# "MANAGEMENT OF ROOT KNOT OF BANANA SEEDLINGS WITH BIO-AGENT, ORGANIC SOIL AMENDMENT, CHEMICAL AND THEIR COMBINATIONS"



**MD. ABU SADAT**



**DEPT. OF PLANT PATHOLOGY**

**SHER-E- BANGLA AGRICULTURAL UNIVERSITY**

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**BY**

**MD. ABU SADAT**

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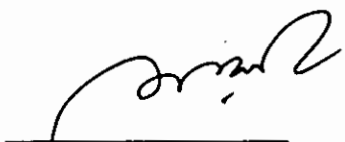
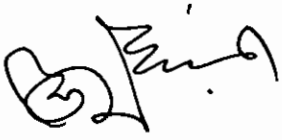


**Dr. Md. Rustom Ali**
**Supervisor**

**Prof. Mrs. Nasim Akhtar**
**Co - Supervisor**



**Dr. Md. Rafiqul Islam**
**Associate Professor**

**Chairman**
**Examination Committee**

*CERTIFICATE*

This is to certify that the thesis entitled "**MANAGEMENT OF ROOT KNOT OF BANANA SEEDLINGS WITH BIO-AGENT, ORGANIC SOIL AMENDMENT, CHEMICAL AND THEIR COMBINATIONS"** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE in PLANT PATHOLOGY,** embodies the result of a piece of *bona fide* research work carried out by **Md. Abu Sadat, Registration No. 25276 / 00381,** under my supervision and guidance. No part of this thesis has been submitted for any other degree in any other institutions.

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



**Dated:** 25.7.06
**Dhaka, Bangladesh**

Dr. Md. Rustom Ali
Principal Scientific Officer
Bangladesh Agricultural Research Institute (BARI)
Supervisor

*Dedicated to*
*My*
*Beloved Parents*
*&*
*Late Pervez*

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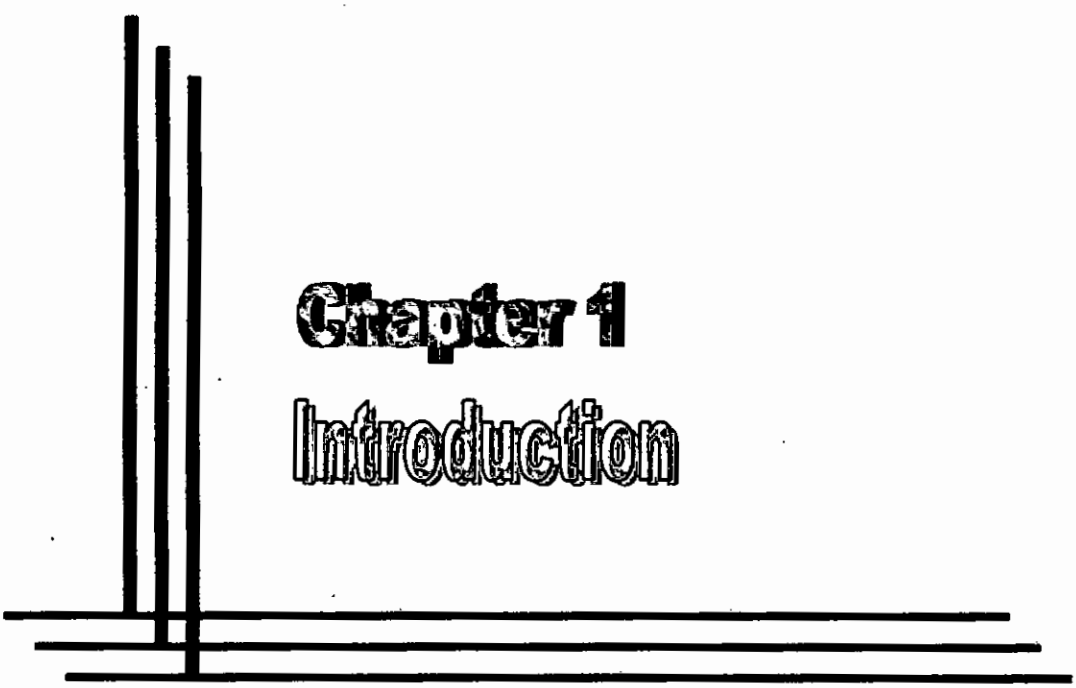
## ABSTRACT

A pot experiment was conducted for the management of root knot nematode infected tissue cultured banana seedlings with nematicides Rugby 10G (@ 7.5 gm / plant) and Furadan 5G (@ 15 gm / plant), a neem product Neembicidin (@ 5 ml / L water), a cyst forming bacterial bio control agent *Pasteuria penetrans* (250 mg or 10,000 spores / plant), and a organic soil amendment Poultry Refuse (@ 2.5 kg / plant either singly or in different combination. Each pot was filled with 8 kg of soil. Six months after the investigation, it was observed that application of the treatments Neembicidin, Poultry Refuse and combination of Rugby 10G, Furadan 5G combined with Poultry Refuse reduced root knot nematodes population, gall index and improved plant growth of banana. Among the treatments poultry refuse combined with Furadan 5G appeared to be the best. Neembicidin and poultry refuse individually did not cause satisfactory improvement of plant growth.



