55993	-46643	-51293	1:0.44	1:0.54	1:0.49
T_4	13.07	16.93	15.00	65350.00	84650.00	75000.00	170723.00	-105373	-86073	-95723	1:0.38	1:0.50	1:0.44
T_5	21.69	21.22	21.46	108450.00	106100.00	107300.00	39723.00	68727.00	66377.00	67577.00	1:2.73	1:2.67	1:2.70
T_6	20.22	18.84	19.53	101100.00	94200.00	97650.00	33018.00	68082.00	61182.00	64632.00	1:3.06	1:2.85	1:2.96
T_7	27.21	22.04	24.63	136050.00	110200.00	123150.00	173705.00	-37655	-63505	-50555	1:0.78	1:0.63	1:0.71
T_8	28.83	19.36	21.60	119150.00	96800.00	108000.00	35700.00	83450.00	61100.00	72300.00	1:3.34	1:2.71	1:3.03

Cost of Chemicals (Rs kg^{-1}/L^{-1})

Metalaxyl MZ (Ridomil MZ) – Rs.1458/-, Copper Oxychloride (Blitox-50) – Rs.228/-
Bleaching powder – Rs.35/- *T. harzianum* – Rs. 256/-
Cost of application (Rs.) – Seed treatment – 1 labour @ 75/-, Drenching- 2 lobour @ 75/- ,Soil application -2 labour @ 75/-
Sale price of ginger – Rs.50/kg

Plate(s) - 21, 22, 23 & 24

Field views of experimental plots

Plate 21

Plate 22

Plate 23

Plate 24

CHAPTER – 5

DISCUSSION

In India, ginger is cultivated in almost all the states. However, Kerala is the major ginger growing state followed by Meghalaya. The other ginger growing states include Orissa, West Bengal, Andhra Pradesh, Karnataka, Sikkim, Mizoram, Madhya Pradesh etc. The crop is popularly cultivated in Jharkhand state also. However, the statistics in regard to the cultivated area and production in the state is not available. One of the major obstacles in the way of increasing ginger production are pernicious diseases like rhizome rot, bacterial wilt, yellows and leaf spot.

Rhizome rot of ginger (*Zingiber officinale* Rosc.) caused *Pythium spp.* was known to exist from 1915 in the Malabar and South Kanara district of South India (Thomas, 1938). Besides *Pythium aphanidermatum* (Edison) Fitzp; Subramanian, 1919, *Pythium myriotylum* Drench and *Pythium vexans* de Bary (Ramakrishnan, 1949), other pathogens reported to cause rhizome rot were *Fusarium oxysporum* Schlecht *f.sp. zingiberi* Trujillo from Madhya Pradesh (Haware and Joshi, 1973); *Fusarium solani* (Mart.) Sacc. from Karnataka (Kumar, 1977) and *Pseudomonas solanacearum* E.F Smith from Kerala (Sarma *et al.,* 1978; Mathew *et al.,* 1979). The ginger crop suffers from rhizome rot in field involving fungi and bacteria which ultimately lead to rhizome rot.

In order to determine the prevalence of rhizome rot disease, surveys were undertaken during *kharif*, 2003-04 and 2004-05 crop seasons. Three convenient routes were followed to cover ginger growing areas in and around Ranchi. The Route-1 included Boreya, Kanke, Sukurhuttu and Pithoria villages. The Route-2 included Ratu and Itki villages and under the Route-3 Ormanjhi and Namkom areas were covered. The ginger plots of pre-identified contact farmers were visited to record total number of plants infected including current and cumulative figures for calculation of percent disease incidence. Rhizome rot

disease was found to be prevalent in all the localities included in the survey programme. The incidence varied from 15 % to 30.37% in different locations.

