# INTEGRATED APPROACH FOR MANAGEMENT OF RHIZOME ROT OF GINGER CAUSED BY *Fusarium oxysporum*

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**DECEMBER, 2010**

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**BY**

**REGISTRATION NO. 05-01820**





**A Thesis**

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# CERTIFICATE

This is to certify that the thesis entitled "**INTEGRATED APPROACH FOR MANAGEMENT OF RHIZOME ROT OF GINGER CAUSED BY *Fusarium oxysporum***" submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (MS) IN PLANT PATHOLOGY**, embodies the results of a piece of bona fide research work carried out by **MD. ZIAUR RAHMAN BHUIYAN, REGISTRATION NO. 05-01820,** under my supervision and guidance. No part of this thesis has been submitted for any other degree in any other institutions.

I further certify that any help or sources of information received during the course of this investigation have been duly acknowledged.



**Dated: APRIL, 2012**
**Dhaka, Bangladesh**

**Prof. Dr. Md. Rafiqul Islam**
**Supervisor**

*Dedicated to*

*My*

*Beloved Parents*

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**The Author**

# INTEGRATED APPROACH FOR MANAGEMENT OF RHIZOME ROT OF GINGER CAUSED BY *Fusarium oxysporum*

## ABSTRACT

An experiment was conducted at Sher-e-Bangla Agricultural University on integrated approach for management of rhizome rot of ginger caused by *Fusarium oxysporum* during 15 March'2011 to February 2012. There were sixteen treatments used including untreated control such as Bavistin 50WP, Poultry waste + Ridiomil gold MZ 72, Poultry waste+ neem leaf extract, Saw dusts + alamanda leaf extract, Poultry waste+ Bavistin 50WP, Saw dusts+ neem leaf extract, *Trichoderma harzianum*, Poultry waste, Saw dusts+ Ridomil gold MZ 72, Poultry waste+ alamanda leaf extract, Saw dusts, Saw dusts+ Bavistin 50WP, Ridomil gold MZ 72, neem leaf extract, alamanda leaf extract. Rhizomes were treated with Bavistin 50WP, Ridomil gold, neem leaf extract, alamanda leaf extract and *Trichoderma harzianum*. Poultry waste and saw dusts were applied in the plot during land preparation. The lowest disease incidence (2.77%) and the highest reduction of disease incidence (95.66%) over untreated control were counted in Poultry waste+Bavistin 50WP followed by Poultry waste+Ridomilgold MZ 72), Poultry waste + Alamanda leaf extract, at 240 DAP. The highest disease incidence (63.88%) was recorded in untreated control. The lowest disease severity (8.23%) and the highest reduction of disease severity (84.62%) over control was recorded at 240 DAP in Poultry waste+Bavistin 50WP followed by Poultry waste+alamanda leaf extract. The highest number of tillers (60) per hill, the highest plant height (65.20 cm) per plot, the highest weight (3039 g) of the healthy rhizome per plot and the lowest weight (307.3 g) of infected rhizome per plot was recorded in case of Poultry waste+Bavistin 50WP. The highest rhizome yield (16.73 t/ha) was achieved in Poultry waste+Bavistin 50WP which was 172.92% increased over the untreated control followed by $T_{11}$ (16.24 t/ha). Poultry waste+alamanda leaf extract was also showed better yield (16.24t/ha) Performance.

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# *Introduction*

# Chapter I

# INTRODUCITION

Ginger (*Zingiber officinale*) belongs to family Zingiberaceae is an important oriental spice crop. It has special significance for tropical countries where it is produced and consumed in large quantities (Rahim, 1992). It is an herbaceous plant and has been used in Asia from very ancient time. The useful parts of this crop are the rhizomes (Purseglove *et. al.*, 1988).

In western countries, ginger is widely used for culinary purpose in ginger bread, biscuits, cakes, pudding, soups and pickles. It is a frequent constituent of curry powder. It is one of the most widely used spices in Chinese cookery. It is also used in medicine as a carminative and aromatic stimulant to the gastrointestinal tract, externally as an aphrodisiac and internally as a counter irritant. Ginger is used popularly as chewing purpose (Purseglove *et. al.*, 1998). In Bangladesh ginger is mainly used as spice. It is cultivated all over the country where Rangpur, Nilpharmari, Tangail, Khulna, Pabna, Jessore, Rangamati, Bandharban, Khagachori, Chittagong and Chittagong Hill tracts of Bangladesh are the most suitable places for its commercial cultivation. Ginger is grown by the small farmers as their cash crop in different parts of Bangladesh. The annual production of ginger was 74841 metric tons where total area of ginger cultivation was about 22403 acres and the yield per acre was about 4541kg (BBS, 2009-2010) in the country. The national production of ginger is not sufficient so, deficit amount is required to import from abroad to meet up the national demand.

Disease is a major constraint for the production of healthy rhizome, some times causing total failure of crop (Fagria *et. al.* 2006). Ginger is affected by various diseases, viz. Rhizome rot, Bacterial wilt, Soft rot and blight etc. Among these, rhizome rot is most damaging one (Chattopadhya, 1997 and Ahmed, 1992) which is caused by *Fusarium oxysporum* and *Pythium* (Ram *et. al.*, 1999). It came slight fading of green color of leaves. The tip of the leaves turns yellow and the color proceeds downwards ultimately resulting in withering and death of the leaf. The infection then manifested on the shoot. The foot of the plant and the rhizomes turn

pale. The portion just above the ground level becomes watery and soft. The rhizomes gradually decompose turning into a decaying mass of tissues enclosed by the comparatively tough rind (Singh, 1978). The disease is important because it causes economic losses to growers resulting in increased prices of products to the consumers. The infected rhizomes become rotten and the crop is completely destroyed (Baruah *et. al.*, 1998).

Many researchers worked on the chemical control of the disease and found very promising effect of different chemicals against the disease (Stirling *et. al.,* 2006; Usman *et. al.,* 2006; Meena and Mathur, 2005; Singh *et. al.,* 2001). Systemic and contact fungicides like Bavistin 50WP, Ridomil gold MZ72, Captan, Dithane M-45, Copper Oxychloride and Bordeaux mixture were reported effective against the disease. However, chemicals treatment increase the cost of production and continuous use of the chemicals results in accumulation of harmful chemical residues in soil as well as plant products causing serious environmental pollution, deleterious effect to non target beneficial soil micro organism. In search of eco-friendly approach several researchers investigated on organic products, bio-agents, plant extract for the management of the disease (Dohroo and Sharma, 1994; Ram *et.al.,* 2002; Anandaraj and Sharma, 2003; Ambia, 2006 and Ahmmed, 2006).

Bio-agent like *Trichoderma* sp. now- a- days is frequently using against soil borne fungal pathogens as biological controlling tools (Ahmmed and Hossain, 2006). Soil amendment using poultry wastes and saw dust are now being considered as environmentally approach that make the soil suppressive improving the antagonistic activities of the soil microorganisms.

Thus, finding out the alternatives of chemical fungicides with eco-friendly components, research need to carrying out with bio-agent, organic soil amendment, plant extracts alone or in combination to formulate the integrated approach for the management of the disease. But no such initiatives have yet been taken in the country for the management of the disease. So, the problem needs to give urgent attention.

Considering the above circumstances, the present investigation has been undertaken to achieve the following objectives:

a) To isolate and identify the causal organism of rhizome rot of ginger.
b) To integrate the selected IPM components for management of the rhizome rot disease of ginger.
c) To formulate an integrated approach for the ginger growers.

# Chapter II
# Review of Literature

## Chapter II

## REVIEW OF LITERATURE

Among the diseases rhizome rot of ginger is very important. A few studies related to control of rhizome rot of ginger have been carried out in the country as well as in the world. The work so far done in Bangladesh is not adequate and conclusive. Some of the important and informative works and research findings so far been done at home and abroad on this aspect have been reviewed in this chapter.

Sharma *et. al.* (1978) assessed systemic and contact fungicides in the control of rhizome rot of ginger caused by *Fusarium oxysporum.* They found that the yield of rhizome was increased when they used fungicides. They reported that Bavistin 50 WP was the best fungicides in controlling rhizome rot of ginger, followed by Captan and Difolatan.

Ichitani (1980) worked on the control of rhizome rot of ginger by cultivating successively and protectively for immature rhizome production in plastic house. He reported that *Fusarium oxysporum* was not consistently isolated from rotted ginger tissues and rhizome rot disease did not develop when disease free rhizomes ware sown in soil fumigated with methyl bromide. He found that rhizome rot incidence was reduced when seed treated with echlomezol and methyl bromide.

Dohroo and Sharma (1983) evaluated fungicides for the control of rhizome rot of ginger caused by *Fusarium equiseti* and *Pythium pleroticum* in storage and obtained good control with Antracol (Propineb, 0.25%), Fycop and Blitox-50 (both copper oxchloride. 0.3%) as 30 min rhizome dips.

Rathaiah (1987) tested soft rot (*Pythium muriotyhum)* of ginger by Ridomil gold and in combination with Captafol, Captan or Mancozeb. He stated that dipping of wetting of seed pieces 1 day before planting and soil drenching with a mixture of Ridomil + Captafol 3 months after planting controlled the disease and significantly increased the yield of ginger.

Ramchandran *et. al.* (1989) evaluated 5 systemic fungicides for efficacy against rhizome rot of ginger. The fungicides were tested as soil and seed treatments and they fund metalaxyl formulations, namely Ridomil 5G garnules and Apron 35 WS gave the best control of the disease.

Raj *et. al.* (1989) conducted an experiment in consideration of soil treatment with 4% formaldehyde combined with treatment of the rhizome planting material with Topsin M-70 at 0.1% gave the best control of this disease, caused by *Fusarium oxysporum*. Ginger rhizome treatment with 0.1% Bavistin or 0.3% Dithane M-45, with the formaldehyde soil treatment, was also satisfactory, through less effective.

A rise in peroxidase activity was recorded by Dohroo (1989) in ginger rhizomes infected by *Pythium pleroticum* and *Fusarium equiseti* 3 days after infection followed by a sharp decline. The decline was nearly double in rhizomes infected by *F. equiseti* compared with that in rhizomes infected by *P. pleroticum.* Polyphenol oxidase activity could not be detected in healthy or inoculated rhizomes.

Dohroo (1989) conducted an experiment with 10 cultivars tested in the field during 1986 and recorded the lowest incidence of *Fusarium oxysporum* f. sp. *zingiberi.* Disease in the field was positively correlated with its occurrence in storage and 87% of the pre-emergence rot and yellows was transmitted from infected rhizomes. The importance of pre-planting chemical treatments for control of this disease was confirmed.

Raj *et. al.* (1989) observed the chemical control of rhizome rot of ginger by seed and soil treatments. They found that soil treatment with 4% formaldehyde combined with treatment of the rhizome planting material with Toprinm-70 (Thiophanate-methyl) at 0.1% gave the best control of this disease caused by *Fusarium oxysporum*. They also noticed that rhizome treated with 0.1% Bavistin (carbendazim) or 0.3% Dithane M-45 (Mancozeb) in combination with soil treated with the formaldehyde gave satisfactory control of this disease.

Chauhan and patel (1990) reported that rhizome rot disease is associated with a *Pythium* spp. and *Fusarium solani*, either or separately. Pathogenicity of both organisms was confirmed experimentally. This is the first report of *F. solani* causing soft rot of ginger and also of combined infection with *Pythium*, resulting in rapid drying of the shoot, followed by rhizome rot. All the metalaxyl formulations tested were effective against *Pythium* spp. and Bordeaux mixture gave the best inhibition of *F. solani*

Das *et. al.* (1990) stated the efficacy of fungicides for seed treatment against pre-emergence rhizome rot of ginger. They reported the lowest incidence of this disease caused by *Fusarium spp. & Pythium* spp. and highest percentage of germination was yielded by seed treatment with captan (0.2%) for 30 min, while Captafol (0.2%) and Dithane M-45 (mancozeb) at 0.3% were also effective.

Sharma and Dohroo (1991) described the post harvest management of rhizome rot (*Fusarium oxysporum* f. sp. *zingiberi trujillo*) of ginger through chemical and antagonist. They also described that *Trichoderma* and *Gliocladium virens* inhibited growth of *Fusarium oxysporum* f. sp. *zingiberi in-vitro* by 73 and 68 percent, respectively.

Several angatonists were tested by Pandey *et. al.* (1992) for the biological control of rhizome rot of ginger caused by *Fusarium oxysporum.* An extract of *Agave americana* was found to be very effective in controlling the disease under laboratory and field conditions, followed closely by culture filtrates/extracts of *Bacillus subtilis, Cannabis sativa, Lyonia ovalifolia* nd *Aspergillus niger*. The respective percent reductions of infection over controls were 75.9, 69.4, 58.5, 54.7 and 52.0.

Dohroo *et. al.* (1994) reported that the incidence of rhizome rot of *Z. officinale* was minimum in soil treated with pinus needle and neem cake powder. The *Meloidogyne* population was reduced to 74% but no Pratylenchus pouplation was recorded in soil following any of the treatments such as neem cake powder, sawdust, pinus needles of Quercus leaves. *Trichoderma* and *Gliocladium* populations were maximum in neem cake and pinus needle treatments.

Kim *et. al.* (1996) reported that average 18.1% rhizome rot of ginger is recorded in Korea Republic and the disease starts early July, spreads rapidly in rainy season.

Choe *et. al.* (1996) evaluated the effects of chemicals on the growth of *Fusarium* spp. & *Pythium zingiberum* causing rhizome rot of ginger and inhabitation of the disease development. They isolated 52 fungal isolates which was obtained form finger rhizomes with rotting symptoms form fields in Wanju (chonbuk) and Seasan (Chungnam), Korea republic, in 1993. They identified the pathogen as *Pythium zingiberum*. These appeared pathogenic to the plant in a pot test, although there were some variations in virulence among the isolates. Responses of the isolates to fungicides including metalaxyl (MTI), metalaxyl + copper oxchloride (MC), echlomezol (EM) and propamocarb hydrochloride (pc) varied depending on the isolates tested. They found mycelial growth was almost completely inhibited by MC a MTI at a concentration of 50 mg/litre.

Shanmugam and Varma (1997) conducted an experiment and native microorganisms were isolated from the rhizosphere of healthy ginger plants among rhizome rot affected plants in diseased fields during October 1994 and screened *in-vitro* for their antagonistic effects against the rhizome rot pathogen *Fusarium oxysporum* and *Pythium aphanidermatum* by dual culture and cell free culture filtrate studies *Aspergillus niger, A. Fumigatus, A. Flavus* and *Trichoderma viride* were found to be potenial antagonists. Among the fungicides tested (Copper oxychloride, Mancozeb and Bordeaux mixture). Mancozeb was compatible with all four antagonists.

Park *et. al.* (1998) reported from their experiment conducted in 1996 that *Zingiber officinale* plants were infected by rhizome rot in Korea Republic, from September of October. The pathogens associated with rhizome rot were isolated and identified as *Pythium* spp., *Fusarium* spp., and bacteria. A total of 68 isolates of *P. zingiberum* were tested for their tolerance to 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 while metalaxyl susceptible isolates could not grow at > 10 ppm. Metalaxyl tolerant isolates were completely inhibited

by metalaxyl with carbendzim and with copper oxchloride at 1000 ppm. Suppression of *Pythium aphanidermatum* and rhizome rot of ginger by *Aspergillus niger, A. tereus, Penicillium* spp. and *Absidia cylindrospora* was reported by Balakrishnan *et. al.* (1997). The former 3 fungi inhibited *P. aphanidermatum* by up to 100% by producing fungitoxic non-volatile metabolities. *A. Cylindrospora* expressed mild inhabitation (7.03%). *Aspergillus cylindraspora* and *P. aphanidermatum* also exhibited mutual overgrowth in dual culture. *Aspergillus niger* showed good protection against rhizome rot. Their severity of rhizome rot infection was low infested soil was treated with *A. terreus, Penicillium* species and *A. cylindrospora*. The highest yield was recorded with *Aspergillus niger.*

Two fungicides, Bavistin 50 WP (0.3%) and Dithane M-45 (0.3%) and three kinds of lining materials, sand, saw dust, and paddy husk were evaluated in a Factorial Experiment in Randomized Completely Block Design (Dake *et. al.*, 1999). The highest percentage of healthy rhizomes was recovered with Dithane M-45 (0.3%) as dip treatment for 20 min, and the lowest percentage of infected rhizomes was observed in seed ginger rhizomes stored in pits lined with saw dust.

