MANAGEMENT OF FUSARIUM AND NEMIC WILTS OF TOMATO BY GRAFTING, SOIL AMENDMENT, CHEMICALS AND BIO-AGENT

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JUNE - 2006

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A Thesis
By

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REGISTRATION NO. 25215/00339

Submitted to the
Department of Plant Pathology
Sher-e-Bangla Agricultural University, Dhaka
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE (M.S.)
IN
PLANT PATHOLOGY
Semester: January-June 2006

DEPARTMENT OF PLANT PATHOLOGY
SHER-E-BANGLA AGRICULTURAL UNIVERSITY
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CERTIFICATE

This is to certify that the thesis entitled, "MANAGEMENT OF FUSARIUM AND NEMIC WILTS OF TOMATO BY GRAFTING, SOIL AMENDMENT, CHEMICALS AND BIO-AGENT" 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 IN PLANT PATHOLOGY**, embodies the result of a piece of bona fide research work carried out by **Md. BELAL HOSSAIN** Registration No- 25215/00339 under my supervision and guidance. No part of the thesis has been submitted for any other degree in any other institutes.

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

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MY BELOVED

PARENTS

ACKNOWLEDGEMENT

The author wishes to acknowledge the immeasurable grace and profound kindness of Almighty Allah the supreme Ruler of the Universe, who has enabled me to carry out this research work and prepare the thesis for the degree of Master of Science (M.S.) in Plant Pathology, Sher-e-Bangla Agricultural University, Dhaka.

The author sincerely expresses his heartfelt indebtedness and sincere appreciation to his supervisor, Dr. Md. Rafiqul Islam, Associate Professor, Department of Plant Pathology, Sher-e-Bangla Agricultural University, Dhaka for his scholastic guidance, precious suggestions, affectionate feelings, constant encouragement and constructive criticisms during the entire period of the research work and preparing of the thesis.

The author wishes to expresses his deep respect to his honorable teacher and co-supervisor, M. Salahuddin M. Chowdhury, Assistant Professor, Department of Plant Pathology, Sher-e-Bangla Agricultural University, Dhaka for his valuable suggestions, cordial guidance and continuous encouragement for completion of the research work.

The author is pleased to submit his gratefulness to all of his respected teachers of the Department of Plant Pathology, Sher-e-Bangla Agricultural University, Dhaka for their inspiration and co-operation during the study period.

The author is indebted and grateful to Mirza Hasanuzzaman, Lecturer, Department of Agronomy, Md. Arfan Ali, Lecturer, Department of Horticulture & Post Harvest Technology and Md Abdur Rahim, Lecturer, Department of Genetics & Plant Breeding. Sher-e- Bangla Agricultural University, Dhaka for his valuable suggestions and co-operation during data analysis for this thesis.

The author desires to express his cordial thanks to all M.S. students of Department of Plant Pathology, Sher-e-Bangla Agricultural University, Dhaka specially Shakil, Zia, Mahfuz, Faruk, Pervez, Aminur, Olliulla and Tonu for their friendly association and co-operation during the study period.

The author feels proud and deeply indebted to his parents, brothers, sisters, relatives and well-wishers without whose blessings, sacrifices and constant inspiration the present research work would not be possible. The author is specially grateful to his father, mother, sisters Mst. Nura Shaba and Mst. Lutfa Begum and Mst. Sultana Begum and brothers Md. Mosharf Hossain, Md. Dulal Haque and Md. Mahbur Rahman for their cordial help through the entire period of research work and preparation of the thesis.

Thanks are extended to Momin Uddin, Laboratory Assistant and all staff of Department of Plant Pathology, Sher-E-Bangla Agricultural University, Dhaka and field officer and laborers specially Md. Joshimuddin for their help and co-operation during the research work.

The author is also grateful to his friends especially Md. Abdur Rashid, Md. Rashedul Islam and roommate Sabuj, Kamrul Hasan and Md. Golam Mostofa whose love and inspiration in all the way, brought him here at this stage.

Lastly the author expresses his indebtedness to beloved parents, brothers, sisters, nephews, grandfather, grandmother, relatives and well-wishers for their blessings, love and affection.

---- The Author

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MANAGEMENT OF FUSARIUM AND NEMIC WILTS OF TOMATO BY GRAFTING, SOIL AMENDMENT, CHEMICALS AND BIO-AGENT

ABSTRACT

Efficacy of eight selected treatments viz. Grafting (T_1), Furadan 5G (T_2), Bavistin (T_3), Cupravit (T_4), *Trichoderma harzianum* (T_5), Sawdust (T_6), Khudepana (T_7) and Control (T_8) were assessed against *Fusarium oxysporum* f.sp. *lycopersici* and *Meloidogyne incognita* for management of wilt diseases of tomato during winter season of 2005-2006 at the farm, allotted for the Department of Plant Pathology, Sher-e-Bangla Agricultural University (SAU), Dhaka. Significant differences were observed among the treatments in terms of wilt incidence, root gall incidence, plant growth and fruit yield. Application of Sawdust (T_6), Furadan 5G (T_5) and Grafting (T_1) showed the highest effect against the wilt pathogens where no wilt and gall incidence were observed even at 85 days after transplanting. The plant growth was influenced and fruit yield were increased by 206.67%, 115.12% and 103.66%, respectively for Sawdust (T_6), Grafting (T_1) and Furadan 5G (T_2) over control. Bavistin (T_3), *Trichoderma harzianum* (T_5) and Khudepana (T_7) also gave better performance against the disease, while Cupravit (T_4) showed least performance in comparison to control. Cost analysis showed that Sawdust resulted the highest BCR (8.57) followed by grafting (7.65) and Furadan 5G (7.16).

Chapter 1
Introduction

INTRODUCTION

Tomato (*Lycopersicon esculentum* Mill.), a member of the family Solanaceae, is a very popular vegetable because of its taste, colour and high nutritive value and also for its diversified use (Boss and Som, 1980). Ripe fruit is used mostly in salads and many other food items. It is an important source of vitamin and minerals (Rashid, 1976, Appendix-1). It is widely grown in almost all countries of the world due to its adaptability to wide range of soil and climate (Ahmad, 1976). In Bangladesh, tomato is cultivated nearly in all homestead gardens besides fields, especially in the winter season. Some advanced farmers are also cultivating summer tomatoes.

The demand of tomato is increasing day by day in the Agro-food industries of Bangladesh. Thus; it is now considered as an important cash crop in this country. In terms of production, it ranks next to potato and sweet potato in the world (Rashid, 1983) and tops the list of canned vegetables (Chowdhury, 1979).

According to recent statistics, tomato was grown in 17 thousand hectares of land in Bangladesh, the production being 67,416 tons/ha in 2004-2005. Thus the average yield was 2.65 metric tons/acre (BBS, 2003/December). This figure is very low as compared to the other leading tomato producing countries (FAO, 2006). There are many factors involved in such low yield of tomato in Bangladesh. Among the various factors infection by fungi, bacteria, nematodes, viruses and the competing weeds are responsible for the low yield. (Villaral, 1980).

However, diseases of tomato act as the chief limiting factor to its economic production. Over 200 diseases have been reported to affect tomato plants in the world (Watterson, 1986). Among the diseases, early blight, late blight, fusarial, bacterial and nemic wilt, viral leaf curl and mosaic are major.

The crop suffers frequently by various soil borne diseases. Wilt of tomato (*Fusarium oxysporum*, *Ralstonia solanacearum*, *Meloidogyne incognita*) is the major constraints for growing of the crop in farmer's field and kitchen garden. In Bangladesh, *Fusarium* wilt (*Fusarium oxysporum*) is common in non-flooded high land where solanaceous vegetables are grown continuously without crop rotation. Sudden wilting of tomato is very acute and occurs commonly in these non-flooded areas. Cultivation of tomato is sometime difficult due to high incidence of the wilt pathogens (Ali *et.al.*, 1994).

Fusarium wilt is one of the most prevalent and damaging disease of tomato wherever tomatoes are grown intensively. The disease is most destructive in warm climates and sandy soil of temperate regions. The organism is specific for tomato and is very long- lived in all regions of the world. The disease develops more quickly in soils that are high in nitrogen and low in potassium.

Root-Knot caused by *Meloidogyne incognita* is another important and widely distributed disease in the country (Talukder, 1974; Timm and Ameen, 1960; Ahmed and Hossain; 1985 and Mian, 1986). The disease is expressed by gall formation in the root system and ultimately the plants become weak due to interruption in nutrient uptake from the soil. At severe infection the plants may die.

There are two traditional methods of controlling soil borne disease. (i) Soil sterilization by chemicals, which is too inconsistent, expensive and not environment friendly.(ii) Use of resistant varieties, but there are very few reports available regarding wilt resistant varieties of tomato (Goth *et al.*, 1986).

Plant health management is now being considered as a young approach, which aimed at the proper use of IPM components with emphasis on environment, economics and social acceptance (Cook, 2000). Understanding the mechanism and exploration of bio-agents for soil treatment in our agro- ecosystem has got importance for plant health management. Therefore, use of bio-agents like *Trichoderma* sp. could be a good option in controlling wilt of tomato. Strains of *Trichoderma harzianum* is reported as potential tool of biological control against plant pathogens (Cook, 1993; Harman, 1989; Weller *et al.*, 1988).

Grafting of tomato on resistant rootstock is an effective technique to control *Fusarium* wilt, Bacterial wilt and root knot diseases. A number of wild relatives of solanum and its amphidiploids were recorded as resistant to those diseases. This rootstock is graft compatible to eggplant and tomato (Khan, 1974; Mochizuki and Yamakawa, 1979a, 1979b, sand Ali et *al.*, 1990a, 1990b, 1992).

Management of wilt diseases of tomato with indigenous plant products and other organic substances as amendment to the soil are relatively a recent innovation. Alam (1987) stated the pollution free control of plant parasitic nematodes by soil amendment with plant wastes or organic substances. Results from the pot experiments proved that chopped plants leaves when incorporated into naturally infested soil effectively suppressed populations of plant parasitic nematodes and improved growth of tomato. Stirling (1989) used poultry manure and sawdust (24, 36 or 48 t/ha) which were incorporated into soil with urea (0-1800kg N/ha) and their effects on the increase of yield of tomato and suppressed nematode populations were assessed.

Considering the above facts the present investigation was undertaken with the following objectives.

OBJECTIVES:

i) To determine the effect of selected IPM components in controlling *Fusarium* and Nemic wilt of tomato.

ii) To find out the ecofriendly IPM components for the management of *Fusarium* and Nemic wilt of tomato from the selected treatments.

Chapter 2
Review of literature

REVIEW OF LITERATURE

Tomato (*Lycopersicon esculentum* Mill.) suffers from many diseases caused by fungi, bacteria, virus and nematodes. Among them *Fusarium* wilt (*Fusarium oxysporum f. sp. lycopersici*) and Nemic wilt (*Meloidogyne sp.*) cause severe crop loss. Research works regarding *Fusarium* wilt and Nemic with emphasis on their management are reviewed in this chapter.

2.1 Symptoms

2.1.1 Symptoms of *Fusarium* wilt

Walker (1969) described the symptoms of wilt caused by *Fusarium sp* as yellowing of the lower leaves, usually affecting the leaflets unilaterally. The affected leaves die and the symptoms continue to appear successively on younger leaves. The plant as a whole is stunted and eventually goes into a permanent wilting of the leaves, which die as they cling to the upright woody stems.

Rangswami (1988) observed the first symptoms of fusarial wilt (*Fusarium oxysporum f. sp. lycopersici)* of the veinlets and chlorosis of the leaf. Soon the petiole and leaves droop off and become wilted. The younger leaves may die in succession and the entire plant may wilt and die in course of a few days.

2.1.2 Symptoms of nemic wilt

Root-Knot caused by *Meloidogyne incognita* is important and widely distributed disease in the country (Talukder, 1974; Timm and Ameen, 1960; Ahmed and Hossain, 1985 and Mian, 1986). The disease is expressed by gall formation in the root system and ultimately the plants become weak due to interruption in nutrient uptake from the soil, at severe infection the plants may die.

Nematode infection of plants results in the appearance of symptom on roots as well as on the aboveground parts of plants. Root symptoms may appear as root knots/ root galls and when nematode infections are accompanied by plant pathogenic or saprophytic bacteria and fungi as root rots. The root symptoms are usually accompanied by non characteristic symptoms in the aboveground parts of plants and appearing primarily as reduced growth, symptoms of nutrient deficiencies such as yellowing of foliage, excessive wilt in hot or dry weather reduced yields and poor quality of products. Incidence of *Fusarium* wilt of tomato increases when the plants are also infected by the root-knot nematodes.

2.2 MANAGEMENT OF WILT DISEASES OF TOMATO

2.2.1 Management through Grafting with wild Solanum (*Solanum siysmbriifolium)*

Some wild species of Solanum and many close relatives of eggplant and some of their amphidiploids have been found partial to complete resistant to soil borne diseases like bacterial wilt and root-knot nematode (Khan, 1974; Khan *et al.*, 1978; Yamakawa and Mochizuki, 1978, 1979; Mochizuki and Yamakawa, 1979; and Kimura, 1989; Ali *et al.*, 1990, 1992).

Mochizuki *et al.* (1979 b) worked on potential utilization of bacterial wilt resistant *Solanum* species as root-stock for commercial cultivation of eggplant. They evaluated wild *Solanum* species as root-stock of cultivated eggplants and tested in the field artificially infested with the bacterial wilt pathogen and in non-infested soil. Observations were made on disease development and yield of the scion eggplants. *Solanum torvum* showed high resistance to bacterial wilt, and the vigor and yield of the scion eggplants were superior to those grafted to *S. integrifolium*, a standard root-stock widely used in Japan. *Solanum toxicarium* was even more resistant to bacterial wilt than *S. torvum*. However, the vigour and total fruit yield of the scion eggplants were not better than those using *S. integrifolium* as root stock, and the yield and fruit quality at early stages of development were rather poor. These two species of *Solanum*, especially *S. torvum* showed potential for use as eggplant root stock because of high resistance to bacterial wilt and good fruit yield of the scion.

Four species of *solanum* namely, *S. torvum*, *S. indicum*, *S. seaforthiaonum* and *S. mammosum* and 10 strains of *S. khasianum* and wild *S. khasianum* were evaluated against *M. incognita*. They were graded as resistant (1-25 galls), moderately resistant (26-50 galls), and susceptible (51-100 galls) and highly susceptible (over 100 galls). *Solanum torvum* and *S. seaforthianum* showed resistant reaction and the rest susceptible reaction to the nematode (Shetty and Reddy, 1985).

Shetty and Reddy (1985) reported that *Solanum sisymbriifolium* and *S. torvum* are effective root stocks to control root knot and wilt, respectively.

Pirog (1986) reported that greenhouse tomatoes were grafted on resistant rootstocks KNVF to prevent attacks of *Pyrenochaeto lycopersicon* or *Meloidogyne sp.*, in trials with 4 cvs., grafted plants produced 30-50% higher yields than non-grafted control plants.