# Chapter 1
# Introduction

# INTRODUCTION

Banana (*Musa spp*) is one of the important fruit crop in our country. It belongs to the family Musaceae. It grows almost year round in Bangladesh. Banana is being cultivated in about 111070 acres of land and its average production is 654280 metric tones / year (B.B.S., 2003).

Bananas are used in various purposes such as ripe fruit or as green banana. Ripe bananas, being one of the most easily digested foods, are widely used in the nutrition of infants and of people suffering from various intestinal disorders. Bananas also have a special place in diets as it contains low fats, cholesterol and salt. In a test in India, it is observed that, two bananas taken a day resulted in 10% drop in blood pressure within a week (Anon, 1999).

Around 98% of world production of banana is grown in developing countries. Developed countries are the usual destination for export bananas. India, Ecuador, Brazil and China alone produced half of the total bananas. World exports of bananas also show a high level of concentration with developing countries according to the bulk of exports. Only Latin America and Caribbean supplied more than 80% of the total exports. The four leading banana exporter countries in 2003 were Ecuador, Costa Rica, Philippines and Colombia, which accounted for about two-third of world exports (FAO, 2004).

Various types of diseases caused by fungi, bacteria, viruses, mycoplasma and nematodes affect banana plant. Among the fungal diseases, most important is Panama wilt caused by *Fusarium oxysporum* f. sp. *cubense* and Sigatoka caused by *Mycosphaerella musicola,* which are serious problem in the field. Bunchy top caused by Mycoplasma, also a problem in the old banana orchard. Various nematodes are associated with banana root system throughout the world, wherever banana is cultivated. Among the nematode diseases Burrowing nematode *Radopholus similis* is a serious problem in many

countries, wherever banana is commercially cultivated (Ayala and Rahman, 1963, Davide and Marasigan, 1985).

The other important nematodes causing root diseases of banana are root-knot caused by *Meloidogyne* spp, Lesion nematode (*Pratylenchus* spp) and spiral nematode (*Helicotylenchus multicintus*) (Mian, 1986). These nematodes are major problems in most bananas producing countries. Besides these, there are other nematodes, which are, minor and cause sporadic problems. In Bangladesh, generally four species of plant parasitic nematodes are associated with banana root systems and caused substantial damage, these are burrowing nematode (*Radopholus similis*), root-knot nematode (*Meloidogyne* spp), lesion nematode (*Pratylenchus* spp) and spiral nematode (*Helicotylenchus multicintus*) (Choudhury *et al.*, 1981 and Mian, 1986).

Root knot is caused by the nematodes of the genus *Meloidogyne*. The 2$^{nd}$ stage larvae of nematode penetrate into young roots of host plants and induced the development of gall, where they can feed and reproduce easily. The vascular tissues are damaged by young larvae and cause impairment of the nutrient and water uptake from the soil. They cause appreciable yield loss of the crops (Rahman *et al.*, 1990).

The species of root knot nematode most commonly found associated with bananas in Bangladesh are *Meloidogyne incognita* and *Meloidogyne javanica* (Mian, 1986). Different species can be seen associated in the same gall (Pinochet, 1977). Stunted growth has been attributed in banana due to root knot nematodes in the India (Sudha & Prabhoo, 1983) and in Taiwan (Lin & Tsay, 1985). The most obvious symptoms of root knot nematodes in banana are galling on primary and secondary roots, sometime causing them to bifurcate and distort. Female nematodes in a favorable banana host produce large number of eggs from which larvae develop and migrate to new positions in roots.

The root knot nematodes, *Meloidogyne* spp possesses wide host range and attack a lot of crops like groundnut, sugarcane, tomato, sweet potato, lady's finger, country bean, rice, jute, bitter gourd, sweet gourd, papaya, pineapple and fruits, tree plants including banana. In Bangladesh as much as 52-62% losses in fruits yield have been estimated in controlled condition (Anon, 1990). Reddy (1986) reported that in India brinjal production was reduced by 27% due to attack of root knot nematodes (*Meloidogyne incognita & M. javanica*) under field condition. Estimation of vegetable crops in the tropics due to root knot nematodes (Sasser, 1979) ranged from 17-20% on eggplant, 18-33% on melon and 24-38% on tomato. Nematicides trial has been demonstrated yield loss due to root knot in egg plant ranged from 30-60% & 50% on cantaloupe and water melon (Lamberti, 1979). In the United States, yield on plots infested with *Meloidogyne incognita* and treated with DD-MENCS (Nematicides) and planted with beans, summer squash, okra or cucumber increased 128, 180, 507 and 1175%, respectively (Johnson, 1985).

Control of nematodes including root knot by using chemical nematicides is reported to be a very effective method (Zaki and Maqbool 1995, Mian *et al.* 1991, Gupta and Sharma 1988, Ahmed and Bhuiyan 1987, Rana and Gupta 1981). Use of resistant varieties is the most successful and low cost method for controlling root knot nematodes as well as other nematodes; if such varieties are available (Winslow and Wills, 1972, Fassuliotis 1979, Sasser 1980, Sasser and Carter 1985). But numbers of such tolerant or resistant varieties are very limited. This is why dependency to the chemical nematicides is an unavoidable reality. But large scale use of chemical nematicides is not feasible under Bangladesh condition due to their scarcity, high cost, hazardous in use, difficult to spray on small fields and risk of environmental pollution (Singh and Sitaramaiah, 1966 and 1973, Nahar *et al.* 1996, Mian and Rodriguez-Kabana 1982).