Ram *et. al.* (1999) reported from their experiment that rhizome rot of ginger is caused by either *Fusarium* spp. *and Pythium* spp. or both. The bio-control agent *Trichoderma harzianum*, isolated from rhizome rot suppressive soils, reduced the disease and increased plant stand and yield of ginger. In order to further enhance the efficiency of disease suppression, *Pseudomonas* spp. was evaluated alone and in combination with *T. harzianum* and also with fungicidal rhizome treatment. Combination of both resulted in better germination and plant stand, reduced disease and increased yield. Soil Application of BCA was more effective compared with seed treatments. Bavisitin 50 WP + Ridomil MZ increased the efficiency of disease control as compared with their individual treatments. Soil application of *T. harzianum* and rhizome treatment with *Pseudomonas* spp. and fungicides was the most effective among all the treatments tested.

Balakrishnan *et.al.* (2000) showed that Rhizome rot caused by *Fusarium oxysporum* is the main production constraint in all ginger growing tracts. As a disease

management practice, soil solarization technique was adopted. This was further integrated with seed treatment and soil drenches with Mancozeb, Captafol, Chlorothalonil and Ridomil-Mancozeb. For comparison, the whole experiment was also conducted under non-solarized conditions in *Pythium*-sick soil. Soil temperature and pathogen population were monitored in solarized and non-solarized plots. Soil solarisation effectively suppressed *Fusarium oxysporum* in soil and as a consequence germination was increased and the incidence of rhizome rot reduced. This in turn reflected in increased yield of rhizomes in solarized plots.

The effect of soil solarization and fungicidal seed and soil treatments of rhizome rot of ginger cv. Jhadole local was studied in Rajasthan, India by Kusum *et. al.* (2001) field plots inoculated with both pathogens were solarized for 20 days under ambient day temperature of 37.7-45.0 and night temperature of 26.27-27.5$^0$C. Seed were dipped in 2000 ppm of Captan (2 g/litre), Ridomil MZ (6.25 g/litre), or Chlorothalonil (2 g/litre) for 40 days before sowing. In non-solarized plots, Seed treatment increased sprouting. Ridomil MZ seed treatment + phorate + Ridomil MZ drench was most effective among the treatments in reducing disease intensity and in increasing the number of sprouts (215) and yield (1.51 kg).

Jacob *et. al.* (2002) carried out a preliminary trail in Kerala, India to manage the rhizome rot of ginger with combined applications of fungicides. The treatments comprised 4 fungicides (triademefon at 1 g/litre, benomyl at 1 g/litre, bitertanlo at 1 g/litre and copper oxchloride at 3 g/litre) and untreated control. Observations on the percentage of infested hills were recorded at 7, 14 and 21 days after treatment (DAT). The infestation was reduced over control in these treatments ranged 25.33 to 31.34.

Resident isolates of bio-control agents (BCAs) *Trichoderma harzianum*, *T. aureoviride* and *Gliocladium virens* and a non-resident isolate of *T. viride* were evaluated by Ram *et. al.* (2002) for suppression of ginger rhizome rot, a rhizome and seed borne disease caused by *Fusarium solani* or *Pythium myriotylum* or both. Rhizomes related with BCA were planted in two set of pots, one with sterilized but pathogen infested soil, and another with unsterilized, rhizome rot infested field soil.

All the four BCAs could establish in ginger rhizosphere and rhizomeplane and significantly increased in population density and reduced that of *Fusarium* spp., correlated well with reduction of the disease and significant increase in the yield. The trend of efficacy of each BCA observed in the unsterilized rhizome rot infested field soil was confirmed in sterilized, pathogen infested soil.

Anandaraj and Sharma (2003) developed an integrated disease management module by selecting disease free rhizomes, dip treatment with a mixture of Dithane M-45 (0.25%) + Bavistin (0.1%) + Durmet (0.1%) for 60 minutes, applying Thimet 10G (12 kg/ha) at field preparation, and using *Trichoderma harzianum* (1kg in 25 kg FYM/ha) as soil treatment in furrows.

Bhat and Srivastava (2003) tested fourteen fungicides (250-1000 ppm; Emisan, Blitox 50 , Captaf , Indofil M-45, Bavistin, Benlate, Roko, Saaf, Calixin, Tilt, Contaf , Topas, RIL F004 and Contaf 5% SC) and four neem formulations against *F. oxysporum, Pythium aphanidermatum, Fusarium solani, F. moniliforme, Sclerotium rolfsii* and *Fusarium* sp. for inhibition and three *Trichoderma* spp. for compatibility *in-vitro*. Emisan and Saaf (250 ppm) and triazoles (250-1000 ppm) were highly inhibitory against both pathogens and *Trichoderma* sp., Bavistin and Benlate completely inhibited *Fusarium* and *Trichoderma* even at 250 ppm. Similarly, Captaf, Calixin, RIL F004, Tilt, and Indofil M-45 completely inhibited *P. aphanidermatum* and *S. rolfsii* at the same concentration. Indofil M-45 was fungistatic against *T. viride*, while showing complete inhibition of *F. solani, F. oxysporum, P. aphanidermatum* and *S. rolfsii* at 500 ppm.

Singh *et. al.* (2004) carried out an experiment in Bihar, India in controlling rhizome rot of ginger caused by *Pythium aphanidermatum* under storage and field conditions. The efficacy of 0.2% Dithane M-45, 0.3% Ridomil MZ, 0.1% Bavistin, 0.2% Saaf, 0.2% Shield, 0.3% Blitox-50 and 0.25% Dithane M-45 + 0.25% Bavistin. Application of 0.3% Ridomil MZ resulted in the lowest incidence of the disease. In field conditions, application of Ridomil MZ resulted in the highest seed germination (96.50) and yield (250.25q/ha) and lowest disease incidence (5.0%).

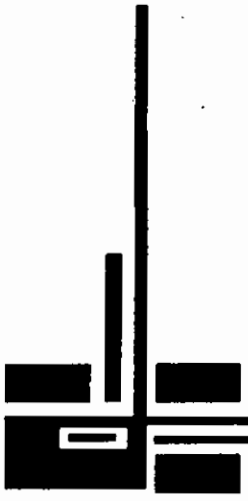
Meena and Mathur (2005) conducted an experiment with three biological control agents i.e. *Trichoderma viride, Gliocladium virens* and *Pseudomonas fluorescens* and an effective fungicidal mixture of Ridomil MZ and Bavistin 50 WP were used for treating seed rhizome and soil, individually and in combinations, for the suppression of rhizome rot of ginger. Crop and disease parameters, such as crop stand, rhizome yield, rotting percentage and pathogen suppression in the rhizosphere, were determined. Pelletion of seed rhizome with biological control agents was not found effective. Pelletion either with the fungicidal mixture or BCAs combined with soil application of BCAs was effective in suppressing the disease and increasing the yield. In the rhizosphere pot study, integrated approach resulted in reduction inoculums 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.

Usman *et. al.* (2006) conducted an experiment in controlling rhizome rot disease of ginger caused by *Fusarium oxysporum* is a serious problem in ginger. As a part of disease management, field evaluation of bio-control agents was carried out in *Fusarium*-sick soil. Further, the efficacy of these bio-control agents in combination with soil solarisation was evaluated as a measure of integration. *Trichoderma viride*, *T. harzianum* I & II, *T. hamatum* and *Gliocladium virens* were the biocontrol agents used and compared with fungicide mancozeb. Two years of field trials showed that the isolate *T. harzianum* was efficient in controlling the disease both in solarized and non-solarized plots. The disease incidence was less and the yield was high in both the years. *T. hamatum* was the second best in both the years. In general, the yield was higher in solarized plots in both the years but significant increase in yield was obtained in the second year only. The weed growth was also suppressed in the solarized plot to an extent of 40%.

Ambia (2006) reported that lowest diseases incidence and disease severity of rhizome rot of ginger was found in case of application of *T. harzianum*, garlic extract, neem leaf extract at different days after planting and those treatment resulted maximum yield of rhizome.

Karuppiyan *et. al.* (2007) treated rhizome with bio-inoculant *Pseudomonas fluorescens* and *Trichoderma harzianum* followed by soil application 60 days after planting to reduce rhizome rot. Soil application of bio-control agents like *T. harzianum* and *P. fluorescence* during planting time @ 2-5% gives effective control of the diseases.

Stirling *et. al.* (2008) added 2 qtls of neem cake per ha before planting. Treated seedling materials with 3g Metalaxyl MZ-72 per litre solution before planting after the notice of drying leaf/initial symptoms Spray Metalaxyl-Mz 3 g/litre of water and also drench the same to affected areas.



# *Chapter III*
# *Materials and Methods*

# Chapter III

# MATERIALS AND METHODS

An experiment was conducted both in the Plant Pathology Laboratory and farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from 15 March 2011 to February 2012 to study integrated approach for management of rhizome rot of ginger. The details of materials and methods of this experiment are presented in this chapter.

## 3.1 Experimental site

The present piece of research work was conducted in the Farm of sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, Bangladesh. The site of the experimental plot is in $23^0$74 N latitude and $90^0$35 E longitudes with an elevation of 8.2 meter from sea level (Anonymous, 1989).

## 3.2 Characteristics of soil

The soil of the experimental area was non-calcarious dark grey and belongs to the Madhupur Tract (UNDP, 1988) under AEZ 28. The selected plot was medium high land and the soil series was Tejgaon (FAO, 1988). The $P^H$ of the soil was 5.6. The characteristics of the soil under the experimental plot were analyzed in the SRDI, Soil Testing Laboratory, Khamarbari, Dhaka and details of the soil characteristics are presented in Appendix-II.

## 3.3 Weather condition of the experimental site

The geographical situation of the experimental site was under the subtropical climate characterized by three distinct seasons, the monsoon or rainy season from November to February and the Pre-monsoon period of hot season from March to April and monsoon period from May to October (Edris *et. al.*, 1997). The total annual rainfall of the experimental site was 218 mm and average monthly maximum and minimum temperature were $29.45^0$c and $13.86^0$c, respectively (Anonymous,1989). Details of the metrological data of air temperature, relative humidity, rainfalls and sunshine during the period of the experiment was collected

from the Bangladesh Metrological Department (Climate Division) and presented in Appendix II.

### 3.4 Planting materials

In this research work, the rhizomes of gingers were used as planting materials. The rhizomes of the ginger were collected from Spices Research Center, Bogra. The rhizomes of ginger were cut into small pieces bearing 1-2 buds. The average weight of individual piece was 45-50 g.

### 3.5 Isolation of pathogen (s) from infected rhizome

The diseased rhizome were collected by using polythene bag and taken to the laboratory of Department of Plant Pathology, Sher-e-Bangla Agricultural University, Dhaka. Then the diseased rhizomes were surface sterilized with Chlorox (1:1000) for one minute. Then the rhizomes were washed into sterilized water thrice and placed in a Petridish. The Petridish containing rhizomes were incubated at $25^0$C for seven days. Then the organism grew freshly on to be transferred on another PDA plate to have pure culture. Finally the pure culture of the pathogen (*Fusarium oxysporum*) was obtained and identified.

### 3.6 *In-vitro* assay of fungicides, botanicals and *T. harzianum*

In the Plant Pathology laboratory, *in-vitro* assay was performed using three fungicides named Bavistin 50WP @ 0.2%, Ridomil gold @ 0.2% and Dithane M-45 @ 0.25%. Two botanicals such as alamanda leaf extract @1:1 and neem leaf extrat @1:1. *Trichoderma harzianum* was also used against the *F. oxysporum*. Cup method and disc method were done to know the percent (%) inhibition of mycelia growth of *F. oxysporum* using selected fungicides, botanicals and *Trichoderma harzianum*.

### 3.7 Treatments of the experiment

The experiment was designed for management of rhizome rot of ginger using different treatments.

Treatments were as follows:

| | |
|---|---|
| $T_1$ = | Untreated control |
| $T_2$= F1 | Seed treatment with Bavistin 50WP (F1) + hill drenching (F1) |
| $T_3$=PW+F2 | Seed treatment with neem leaf extract (P1) + hill drenching (P1) |
| $T_4$=PW+P1 | Seed treatment with alamanda leaf Extacts (P2) + hill drenching (P2) |
| $T_5$=SD+P2 | Seed treatment with Ridomil Gold MZ 72 (F2) + hill drenching (F2) |
| $T_6$=PW+F1 | Seed treatment with neem leaf extract (P1) + hill drenching (P1) + Saw dust |
| $T_7$=SD+P1 | Seed treatment with Poultry waste (PW) +F2 + hill drenching (F2) |
| $T_8$=*T. harzianum* | Seed treatment with Saw dust (SD) + F1 + hill drenching (F1) |
| $T_9$=PW | Seed treatment with Poultry waste + F2 + hill drenching (F2) |
| $T_{10}$=SD+F2 | Seed treatment with neem leaf extract (P1) + hill drenching (P1) + PW |
| $T_{11}$=PW+P2 | Seed treatment with alamanda leaf extacts (P2) + hill drenching (P2) +PW |
| $T_{12}$=SD | Seed treatment with Poultry waste + F1 + hill drenching (F1) |
| $T_{13}$=SD+F1 | Seed treatment with alamanda leaf extacts (P2) + hill drenching (P2) + Saw dust |
| $T_{14}$=F2 | Seed treatment with *Trichoderma harzianum* + hill drenching with *Trichoderma harzianum* |
| $T_{15}$=P1 | Seed treatment with *Trichoderma harzianum* + hill drenching with *Trichoderma harzianum* + PW |
| $T_{16}$=P2 | Seed treatment with *Trichoderma harzianum* + hill drenching with *Trichoderma harzianum* + SD |

F1= Bavistin 50WP (0.2%)
SD= Sawdust (5kg/plot)
F2= Ridomil goldMZ 72 (0.2%)
P2= Neem leaf extract (1:1)
PW=Poultry waste (5kg/plot)
P2= Alamanda leaf extract (1:1)

### 3.8 Layout of the experiment

The experiment was laid out in the single factors RCBD (Randomized Completely Block Design) with three replications. The layout of the experiment was prepared for distributing the treatment into every plot of each block. Each block was divided into 16 plots where 16 treatments were allotted at random. There were 48 unit plots altogether in the experiment. The size of the plot was 2.0 m X 1.0 m. The distance maintained between two blocks and two plots were 1.0 and 0.5 m respectively. Layout of the experimental field was presented in Appendix I.

### 3.9 Preparation of the main field

The plot selected for the experiment was opened in the second week 15 March 2011 with a power tiller and was exposed to the sun for a week, after one week the land was harrowed, ploughed and cross-ploughed several times followed by laddering to obtain a good tilth. Weeds and stubbles were removed, and finally obtained a desirable tilth of soil for planting of ginger rhizomes. The experimental plot was partitioned into the unit plots in accordance with the experiment design. Recommended doses of well-rotten cow-dung manure and chemical fertilizers were applied in the soil of each unit plot (Table 1.).

