MANAGEMENT OF FUSARIUM WILT AND NEMIC WILT OF EGGPLANT THROUGH SOME SELECTED TREATMENTS

A THESIS

BY

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CERTIFICATE

This is to certify that the thesis entitled, **"MANAGEMENT OF FUSARIUM WILT AND NEMIC WILT OF EGGPLANT THROUGH SOME SELECTED TREATMENTS"** 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 bonafide research work carried out by **Abu Noman Faruq Ahmmed, Registration No. 01523,** 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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Dedicated
to my
beloved parents

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ABSTRACT

The effect of eight selected treatments viz. Grafting (T_1), Furadan 5G (T_2), Cupravit (T_3), Bavistin (T_4), *Trichoderma harzianum* T_{22} (T_5), Sawdust (T_6), Khudepana (T_7) and Control (T_8) were tested against *Fusarium oxysporum* f. sp. *melongenae* and *Meloidogyne incognita* for the management of wilt disease of eggplant during 55 days after transplanting to 95 days after transplanting at the Farm of Sher-e-Bangla Agricultural University, Dhaka. The efficacy of the treatments varied significantly in terms of wilt incidence, root knot incidence, plant growth and fruit yield. Soil application of Sawdust (T_6), *Trichoderma harzianum* T_{22} (T_5), Furadan 5G (T_2) and Grafting (T_1) showed promising effect against the wilt pathogens. The applied treatments enhanced plant growth and increased fruit yield by 622.08%, 605.54%, 526.25% and 501.67%, respectively over untreated Control (T_8). Cost benefit analysis showed that soil application of Sawdust resulted the highest BCR (4.17) followed by Furadan 5G (3.83), *Trichoderma harzianum* T_{22} (3.83), and Grafting (3.16) in comparison to Control (0.70).

Chapter 1

INTRODUCTION

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Eggplant or Brinjal (*Solanum melongena* L.) belongs to the family Solanaceae, is the most important and widely consumed nutritious vegetable in Bangladesh (Appendix 1). It is cultivated as a popular and commercial vegetable throughout the tropical and sub-tropical region of the world. In tropical climate, eggplant can be grown throughout the year as perennial crop and in sub-tropical, it is grown as summer annual. It is grown extensively in Bangladesh, China, India, Pakistan and Philippines. It is also popular in other countries like Balkan area, France, Indonesia, Italy, Japan, Mediterranean, Turkey and United states (Bose and Som, 1986).

Brinjal is locally known as "Begoon" and its early European name is Aubergine or Eggplant. Eggplant is the species of *S. melongena* also known as Guinea squash and garden egg (Nonnecke, 1989). It is thought to be originated in Indian sub-continent because of maximum genetic diversity and closely related species of *Solanum* are grown in this region (Rashid, 1976; Zeven and Zhukovsky, 1975).

Eggplant is nutritious vegetable and has got multifarious use as a dish item (Bose and Som, 1986 and Rashid, 1993). It is largely cultivated in almost all districts of Bangladesh. It can be grown at homestead area and kitchen garden because of its popularity especially for urban people. About 8 million farm families are involved in eggplant cultivation (Islam, 2005). This gives small, marginal and landless farmers a continuous source of income and provides employment facilities for the rural people. For most of the time, except peak production period, market price of eggplant compared to other vegetables remains high which is in favour of the farmer's solvency. So, it plays a vital role to boost our national economy.

Eggplant is the second most important vegetable crop next to potato in Bangladesh in respect of acreage and production (BBS, 2005). The total area of eggplant cultivation is 60100 hectare where 22500 ha in Kharif season and 37500 ha in Rabi season with total annual production of 358400 mt. and the average yield is 6.0 t/ha in 2003-04 year (BBS, 2005). It is grown round the year both as winter (Rabi) and summer (Kharip) crops (Rashid, 1993).

Of many reasons for high price of eggplant, lower production rate is important. Incidence of insect pests and diseases greatly hampered the production of eggplant. This crop suffers from the various diseases; about 13 different diseases so far recorded in Bangladesh (Das *et al.* 2000; Khan *et al.* 2002 and Rashid, 2000). Among those diseases wilt of eggplant has been treated as one of the major constrains in eggplant cultivation in the country (Ali, 1993). In Bangladesh, problem of the diseases is common in non-flooded high lands where solanaceous vegetables are grown continuously without crop rotation. Sudden wilting of eggplant is very acute and occurs commonly in kitchen gardens in these non-flooded areas (Ali *et al.,* 1994).

Eggplant cultivation in Bangladesh is severely impaired by three important wilt causing pathogens viz. *Pseudomonas solanacearum, Fusarium oxysporum* and *Meloidogyne incognita,* the causal agent of Bacterial wilt, Fusarium wilt and root-knot nematode also known as Nemic wilt respectively and caused devastating damage of eggplant (Timm and Ameen, 1960; Talukder, 1974; Ahmed and Hossain, 1985; Mian, 1986 and Ali *et al.*, 1994). These are also the major limiting factors for eggplant production throughout the world (Hinata, 1986). Wilt and nematode problems are especially severe in the humid tropics. In some cases 100% of the plants are found to die in Kitchen gardens of Bangladesh due to wilt problem (Ali *et al.*, 1994). In Bangladesh root Knot may cause as much as 27.2% loss in fruit yield of eggplant (Bari, 2001).

The Fusarium wilt and Nemic wilt are very acute in Bangladesh. Once the plant is affected by wilting organisms, it does not produce yield and gradually die. The nematode infection is expressed by gall formation in the root system and ultimately the plant become weak due to interruption in nutrient uptake from the soil. Moreover, due to nematode infection, the root system becomes injured facilitating easy entry of the wilt causing organisms into the plant root system.

The Fusarium wilt is expressed by one sided wilting of plant. The fungal growth blocks the xylem vessel of the affected plant and interrupts with the water and nutrient uptake from the soil. Thus the plant become weakens and ultimately wilted.

There are two traditional methods of controlling the soil-borne diseases; i) soil Sterilization by chemicals, which is very expensive and not feasible for the farmers, and ii) use of resistant varieties, which are not available (Ali *et al.*, 1994). Some of the wild *Solanum* species are reported to have resistance to these diseases. But the transfer of resistance from the wild species to the cultivated eggplant is very difficult due to interspecific or intergeneric incompatibility or hybrid sterility. (Khan, 1974; McCammon and Honma, 1983; Ozaki, 1985 and Ali, 1993).

To avoid the problems of wilt diseases, grafting of eggplant on the resistant rootstocks as an alternative, is being practiced in Puerto Rico (Purseglove, 1974) and in Japan (Matsuzoe *et al.*, 1990 and Ali *et al.*, 1990a). Japanese growers have been using this technique since the 1930s. In 1990, about 95% of Japanese commercial growers have been reported to grow grafted eggplants. Shetty and Reddy (1985) and Ali *et al.*, (1990a, 1990b) reported that *Solanum sisymbriifolium* and *S. torvum* are effective rootstocks to control root-knot and wilt diseases of eggplant and tomato.

Chemical control of wilt disease is very difficult and some times the suitable chemicals are not practically available (Hillocks and Waller, 1997a; Martin, 1981 and Mondal *et al.* 1991). Furadan 5G are being used to control root Knot nematode and other soil borne pathogen of eggplant (Hillocks and Waller, 1997a and Hossain *et al.*, 2003).

Organic soil amendment is another important option and ecofriendly approach for controlling soil borne pathogen by developing suppressive soil (Palti and Katan, 1997 and Singh and Sitaramaiah, 1971). Bio-control agent like *Trichoderma harzianum* is reported to have great effect against soil borne pathogen (Moon *et al.*, 1988; Singh *et al.*, 1997; Reddy *et al.*, 1998 and Rao *et al.*, 1998)

Under the scenario discussed above, to identify the components for management of Fusarium wilt and Nemic wilt of eggplant is an urgent demand. But there exists a few evidence of research work for management of Fusarial wilt and Nemic wilt of eggplant in Bangladesh. Hence this experiment has been designed to achieve the following objective:

1. To identify the ecofriendly components and determine their effect on *Fusarium* and *Meloidogyne* spp. for the management of wilt disease of eggplant.

Chapter 2

REVIEW OF LITERATURE

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REVIEW OF LITERATURE

Eggplant (*Solanum melongena* L.) is a popular solanaceous vegetable crop. Eggplant suffers from many diseases caused by fungi, bacteria, virus, nematode and mycoplasma. Of them, root disease like Fusarium wilt and Nemic wilt caused by *Fusarium oxysporum* and *Meloidogyne incognita*, respectively are responsible for devastating damage of eggplant (Ahmed and Hossain, 1985; Mian, 1986; Ali 1993). Thus these diseases are important threat for eggplant production of our country. Evidences of research work regarding management of Fusarium wilt and Nemic wilt of eggplant are very limited. However some available and important findings on various aspects of management of Fusarium wilt and Nemic wilt has been compiled and presented below.

2.1. Symptoms of Fusarium wilt of eggplant

Fusarium are generally classified as soilborne fungi that cause various vascular wilts and root and stem rots of cultivated plants (Armstrong and Armstrong, 1975; Burgess, 1981).

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 on successively younger leaves. The plant as a whole is stunted and eventually goes into a permanent wilt.

Roberts and Boothroyd (1972) described that, all vascular wilt disease symptoms of *Fusarium* and *Verticillium* infection include drooping of above-ground parts. In the early stages of disease, plants wilt during the day and recover their turgor at night. As the disease progresses, the permanent wilting point is reached and turgor is never regained. The diagnostic symptom of any pathological wilt disease is the brown discoloration of the vascular region, visible in cross-sections of infected stems or roots and in sections tangential to the xylem.

Rangswami (1988) observed the symptoms of fusarium wilt that the younger leaves may die in succession and the entire plant may wilt and die in the course of a few days.

Hartman and Datnoff (1997) stated that, plants infected with the fungus *Fusarium sp.* that caused wilt and root rot have yellow leaf margins on the oldest leaves (Sherf and MacNab, 1985). Lower leaves become necrotic and drop off from the plant. Plants defoliate from lower to upper leaves as they becomes more necrotic. Plants may wilt and die quickly. Roots become dry and the cortex and xylem turn brown.

Miller *et al.* (2005) also described details about Fusarium wilt of solanaceous crops. The wilt organism usually enters the plant through young roots and then grows into the water conducting vessels of the roots and stem. As the vessels are plugged and collapse, the water supply to the leaves is blocked. With a limited water supply, leaves begin to wilt on sunny days and recover at night. The process may continue until the entire plant is wilted, stunted, or dead. In many cases a single shoot wilts before the rest of the plant shows symptoms or one side of the plant is affected first. If the main stem is cut, dark, chocolate brown streaks may be seen running lengthwise through the stem. This discoloration often extends upward for some distance and is especially evident at the point where the petiole joins the stem.

2.2. Pathogenic description of *Fusarium oxysporum*

Barnett and Hunter (1972) described details about *Fusarium spp.* Mycelium of *Fusarium* is extensive and cottony in culture, conidiophores variable, slender, simple, short, branched irregularly or bearing a whorl of phialides, single or grouped into sporodochia; conidia hyaline, variable, principally of two kinds, macroconidia several-celled slightly curved or bent at the pointed ends, microconidia 1-celled, ovoid to oblong, borne singly or in chains.

Roberts and Boothroyd (1972) described that, *Fusarium* wilt is induced by any of the several formae specials of *Fusarium oxysporum.* These forms, structurally indistinguishable from one another, vary with respect to their pathogenicity to different species of suscept plants. *Fusarium spp.* can be isolated and grown in pure culture, where it usually sporulates profusely. Also, the sporulating stage of fungus will develop within one or two days on the split stems of diseased plants, provided the stems are kept moist. *Fusarium* produces sickle-shaped, multi-septate conidia on sporodochia. *Fusarium* survives for five to ten years in the soil as a "saprophyte". The fungus could survive for some years without obtaining anything more than water from the soil solution. In any event, soil, once infested with *Fusarium oxysporum,* is likely to remain infested for five to ten years. The primary cycle begins when the roots of susceptible plants contact hyphal strands developing from germinating chlamydospores or microsclerotia. Ingress by either fungus may occur through the openings made by the emergence of lateral roots, through mechanically injured areas, or by direct penetration of hyphae through the tender root tissues in the regions of cell elongation or meristematic activity. The fungus grows to the region of the xylem and develops in the tracheids and vessels, and also invades the xylem parenchyma. *Fusarium* secretes pectolytic enzymes that catalyze the hydrolytic reactions that result in the partial destruction of the middle lamellae of the xylem parenchyma and in the degradation of pectic compounds in the walls of vessels and tracheids. Parenchymatous cells are killed and turn brown, and a brown-staining reaction occurs in the walls of affected vessels and tracheids. This brown discoloration, which is the diagnostic symptom of pathological wilting, apparently results from the oxidation of polyphenols, giving rise to the dark melanin pigments. Although considerable mycelium may form in the vessels, and although spores may be produced there, the amount of fungus produced is insufficient to amount for wilting as a result of mechanical plugging of the tracheary elements, by the gel formed by the mixture of pectolytic breakdown products and the cell contents. Also, *Fusarium* produces extracellular toxins that move to the leaves, where they induce loss of turgor in the ground parenchyma. The combined effects of toxins, plugging by the fungus, and plugging by the gel of pectic compounds probably account for the wilting of plants infected by *Fusarium oxysporum.* It is becoming increasingly evident that similar effects result in pathological wilting, irrespective of the causal fungus.

Hartman and Datnoff (1997) and Miller *et al.* (2005) described about the pathogen of Fusarium wilt of solanaceous crops is caused by several types of the fungus *Fusarium oxysporum*. These are *F. oxysporum* f. sp. *lycopersici* (tomato), *F. oxysporum* f. sp. *melongenae* (eggplant) and *F. oxysporum* f. sp. *vasinfectum* (pepper). All of the Fusarium wilt pathogens are generally specific to their hosts and are soilborne. The fungus persists in the soil as chlamydospores and penetrates the host roots directly or through wounds.

2.3. Symptoms of Nemic wilt of eggplant

Root-Knot caused by *Meloidogyne incognita* is another important and widely distributed disease in the country (Talukder, 1974; Ahmed and Hossain, 1985 and Mian, 1986). The nematodes are soil borne roundworms that attack the root system of eggplant, preventing water and nutrient uptake. The plant will be stunted and wilt during the day and recover their turgor at night and finally they exhibit wilting.

Ali (1993) reported that, the problems of root knot nematode infection in eggplant is expressed by gall formation in the root system and ultimately the plant become weak due to interruption in nutrient uptake from the soil and ultimately the infected plant may also die. Moreover, due to nematode infection, the root system becomes injured facilitating easy entry of the wilt causing organisms like bacteria and fungi into the plant. 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 characteristics 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. Fusarium wilt of eggplant increases in incidence when the plants are also infected by the root-knot.