This is why greater attention is given on controlling root knot nematodes involving physical, cultural and biological approaches. In physical method hot water treatment, soil solarization and elimination of weeds and roots of diseased crops can be used to control this disease (Zhang 1987). Crop rotation, fallow, deep ploughing and use of resistant varieties are the useful cultural methods against nematodes (Zhang 1987, Chakraborty 1998). Now a day's biological control method and integration of different cultural methods are being used as effective control measures against nematodes, to avoid or reduce the use of chemical nematicides (Mohanty *et al.* 2003, Sudarshan and Chakraborty, 2001).

Recently Integrated Pest Management (IPM) approach is gaining popularity, where various management (such as host resistance, cultural control, chemical control and biological control) approaches is followed in integrated way to ensure eco friendly condition. Though the use of resistant varieties are cheap, easy to use and non hazardous, production of host resistant has not yet become an available method because of frequent failure of resistance in the host and formation of new virulent strain or races or biotypes among the pathogen (Gaur and Gaur 2003).

Available literature indicate that the soil borne disease can be managed to a great extent by using organic soil amendments, which do not have adverse effect on beneficial microorganism (Palakshappa *et al.* 1989). So, it is the demand of time to introduce alternative methods for plant disease control practices. Control through organic amendments of soil is increasing day by day and gaining popularity as an alternative possible agricultural method for soil pathogen control.

In the present socio-economic situation of Bangladesh cultural practices like organic amendments to soil are considered as the cheapest method for nematode control. Various types of low cost organic amendments including

poultry refuse (chicken manures), cow dung, farm yard manure (FYM), saw dust, different oil cakes have been reported to be effective in controlling root knot nematodes (Singh and Sitaramaiah 1973, Mian and Rodriguez-Kabana 1982).

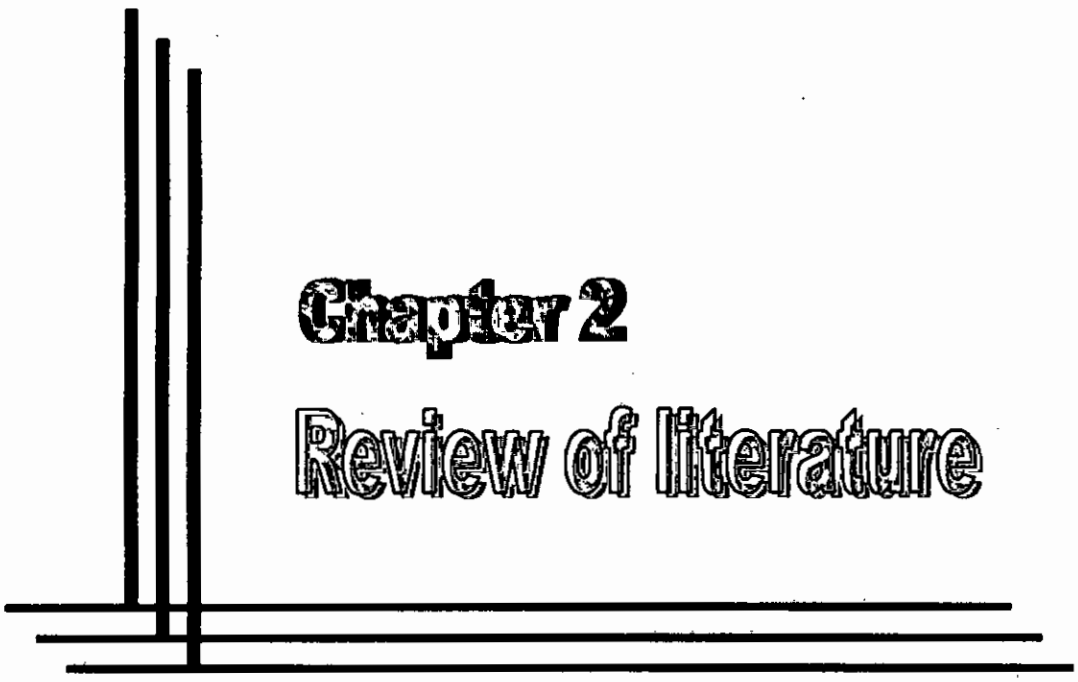
Organic amendments using saw dust, oil cakes, animal faces and other easily decomposable materials are proved highly effective against nematodes in different countries (Mian and Rodriguez-Kabana 1982, Fatema and Sweelam 2001, Nahar *et al.* 1996). The available literature suggests that the intense microbial activities during decomposition of organic matter increase in the number of flora and fauna that can suppress phytonematodes. Another hypothesis says the microbial activity in amended soils leads to release of a wide variety chemical substance some of which may be effectively toxic to nematodes and at the same time these chemicals also change osmotic concentration of soil solutes which play an important role to suppress the pathogenic nematodes (Singh and Sitaramaiah 1973, Mian and Rodriguez-Kabana 1982).