### 3.10 Application of manures and fertilizers

Well decomposed cow-dung manure 5 t/ha was applied at the time of final land preparation. The sources of fertilizers used for N, P and K were Urea, TSP and MP was applied respectively. The entire amount of TSP, MoP applied during the final preparation of land. Urea was applied in three equal installments at 30, 45 and 60 Days after planting.

**Table1. The dose and installment of application of fertilizers**

| Fertilizers | Dose (Kg/ha) | Application (%) | | | |
|---|---|---|---|---|---|
| | | Basal | 15 DAT | 30 DAT | 60 DAT |
| Urea | 100 | -- | 33.33 | 33.33 | 33.33 |
| TSP | 170 | 100 | -- | -- | -- |
| MoP | 160 | 100 | -- | -- | -- |
| Gypsum | 110 | 100 | -- | -- | -- |
| ZnO | 2 | 100 | -- | -- | -- |

Source: Krishi Projukti Hatboi, BARI, Joydebpur, Gazipur, Bangladesh (2009).

### 3.11 Application of the treatments

#### 3.11.1 Collection and preparation of plant extracts

For extraction of juice, required amount of neem leaf and alamanda leaf were taken, washed in tap water, crushed in a mortar and pestle. The crushed materials were blended in an electric blender adding equal amount of sterile water for 1:1 solution. The blend was filtered through sterile cheesecloth. Their supernatant was diluted in equal amount of sterile water for 1:1 solutions.

#### 3.11.2 Collection and Preparation of spore suspension of *Trichoderma harzianum*

*Trichoderma harzianum* was collected from Prof. Dr. Md. Rafiqul Islam, Dept. of Plant Pathology, SAU and grown on Potato Dextrose Agar (PDA) medium. After formation of conidia (in about 7-10 days), 5 ml/plate sterile water was added and the spore masses was scraped away with sterile scalpel. The conidial suspension thus made with additional water adjusted 3 liter volume.

#### 3.11.3 Collection and preparation of chemicals solution

All of the chemical fungicides were collected from local market. Fungicide solutions were prepared by adding required amount of water and taken in had sprayer for each concentration used.

#### 3.11.4 Rhizome treatments

Rhizomes were treated by dipping rhizomes in different fungicidal solution, plant extracts and in the spore suspension of *T. harzianum* for 30 minutes. Then the rhizomes were kept over night open to remove excess moisture.

#### 3.11.5 Planting of rhizome

Treated rhizomes were sown at 2nd May'2011 in the morning. In this experiment plant to plant distance was maintained 20 cm and row to row distance was 45 cm. Rhizomes were sown at a depth of 5 to 7 cm.

### 3.11.6 Hill drenching with fungicides, botanicals and *T. harzianum* in the field

Hill drenching was done when the rhizomes sprouted. The treatment was applied five times with fifteen days interval starting from 30 June, 2011 treatments were applied in soils at the base of the plants and on leaves by using hand sprayer.

### 3.12 Intercultural operations

When the seedlings started to emerge in the beds it was always kept under careful observation. After emergence of seedlings, various intercultural operations were accomplished for better growth and development of the ginger as and when necessary.

### 3.12.1 Irrigation

Light over-head irrigation was provided with a watering can to the plots immediately after sowing of rhizome seeds. Surface irrigation was given time to time as needed.

### 3.12.2 Weeding

Weeding is carefully done for proper growth and development of rhizomes with required intervals.

### 3.12.3 Plant protection

The crop was protected from the attack of insect-pest by spraying insecticide Ektara @ 0.25ml/L.

### 3.13 Isolation and identification of pathogen from rhizosphere soil and infected rhizomes

Isolation pathogen was done by 2-methods

**A. Soil dilution technique**

Soil from the rhizosphere zone of infected rhizome was collected. 5-different test tubes were taken each of which contains 9 ml sterile water. From the collected soil sample 5 g soil taken and diluted it into a test tube containing 9 ml sterile water and from the prepared solution (1:10) 1 ml suspension to the next test tube (1:100) and likewise soil suspension transferred to the rest of the test tubes will contain

concentration 1:1000, 1:10000 and 1:100000 respectively. Suspension of 0.1 ml from each concentration spraded on PDA plates with the help of a L-shaped sterile glass rod. The plates were kept in an incubator at 22±1 for 7 days. Purification was done by reculturing organism from the individual colony by hyphal tip culture method.

**B. Tissue planting method**

The diseased rhizomes were collected from the field and isolation was done as described in 3.5.

### 3.14 Harvesting

Harvesting was done when rhizomes were properly matured. In this experiment rhizome of ginger was harvested on 12th February, 2012.

### 3.15 Data recording

The data were collected from the inner rows of plants of each treatment to avoid the border effect. In each unit plot, four plants (two plants from each row) were selected at random for data collection. Data were collected in respect of the plant growth characters and yield of ginger. Data on germination of rhizome, number of rhizome rot infected plant height, disease severity, weight of rhizomes was collected. The following parameters were set up for recording data and for the interpretation of the results :

#### 3.15.1 Procedure of data collection :

$$\% \text{ Hill infection (Disease Incidence)} = \frac{\text{No. of infected hill}}{\text{No. of total infected hill}} \times 100.$$

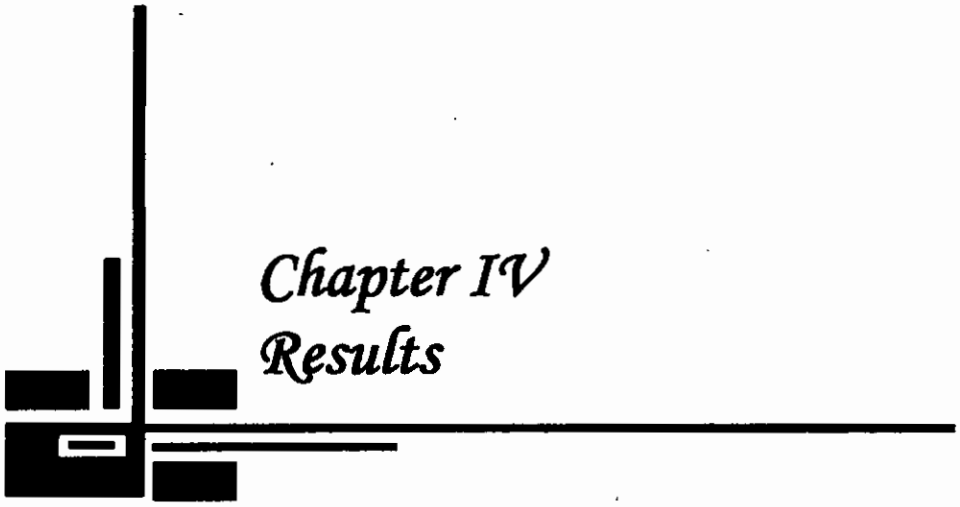
$$\% \text{ Disease Severity} = \frac{\text{Total number of dead tillers/plot}}{\text{Total number of tillers/plot}} \times 100.$$

### 3.16 Yield of Rhizome

The weight of rhizome per plot was recorded after harvesting. The weight of rhizome per plot was converted into per hectare yield.

### 3.17 Statistical Analysis

The data obtained for different characters were statistically analyzed to find out the significance of the difference of treatment on yield and yield contributing characters of ginger. The mean values of all characters were evaluated and analysis of variance was performing by "F" value test. The significance of the difference among the treatments and treatment combinations means of laboratory experiment and field experiment were estimated by the Duncan's Multiple Range Test (DMRT) at 0.01 and 0.05% level of probability (Gomez and Gomez, 1984).



# Chapter IV
# Results

# CHAPTER IV

# RESULTS

**Pathogen(s):** Isolated pathogen was *Fusarium oxysporum* (Figure 1 and 2) following the keys of "The evolutionary biology of *Fusarium oxysporum* (Gordon and Martyn, 1997)".

***In-vitro* assay of selected fungicides, plant extracts and *Trichoderma harzianum* against *Fusarium oxysporum* causing rhizome rot of ginger.**

The *in-vitro* assay of selected fungicides, plant extracts and *Trichoderma harzianum* against *Fusarium oxysporum* has been conducted in cup method and disc method. The effect of selected fungicides, plant extracts and *Trichoderma harzianum* against *Fusarium oxysporum* has been presented in table 2 and figure 3,4,5,6 and 7. All the selected treatments showed significant inhibition of mycelial growth and spore germination in comparison to untreated control. The inhibitory effect of the selected treatment against *Fusarium oxysporum* differred significantly among themselves both in cup and disc method. In cup method, the highest inhibition (86.33%) of mycelial growth of *Fusarium oxysporum* was observed in case of Bavistin 50 WP. The second highest inhibition (83.77%) of mycelial growth was recorded in case of Ridomil gold MZ-72 which is significantly indifferent with Dithane M-45 (82.66%). The *Trichoderma harzianum* also showed promising effect resulting 81.11% inhibition of mycelial growth against *Fusarium oxysporum* followed by alamanda leaf extract (77.7%) and neem leaf extract (76.0%). The effect of neem leaf extract and alamanda leaf extract also found statistically similar in inhibition of radial growth of *Fusarium oxysporum*. The highest mycelial growth was recorded in untreated control. In Disc method, the performance of selected treatments against the mycelial growth and spore germination of *Fusarium oxysporum* were more or less similar with the result of cup method. The highest inhibition zone (5.53 cm) was recorded in case of Bavistin 50WP followed by Ridomil gold MZ-72 (4.90 cm), Dithane M-45 (4.73 cm). The effect of Ridomil gold MZ-72 and Dithane M-45 also found statistically similar in producing inhibition zone. Among the botanicals, the effect of neem leaf extract (4.10 cm) was found better than the alamanda leaf extract (3.36 cm) which was statistically identical with the inhibitory effect of *Trichoderma harzianum* (3.36 cm). No inhibition zone was formed in untreated control.

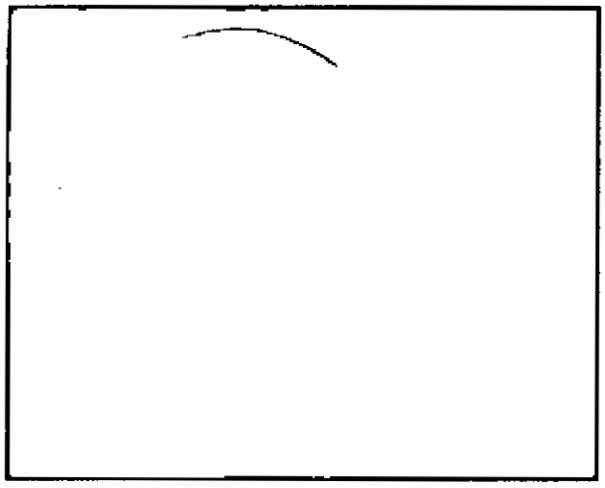


Figure 1. Pure culture of *Fusarium oxysporum*

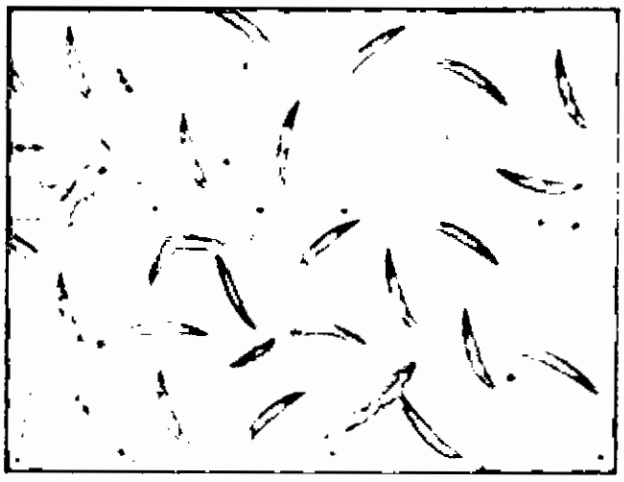


Figure 2. Macro and micro conidia of *Fusarium oxysporum*

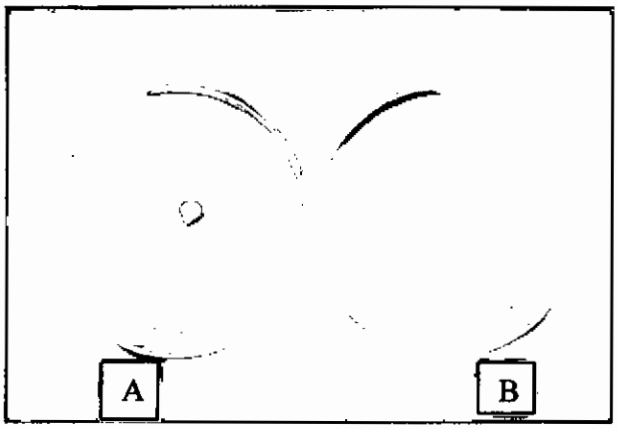



Figure 3. *In- vitro* assay of (A) Bavistin 50 WP and (B) control plate showing radial growth of *Fusarium oxysporum* in cup method.

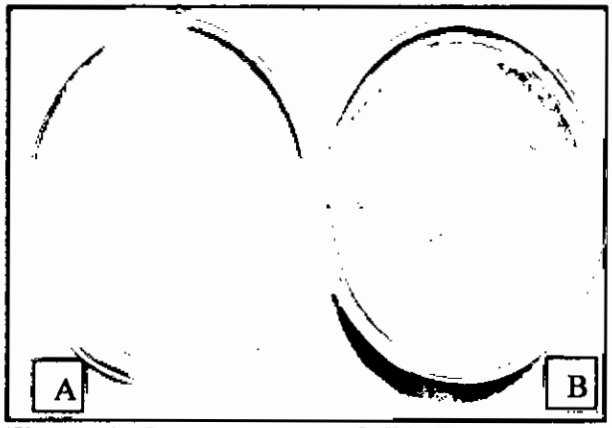



Figure 4. *In-vitro* assay of (B) *Trichoderma harzianum* and (A) control plate showing radial growth of *Fusarium oxysporum* in cup method.

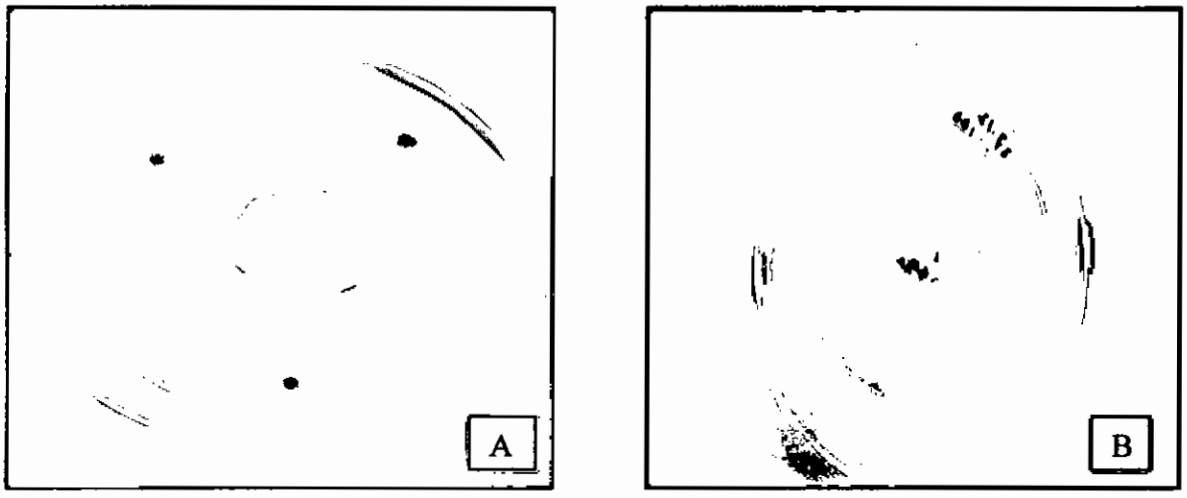



Figure 5. *In- vitro* assay of (A) Alamanda leaf extract and (B) control plate showing radial growth of *Fusarium oxysporum* in cup method.