The disease normally appeared during last week of June or fast week of July. Maximum number of infected plants (current figures) were recorded during the month of August. Dake and Edison during the year 1988, 1989 surveyed 195 ginger fields spread all over Kerala state including 12 districts. The disease incidence in the samples collected were between 8.84% to 29.61%. Dohroo (1992) recorded the occurrence of wilt of ginger caused by *Pseudomonas solanacearum* in Sirmaur district of Himachal Pradesh during surveys conducted in 1989 and 1990 crop seasons. Srivastava (1992) reported rhizome rot incidence of ginger ranging from 15-35% from Sikkim. Das *et al.* (1997) from Assam reported an incidence of 45-50% in heavily infested areas. The prevalence of rhizome rot disease has also been reported from different district of Karnataka ranging from 5.23% to 47.23 %(Kulkarni *et al.,* 2006).

The initial symptoms of rhizome rot were recorded on the leaves in the form of slight paleness followed by yellowing of leaves. The infected leaves ultimately withered. The infection gradually spread down the leaf sheath, the dead leaves drooped and hung along the stem. The pseudostem became watery and soft. The infected rhizomes became discoloured and later showed rotting. The infected shoot could be easily pulled out at the point of attachment to the rhizome leaving the rotten and decomposed rhizome in the soil. Symptomatological observations have been made and reported in literature from different parts of the country (Shahare and Asthana, 1962; Haware and Joshi, 1973; Sarma *et al.,* 1978; Dake and Edison, 1989; Ramchandran *et al.* 1989; Dohroo, 1992; Bora and Das, 2002; Rajan *et al.,* 2002). The infected and partially rotten rhizomes considerably reduced the market value and rendered it unfit for seed purposes.

Pure culture isolations were made from infected rhizomes, pseudostem and from sick soil samples. Out of a total of 160 isolations made from infected

rhizomes 67 samples yielded *Pythium spp.,* 22 *Fusarium spp.* and remaining 24 yielded culture of *Ralstonia*. In isolations made from sick soil 47 samples yielded *Pythium spp.,* 13 *Fusarium spp.* and 11 samples yielded *Ralstonia*. The identity of isolated pathogens were confirmed at ITCC, Division of Plant Pathology, IARI, New Delhi. The results of present studies provided further support to the earlier reported work on complex nature of rhizome rot disease (Shahare and Asthana, 1962; Kothari, 1966, Haware and Joshi, 1973; Sarma *et al.,* 1978; Mathur *et al.,* 1984; Dahroo *et al.,* 1987; Doshi and Mathur, 1987; Rathaiah, 1987; Bhardwaj *et al.,* 1988; Yang *et al.,* 1988; Dake and Edison, 1989; Ramchandran *et al.,* 1992; Ram *et al.,* 1999; Sheel *et al.,* 1995; Das *et al.,* 2001; Rajan *et al.,* 2002; Kumar and Sarma, 2004; Kulkarni *et al.,* 2006). However, local variation in regard to dominance of *Pythium aphanidermatum* as compared to *F. oxysporum f.sp. zingiberi* and *Ralstonia solanacearum* in the region is to be noted for further work on disease management.

Laboratory *in vitro* evaluations were made to select fungicides, bioagents and the oil cake for inclusion in field trials. Based on efficacies in *in vitro* evaluations, six fungicides viz., carbendazim, mancozeb, Metalaxyl MZ, copper oxychloride, carbendazim 12% + mancozeb 63% (Companion) and Benomyl were selected. Among bioagents and the oil cakes, the bioagents *T. harzianum* and the oil cake of *P. glabra* were selected.

The ginger variety, Maran with disease incidence of 8.89% and 11.11% during the two years of trial showed Resistant (R) reaction. The varieties, Suruchi, Suprabha and Wynad showed Moderately Resistant (MR) reaction and the variety, Ranchi local showed Susceptible (S) reaction in 0-5 rating scale (Das, 1999).

Resistance of the ginger variety, Maran against *P. aphanidermatum* has been reported from Kerala State (Indrasenan and Paily, 1974). Indrasenan *et al.* (1982) reported susceptibility of almost all the ginger varieties against the bacterial wilt pathogen while evaluating the available ginger genotype against *Pythium spp.* Ali *et al.* (1995) reported the cultivar, SG-600 to be resistant showing only 8% mortality as compared to 42.92% mortality in the local cultivar. From Karnataka State, Shetty *et al.* (1995) recorded least (less than 3%) rhizome rot incidence in the varieties, Suprabha and Himachal Pradesh.