The soil and climatic condition of Bangladesh has made her an ideal abode for nematodes. A preliminary survey found 15 genera of plant parasitic nematodes associated with commercial crops in Bangladesh where root-knot nematode *Meloidogyne* is the most abundant and widespread (Timm and Ameen, 1960 and Ahmad, 1977a). Moreover, the nematode population in the soils of Bangladesh is increasing day by day (Chowdhury, 1976). In Bangladesh , root knot disease ranks as one of the most important disease of crop because of its wide host range. The common species of root-knot nematode are *Meloidogyne incognita* and *Meloidogyne javanica*. They attack wide variety of field, fruit and vegetable crop including brinjal (Biswas, 1979). In certain crops, the loss is increased because root knot predisposes the plants to injure by other diseases (Chester, 1950).

2.4. Pathogenic description of *Meloidogyne incognita*

Singh and Sitaramaiah (1994) stated that, root knot nematode *Meloidogyne spp.* are the first plant parasitic nematode to be recognized. The mature female of *Meloidogyne sp.* are swollen, pear or subspherical in shape. They are sedentary endoparasites. The body will remains soft, white and does not form a cyst. Female stylet is slender with well developed basal knobs. First moult occurs within the egg. Males are vermiform and migratory.

Second stage juveniles are vermiform, migratory and infective. Third and fourth larval stages are swollen.

Hillocks and Waller (1997b) reported that, sedentary endoparasitic nematodes such as the root-knot nematodes (RKN) (*Meloidogyne spp.*) enter into the root and move through the cortex to the vascular system, where they begin to feed and remain to complete the life cycle. In general, the sedentary endoparasites have the most profound effects on the physiology of their hosts and the most complex effects on disease susceptibility. The cortical feeding nematodes may predispose the root to infection but the effect is localized, providing entry sites for pathogens or increasing nutrient leakage.

2.5. Association of *Meloidogyne spp.* with *Fusarium oxysporum*

Van Gundy and Tsao (1963) found that the *Fusarium* population was favoured to roots gall by *Meloidogyne javanica.*

Lue *et al.* (1990) stated that, root-invading nematodes can be important in the process of infection by soilborne fungi and bacteria. The feeding of nematodes on crop roots increases nutrient leakage and provides wounds through which pathogens can gain entry to the root cortex. *Meloidogyne spp.* assist fungal growth after invasion of the root and they also interfere with physiological processes involved in host defenses against vascular infection.

Singh and Sitaramaiah (1994) stated that, *Meloidogyne incognita* increases severity of Fusarial wilt of tomato, eggplant, cotton, tobacco, muskmelon, cabbage and other plants. Fusarium wilt of sesame is associated with a high nematode (*Meloidogyne spp.*) population in South America (Kolte, 1985).

Hillocks and Waller (1997b) reported that, sedentary endoparasitic nematodes increased disease caused by vascular wilt fungi. Localized wounding and nutrient sink effects around the nematode feeding site play a role in increased infection by Fusarium wilt pathogens. *Meloidogyne spp.* also exerts a systemic effect on disease susceptibility in some hosts. Mechanism of nematode enhanced susceptibility was shown to be a retardation of host defense mechanisms in the xylem.

Corazza (1998) observed that presence of *Meloidogyne spp.* can reduce or annihilate the resistance of plants to *Fusarium oxysporum* f. sp. *melonis.* Coffee wilt caused by *Fusarium oxysporum* develops vascular wilt symptoms and is associated with nematode damage. In case of Fusarium wilt of sunflower (*Fusarium oxysporum* f. sp. *carthami*), the nematode *Meloidogyne incognita* plays a vital role in enhancing disease severity (Kulthe and Pedgaonkar, 1991).

Avelar *et al.* (2001) found that the root knot nematodes initiated the attack and the magnitude of the symptoms could be due to the presence of fungi which caused root rot. In the case of tobacco, *M. incognita* increased Fusarium wilt infection when nematode and fungus were on opposite root halves. However, when similar work was done with cowpea and cotton, infection was increased only when the two organisms were inoculated onto the same root half (Hillocks, 1986).

2.6. MANAGEMENT OF WILT DISEASE

2.6.1 Management through fungicides

The use of soil fungicides should aim to control the pathogen with minimal disturbance of the ecosystem. It is generally recognized that eradication of a pathogen from a field through chemicals is practically impossible, but the pathogen is more easily inhibited when inoculum levels are low and, under these conditions, less chemical is required (Munnecke, 1972 and Ludwig, 1970).

Dwivedi and Shukla (1980) observed that, the effects of fungicides (Bavistin and Difolatan) were found effective to cheek this pathogen (*Fusarium oxysporum*) growth. They used 0.1% concentration of Bavistin and sprayed on plant after immediately appeared the symptom.

Mantecon *et al.* (1984) conducted seed potato treatment by fungicides for control of wilt and stem end rot of potato caused by *Fusarium solani.* All the systemic fungicides increased yield and reduced percentage diseased plants but only Thiabendazole, Benomyl and Carbendazim significantly reduced tuber infection.

Dhrub and Singh (1988) reported that, an isolate of *Fusarium solani* from wilted seedling of kagazi lime was completely inhibited in vitro by Carbendazim at 0.1%.

Pandey and Upadhyay (1999) stated that, Bavistin (Carbendazim) was highly effective to Fusarium wilt of pegeonpea. In another experiment showed, Carbendazim treated corms gave better disease control of Fusarium wilt of gladiolus and gave higher corm yield then other fungicides (Chandel and Bhardwij, 2000)

Ram *et al.* (1999) described integrated management of rhizome rot of ginger caused by *Pythium sp.* or *Fusarium sp.* or both. They reported that integration of soil application of biocontrol agent with fungicidal rhizome treatment Bavistin (Carbendazim + Ridomil MZ) increased the efficiency of disease control as compared with other individual treatments.

Ramesh and Manjunath (2002) used *Trichoderma spp.*, 0.2% Carbendazim and 0.3% Copper Oxychloride for management of wilt disease (caused by *Ralstonia solanacearum, Fusarium oxysporum* and *Verticillium dahliae*) on eggplant. Maximum infection was observed in plots treated with Carbendazim (17.88%) and control plot (10.65%), whereas the lowest infection was recorded in plots treated with *Trichoderma spp.* (2.78%) and Copper oxychloride (2.88%). However the highest yield was obtained with Carbendazim (11.88 t/ha).

Islam (2004) was conducted an experiment for the management of Fusarium wilt (*Fusarium oxysporum* f. sp. *ciceri*) of chickpea through soil application of botanics (neem cake, linseed cake and neem oil), solar heating and fungicides (Dithane M45 and Cupravit). Solarization in combination with a dose of fungicides (Dithane M45 and Cupravit) gives statistically significant result to reduce the incidence of chickpea wilt in field trials.

Wei Tang *et al.* (2004) observed the effect of seven fungicides against wilt pathogen *Fusarium oxysporum*. They used Prochloraz, Carbendazim, Thiram, Toclofos-Methyl, Hymexazol, Azoxystrobin and Carboxin. Where Prochloraz and Carbendazim were the most effective fungicides in inhibiting mycelial growth. The preventive effect was 87.0% after 5 mg/ml Carbendazin was added to the liquid media for 2 weeks with a curative effective 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.

2.6.2 Management through Furadan 5G (Carbofuran)

Furadan 3G is highly effective nematicide owing to its rapid dispersal in soil and its systemic action when taken up by plants and most effective in controlling *Meloidogyne sp.* (Homeyer, 1973; Yaringano and Villalba 1977).

Sitaramaiah *et al.* (1976) reported that Carbofuran, Fensulfothion and Sawdust + NPK all significantly reduced *Meloidogyne javanica* parasitism on Pusa sawani, and the sawdust treatment gave the greatest yield.

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 the soil and in the roots and inhibited gall formations with efficacy index of 74-78%.

Deol *et al.* (1989) conducted an experiment for control of combined infection of *Meloidogyne incognita* and *Fusarium solani* in brinjal. This combined infection of inoculated aubergine plant was best controlled by Carbofuran at 2 kg a.i./ha + Bavistin (Carbendazim) at 2000ppm.

Hasan (1995) carriedout research with Furadan 5G and Miral 3G tested 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.

Enokpa *et al.* (1996) investigated the effect of Furadan 3G (Carbofuran) on the control of *Meloidogyne incognita* with 3 concentrations of Carbofuran (12.35, 24.7, and 49.4 kg a.i./ha), the best vegetative growth occurred with 24.7 kg a.i./ha. There was a significant difference in the plant dry weight and galling incidence at the different treatment levels.

Devappa *et.al.* (1997) observed the effect of Carbofuran at 2 kg a.i./ha, neem cake at 12.5 t/ha either singly or in combination, for the management of *Meloidogyne incognita* infecting sunflower, under the field condition. A combination of Carbofuran and neem cake increase the plant growth characteristics like shoot height, shoot weight, root length, root weight and grain yield, and reduced the nematode population in soil and root galling.

Nanjegowda *et al.* (1998) studied the efficacy on various neem products and a nematicide (Carbofuran) against *Meloidogyne incognita* in a tomato nursery. All the neem products and Carbofuran significantly reduced the nematode population and increased the plant growth compared to control. However, Carbofuran was found to be more effective in reducing root gall and increasing plant growth, followed by neem kernel, neem cake and nimbecedine.

Sharma (1999) observed that Carbofuran at 2 kg a.i./ha was the most effective in improving yield of tomato and reducing nematode numbers. This was followed by water hyacinth compost (*Eichhornia crassipes*), mustard straw, and rice husk and asparagus compost applied at 25 q /ha.

Singh *et al.* (2001) studied the efficacy of neem cake and /or Carbofuran for management of disease complex caused by *Fusarium oxysporum* and *Meloidogyne incognita* on cowpea and found that application of both neem cake and carbofuran, in general, significantly increased plant growth and reduced nematode multiplication.

Hossain *et al.* (2003) conducted an experiment to determine the efficacy of pre plant soil treatment with a nematicide and organic amendments to the soil for the management of root-knot nematodes (*Meloidogyne sp.*) of aubergines (eggplant) in Jamalpur, Bangladesh. Among the treatments, Furadan 5G supplemented with poultry refuse gave the best result in reducing root-knot disease and to improve plant growth and fruit yield of aubergine (eggplant).

2.6.3 Management through grafting with wild *Solanum spp.*

It is revealed from the review that fusarium wilt, bacterial wilt and root-knot nematodes caused severe damage to eggplant, the cultivated variety of *Solanum* are particularly susceptible to these diseases. However, few wild *Solanum spp.* were found resistant to these diseases. Grafting of eggplant varieties on resistant *Solanum* rootstock has been suggested to overcome these diseases.

Yamakawa and Mochizuki (1978) investigated native and introduced eggplant cultivars and their related wild *Solanum* species for their resistance to Fusarium wilt by inoculation of young seedlings and reported that among eggplant cultivars tested, differences were observed in incidence and symptom severity, but none were completely resistant. Wild *Solanum* species were completely resistant except *S. insanum* which segregated into both resistant and susceptible individuals.

Mochizuki and Yamakawa (1979b) 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*.

Shethy and Reddy (1985) were evaluated four species of *Solanum* namely, *S. torvum*, *S. indicum*, *S. seaforthiaonum* and *S. mammosum* and 10 strains of *S. khasianum* and wild *S. khasianum* 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). *S. torvum* and *S. seaforthianum* showed resistant reaction and the rest susceptible reaction to the nematode.

Islam (1992) reported that, 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 and it was reported that *S. siysmbriifolium*, was found as resistant, *S. indicum* and *S. suranttentse* as susceptible and *S. integrifiolium*, *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.

Ali (1993) reported that, seedlings of different tomato and eggplant cultivars at the age of 30 and 45 days, respectively were grafted on seedlings of *Solanum sisymbriifolium,* and on a *Solanum* amphidiploid of about 70 days old to exploit soil borne disease resistance, Generally, 70 to 95% grafting success rate was observed. Grafting plants produce many fold higher yield then non grafted ones. Death rate and virus infection is very high in non-grafted plant as compared to the grafted populations. He also reported that, *Solanum ferox, S. gilo, S. indicum, S. integrifolium, S. khasianum, S. mammosum, S. sisymbriifolium, S. surattense, S. torvum* and *S. toxicarium* show resistant reaction against Fusarium wilt, where *Solanum ferox, S. khasianum, S. sisymbriifolium S. torvum* and *S. toxicarium* show resistant reaction against root knot nematode. *S. sisymbriifolium S. torvum and S. toxicarium* was found highly resistant to bacterial, fusarial and nemic wilt of tomato and eggplant.

Akther (1994) reported that, grafting with *S. torvum, S. indicum, S. sisymbriifolium, S. toxicarum* show resistance to *Meloidogyne incognita*. At 30 days after inoculation of 1000 freshly hatched larvae of *M. incognita*, maximum 95.34 gall/g root were recorded from non-grafted plant where 0.05-3.00 gall/g root were found in grafted plant by wild *Solanum*. In case of bacterial wilt of eggplant, death rate of plant reduced to 20.69% and 10.34% when "Utttara" was grafted on *S. sisymbriifolium* and *S. torvum*, respectively. But 90% of plants died within 3 month of transplanting in non-grafted Uttara due to bacterial wilt.

Rahman (2000) observed grafting compatibility of eggplant varieties with wild *Solanum* root-stocks. Six wild *Solanum* root-stocks namely, *Solanum sisymbriifolium , S. torvum, S. indicum, S. sanitwonsci, S. integrifolium* and *S. khasianum* were screened against bacterial wilt (*Ralstonia solanacearum*) and root-knot nematode (*Meloidogyne incognita*). The root stocks *Solanum sisymbriifolium* and *S. torvum* showed resistant reaction against both the diseases in field condition.

Some wild species of *Solanum* and many close relatives of eggplant and some of there amphidiploids have been found partial to complete resistant to soil borne diseases like bacterial wilt and root-knot nematode (Mochizuki and Yamakawa, 1979a; McCammon and Honma, 1983; Ozaki, 1985; Ali *et al.*, 1990a, 1990b, 1992).

2.6.4 Management through organic soil amendments

To control soil borne diseases of crops with organic amendments are relatively a recent and ecofriendly innovation. Some important literature related to the organic amendments of soil to the control soil borne disease especially of root knot disease caused by *Meloidogyne spp.* are reviewed in this chapter.

Singh and Siteramaih (1971) observed that application of sawdust at the rate of 2,200 1bs/acre 3 weeks before planting followed by inorganic nitrogenous fertilizers with P and K at the time of planting, effectively reduced the population of *Meloidogyne javanica* on okra, and increased the yields many-fold. The sawdust amendment also showed residual effects in the next susceptible crop (tomato).

Srivastava *et al.* (1972) conducted a test with oilcakes of neem, castor, linseed, mustard groundnut, sawdust and mahua as organic amendments to the soil to determine their efficacy against *Meloidogyne javanica* on tomato and brinjal, it was found that the sawdust at 1088.44 kg/acre were most effective in reducing the gall formation on the crops.