In tomato, grafting is being practiced where there are severe problems of root disease. *Lycopersicon pimpinellifoleium* and some other *Fusarium* resistant stocks are used against root diseases (Kallo, 1986). ''OTB-2'' (Okuda *et al.*1972) and ''IRB-3OI-3I'' (Thrope and Jarvis, 1981) have been reported as best root stock for the control of *Fusarium oxysporum f. sp. lycopersici.*

Ali *et al.* (1990a, 1990 b) also reported that *Solanum sisymbriifolium* and *S. torvum* are effective rootstocks to control root-knot nematode and wilt diseases. Resistance of eggplant and its wild relatives was evaluated against *Meloidogyne incognita* through inoculation of seedlings . High resistance was found in *Solanum khashianum*, *S. torvum* and *S. toxicarium. Solanum integrifolium* was susceptible while *S. indicum* and *S. surattense* were highly susceptible, small swellings were formed in *S. sisymbriifolium* but the nematode failed to develop and reproduce in its root system.

Matsuzoe *et al.* (1990) observed that the yield and quality of tomato fruits of grafted plants on the amphidiploid root stock were equivalent to or higher than those of non grafted plants.

Ali *et al.* (1992) evaluated resistance of eggplant, its wild relatives, interspecific *Solanum* hybrids and amphidiploids to *M. incognita* through inoculation of seedlings and grafted and non-grafted plants. They observed immunity or high resistance in *S. khasianum, S. torvum* and *S. toxicarium.* Small swelling was formed in *S. sisymbriifolium,* their hybrids and amphidiploids, and *S. indicum* failed to show resistance against the root-knot nematode. *Solanum mammosum* and *S. surattense* were highly susceptible to *M. incognita.*

In Bangladesh four species of wild *Solanum* were evaluated for their resistance to root-knot nematode (*M. incognita*) and their susceptibility was graded on the development of gall and nematode in root systems. It was reported that *Solanum siysmbriifolium* was found as resistant, *S. indicum* and *S. suranttentse* as susceptible and *S. integrifolium*, *S. insanum* as highly susceptible. The compatibility of cultivated eggplant varieties for grafting on *S. sisymbriifolium* was studied and it was found to be an effective root stock for grafting susceptible eggplant to reduce the severity of root-knot disease (Islam, 1992).

Recent reports from Bangladesh indicate that grafting of tomato and eggplant on resistant wild *Solanum* rootstocks is an effective technique to control bacterial wilt and root-knot nematode diseases (Islam 1992, Ali *et al.*, 1994).

A pot experiment was carried out at the Institute of Postgraduate Studies in Agriculture (IPSA), Salna, Gazipur, Bangladesh during November 1996 to March 1997 to find out the optimum organic residues and urea requirement for grafted tomato in potted soil. Islam (1996) conducted a pot experiment to optimize the requirement of nitrogen fertilizer on yield of tomato. He reported that the highest average yield (145g/plant) of tomato was obtained with 200kg N/ha (5.40gN/pot) applied in a split dose, with one half at 15 days after transplantation and the other half at 35 days after transplantation.

2.2.2 Management through Furadan 5G

Research works have been carried out to control nemic diseases of crops with chemical nematicides and organic substances especially with seed extracts. Chemicals are generally applied to the field crops both as granular and liquid forms.

Homeyer (1973) observed that Curaterr (Carbofuran) was highly effective insecticide/nematicide owing to its rapid dispersal in soil and its systemic action when taken up by plants.

Yaringano and Villalba (1977) reported that among the nematicides, Furadan 5G was the most effective in controlling *Meloidogyne sp.* in tomatoes in the dry-tropics.

Rajendran and Naganathan (1978) reported that in a vineyard infested with *Meloidogyne incognita* in Coimbatore, India treatment with Aldicarb, DBCP (1.2g/m^2) or Carbofuran (0.6gai/vine) decreased the number of galls/g of root by approximately 25%. Yield increased for the treatments by 96.4, 72.6 and 70.8%, respectively.

Katalon-Gateva *et al.* (1979) reported that the application of Furadan 10G (Carbofuran) granules at kg/1000 m^2 twice (once before and once after planting tobacco) or once at 10kg/100 m^2 (before planting), greatly reduced the number of nematodes (adult and larvae) in the soil. In tobacco roots, Carbofuran greatly reduced the number of *Meloidogyne incognita* in soil and in roots and inhibited gall formations with efficacy index of 74-78%.

Perlaza *et.al.* (1979) applied metham-sodium, Phenamiphos (Nemacur 5kg a. i./ha), Carbofuran (Furadan 6 kg a. i./ha) and Aldicarb (Temik 5kg a. i. /ha) alone or in combination with fungicides to carrot fields infested with *Meloidogyne incognita, M. hapla and Alternaria sp.* in Costa Rica. They reported that all nematicides significantly increased root-length and decreased the percentage of deformed roots and index of root nodules. All except Aldicarb significantly increased root weight..

Kartono (1980) stated that Temik 10G, Furadan 3G and Nemagon 20G reduced the population of *Meloidogyne sp.* in soil upto the 60^{th} day. Temil 10G appeared to give better results than Furadan or Nemagon.

Reddy (1988) evaluated Aldicarb, Carbofuran, Phorate and Quinalphos each 1, 2 and 4kg a.i./ha against *Meloidogyne incognita* infecting tomato under nursery and field conditions. Aldicarb and Carbofuran were effective in increasing the number of seedling per bed, the weight of seedlings and in reducing the gall index in the nursery. Seedling rose from Aldicarb and Carbofuran treated beds also gave better fruits yield than control and showed least root-knot index under field conditions. Phorate and Quinalphos were moderately effective.

Hossain *et al.* (1989) evaluated the efficacy of 3 synthetic nematicides D–D (1,2-dichloropropanc and 1,3-dichloropropene), Carbofuran and Sodium azide, and extracts of mustard (*Brassica campestris*) and cotton seed against *Meloidogyne incognita* in potato seedlings raised from true potato seeds (TPS) in pot experiments. Nematode-infested soil was treated with D-D at 0, 0.05, 0.10 and 0.15 ml/kg, and Sodium azide at 0, 25, 50 and 75mg/kg soil 2 weeks before sowing. Carbofuran was applied at 0, 0.0450, 0.0675 and 0.0900mg/kg soil 2h before sowing. The treatment of soil with the nematicides and seed extracts gave significant reductions in gall incidence and number of galls and females per gram of roots. Higher doses gave better control of the nematode. Complete elimination of *Meloidogyne incognita* was achieved only with the treatment using the highest dosage of Sodium azide. All other treatments significantly improved plant growth in terms of shoots and root weight.

Hassan (1995) tested Furadan 5G and Miral 3G against root-knot (*Meloidogyne javanica*) of brinjal in granular and liquid forms of application, either alone or in combination. The two chemicals on higher concentration and combination in both types of application gave superior response in plant growth characters with corresponding lower number of galls, adult females and egg masses. Larval population was more suppressed by Furadan 5G.

Faruk *et al.* (2001) conducted two separate experiments in Bangladesh to evaluate the efficacy of re-plant soil treatment with poultry refuse, neem leaf powder, neem seed powder and Furadan 5G for the management of root-knot nematodes (*Meloidogyne spp.*) of tomato. Soil inoculated with root-knot nematodes were treated with poultry refuse at 200g and neem leaf and seed powder at 10g and Furadan 5g at 2g per pot. On the other hand, in the field experiment, soils were treated by neem leaf powder, poultry refuse and Furadan 5G @ 0.5t/ha, 10t/ha and 2g/pit, respectively. Among the treatments neem leaf powder and its combination with Furadan 5G gave considerable reduction of root-knot disease. The treatments also improved plant growth (weight and length of shoot and root) and increased significantly yield of tomato in the field.

2.2.3 Effect of fungicide

Dwivedi and Pathak (1980) observed that the effects of fungicides (Bavistin and Difolatan) were effective to cheek the pathogen (*Fusarium oxysporum f. sp. lycopersici*) growth. They sprayed 0.1% concentration of Bavistin on plant immediately after the symptom appeared.

Moubasher and Hack (2000) described that the Fenugreek seed saponis were found to be more toxic to mycelial growth of *F. oxysporum f. sp. lycopersici* than that of tomatine, and race 1 was more sensitive than race 2. Saponins, unlike tomatine, did not induce the production of saponninase (s), and thus their toxicity could persist. Saponins were hydrolyzed very slowly by the culture filtrates of the tested fungi grown in tomatine containing media.

Wei Tang *et al.* (2004) observed the effect of seven fungicides against the wilt pathogen *Fusarium oxysporum* Klotz. They used Prochloraz, Carbendazim, Thiram, Toclofos-Methyl, Hymexazol, Azoxystrobin and Carboxin, *in vitro* for assessing their inhibitory activities against the pathogen by mycelial growth inhibition with median effective concentration (EC50) values of 0.19, 0.235, 26.292, 53.606, 69.961, 144.58 and 154.03 microng/ml separately. Prochloraz and Carbendazim were the most effective fungicides in inhibiting mycelial growth. The preventive effect was 69.6% after 0.4 μg/ml Prochloraz was added to the liquid media for 2 weeks with a curative effect of 50.0%. The preventive effect was 87.0% after 5 μg /ml Carbendazim was added to the liquid media for 2 weeks with a curative effect of 34.4%. It was observed that tomato wilt disease could be well controlled by low toxicity and systemic fungicides added in a hydroponics system at their appropriate concentration.

2.2.4 Management through *Trichoderma harzianum*

2.2.4.1 Interaction of *Fusarium* spp. and *Meloidogyne spp.*

Pitcher (1965) stated that in addition to disease causing fungi, a number of plant parasitic nematodes are found associated with sugar beet seedlings suffering from various kinds of root disorders and wilt. Nematodes are known as initiators of wounds through which fungal pathogens can enter into plant tissues making them more vulnerable for invasion and multiplication of the disease causing agents.

2.2.4.2 *Trichoderma* spp. antagonistic to *Fusarium* spp.

Moon *et al.* (1988) reported that in dual culture, *T. harzianum* parasitized *F. oxysporum f. sp. fragarie* and inhibited mycelial growth. The processes of mycoparasitism including coiling round and penetration into the hypae or breaking the septa of hyphae were noticed.

Sivan and Chet (1989) investigated the possible role of competition between *Trichoderma harzianum* and *Fusarium oxysporum* on rizosphere colonization. They found that addition of conidia of *Trichoderma harzianum* in soil or seed significantly reduced the chlamydospore germination rate of both *F. oxysporum f. sp. vasinfectum* and *F. oxysporum f. sp. melonis*. They further added that the inhibition of germination of chlamydospores might be due to competition.

2.2.4.3 Effect of *Trichoderma*

Mikorva (1982) studied the antagonistic activity of *Trichoderma spp.* against some soil pathogens and reported that among 5 *Trichoderma spp.*, 3 isolates of *Trichoderma harzianum* were most antagonistic.

Rai and Srivastava (1983) reported that *Trichoderma harzianum* possessed higher degree of decomposition and competitive colonization ability.

Jacobs and Kaboen (1986) found that *Trichoderma harzianum* produced cell wall lysing enzymes, which antagonized against plant pathogens and improved bio-control activity.

Field study of Sivan *et al.* (1987) on biological control of Fusarium crown rot of tomato by *Trichoderma harzianum* showed that *Trichoderma harzianum* has potentiality for protecting crown rot caused by *Fusarium oxysporum f. sp. radiacies lycopersici* and the total yield of tomatoes in the treated plots was increased by 26.2% over control.

Shin *et al.* (1987) reported that the isolates *Trichoderma spp.* were antagonistic to *Fusarium oxysporum.* They observed that normal sesame seedlings on beds treated with antagonist grew better than seedlings in untreated soil.

Ordentlich and Chet (1989) conducted an experiment in greenhouse and found that *Trichoderma harzianum* obtained from field soils were effective for control of diseases of various crops when grown in a semi-solid fermentation medium on wheat bran peat.

Calvet *et al.* (1990) found that non- volatile compounds released by *Trichoderma harzianum* isolates growing on cellophane discs over maltiagar significantly inhibited growth of *Fusarium oxysporum.*

Parveen and Ghaffar (1991) observed that seed treatment with *Trichoderma harzianum* gave complete control of *Fusarium oxysporum* on 30 and 120 days old tomato plants.

Quarles (1993) used seed treatment with *Trichoderma* as an alternative to methyl bromide and reported that in some crops *Trichoderma spp.* protected plants as effectively as chemical seed treatments, resulting in improved yields.

Weber and Knaflewski (1993) reported *Trichoderma spp.* as antagonistic to *Fusarium oxysporum in vitro* and in the field condition.

Chet and Inbar (1994) found *Trichoderma harzianum* as affective biocontrol agent against soil borne plant pathogenic fungi. Lectins were found to be involved in recognition between *Trichoderma* and its host fungi; whereas Chitinase is involved in the degradation of the host wall.

Kulkarni and Srikant kulkarni (1994) reported that seed treatment with *Trichoderma harzianum* reduced seedling mortality effectively than other biocontrol agents. They also observed that soil drenching was more effective than seed treatment.

Scarselletti and Faull (1994) reported that the compund 6-pentyl-α-pyrone (6-p-p) produced by *Trichoderma harzianum* when added to agar at 0.3mg/ ml caused a 69.6% and 31.7% reduction in growth of *Rhizoctonia solani* and *Fusarium oxysporum f. sp. lycopersici*, respectively after 2 days and at a concentration of 0.45 mg/ml 6-p-p completely inhibited *Fusarium* spore germination.

Padmodaya and Reddy (1996) tested a total of 10 isolates of *Trichoderma spp. in vitro* for their efficacy in suppressing the growth of *Fusarium oxysporum f. sp. lyopersici. Trichoderma viride* (H) was found highly inhibitory to *Fusarium oxysporum f, sp. lycopersici* in dual culture followed by *Trichoderma harzianum*. Studies on the production of volatile compounds by *Trichoderma sp.* revealed that *T. viride* (H), *T. viride* (A.P.) and *Trichoderma sp.* (G.) were equally effective in reducing radial growth of the pathogen after 3 days but *T. viride* (H) was significantly superior in reducing radial growth of *Fusarium oxysporum f. sp. lycopersici* in a study on the production of non volatile compounds by *Trichoderma sp.*

Ellil *et al.* (1998) reported that *Trichoderma harazianum* reduced the root rot infection by 6.7-45.0% in bean. *Trichoderma spp.* obviously antagonized the effects caused by the pathogen, *Sclerotium rolfsii* and *Fusarium solani.*

2.2.4.4 *Trichoderma spp.* antagonistic to *Meloidogyne spp.*

Sharma and Saxena (1992) found that *T. viride* adversely influenced hatching of *M. incognita* larvae with the highest inhibition of hatching occurring in the standard concentration of filtrate.