Management of nematode diseases of banana has been conducted through the use of chemical nematicides, neem seed extracts or neem product, organic soil amendments and biological control agents in many countries (Arayer and Cheves 1996 & 1997, Martin *et al.* 1996, Ciancio 1995, Fulton *et al.* 1996, Musabyimana and saxeena, 1999). Management on root knot and other nematodes in banana has been attempted in Bangladesh in a limited scale (Anon. 2002 & 2004). However, detailed studies on the management of root knot nematodes have not yet been conducted. Integrated Management has not been conducted on root knot of banana in our country yet. Few researches are conducted on this disease management but those are not practiced in the farmer's level. So, to manage the root knot disease easily and cheaply more researches on root knot nematodes of banana should be undertaken.

To grow banana successfully and profitably nematode problems should be properly addressed. This will help to increase banana yield and farmer's income. Therefore, the present study was undertaken to fulfill the following objectives:

**Objectives:**

1. To find out the comparative efficacy of Furadan 5G, Rugby 10G and Neembicidin either alone or in combination with organic amendments in controlling root knot of banana
2. To evaluate the effect of *Pasteuria penetrans* on root knot of banana



# Chapter 2

# Review of literature

# REVIEW OF LITERATURE

Root knot is a major nemic disease not only in Bangladesh but also in other countries of the world like Srilanka, Philippines, Pakistan, India and where ever bananas are produced. This disease is caused by nematodes of *Meloidogyne spp.* Also some other nematodes like *Pratylenchus spp, Hirschmanniella spp, Helicotylenchus spp* are associated with root of banana. Many researches have been conducted to control this nemic disease with nematicides, biological agents and with organic soil amendments in many countries of the world. Some of the works pertinent to the present studies have been reviewed in this chapter.

## 2.1. Chemical nematicides to control root- knot nematodes.

Arayer and Cheves (1996 and 1997) conducted two experiments to evaluate the nematicidal effect of four nematicides namely Counter 10G, Mocap 10G, Furadan 10G and Rugby 10G on nematode population in banana roots, recovery of root system and their effect on yield. They observed that Counter 10G, Mocap10G and Rugby 10G decreased the populations in functional roots compared with untreated plots in both the experiments.

Zaki and Maqbool (1995) showed in a field experiment that the nematicide, Furadan significantly reduced M*eloidogyne* spp. infection in tomato.

Zahid *et al.* (1992) observed that Basamid, @ 300,400, and 500 kg, Sunfuran, 30, 40, and 50 kg, Smite 50, 75, and 100 kg and Furadan 5G 30 kg/ha were effective in reducing the severity of the root-knot disease of brinjal, producing reduced number of galls, larvae and females in roots. They also found that Sunfuran 3G @ 50 kg/ha appeared to be the best in reducing the severity of root gall and improving plant growth.

Mian *et al.* (1991) reported control of root knot diseases (*Meloidogyne incognita)* in potato ( *Solanum tuberosum* ) with Furadan 3G. They observed enhanced plant growth and decreased development of nematode and severity of root knot. They also observed that better plant growth and nematode control corresponded to the higher rate of chemical applied to the soil ranging from 1.0 to 2.5 mg /kg soil.

Bhagawati and Phukar (1990) tested four chemicals viz. Carbofuran, Diazinon, Ekalux and Phorate each @ 1, 2 and 3% (w/w) as treatment for the control of *Meloidogyne incognita* infecting pea under laboratory and field conditions. All the chemicals were effective even at lower application in reducing gall and egg masses in the roots of pea and increased yield. The best result was found with carbofuran at 3% level.

Gupta and Sharma (1988), found Carbofuran as the most effective chemical nematicides in reducing the average number of galls on papaya plant. Plant height and weight were also improved by the treatment.

Ahmed and Bhuiyan (1987) tested Furadan 3G and Ekalux 5G against root knot disease of brinjal and found that the chemicals were most effective when applied at 0.1 g/hole during transplantation.

Haq and Saxena (1986) compared foliar sprays, soil drench and root dip application of Carbofuran 3G @ 500, 100, 50, and 10 ppm concentration in reducing population of *Meloidogyne incognita* and improving plant growth in tomato seedling. Root dip treatment with 100 and 500 ppm of Carbofuran gave effective control as did foliar spray with 500 ppm.

Maqbool *et al.* (1985) showed that Aldicarb or Carbofuran were effective in controlling *Meloidogyne incognita* in cauliflowers. Aldicarb at 2 kg/ha gave

nearly complete control of the nematode and caused increased plant growth up to 47%.

Naganathan (1984) found that pre plant application of Metham sodium, Carbofuran or Aldicarb reduced the root galling of tomato plants infested with *Meloidogyne incognita*.

Gichure and Ondieki (1984) applied Aldicarb, Phenamiphos, Carbofuran or Dazamet to potato field infested with *Meloidogyne incognita* and found that Phenamiphos was the most effective nematicide in reducing *Meloidogyne* population and increased yield followed by Dazamet, Carbofuran and Ethoprop.