Sikora *et al.* (1973) found that, after the application of rice husk and sugarcane bagasse (at 3,000 and 6,000 kg / hectare and 2,000 and 4,000 kg/hectare, respectively) without pre-decomposition to field plots 5 weeks before planting, no effect of rice husk on the percentages of roots galled by *Meloidogyne javanica* but it decreased the tomato yield. After 50 days of addition of the amendments rice husk reduced the number of *Meloidogyne* larvas to more than 70% and in 100 to 150 days after planting, the reduction was 90%.

Singh and Siteramaih (1973) found that application of sawdust at the rate of 25 quintals/hectare along with standard NPK fertilizers was cheaper and equally effective in reducing root-knot disease.

Mian and Rodriguez-kabana (1982) studied about the nematicidal efficacy of the soil amendments. 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%.

Bora and Phukan (1983) tested 4 soil amendments (mustard oil cake, poultry manure, sawdust and decaffeinated tea waste) that gave significant reductions of *Meloidogyne incognita* populations on jute. 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 wet weights of shoots and roots.

Mesfin *et al.* (1987) conducted a factorial experiment to determine the effectivity of five control strategies in controlling *Meloidogyne incognita* in kenaf. 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). All the strategies reduced root-knot nematode population, eggmass number per root and root galling based on the comparison with control.

Duhaylongsod (1988) incorporated various organic amendments along the furrows of microplots at the rates of 10 tons/ha in soil infested with *Meloidogyne incognita or Rotylenchulus reniformis.* Fresh chicken dung and composed sawdust caused the most initial and final reductions in *R. reniformis* levels. Rice straw and sawdust also reduces *M. incognita* populations.

Pathak *et al.* (1988) reported that, fresh, chopped, dried and ground leaves and plant parts and compost of water hyacinth (*Eichhornia crassipes*) and dried and ground neem leaves at 30 q/ha were added to pots of aubergines (eggplant) infested with *M. incognita.* All treatment significantly decreased numbers of galls and egg masses.

Hanudin *et al.* (1995) reported that, control of soil borne diseases by organic amendments has been well documented and was effective in controlling Fusarium wilt and Clubroot on water melon and Chinese cabbage, respectively. Organic mixture also effectively suppressed bacterial wilt of tomato.

Rahman *et al.* (2001) stated that, soil amendments, such as incorporation of poultry refuse, mustard-oil cake, neem-oil cake and burning of sawdust were highly effective in controlling soil-borne pathogens in vegetables seedbeds and in main planting fields. These practices reduced the disease include plant mortalities, enhanced plant growth and yields and brought higher economic returns to the farmers. Among the treatments, the use of poultry refuse and mustard-oil cake showed best results.

2.6.5 Management through *Trichoderma harzianum*

2.6.5.1 *Trichoderma spp.* antagonistic to *Fusarium spp.*

Shin *et al.* (1987) reported that of the *Trichoderma spp.* isolates, 60 % were antagonistic to *Fusarium oxysporum.* They observed that normal sesame seedlings on beds treated with antagonist grew better than seedlings in untreated soil.

Moon *et al.* (1988) reported that in dual culture, *T. harzianum* parasitized *F. oxysporum* f. sp. *fragarie* and inhibited mycelial growth. The process of mycoparasitism included coiling round and attachment to host hyphae, penetration into the hypae or breaking the septa of hyphae and conidia.

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

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

Parveen *et al.* (1993) recored that seed treatment with *Trichoderma harzianum* gave complete control of *Fusarium oxysporum* on 30- and 120 – days old tomato plants.

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

Mukhopadhayaya (1995) used *Trichoderma harzianum* for treating various crop seeds like chickpea, lentil, groundnut, tomato and cauliflower for protection against a wide range of soil borne pathogens viz. *Rhizoctonia solani, Sclerospora rolfsii, Pythium spp.* and *Fusarium oxysporum*. The bioagent proliferates on the seed coat of the germinating seeds and colonizes the additional plant parts such as roots and collar region and protect pathogens.

Singh *et al.* (1997) recorded mycoparasitism of *Trichoderma* against the causal agent of chickpea wilt. In sterilized and unsterilized soil inoculated with *Trichoderma harzianum* and *Fusarium oxysporum* f. sp. *ciceri*, 80 and 60% chickpea plants remained healthy respectively. They also observed that the growth of chickpea roots, shoots and leaves was enhanced in the presènce of all antagonists, with maximum growth in soil inoculated with *T. harzianum.*

Kumar *et al.* (1998) reported that *Trichoderma harzianum* as hyperparasite of *F. solani* by forming appressoria like structures over the pathogenic hyphae and tightly coiling around it, with 96 H of contact and with 6 days, the *F. solani* was completely inhibited.

Hamed (1999) reported that the inhibitory effect of 6 *Trichoderma spp.* against *Pythium ultimum* and *Fusarium oxysporum* f. sp. *cucumerinum* was assessed in *vitro* and in *vivo* and found that the isolates of *T. harzianum* suppressed Fusarium wilt by 26.3%.

Pinzon *et al.* (1999) reported that, the antagonism of different isolates of *Trichoderma spp.* was evaluated against *F. oxysporum* isolated. All the isolates of *Trichoderma* evaluated showed antagonism towards *F. oxysporum* f. sp. *dianthi.* It has been possible to obtain promising results by *Trichoderma* where monoculture practiced for more than 15 years were suffering severe losses due to the vascular wilt disease

Bari (2001) observed that, antagonism of *Trichoderma harzianum* against *Rhizoctonia solani* and *Fusarium solani* causing seedling diseases of tomato was found. Seedling mortality of tomato grown in pots caused by *R. solani* and *F. solani* was reduced appreciably by the *T. harzianum* isolates in inoculated pot soil. Fresh weight and dry weight of seedling also improved. Better performance was displayed by the isolate TMG-2 regarding disease control and growth promotion of tomato seedlings.

2.6.5.2 *Trichoderma spp.* antagonistic to *Meloidogyne spp.*

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

Nagesh *et al.* (1998) used *Trichoderma harzianum, T. viride,* neem cake and their combination for the control of Fusarium wilt and root-knot nematode on Gladiolus under glasshouse condition. Result showed that, both *Trichoderma harzianum* and *T. viride* controlled wilt in the presence of *Meloidogyne incognita* for 6 weeks of plant imergence.

Rao *et al.* (1998) reported that *T. harzianum* to nursery beds of aubergine was effective in producing vigorous seedling with the least root galling. The above treatment also increased root colonization and parasitization of *M. incognita* females by *T. harzianum.*

Reddy *et al.* (1998) reported that egg parasitisation was highest when neem cake was integrated with *T. harzianum.*

Spiegel and Chet (1998) were tested different *Trichoderma harzianum* and *T. viride* for their nematicidal activity against the root-knot nematode *Meloidogyne javanica*. In short-term experiments, improved growth of nematode- infected plants and decreases in the root-galling index and the number of eggs per gram of root were achieved when nematode-infested soils were pre-exposed to the *T. harzianum* preparation.

Davila *et al.* (1999) stated that species of *Trichoderma* especially *T. harzianum* which has great potential as bio-control agent for nematode have been found associated with eggs, larvae and females of *Meloidogyne spp.*

Faruk *et al.* (1999) treated soil with six isolated of *Trichoderma sp.* designated as W-108, W-120, W-127 and TB-1 @ 2.5, 5.0, 7.5 and 10.0g and Furadan 5G @ 2.0 g per 4 kg soil to evaluate their efficacy in suppressing root-knot (*Meloidogyne spp.*) of tomato. All the *Trichoderma* isolates and Furadan significantly reduced severity of gall and increased plant growth over control. The efficacy of Furadan to suppress root-knot was lower then *Trichoderma* isolates.

Bari (2001) observed that , seven isolates of *Trichoderma spp.* designated as W-107, W-108, W-120, W-127,TB-1, TK and TY @ each 5.0 and 10.0g per 4kg soil were evaluated to determine their efficacy on suppressing root-knot (*Meloidogyne spp.*) of brinjal. All *Trichoderma* isolates significantly reduced severity of gall and increased plant growth over control. In case of shoot and root weight, no significant variation was observed among the treatments.

Siddiqua (2003) used *Trichoderma harzianum* as bio agent and Furadan 5G as soil treatment against root-knot nematode (*Meloidogyne javanica*) and wilt fungus (*Fusarium solani*) of chilli. Both are significantly increased plant growth and suppressed nematodes by galling and wilt incidence. But better response was found with *T. harzianum* compared to Furadan 5G.

Chapter 3

MATERIALS AND METHODS

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3.1 Experimental site

The experiment was conducted in the Field of SAU (Sher-e-Bangla Agricultural University) farm allotted for the Department of Plant Pathology, Sher-e-Bangla Agricultural University, Dhaka-1207 (Plate 9).

3.2 Experimental period

The experiment was carried out during the period form September 2005 to April 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 is sited below:-

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 and is presented below (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).

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- 3.

3.6 Variety used

Eggplant variety Luffa-S (oblong) was used for the experiment.

3.7 Collection of seeds

Healthy, matured and disease free seeds of eggplant variety Luffa-S (oblong) were collected from Sherpur district on the first week of September. Ten grams (10g) of healthy seeds were collected.

3.8 Treatments of the experiment

In this study eight (8) treatments were used as designated by T_1, T_2, T_3, T_4, T_5, T_6, T_7, and T_8 which were as follows:-

T_1 = Grafting (using *Solanum sisymbriifolium* as a root-stock)

T_2 = Furadan 5G to control of soilborne pathogen

T_3 = Cupravit 50 WP for seedling root dressing and soil drenching.

T_4 = Bavistin 50 WP for seedling root dressing and soil drenching.

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

T_6= Soil amendment with sawdust.

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

T_8= Control.

3.9 Collection of test materials

Seeds of wild *Solanum* (*Solanum sisymbriifolium)* were collected from SAU campus of Dhaka. Furadan 5G, Bavistin 50wp, and Cupravit 50wp were purchased from the market. *Trichoderma harzianum* T_{22} collected from culture stock of MS laboratory, Department of Plant Pathology, Sher-e-Bangla Agricultural University, Dhaka. Sawdust was collected from the Mohammadpur Sawmills and Khudepana was collected from the pond of SAU campus.

3.10 Land preparation

The land was firstly ploughed with a power tiller and prepared using well decomposed cowdung in the first week of November 2005 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. The soil was also pulverized by several spading. After each ploughing weeds and rubbish were removed to obtain desirable tilth. Finally spade (Kodal) was used to prepare plots and drains.,

3.11 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, 1997).

Fertilizers and manures used in the experimental field

Fertilizers and manures	Rate (Kg / ha)
Urea	130.00
TSP	125.00
MP	100.00
Cowdung	10,000.00

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.

3.12 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 unit 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. Plant to plant distance was maintained 75 cm respectively and each unit plot contained five plants (Appendix 4).

3.13 Raising of seedlings

Plastic trays were taken and filled up with fertile soil. Weeds and other rubbish were removed carefully from the soil. Then the seeds of eggplant cultivar (Luffa-S) were treated with Vitavax-200 (0.2%). Seeds were sown in plastic trays containing sterilized sandy soil on 18th November' 2005. Seeds were sown in parallel line on the surface level of the seedbed making about 2 cm. line depth and then a very thin cover was made with sandy soil. Four trays were taken for raising of seedlings. Seedlings were observed regularly and watering was done as per necessity upto transplanting in the field (Plate 1).

3.14 Grafting

3.14.1 Raising of rootstock seedling (wild *Solanum*)

Seed of wild Solanum (*Solanum sisymbriifolium)* were sown in plastic tray containing sterilized sandy soil on 18th October' 2005. Seedling were transferred to 9 cm polyethylene bag containing a medium of soil and well decomposed cowdung of equal proportion on 25th November'2005. Old seeds is better to avoid seed dormancy. After 60-70 days of sowing the rootstock seedling were ready for grafting with cultivar Luffa-S (Plate 2).

3.14.2 Grafting procedure

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

1. Roots of uprooted eggplant 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 eggplant) 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 or polyethylene stripe.

3.14.3 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 (Plate 4). 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 about 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 seedling was transplanted in the main field on 16th January' 2006.

3.15 Application of sawdust

Sawdust was applied @ 5 kg / plot to the soil in specific plots at 20 days before transplanting and was mixed properly with the soil by spading at a depth of 4-6 inches. A mixture of Mango, Garjan, Shegun, Gamari, Teak chambal and Sheel Khoroi sawdust was used.

3.16 Application of khudepana

Fresh khudepana @ 10 kg / plot was applied to the soil in specific plots at 20days before transplanting and were mixed with the soil by spading at a depth of 4-6 inches.

3.17 Application of Furadan 5G in soil

Furadan 5G was applied in the soil during transplantion 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 details of Furadan 5G is given below:-

Details of Nematicide

Trade name	Chemical name	Active ingredient	Mode of action
Furadan 5G	Carbamic acid, methyl-2,3-dihydro-2,2-dimethyl-7-benzofuranyl ester	Carbofuran	Systemic

(Rashid, 2000)

3.18 Preparation and application of fungicide

Fungicidal solutions were prepared by dissolving required amount of fungicide in water. Then the seedlings root dressing were done by dipping in fungicides solution and also soil drenching done in the assign plots after transplanting.

Details of Fungicides

Trade name	Chemical name	Active ingredient	Mode of action	Conc. (ppm)/(μg/ml) used
Bavistin 50wp	Methyl -2- Benzimidazole Carbamate	Carbendazim	Systemic	50, 100
Cupravit 50wp	Copper Oxychloride ($CuOCl_2$)	Copper Oxychloride	Contact	50, 100

(Rashid, 2000)

3.19 Multiplication of *Trichoderma harzianum* T_{22} and application in soil

Trichoderma harzianum T_{22} was collected from the MS laboratory of the Department of Plant Pathology, SAU, Dhaka and multiplied in PDA (Potato Dextrose Agar) medium (Plate 5, Appendix. 2). 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 @ 1 Lt/plot with the help of compressed air hand sprayer following pulverized the soil to mix up the *Trichoderma harzianum* T_{22} spores thought to the soil.

3.20 Transplantation of seedling

After preparation of main field 45 days old seedling were uprooted from the seedbed and transplanted in the experimental plots on the 16th January' 2006 in the afternoon of the same day. Two hour before transplanting the seedlings was watered before removing the seedlings from the pots to minimize root damage. Plant to plant distance was maintained 75cm and each plot contain five plants. A sufficient irrigation was given just after transplantation with the help of a bucket sprinkler. For keeping seedlings upright, support with bamboo sticks were provided. One seedling was placed in a pit. The transplanted seedlings were protected from the sunlight, shading with banana leaf sheath cuttings. Shading and watering was continued till the seedlings were established in the field. The grafted seedling also transplanted in the field at the same time.

3.21 Intercultural operations

After transplantation gap filling was done in case any seedling died. In 15 to 20 days after planting (DAP) weeding was done which followed split doze fertilizer application. First split application of fertilizer was done on the 5^{th} February' 2006 and the second split application was done on the 25 February' 2006 as treatment of double dose nitrogenous fertilizer. After weeding and fertilizer application flood 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. Insects were controlled as and when necessary by spraying insecticides named Aaktara and Malathion @ 0.2%.