Parveen *et al.* (1993) studied the comparison of *Trichoderma harzianum, T. koningii, Gliocladium virens, Paecilomyces lilacinus, Bradyrhizobium japonicum* and *Rhizobium meliloti* with Carbofuran for control of *M. javanica* on tomato and okra in soil naturally or artificially infested with *F. oxysporum*. Artificial infestation of soil with *F. oxysporum* significantly reduced gall formation. *T. harzianum, T. koningii* and *G. virens* showed better control of *M. `javanica* in naturally infested soil than in *Fusarium* infested soil on both the plant spesies. *P.lilacinus, B.japonicum* and Carbofuran signficantly controlled gall formation on tomato and okra roots in natural and *Fusarium*-infested soil.

2.2.5 Management through soil amendment with organic substances

To control nemic diseases of crops with indigenous plant products and others organic substances as amendments to the soil are relatively a recent innovation. Some important literature related to the organic amendments of soil to the control of nemic diseases of crop plants especially of root –knot caused by *Meloidogyne spp.* are reviewed below.

Mian and Rodriguez-kabana (1982) studied the nematicidal properties of 15 materials of plant origin in greenhouse experiments with a soil infested with *Meloidogyne arenaria* (Neal) Chitwood. Amendments to soil were most effective to reduce root galling caused by nematode on summer crookneck squash (*Cucurbita pepo L.*). The nematicidal efficacy of all the soil amendments in the study was directly correlated with their nitrogen content and inversely related to their C/N ratios. Amendments with material having C/N ratios in the ranges of 15-20 were the most efficacious against the nematode when all the amendments were applied at 1.0%; application of materials with narrower C/N ratios resulted in severe phytotoxicities.

Bora and Phukan (1983) tested 4 soil amendments (mustard oil cake, poultry manure, sawdust and decaffeinated tea waste) in pots containing 3, 5 kg soil gave significant reductions of *Meloidogyne incognita* populations on jute (as judged by gall number and egg mass /g root and by the nematode population in soil). Mustard oil cake was the most effective but was also phytotoxic. Sawdust was more effective than tea waste and poultry manure at the lowest dose was the least effective. Sawdust and to lesser extent tea waste, had the best effect on plant height and the dry and fresh weights of shoots and roots.

Chindo and Khan (1986) observed that growth and fruit yield of tomato increased and nematode damage lessened with increasing level of poultry manure; yield increase was significant at 4 t/ha. The nematode population declined greatly by mid-season but increased towards harvest. The optimum rate of manure for nematode control and crop growth was about 4t/ha; the highest level; did not increase yield further and resulted in more vegetative growth and delayed fruiting.

Alam (1987) stated the pollution free control of plant parasitic nematodes by soil amendment with plant wastes. Results from experiments proved that chopped plant leaves when incorporated into naturally infested soil effectively suppressed populations of plant parasitic nematodes and improved growth of tomato.

Mesfin *et al.* (1987) conducted an experiment in December, 1986-1987 to determine the effectivity of five control strategies in controlling *Meloidogyne incognita* on potted kenaf fertilized with three levels of urea. The control strategies used were the application of chicken dung (5t/ha), sawdust (5t/ha), neemcake (294kg/ha), *Paecilomyces lilacinus* (Tom.) samson (50,000 spores/ml) and Phenamiphos 10g (5kg a.i./ha). Pots treated with urea at the equivalent rates of 72 (N_1) and 132 kg/ha (N_3) were used as control. All control strategies reduced root-knot nematode population, egg mass number per root and root galling based on the comparison with control.

Duhaylongsod (1988) incorporated various organic amendments along the furrows of microplots at rates of 10 tons/ha in soil infested with *Meloidogyne incognita or Rotylenchulus reniformis.* Three week old tomato CV. VC-11-1 seedlings were then transplanted to the plots. Fenamiphos at 10k a.i./ha was applied as a comparative control. Fresh chicken waste and composed sawdust caused the most initial and final reductions in *R. reniformis* levels. Composed Gliricidia leaves were ineffective against the nematode. Fresh Gliricidia leaves and chicken dung initially reduced *M. incognita* leaves but only the later remained effective throughout the seasons, and fresh dung was more effective than Fenamiphos. Rice straw and sawdust also reduced *M. incognita* populations.

Duque (1988) conducted a pot experiment outside the greenhouse to compare the effectiveness of two rates of each of chicken dung (8.11

and 16.22g/pot), urea (0.42 and 0.68g/pot) and BIOACT (10 ml of 10g/40 litre and 10ml of g/25 litre suspension which are equivalent to 1 million and 2 million spores per ml, respectively) in controlling nematodes and in increasing tomato yield.

Fayad and Sweelam (1989) studied in a pot experiment with tomato plants which were inoculated with *M. javanica* and then given various applications of superphosphate and organic fertilizers. Application of triple phosphate as a source of phosphorus together with cattle manure reduced nematode populations and thus increased the nutrient uptake and tomato growth.

Stirling (1989) used poultry manure and sawdust @ 24, 36 or 48 t/ha were incorporated into soil with urea (0-1800kg nitrogen/ha) and their effects on yield of ginger and populations of *M. incognita* were compared with those of nematicide programmes involving ethylene-dibromide and /or Fenamiphos. The pre-plant nematicide treatments proved inadequate but improved nematode control was achieved when these treatments were followed by post-plant applications of Fenamiphos. Total yields in soil amended with poultry manure or sawdust plus urea were greater than in non-amended soil and equal to or greater than those in the best nematicide treatments. The yield increased for poultry manure appeared to be due in part to its beneficial effects on soil fertility.

Chapter 3
Materials and Methods

MATERIALS AND METHODS

The materials and methods used in conducting the experiment have been presented in this chapter.

3.1 Experimental site

The experiment was conducted in the Field of SAU farm allotted for the Department of Plant Pathology, Sher-e-Bangla Agricultural University, Dhaka-1207.

3.2 Experimental period

The experiment was carried out during the period from September 2005 to March 2006.

3.3 Soil type

The soil of the experimental plot was loam to clay loam in texture belonging to the Madhupur Tract (AEZ-28).The description of the Agro-ecological Zone (UNDP and FAO, 1988) of the experimental site was as follows:

Agro-ecological region	: Madhupur Tract (AEZ-28).
Land Type	: Medium high land.
General soil type	: Non-Calcareous Dark gray floodplain soil
Soil series	: Tejgaon
Topography	: Up land
Elevation	: 8.45
Location	: SAU Farm, Dhaka.
Field level	: Above flood level.
Drainage	: Fairly good.
Firmness (consistency)	: Compact to friable when dry.

The physical and chemical characteristics of the soil collected from Soil Resource Development Institute (SRDI), Farmgate, Dhaka is presented bellow (For 0-14 cm depth): -

Particle size distribution:

Sand	: 34%
Silt	: 46%
Clay	: 20%

Soil texture: Loam to clay loam.

3.4 Climate

The climate of the experimental area was of sub-tropical in nature characterized by high temperature associated with heavy rainfall during *Kharif* season (April to September) and scanty rainfall with moderately low temperature during Rabi season (October to March), (Anonymous, 1960).

3.5 Weather

The monthly mean of daily maximum, minimum and average temperature, relative humidity, monthly total rainfall and sunshine hours received at the experimental site during the period of the study have been collected from the surface synoptic Data card, Bangladesh Meteorological Department, Sher-e-Bangla Nagar, Dhaka and Shown in Appendix-2.

3.6 Variety used:

Tomato variety BARI-6 (choithy) was used for the experiment.

3.7 Collection of seeds

Seeds of tomato variety BARI-6 (Choithy) were collected from Horticulture farm, vegetable seed centre of BARI on the first week of September. Ten grams (10g) of healthy seeds were collected.

3.8 Treatments of the experiment

Eight (8) treatments were assessed in the experiment which was as follows-

T_1=Grafting compatibility (using wild solanum sp. *Solanum sisymbriifolium*)

T_2=Furadan 5G to control of nematode

T_3=Bavistin 50WP for seedling root dressing and soil drencing.

T_4=Cupravit 50WP for seedling root dressing and soil drencing.

T_5=Bio-agent (*Trichoderma harzianum* T_{22}).

T_6=Soil amendment with sawdust.

T_7=Soil amendment with khudepana (*Azzola pinnata)*.

T_8=Control.

3.9 Collection of test materials

Seeds of wild Solanum (*Solanum sisymbriifolium)* were collected from SAU campus and the field allotted for international trade fair Dhaka, Furadan 5G, Bavistin 50wp, Cupravit 50wp, were purchased from the market. Sawdust was collected from the Mohammadpur Sawmills; Khudepana was collected from the pond of SAU campus and *Trichoderma harzianum* T22 was collected from the MS laboratory of the Department of Plant Pathology, SAU, Dhaka.

3.10 Raising seedling for rootstock

Seed of wild Solanum (*Solanum sisymbriifolium)* were sown in seed bed and seedlings with 2-3 true leaf stage were transplanted in individual polyethylene bag. After 60-70 days of sowing the rootstock seedling were ready for grafting with the cultivar selected for the experiment (Plate-1).

3.11 Raising of cultivar (BARI 6) seedlings

Tomato seedlings were raised in plastic trays. The trays were filled up with fertile soil. Weeds and other rubbish were removed carefully from the soil. Then the seeds were sown in lines on 17th November 2005. Four trays were taken for raising seedlings. Seedlings were observed regularly and watering was done as per necessity up to transplanting in the field (Plate-2).

A

B

Plate-1. Seedling of wild solanum at 15 DAS (A) and at 20 DAS (B)

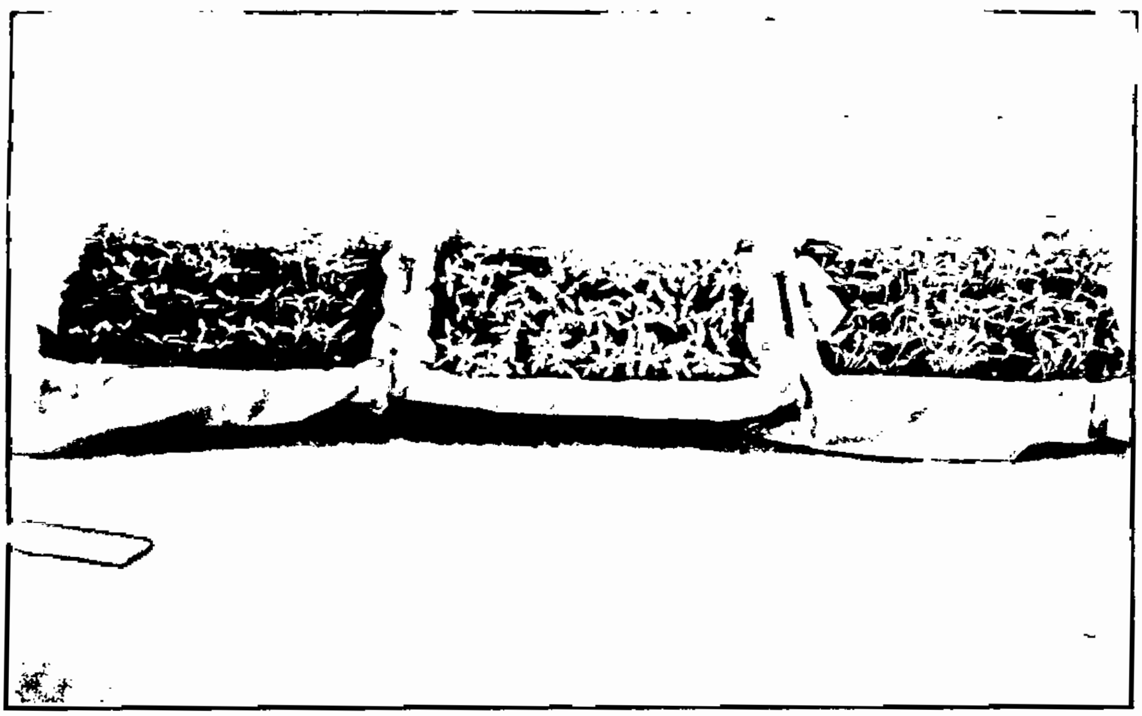


Plate-2. Seedling of tomato in tray

3.12 Rootstock preparation:

Rootstock (wild Solanum) in poly bag was held tightly between knees. The top of the rootstock is cut horizontally with sharp razor blade. A vertical cut for grafting of about 1 cm depth was made.

3.13 Scion preparation:

4-5 cm long shoot with growing point from the scion seedling (tomato) was cut with the help of a sharp blade. Lower leaves were removed from the scion to reduce transpiration. For grafting scion bottom cut as "V" shape.

3.14 Grafting procedure

Forty to fifty days old root stock seedling (3– 4 leaf stage) and tomato plant seedlings of 3– 4 leaf stage were used as grafting materials. Grafting was done on 15^{th} December to 24^{th} December'2005 following the steps laid down by Ali *et al.* (1994) (Plate-3).

1. Roots of uprooted tomato seedlings were washed. Seedlings were then kept in a bucket containing little water at the bottom.
2. Then the polyethylene bag of wild eggplant was hold tightly between knees.
3. The top of the root stock was removed by a sharp razor blade retaining 1 – 2 leaves with the stock plant.
4. A vertical cut about I cm depth was made so that the tip of the root stock stem is divided into two equal halves.
5. Then a 4 – 5 cm long shoot from the scion (seedling of tomato plant) was taken and large leaves were removed to avoid excessive water loss.
6. Two angular cut about 1 cm long on opposite side of the bottom end of the scion were made. The lower end appeared "V" shaped.
7. Then the "V" shaped cut end was inserted into the vertical cut of the root stock and the inserted scion was attached with the root stock by using a grafting clip.