Rana and Gupta (1981) observed reduction in root galling and increase in growth of chickpea as a consequence of pre plant application of Carbofuran at the rate of 1.5 and 3.0 kg/ha to soil infested with *Meloidogyne javanica.*

**2.2. Neem product to control root knot nematode:**

Zarina *et al.* (2003) reported that Neem leaf extract showed better result followed by *Calotropis procera*, and *Datura fastuosa* at a higher concentration giving maximum plant height, number of leaves fresh and dry weight of shoot and significantly suppressed the root galls and egg masses per plant on brinjal in Pakistan.

Prakash *et al.* (2002) showed that Nimin (a product of Neem) was the most beneficial treatment followed by oil of Neem, castor, and rocked salad on the growth of okra. Higher doses were more effective than the lower doses. The growth, dry weight and chlorophyll content of okra plant also improved. Sharma *et al.* (2000) reported significant reduction in the number of galls with soaking of okra seeds of in 5% Neemark and Nimbicidin for 6 and 24 hours.

Plant growth improved with the increase in the concentration of Neemark and Nimibicidin.

Hossain *et al.* (1999) reported that organic soil amendment with leaves of *Chrysanthemum* sp., *Azadirachta indica*, *Tagetes* sp. as well as sesame oil, neem oil, and coconut oil cake significantly reduced the root knot severity and increase the length and weight of shoots and roots and the growth of rice seedlings.

Akter and Mahmood (1996) reported that populations of plant parasitic nematodes on potato were significantly suppressed when the soil was treated with oilcakes or leaves of neem (*Azadirachta indica*) and castor (*Ricinus communis*)

Darekar *et al.* (1990) tested the effect of neem (*Azadirachta indica*) Karanji (*Pongamia glabra*), Mahua (*Madhuca indica*) and Castor (*Ricinus communis*) oil cakes in a field experiment on control of *Meloidogyne incognita* of tomato. All treatments at 400 kg/ha reduced *M. incognita* population and gall index, with neem and karjan cake being the most effective.

Chhabra *et al.* (1988) reported that the leaf extract of *Ricinus conmmunis. Leucaena leucocephala*, *Populus deltoides*, *Azadirachta indica, Lantana camara* and *Eucalyptus hybride* were highly toxic to J2 of *Meloidogyne incognita.* Among these, leaf extract of *Richinus communis* was found to be the most toxic to *M. incognita.*

Lee (1987) found that leaf and seed extract of *Melia azadirachta* inhibited the hatching of root-knot nematode, *Meloidogyne incognita* and killed the larvae in four months old *Paulownia taiwaniana* saplings and resulted greater height and fewer root-knots.

Siddique and Alam (1987) reported that water soluble extract of *Azadirachta indica* and *Melia azedarach* were effective against *Meloidogyne incognita* or *Rotylenchus reniformis* population in seedlings of tomato and okra.

Nanjegowda *et al.* (1985) reported that neem (*Azadirachta indica*) oil cake at 2 $kg/m^2$ was the most effective treatment in increasing the germination of tobacco seedling and reducing the number of root knot infested seedling and gall/plant.

Zaiyd (1977) showed that Neem leaves (*Azadirachta indica*) gave some control against root knot disease of okra caused by *Meloidogyne javanica.*

Siddiqui *et al.* (1976) reported that oil cakes of neem (*Azadirachta indica* ), groundnut (*Arachis hypogaea*), mustard (*Brassica campestris* ), castor (*Ricinus communis* ) and mahua (*Madhuca indica*) gave effective result in controlling nematode populations and increasing yields of several vegetables such as sugar beet, radish, and turnip.

**2.3. Biological agent (*Pasteuria penetrans*) to control root knot nematode.**

An experiment conducted by Mohanty *et al.* (2003) against root knot nematode infecting brinjal and reported that Carbofuran gave the highest reduction in the number of galls where as bio-agent; *Pasteuria penetrans* caused approximately 58% reduction at the time of transplanting of brinjal seedlings.

Zareen *et al.* (2002) observed that four isolates of *Pasteuria penetrans* (one UK, three local viz.PK1, PK2 and PK3) and a mixed inoculum of four isolates were tested against *Meloidogyne javanica* on tomato; UK isolate suppressed the nematodes greater than the other isolates.

Athanasiadou *et al.* (1999) monitored the specific type of chemical and *Pasteuria penetrans* to control the nematode in green house. The chemicals

gave the satisfactory result but the *Pasteuria penetrans* were not found to be parasitised Meloidogyne females.

The role of *Pasteuria penetrans* in suppressing numbers of root knot nematode in a 7 years monoculture, naturally infested with a mixed population of *Meloidogyne incognita* race1 and *Meloidogyne javanica* investigated by Fulton *et al.* (1996). Both the *Meloidogyne spp* were suppressed in micro waving soil as well as in dry soils; the reduction in root galling as well as numbers of egg masses by *Pasteuria penetrans.*

Ciancio (1995) characterized the *Pasteuria penetrans* by density dependence, host specificity and durable resting endospore. To reduce the host population at non damping density levels through *Pasteuria penetrans* spore treatments required the described condition.