Soil solarization for a period of six week recorded 16.40% pre-emergence and 9.38% post-emergence rhizome rot compared to 40.88% and 19.51%, respectively, in non-solarized control plots. Yield of fresh rhizome in plots solarized for 6 weeks and in non-solarized plots recorded were 3.186 kg/plot and 1.812 kg/plot, respectively, indicating significant differences in both rhizome rot incidence and yields of fresh rhizomes.

Mohan *et al.* (2004) attempted soil solarization using 100 micrometer thick polythene sheet. An increase of soil temperature by 6.0 – 12.7°C as compared to non-solarized plots was recorded. This heating of soil was found to be effective in controlling the disease due to greater reduction in soil propagules of *F. oxysporum f.sp. zingiberi*.

Soil amendment with *Pongamia glabra* recorded 77.58% germination, 23.75% incidence of rhizome rot, 54.4% disease control and 20.94% yield increase over control. The effect of organic soil amendment has been studied and reported in literature. Thakore *et al.* (1987) reported reduction of rhizome rot following soil amendment of cake made from *Azadirachta indica, Calophylum inophyllum* or *Pongamia glabra*. Dohroo *et al.* (1994) reported minimum incidence of rhizome rot in soil treatment with Pinus needle and neem cake powder. The efficacy of soil amendment with *P. glabra* cake against rhizome rot recorded in the present studies lends support to the earlier reported work as stated above.

In studies on the effect of soil application of *Trichoderma spp.* on management of rhizome rot, *T. harzianum* was recorded to be the most effective bio-control agent with 77.50% germination and 27.50 % rhizome rot incidence. *T. harzianum* provided 50.74% disease control and recorded fresh rhizome yield of 101 g/plant. The next efficacious bio-control agent, *T. viride* recorded 70.86% germination, 30% rhizome rot incidence, affoarded 46.27% disease control and recorded fresh rhizome yield of 95.22 g/plant. Rajan *et al.* (2002) from Sikkim while working on the management of rhizome rot have reported the efficacy of *T. harzianum* against the disease. *T. harzianum* was incorporated into the soil @ 5 g/pot at the time of planting.

Among fungicides, Metalaxyl MZ (0.15%) and Copper oxychloride (0.3%) were recorded to be effective chemicals for seed rhizome treatment. Metalaxyl MZ (0.15%) affoarded 39.63% disease control with 76.67% germination and 27.92% rhizome rot incidence at maturity. Seed rhizome treatment with Metalaxyl MZ (0.15%) recorded fresh rhizome yield of 83.49 q/ha with cost benefit ratio of 1:16.26. Copper oxychloride (0.3%) affoarded 30.64% disease control with germination of 75.42% and rhizome rot incidence of 32.08% at maturity. Although seed rhizome treatment with copper oxychloride (0.3%) recorded a lower fresh rhizome yield of 74.31 q/ha, the cost benefit ratio was more favourable i.e. 1:18.05 in view of lower cost of the fungicide.

Sharma and Dohroo (1982) reported control of rhizome rot caused by *P. pleroticum* and *F. equiseti* through rhizome dip treatment in 0.2% solution of Dithane M-45 (mancozeb) or Daconil (chlorothalonil) under field conditions. Dohroo and Sharma (1985 a) reported efficacies of chemicals such as, Antracol (propineb 0.25%), Fycop and Blitox 50 (copper oxychloride 0.3%) against rhizome rot when used as 30 minutes dip treatment for rhizomes before planting. Das *et al.* (2001) reported that Ridomil MZ-72 @ 0.1% effectively reduced the disease with only 18.63% disease incidence. Ridomil MZ-72 treated

rhizome showed maximum germination as well as the highest yield among the treatments studies.