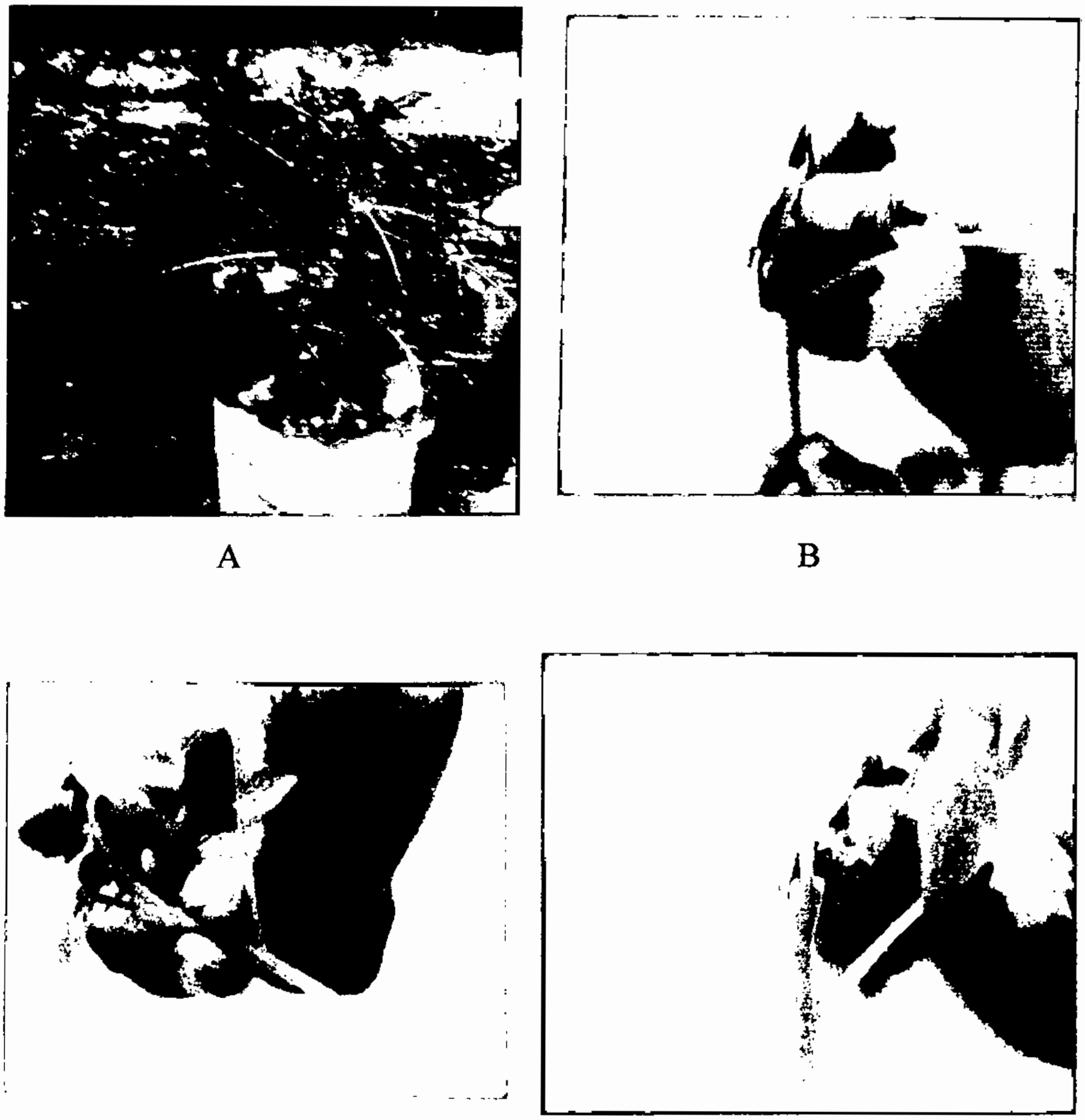


Plate-3. Grafting procedure: A) Seedling of Rootstock, B) Preparation of Rootstock, C) Preparation of Scion and D) Scion Insert in Rootstock and held with clip.

3.15 After care of grafted seedling

After grafting, the scion was sprayed with water with a hand sprayer. The graft plants were placed in a small tunnel built near a shady place. The tunnel was covered with a sheet of transparent polyethylene. A black cotton cloth was placed above the transparent sheet to maintain high humidity and to prevent sunlight. Plants were sprayed with water 3 – 4 times a day for 7 days. The polyethylene sheet was removed from the top of tunnel after a week. The black cotton cloth was retained for another few days until the graft union was fully established. After 10 - 12 days the scion stared to grow on the root stock. Observations were made everyday on the survival percentage of the grafted plants. Grafted seedlings were transplanted in the main field on 5^{th} December'2005.

3.16 Land preparation

The land was firstly ploughed with a power tiller in the first week of November 2003 and left exposed to sunlight for 7 days. Then the land was ploughed and cross-ploughed by a country plough until the soil had a good tilth. It required six times ploughing and every ploughing was followed by laddering to level the land and break up clods. After each ploughing weeds and rubbish was removed. Finally spade (Kodal) was used to prepare plots and drains.

3.17 Application of manure and fertilizers

Manure and fertilizers were applied as per standard recommendation. The following doses were used for carrying out the field study (Anonymous, 1998).

Manures /Fertilizers	Rate /ha
Cowdung	10 tones
Urea	226 kg
TSP	222 kg
MP	250 kg

A half of the total amount of cow dung and TSP were applied during final land preparation and remaining half was applied in the pits before transplanting. Urea and MP were applied in two installments as ring dressing after 15 and 35 days of transplanting.

3.18 Design and layout of the experiment

The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. The whole plot was divided into three blocks each containing eight (8) plots of 3.5m x 1.0m size, giving 24 units plots. Each of the treatment combination put once at each block. The space kept between the blocks was 1m wide and between plots it was 0.5m. (Appendix-3)

3.19 Application of sawdust

Sawdust @ 5kg /plot was applied to the soil in specific plots at twenty days before transplanting and mixed with soil properly.

3.20 Application of khudepana (*Azzola pinnata*).

Khudepana @ 10kg/plot was applied to the soil in specific plots at one month before transplanting and mixed with soil properly.

3.21 Application of Furadan 5G in soil

Furadan 5G was applied in the soil during transplantation of seedlings for those plot that are assigned for Furadan 5G application. 5gm Furadan 5G was put in each pit and mixed up the adjacent soil before transplanting the seedlings. The specification of nematicide is described in Table 1

Table 1. Details of Nematicide (Furadan 5G)

Trade name	Chemical name	Active ingredient(a.i)	Mode of action
Furadan	carbamic acid, methyl-2,3-dihydro-2,2-dimethyl-7-benzofuranyl ester	Carbofuran 5G	Systemic

(Rashid, 2000)

3.22 Preparation and application of fungicides solution

Fungicidal solutions were prepared dissolving required amount of fungicide in water for each concentration in 100 ml Erlenmeyer flask. Flasks were labeled appropriately and shaken thoroughly before use. Then the fungicide solution was applied in assigned plots for soil drenching. Flasks were labeled appropriately and shaken thoroughly before use of fungicide solutions. The description of fungicides used in this study is given in Table 2

Table 2. Details of fungicides

Common name	Chemical name	Active ingredient(a.i)	Conc. (ppm)/(µg/ml) used
Bavistin 50wp	Methyl-2-Benzimidazole Carbamate	50% Carbendazim	50, 100
Cupravit 50wp	Copper oxychloride ($Cuocl_2$)	50% Copper oxychloride	50, 100

(Rashid, 2000)

3.23 Multiplied of *Trichoderma harzianum* T22 in PDA media and application to the soil.

Trichoderma harzianum T22 was collected from the MS laboratory of the Department of Plant Pathology, SAU, Dhaka and multiplied on PDA medium (Plate-4). Spore suspension was made by scraping the 10-15 days old culture substrate with the help of blender and adjusted the concentration 10^7 conidia/ml solution. Then, soil of the specific plot was drenched with the spore suspension @ 1lt/plot with the help of compressed air hand sprayer following pulsating the soil to mix up the *Trichoderma harzianum* T22 spores thought out the soil.

3.24 Transplantation

Thirty days old seedlings were uprooted from the seedbed on the 18^{th} in December 2005 at the afternoon and carried to the field laboratory and transplanted immediately. Plant to plant distance was maintained at 75cm. For keeping seedlings upright, support with bamboo sticks were provided. Sufficient irrigation was given just after transplantation with the help of a bucket sprinkler. One seedling was placed in a pit. The transplanted seedlings were protected from the sun for five consecutive days.

3.25 Intercultural operations

After transplantation gap filling was done in case any seedling died. In 15/20 days after planting (DAP) weeding was done which followed split doze fertilizer application. First split application of fertilizer was done on the 10^{th} January 2006 and the second split application was done on 30^{th} January 2006 as treatment of double dose nitrogenous fertilizer. After weeding and fertilizer application flood

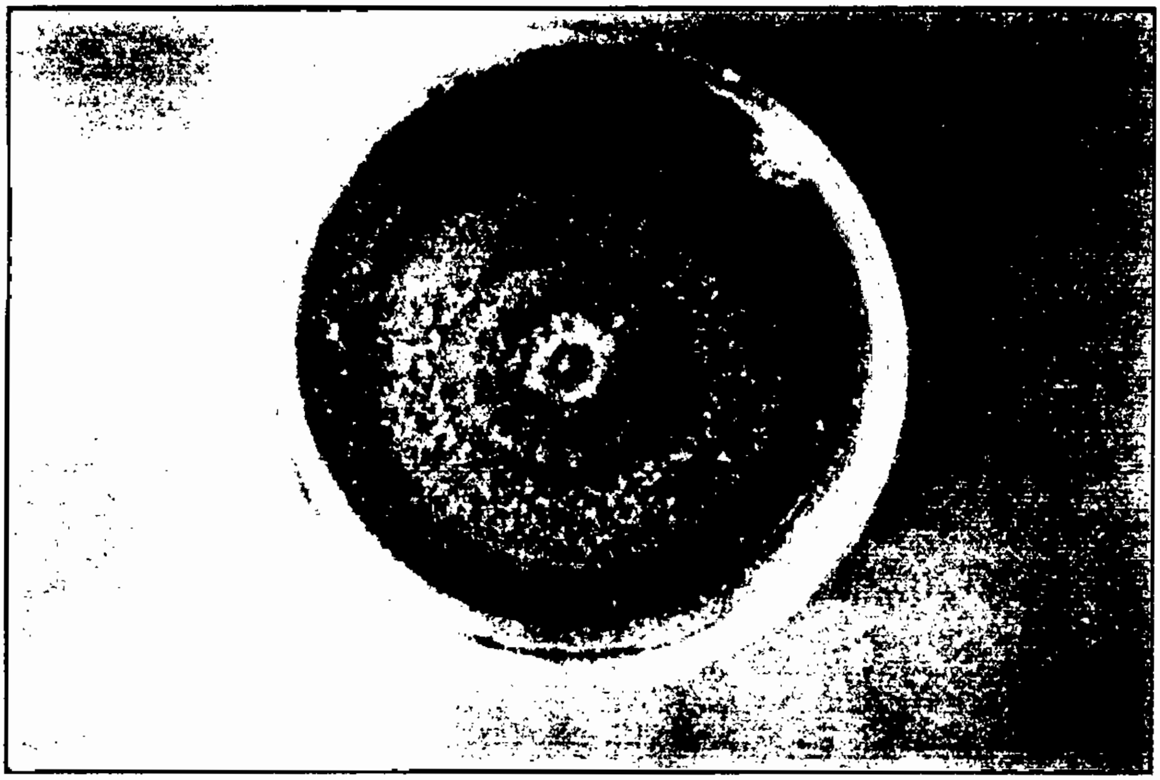


Plate-4. Growth of *Trichoderma harzianum*T22 on PDA irrigation was given (in case of second split) by filling the drains surrounding the beds by pumping water in those drains with a water pump. After soaking the plots excess water was allowed to be drained out. The plants were observed regularly. General field sanitation was maintained throughout the growing period by removing infected and blighted leaves wilted and dead plants.

3.26 Isolation and identification of *Fusarium* wilt Pathogen

Collected diseased stem with root from the experimental site by using polythylene bag was taken to the laboratory of the Department of Plant Pathology, Sher-e- Bangla Agricultural University, Dhaka. The diseased stem was cut into small pieces (about 0.5-1cm) from the vascular region of the stem and surface sterilized by dipping in 10% sodium hypochlorite solution for 2-3 minutes or $Hgcl_2$ solution (0.01%) for 30 second. The cut pieces were then washed in water at three times and were placed onto PDA media in sterilized Petri dish with help of sterile forceps and incubated were at 25 ± 1^0c for 7-10 days. Later the pathogen was purified using hyphal tip culture method and grown on PDA media at 25 ± 1^0c for 2 weeks and identified as *Fusarium oxysporum f. sp. lycopersici.*

3.27 Data recording and harvesting

Data on incidence of wilts were recorded at 55, 65, 75 and 85 days after transplanting by observation of visual symptoms. The disease incidence was calculated by the following formula.

$$\% \text{ Disease incidence} = \frac{\text{Number of infected plants}}{\text{Number of total plants}} \times 100$$

The following parameters were considered for data collection.

Observations : (Yield and yield contributing characters)

a. Plant height (cm)
b. Plant weight (g)
c. Root length (cm)
d. Root weight (g)
e. Number of fruits / plot
f. Total weight of fruit / plant
g. Total weight of fruit / plot
h. Yield /ha

Observations: (Disease incidence)

a. Number of wilted plant/plot
b. % plant infected (disease intensity)
c. Number of galls/plant.

3.28 Cost-benefit analysis and Benefit-Cost Ratio

Costing of application of treatments for management of wilt of tomato was done based on the current market price of input, rate of hiring labour and agricultural machineries. Price of the field produce was determined on the basis of current market value (Appendices 4& 5). Estimation of Cost-Benefit Ratio (BCR) was done according to Gittinger (1982), DAE (Anon, 1997) and Islam *et al.*, (2004) using the following formula-

$$\text{BCR} = \frac{\text{Yield of treated plot - Yield of control plot}}{\text{Cost of treating materials}} \times \text{price of the product}$$

3.29 Analysis of data

The data were statistically analyzed using analysis of variance to find out the variation of results from experimental treatments. Treatment means were compared by DMRT (Duncan's Multiple Range Test). Correlation and Regression study was done to establish relationship between shoot length, shoot weight and root length and root weight with galling incidence among the treatments.

Chapter 4
Results

RESULTS

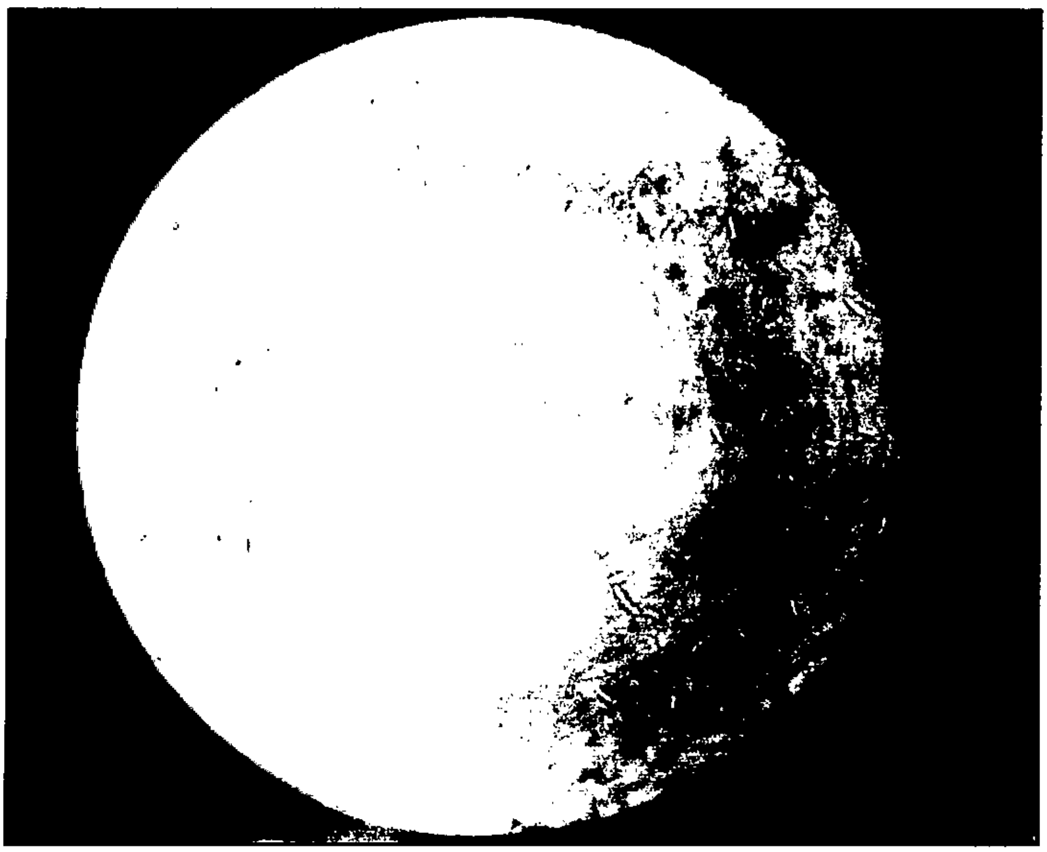
The results obtained from the present study on the effect of eight different treatments viz. grafting with wild *Solanum* (*Solanum sisymbriifolium*), a nematicide (Furadan 5G), two fungicides (Bavistin & Cupravit), a bio-agent (*Trichoderma harzianum* T_{22}), two soil amendment (Sawdust & Khudepana) and control (un-treated) for the management of Fusarium wilt and Nemic wilt of eggplant were presented in this chapter. The efficacy of the treatments was assessed based on different parameter like wilt incidence, galling incidence, plant growth characters and yield.