3.22 Preparation of spore suspension of *Fusarium oxysporum* f. sp. *melongenae* and inoculation

Fusarium oxysporum f. sp. *melongenae* grown on PDA (Potato Dextrose Agar) medium at 25^0C temperature. After sporulation (in about 15-20 days), 5 ml sterile water was added in each plate and the spore masses was scraped away with sterile needle / scalpel. The conidial suspension thus made with additional water was then blended in a Moulinex blender for 2 minutes in medium speed and filtered through sterile cheesecloth, adjusted the concentration 1.2 X 10^7 conidia / ml solution. Then, inoculation done at the root zone of plant by drenching of spore suspension @ 250ml / plant with the help of compressed air hand sprayer following pulverized the soil to mix up the *Fusarium oxysporum* spores thoroughly to the soil. Inoculation done at 30 Days After Transplanting (DAT).

3.23 Isolation and identification of the causal organisms of Fusarium wilt

The experimental plots were inspected routinely to observe the Fusarium wilted plant. To identify the pathogen, the diseased plants were collected from the field and were taken to the laboratory, 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 into PDA media in sterilized Petri dish with help of sterile forceps and incubated were at 25 ± 1^0c for 10-15 days. Later the pathogen was purified using hyphal tip culture method and grown on PDA media at 25 ± 1^0c for 2 weeks. Causal organism was identified under stereobinocular and compound microscopes.

3.24 Data recording and harvesting

Data on incidence of wilts were recorded at 55, 65, 75, 85 and 95 days after transplanting by observation of visual symptoms. The disease incidence was calculated by the following formula:-

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

The following parameters were considered for data collection.

Observations: (Disease incidence)

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

Observations : (Yield and yield contributing characters)

a. Length of shoot (cm)
b. Fresh weight of shoot (g)
c. Length of root (cm)
d. Fresh weight of root (g)
e. Branching / plant
f. Number of fruits / plot
g. Total weight of fruit / plant
h. Total weight of fruit / plot
i. Yield / ha

3.25 Measurement of length of shoot and root, fresh weight of shoot and root and number of branching

For this purpose, the whole plant along with soil attached to its roots was lifted from the soil and dipped in a bucket full of water. Before placing the roots in the bucket a sieve was placed at the bottom of the bucket. Then by gradual to and fro movement of the roots in water, the roots were separated from the soil. Roots were further cleaned in gently running tap water and clinging peat masses were removed with forceps. Any broken root portion collected in the sieve was carefully washed out. The root portion was separated from shoot. The length of the shoot was measured from the base of the stem to the growing point of the youngest leaf. The length of the root was measured from the growing point of root to the longest available lateral root apex. For fresh weight of shoot and root, the portion was blotted dry and the weight was recorded before the materials could get dessicated. The number of primary and secondary branching also counted.

3.26 Counting of nematode galls

After washing, the roots were preserved in 5% formalin solution. For easy observation, the bigger roots were cut into small pieces and individual piece was examined for counting the number of galls formed. The galls were indexed on a 0-4 scale to score galling level as followed by Ahmed (1977b) modified from Daulton and Nusbaum, 1961; Cook, 1972; Fassuliotis, 1973 and Amosu and Franckowiak 1974 as described below:

Galling level index

Scales	Specification	No. of galls
0	No galling	0
1	Light galling	<10
2	Moderate galling	10-50
3	Heavy galling, mostly discrate	50-100
4	Very heavy galling, many coaleasced	>100

3.27 Cost-benefit analysis and calculation of Benefit Cost Ratio (BCR)

Costing of application of management of wilt of eggplant 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 5 & 6). Estimation of Benefit Cost Ratio (BCR) was done according to Gittinger (1982) using the following formula-

$$\text{BCR} = \frac{\text{Gross return (Tk. / ha)}}{\text{Total cost of production (Tk. / ha)}}$$

3.28 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, root length, root weight with galling incidence among the treatments.

Plate 1. Seedlings of eggplant (Luffa-S)

Plate 2. Seedlings of wild Solanum (*Solanum sisymbriifolium*)

Plate 3. Scion and root stock for grafting

Plate 4. Grafted seedlings of eggplant

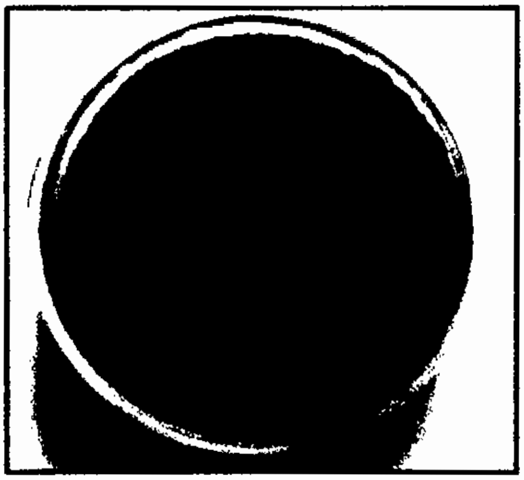


Plate 5. Pure culture of *Trichoderma harzianum* T_{22} on PDA medium

Chapter 4

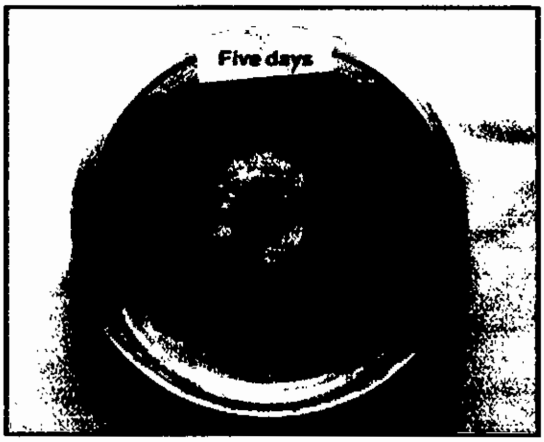
RESULTS

RESULTS

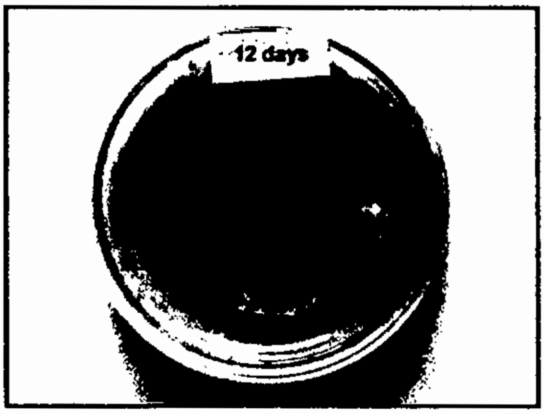
The results obtained from the present study on the effect of eight different treatments viz. grafting with wild *Solanum* (*Solanum sisymbriifolium*), Furadan 5G, Bavistin 50 WP, Cupravit 50 WP, *Trichoderma harzianum* T_{22}, Sawdust, Khudepana and control (un-treated) for the management of Fusarium wilt and Nemic wilt of eggplant were presented in this chapter. The efficacy of the treatments was assessed based on different parameters like wilt incidence, galling incidence, plant growth characters and yield.

4.1. Isolation and identification of causal agent

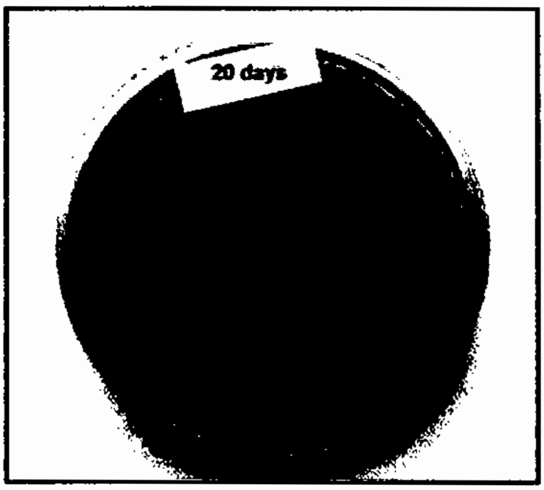
The causal fungus was isolated from stem of infected plant and studied in the laboratory. The fungus was purified and identified as *Fusarium oxysporum* (Roberts and Boothroyd, 1972 and Barnett and Hunter, 1972). In PDA, the fungus grew with whitish mycelium which later developed light gray colour colony due to sporulation (Plate 6). The pathogen produced single cell microconidia and 2- or 3- celled slightly curved macroconidia in pure culture (Plate 7). The nematodes observed in semi permanent slide (prepared from root gall) under microscope were pear shaped surrounded by eggmasses and was identified as *Meloidogyne spp.* (Plate 8).



Five days old culture



Twelve days old culture



Twenty days old culture

Plate 6. Pure culture of *Fusarium oxysporum* f. sp. *melongenae* on PDA medium

Plate 7. Microconidia and macroconidia of *Fusarium oxysporum* (X 400)

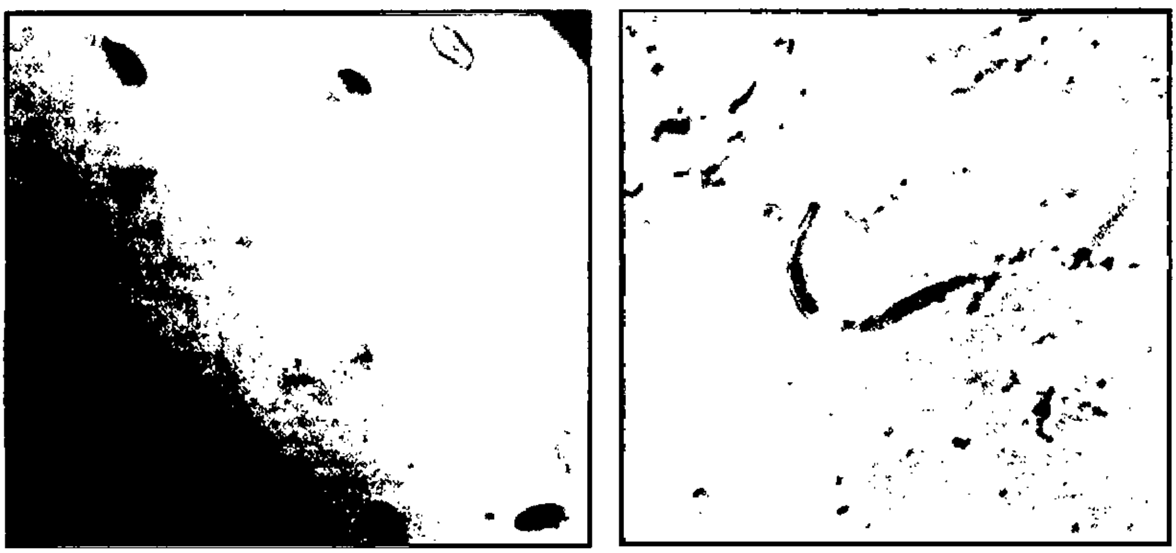


Plate 8. Eggmass and juvenile of *Meloidogyne incognita* in a crush gall of eggplant root (X 400)

4.2. Effect of the treatments on the wilt incidence at 55 Days After Transplanting (DAT) and 25 Days After Inoculation (DAI)

The effect of different treatments in terms of wilt incidences was differed significantly in comparison to control. The treatment effects other than control did not differed significantly among themselves as there were no wilted plant. Wilt incidence was recorded 13.33% in control treatment (Table.1).

4.3. Effect of the treatments on the wilt incidence at 65 Days After Transplanting (DAT) and 35 Days After Inoculation (DAI)

The treatments effect varied significantly for wilt incidence at 65 DAT (Table 2.). No wilt incidence was observed in case of Grafting, Furadan 5G, Bavistin, *Trichoderma harzianum* T_{22}, Sawdust and Khudepana. The highest wilt incidence (26.67 %) was observed in Control treatment which was statistically identical with Cupravit (13.33 %).

4.4. Effect of the treatments on the wilt incidence at 75 Days After Transplanting (DAT) and 45 Days After Inoculation (DAI)

The effect of treatments differed significantly for wilt incidence at 75 DAT which ranged from 0.00 to 60.00% (Table.3). The highest wilt incidence was obtained in Control (60.00%). The second highest wilt incidence was recorded in case of Cupravit and Bavistin (20.00%) treatments. The highest effect of the treatments against wilt disease observed in Grafting, Furadan 5G, *Trichoderma harzianum* T_{22} and Sawdust where no wilt incidence was found and which were statistically simillar with Khudepana.

4.5. Effect of the treatments on the wilt incidence at 85 Days After Transplanting (DAT) and 55 Days After Inoculation (DAI)

Treatments effects were differed significantly in respect of wilt incidence at 85 DAT (Table. 4). Significantly the highest wilt incidence was recorded in Control (73.33%) which was statistically identical with Cupravit (33.33%). The second highest wilt incidence was observed in case of Bavistin (26.67%) that was statistically identical with Khudepana. No wilt incidence was noticed in case of Furadan 5G, Sawdust and *Trichoderma harzianum* T_{22} which was statistically similar with Grafting.

4.6. Effect of the treatments on the wilt incidence at 95 Days After Transplanting (DAT) and 65 Days After Inoculation (DAI)

A remarkable effect was observed among the treatments in controlling wilt disease of eggplant at 95 DAT. The treatments effects were differed significantly in terms of wilt incidence. The highest effect against the disease was observed in case of Furadan 5G and *Trichoderma harzianum* T_{22} where no plant was wilted. The effect of Grafting, Sawdust and Khudepana was also statistically identical with the effect of Furadan 5G and *Trichoderma harzianum* T_{22}. The highest wilt incidence was recorded in Control treatment (93.33%) followed by Cupravit (66.67%) and Bavistin (46.67%) (Table. 5). The treatments effects in terms of wilt incidence recorded from 55 DAT to 95 DAT with 10 days intervals was graphically represented in Fig. 1 (Plate 16).

Table 1. Effect of different treatments on the wilt incidence of eggplant 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 (Cupravit 50 WP)	0.00 (0.71) b
T_4 (Bavistin 50 WP)	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)	13.33 (3.26) a
CV (%)	81.65

* The figures in the parenthesis are the square root transformed value.

Table 2. Effect of different treatments on the wilt incidence of eggplant at 65 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 (Cupravit 50 WP)	13.33 (3.26) a
T_4 (Bavistin 50 WP)	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)	26.67 (5.14) a
CV (%)	53.11

* The figures in the parenthesis are the square root transformed value.

Table 3. Effect of different treatments on the wilt incidence of eggplant 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 (Cupravit 50 WP)	20.00 (4.53) b
T_4 (Bavistin 50 WP)	20.00 (4.53) b
T_5 (*Trichoderma harzianum* T_{22})	0.00 (0.71) c
T_6 (Sawdust)	0.00 (0.71) c
T_7 (Khudepana)	6.67 (1.98) c
T_8 (Control)	60.00 (7.78) a
CV (%)	28.80

* The figures in the parenthesis are the square root transformed value.