Rhizome pelleting with *T. harzianum* recorded 75.82 percent germination, 35.83 percent rhizome rot incidence and recorded 31.75 disease control. Rhizome pelleting with *T. harzianum* recorded fresh rhizome yield of 81.38 g/plant. Rhizome pelleting with *T. viride* recorded 70% germination, 43.33% incidence and 17.47% disease control. Pelleting treatment with *T. viride* recorded fresh rhizome yield of 75.88 g/plant being at par with rhizome pelleting treatment with *T. harzianum.*

According to Dohroo and Sharma (1985 b) pre storage dipping or steeping rhizomes in *T. hamatum* suspension or smearing of rhizomes with *T. viride* proved effective against *F. equiseti.* Shaktawat (1987) and Ram (1988) reported significant suppression of rhizome rot of ginger by either pelleting the rhizome seed with *T. viride* or soil amendment of this bio agent just before sowing.

Among chemical toxicants evaluated, soil drenching with copper oxychloride @ 0.3% recorded 71.88% germination, 26.04% rhizome rot incidence and highest disease control of 50.99%. Drenching with copper oxychloride recorded fresh rhizome yield of 638.33 g/3 m row length. Soil application of the fungicide, Metalaxyl MZ @ 0.02% recorded highest germination 76.04%. Metalaxyl MZ recorded 28.13% rhizome rot incidence with 47.05% disease control and fresh rhizome yield of 428.33 g/3 m row length. Efficacies of Bordeaux mixture (2:2.50), Dithane Z-78, Difolatan, Ridomil 5G, Alliette (Fosetyl Aluminium) and Dithane M-45 has been reported in literature (Bhagwat, 1960, Shahare and Asthana, 1962, Sharma *et al.,* 1980, Doshi and Mathur, 1987 and Srivastava, 1992).

The efficacy of copper oxychloride against both fungal and bacterial pathogens and of Metalaxyl MZ against *Pythiaceous* fungi has been reported in literature (Devaki and Bhat, 1992; Dahroo *et al.*, 1984, Kulkarni *et al.,* 2006).

Effect of organic mulching on incidence of rhizome rot was studied using green leaves of *P. glabra*, *E. citriodora*, *M. indica* and *B. monosperma* applied @ 2.5 kg/m2 and paddy straw applied @ 2 kg/m2. First mulching was done immediately after planting, it was followed by second and third mulching at 45 and 90 days after planting. Mulching with *E. citriodora* leaves recorded pre-emergence and post-emergence rhizome rot of 7.50% and 8.19% respectively. Mulching with *E. citriodora* recorded fresh rhizome yield of 1.81 kg/sq.m. Organic mulching with leaves of *P. glabra* with pre-emergence, post-emergence rhizome rot and fresh rhizome yield of 13.33%, 16.39% and 2.02 kg/sq.m, respectively, was the second best treatment. Suppression of early weed growth and higher yield following mulching of ginger plots with dried leaves or straw have been reported (Mishra and Mishra, 1982). Contribution of nematicidal properties of the leaves used for mulching has also been reported (Das, 1999; Senapati *et al.,* 2006).

For integrated management of rhizome rot of ginger under Ranchi conditions, the following Modules with different sets of packages were evaluated during *Kharif,* 2005-06 and 2006-07 crop seasons under natural epiphytotics.

Module packages 1. Integrated management of rhizome rot of ginger with fungicides, bioagents and oil cakes.

Module packages 2. Biological management of rhizome rot involving bio-agent, oil cake and mulching.

Module packages 3. Combined effect(s) of ginger varieties and pre-sowing rhizome treatment with fungicides.

Module packages 4. Integration of fungicides/ bactericide and bio-agent on rhizome rot of ginger in solarized and non-solarized fields.

Integration of soil application of the bio-agent, *T. harzianum* @ 5 kg/ha, rhizome dip treatment with the fungicide, copper oxychloride @ 0.3%

followed by two soil drenchings with Metalaxyl MZ solution @ 0.02% recorded 73.87 % germination and 23.34 % rhizome rot incidence. The above treatment set affoarded 46.82% disease control, recorded fresh rhizome yield of 90.36 q/ha. The cost benefit ratio worked out in the package was 1:7.54. Highest fresh rhizome yields were obtained in the package, soil application of *T. harzianum* @5 kg/ha + oil cake of *P. glabra* @ 20 q/ha, rhizome dip treatment with Metalaxyl MZ @ 0.15% for a period of 30 minutes,two drenchings with Copper oxychloride @ 0.3% but the cost benefit ratio was less favorable.