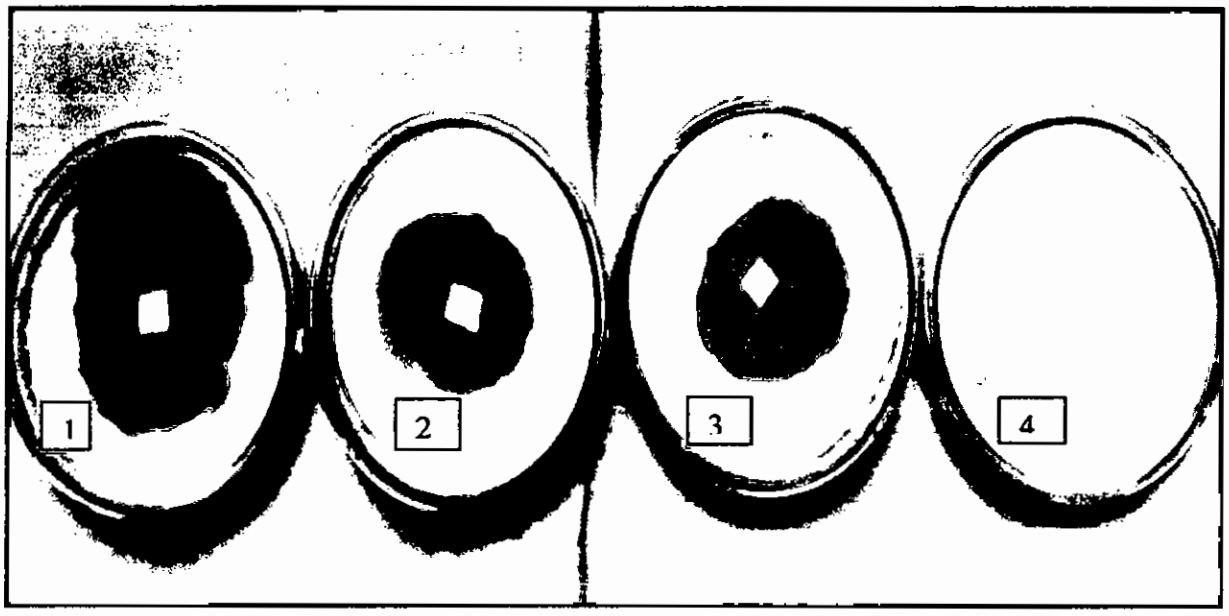
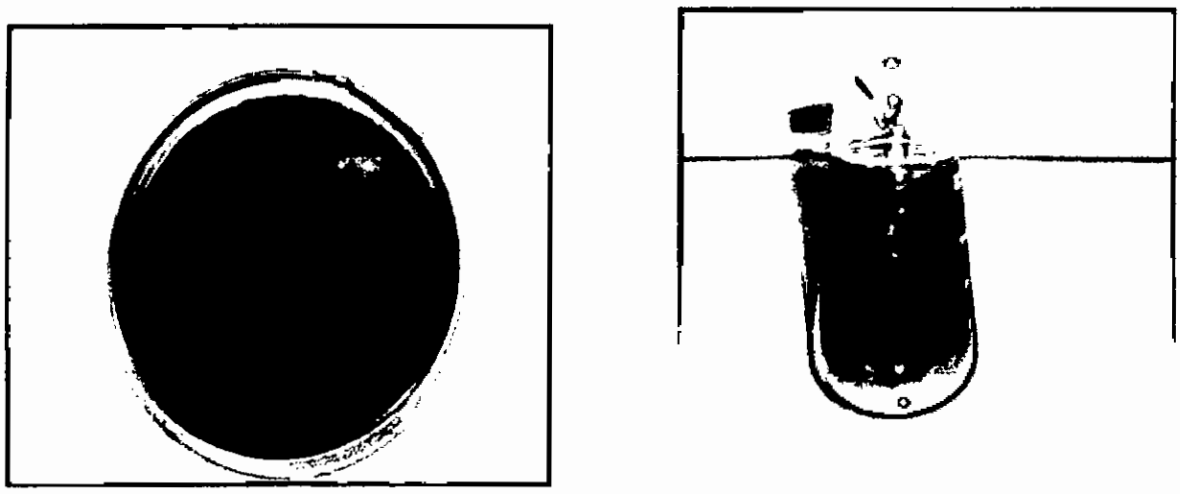



Figure 6. *In- vitro* assay of selected fungicides (Bavistin 50 WP (1), Ridomil gold MZ72 (2), Dithane M-45 (3) and control plate (4) showing inhibition zone against *Fusarium oxysporum* in disc method.

A B

Figure 7. *In- vitro* assay of plant extract (A) Alamanda leaf extract and (B) control plate showing inhibition zone against *Fusarium oxysporum* in disc method.



A B

Figure 8. (A) Pure culture of *Trichoderma harzianum* and (B) suspension of *Trichoderma harzianum* prepared from pure culture of *Trichoderma harzianum*.

Figure 9: Experimental field of ginger prior to rhizome planting.

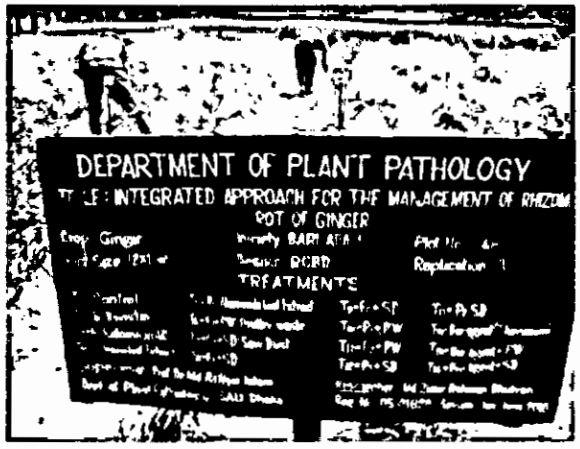



Figure 10: Experimental field of ginger.

Table 2. ***In-vitro*** **assay of selected fungicide, plant extract and** ***Trichoderma harzianum*** **against** ***Fusarium oxysporum*** **causing rhizome rot of ginger.**

| Treatments | Radial growth (diameter) in cm | Inhibition zone (diameter) in cm |
|---|---|---|
| | **Cup method** | **Disc method** |
| Bavistin50 WP | 1.23 e (86.33) | 5.53 a |
| Ridomil gold | 1.46 d (83.77) | 4.90 b |
| Dithane M-45 | 1.56 d (82.66) | 4.73 b |
| Neem leaf extract | 2.16 b (76.0) | 4.10 c |
| Alamanda leaf extract | 2.03 b (77.77) | 3.36 d |
| *Trichoderma harzianum* | 1.73 c (81.11) | 3.26 d |
| Untreated control | 9.00 a | 0.0 e |
| $LSD_{(0.01)}$ | 0.136 | 0.305 |
| CV(%) | 1.87 | 3.29 |

Data in parenthesis indicate % inhibition of mycelial growth over control.

**Incidence of rhizome rot of ginger in response to different treatment combination against** ***Fusarium oxysporum*** **recorded at different Days After Planting (DAP).**

Incidence of rhizome rot of ginger in plot under different treatment combination against *Fusarium oxysporum* recorded at different Days After Planting (DAP) is presented in Table 3.

Table 3. **Incidence of rhizome rot of ginger at different days after Planting (DAP)**

| Disease incidence of rhizome rot of ginger (%) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Treatments | 30 DAP | 60 DAP | 90 DAP | 120 DAP | 150 DAP | 180 DAP | 210 DAP | 240 DAP |
| $T_1$ = Untreated control | 16.66 a | 16.66 a | 25.00 a | 33.33 a | 38.88 a | 47.22 a | 55.55 a | 63.88 a |
| $T_2$= F1 | 2.777 b | 5.55 b | 11.11 bc | 13.88 bc | 13.88 b | 19.44 bc | 27.78 bc | 30.55 b-d (52.17) |
| $T_3$=PW+F2 | 5.553 b | 5.55 b | 5.553 cd | 5.55 cd | 5.553 c | 11.11 e | 11.11 f | 11.11 fg (82.60) |
| $T_4$=PW+P1 | 5.553 b | 8.33 b | 13.88 b | 13.88 bc | 13.88 b | 13.88 c-e | 13.88 ef | 19.44 ef (69.56) |
| $T_5$=SD+P2 | 5.553 b | 5.55 b | 8.330 b-d | 11.11 bcd | 13.88 b | 19.44 bc | 19.44 de | 22.22 de (65.21) |
| $T_6$=PW+F1 | 2.77 b | 2.77 b | 2.77 d | 2.77 d | 2.77 c | 2.777 f | 2.77 g | 2.77 g (95.66) |
| $T_7$=SD+P1 | 5.55 b | 5.55 b | 8.33 b-d | 11.11 b-d | 13.88 b | 19.44 bc | 22.22 cd | 30.55 b-d (52.17) |
| $T_8$=*T. harzianum* | 2.77 b | 5.55 b | 11.11 bc | 16.66 b | 19.44 b | 22.22 b | 30.55 b | 38.88 b (39.13) |
| $T_9$=PW | 2.77 b | 5.55 b | 11.11 bc | 13.88 bc | 13.88 b | 19.44 bc | 27.78 bc | 33.33 bc (47.84) |
| $T_{10}$=SD+F2 | 5.55 b | 8.33 b | 13.88 b | 13.88 bc | 13.88 b | 13.88 c-e | 13.88 ef | 19.44 ef (69.56) |
| $T_{11}$=PW+P2 | 5.55 b | 5.55 b | 5.55 cd | 5.55 cd | 5.553 c | 11.11 de | 11.11 f | 11.11 fg (82.60) |
| $T_{12}$=SD | 5.55 b | 8.33 b | 13.88 b | 16.66 b | 19.44 b | 22.22 b | 27.78 bc | 36.11 bc (43.47) |
| $T_{13}$=SD+F1 | 5.55 b | 5.55 b | 8.330 b-d | 11.11 b-d | 13.88 b | 16.66 b-d | 16.66 d-f | 19.44 ef (69.56) |
| $T_{14}$=F2 | 2.77 b | 5.55 b | 11.11 bc | 13.88 bc | 13.88 b | 19.44 bc | 27.78 bc | 27.78 c-e (56.51) |
| $T_{15}$=P1 | 2.77 b | 5.55 b | 11.11 bc | 16.66 b | 19.44 b | 22.22 b | 30.55 b | 38.88 b (39.13) |
| $T_{16}$=P2 | 5.55 b | 8.33 ab | 13.88 b | 16.66 b | 19.44 b | 22.22 b | 27.78 bc | 36.11 bc (43.47) |
| $LSD_{(0.05)}$ | 7.39 | 6.88 | 7.00 | 8.39 | 6.23 | 5.04 | 5.60 | 8.17 |
| CV(%) | 85.18 | 58.06 | 38.41 | 37.20 | 24.77 | 16.00 | 14.66 | 17.76 |

Data in parenthesis indicate % reduction of disease incidence over control.

$F_1$= Bavistin 50WP
$F_2$= Ridomil gold
$P_2$= Alamonda leaf extract
$P_1$= Neem leaf extract
PW=Poultry waste
SD= Sawdust

Figure 11. A ginger plant showing rhizome rot symptom at early stage.

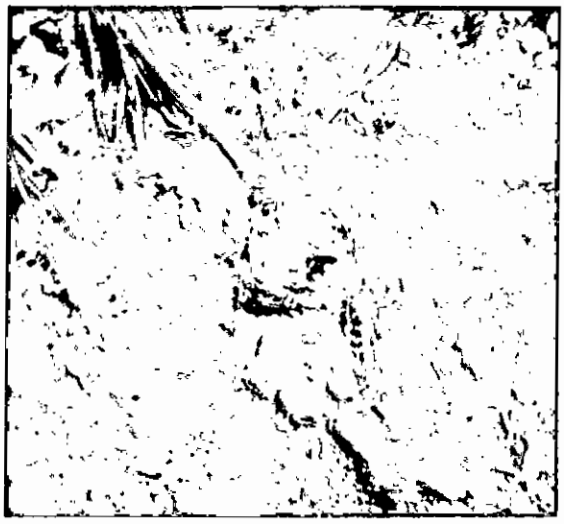


Figure 12. A severely infected plant showing rotten ginger.


Figure 13. A treated plot (Poultry waste + Bavistin 50 WP) of ginger plant.

Figure 14. An infected ginger plant in control plot showing yellowing of the plant and ultimately died.

Different treatment either alone or in combination showed remarkable effect on the incidence of rhizome rot of ginger. The combined performance of the selected treatments in reducing the incidence of rhizome rot were found always higher in comparison the individual performance of fungicides or plant extracts or *Trichoderma harzianum* or the organic soil amendment irrespective of Days After Planting (DAP).The incidence of rhizome rot of ginger in response to different treatments were recorded at different days after planting starting from 30 DAP to 240 DAP with 30 days interval. At the beginning at 30 DAP the treatment effects were significantly differed with control but among the treatments, the effect on disease incidence were statistically similar. The differences of treatment effect become sharpen with the age of the crop and distinct difference were found at 240 DAP among the treatments (Table 3.). At 60 DAP, the lowest disease incidence (2.77 %) was recorded in case of $T_6$ (Poultry waste+Bavistin 50WP) where soil was amended with poultry waste and rhizomes were treated with Bavistin 50 WP followed by foliar spray with Bavistin 50 WP which was statistically indifferent with rest of the treatments except untreated control. Disease incidence was recorded 16.66% in untreated control. At 90 DAP, the incidence did not increase and were remain equal to 60 DAP in case of $T_3$ (Poultry waste+Ridomil gold MZ72), $T_6$ (Poultry waste+Bavistin 50 WP), $T_{11}$ (Poultry waste+Alamanda leaf extract). The highest disease incidence was increased to 25.0% in case of untreated control. The lowest disease incidence was remain 2.77% in case of $T_6$ (Poultry waste +Bavistin 50 WP) which was statistically indifferent with $T_3$ (Poultry waste+Ridomil gold MZ72), $T_5$ (Saw dust+Alamanda leaf extract), $T_7$ (Saw dust+Neem leaf extract), $T_{11}$ (Poultry waste+Alamanda leaf extract) and $T_{13}$ (Saw dust+Bavistin 50 WP). At 120 DAP, the disease incidence did not increase and remain unchanged (2.77%, 5.55%, 5.55%) in case of $T_6$ (Poultry waste + Bavistin 50 WP), $T_3$ (Poultry waste + Ridomil gold MZ72) and $T_{11}$ (Poultry waste + Alamanda leaf extract) respectively. In case of rest of the treatment the incidence was slightly increased but differed significantly in response to untreated control (33.33%). At 150 DAP, the disease incidence were also remain unchanged in case of $T_6$ (Poultry waste + Bavistin 50 WP), $T_{11}$ (Poultry waste + Alamanda leaf extract) and $T_3$ (Poultry waste + Ridomil gold MZ72). Thus the lowest disease incidence (2.77) was noted in case of $T_6$ (Poultry waste +