Table 4. Effect of different treatments on the wilt incidence of eggplant at 85 Days After Transplanting (DAT)

Treatments	Wilt incidence (%)
T_1 (Grafting)	6.67 (1.98)* c
T_2 (Furadan 5G)	0.00 (0.71) c
T_3 (Cupravit 50 WP)	33.33 (5.75) ab
T_4 (Bavistin 50 WP)	26.67 (5.14) b
T_5 (*Trichoderma harzianum* T_{22})	0.00 (0.71) c
T_6 (Sawdust)	0.00 (0.71) c
T_7 (Khudepana)	13.33 (3.26) bc
T_8 (Control)	73.33 (8.57) a
CV (%)	36.60

* The figures in the parenthesis are the square root transformed value.

Table 5. Effect of different treatments on the wilt incidence of eggplant at 95 Days After Transplanting (DAT)

Treatments	Wilt incidence (%)
T_1 (Grafting)	6.67 (1.98)* b
T_2 (Furadan 5G)	0.00 (0.71) b
T_3 (Cupravit 50 WP)	66.67 (8.05) a
T_4 (Bavistin 50 WP)	46.67 (6.83) a
T_5 (*Trichoderma harzianum* T_{22})	0.00 (0.71) b
T_6 (Sawdust)	6.67 (1.98) b
T_7 (Khudepana)	13.33 (2.59) b
T_8 (Control)	93.33 (9.67) a
CV (%)	41.33

* The figures in the parenthesis are the square root transformed value.

Legend : T1 = Grafting | T2 = Furadan 5G | T3 = Cupravit 50 WP | T4 = Bavistin 50 WP | T5 = *Trichoderma harzianum* T22 | T6 = Sawdust | T7 = Khudepana | T8 = Control

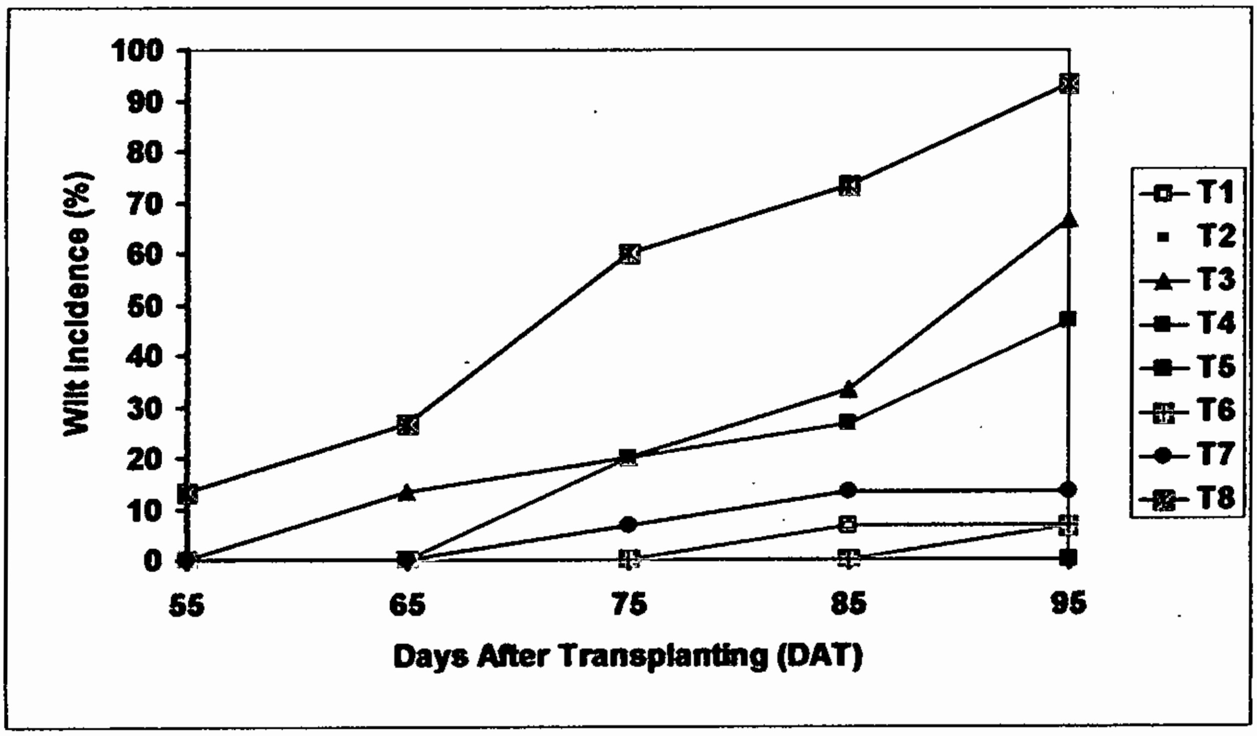


Fig. 1. Effect of different treatments on the disease incidence of wilt of eggplant recorded from 55 DAT to 95 DAT with 10 days intervals

4.7. Effect of different treatments on number of gall formation / plant at 95 Days After Transplanting (DAT)

The treatment effects against gall formation in controlling Nemic wilt was presented in Table 6. The highest effect was observed in case of Furadan 5G and *Trichoderma harzianum* T_{22} where no gall formation was found (indexed as 0). The effect of Grafting, Sawdust and Khudepana was statistically similar to Furadan 5G and *Trichoderma harzianum* T_{22}. The highest gall formation was recorded in control treatment (141.0 galls / plant) followed by Cupravit (79.00 galls / plant) and Bavistin (52.00 galls/ plant). Wilt incidence increased with the increase of number of gall per plant (Fig. 2).

Table 6. Effect of different treatments on number of gall formation per plant of eggplant at 95 Days After Transplanting (DAT)

Treatments	No. of gall / plant	Galling Index
T_1 (Grafting)	2.67 d	1
T_2 (Furadan 5G)	00.00 d	0
T_3 (Cupravit 50 WP)	79.00 b	3
T_4 (Bavistin 50 WP)	52.00 c	3
T_5 (*Trichoderma harzianum* T_{22})	00.00 d	0
T_6 (Sawdust)	3.00 d	1
T_7 (Khudepana)	9.00 d	1
T_8 (Control)	141.00 a	4
CV (%)	17.20	

Legend : T_1 = Grafting T_2 = Furadan 5G T_3 = Cupravit 50 WP T_4 = Bavistin 50 WP T_5 = *Trichoderma harzianum* T_{22} T_6 = Sawdust T_7 = Khudepana T_8 = Control

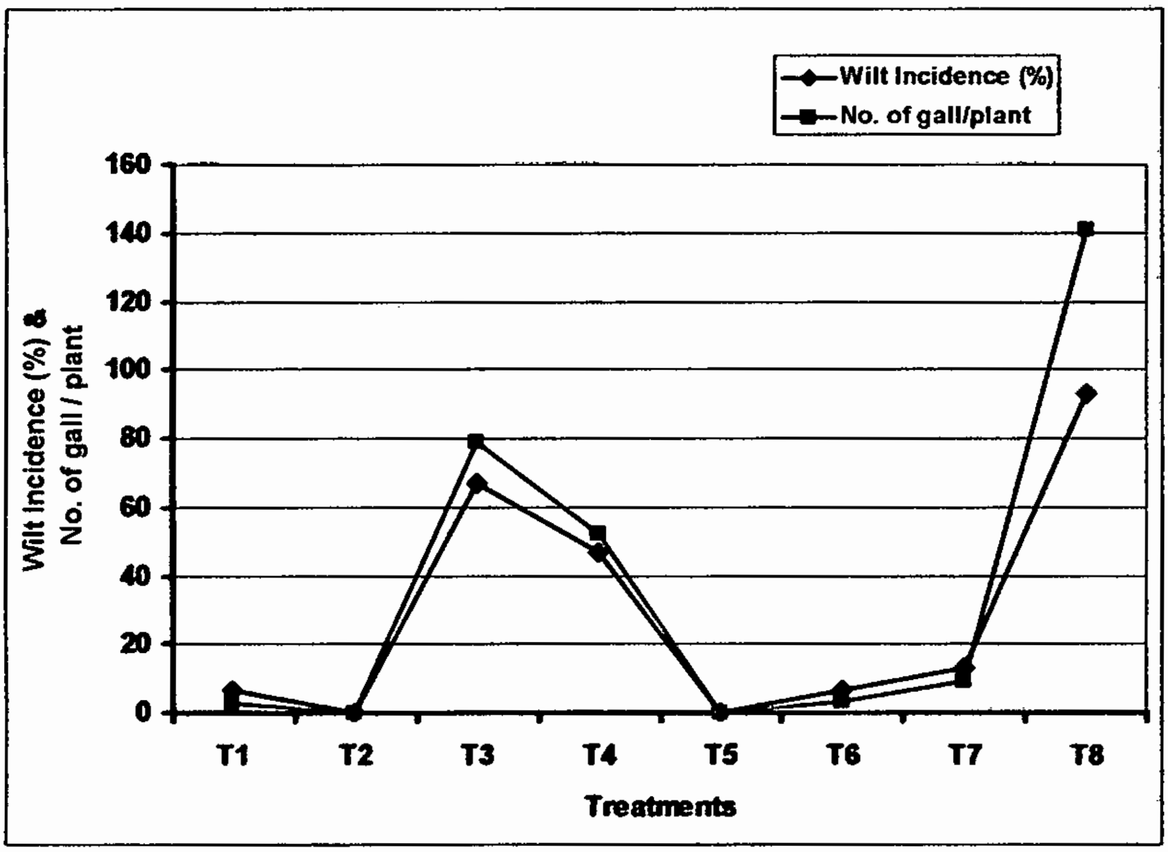


Fig. 2. Showing the increase of wilt incidence with the increase of number of gall per plant in different treatments at 95 DAT

4.8. Effect of the treatments on different plant growth characters of eggplant at 95 Days After Transplanting (DAT)

The effect of the treatments on growth characters of eggplant viz. length of shoot, fresh weight of shoot, length of root, fresh weight of root and branching per plant studied in respect of controlling Fusarium wilt and Nemic wilt were presented in Table. 7 (Plate 10, 11, 12, 13, 14 and 15).

In case of length of shoot, the highest shoot length (139.4 cm) was observed in case of soil amendment with Sawdust whereas the lowest shoot length was recorded in the Control treatment (85.60 cm). The shoot length in case of application of Furadan 5G, Grafting, *Trichoderma harzianum* T_{22}, Khudepana and Bavistin were also statistically identical with Sawdust. It was observed that sawdust and Furadun 5G gave good growth performance among the treatments (Table 7).

The highest fresh weight of shoot (1328 g / plant) was recorded in case of soil amendment with Sawdust which was statistically simillar to that of Furadan 5G, *Trichoderma harzianum* T_{22}, Grafting and Khudepana. The lowest shoot weight (286.7 g / plant) was recorded in the Control treatment preceeded by Cupravit (683.3 g / plant), Bavistin (856.7 g / plant) and Khudepana (1060.0 g / plant). It was noted that, soil amendment, bio-agent and grafting increase fresh weight of shoot in respect of wilt and gall incidence (Table. 7).

In terms of length of root, treatments effect differed significantly among themselves. Maximum root length per plant was observed in case of application of Furadan 5G (47.13 cm) which was statistically identical with Sawdust (47.00 cm), *Trichoderma harzianum* T_{22} (46.40 cm) and Grafting (45.80 cm). The lowest root length per plant (29.40cm) was recorded in Control followed by Cupravit, Bavistin and Khudepana (Table. 7).

Considering fresh weight of root per plant, the highest root weight was observed in the case of Sawdust (135.3 g) that was statistically identical with Furadan 5G, *Trichoderma harzianum* T_{22}, Grafting and Khudepana. The lowest root weight (63.33 g) was recorded in the Control treatment which was also statistically simillar with Cupravit and Bavistin (Table. 7). The result showed that soil amendment, bio-agent and grafting increase fresh weight of root in comparison to control.

The highest branching was observed in case of soil amendment with Sawdust (16.20) that was statistically alike with *Trichoderma harzianum* T_{22}, Furadan 5G, and Grafting. The lowest branching per plant was recorded in Control treatment (10.07) followed by Cupravit and Bavistin (Table 7).

Table 7. Effect of different treatments on the plant growth parameters of eggplant at 95 Days After Transplanting (DAT)

Treatments	Length of shoot (cm)	Fresh weight of shoot (g)	Length of root (cm)	Fresh weight of root (g)	No. of branching /plant
T_1 (Grafting)	132.9 ab	1127.0 ab	45.80 a	121.3 a	15.13 ab
T_2 (Furadan 5G)	137.9 a	1317.0 a	47.13 a	130.0 a	15.47 ab
T_3 (Cupravit 50 WP)	110.5 b	683.3 c	31.13 b	86.67 b	11.53 cd
T_4 (Bavistin 50 WP)	118.1 ab	856.7 bc	38.53 ab	82.67 b	12.20 c
T_5 (*Trichoderma harzianum*)	132.1 ab	1306.0 a	46.40 a	124.3 a	15.53 ab
T_6 (Sawdust)	139.4 a	1328.0 a	47.00 a	135.3 a	16.20 a
T_7 (Khudepana)	131.7 ab	1060.0abc	41.67 ab	112.7 a	14.20 b
T_8 (Control)	85.60 c	286.7 d	29.40 b	63.33 b	10.07 d
CV(%)	8.14	14.99	11.72	9.27	4.93

4.9. Effect of different treatments on the fruit yield of eggplant against wilt disease

The yield of eggplant differed significantly among the treatments against wilt disease ranged from 17.33 to 2.40 t/ha (Table 8). The highest fruit yield (17.33 t/ha) was obtained in case of application of Sawdust that was statistically identical with the application of Furadan 5G (16.93 t/ha). The lowest fruit yield was recorded in Control (2.40 t/ha) preceeded by Cupravit, Bavistin and Khudepana. *Trichoderma harzianum* T_{22} and Grafting also showed better performance in comparison to other treatments against Fusarium and Nemic wilt.

4.9.1 Effect of different treatments on yield increased over control (%)

The maximum fruit yield was increased over control in case of the treatment Sawdust (622.08%) followed by Furadan 5G (605.54%), *Trichoderma harzianum* T_{22} (526.25%) and Grafting (501.67%). Chemical fungicides Cupravit showed lowest (274.16%) performance preceeded by Bavistin (324.17%) (Table.8).

Table 8. Effect of different treatments on fruit yield of eggplant against Fusarium and Nemic wilt

Treatments	Yield/plant (g)	Yield (t/ha)	Yield increased over control (%)
T_1 (Grafting)	1083.0 b	14.44 b	501.67
T_2 (Furadan 5G)	1270.0 a	16.93 a	605.54
T_3 (Cupravit 50 WP)	673.3 e	8.98 e	274.16
T_4 (Bavistin 50 WP)	763.3 d	10.18 d	324.17
T_5 (*Trichoderma harzianum* T_{22})	1127.0 b	15.03 b	526.25
T_6 (Sawdust)	1300.0 a	17.33 a	622.08
T_7 (Khudepana)	923.3 c	12.31 c	412.92
T_8 (Control)	180.0 f	2.40 f	----
CV (%)	3.15	3.15	---

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

Cost- benefit analysis of different treatments was done (Appendix 5 & 6) and shown in Table 9. The highest gross margin 131754 Tk./ ha was obtained in Sawdust application followed by Furadan 5G (125054 Tk./ ha) and *Trichoderma harzianum* T_{22} (111004 Tk./ ha). The negative gross margin (-10546 Tk./ ha) was recorded in control treatment where total cost is greater than the gross return. Grafting (98754 Tk./ ha) and Khudepana (81554 Tk./ ha) gave comparatively higher gross margin than chemical fungicides.