Rrhizome treatment with *T. harzianum* @ 6g/L+ soil amendment with *P. glabra* oil cake @ 20 q/ha + mulching with *E. citriodora* leaves @ 2.5 kg/m^2 recording 80.00 % germination, 23.33 % disease incidence and affoarded 43.89 % disease control. The above package recorded fresh rhizome yield of 97.26 q/ha with cost benefit ratio of 1:10.44 .The package including *T. harzianum* @ 6g/L+ soil amendment with *P. glabra* oil cake @ 20 q/ha recorded 75.83 % germination, 29.58 % disease incidence and affoarded 28.86 % disease control. The above package recorded fresh rhizome yield of 87.41 q/ha with cost benefit ratio of 1:2.99 .

The ginger variety, Maran, pre-sowing rhizome treatment with Metalaxyl MZ @ 0.15%, recorded maximum germination of 84.02%, minimum disease incidence of 6.25% and highest fresh rhizome yield of 117.17 q/ha.

Rhizome dip treatment with Metalaxyl MZ @ 0.15 % + two drenchings with Copper oxychloride @ 0.3% + soil application of the bioagent *T. harzianum* @ 5 kg/ha recorded 10.84% incidence and highest fresh rhizome yield of 110.34 q/ha. The above package was followed by treatments including rhizome dip treatment with Copper oxychloride @ 0.3 % + two drenchings with Metalaxyl MZ@ 0.02% + soil application of *T. harzianum* @ 5 kg/ha. The package recorded 14.17 % rhizome rot incidence and fresh rhizome yield of 105.57 q/ha. Considering the cost benefit ratio in solarized fields the package, rhizome dip treatment with Metalaxyl MZ @ 0.15 % + soil application of

bleaching powder @ 15 kg/ha recorded highest cost benefit ratio of 1:3.03 followed by the package, rhizome dip treatment with Copper oxychloride @ 0.3% + soil application of bleaching powder @ 15 kg/ha which recorded cost benefit ratio of 1:2.96. In case of non-solarized fields, the package, rhizome dip treatment with Copper oxychloride @ 0.3% + soil application of bleaching powder @ 15kg/ha recorded highest cost benefit ratio of 1:14.07, followed by the package including rhizome dip treatment with Metalaxyl MZ @ 0.15 % + soil application of bleaching powder @ 15kg/ha which recorded cost benefit ratio of 1:8.80. The unfavourable cost benefit ratio in the package, rhizome dip treatment with Metalaxyl MZ @ 0.15 % + two drenchings with Copper oxychloride @ 0.3% + soil application of *T. harzianum* @ 5kg/ha apparently was due to the cost of Copper oxychloride used. Reduction of the dose of the fungicide would possibly result in a more favourable cost benefit ratio.

Rathiah (1987) observed that dipping or wetting of seed pieces one day before planting and soil drenching with a mixture of Ridomil + Captafol three months after planting controlled rhizome rot and increased the yield of ginger.

Kumar *et al.* (1989) reported best control of rhizome rot disease caused by *F. oxysporum* following soil treatment with 4% Formaldehyde combined with treatment of seed rhizomes with Topsin M-70 (thiophonate methyl) at 0.1%.

Srivastava (1994) managed soft rot caused by *P. aphanidermatum* in Sikkim effectively by drenching the soil with Zineb or Mancozeb following rhizome treatment with Carbendazim and incorporating thiodan dust into soil to control insect invasion.

While working on integrated management of ginger yellows, Dohroo (1995) reported reduction in disease incidence and increased yield of rhizomes following seed treatment in a solution of Mancozeb 0.25 % and Carbendazim 0.1 % for 60 minutes. The affect of seed treatment with fungicides as above further increased when BCAs were used either alone or in combination at the time seed

bed preparation. The author found that fungicidal seed treatment and BCAs i.e *T. harzianum* and *T. hamatum* each at 350/3m^2 decreased the incidence of yellows and increased the yield significantly. Ram *et al.* (1999) evaluated the efficacy of *Pseudomonas* species alone or in combination with *T. harzianum* and also with fungicidal rhizome treatment. Combination of both BCAs resulted in better germination and plant stand, reduced disease incidence and increased yield. Soil application of BCAs was found to be more effective as compared to seed treatment. Integration of soil application of BCAs with fungicidal rhizome treatment [Bavistin + Ridomil MZ (Metalaxyl + Mancozeb] increased the efficiency of disease control as compared with their individual treatments. Soil application of *T. harzianum* and rhizome treatment with Pseudomonas species and fungicide was most effective among all the tested treatment.