**2.4. Organic amendments to control root-knot nematodes.**

El-Nagdi *et al.* (2003) reported that soil amended with composted and non composted sugarcane residue showed significant reduction in the number of galls and egg masses of *Meloidogyne incognita* causal agent of root knot disease of okra cv. Baladi. Plant growth parameters also increased compared to untreated the control.

Fatema and Sweelam (2001) tested the efficacy of different organic manures such as farmyard manure (FYM), chicken and pigeon manures and potassium fertilizer on the growth, dry matter yield and nutrient uptake of faba bean cv. Giza 20 under root knot *Meloidogyne javanica* infestation in pot experiment. They found that chicken and pigeon manures were the most effective among the organic sources in improving different plant growth parameters & suppressing nematodes.

Marull *et al.* (1997) reported that soil amendment with olive (*Olea europeae)* oil cake, chicken litter and municipal compost gave significant control of *Meloidogyne javanica* in green pepper (*Capsicum annum*) under greenhouse condition. They also found that plants in soil amended with the materials had lower numbers of *M. javanica.*

Five organic amendments viz. marigold, poultry refuse, pigeon refuse, mixed application of poultry and pigeon refuse and mustard oilcake were tested against root knot nematode by Nahar *et al.* (1996). They found that all caused reduction of root-knot severity and improved growth of tomato plants. They also observed that mixed application of poultry and pigeon refuse gave the best result followed by poultry refuse, mustard oilcake, pigeon refuse and marigold.

The effect of poultry manure on *Meloidogyne* spp. in tomato was investigated by Wahundeniya (1991) and he found that application of high rates of poultry manure (10 ton/ha.) reduced root-knot nematode population considerably in infested soil.

Ali and Mian (1989) found that amendment of soil with oil cake of cotton and mustard gave significant control of root knot of potato and increased plant growth of potato.

Sharma *et al.* (1985) studied amendment of soil with leaf powders of plants (at 5.0, 7.5 or 10.0 g/kg soil) and those were applied to *Cucumis melo* in pots for control of *M. incognita*. Lowest population after 45 days were found in soil treated with *Tagetes* or *Xanthium* leaf powder, followed by *Verbesina* and *Artemisia.*

Mian and Rodriguez-Kabana (1982) investigated the effect of soil amendments with oil cake and chicken litter for the control of *Meloidogyne arenaria* in

green house experiment with squash (*Cucurbita pepo* L.) and found that, the amendments reduced galling caused by nematode and stimulated plant growth.

Mahmood *et al.* (1982) reported that amending soil with different concentration of leaf and seed extracts of various indigenous medicinal plants showed increased mortality of *Rotylenchus reniformis* and *Meloidogyne incognita*. The mortality rate increased with the increase of the extract and exposure period.

D'Errico and Maio (1980) reported that addition of dried poultry faces, dried poultry manure, and composted oilcake, municipal refuse and partially composted poultry manure to field significantly reduced infestation of *Meloidogyne incognita* in tomato.

Badra *et al.* (1979) evaluated the nematicidal properties of pigeon and poultry droppings against *Rotylenchulus reniformis* and *Trylenchulus reniformis.* Both the amendments at 5, 10, 15, or 20 gm/liter soil killed all nematodes of both the species.

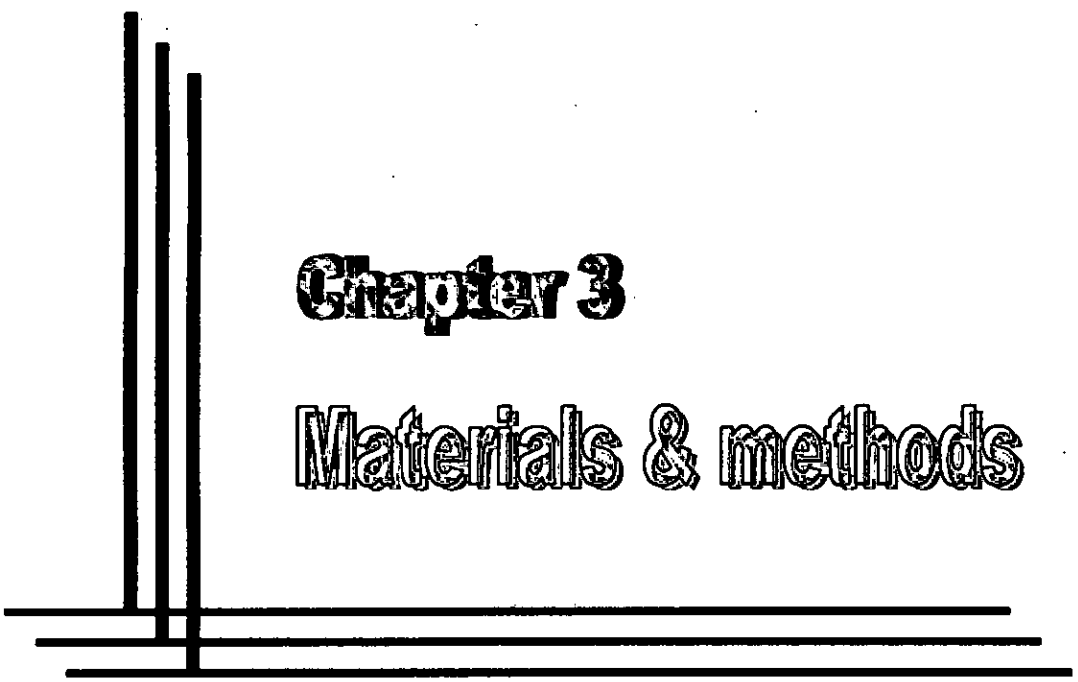
Gall caused by *Meloidogyne javanica* were reduced and top weight increased by amending soil incorporating mustard cake, groundnut cake, linseed cake and castor cake to okra plant in pot trials performed by Zaiyd (1977).