Bavistin 50 WP) which was statistically identical with $T_3$ (Poultry waste + Ridomil gold MZ72) and $T_{11}$ (Poultry waste + Alamanda leaf extract). The incidence of rest of the treatments either alone or in combination was significantly indifferent among them but differed with untreated control (38.88%). At 180 DAP, the lowest disease incidence (2.77%) was recoded in case of $T_6$ (Poultry waste + Bavistin 50 WP) followed by $T_3$ (11.11%), $T_{11}$ (11.11%), $T_4$ (13.88%) and $T_{10}$ (13.88%). The highest disease incidence was recoded in untreated control (47.22%). The effect of treatment $T_2$ (30.55%), $T_5$ (22.22%), $T_7$ (30.55%), $T_8$ (38.88%), $T_9$ (33.33%), $T_{12}$ (36.11%), $T_{13}$ (19.44%), $T_{14}$ (27.78%), $T_{15}$ (38.38%) and $T_{16}$ (36.11%) were significantly indifferent in respect of disease incidence. At 210 DAP, the lowest disease incidence (2.77%) was recoded in case of $T_6$ (Poultry waste + Bavistin 50 WP) followed by $T_3$ (11.11%), $T_{11}$ (11.11%), $T_4$ (13.88%) and $T_{10}$ (13.88%). The highest disease incidence was recoded in untreated control (55.55%). The effect of treatment $T_2$ (27.78%), $T_9$ (27.78%), $T_{12}$ (27.78%), $T_{14}$ (27.78 %,), $T_{16}$ (27.78%), T8 (30.55%) and $T_{15}$ (30.55%) were statistically similar in respect of disease incidence. At 240 DAP, when crop was in mature stage, the disease incidence of rhizome rot of ginger reached to the highest level in each case of the treatment applied. The highest disease incidence (63.88%) was recorded in case of untreated control while the lowest disease incidence (2.77%) was recorded in case of $T_6$ (Poultry waste + Bavistin 50 WP) which was statistically similar to $T_3$ (Poultry waste + Ridomil gold MZ72) and $T_{11}$ (Poultry waste + Alamanda leaf extract). The treatment either alone or in combination showed promising effect in reducing the disease incidence and the highest reduction of disease incidence (95.66%) was counted in case of $T_6$ (Poultry waste + Bavistin 50 WP) followed by $T_3$ (Poultry waste + Ridomil gold MZ72),$T_{11}$(Poultry waste + Alamanda leaf extract), $T_4$ (Poultry waste +Neem leaf extract), $T_{10}$ (Saw dust+Ridomil gold MZ72) and $T_5$ (Saw dust + Alamanda leaf extract). The lowest reduction of disease incidence was counted in case of $T_8$ (*Trichoderma harzianum*) preceded by $T_{12}$ (Saw dust), $T_9$ (Poultry waste), $T_7$ (Saw dust+Neem leaf extract) and $T_2$ (Bavistin 50 WP).

**Effect of different treatment combinations on the severity of rhizome rot of ginger at different Days After Planting (DAP).**

The severity of rhizome rot of ginger in response to different treatments alone or in combination were recorded at 80 DAP, 160 DAP, 240 DAP and presented in Table 4.

In case of 80 DAP, the lowest severity (6.43%) was recorded in $T_6$ (Poultry waste +Bavistin 50WP) where soil was amended with poultry waste and rhizomes were treated with Bavistin 50 WP followed by foliar spray with the Bavistin 50 WP. The second lowest (8.30%) severity was recorded in $T_{11}$ (Poultry waste +Alamanda leaf extract) preceded by $T_3$ (PW+$F_2$), $T_4$ (Poultry waste +Neem leaf extract), $T_{10}$ (Saw dust+ Ridomil gold MZ72), $T_{13}$ (Saw dust+ Bavistin 50WP) and $T_5$ (Saw dust+ Alamanda leaf extract). The highest disease severity was recorded in untreated control (45.50%). The individual performance of plant extracts, fungicides, bio-agent (*Trichoderma harzianum*) as foliar spray and organic soil amendment with poultry waste and saw dust were lower than the combined effect of the treatment but much higher than the control. In case of 160 DAP, the lowest disease severity (7.46%) was recorded in case of $T_6$ (Poultry waste +Bavistin 50WP) where soil was amended with poultry waste and rhizomes were treated with Bavistin 50 WP followed by foliar spray with the Bavistin 50 WP. The second lowest severity (9.40%) was recorded in case of $T_{11}$ (Poultry waste +Alamanda leaf extract) preceded by $T_3$ (PW+$F_2$), $T_4$ (Poultry waste +Neem leaf extract), $T_{10}$ (Saw dust+ Ridomil gold MZ72), $T_{13}$ (Saw dust+ Bavistin 50 WP) and $T_5$ (Saw dust+ Alamanda leaf extract). The highest disease severity was recorded in untreated control (49.07%). The individual performance of plant extracts, fungicides, bio-agent (*Trichoderma harzianum*) as foliar spray and organic soil amendment with poultry waste and saw dust were lower than the combined effect of the treatment but much higher than the untreated control. In case of 240 DAP, the lowest disease severity (8.23%) was recorded in case of $T_6$ (Poultry waste +Bavistin 50WP) where soil was amended with poultry waste and rhizomes were treated with Bavistin 50 WP followed by foliar spray with the Bavistin 50 WP. The second lowest severity (10.30%) was recorded in case of $T_{11}$ (Poultry waste +Alamanda leaf extract)

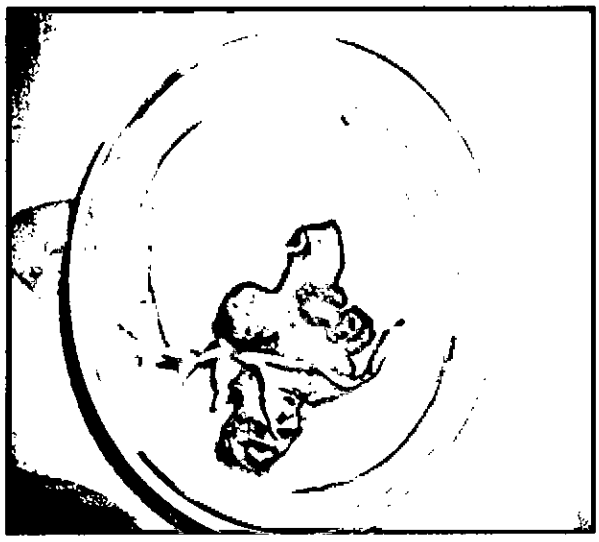


Figure 15. White cottony mycelium of *Fusarium oxysporum* grew over rhizome of ginger.

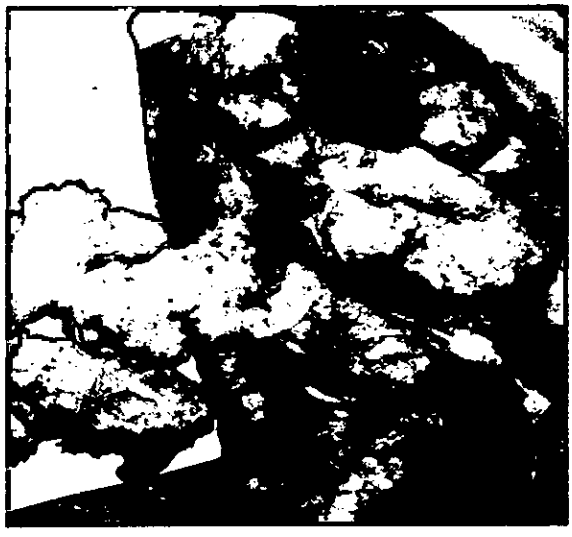


Figure 16. Healthy rhizomes of ginger.

preceded by $T_3$ (Poultry waste+ Ridomil gold MZ72), $T_4$ (Poultry waste +Neem leaf extract), $T_{10}$ (Saw dust+ Ridomil gold MZ72), $T_{13}$ (Saw dust+ Bavistin 50 WP) and $T_5$ (Saw dust+ Alamanda leaf extract). The highest disease severity was recorded in untreated control (53.53%). The individual performance of plant extracts, fungicides, bio-agent (*Trichoderma harzianum*) as foliar spray and organic soil amendment with poultry waste and saw dust were lower than the combined effect of the treatment but higher than the untreated control. On the basis of reduction of severity of rhizome rot of ginger, it is revealed that the highest reduction of severity (84.62%) was recorded in case of $T_6$ ($PW+F_1$) where soil was amended with poultry waste followed by foliar spray with the Bavistin 50 WP. The second highest reduction of severity (80.75%) was recorded in case of $T_{11}$ (Poultry waste+ Alamanda leaf extract), $T_{10}$ (Saw dust+ Ridomil gold MZ72) which is statistically similar with $T_{13}$ (Saw dust +Bavistin 50 WP). The lowest reduction of severity (44.5%) of rhizome rot of ginger was recorded in case of $T_8$ (*Trichoderma harzianum*) which was statistically similar with neem leaf extract (45.20%) followed by $T_{16}$ (Alamanda leaf extract), $T_{12}$ (Saw dust) and $T_2$ (Bavistin 50 WP).

Table 4. **Severity of rhizome rot of ginger at different Days After Planting (DAP).**

| Disease severity of rhizome rot of ginger (%) | | | |
|---|---|---|---|
| Treatments | 80 DAP | 160 DAP | 240 DAP |
| $T_1$ = Untreated control | 22.17 d (51.27) | 22.80 d (53.53) | 23.13 d (56.79) |
| $T_2$= F1 | 45.50 a | 49.07 a | 53.53 a |
| $T_3$=PW+F2 | 11.57 k (74.57) | 12.13 k (75.28) | 12.67 j (76.33) |
| $T_4$=PW+P1 | 13.50 j (70.32) | 14.03 j (71.40) | 15.03 i (71.92) |
| $T_5$=SD+P2 | 18.10 g (60.21) | 18.33 g (62.64) | 19.17 g (64.18) |
| $T_6$=PW+F1 | 6.433 m (85.86) | 7.467 m (84.79) | 8.233 l (84.62) |
| $T_7$=SD+P1 | 19.17 f (57.86) | 19.37 f (60.52) | 19.63 g (63.32) |
| $T_8$= *T. harzianum* | 28.20 b (38.02) | 28.93 b (41.04) | 29.67 b (44.57) |
| $T_9$=PW | 19.50 f (57.14) | 19.90 f (59.44) | 20.83 f (61.08) |
| $T_{10}$=SD+F2 | 16.33 i (64.10) | 16.43 i (66.51) | 17.30 h (67.68) |
| $T_{11}$=PW+P2 | 8.300 l (81.75) | 9.400 l (80.84) | 10.30 k (80.75) |
| $T_{12}$=SD | 25.57 c (43.80) | 25.70 c (47.62) | 26.20 c (51.05) |
| $T_{13}$=SD+F1 | 17.23 h (62.13) | 17.43 h (64.47) | 17.70 h (66.93) |
| $T_{14}$=F2 | 20.63 e (54.65) | 21.10 e (57.00) | 21.80 e (59.27) |
| $T_{15}$=P1 | 28.20 b (38.02) | 28.93 b (41.04) | 29.33 b (45.20) |
| $T_{16}$=P2 | 25.53 c (43.89) | 26.17 c (46.66) | 27.07 c (49.43) |
| LSD $_{(0.05)}$ | 0.84 | 0.79 | 0.93 |
| CV (%) | 1.85 | 1.67 | 1.90 |

Data in parenthesis indicate % reduction of disease severity over control.

$F_1$= Bavistin 50WP
SD= Sawdust
$P_2$= Alamanda leaf extract
$P_1$= Neem leaf extract
PW=Poultry waste
$F_2$= Ridomil gold

**Effect of different treatments on yield and yield contributing characters.**

Different yield contributing characters like number of tillers per hill, number of rhizome per plot, plant height and yield of rhizome were recorded against rhizome rot ginger in response to different treatment combination and presented in Table 5.

The performance of the treatment either alone or in combination against rhizome rot of ginger in respect of different parameters varied significantly. The highest number of tillers (60) per hill was noted in case of treatment $T_6$ (Poultry waste+ Bavistin 50WP) where soil was amended with poultry waste and rhizomes were treated with Bavistin 50 WP followed by foliar spray with the Bavistin 50 WP. The performance of $T_6$ (Poultry waste +Bavistin 50 WP) was statistically similar with $T_3$ (Poultry waste +Ridomil gold MZ72), $T_4$ (Poultry waste+ neem leaf extract), $T_{11}$ (Poultry waste +alamanda leaf extract), $T_{10}$ (Saw dust +Ridomil gold MZ72) and $T_{13}$ (neem leaf extract). The individual performance of the treatments in respect of number of tillers per hill was lower than the combined effect of the treatment but much higher compared to untreated control. The lowest number of tillers (18) per hill was recorded in case of untreated control. In case of plant height, significantly the highest plant height (65.20 cm) was recorded in case of treatment combination $T_6$ (PW+F1) where soil was amended with poultry waste followed by foliar spray with the Bavistin 50 WP and $T_7$ (Saw dust+ neem leaf extract) which were statistically identical with that of $T_{11}$ (Poultry waste+ alamanda leaf extract), $T_3$ (Poultry waste+ Ridomil gold MZ72) and $T_4$ (Poultry waste+neem leaf extract). The lowest plant height (29.73cm) was recorded in untreated control preceded by $T_{16}$ (48.33 cm), $T_{13}$ (48.50 cm), $T_{12}$ (48.50 cm), $T_9$ (49.47 cm), $T_{15}$ (50.17 cm), $T_1$ (50.17 cm), $T_2$ (50.63 cm), $T_8$ (50.87 cm), $T_5$ (52.50 cm) and $T_{14}$ (53.13 cm) but performance of these treatment regarding plant height were significantly similar among themselves.

**Table 5. Effect of different treatment on yield and yield contributing characters of ginger**

| Treatments | Number of tillers/hill | Plant height (cm) | Infected rhizome/plot (g) | Healthy rhizome/plot(g) | Number of rhizome/plot | Yield/plot(g) | Yield (t/ha) |
|---|---|---|---|---|---|---|---|
| $T_1$ = Untreated control | 18.00 h | 29.73 f | 758.0 a | 468.7 o | 29.67 l | 1227 m | 6.13 m |
| $T_2$= F1 | 41.00 d-g | 50.63 c-e | 478.7 e | 1462 j | 46.00 hi | 1940 i | 9.71 i (58.40) |
| $T_3$=PW+F2 | 56.33 a-c | 61.10 a-c | 357.7 l | 2834 c | 78.67 b | 3192 c | 15.96 c (160.35) |
| $T_4$=PW+P1 | 54.00 a-d | 59.67 a-d | 377.7 k | 2742 d | 75.33 c | 3120 d | 15.60 d (154.48) |
| $T_5$=SD+P2 | 48.00 b-f | 52.50 b-e | 418.3 i | 1616 f | 53.33 e | 2035 f | 10.17 f (65.90) |
| $T_6$=PW+F1 | 66.00 a | 65.20 a | 307.3 n | 3039 a | 81.00 a | 3347 a | 1 6.73 a (172.92) |
| $T_7$=SD+P1 | 45.33 b-g | 65.20 a | 434.3 h | 1264 n | 50.33 fg | 2025 fg | 10.13 fg (65.25) |
| $T_8$= *T. harzianum* | 31.0 gh | 50.87 c-e | 555.7 b | 1563 h | 42.33 k | 1820 l | 9.09 l (48.41) |
| $T_9$=PW | 31.0 gh | 49.47 de | 448.3 g | 2172 e | 48.33 gh | 2012 g | 10.06 g (64.11) |
| $T_{10}$=SD+F2 | 51.0 a-e | 50.17 de | 394.3 j | 2919 b | 61.33 d | 2566 e | 12.83 e (109.29) |
| $T_{11}$=PW+P2 | 59.67 ab | 62.00 ab | 327.7 m | 2919 b | 78.00 b | 3247 b | 16.24 b (164.92) |
| $T_{12}$=SD | 38.00 d-g | 48.50 e | 497.7 d | 1405 k | 45.33 i | 1902 j | 9.52 j (55.36) |
| $T_{13}$=SD+F1 | 50.33 a-e | 48.50 e | 409.0 i | 1617 f | 48.33 gh | 2026 fg | 10.13 fg (65.25) |
| $T_{14}$=F2 | 43.00 c-g | 53.13 b-e | 467.7 f | 1501 i | 51.67 ef | 1969 h | 9.84 h (60.65) |
| $T_{15}$=P1 | 33.33 fg | 50.17 de | 529.3 c | 1293 m | 42.33 jk | 1822 l | 9.11 l (48.61) |
| $T_{16}$=P2 | 36.0 e-g | 48.33 e | 537.3 c | 1335 l | 44.67 ij | 1872 k | 9.36 k (52.69) |
| LSD $_{(0.05)}$ | 14.33 | 9.51 | 9.65 | 25.30 | 2.27 | 21.04 | 0.10 |
| CV(%) | 2.61 | 1.48 | 0.94 | 0.63 | 1.85 | 0.42 | 0.41 |

Data in parenthesis indicate % reduction of disease severity over control.