Beena and Sarma (2000) reported seed treatment with Metalaxyl (Ridomil MZ) and soil application of *T. harzianum* to be effective in the suppression of rhizome rot.

Jayasekhar *et al.* (2000) evaluated fungicidal seed ginger treatment as well as BCAs (*T. harzianum* + neem cake or *T. viride* + neem cake) which were incorporated in FYM and applied to the soil prior to sowing. All the tested fungicides and BCAs exhibited effectiveness against rhizome rot caused by *P. aphanidermatum* and increased rhizome yield. Metalaxyl MZ @ 0.1 % recorded lowest disease incidence (4.23%). Cost benefit ratio was highest (1:2.85) with *T. harzianum* + neem cake application followed by 0.1% Metalaxyl (1:2.71). Meena and Mathur (2003) used three BCAs i.e. *T. viride, G. virens, Ps. fluorescens* and an effective fungicidal mixture of Ridomil MZ (Metalaxyl) 6.25 g and Bavistin (Carbendazim 50 WP) 2 g/L for treating seed rhizomes and soil individually and in combination for the suppression of rhizome rot caused by *F. solani* and *P. myriotylum*. Crop and disease parameters such as crop stand, rhizome yield, rotting percentage and pathogen suppression in the rhizosphere were determined. Pelleting of seed rhizomes with BCAs was not found effective.

Pelleting either with fungicidal mixture or BCAs combined with soil application of BCAs were effective in suppressing the disease and increasing the yield.

Das *et al.* (2001) studied the effect of different varieties and fungicides against rhizome rot. The authors examined six varieties of ginger along with five fungicidal treatments. They observed that 'Maran' variety yielded 114.08 q/ha which was followed by Rio de-Janeiro (106.47 q/ha).

Mathur *et al.* (2002) studied integration of soil solarization and pesticides for management of rhizome rot of ginger. In non-solarized field, seed treatment with Ridomil MZ @ 6.5 g/L and soil application of Phorate @ 10 g/sq. m plus Ridomil MZ @ 10 L/pot drench significantly reduced the disease recording only 3.7% rotting. In the solarized field, Ridomil MZ seed dressing plus drench and Ridomil MZ seed dressing plus Phorate application and Ridomil MZ drench resulted in less disease (2.6 – 4.6 %) and higher yield (1.6 – 1.36 kg) over untreated control.

CHAPTER-6

SUMMARY AND CONCLUSION

Ginger (*Zingiber officinale* Rosc.) is one of the important spices grown in India. The crop is vulnerable to various diseases viz., rhizome rot, wilt, yellows, leaf spot etc. Among these, rhizome rot is most severe in Chotanagpur region of Jharkhand state.

Rhizome rot disease of ginger was found to be prevalent in all the localities surveyed. The disease incidence varied from 15 % to 30.37 % in different locations during *Kharif,* 2003-04 and 2004-05 crop seasons. The disease normally appeared during last week of June or 1st week of July. Maximum number of infected plants were recorded during the month of August.

The initial symptoms of rhizome rot were recorded on the above ground parts in the form of slight paleness at the tip of terminal leaves followed by yellowing of leaves. The infected leaves ultimately withered. The infection gradually spread down the leaf sheath, the dead leaves drooped and hung along the stem. The pseudostem became watery and soft. The disease extended further down from the collar region to the rhizomes. The infected rhizomes became discoloured and later showed rooting. The infected shoot could be easily pulled out at the point of attachment to the rhizome leaving the rotten and decomposed rhizome in the soil.