Hameed (1970) indicated that mustard oil cake was more effective than other oil cake in reducing population of *Meloidogyne incognita* in tomato.

An experiment with the oil cake of neem, castor, linseed, mustard, ground nut, sawdust, and mahua as organic amendments to the soil to evaluate their efficacy against *Meloidogyne javanica* on tomato and brinjal were conducted by Srivastava *et al.* (1972). They found that sawdust @ 10880.44 kg/acre and neem cake @ 486 kg/acre showed maximum efficacy in reducing the gall formation on the root.

Singh and Sitaramaiah (1966) obtained reduction in the incidence of root-knot nematodes in tomato and okra by soil amendment with leaves of karanj, margosa, *Melia azadirachta* L., *Cassia fistula* L., *C. occidentalis* L., crotalaria (*Crotalaria juncea* L.), and *Sesbania aculeata* Pers.

Linford and Yap (1938) showed that the incidence of root-knot nematode could be significantly reduced by amending soil with chopped pineapple leaves @ of 50-100 tons/acre in *Melilotus alba* var *annua* and sorghum (*Sorghum vulgaris* L.)



# Chapter 3

# Materials & methods

# MATERIALS AND METHODS

## 3.1 Experimental site:

The experiment was conducted in the pot house of the Plant Pathology Division, Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur.

## 3.2 Experimental period:

The experiment was carried out during the period of April to October 2005.

## 3.3 Preparation of soil and potting:

Pot soil was prepared by mixing silt loam soil and well decomposed cow dung at the ratio of 4:1. These were well mixed. The mixed soil has pH 6.5 and contained less than 1.0% organic matter. The mixed soil was screened (2 mm mesh) to remove large particles and debris and appertained into 7 kg and filled to a 25 cm dia. earthen pot.

## 3.4 Selection of variety:

The banana BARI– banana 1 variety was used in the experiment.

## 3.5 Experimental materials:

The experimental materials for this investigation were heavily root knot infested banana seedlings (Var.BARI-banana 1) which were produced by biotechnology laboratory of BARI. After hardening of these seedlings, these were transferred to polybags containing 1 kg soil. The soils, which were used, collected from nearby vegetable fields and were not sterilized. As a result, the seedlings were soon affected by root knot nematodes. These two months old nematode infested seedlings were selected and were collected as experimental materials for the integrated management of banana nematode. Before addition of any treatments initial data on the plant growth, nematode infestation and population of nematode in soil was determined and recorded (Table 1).

Table 1. Initial plant and nematode growth characteristics of five tissue cultured banana seedlings grown in polybags.

| Items studied | Values* |
|---|---|
| Stem height (cm) | 19.5 |
| Leaf length (cm) | 18.66 |
| Leaf breadth (cm) | 9.87 |
| Total plant weight (g) | 35.06 |
| Root length (cm) | 117.8 |
| Root weight (g) | 12.86 |
| Numbers of galls /10 g root | 38 |
| Nematodes / 10 g soil | 32 |
| % Necrosis of roots | 42 |
| Gall index (0-10 scale) | 4.1 |

* Values are averages of 5 plants.

### 3.6 Design of the experiment:

The experiment was set up in the pothouse of the Plant Pathology Division of BARI, Joydebpur, Gazipur, following Complete Randomized Design (CRD). The pots were arranged randomly. There were eleven treatments including control. Each treatment was replicated five times. There were altogether 55 pots.

The treatments used in the experiment were as follows:

$T_1$: Rugby 10G @ 30 kg/ha (7.5 gm / plant).
$T_2$: Furadan 5G @ 60 kg/ha (15 gm / plant).
$T_3$: Neembicidin @ 5 ml/L water.
$T_4$: *Pasteuria penetrans* (Cyst forming bacterial bio control agent) (@250 mg/ plant or 10,000 spores / plant).
$T_5$: Poultry refuse @ 10 ton /ha (2.5 kg / plant).
$T_6$: Rugby 10G + Poultry refuse
$T_7$: Furadan 5G + Poultry refuse
$T_8$: Poultry refuse + Neembicidin
$T_9$: Neembicidin + Poultry refuse + Rugby 10G
$T_{10}$: Furadan 5G + Poultry refuse + Neembicidin
$T_{11}$: Control

### 3.7 Application of the poultry refuses:

Fresh poultry refuse was collected from a nearby layer poultry farm containing 90% liter and 10% feed ingredients and other debris. The requisite quantities of poultry refuse @ 10 ton / ha, or 2.5 kg / plant was added to the pot soil and allowed to decompose for two weeks. To avoid direct phytotoxicity to the banana plantlets, the pots were ready for plantlets transformation after 14 days of poultry refuse application. Each pot contained 8-kg soil.