4.1 Isolation and identification of causal agents

Collected diseased stem with root from the experimental site by using polythylene bag were taken to the laboratory of the Department of Plant Pathology, Sher-e-Bangla Agricultural University, Dhaka. The diseased stem were cut into small pieces (about 0.5-1cm) from the vascular region of the stem and surface sterilized by dipping in 10% sodium hypochlorite solution for 2-3 minutes or $Hgcl_2$ solution(0.01%) for 30 second. The cut pieces were then washed in water at three times and were placed onto PDA media in sterilized Petri dish with help of sterile forceps and incubated were at 25 ± 1^0c for 7-10 days. Later the pathogen was purified using hyphal tip culture method and grown on PDA media at 25 ± 1^0c for 2 weeks and identified as *Fusarium oxysporum f. sp. lycopersici* (Plate-5).

The nematodes observed in semi-permanent slide prepared from root gall under microscope were pear shaped surrounded by egg mass that was identified as *Meloidogyne incognita* (plate-6).

a



b

Plate-5(a). Pure culture of *Fusarium oxysporum* f. sp. *lycopersici* on PDA

(b). Photomicrograph of sporodochia and conidia of *Fusarium oxysporum* f. sp. *lycopersici*

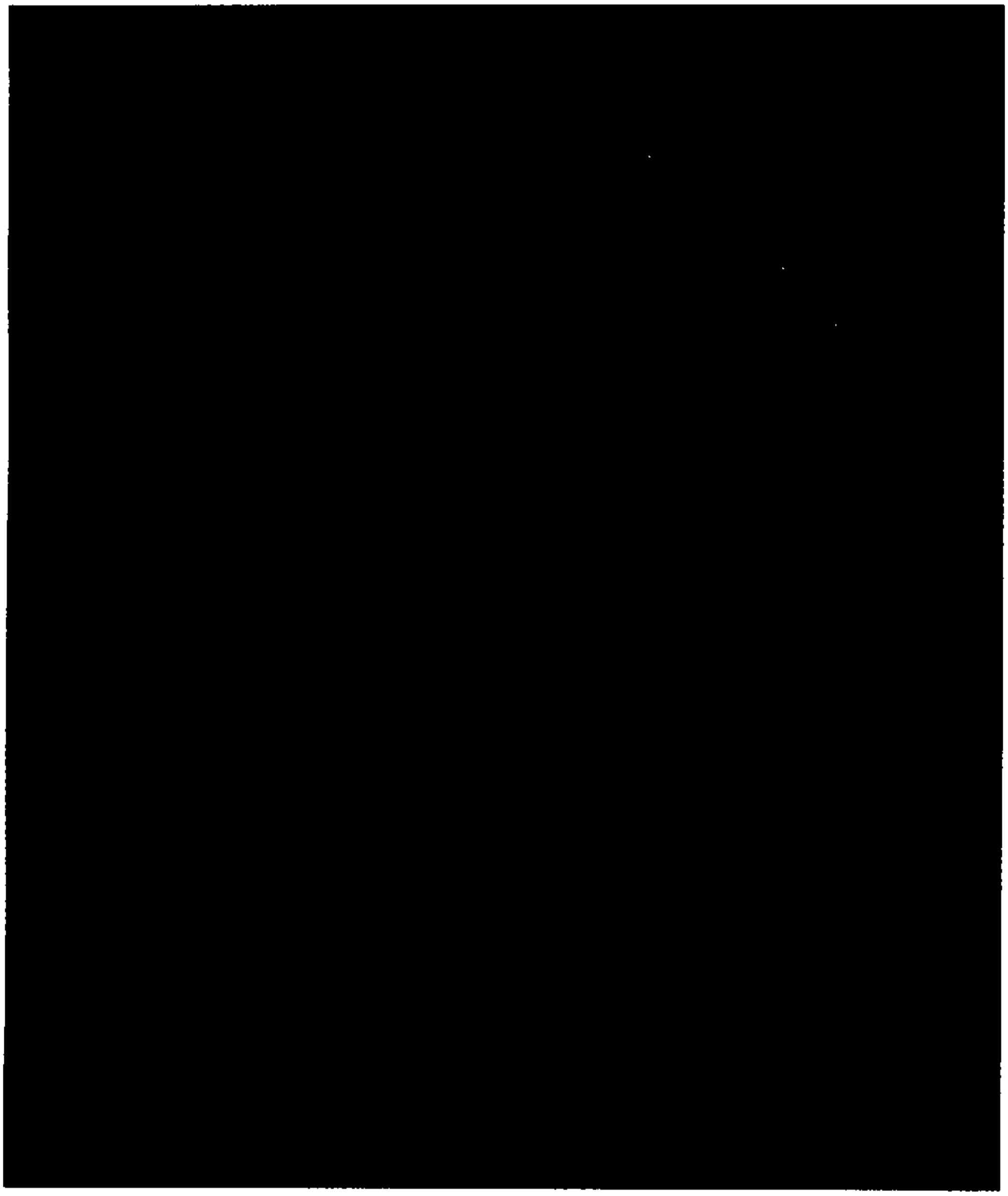


Plate- 6. Egg mass of *Meloidogyne incognita*

4.2 Effect of different treatments on the wilt incidence of tomato at 55 days after transplanting (DAT) and 25 days after inoculation (DAI)

The effects of different treatments in controlling wilt incidence of tomato at 55 DAT was presented in Table-3. The effect of treatments in controlling wilt of tomato was differed significantly in comparison to untreated control. It was observed that no plants were wilted in case of all the treatments except control. Result showed that 16.67% plants were wilted in control treatment.

4.3 Effect of different treatments on the incidence of wilt of tomato at 65 days after transplanting (DAT) and 35 days after inoculation (DAI)

The effects of different treatments in controlling wilt incidence of tomato at 65 DAT was presented in Table-4. The effect of treatments in controlling wilt of tomato was differed significantly in comparison to control (T_8). It was observed that no plants were wilted in case of all the treatments except control treatment (T_8) and Cupravit (T_4). Result showed that the highest wilt incidence was observed in control treatment (38.89%) followed by the Cupravit where 16.67% wilt incidence was recorded.

4.4 Effect of different treatments on the incidence of wilt of tomato at 75 days after transplanting (DAT) and 45 days after inoculation (DAI)

The effect of different treatments on the wilt incidence of tomato at 75 DAT was presented in Table-5. The effect of different treatments in controlling the disease incidence differed significantly. Some treatments showed promising effect in controlling the disease. It was observed that no wilted plant was recorded in case of Grafting (T_1), Furadan 5G (T_2), Bavistin 50wp (T_3), *Trichoderma harzianum* (T_5) and Sawdust (T_6).The highest wilt incidence (72.22%) was recorded in control treatment. The second highest wilt incidence was recorded in Cupravit treatment (27.78%) which was statistically similar to the Khudepana (T_7) where wilt incidence was 16.67%. It was observed that the wilt incidence increased with the increase of time after transplantation depending on the treatments.

4.5 Effect of different treatments on the disease incidence of wilt of tomato at 85 days after transplanting (DAT) and 55 days after inoculation (DAI)

A remarkable effect of the different treatments on the wilt incidence of tomato was observed at 85 DAT that presented in Table-6. The effect of different treatments in controlling the disease incidence differed significantly. Some treatments showed promising effect in controlling wilt incidence. The highest effect against the wilt was noticed in case of Grafting (T_1), Furadan 5G (T_2) and Sawdust (T_6) where no incidence was found (plate7). A few plants were wilted in case of Bavistin 50wp (T_3) and *Trichoderma harzianum* (T_5) but their incidence were statistically similar to that of Grafting (T_1), Furadan 5G (T_2) and Sawdust (T_6). The highest wilt incidence (100%) was recorded in control treatment (plate 8). The Cupravit didn't show any remarkable effect in reducing the wilt incidence in the experiment.

Table 3: Effect of different treatments on the wilt incidence of tomato at 55 days after transplanting (DAT)

Treatments	**Wilt incidence (%)**
T_1 (Grafting)	0.00(0.71) b
T_2 (Furadan 5G)	0.00(0.71) b
T_3 (Bavistin)	0.00(0.71) b
T_4 (Cupravit)	0.00(0.71) b
T_5 (*Trichoderma harzianum* T_{22})	0.00(0.71) b
T_6 (Sawdust)	0.00(0.71) b
T_7 (Khudepana)	0.00(0.71) b
T_8 (Control)	16.67(4.14) a
CV (%)	114.71

The values within the parenthesis are the transformed values (Square root transformation)

Table 4: Effect of different treatments on the disease incidence of wilt of tomato at 65 days after transplanting (DAT)

Treatments	Wilt incidence (%)
T_1 (Grafting)	0.00(0.71) c
T_2 (Furadan 5G)	0.00(0.71) c
T_3 (Bavistin)	0.00(0.71) c
T_4 (Cupravit)	16.67(4.14) b
T_5 (*Trichoderma harzianum* T_{22})	0.00(0.71) c
T_6 (Sawdust)	0.00(0.71) c
T_7 (Khudepana)	0.00(0.71) c
T_8 (Control)	38.89(6.25) a
CV (%)	14.38

The values within the parenthesis are the transformed values (Square root transformation)

Table 5. Effect of different treatments on the wilt incidence of tomato at 75 days after transplanting (DAT)

Treatments	Wilt incidence (%)
T_1 (Grafting)	0.00(0.71) c
T_2 (Furadan 5G)	0.00(0.71) c
T_3 (Bavistin)	0.00(0.71) c
T_4 (Cupravit)	27.78(5.26) b
T_5 (*Trichoderma harzianum* T_{22})	0.00(0.71) c
T_6 (Sawdust)	0.00(0.71) c
T_7 (Khudepana)	16.67(4.14) b
T_8 (Control)	72.22(8.44) a
CV (%)	23.07

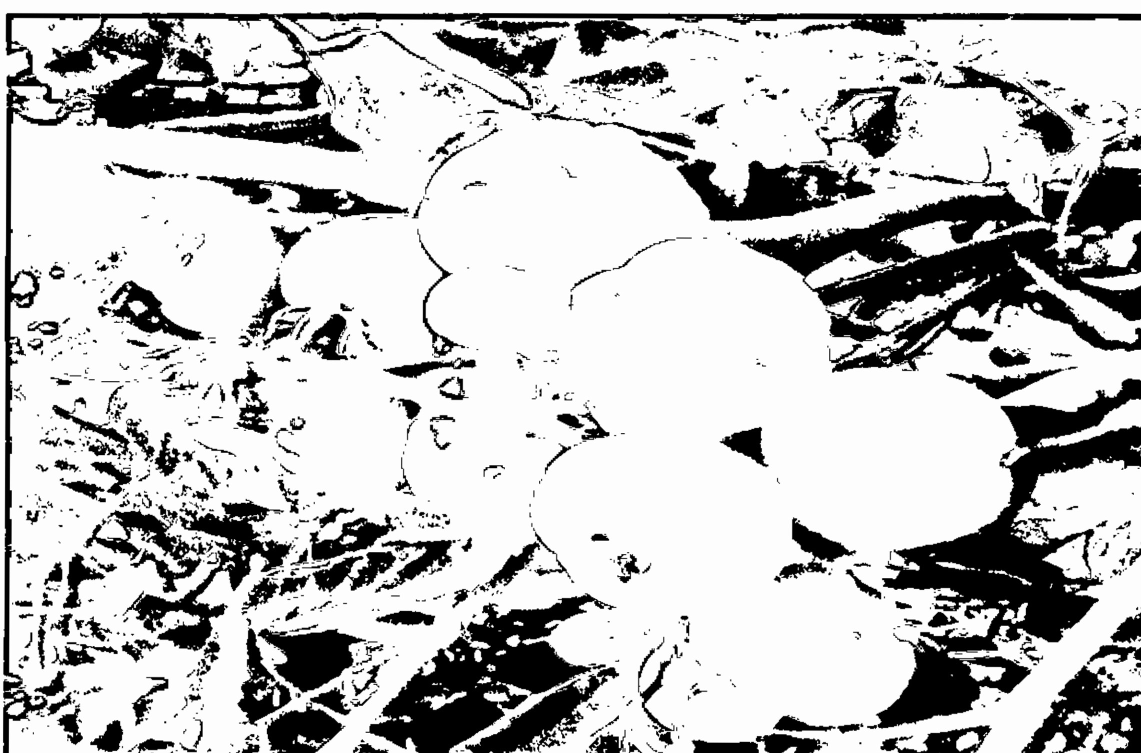
The values within the parenthesis are the transformed values (Square root transformation)

Table 6: Effect of different treatments on the wilt incidence of tomato at 85 days after transplanting (DAT)

Treatments	Wilt incidence (%)
T_1 (Grafting)	0.00(0.71) d
T_2 (Furadan 5G)	0.00(0.71) d
T_3 (Bavistin)	11.11(2.99) cd
T_4 (Cupravit)	44.44(6.61) b
T_5 (*Trichoderma harzianum* T_{22})	11.11(2.99) cd
T_6 (Sawdust)	0.00 (0.71) d
T_7 (Khudepana)	22.22(4.70) bc
T_8 (Control)	100 (10.02) a
CV (%)	26.89

The values within the parenthesis are the transformed values (Square root transformation)

A



B

Plate-7.A) Growing healthy tomato plants in Sawdust treated plots.

B) Healthy tomato plant with fruits in Sawdust treated plots.

A

B

Plate-8. Wilt of tomato

A. Initial wilt of tomato in a control plot at 55 DAT

B. Severe wilt of tomato in a control plot at 85 DAT

4.6 Effect of different treatments on the plant growth characters and gall formation in tomato root.

The effects of different treatments on growth parameters viz. length of shoot, dry weight of shoot, length of root and dry weight of root and gall formation at 85 DAT were measured and presented in Table 7.