Rhizome rot of ginger was recorded to be a complex disease and association of *Pythium aphanidermatum, Fusarium oxysporum f.sp. zingiberi* and *Ralstonia solanacearum* was confirmed based on morphotaxonomic features. The identity was confirmed at ITCC (Indian Type Culture Collection), Division of Plant Pathology, IARI, New Delhi. Predominance of *P. aphanidermatum* was also recorded.

Laboratory *in vitro* evaluations showed efficacies of fungicides viz., Carbendazim, Mancozeb, Metalaxyl MZ, Copper oxychloride, Carbendazim 12% + Mancozeb 63%, Benomyl, the bio-agent, *Trichoderma harzianum* and the oil cake, *Pongamia glabra* and these were selected for field trials.

The variety, Maran with disease incidence of 8.89% and 11.11% during the two years of trial showed Resistant (R) reaction. The varieties, Suruchi, Suprabha and Wynad showed Moderately Resistant (MR) reaction. The varieties Pune Local and Nadia showed Moderately Susceptible (MS) reaction and the variety, Ranchi local showed Susceptible (S) reaction in 0-5 rating scale.

Soil solarization for a period of six weeks recorded 16.40% pre-emergence and 9.38% post-emergence rhizome rot as compared to 40.88% and 19.51% pre and post-emergence rhizome rot, respectively, in non-solarized plots. Yield(s) of fresh rhizomes in plots solarized for six weeks and non-solarized plots recorded were 3.19 kg/plot and 1.81 kg/plot, respectively indicating significant differences in both rhizome rot incidence and yields of fresh rhizomes.

Soil amendment with *P. glabra* oil cake recorded 77.58% germination and 23.75% incidence of rhizome rot. The *P. glabra* cake recorded disease control of 54.4% fresh rhizome yield of 90.83 q/ha giving 20.94% yield increase over control.

T. harzianum was recorded to be the most effective biocontrol agent with 77.50% germination and 27.50% rhizome rot incidence. *T. harzianum* provided 50.74% disease control and recorded fresh rhizome yield of 101.00 g/plant. The next efficacious biocontrol agent, *T. viride* recorded 70.86% germination, 30% rhizome rot incidence, afforded 46.27 percent disease control and recorded fresh rhizome yield of 95.22 g/plant.

Soil drenching with Copper oxychloride @ 0.3% recorded 71.88% germination, 26.04% rhizome rot incidence and highest disease control of 50.99%. Drenching with Copper oxychloride recorded fresh rhizome yield of

638.33 g/3 m row length. Soil drenching of the fungicide, Metalaxyl MZ applied @ 0.02% recorded highest germination (76.04%). Metalaxyl MZ recorded (28.13%) rhizome rot incidence with (47.05%) disease control and fresh rhizome yield of 428.33 g/3 m row length.

Among fungicides, Metalaxyl MZ (0.15%) and copper oxychloride (0.3%) were recorded to be effective chemicals for seed rhizome treatment. Metalaxyl MZ (0.15%) affoarded 39.63% disease control with 76.67% germination and 27.92% rhizome rot incidence at maturity. Seed rhizome treatment with Metalaxyl MZ (0.15%) recorded fresh rhizome yield of 83.49 q/ha with cost benefit ratio of 1:16.26. Copper oxychloride 0.30% affoarded 30.64% disease control with germination of 75.42% and rhizome rot incidence of 32.08% at maturity. Although seed rhizome treatment with copper oxychloride @ 0.3% recorded a lower fresh rhizome yield of 74.31 q/ha, the cost benefit ratio was more favourable i.e. 1:18.05 in view of lower cost of the fungicide.

Rhizome pelleting with *T. harzianum* recorded 75.82 percent germination, 35.83 percent rhizome rot incidence and recorded 31.75 disease control. Rhizome pelleting with *T. harzianum* recorded fresh rhizome yield of 81.38 g/plant. Rhizome pelleting with *T. viride* recorded 70% germination, 43.33% incidence and 17.47% disease control. Pelleting treatment with *T. viride* recorded fresh rhizome yield of 75.88 g/plant being at par with rhizome pelleting treatment with *T. harzianum.* For Integrated management of rhizome rot under Ranchi conditions, modules with different sets of packages were evaluated during *Kharif*, 2005-06 and 2006-07 crop seasons under natural epiphytotics.