$F_1$= Bavistin 50WP
SD= Sawdust
$P_2$= Alamonda leaf extract
$P_1$= Neem leaf extract
PW=Poultry waste
$F_2$= Ridomil gold

In case of infected Rhizome, significantly the highest weight (758.0g) of the infected rhizome was recorded in untreated control preceded by $T_8$ (555.7g), $T_{15}$ (529.3 g), $T_{16}$ (537.3g), $T_{12}$ (497.7g), $T_2$ (478.7g). The lowest weight (307.3g) of infected rhizome per plot was recorded in $T_6$ (Poultry waste+ Bavistin 50 WP) followed by $T_{11}$ (327.7 g), $T_3$ (357.7g), $T_4$ (377.7g), $T_{10}$ (394.3g), $T_{13}$ (409.0g), $T_7$ (434.3 g), $T_9$ (448.3 g). In case of healthy rhizome of ginger, significantly the highest (3039g) weight of the healthy rhizome was recorded in case of treatment combination $T_6$ (Poultry waste+Bavistin 50 WP). The second highest weight (2919 g) of rhizome per plot was recorded in case of treatment $T_{10}$ (Sawdust+ Ridomil gold MZ72) and $T_{11}$ (Poultry waste +alamanda leaf extract) which are statistically identical followed by $T_3$ (2834g), $T_4$ (2742g), $T_9$ (2172g). The lowest weight (468.7g) of the healthy rhizome per plot was recorded in untreated control preceded by $T_7$ (1264 g), $T_{15}$ (1293 g), $T_{16}$ (1335 g), $T_{12}$ (1405 g), $T_2$ (1462 g), $T_{14}$ (1501g), $T_8$ (1563g). In case of yield of rhizome, the yield performance of the treatment combination differed remarkably. The highest yield (16.73 t/ha) was recorded in $T_6$ (Poultry waste+Bavistin 50 WP) which was 172.92% increased over the untreated control. The second highest yield (16.24 t/ha) was recorded in $T_{11}$ (Poultry waste+alamanda leaf extract) which was 164.92% increased over the control followed by $T_3$ (PW+F2), $T_4$ (Poultry waste+neem leaf extract), $T_{10}$ (Sawdust+Ridomil gold MZ72) and $T_{13}$ (Saw dust+Bavistin 50WP). Individual yield performance of among the fungicides, the highest yield (9.84 t/ha) was recorded in $T_2$ (Bavistin 50WP) followed by Ridomil gold MZ72 (9.71 t/ha). Among the plant extracts, the highest yield was recorded in case of alamanda leaf extract (9.26 t/ha) followed by neem leaf extract (9.11 t/ha). The lowest yield (6.13 t/ha) was recorded in control treatment preceded by $T_8$ (*Trichoderma harzianum*).

# CHAPTER V

# DISCUSSION

The present experiment was conducted for the management of rhizome rot of ginger. The anlysis of variance (ANOVA) on *in-vitro* assay of selected treatment, number of tillers per hill, plant height, disease incidence, disease severity and yield are given in Appendix Chapter. The result have been discussed and possible interpretations have been given below:

The *in-vitro* assay of selected fungicides, plant extracts and *Trichoderma harzianum* against *Fusarium oxysporum* has been conducted in cup method and disc method (Table 2). In cup method, the highest inhibition (86.33%) of mycelial growth of *Fusarium oxysporum* was observed in case of Bavistin 50 WP. The second highest inhibition (83.77%) of mycelial growth was recorded in case of Ridomil gold MZ72 which is statistically similar with Dithane M-45 (82.66%). The *Trichoderma harzianum* also showed promising effect (81.11%) against *Fusarium oxysporum* followed by alamanda leaf extract (77.7%) and neem leaf extract (76.0%). The effect of neem leaf extract and alamanda leaf extract also found significantly similar in inhibition of radial growth of *Fusarium oxysporum*. The highest mycelia growth was recorded in untreated control. In Disc method, the highest inhibition zone (5.53 cm) was recorded in Bavistin 50WP followed by Ridomil gold MZ72 (4.90 cm), Dithane M-45 (4.73 cm). The effect of Ridomil gold MZ72 and Dithane M-45 also found statistically similar in making inhibition zone. Among the botanicals, the effect of neem leaf extract (4.10 cm) was found better than the alamanda leaf extract (3.36 cm) which was statistically identical with the inhibitory effect of *Trichoderma harzianum* (3.36 cm). No inhibition zone was made in untreated control. Singh *et. al.*, 2004 reported that the application of Ridomil MZ resulted in the highest yield (250.25q/ha) and lowest disease incidence (5.0%). Choe *et. al.* (1996) reported that Ridomil gold MZ-72 almost completely inhibited the mycelia growth of *Fusarium oxysporum* in *in-vitro* condition. The incidence of rhizome rot of ginger in response to different treatments were recorded at different days after planting starting from 30 DAP to 240 DAP with 30 days interval. At the beginning at 30 DAP the treatment effects were significantly differed with untreated control but among the treatments, the effect on disease incidence were significantly indifferent. The differences of treatment effect become sharpen with the age of the crop and distinct difference were

found at 240 DAP among the treatments (Table 2.). At 60 DAP, the lowest disease incidence (2.77 %) was recorded in $T_6$ (Poultry waste+Bavistin 50WP) which was statistically similar with rest of the treatments except control. Disease incidence was recorded highest (16.66%) in control treatment. At 90 DAP; the highest disease incidence was increased to 25.0% in case of control. The lowest disease incidence was remain 2.77% in $T_6$ (Poultry waste +Bavistin 50 WP) which was statistically indifferent with $T_3$ (Poultry waste+Ridomil gold MZ72), $T_5$ (Sawdust+alamanda leaf extract), $T_7$ (Saw dust+neem leaf extract), $T_{11}$ (Poultry waste+alamanda leaf extract) and $T_{13}$ (Saw dust+Bavistin 50 WP). In case of severity, at 80 DAP, the lowest severity (6.43%) was recorded in $T_6$ (Poultry waste +Bavistin 50WP) where soil was amended with poultry waste and rhizomes were treated with Bavistin 50 WP followed by foliar spray with the Bavistin 50 WP. The second lowest severity (8.30%) was recorded in $T_{11}$ (Poultry waste +Alamanda leaf extract) preceded by T3 ($PW+F_2$), $T_4$ (Poultry waste +Neem leaf extract), $T_{10}$ (Saw dust+ Ridomil gold MZ72), $T_{13}$ (Saw dust+ Bavistin 50WP) and $T_5$ (Saw dust+ Alamanda leaf extract). The highest disease severity was recorded in controlled treatment (45.50%). The individual performance of plant extracts, fungicides, bio-agent (*Trichoderma harzianum*) as foliar spray and organic soil amendment with poultry waste and saw dust were lower than the combined effect of the treatment but much higher than the control. At 120 DAP, the disease incidence did not increase and remain unchanged (2.77%, 5.55%, 5.55%) in $T_6$ (Poultry waste + Bavistin 50 WP), $T_3$ (Poultry waste + Ridomil gold MZ72) and $T_{11}$ (Poultry waste + Alamanda leaf extract) respectively. At 150 DAP, the disease incidence were also remain unchanged in $T_6$ (Poultry waste + Bavistin 50 WP), $T_{11}$ (Poultry waste + Alamanda leaf extract) and $T_3$ (Poultry waste + Ridomil gold MZ72). Thus the lowest disease incidence (2.77%) was noted in $T_6$ (Poultry waste + Bavistin 50 WP). The incidence of rest of the treatments either alone or in combination was significantly indifferent among them but differed with untreated control (38.88%). In case of disease severity, at 160 DAP; the lowest disease severity (7.46%) was recorded in $T_6$ (Poultry waste +Bavistin 50WP) where soil was amended with poultry waste and rhizomes were treated with Bavistin 50 WP followed by foliar spray with the Bavistin 50 WP. The second lowest disease severity (9.40%) was recorded in case of $T_{11}$ (Poultry waste +Alamanda leaf extract) preceded by $T_3$ ($PW+F_2$), $T_4$ (Poultry waste +Neem leaf extract), $T_{10}$ (Saw dust+ Ridomil gold MZ72), $T_{13}$ (Saw dust+ Bavistin 50 WP) and $T_5$ (Saw dust+ Alamanda leaf extract). The highest disease

severity was recorded in untreated control (49.07%). At 210 DAP, the lowest disease incidence (2.77%) was recoded in $T_6$ (Poultry waste + Bavistin 50 WP) followed by $T_3$ (11.11%), $T_{11}$ (11.11%), $T_4$ (13.88%) and $T_{10}$ (13.88%). The highest disease incidence was recoded in untreated control (55.55%). The effect of treatment $T_2$ (27.78%), $T_9$ (27.78%), $T_{12}$ (27.78%), $T_{14}$ (27.78 %,), $T_{16}$ (27.78%), $T_8$ (30.55%) and $T_{15}$ (30.55%) were significantly indifferent in respect of disease incidence. At 240 DAP, when crop was in mature stage, the disease incidence of rhizome rot of ginger reached to the highest level in each case of the treatment applied. The highest disease incidence (63.88%) was recorded in case of control treatment while the lowest disease incidence (2.77%) was recorded in $T_6$ (Poultry waste + Bavistin 50 WP) which was statistically similar to $T_3$ (Poultry waste + Ridomil gold MZ72) and $T_{11}$ (Poultry waste + Alamanda leaf extract). The treatment either alone or in combination showed promising effect in reducing the disease incidence and the highest reduction (95.66%) of disease incidence was counted in $T_6$ (Poultry waste + Bavistin 50 WP) followed by $T_3$ (Poultry waste + Ridomil gold MZ72), $T_{11}$ (Poultry waste + Alamanda leaf extract), $T_4$ (Poultry waste +Neem leaf extract), $T_{10}$ (Saw dust+Ridomil gold MZ72) and $T_5$ (Saw dust + Alamanda leaf extract). The lowest reduction of disease incidence was counted in case of $T_8$ (*Trichoderma harzianum*) preceded by $T_{12}$ (Saw dust), $T_9$ (Poultry waste), $T_7$ (Saw dust+Neem leaf extract) and $T_2$ (Bavistin 50 WP). In case of 240 DAP, the lowest disease severity (8.23%) was recorded in $T_6$ (Poultry waste +Bavistin 50WP) where soil was amended with poultry waste and rhizomes were treated with Bavistin 50 WP followed by foliar spray with the Bavistin 50 WP. The second lowest disease severity (10.30%) was recorded in $T_{11}$ (Poultry waste +Alamanda leaf extract) preceded by $T_3$ (Poultry waste+ Ridomil gold MZ72), $T_4$ (Poultry waste +Neem leaf extract), $T_{10}$ (Saw dust+ Ridomil gold MZ72), $T_{13}$ (Saw dust+ Bavistin 50 WP) and $T_5$ (Saw dust+ Alamanda leaf extract). The highest disease severity was recorded in untreated control (53.53%). The individual performance of plant extracts, fungicides and *Trichoderma harzianum* as foliar spray and organic soil amendment with poultry waste and saw dust were lower than the combined effect of the treatment but much higher than the control. On the basis of reduction of severity of rhizome rot of ginger, it is revealed that the highest reduction of severity (84.62%) was recorded in case of $T_6$ ($PW+F_1$) where soil was amended with poultry waste followed by foliar spray with the Bavistin 50 WP. The second highest reduction of severity (80.75%) was recorded in case of $T_{11}$ (Poultry waste+ Alamanda leaf extract),

$T_{10}$ (Saw dust+ Ridomil gold MZ72) which is statistically similar with $T_{13}$ (Saw dust +Bavistin 50 WP). The lowest (44.5%) reduction of severity of rhizome rot of ginger was recorded in case of $T_8$ (*Trichoderma harzianum*) which was statistically similar with neem leaf extract (45.20%) followed by $T_{16}$ (Alamanda leaf extract), $T_{12}$ (Saw dust) and $T_2$ (Bavistin 50 WP). The performance of the treatment either alone or in combination against rhizome rot of ginger in respect of different parameters varied significantly. The highest number of tillers (60) per hill was noted in case of treatment $T_6$ (Poultry waste+ Bavistin 50WP) where soil was amended with poultry waste and rhizomes were treated with Bavistin 50 WP followed by foliar spray with the Bavistin 50 WP. The performance of $T_6$ (Poultry waste +Bavistin 50 WP) was significantly indifferent with $T_3$ (Poultry waste +Ridomil gold MZ72), $T_4$ (Poultry waste+ Neem leaf extract), $T_{11}$ (Poultry waste +Alamanda leaf extract), $T_{10}$ (Saw dust +Ridomil gold MZ72) and $T_{13}$ (Neem leaf extract). The individual performance of the treatments in respect of number of tillers per hill were lower than the combined effect of the treatment but much higher compare to untreated control. The lowest number of tillers (18) per hill was recorded in control treatment. In case of plant height, significantly the highest plant height (65.20 cm) was recorded in case of treatment combination $T_6$ (Poultry Waste+Bavistin 50WP) and $T_7$ (Saw dust+ Neem leaf extract) which were statistically identical with that of $T_{11}$ (Poultry waste+ Alamanda leaf extract), $T_3$ (Poultry waste+ Ridomil gold MZ72) and $T_4$ (Poultry waste+Neem leaf extract). The lowest plant height (29.73cm) was recorded in untreated control preceded by $T_{16}$ (48.33 cm), $T_{13}$ (48.50 cm), $T_{12}$ (48.50 cm), $T_9$ (49.47 cm), $T_{15}$ (50.17 cm), $T_1$ (50.17 cm), $T_2$ (50.63 cm), $T_8$ (50.87 cm), $T_5$ (52.50 cm) and $T_{14}$ (53.13 cm) but performance of these treatment regarding plant height were statistically similar among themselves. In case of Infected Rhizome, significantly the highest weight (758.0g) of the infected rhizome was recorded in untreated control preceded by $T_8$ (555.7g), $T_{15}$ (529.3 g), $T_{16}$ (537.3g), $T_{12}$ (497.7g), $T_2$ (478.7g). The lowest weight (307.3g) of infected rhizome was recorded in case of treatment combination $T_6$ (Poultry waste+ Bavistin 50 WP) where soil was amended with poultry waste followed by foliar spray with the Bavistin 50 WP followed by $T_{11}$ (327.7 g), $T_3$ (357.7g), $T_4$ (377.7g), $T_{10}$ (394.3g), $T_{13}$ (409.0g), $T_7$ (434.3 g), $T_9$ (448.3 g). In case of healthy rhizome of ginger, significantly the highest weight (3039g) of the healthy rhizome was recorded in case of treatment combination $T_6$ (Poultry waste + Bavistin 50 WP). The second highest weight (2919 g) of rhizome was recorded in case of treatment $T_{10}$ (Saw dust+ Ridomil gold