4.6.1 Length of shoot

The length of shoot differed significantly among the treatments. The highest shoot length was observed in soil application of Sawdust (113.50 cm) followed by Khudepana (95.67 cm), *Trichoderma harzianum* T_{22} (91.33 cm) and Furadan 5G (85.50 cm). The lowest length of shoot was recorded in control treatment (61.50 cm.) preceded by Grafting (T_1), Cupravit (T_4) and Bavistin (T_3), where lengths were 72.50cm, 79.87cm and 80.60cm, respectively.

4.6.2 Dry weight of shoot

The dry weight of shoot per plant also differed significantly among the treatments. The highest shoot weight was observed in Sawdust (T_6) which was 65.17 g followed by Khudepana (62.17 g), *Trichoderma harzianum* T_{22} (54.60 g) and Furadan 5G (48.33 g). The lowest dry weight of shoot/plant was recorded in control treatment which was 31.00 g. preceded by Grafting (T_1), Cupravit (T_4) and Bavistin (T_3), where shoot weight/plant was 39.27g, 39.83g and 41.27g, respectively.

4.6.3 Length of root

The effects of different treatments on length of root differed significantly. The highest length of root was recorded in Sawdust (17.50cm.) which was statistically identical with Khudepana (16.00 cm), *Trichoderma harzianum* T_{22} (15.13 cm) and Furadan 5G (15.00 cm). The lowest length of root was recorded in control treatment (11.50 cm) which was statistically similar to Cupravit (T_4), Grafting (T_1), and Bavistin (T_3), where the root length were 13.30 cm, 13.27 cm and 13.10 cm, respectively.

4.6.4 Dry weight of root

The effects of different treatments on dry weight of root also differed significantly. The highest root weight was recorded in application of Sawdust (5.00 g). The second highest root weight was recorded in Khudepana (4.633 g) which was statistically identical with *Trichoderma harzianum* T_{22} (4.500 g) and Furadan 5G (4.317g) followed by Bavistin (3.70 g). The lowest root weight was recorded in control treatment (3.017gm) which was statistically similar to Cupravit (3.133g) and Grafting (3.017g).

4.6.5 Number of gall/ plant

The effects of different treatments on gall formation differed significantly. The highest number of galls (18 galls/plant) was recorded in control treatment (T_8) followed by Cupravit (7galls/plant). The number of galls per plant recorded in case of Bavistin was 4 which were equivalent to that of treatment *Trichoderma harzianum* T_{22} (T_5). It was observed that no gall formation occurred under the treatment Grafting (T_1), Furadan 5G (T_2) and Sawdust (T_6).

Table 7. Effect of different treatments on the plant growth characters and gall formation in tomato root

Treatments	Length of shoot (cm)	Dry weight of shoot/ plant(g)	Length of root (cm)	Dry weight of root/ plant (g)	Number of gall/ plant
T_1 (Grafting)	72.50 f	39.27 e	13.27 bc	3.01 d	0.00 e
T_2 (Furadan 5G)	85.50 d	48.33 d	15.00 ab	4.31 b	0.00 e
T_3 (Bavistin)	80.60 e	41.27 e	13.10 bc	3.70 c	4.00 cd
T_4 (Cupravit)	79.87 e	39.83 e	13.30 bc	3.13 d	7.00 b
T_5 (*Trichoderma harzianum* T_{22})	91.33 c	54.60 c	15.13 ab	4.50 b	4.00 d
T_6 (Sawdust)	113.50 a	65.17 a	17.50 a	5.00 a	0.00 e
T_7 (Khudepana)	95.67 b	62.17 b	16.00 a	4.63 b	5.33 c
T_8 (Control)	61.50 g	31.00 f	11.50 c	3.01 d	18.00 a
CV(%)	**2.41**	**2.92**	**9.61**	**4.89**	**15.86**

4.7 Correlation and regression study between growth parameters and gall formation

Correlation study was done to determine the relationship between gall formations and shoot and root length and shoot and root weight. Significant and negative correlations was observed between gall number and shoot length (Fig. 3); gall number and shoot weight (Fig. 4); gall number and root length (Fig. 5)and gall number and root weight (Fig. 6) where the regression equations were $y = -113.5x + 22.7$ ($R^2=1$), $y = -0.2725x+ 017.792$ ($R^2 = 0.3021$), $y = -2.0184x+33.755$ ($R^2 =$ o.418), $y = -3.5073x+18.561$ ($R^2 = 0.2124$), respectively. The study revealed that the applications of treatments gave positive response in increasing the growth characters of tomato by suppressing the nematode activities as evident with no or less gall formation in the treated plants compared to the treatments T_8 (control).

4.8 Correlation and regression study between wilt incidence and gall formation

Correlation study was done to determine the relationship between wilt incidence (%) and number of gall formation of tomato. Results showed that significant and positive correlation existed between wilt incidence (%) and gall formations of tomato at 85 DAT (Fig. 7). Wilt incidence was increased with the increase of time and number galls/plant.

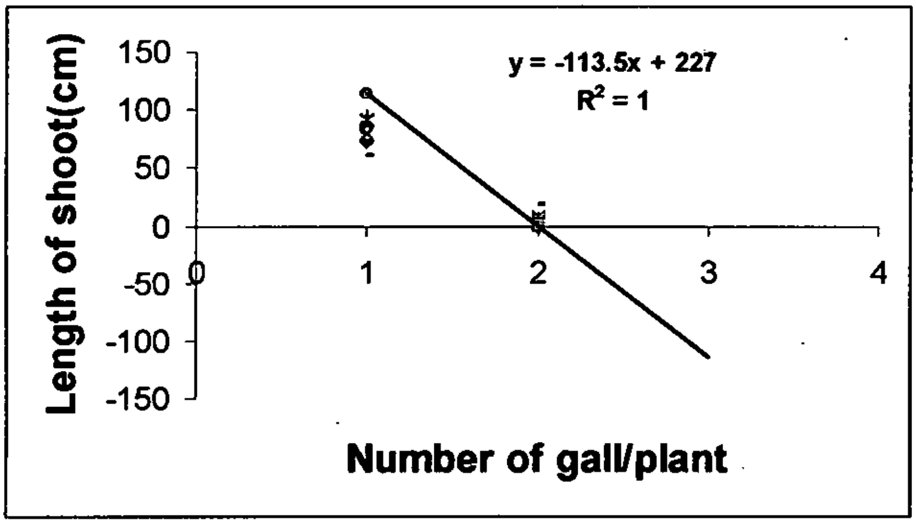


Fig. 3. Relationship between gall number and shoot length under selected treatments

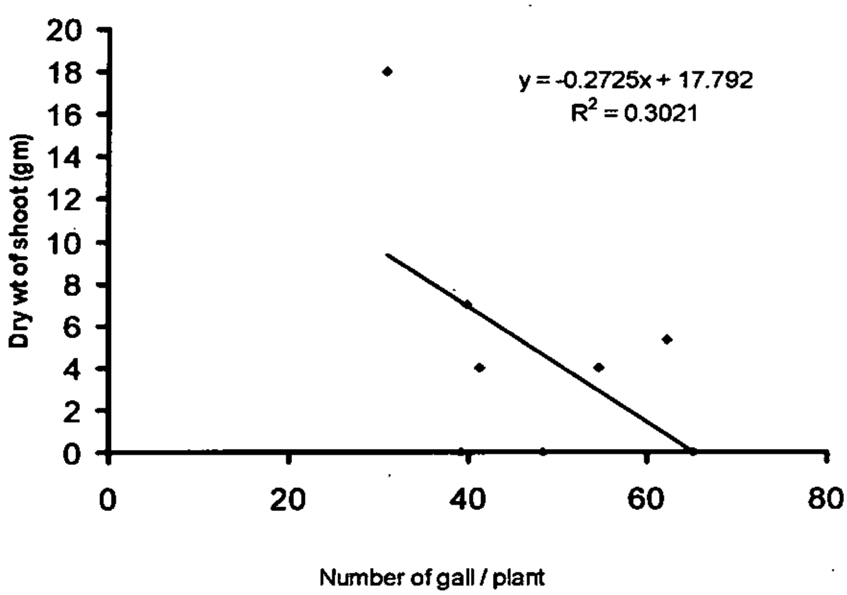


Fig. 4. Relationship between gall number and dry wt. of shoot under selected treatments

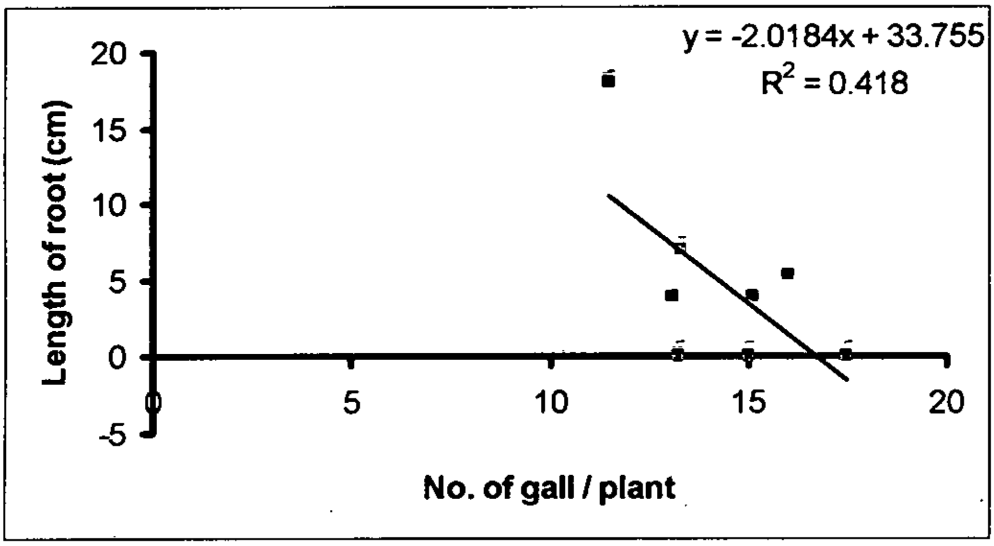


Fig. 5. Relationship between gall number and length of root under selected treatments

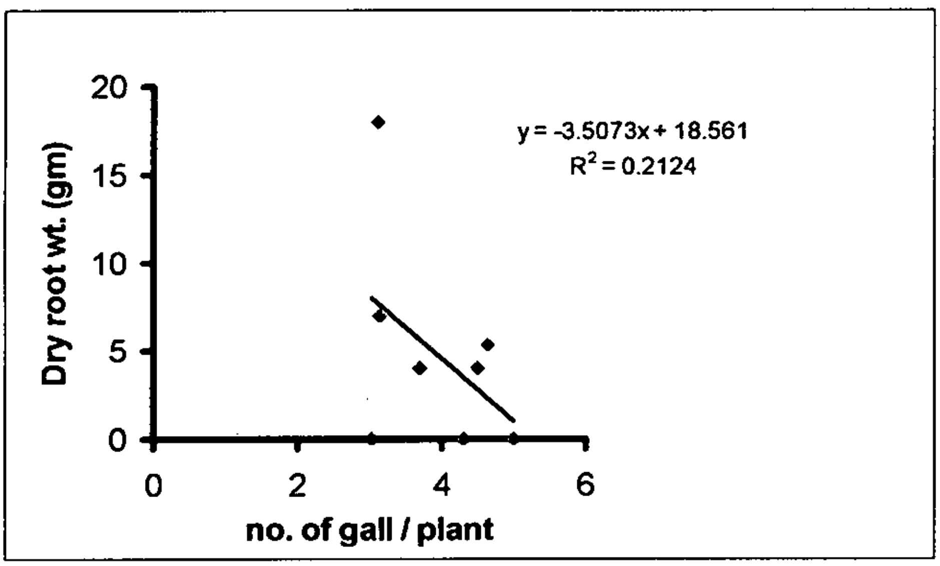


Fig.6. Relationship between gall number and dry wt. of root under selected treatments

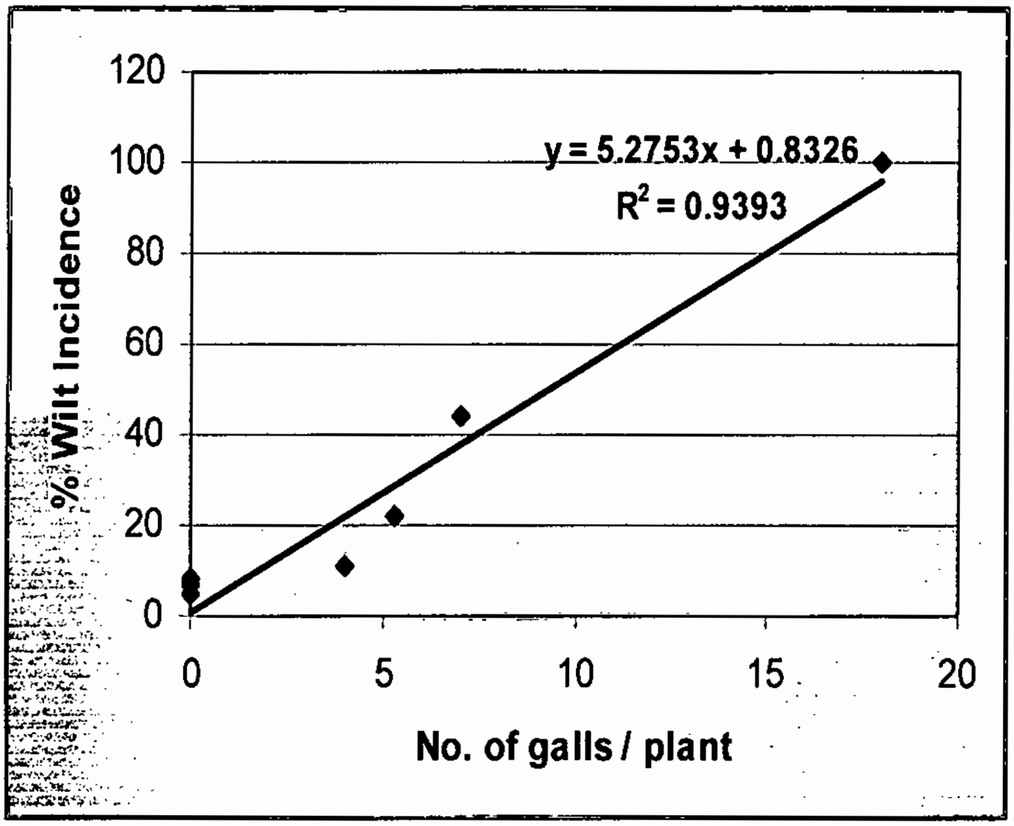


Fig. 7. Relationship between wilt incidence (%) and number of gall formations

4.9 Effect of different treatments on yield parameters of tomato against wilt diseases

The effect of different treatments on tomato yield against diseases have been shown in Table 8.The interestingly common trends, expressed in these results are that, the administration of sawdust recovered the loss in terms of fruit production giving significantly the highest yield parameters. The control treatments gave the lowest yield parameters. The effects of the treatments were significant.