Mulching with *Eucalyptus citriodora* leaves recorded pre-emergence and post-emergence rhizome rot of 7.50% and 8.19%, respectively. Mulching with *E. citriodora* recorded fresh rhizome yield of 2.81 kg/sq. m. Organic mulching with leaves of *P. glabra* with pre-emergence, post-emergence rhizome rot and fresh rhizome yield of 13.33%, 16.39% and 2.02 kg/sq.m, respectively, was the second best treatment.

For Integrated management of rhizome rot under Ranchi conditions, Modules with different sets of packages were evaluated during *Kharif*, 2005-06 and 2006-07 crop seasons under natural epiphytotics. Integration of soil application of the bio-agent, *T. harzianum* @ 5 kg/ha, rhizome dip treatment with the fungicide, Copper oxychloride @ 0.3% followed by two soil drenchings with Metalaxyl MZ solution @ 0.02% recorded 73.87 % germination and 23.34 % rhizome rot incidence. The above treatment set affoarded 46.82% disease control, recorded fresh rhizome yield of 90.36 q/ha. The cost benefit ratio worked out in the package was 1:7.54. Highest fresh rhizome yields were obtained in the package, soil application of *T. harzianum* @5 kg/ha + oil cake of *P. glabra* @ 20 q/ha, rhizome dip treatment with Metalaxyl MZ @ 0.15% for a period of 30 minutes,two drenchings with copper oxychloride @ 0.3% but the cost benefit ratio were less favourable.

Rhizome treatment with *T. harzianum* @ 6g/L+ soil amendment with *P. glabra* oil cake @ 20 q/ha + mulching with *E. citriodora* leaves @ 2.5 kg/m^2 recording 80.00 % germination, 23.33 % disease incidence and affoarded 43.89 % disease control. The above package recorded fresh rhizome yield of 97.26 q/ha with cost benefit ratio of 1:10.44.

The ginger variety, Maran, pre-sowing rhizome treatment with Metalaxyl MZ @ 0.15%, recorded maximum germination of 84.02%, minimum disease incidence of 6.25% and highest fresh rhizome yield of 117.17 q/ha. The above package was followed by the use of ginger variety, Wynad and pre-sowing rhizome treatment with Metalaxyl MZ @ 0.15% recorded 81.25% germination, 11.81% disease incidence and fresh rhizome yield of 84.92 q/ha.

Rhizome dip treatment with Metalaxyl MZ @ 0.15% + two drenchings with Copper oxychloride @ 0.3% + soil application of the bioagent *T. harzianum* @ 5 kg/ha recorded 10.84% incidence and highest fresh rhizome yield of 110.34 q/ha. The above package was followed by treatments including

rhizome dip treatment with Copper oxychloride @ 0.3% + two drenchings with Metalaxyl MZ@ 0.02% + soil application of *T. harzianum* @ 5 kg/ha. The package recorded 14.17% rhizome rot incidence and fresh rhizome yield of 105.57 q/ha. Considering the cost benefit ratio in solarized fields the package, rhizome dip treatment with Metalaxyl MZ @ 0.15 % + soil application of bleaching powder @ 15 kg/ha recorded highest cost benefit ratio of 1:3.03 followed by the package, rhizome dip treatment with Copper oxychloride @ 0.3% + soil application of bleaching powder @ 15 kg/ha which recorded cost benefit ratio of 1:2.96. In case of non-solarized fields the treatment, rhizome dip treatment with Copper oxychloride @ 0.3 % + soil application of bleaching powder @ 15kg/ha recorded highest cost benefit ratio of 1:14.07, followed by the package including rhizome dip treatment with Metalaxyl MZ @ 0.15% + soil application of bleaching powder @ 15kg/ha which recorded cost benefit ratio of 1:8.80. The unfavourable cost benefit ratio in the package, rhizome dip treatment with Metalaxyl MZ @ 0.15 % + two drenchings with Copper oxychloride @ 0.3% + soil application of *T. harzianum* @ 5kg/ha apparently was due to the cost of Copper oxychloride used. Reduction of the dose of the fungicide would possibly result in a more favourable cost benefit ratio.

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