$T_{10}$ (*Sun* dust + Ridomil gold MZ72) which is statistically similar with $T_{11}$ (*Sun* dust +Bavistin 50 WP). The lowest (44.2% ) reduction of severity of rhizome rot of ginger was recorded in case of $T_8$ (*Trichoderma harzianum*) which was statistically similar with neem leaf extract (45.20%) followed by $T_7$ (Alamanda leaf extract), $T_{12}$ (*Sun* dust) and $T_9$ (Bavistin 50 WP). The performance of the treatmen either alone or in combinatio against rhizome rot of ginger in respect of different parameters varied significantly. The highest number of tillers (60) per hill was noted in case of treatment $T_6$ (Poultry waste Bavistin 50WP) where soil was amended with poultry waste and rhizome were treated with Bavistin 50 WP followed by foliar spray with the Bavistin 50 WP. The performance of $T_6$ (Poultry waste +Bavistin 50 WP) was significantly indifference with $T_5$ (Poultry waste+Ridomil gold MZ72), $T_4$ (Poultry waste + Neem leaf extract), $T_3$ (Poultry waste +Alamanda leaf extract), $T_2$ (*Sun* dust +Ridomil gold MZ72) and $T_{11}$ (Neem leaf extract). The individual performance of the treatments in respect of number of tillers per hill were lower than the combined effect of the treatment but much higher compare to untreated control. The lowest number of tillers (18) per hill was recorded in control treatment. In case of plant height significantly the highest plant height (65.20 cm) was recorded in case of treatment combination $T_6$ (Poultry Waste- Bavistin 50WP) and $T_{10}$ (*Sun* dust- Neem leaf extract) which was statistically identical with that of $T_{11}$ (Poultry waste+ Alamanda leaf extract), $T_5$ (Poultry waste + Ridomil gold MZ72) and $T_4$ (Poultry waste+ Neem leaf extract). The lowest plant height (29.73cm) was recorded in untreated control preceded by $T_{10}$ (48.33 cm). $T_{11}$ (48.50 cm), $T_{12}$ (48.50 cm), $T_9$ (49.47 cm), $T_1$ (50.17 cm), $T_7$ (50.17 cm), $T_8$ (50.63 cm), $T_9$ (50.8 cm), $T_1$ (52.50 cm) and $T_{13}$ (52.13 cm) but performance of these treatment regarding plant height were statistically similar among themselves. In case of infected Rhizome, significantly the highest weight (758.0g) of the infected rhizome was recorded in untreated control preceded by $T_6$ (555.7g), $T_{12}$ (529.3 g), $T_{10}$ (537.3g), $T_{11}$ (497.7g), $T_1$ (478.7g). The lowest weight (307.3g) of infected rhizome was recorded in case of treatment combination $T_6$ (Poultry waste- Bavistin 50 WP) where soil was amended with poultry waste followed by foliar spray with the Bavistin 50 WP followed by $T_{11}$ (327.5 g), $T_{12}$ (352.7g), $T_4$ (377.7g), $T_{10}$ (394.3g), $T_{13}$ (409.0g), $T_7$ (434.1 g), $T_9$ (448.3 g). In case of healthy rhizome, ginger significantly the highest weight (2079g) of the healthy rhizome was recorded in case of treatment combination $T_6$ (Poultry waste + Bavistin 50 WP). The second highest weight (2919 g) of rhizome was recorded in case of treatment $T_{10}$ (*Sun* dust + Ridomil gold

MZ72) and $T_{11}$ (Poultry waste +Alamanda leaf extract) which are statistically identical followed by $T_3$ (2834g), $T_4$ (2742g), $T_9$ (2172g). The lowest weight (468.7g) of the healthy rhizome was recorded in untreated control preceded by $T_7$ (1264 g), $T_{15}$ (1293 g), $T_{16}$ (1335 g), $T_{12}$ (1405 g), $T_2$ (1462 g), $T_{14}$ (1501g), $T_8$ (1563g). In case of yield of rhizome, the yield performance of the treatment combination differed remarkably. The highest yield (16.73 t/ha) was recorded in $T_6$ (Poultry waste + Bavistin 50 WP) which was 172.92% increased over the control. The second highest yield was recorded (16.24 t/ha) in case of $T_{11}$ (Poultry waste + Alamanda leaf extract) which was 164.92% increased over the control followed by T3 (PW+F2), $T_4$ (Poultry waste+Neem leaf extract), $T_{10}$ (Saw dust+Ridomil gold MZ72) and $T_{13}$ (Saw dust+Bavistin 50WP). Individual yield performance of among the fungicides, the highest yield (9.84 t/ha) was recorded in case of $T_2$ (Bavistin 50WP) followed by Ridomil gold MZ72 (9.71 t/ha). Among the plant extracts, the highest yield was recorded in case of alamanda leaf extract (9.26 t/ha) followed by neem leaf extract (9.11 t/ha). The lowest yield (6.13 t/ha) was recorded in case of untreated control preceded by $T_8$ (*Trichoderma harzianum*).

The results of the present experiment are supported by the previous workers (Meena and Mathur, 2003; Ram *et. al.,* 2000; Dohroo *et. al.,* 1994, Sharma and Dohroo, 1991) reported that *Trichoderma harzianum* inhibited the growth of *Fusarium oxysporum* by 73% that were suggested to control the rhizome rot of ginger as post harvest management. Ram *et.al.* (1999) reported that soil application of *T. harzianum* increase the suppressive of the soil that control the rhizome rot of ginger. Meena and Mathur (2003) repoted that palliating of seed rhizome with biological control agent *Trichoderma harzianum, Psudomonas florescence* could effectively control the rhizome rot disease of ginger. Dohroo *et. al.* (1994) showed that the application of neem cake in the soil maximize the population of *Trichoderma harzianum* that reduce the incidence of rhizome rot of ginger. Rhizome treated with Bavistin 50WP or Dithane M-45 with formaldehyde gave effective control of the rhizome rot disease of ginger (Raj *et. al.,* 2001). Kusum carried out an experiment by using Ridomil gold MZ resulted most effective treatment in reducing the disease severity and increased the number of tillers. Ananda and Sharma (2003) developed an integrated disease management module by using selective mixture of fungicides with *Trichoderma harzianum* for soil treatment. In field condition, application of Ridomil gold MZ resulted the highest rhizome germination and yield (Singh *et. al.*, 2004).

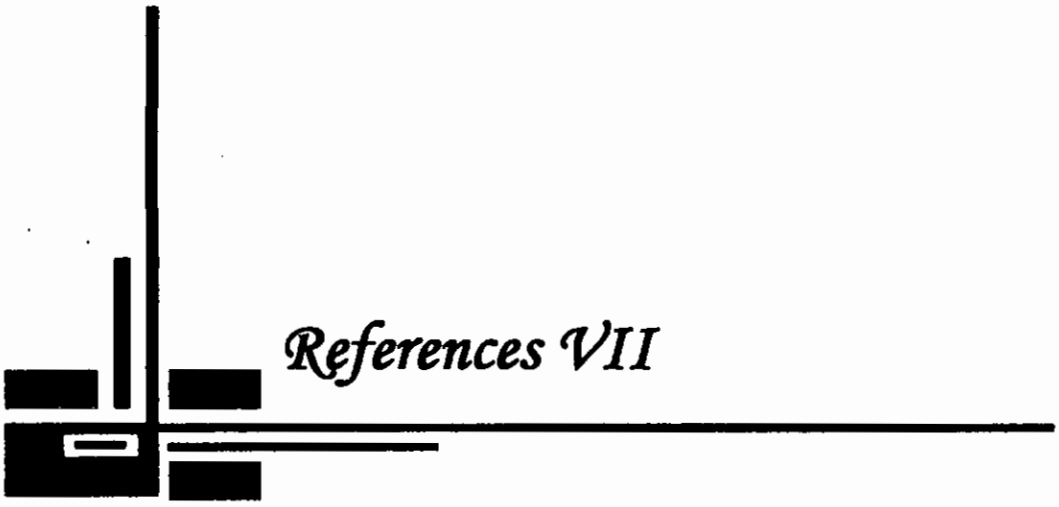
# Chapter VI
# Summary and Conclusion

# CHAPTER VI

# SUMMARY AND CONCLUSION

An experiment was conducted in the Plant Pathology Laboratory and farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh respectively during the period of 15 March'2011 to February 2012 to study the integrated approach for management of rhizome rot of ginger using selected fungicides, *Trichoderma harzianum*, organic soil amendment and plant extracts. The experiment was laid out in the single factors RCBD (Randomized Complete Block Design) with three replications. In laboratory experiment, the highest inhibition (86.33%) of mycelial growth of *Fusarium oxysporum* was observed in case of Bavistin 50 WP. The second highest inhibition (83.77%) of mycelial growth was recorded in Ridomil gold MZ72 which is statistically similar with Dithane M-45 (82.66%). The *Trichoderma harzianum* also showed promising effect (81.11%) against *Fusarium oxysporum* followed by alamanda leaf extract (77.7%) and neem leaf extract (76.0%). The effect of neem leaf extract and alamanda leaf extract also found significantly similar in inhibition of radial growth of *Fusarium oxysporum*. The highest mycelial growth was recorded in untreated control. The incidence of rhizome rot of ginger in response to different treatments were recorded at different days after planting starting from 30 DAP to 240 DAP with 30 days interval. At the beginning at 30 DAP the treatment effects were significantly differed with untreated control but among the treatments, the effect on disease incidence were statistically similar. The lowest disease incidence (2.77 %) was recorded at 60 DAP in $T_6$ (Poultry waste+Bavistin 50WP). Disease incidence was recorded highest (16.66%) in untreated control. The highest disease incidence was increased to 25.0% at 90 DAP in case of untreated control. The lowest disease incidence remained 2.77% in $T_6$. At 120 DAP, the disease incidence did not increase and remain unchanged (2.77%, 5.55%, 5.55%) in case of $T_6$, $T_3$ and $T_{11}$ respectively. The lowest disease incidence (2.77%) was noted in $T_6$ at 150 DAP and the highest disease incidence (55.55%) was recorded in untreated control. The lowest disease incidence (2.77%) at 210 DAP was recoded in $T_6$ followed by $T_3$ (11.11%), $T_{11}$ (11.11%), $T_4$ (13.88%) and $T_{10}$ (13.88%). The highest disease incidence was recoded in untreated control (55.55%). The effect of treatment $T_2$ (27.78%), $T_9$ (27.78%), $T_{12}$ (27.78%), $T_{14}$ (27.78 %,), $T_{16}$ (27.78%), T8 (30.55%) and $T_{15}$ (30.55%) were statistically similar in respect of disease incidence. The highest disease incidence (63.88%) was recorded at 240 DAP in untreated control while the lowest disease incidence was 2.77% in $T_6$. The lowest disease severity (8.23%) was recorded at 240 DAP in $T_6$ and the second lowest

disease severity was 10.30% in $T_{11}$. The highest (84.62%) reduction of severity was recorded in case of $T_6$.The highest reduction of severity (84.62%) was recorded in $T_6$. The second highest reduction of severity (80.75%) was recorded in $T_{11}$. The highest number of tillers (60) per hill was noted in treatment $T_6$. The lowest number of tillers (18) per hill was recorded in untreated control. In case of plant height, significantly the highest plant height (65.20 cm) was recorded in treatment combination $T_6$ (PW+F1) and $T_7$ (Saw dust+ neem leaf extract) which were statistically identical with that of $T_{11}$, and $T_4$. The lowest plant height (29.73cm) was recorded in untreated control preceded by $T_{16}$ (48.33 cm), $T_{13}$ (48.50 cm), $T_{12}$ (48.50 cm), $T_9$ (49.47 cm), $T_{15}$ (50.17 cm), $T_1$ (50.17 cm), $T_2$ (50.63 cm), $T_8$ (50.87 cm), $T_5$ (52.50 cm) and $T_{14}$ (53.13 cm). The highest weight (758.0g) of the infected rhizome was recorded in untreated control preceded by $T_8$ (555.7g), $T_{15}$ (529.3 g), $T_{16}$ (537.3g), $T_{12}$ (497.7g), $T_2$ (478.7g). The lowest weight (307.3g) of infected rhizome was recorded in case of treatment combination $T_6$ followed by $T_{11}$ (327.7 g), $T_3$ (357.7g), $T_4$ (377.7g), $T_{10}$ (394.3g), $T_{13}$ (409.0g), $T_7$ (434.3 g), $T_9$ (448.3 g). The highest weight (3039g) of the healthy rhizome was recorded in treatment combination $T_6$. The second highest weight (2919 g) of rhizome was recorded in $T_{10}$ (Saw dust+ Ridomil gold MZ72) and $T_{11}$ (Poultry waste +alamanda leaf extract) which are statistically identical followed by $T_3$ (2834g), $T_4$ (2742g), $T_9$ (2172g). The lowest weight (468.7g) of the healthy rhizome was recorded in untreated control preceded by $T_7$ (1264 g), $T_{15}$ (1293 g), $T_{16}$ (1335 g), $T_{12}$ (1405 g), $T_2$ (1462 g), $T_{14}$ (1501g), $T_8$ (1563g). The highest yield (16.73 t/ha) was recorded in case of $T_6$ which was 172.92% increased over the untreated control. The second highest yield (16.24 t/ha) was recorded in case of $T_{11}$ which was 164.92% increased over the untreated control followed by $T_3$, $T_4$, $T_{10}$ and $T_{13}$. Individual yield performance of among the fungicides, the highest yield (9.84 t/ha) was recorded in $T_2$ (Bavistin 50WP) followed by Ridomil gold MZ72 (9.71 t/ha). Among the plant extracts, the highest yield was recorded in case of alamanda leaf extract (9.26 t/ha) followed by neem leaf extract (9.11 t/ha). The lowest yield (6.13 t/ha) was recorded in case of untreated control preceded by $T_8$ (*Trichoderma harzianum*). Considering the overall results, use of poultry waste, alamanda leaf extract or neem leaf extract, saw dust alone or in combination might be recommended as eco-friendly approach for the management of rhizome rot of ginger. However, further investigation is needed to justify the present findings in different Agro Ecological Zone (AEZ) in the country for consecutive year.