4.9.1 Effect of treatments on fruit weight per plant

The significant variation on fruit weight per plant was observed among the treatments tested (Table 8).The highest fruit weight per plant (1.85 kg) was found in the treatment T_6 (Sawdust). The lowest fruit weight was found in the control treatment (0.60 kg). The treatment T_5 (*Trichoderma harzianum*) contributed 1.34 kg per plant that was the second highest yield which was statistically alike with that of treatment T_7 (Khudepana), T_1 (Grafting) ,T_2 (Furadan 5G), and T_3 (Bavistin) having the yield of 1.27kg, 1.30kg, 1.23kg and 1.20kg per plant, respectively.

4.9.2 Effect of treatments on fruit yield per plot

The effect of treatments on fruit weight per plant has been reflected in the yield of tomato per plot, the statistical levels of significance remaining the same.

The significant variation observed on fruit yield per plot among the treatments has been given in Table 8.The highest fruit yield per plot, 11.12 kg was found in the treatment T_6 (Sawdust) and the lowest fruit yield was found in the control treatment (T_8) having the value of 3.63 kg. The treatment T_1 (Grafting) having 7.81 kg was the second highest and the treatment T_5 (*Trichoderma harzianum*), T_7 (Khudepana),T_2 (Furadan 5G), and T_3 (Bavistin) were statistically alike which having the values of 7.70kg, 7.61kg, 7.40kg and 7.25 kg per plot, respectively.

4.9.3 Effect of treatments on fruit yield of tomato (ton/ hectare)

There were significant variations in yield per hectare among the different treatments (Table 8). The highest yield (31.77 ton/ha) was obtained from the treatment T_6 (Sawdust) and the lowest yield (10.38 ton/ha) was obtained in the control treatment (T_8). The treatment T_1 (Grafting) having 22.33 ton/ha scored the second highest yield, which were statistically similar to the treatment T_5 (*Trichoderma harzianum*), T_7 (Khudepana), T_2 (Furadan 5G), and T_3 (Bavistin) having the values of 21.95 ton/ha, 21.76ton/ha, 21.14ton/ha and 20.72ton/ha, respectively. The fruit yield was increased by 206.67% under the treatment T_6 (Sawdust) followed by T_1 (Grafting) having the value of 115.12% over control (T_8).

The treatments effect on the fruit yield of tomato obtained in the experiment was also graphically presented in the figure 8.

Table 8. Effect of different treatments on fruit yield of tomato against wilt diseases

Treatments	Yield/plant (kg)	Yield/ plot (kg)	Yield (ton/ha)	Yield increased over control (%)
T1 (Grafting)	1.30 b	7.81 b	22.33 b	115.12
T2 (Furadan 5G)	1.23 b	7.40 b	21.14 b	103.66
T3 (Bavistin)	1.20 b	7.25 b	20.72 b	99.62
T4 (Cupravit)	0.98 c	5.92 c	17.19 c	65.61
T5 (*Trichoderma harzianum*)	1.34 b	7.70 b	21.95 b	111.46
T6 (Sawdust)	1.85 a	11.12 a	31.77 a	206.67
T7 (Khudepana)	1.27 b	7.61 b	21.76 b	109.67.
T8 (Control)	0.60 d	3.63 d	10.38 d	----
CV (%)	**7.52**	**5.75**	**5.62**	---

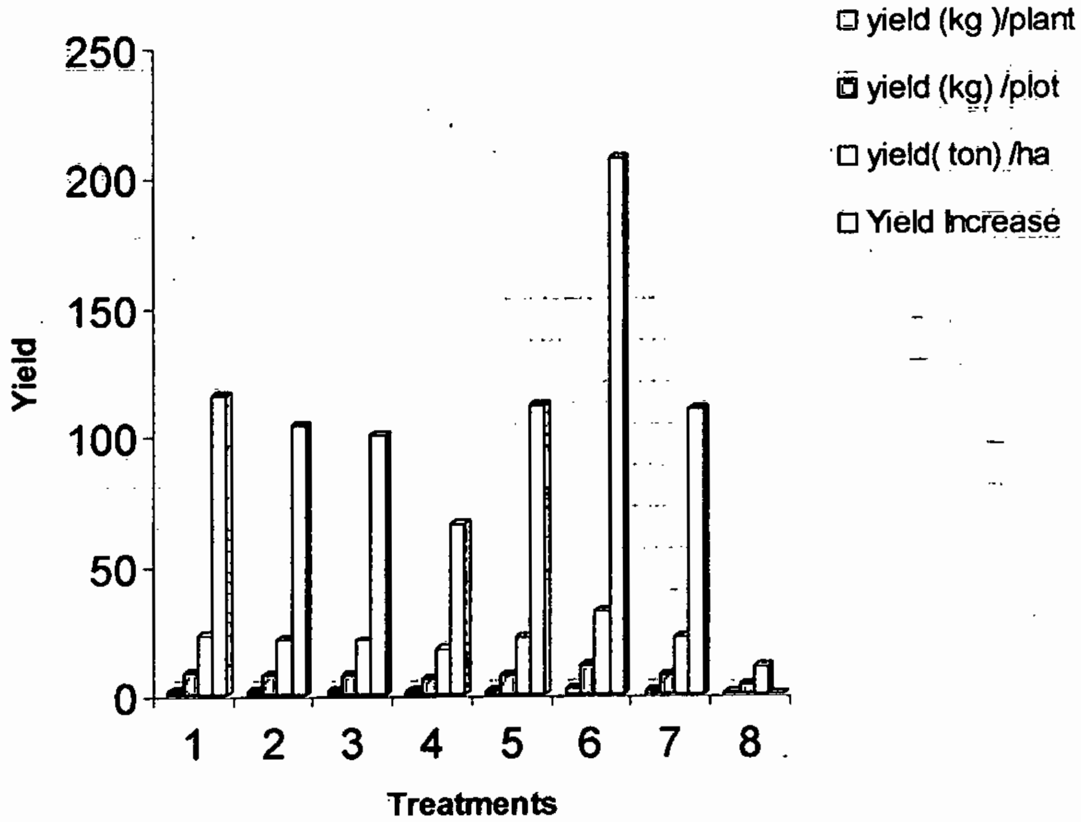


Fig. 8. Effect of different treatments on fruit yield of tomato against wilt diseases.

Legend:	1 =T_1(Grafting)	5=T_5 (*Trichoderma harzianum* T_{22})
	2=T_2 (Furadan 5G)	6=T_6 (Sawdust)
	3=T_3 (Bavistin)	7=T_7 (Khudepana)
	4=T_4 (Cupravit)	8=T_8 (Control)

4.10 Cost-benefit analysis and estimation of Benefit-Cost Ratio (BCR) of the treatments used for management of Fusarium wilt and Nemic wilt of tomato

4.10.1 Cost-benefit analysis

Cost-benefit analysis of different treatments has been estimated and shown in Table 9. The highest gross margin of Tk 280630/ha was obtained in Sawdust application which was 170.36% higher over control. The higher gross margin of Tk 194130/ha was obtained in Grafting which was 87.02% higher over control followed by T_5 (*Trichoderma harzianum*), T_7 (Khudepana), T_2 (Furadan 5G) and T_3(Bavistin) with gross margin Tk 190350/ha, Tk 188730/ha, Tk 181880 and Tk 178670 having increased gross margin of 83.38%, 81.82%, 75.22% and 72.12% over control respectively. The lowest gross margin of Tk 103800/ha was obtained in T_8(control).

4.10.2 Benefit-cost ratio (BCR)

Benefit-cost ratio for all the treatments was shown in Table 10. It has been found that use of sawdust (T_6) result 8.57 BCR in comparison of untreated control and was significantly higher than other treatments. It was due to low cost of treatment as shown in Table 10. Out of other treatments use of Grafting(T_1) technology with wild Solanum gave higher BCR which was 7.65 in comparison of untreated control followed by use of Khudepana(T_7),*Trichoderma harzianum* (T_5),Fungicide Bavistin(T_3), and Furadan 5G(T_2) resulted 7.54, 7.53, 7.26 and 7.16 BCR, respectively.

Table 9: Cost-benefit analysis for production of tomato under eight (8) different treatments

Treatments	Yield (ton/ha)	Gross Return (Tk/ha)	Total cost Treatments(Tk/ha)	Gross margin (Tk/ha)	Increase of gross margin over control (%)
T_1 (Grafting)	22.33	223300	27370+1800 =29170	194130	87.02
T_2 (Furadan 5G)	21.14	211400	29520	181880	75.22
T_3 (Bavistin)	20.72	207200	28530	178670	72.12
T_4 (Cupravit)	17.19	171900	29970	141930	36.73
T_5 (*Trichoderma harzianum* T_{22})	21.95	219500	29150	190350	83.38
T_6 (Sawdust)	31.77	317700	37070	280630	170.36
T_7 (Khudepana)	21.76	217600	28870	188730	81.82
T_8 (Control)	10.38	103800	27370	103800	---

*Price: Tomato Tk 10/kg

*Other information cited in the appendix 5 and 6.

Table 10. Benefit Cost Ratio (BCR) for production of tomato under eight (8) different treatments

Treatments	Yield (ton/ha)	Gross return (Tk/ha)	Gross margin over control (Tk/ha)	Total cost of treatments (Tk /ha)	BCR
T_1 (Grafting)	22.33	223300	119500	29170	7.65
T_2 (Furadan 5G)	21.14	211400	107600	29520	7.16
T_3 (Bavistin)	20.72	207200	103400	28530	7.26
T_4 (Cupravit)	17.19	171900	68100	29970	5.74
T_5 (*Trichoderma harzianum* T_{22})	21.95	219500	115700	29150	7.53
T_6 (Sawdust)	31.77	317700	213900	37070	8.57
T_7 (Khudepana)	21.76	217600	113800	28870	7.54
T_8 (Control)	10.38	103800	----	----	----

Chapter 5
Discussion

DISCUSSION

The present study was carried out with eight different treatments to determine their efficacy in controlling Fusarium wilt caused by *Fusarium oxysporum f. sp. lycopersici* and Nemic wilt caused by *Meloidogyne incognita* in field condition. The performance of the treatments was determined on the basis of wilt incidence, root gall incidence, growth parameters of the plant and finally fruit yield.

5.1 Effect of soil amendment with sawdust and khudepana

The experimental findings for the soil application of sawdust and khudepana recorded at different days after transplantation showed that sawdust had tremendous effect against wilt pathogen in reducing wilt incidence and root gall incidence and increasing fruit yield contributing the growth parameters. No wilt incidence as well as root gall incidence were found even at 85 days after transplanting in the soil of the plot amended with sawdust. Growth parameters of the plant like shoot length, root length, dry weight of shoot and root promisingly increased in comparison to control that contributed a good harvest. The performance of the application of khudepana was not so remarkable like sawdust but far better than control. The present finding were supported pervious research reports (Bora and Phukan , 1983; Mesfin *et al.*, 1987; Striling, 1989) . Bora and Phukan (1983) found that application of sawdust for soil amendment significantly reduced the population of *Meloidogyne incognita* in jute compared to tea waste, poultry manure and control. Mesfin *et al.* (1987) observed the remarkable effect of sawdust against *Meloidogyne incognita* on potted kenaf reading egg mass and root galling. Stirling (1989) reported that soil application of sawdust incorporated with urea controlled *Meloidogyne incognita* and increased yield in ginger.

The reason for the control of wilt incidence and gall incidence of plant by the soil application of sawdust and khudepana might be due to the influence of antagonists of the soil that acts against the wilt pathogens.

5.2 Effect of chemicals against wilt pathogens.

Three chemicals viz. Furadan 5G, Bavistin 50wp and Cupravit 50wp were used in the experiment Furadan 5G had promising effect in controlling the wilt pathogens. It was observed from the experimental findings that no wilt incidence and also root gall formation was noticed even at 85 days after transplanting (DAT) for the application of Furadan 5G as soil application in the surrounding of root zone. The growth parameters like shoot & root length and shoot & root weight were positively influenced by the application of the Furadan 5G that contributed a good harvest compared to other chemicals and control. The performance of Bavistin in controlling wilt incidence and root gall formation was not upto the mark like Furadan 5G, but far better than Cupravit and control. The present findings are keeping in with the findings of Hossain *et al.* (2003); Faruk *et al.* (2001); Hassan (1995); Kartono (1980); Perlaza *et al.* (1979) and Homeyer (1973) who reported Furadan 5G (Carbofuran) as the most effective chemical in controlling *Meloidogyne incognita* and *M. Javanica* causing wilt disease of tomato. The literature is in favorable of Bavistin in controlling Fusarium wilt caused by *Fusarium oxysporum* f. SP. *lycopersici* were also available in the previous research reported by Wei Tang *et al.* (2004); Dwivedi and Pathak (1980). The reason behind the excellent performance of Furadan 5G in controlling the Nemic wilt and also Fusarium wilt might be due to the direct action of Furadan 5G on nematode population and enhance the nematode population (larvae) once decrease it decrease the change of root injury by nematode that indirectly inhibited the infection by *Fusarium oxysporum.*

5.3 Effect of grafting against wilt disease

Grafting of tomato plant as scion with rootstock of wild Solanum (*Solanum sisymbriifolium*) showed excellent performance against Fusarium wilt as well as Nemic wilt. No wilt incidence as well as root gall formation was noticed even at 85 days after transplanting (DAT). Moderate plant growth and yield were recorded in grafted plants. These findings are in agreement with the findings of Ali *et al.*(1990a, 1990b); Ali *et al.*(1992b); Islam (1992) and Shetty & Reddy (1985) who reported that the wild Solanum(*Solanum sisymbrrifolium*) was resistant against Fusarium wilt and Nemic wilt that could be used as a rootstock for the management of wilt complex.

5.4 Effect of *Trichoderma harzianum* T_{22} against wilt pathogens :

The Bio- agent *Trichoderma harzianum* T_{22} also had promising performance in controlling wilt disease of tomato. No wilt incidence as well as gall formation was observed even at 75 days after transplanting (DAT). Though limited wilt incidence (11.11%) and gall formation (4 galls plant) were recorded at 85 days after transplanting (DAT), minor effect was observed on yield and yield contributing characters. The literature in favor of *Trichoderma harzianum* T22 against Fusarium wilt (*Fusarium oxysporum f. sp.lycopersici*) and Nemic wilt (*Meloidogyne incognita.*) are available in the earlier research reports (Praveen *et al.* 1993; Sharma and Saxena 1992; Moon *et al.*1988 and Sivan and Chet 1989b). *Trichoderma harzianum* T_{22} is a non- pathogenic fungus that captures the root zone for its profuse growth and competes with pathogenic microorganisms for space and nutrition. Some times *Trichoderma harzianum* secrets certain toxin and enzyme injurious to the pathogenic organisms. Moreover, it can be directly parasitic with other soil borne pathogens. This micro parasitism might be the reason of controlling wilt pathogens by *Trichoderma harzianum*.