Table 9. Cost-benefit analysis of eight (8) different treatments for controlling Fusarium and Nemic wilt of eggplant (Laffa-S)

Treatments	Average Yield (t/ha)	Gross Return (Tk./ha)	Total cost (Tk./ha)	Gross margin (Tk./ha)	Increases of gross margin over control (Tk./ha)
T_1 (Grafting)	14.44	144400	34546 +11100 =45646 (a +b)*	98754	109300
T_2 (Furadan 5G)	16.93	169300	34546 + 9700 = 44246 (a + c)	125054	135600
T_3 (Cupravit 50 WP)	8.98	89800	34546 + 9400 = 43946 (a + d)	45854	56400
T_4 (Bavistin 50 WP)	10.18	101800	34546 + 7330 = 41876 (a + e)	59924	70470
T_5 (*Trichoderma sp.*)	15.03	150300	34546 + 4750 = 39296 (a + f)	111004	121550
T_6 (Sawdust)	17.33	173300	34546 + 7000 = 41546 (a + g)	131754	142300
T_7 (Khudepana)	12.31	123100	34546 +7000 = 41546	81554	92100
T_8 (Control)	2.40	24000	34546 (a + h)	-10546	------

* Information cited in the appendix 5 and 6.

4.10.1 Benefit Cost Ratio (BCR)

Benefit Cost Ratio for all the treatments was estimated and shown in Table 10. Estimation showed that application of sawdust for soil amendment gave the highest BCR (4.17) then the other treatments, where Tk. 4.17 could be earned investing Tk. 1.00. The second highest BCR (3.83) estimated in case of application of Furadan 5G and bio-agent *Trichoderma harzianum* T_{22} whereas the lowest BCR (0.70) observed in Control treatment. Benefit Cost Ratio was estimated 3.16, 2.96, 2.43 and 2.04, respectively for the treatments Grafting, Khudepana, Bavistin and Cupravit in comparison to control.

Table 10. Benefit Cost Ratio (BCR) of eight (8) different treatments for controlling Fusarium and Nemic wilt of eggplant (Laffa-S)

Treatments	Yield (t/ha)	Gross return (Tk./ha)	Total cost (Tk./ha)	Gross margin (Tk./ha)	BCR
T_1 (Grafting)	14.44	144400	34546 +11100 = 45646 (a + b)*	98754	3.16
T_2 (Furadan 5G)	16.93	169300	34546 + 9700 = 44246 (a + c)	125054	3.83
T_3 (Cupravit 50 WP)	8.98	89800	34546 + 9400 = 43946 (a + d)	45854	2.04
T_4 (Bavistin 50 WP)	10.18	101800	34546 + 7330 = 41876 (a + e)	59924	2.43
T_5 (*Trichoderma sp.*)	15.03	150300	34546 + 4750 = 39296 (a + f)	111004	3.83
T_6 (Sawdust)	17.33	173300	34546 + 7000 = 41546 (a + g)	131754	4.17
T_7 (Khudepana)	12.31	123100	34546 +7000 = 41546	81554	2.96
T_8 (Control)	2.40	24000	34546 (a + h)	-10546	0.70

* Information cited in the appendix 5 and 6.

4.11 CORRELATION AND REGERSSION STUDY

4.11.1 Correlation and regression study between growth parameters and gall formation

Correlation study was done to determine the relationship between number of galls / plant and shoot and root length; fresh shoot and root weight. From the study it was revealed that significant and negative correlations were existing betweens gall number and shoot length (Fig. 3), gall number and fresh shoot weight (Fig. 4), gall number and root length (Fig. 5), gall number and fresh root weight (Fig. 6) where the regression equations were $y = -0.3492x + 136.04$ ($R^2 = 0.9783$), $y = -6.9658x + 1245.2$ ($R^2 = 0.9517$), $y = -0.1326x + 45.634$ ($R^2 = 0.9005$) and $y = -0.4753x + 124.06$ ($R^2 = 0.8816$), respectively. The galling incidence hampered the crop growth in terms of shoot and root length along with shoot and root weight. Increases of gall number significantly reduced shoot and root length as well as shoot and root weight of plant. Treatment T_2 (Furadan 5G) and T_5 (*Trichoderma harzianum* T_{22}) gave highest response and T_1 (Grafting), T_6 (Sawdust) and T_7 (Khudepana) also gave moderate response in contributing the growth characters of eggplant by suppressing the nematode activities as evident with lower galling incidence.

4.11.2 Correlation and regression study between different DAT with wilt incidence and number of galls per plant with wilt incidence

Another correlation study was done to determine the relationship between different Days After Transplanting (DAT) with wilt incidence and number of gall / plant with wilt incidence of eggplant. Result showed that significant and positive correlation existed betweens different Days After Transplanting (DAT) with Disease incidence of wilt and number of gall / plant with wilt incidence (%) of eggplant (Fig. 7 and 8). Wilt incidence was increased with the increase of days after transplanting and number of gall / plant.

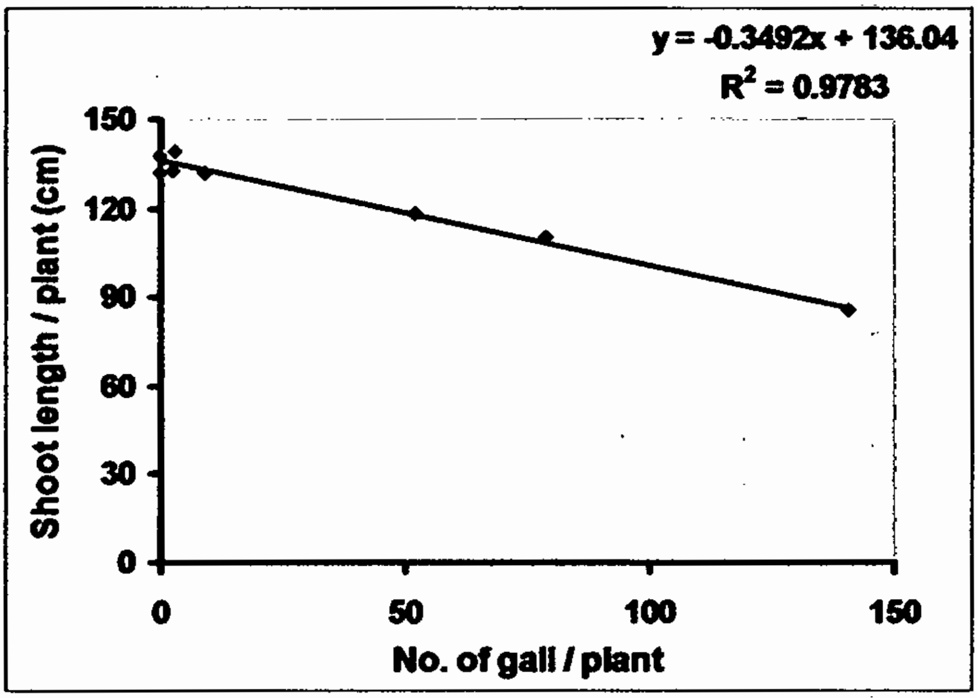


Fig. 3. Relationship between gall number and shoot length (cm) per plant in relation to wilt incidence of eggplant at 95 Days After Transplanting (DAT)

number of gall / plant with wilt incidence of eggplant. Result showed that significant and positive correlation existed betweens different Days After Transplanting (DAT) with Disease incidence of wilt and number of gall / plant with wilt incidence (%) of eggplant (Fig. 7 and 8). Wilt incidence was increased with the increase of days after transplanting and number of gall / plant.

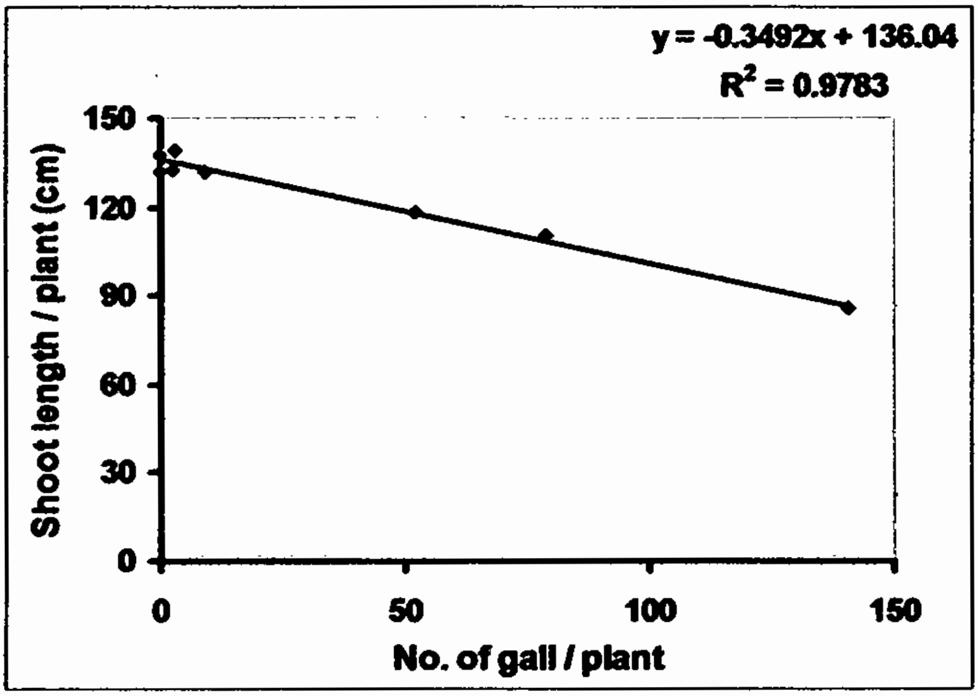


Fig. 3. Relationship between gall number and shoot length (cm) per plant in relation to wilt incidence of eggplant at 95 Days After Transplanting (DAT)

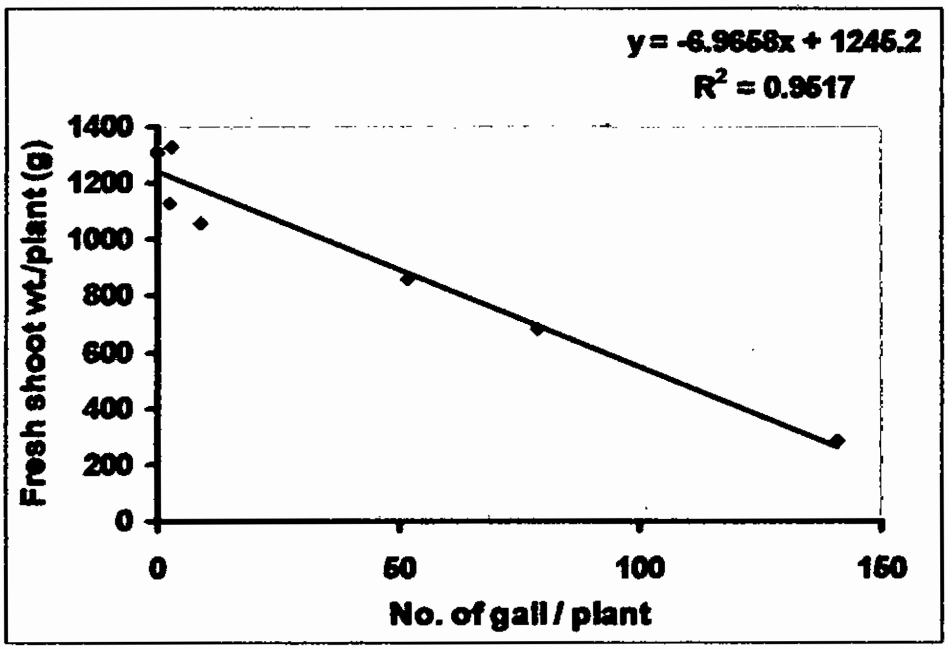


Fig. 4. Relationship between gall number and fresh shoot weight (g) per plant in relation to wilt incidence of eggplant at 95 Days After Transplanting (DAT)

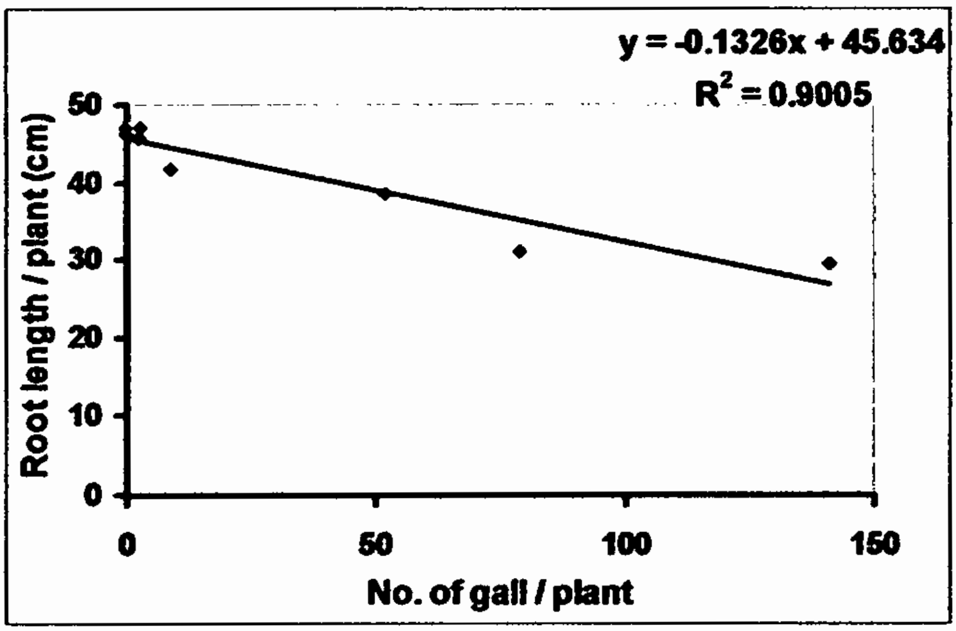


Fig. 5. Relationship between gall number and root length (cm) per plant in relation to wilt incidence of eggplant at 95 Days After Transplanting (DAT)