References VII

# CHAPTER VII

# REFERENCE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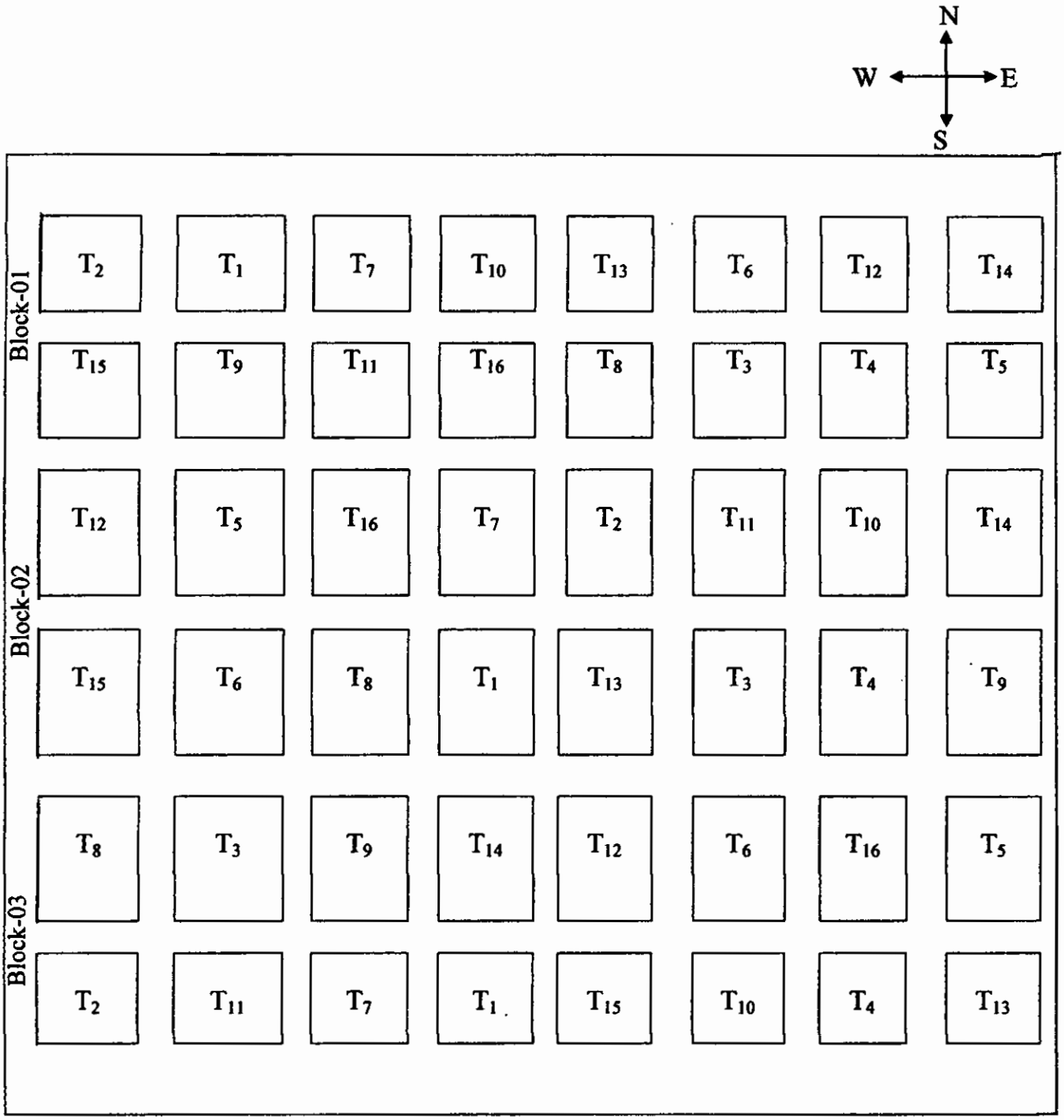
**Appendix I: Layout of the experimental field.**

Unit plot: (2.0X1.0) $m^2$, Distance: Plot to Plot: 0.5m, Block to Block: 1.0 m



**Appendix II. Results of mechanical and chemical analysis of soil of the experimental plot.**

**Mechanical analysis**

| Constituents | Percent (%) |
|---|---|
| Sand | 33.45 |
| Silt | 60.25 |
| Clay | 6.25 |
| Textural class | Silt clay |

**Chemical analysis**

| Soil properties | Amount |
|---|---|
| Soil $P^H$ | 6.12 |
| Organic Carbon | 1.32 |
| Total nitrogen (%) | 0.08 |
| Available P (ppm) | 20 |
| Exchangeable K (&) | 0.2 |

**Appendix III. Analysis of variance of the data on *in –vitro* assay of radial growth of mycelium and % inhibition of mycelia growth in cup method.**

| Source | Degrees of Freedom | Sum of Squares | Mean Square | F-value | Prob |
|---|---|---|---|---|---|
| Replication | 2 | 0.01 | 0.004 | 1.64 | 0.2353 |
| Treatment | 6 | 138.89 | 23.149 | 8838.55 | 0.0000 |
| Error | 12 | 0.03 | 0.003 | | |

Coefficient of Variation= 1.87%
Significant at 0.01% level of probability

**Appendix IV. Analysis of variance of the data on the disease incidence of rhizome rot of ginger at 30 DAP (Days After Planting) in response to different treatments.**

| Source | Degrees of Freedom | Sum of Squares | Mean Square | F-value | Prob |
|---|---|---|---|---|---|
| Replication | 2 | 242.82 | 121.410 | 6.17 | 0.0057 |
| Treatment | 15 | 503.30 | 33.553 | 1.71 | 0.1039 |
| Error | 30 | 590.01 | 19.667 | | |

Coefficient of Variation= 85.18%
Significant at 0.05% level of probability

**Appendix V. Analysis of variance of the data on the disease incidence of rhizome rot of ginger at 60 DAP (Days After Planting) in response to different treatments.**

| Source | Degrees of Freedom | Sum of Squares | Mean Square | F-value | Prob |
|---|---|---|---|---|---|
| Replication | 2 | 228.35 | 114.173 | 6.69 | 0.0040 |
| Treatment | 15 | 507.60 | 33.840 | 1.98 | 0.0539 |
| Error | 30 | 511.97 | 17.066 | | |

Coefficient of Variation= 58.06%
Significant at 0.05% level of probability

**Appendix VI. Analysis of variance of the data on the disease incidence of rhizome rot of ginger at 90 DAP (Days After Planting) in response to different treatments.**

| Source | Degrees of Freedom | Sum of Squares | Mean Square | F-value | Prob |
|---|---|---|---|---|---|
| Replication | 2 | 164.85 | 82.425 | 4.67 | 0.0171 |
| Treatment | 15 | 1132.47 | 75.498 | 4.28 | 0.0003 |
| Error | 30 | 529.20 | 17.640 | | |

Coefficient of Variation= 38.41%
Significant at 0.05% level of probability

**Appendix VII. Analysis of variance of the data on the disease incidence of rhizome rot of ginger at 120 DAP (Days After Planting) in response to different treatments.**

| Source | Degrees of Freedom | Sum of Squares | Mean Square | F-value | Prob |
|---|---|---|---|---|---|
| Replication | 2 | 164.86 | 82.431 | 3.25 | 0.0527 |
| Treatment | 15 | 2077.20 | 138.480 | 5.46 | 0.0000 |
| Error | 30 | 760.66 | 25.355 | | |

Coefficient of Variation= 37.20%
Significant at 0.05% level of probability

**Appendix VIII. Analysis of variance of the data on the disease incidence of rhizome rot of ginger at 150 DAP (Days After Planting) in response to different treatments.**

| Source | Degrees of Freedom | Sum of Squares | Mean Square | F-value | Prob |
|---|---|---|---|---|---|
| Replication | 2 | 321.07 | 160.535 | 11.48 | 0.0002 |
| Treatment | 15 | 2960.92 | 197.395 | 14.12 | 0.0000 |
| Error | 30 | 419.52 | 13.984 | | |

Coefficient of Variation= 24.77%
Significant at 0.05% level of probability

**Appendix IX. Analysis of variance of the data on the disease incidence of rhizome rot of ginger at 180 DAP (Days After Planting) in response to different treatments.**

| Source | Degrees of Freedom | Sum of Squares | Mean Square | F-value | Prob |
|---|---|---|---|---|---|
| Replication | 2 | 558.92 | 279.458 | 30.48 | 0.000 |
| Treatment | 15 | 3853.00 | 256.867 | 28.02 | 0.000 |
| Error | 30 | 275.03 | 9.168 | | |

Coefficient of Variation= 16.00%
Significant at 0.05% level of probability

**Appendix X. Analysis of variance of the data on the disease incidence of rhizome rot of ginger at 210 DAP (Days After Planting) in response to different treatments.**

| Source | Degrees of Freedom | Sum of Squares | Mean Square | F-value | Prob |
|---|---|---|---|---|---|
| Replication | 2 | 633.46 | 316.728 | 28.07 | 0.000 |
| Treatment | 15 | 6598.03 | 439.869 | 38.99 | 0.000 |
| Error | 30 | 338.49 | 11.283 | | |

Coefficient of Variation= 14.66%
Significant at 0.05% level of probability

**Appendix XI. Analysis of variance of the data on the disease incidence of rhizome rot of ginger at 240 DAP (Days After Planting) in response to different treatments.**

| Source | Degrees of Freedom | Sum of Squares | Mean Square | F-value | Prob |
|---|---|---|---|---|---|
| Replication | 2 | 1362.42 | 681.212 | 28.36 | 0.000 |
| Treatment | 15 | 9465.36 | 631.024 | 26.27 | 0.000 |
| Error | 30 | 720.58 | 24.019 | | |

Coefficient of Variation= 17.76%
Significant at 0.05% level of probability

**Appendix VIII. Analysis of variance of the data on the disease incidence of rhizome rot of ginger at 150 DAP (Days After Planting) in response to different treatments.**

| Source | Degrees of Freedom | Sum of Squares | Mean Square | F-value | Prob |
|---|---|---|---|---|---|
| Replication | 2 | 321.07 | 160.535 | 11.48 | 0.0002 |
| Treatment | 15 | 2960.92 | 197.395 | 14.12 | 0.0000 |
| Error | 30 | 419.52 | 13.984 | | |

Coefficient of Variation= 24.77%
Significant at 0.05% level of probability

**Appendix IX. Analysis of variance of the data on the disease incidence of rhizome rot of ginger at 180 DAP (Days After Planting) in response to different treatments.**

| Source | Degrees of Freedom | Sum of Squares | Mean Square | F-value | Prob |
|---|---|---|---|---|---|
| Replication | 2 | 558.92 | 279.458 | 30.48 | 0.000 |
| Treatment | 15 | 3853.00 | 256.867 | 28.02 | 0.000 |
| Error | 30 | 275.03 | 9.168 | | |

Coefficient of Variation= 16.00%
Significant at 0.05% level of probability

**Appendix X. Analysis of variance of the data on the disease incidence of rhizome rot of ginger at 210 DAP (Days After Planting) in response to different treatments.**

| Source | Degrees of Freedom | Sum of Squares | Mean Square | F-value | Prob |
|---|---|---|---|---|---|
| Replication | 2 | 633.46 | 316.728 | 28.07 | 0.000 |
| Treatment | 15 | 6598.03 | 439.869 | 38.99 | 0.000 |
| Error | 30 | 338.49 | 11.283 | | |

Coefficient of Variation= 14.66%
Significant at 0.05% level of probability

**Appendix XI. Analysis of variance of the data on the disease incidence of rhizome rot of ginger at 240 DAP (Days After Planting) in response to different treatments.**

| Source | Degrees of Freedom | Sum of Squares | Mean Square | F-value | Prob |
|---|---|---|---|---|---|
| Replication | 2 | 1362.42 | 681.212 | 28.36 | 0.000 |
| Treatment | 15 | 9465.36 | 631.024 | 26.27 | 0.000 |
| Error | 30 | 720.58 | 24.019 | | |

Coefficient of Variation= 17.76%
Significant at 0.05% level of probability

**Appendix XII. Analysis of variance of the data on the disease severity of rhizome rot of ginger at 80 DAP (Days After Planting) in response to different treatments.**

| Source | Degrees of Freedom | Sum of Squares | Mean Square | F-value | Prob |
|---|---|---|---|---|---|
| Replication | 2 | 0.35 | 0.173 | 1.22 | 0.3101 |
| Treatment | 15 | 3927.60 | 261.840 | 1846.29 | 0.0000 |
| Error | 30 | 4.25 | 0.142 | | |

Coefficient of Variation= 1.85%
Significant at 0.05% level of probability

**Appendix XIII. Analysis of variance of the data on the disease severity of rhizome rot of ginger at 160 DAP (Days After Planting) in response to different treatments.**

| Source | Degrees of Freedom | Sum of Squares | Mean Square | F-value | Prob |
|---|---|---|---|---|---|
| Replication | 2 | 0.18 | 0.092 | 0.74 | 0.4836 |
| Treatment | 15 | 4364.96 | 290.997 | 2341.51 | 0.00 |
| Error | 30 | 3.73 | 0.124 | | |

Coefficient of Variation= 1.67%
Significant at 0.05% level of probability

**Appendix XIV. Analysis of variance of the data on the disease severity of rhizome rot of ginger at 240 DAP (Days After Planting) in response to different treatments.**

| Source | Degrees of Freedom | Sum of Squares | Mean Square | F-value | Prob |
|---|---|---|---|---|---|
| Replication | 2 | 0.71 | 0.357 | 2.05 | 0.1462 |
| Treatment | 15 | 5007.48 | 333.832 | 1918.73 | 0.0000 |
| Error | 30 | 5.22 | 0.174 | | |

Coefficient of Variation= 1.90%
Significant at 0.05% level of probability

**Appendix XV. Analysis of variance of the data on number of tillers per hill of ginger at in response to different treatments.**

| Source | Degrees of Freedom | Sum of Squares | Mean Square | F-value | Prob |
|---|---|---|---|---|---|
| Replication | 2 | 7.29 | 3.646 | 2.69 | 0.0845 |
| Treatment | 15 | 6459.48 | 430.632 | 317.35 | 0.000 |
| Error | 30 | 40.71 | 1.357 | | |

Coefficient of Variation= 2.61%
Significant at 0.05% level of probability

**Appendix XVI. Analysis of variance of the data on number of average height of ginger plant in response to different treatments.**

| Source | Degrees of Freedom | Sum of Squares | Mean Square | F-value | Prob |
|---|---|---|---|---|---|
| Replication | 2 | 1.40 | 0.701 | 1.17 | 0.3238 |
| Treatment | 15 | 2925.65 | 195.043 | 325.61 | 0.00 |
| Error | 30 | 17.97 | 0.599 | | |

Coefficient of Variation= 1.48%
Significant at 0.05% level of probability

**Appendix XVII. Analysis of variance of the data on weight of infected rhizome in response to different treatments.**

| Source | Degrees of Freedom | Sum of Squares | Mean Square | F-value | Prob |
|---|---|---|---|---|---|
| Replication | 2 | 2276.38 | 1138.188 | 61.53 | 0.000 |
| Treatment | 15 | 533553.98 | 35570.265 | 1922.86 | 0.000 |
| Error | 30 | 554.96 | 18.499 | | |

Coefficient of Variation= 0.94%
Significant at 0.05% level of probability

**Appendix XVIII. Analysis of variance of the data on yield of rhizome (t/ha) in response to different treatments.**

| Source | Degrees of Freedom | Sum of Squares | Mean Square | F-value | Prob |
|---|---|---|---|---|---|
| Replication | 2 | 0.62 | 0.308 | 146.48 | 0.000 |
| Treatment | 15 | 449.62 | 29.975 | 14239.85 | 0.000 |
| Error | 30 | 0.06 | 0.002 | | |

Coefficient of Variation= 0.41%
Significant at 0.05% level of probability

## Appendix XIX. List of symbol and abbreviations

| | | |
|---|---|---|
| % | = | Percentage |
| *et. al.* | = | and others |
| Spp. | = | Species |
| No. | = | Number |
| viz. | = | Namely |
| df. | = | Degrees of freedom |
| @ | = | At the rate of |
| etc | = | Etcetera |
| PDA | = | Potato Dextrose Agar media |
| $^0$C | = | Degree Celsius |
| Cm | = | Centimeter |
| J. | = | Journal |
| BBS | = | Bangladesh Bureau of Statistics |
| RH | = | Relative Humidity |
| ANOVA | = | Analysis of variances |
| CV% | = | Percentages of Co-efficient of Variance |
| LSD | = | Least Significant Difference |
| Sci. | = | Science |
| BBS | = | Bangladesh Bureau of Statistics |
| DI | = | Disease Incidence |
| DS | = | Disease Severity |
| DAP | = | Days After Planting |