5.5 Cost Analysis

From cost analysis of the treatments applied in the experiment for management of Fusarium and Nemic wilt of tomato, it was revealed that benefit cost ratio (BCR) of application of sawdust was the highest (8.57), where the farmers could earn Tk. 8.57 by investing Tk 1.0. The BCR 7.16 for the application of Furadan 5G was next then *Trichoderma harzianum* less then that of sawdust. This was because the purchase cost of Furadan 5G and formulation cost of *Trichoderma harzianum* were greater than sawdust.

Besides, the application of sawdust contributed the higher yield as the sawdust not only suppressed the soil borne pathogens, but also added organic matter in the soil. The lower BCR for the application of other treatments are due to the lower yield of those treatments.

Chapter 6
Summary and conclusion

SUMMARY AND CONCLUSION

The present piece of research work was carried out in the field allotted for the Department of Plant Pathology, Sher-e-Bangla Agricultural University, Dhaka, during the period from October 2005 to March 2006 following RCBD having 3 replications. In this study, eight (8) different selected treatments were used to observe their efficacy for managing wilt diseases of tomato and also their effects on plant growth and fruit yield of tomato. The cost-benefit analysis and benefit-cost ratio of tomato cultivation in the field have been calculated based upon the obtained results from different treatments.

The maximum wilt incidence of tomato (100%) was observed in control plots at 85 days after transplanting (DAT) and the minimum (11.11%) was in the plots which were treated with treatments T_3 (Bavistin) and T_5 (*Trichoderma harzianum* T_{22}) and moderate wilt was occurred in treatments T_4 (Cupravit), T_7 (Khudepana). No wilted plants were observed under treatments T_1 (Grafting), T_2 (Furadan) and T_6 (Sawdust) upto 85 days after transplanting (DAT).

The maximum root gall formation was found in control treatment and the minimum root gall formation was found in Cupravit treatment followed by Khudepana, Bavistin and *Trichoderma harzianum*, respectively. No gall was found in Sawdust, Furadan 5G and Grafting treated plants.

The maximum plant height (113.5 cm) and fruit yield (31.77 t/ha) were obtained in plots where sawdust was applied in soil and also yield was increased by 22.34% over control. It was also observed that plots which were treated with Furadan 5G and *Trichoderma harzianum* performed better by having least number of wilted plant/plot.

Cost-benefit analysis of using the selected treatments showed that the highest gross margin of Tk. 280630/ha was obtained in plots with Sawdust (170.36%) followed by Grafting (87.02%), *Trichoderma harzianum* (83.38%),Khudepana(81.82%) and Furadan 5G(75.22%) over control, respectively. The treatment using chemicals resulted gross margin of Tk 178670/ha and 141930/ha which were close to control. As regard to benefit-cost ratio, the maximum BCR (8.57) was obtained from use of sawdust followed by use of Grafting (7.65), Khudepana (7.54) and *Trichoderma harzianum* (7.53). It is evident from the results that higher cost of treatment was responsible for relatively lower BCR (5.74) due to use of chemical Cupravit.

Considering the over all performances of the treatments applied in the experiment in controlling Fusarium wilt and Nemic wilt of tomato, application of sawdust, Khudepana, *Trichoderma harzianum* and Grafting of tomato with wild Solanum (*Solanum sisymbriifolium*) could be used as ecofriendly approach and may be advised to the farmers for profitable production. The chemical Furadan 5G could be used for controlling the disease as the last option. However, further study need to be carried out for a consecutive years including more options as management practices in different Agro-ecological zones (AEZs) of the country.

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Appendices

APPENDICES

Appendix-1: Composition of 100 g fresh peeled fruit of tomato

Ingredients	Amount
Protein	0.9gm
Fat	0.1gm
Carbohydrates	3.5gm
Vitamin "A"	500-1500 IU
Vitamin "C"	20-25 mg
Thiamin	0.1mg
Riboflavin	0.02mg
Niacin	0.6mg
Calcium	6-9mg
Iron	0.1-0.3mg
Energy	15-20Kcal

Source: Rashid *et al.*, 1976.

Appenedix-2. Monthly mean of daily maximum, minimum and average temperature, relative humidity, total rainfall and sunshine hours during December/2005 to March/2006

Month	**Temperature(^{0}C)			**Relative Humidity (%)	*Rainfall (mm)	*Sunshine (hrs)
	Max.	min.	Ave			
December	27.1	15.7	21.4	64.0	Trace	212.5
January	25.3	18.2	21.8	67.6	00	195.2
February	31.3	19.4	25.33	61.3	00	225.5
March	33.2	22.0	27.6	48.5	Trace	220.4

Source: Station name: PBO, Dhaka, Station no: 41923, Surface synoptic data card, Bangladesh Meteorological Department, Sher-e-Bangla Nagar, Dhaka-1207.

*=Monthly total
**=Monthly average

Appendix-3.

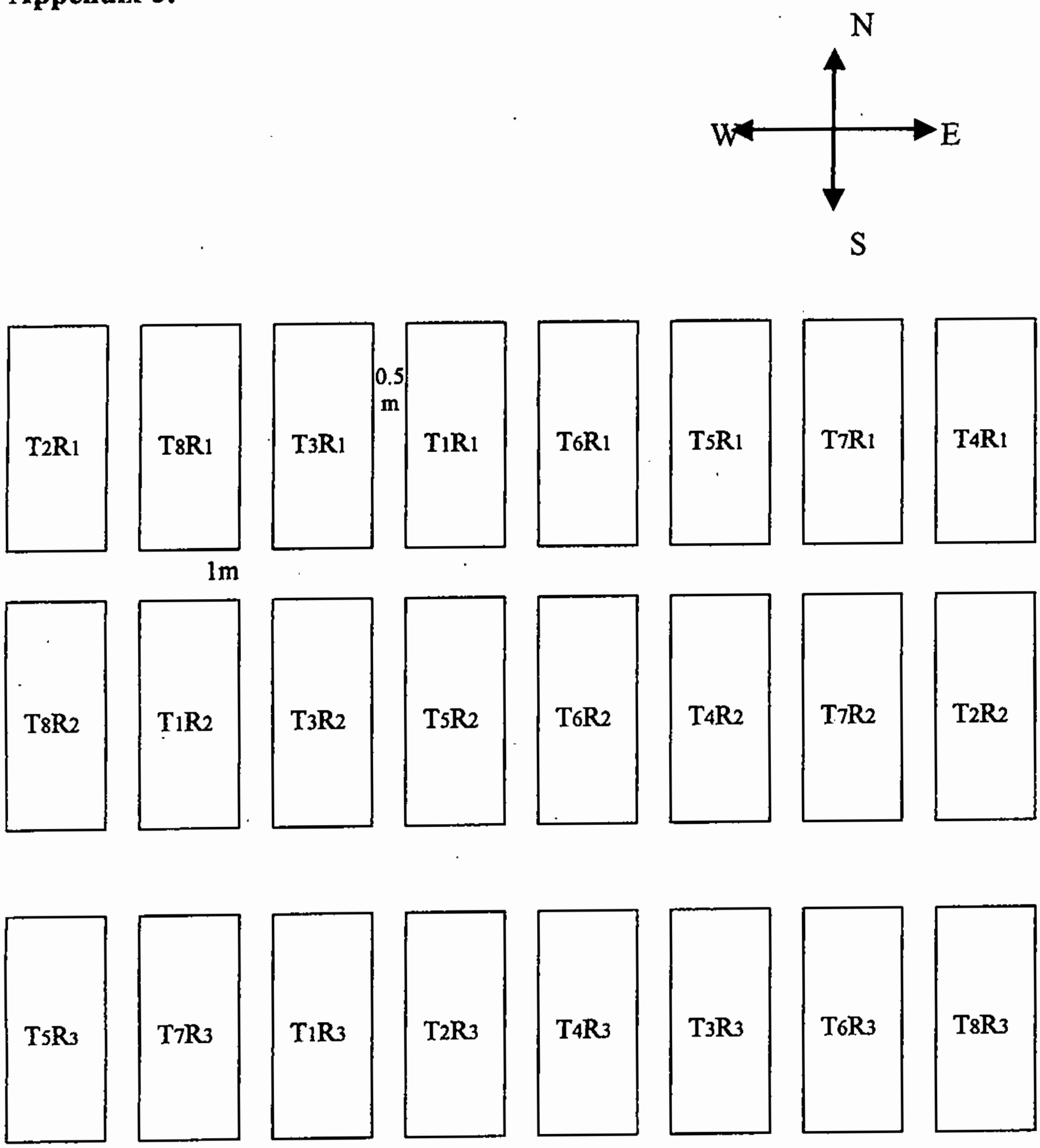

Fig.1 Layout of a field experiment (RCBD)

Appendix-4. Field View

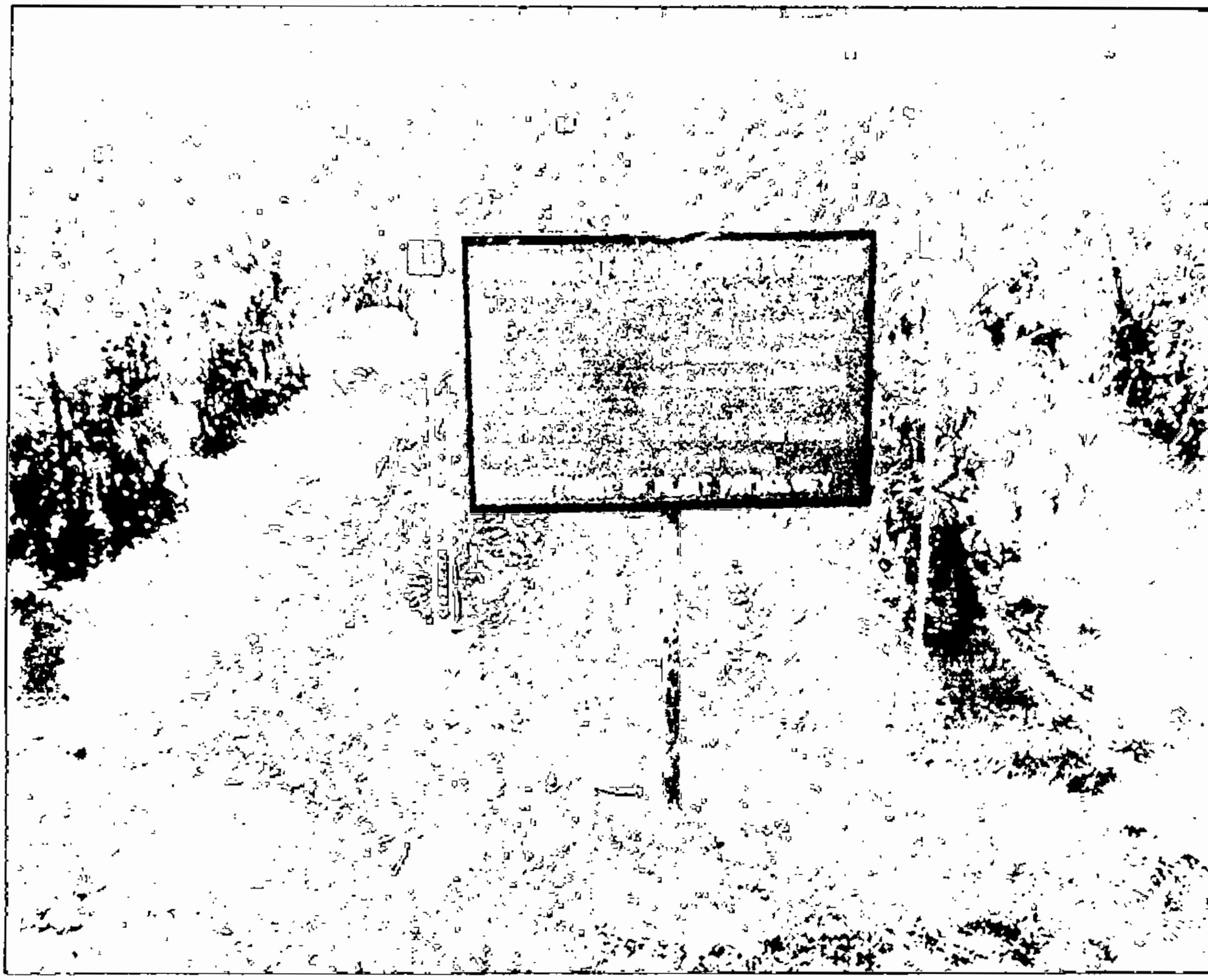

Plate-10. Field view of the experiment.

Appendix-5. Cost analysis for application of common cultural practices in production of tomato

Cost items	Per hectare cost in Tk.				
	Unit	Quantity	Cost/ unit	Times	Total cost
Seed	Kg	0.10	4000	---	500
Land preparation					
-Tractor hired	----	---	---	--	1500
-Ploughing	Bull pair	10	250	---	2500
-Human labour	Man day^{-1}	10	100	---	1000
Seedling preparation	Man day^{-1}	5	100	---	500
Seedling plantation					
-Human labour	Man day^{-1}	15	100	---	1500
Fertilization and Manuring					
-Urea	Kg	226	7	---	1582
-TSP	Kg	222	14	---	3108
-MP	Kg	250	15	---	3750
-Cowdung	Ton	10	500	---	5000
-Human labour	Man day^{-1}	10	100	---	1000
Weeding					
-Human labour	Man day^{-1}	12	100	2	2400
Insecticides spraying					
-Aktara	Kg	0.5	2500	2	2500
-Human labour	Man day^{-1}	1	100	3	300
-Sprayer hired	—	2	115	--	230
Total (a)					27370

**** Calculation on the basis of market price of 2006.**

Appendix 6. Analysis of cost of application for management practices in production of tomato plant

Cost items	Per hectare cost in TK.				
	Unit	Quantity	Cost/Unit *	Times	Total cost
Grafting					
➢ Human labour	Man day^{-1}	10	100	1	1000
➢ Clip	–	6400	0.10	1	640
➢ Polyethylene	Kg	2	100	1	200
Total (b)					1490
Soil application of Furadan					
➢ Furadan	Kg	15	110	1	1650
➢ Human labour	Man day^{-1}	5	100	1	500
Total (c)					2150
Root dressing and soil drenching Cupravit					
➢ Cupravit	Kg	10	540	1	660
➢ Human labour	Man day^{-1}	40	100	1	500
Total (d)					1160
Root dressing and soil drenching Bavistin					
➢ Bavistin	Kg	3	1110	1	2100
➢ Human labour	Man day^{-1}	40	100	1	500
Total (e)					2600
Soil application of *Trichoderma*					
➢ *Trichoderma*	Kg	30	25	1	1280
➢ Human labour	Man day^{-1}	40	100	1	500
Total (f)					1780
Using Sawdust					
➢ Sawdust	Ton	1.5	2000	1	1000
➢ Human labour	Man day^{-1}	40	100	1	500
Total (g)					1500
Using Khudepana					
➢ Khudepana	Ton	30	100	1	1000
➢ Human labour	Man day^{-1}	40	100	1	500
Total (h)					1500

- Calculated on the basis of market price of 2005.