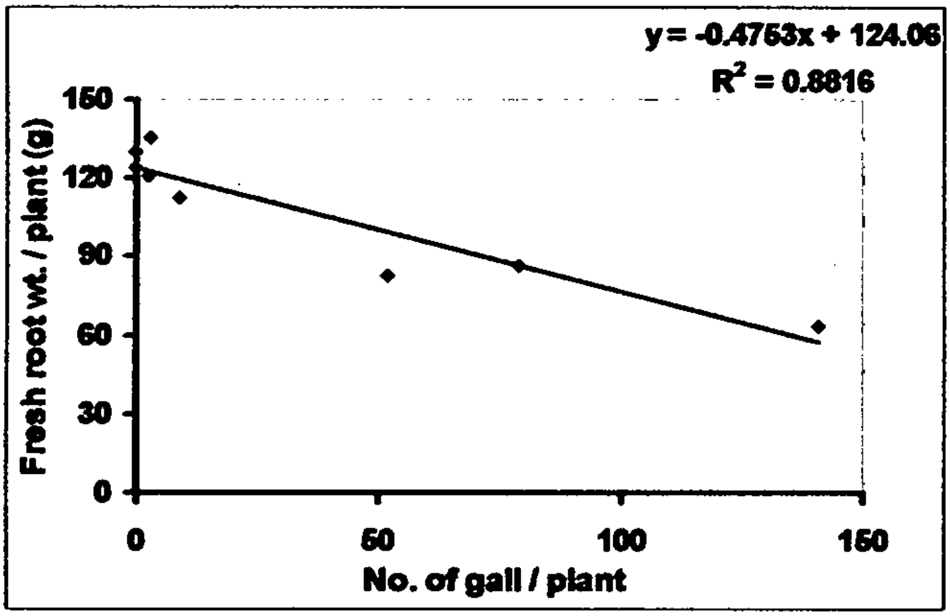


Fig. 6. Relationship between gall number and fresh root weight (g) per plant in relation to wilt incidence of eggplant at 95 Days After Transplanting (DAT)

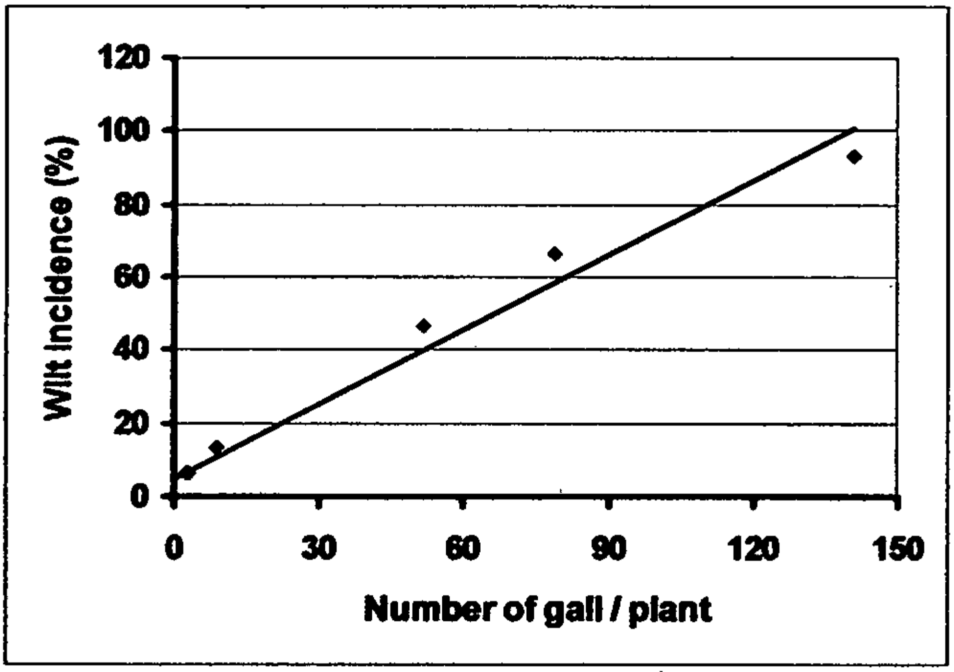


Fig. 7. Relationship between number of gall / plant and wilt incidence of eggplant at 95 Days After Transplanting (DAT)

Legend : T_1 = Grafting
T_2 = Furadan 5G
T_3 = Cupravit 50 WP
T_4 = Bavistin 50 WP
T_5 = *Trichoderma harzianum* T_{22}
T_6 = Sawdust
T_7 = Khudepana
T_8 = Control

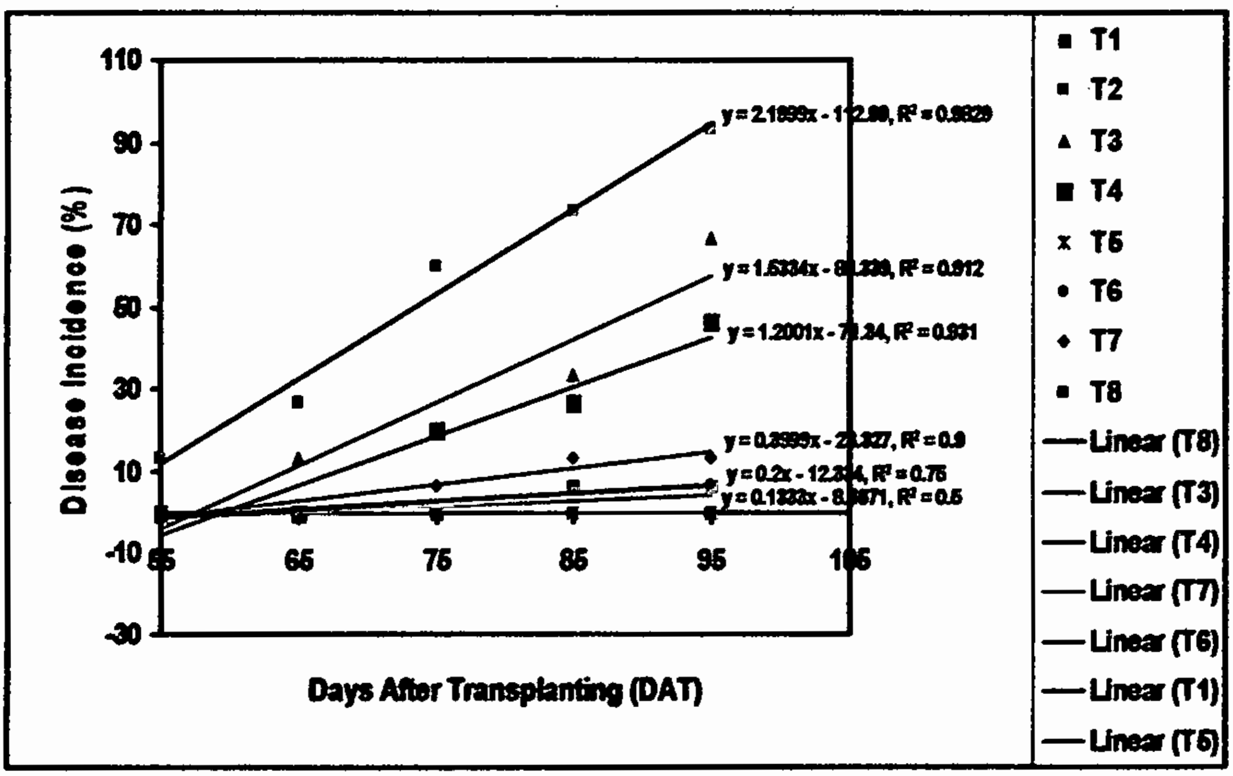


Fig. 8. Relationship between different Days After Transplanting (DAT) with Disease incidence of wilt of eggplant

Plate 9. View of the experimental field

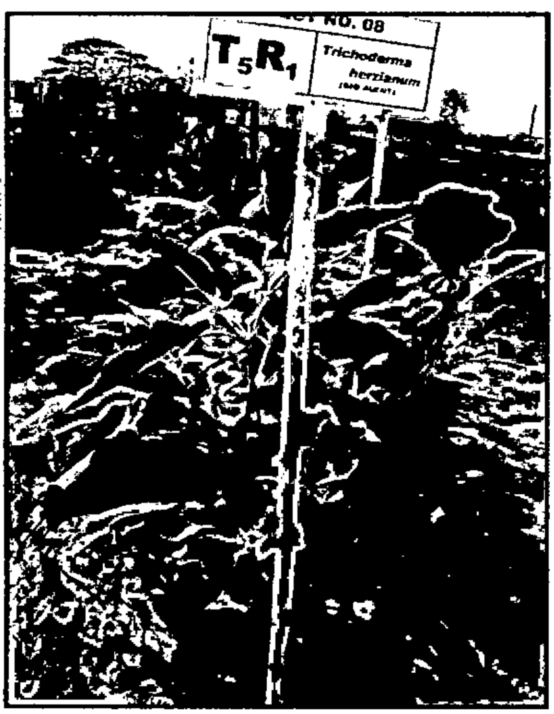


Plate 10. *Trichoderma harzianum* treated plot

Plate 11. Khudepana treated plot

Plate 12. Vigorous growth of Sawdust treated plot

Plate 13. Furadan 5G treated plot

Plate 14. Plot of grafted eggplant

Plate 15. Mature grafted eggplant showing root stock and scion

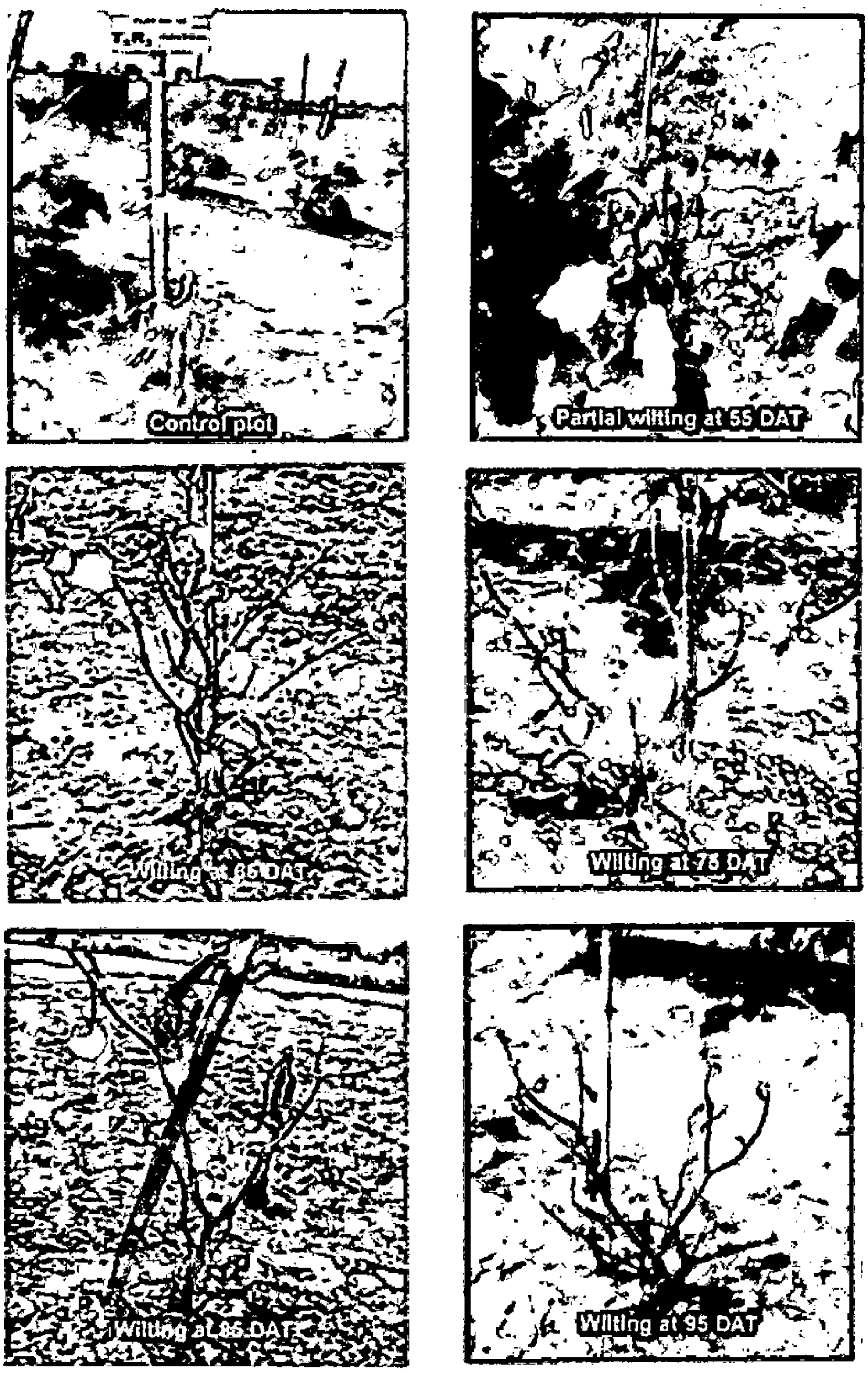


Plate 16. Reaction of eggplant in control plot to Fusarium and Nemic wilt at different DAT

Chapter 5

DISCUSSION

DISCUSSION

DISCUSSION

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

5.1 Effect of soil amendment with Sawdust and Khudepana against wilt disease

It is revealed from the experimental findings recorded for the soil application of sawdust and khudepana (*Azzola pinnata*) at different days after transplantation showed that sawdust had remarkable effect against wilt pathogen in reducing wilt incidence and gall incidence with increasing fruit yield and the growth parameters. No wilt incidence as well as root gall formation was noticed even at 65 days after transplanting. Very negligible wilt incidence and gall formation was observed at 75, 85 and 95 days after transplanting which had a minor effect on yield and yield contributing characters. Growth parameters of the plant like shoot length, root length, fresh 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 (Mesfin *et al.,* 1987; Bora and Phukan , 1983 and Srivastava *et al.*, 1972) . Bora and phukan (1983) found that application of Sawdust for soil amendment significantly reduced the population of *Meloidogyne incognita* in jute. Mesfin *et al.* (1987) observed the remarkable effect of Sawdust against *Meloidogyne incognita* on potted kenaf. Srivastava *et al.* (1972) reported that, Sawdust at 1088.44 kg / acre was most effective than different oilcakes against *Meloidogyne javanica* in reducing the gall formation on the tomato.

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 pathogen

Among the chemicals viz. Furadan 5G, Bavistin 50 WP and Cupravit 50WP, Furadan 5G had a promising effect in controlling the wilt pathogens. It is observed from the experimental findings that no wilt incidence and also root gall formation was noticed even at 95 Days After Transplanting (DAT) for the application of Furadan 5G as soil application surrounding the root zone. The growth performance like shoot and root length as well as shoot and root weight and branching of plant were positively influenced by the application of Furadan that contribute a good harvest compare to other chemicals and control. The performance of Bavistin in controlling wilt incidence and gall formation was not upto the mark like Furadan but far better than Cupravit and Control. The present findings are keep in with the findings of Hossain *et al.* (2003); Singh *et al.* (2001); Nanjegowda *et al.* (1998); Devappa *et al.* (1997) and Hasan (1995) who reported Furadan 5G

(Carbofuran) as the most effective chemicals in controlling *Meloidogyne incognita* and *Meloidogyne javanica* causing wilt disease of eggplant.

The literature in favour of Bavistin in controlling Fusarium wilt caused by *Fusarium oxysporum* f. sp. *melongenae* were also available in the previous research report. A very few report were found in favour of Cupravit in controlling Fusarium wilt. Ramesh and Manjunath (2002) was observed maximum wilt infection in the eggplant plots treated with Carbendazim (17.88%) and control plot (10.65%), whereas the lowest infection was recorded in plots treated with *Trichoderma spp.* (2.78%) and Copper Oxychloride (2.88%).

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 on nematode populations and hence the nematode population (larvae) once decreased, it decreased the chance of root injury by nematode that indirectly inhibited the infection by *Fusarium oxysporum*.

5.3 Effect of Grafting against wilt disease

Grafting of eggplant as a scion with root stock of wild *Solanum* (*Solanum sisymbriifolium*) showed remarkable performances against Fusarium wilt as well as Nemic wilt. No wilt incidence as well as root gall formation was noticed even at 75 days after transplanting. Very negligible wilt incidence and gall formation was observed at 85 and 95 days after transplanting which had a minor effect on yield and yield contributing characters. This findings are agree with the findings of Rahman (2000);

Akhter (1994); Ali (1993); Islam (1992) and Ali *et al.* (1990a, 1990b), who reported that the wild *Solanum* (*Solanum sisymbriifolium*) found resistant against Fusarium wilt and Nemic wilt that could be used as a root stock for the management of wilt complex.

5.4 Effect of *Trichoderma* against wilt pathogen

Bio-agent *Trichoderma harzianum* T_{22} also showed tremendous performance in controlling wilt disease of eggplant. No wilt incidence as well as gall formation was noticed even at 95 days after transplanting. The growth performance like shoot and root length as well as shoot and root weight and branching of plant were positively influenced by the application of *Trichoderma harzianum* T_{22}. The literature in favour of *Trichoderma harzianum* against Fusarium wilt (*Fusarium oxysporum*) and Nemic wilt (*Meloidogyne incognita*) are available in the previous report (Pinzon *et al.*, 1999; Hamed, 1999; Singh *et al.*, 1997; Parveen *et al.*, 1993; Bari, 2001; Davila *et al.*, 1999; Rao *et al.*, 1998 and Spiegel and Chet, 1998).

The *Trichoderma harzianum* is a non pathogenic fungus that captured the root zone for its profuse growth and compete with the pathogenic microorganisms for space and nutrition. Sometimes *Trichoderma* secretes some toxin and enzyme injurious to pathogenic organisms more over it can directly parasitised other soil borne pathogens. This mycoparasitism might be the reason of controlling wilt pathogens by *Trichoderma harzianum*.

5.5 Cost analysis

From the cost analysis of the treatments applied in the experiment for management of Fusarium wilt and Nemic wilt of eggplant, it was revealed that Benefit Cost Ratio (BCR) of application of Sawdust was the higher (4.17) where the farmer could earn Tk. 4.17 by investing Tk. 1. The BCR (3.83) for application of Furadan and *Trichoderma harzianum* T_{22} less than that of Sawdust. This is because the purchase cost of Furadan and formulation of *Trichoderma harzianum* T_{22} is greater than Sawdust. Besides the application of Sawdust contributed the higher yield as the Sawdust not only suppressed the soilborne pathogen but also acted as organic matter in the soil. The lower BCR for the application of other treatments were due to the lower yield under those treatments.

Chapter 6

SUMMARY AND CONCLUSION

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Experiment were conducted to control Fusarium wilt and Nemic wilt of eggplant through some selected treatments during Rabi season of 2005-2006 (November - April). Three chemicals viz. Furadan 5G (Carbofuran), Bavistin 50WP (Carbendazim) and Cupravit 50 WP (Copper-oxychloride), two organic soil amendment Sawdust and Khudepana (*Azzola pinnata*), one bio-agent *Trichoderma harzianum* T_{22} and Grafting were evaluated against *F. oxysporum* f. sp. *melongenae* and *Meloidogyne incognita* causing Fusarium wilt and Nemic wilt, respectively in the field condition.

The effect of the selected treatments in controlling Fusarium and Nemic wilt were determined by recording data at different Days After Transplanting (DAT) in terms of wilt incidence and root galls formation. The treatment effects also observed on yield and yield contributing characters of eggplant against wilt disease.

At 55 Days After Transplanting (DAT), the treatment effects other than control did not differed significantly among themselves as there were no wilted plant. At 65 and 75 DAT, no wilt incidence was observed in case of Grafting, Furadan 5G, *Trichoderma harzianum* T_{22} and Sawdust. At 85 DAT, Significantly the highest wilt incidence was recorded in Control (73.33%) which was statistically identical with Cupravit (33.33%). No wilt incidence was noticed in case of Furadan 5G, Sawdust and *Trichoderma harzianum* T_{22} which was statistically similar with Grafting.

Finally at 95 Days After Transplanting (DAT), the highest effect against the disease was observed in case of Furadan 5G and *Trichoderma harzianum* T_{22} where no plant were wilted. The effect of Grafting, Sawdust and Khudepana was also statistically identical with the effect of Furadan 5G and *Trichoderma harzianum* T_{22}. The highest wilt incidence was recorded in Control treatment (93.33%) followed by Cupravit (66.67%) and Bavistin (46.67%). From the study it was revealed that, wilt incidence was increased with the increase of DAT.

In case of root gall formation at 95 DAT, the highest effect observed by Furadan 5G and *Trichoderma harzianum* T_{22} where no gall formation was found. The effect of Grafting, Sawdust and Khudepana was statistically similar to Furadan 5G and *Trichoderma harzianum* T_{22}. The highest gall formation was recorded in Control treatment (141.0 galls / plant) followed by Cupravit (79.00 galls / plant) and Bavistin (52.00 galls/ plant). Wilt incedence increased with the increase of number of gall per plant.

Treatments effects were differed significantly in respect of plant growth characters viz. length of shoot, fresh weight of shoot, length of root, fresh weight of root and branching per plant at 95 DAT. The highest growth was observed in case of Sawdust and Furadan 5G where Grafting, *Trichoderma harzianum* T_{22} and Khudepana also show remarkable growth effect in compare to Bavistin, Cupravit and Control treatments. The galling incidence hampered the crop growth in terms of shoot and root length along with shoot and root weight. Increases of gall number significantly reduced shoot and root length as well as shoot and root weight of plant.

The yield of eggplant differed significantly among the treatments against wilt disease ranged from 2.40 to 17.33 t/ha. The highest fruit yield (17.33 t/ha) was obtained in case of application of Sawdust that was statistically identical with the application of Furadan 5G (16.93 t/ha). The lowest fruit yield was recorded in Control (2.40 t/ha) preceeded by Cupravit, Bavistin and Khudepana. *Trichoderma harzianum* T_{22} and Grafting also showed better performance in comparison to other treatments against Fusarium and Nemic wilt.

In case of Benefit Cost Ratio (BCR), estimation showed that application of Sawdust gave the highest BCR (4.17) than the other treatments, where Tk. 4.17 could be earned investing Tk. 1.00. The second highest BCR (3.83) estimated in case of application of Furadan 5G and bio-agent *Trichoderma harzianum* T_{22} whereas the lowest BCR (0.70) observed in Control treatment.

Considering the overall performance of the treatments applied in the experiment in controlling Fusarium wilt and Nemic wilt of eggplant, application of Sawdust, *Trichoderma harzianum* T_{22}, and Grafting of eggplant with wild *Solanum* (*Solanum sisymbriifolium*) could be used as eco-friendly approach and may be adviced 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 consecutive years for including more options as management practices in different Agro Ecological Zones (AEZs) of the country.

Chapter 7

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APPENDICES

Appendix 1. Nutritive components in 100 gm of edible portion of eggplant

Components	Composition
Calories	24.0
Moisture (%)	92.7
Carbohydrates (g)	4.0
Protein (g)	1.4
Fat (g)	1.3
Oxalic acid (mg)	18.0
Calcium (mg)	18.0
Magnesium (mg)	47.0
Iron (mg)	0.9
Sodium (mg)	3.0
Copper (mg)	0.17
Potassium (mg)	2.0
Sulphar (mg)	44.0
Chlorine (mg)	52.2

Sourse : Internet (www. Agridept.gov.lk)

Appendix 2. Composition of Potato Dextrose Agar (PDA)

Components	Composition
Potato (Peeled and sliced)	200g
Dextrose	20g
Agar	20g
Water	1000ml

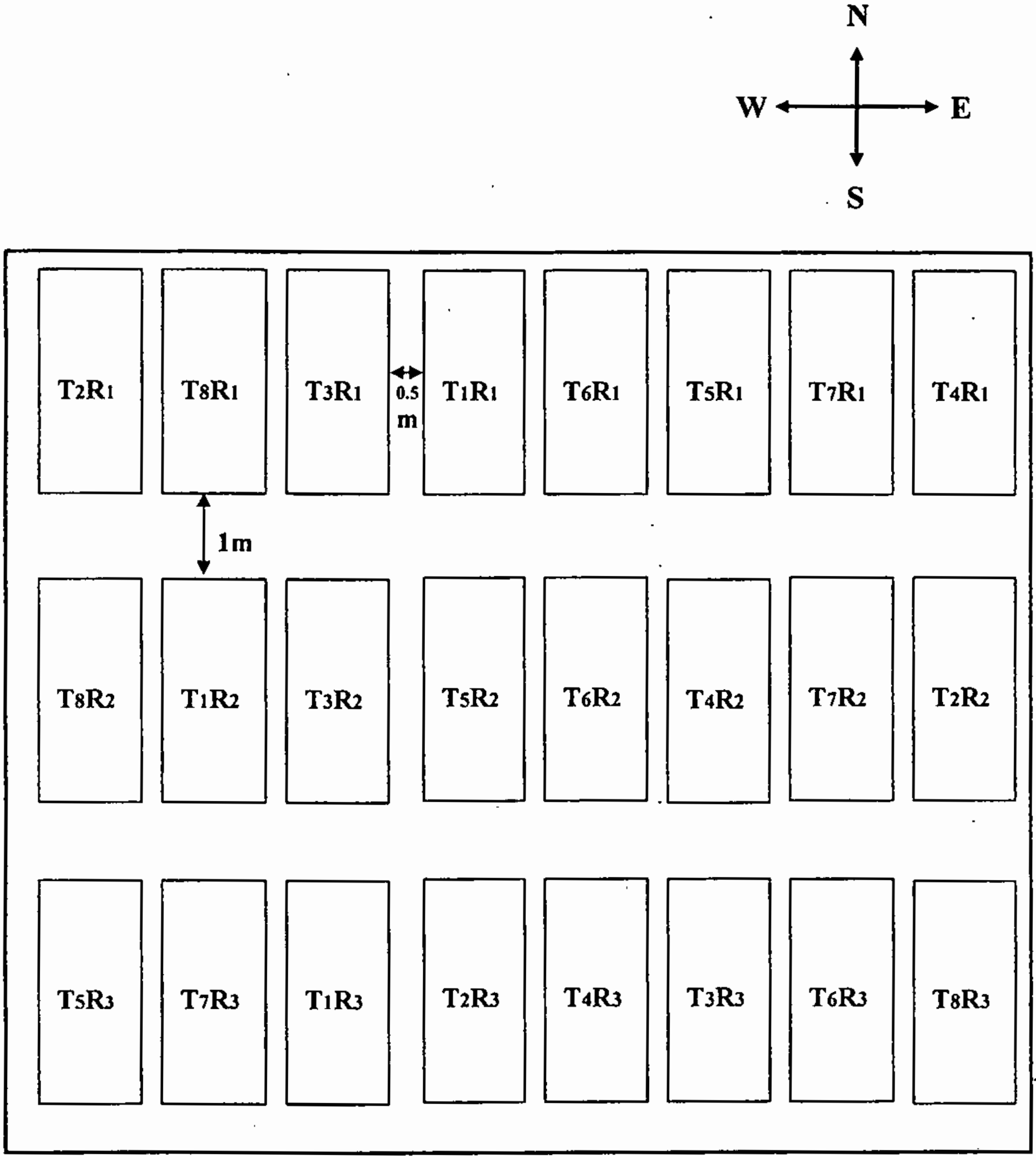
Appendix 3. Monthly mean of daily maximum, minimum and average temperature, relative humidity, total rainfall and sunshine hours during December/2005 to March/2006

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 4. Layout of the experimental field (RCBD)



Appendix 5. Analysis of cost of application of common culture practices in production of eggplant

Cost items	Per hectare cost in TK.				
	Unit	Quantity	Cost/Unit *	Times	Total cost
Seed	Kg	0.10	1000	_	100
Seedling production ➢ Human labour	Man day^{-1}	10	100	_	1000
Land preparation ➢ Ploughing ➢ Power tiller hired ➢ Human labour	 Bull pair Hour Man day^{-1}	 5 6 20	 200 400 100	 _ _ _	 1000 2400 2000
Seeding plantation ➢ Human labour	Man day^{-1}	25	100	_	2500
Fertilization and manuring ➢ Urea ➢ TSP ➢ MP ➢ Cow dung	 Kg Kg Kg Ton	 226 222 200 10	 7 12 14 500	 _ _ _ _	 1582 2664 2800 5000
Weeding and inter-cultural operation ➢ Human labour	Man day^{-1}	20	100	3	6000
Insecticide spraying ➢ Aktara ➢ Human labour ➢ Sprayer hired	 Kg Man day^{-1} Hour	 0.2 2 4	 2500 100 50	 5 4 4	 2500 800 800
Irrigation ➢ Human labour	Man day^{-1}	3	100	8	2400
Harvesting ➢ Human labour	Man day^{-1}	2	100	5	1000
Total (a)					34546

* Calculated on the basis of market price of 2005.

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

Cost items	Per hectare cost in TK.				
	Unit	Quantity	Cost/Unit *	Times	Total cost
Grafting ➤ Human labour ➤ Clip ➤ Polyethylene	Man day^{-1} – Kg	40 14000 4	100 0.50 25	1 1 1	4000 7000 100
Total (b)					11100
Soil application of Furadan ➤ Furadan ➤ Human labour	Kg Man day^{-1}	70 20	110 100	1 1	7700 2000
Total (c)					9700
Root dressing and soil drenching Cupravit ➤ Cupravit ➤ Human labour	Kg Man day^{-1}	10 40	540 100	1 1	5400 4000
Total (d)					9400
Root dressing and soil drenching Bavistin ➤ Bavistin ➤ Human labour	Kg Man day^{-1}	3 40	1110 100	1 1	3330 4000
Total (e)					7330
Soil application of *Trichoderma* ➤ *Trichoderma* ➤ Human labour	Kg Man day^{-1}	30 40	25 100	1 1	750 4000
Total (f)					4750
Using Sawdust ➤ Sawdust ➤ Human labour	Ton Man day^{-1}	1.5 40	2000 100	1 1	3000 4000
Total (g)					7000
Using Khudepana ➤ Sawdust ➤ Human labour	Ton Man day^{-1}	30 40	100 100	1 1	3000 4000
Total (h)					7000

* Calculated on the basis of market price of 2005.