### 3.8 Application of chemical nematicides:

Two nematicides were used in the present investigation. These were Carbofuran or Furadan 5G and Cadusafos or Rugby 10G. Cadusafos belongs to the organophosphate class of chemical component. The other nematicide Furadan is a carbamate compound. Both nematicides were applied twice during the experimental period. First as basal dose during transplantation and 2nd split at 3 months after transplantation. The 1st doses of the two nematicides (Furadan 5G and Rugby 10G) were 60 & 30 kg/ha i.e.15 & 7.5 gm/plant. The second split doses were @ 30 kg and 15 kg/ha or 7.5 or 3.75 gm/ plant, respectively for Furadan 5G and Rugby 10G. The doses of nematicides were estimated on the basis of 4,000 plantlets /ha.

### 3.9 Collection and preparation of *Pasteuria penetrans*:

The cyst forming bacterial bio control agent of root knot nematodes *Pasteuria penetrans* isolates were collected from Japan. It was artificially multiplied in the roots of tomato in sterile condition and the roots were made powder. There were 40,000 spores / gm powder, which were added to the banana plants @ 250 gm / plant or 10,000 spores / plant. Before application the powder of the tomato roots containing *Pasteuria penetrans* were wetted in 500 ml water for 3-4 hours and then applied at the base of the plant.

### 3.10 Application of neembicidin:

Neembicidin is a commercial product of neem seed extract, marked by pesticide company ACI, Bangladesh, were applied @ 5 ml / lit. water. Neembicidin was mixed with the water and applied twice to the pot soil. First during transplantation of the seedlings and 2nd split was added one week after transplantation of the seedlings.

### 3.11 Transplantation of banana plantlets:

After fourteen days after application of poultry refuse banana plants were transplanted in the prepared pots. Plantlets were placed at the middle of the

earthen pots. Initially the polybags were removed gently and the plantlets were placed on the center of the pot. Transplantation was done in the afternoon. Immediately after transplantation all pots were watered.

**3.12 Application of chemical fertilizers**:

Chemical fertilizers Urea, TSP and MP were applied @ 120, 80 and 90 kg /ha or 30, 20 and 22.5 gm / plant, respectively. One third urea, full TSP and half MP was applied during transplantation. The rest urea was added two and three months after transplantation. The rest MP was added after two months of transplantation.

**3.13 Irrigation:**

Irrigation was done by watercane whenever necessary.

**3.14 Intercultural operation**:

During the experimental period the pot was kept weed free. The soil of every pot was loosening. The unexpected suckers which were arisen from the plants were cut down. Dry leaves of plants were removed. While the banana plants were growing up, the pots were spreaded, to provide proper sunlight and air. Chemical fertilizers were added as per schedule.

**3.15 Data collection**:

Data were collected twice during the investigation. First data were collected from the seedlings from the polybags, which were called as primary data and 2nd data were collected after the end of the investigation from the earthen pots, which were called as final data.

**3.15.1 Primary data**:

Primary data was collected from the banana plantlets before transplantation to the earthen pots. Five randomly selected banana plantlets were used to record the data. The plantlets were gently spreaded from the polybags; the roots were

washed in the tap water. These were air dried for one hour before data collection. The following parameters were recorded:

1. Stem height (cm)
2. Leaf length and breadth(cm)
3. Total plant weight (g)
4. Root length (cm)
5. Root weight (g)
6. Number of galls / 10 g roots.
7. Number of nematodes / 100 g soil
8. % Necrosis of roots
9. Gall Index (0-10 scale, Zeck, 1971)

**3.15.2 Final data**:

After six months, banana plants were uprooted from the pots. At first the soil of the pot was watered to make it moist and lose for easy uprooting. Then the corm of the banana plant were dipped in the water, it was further cleaned under running tap water and carefully washed out. Data on following plant growth and nematode development characteristics were determined and recorded:

1. Stem height (cm)
2. Diameter of stem (cm)
3. Leaf length (cm)
4. Leaf breadth (cm)
5. Total plant weight (kg)
6. Root length (cm)
7. Root weight (kg)
8. Galls / 100 cm root
9. Number of nematodes / 10 cm root
10. % Necrosis of roots.
11. Gall Index ( 0-10 scale, Zeck, 1971)

### 3.15.2.1 Stem height and diameter of stem (cm):

Stem height (cm) of each banana plant was determined by uprooting of the plant from the pot. The corms were separated from the stem. Measurement of the stem height was taken from the top of the corm at the bottom and the highest upper point of the stem up to the level of center leaves. The stem heights of five plants of each treatment were taken and averaged. Diameter of stem was determined by measuring three places (upper, middle and lower portion) of the stem. Then it was averaged.

### 3.15.2.2 Leaf length and leaf breadth (cm):

At first, five leaves were separated from each plant of the same treatment. Then the length of leaf was determined by measuring tape. For the determination of leaf breadth, same leaves were used. It was determined by placing tape in three portions (upper, middle and lower portion), then averaged.

### 3.15.2.3 Total plant weight (kg):

After uprooting the banana plants, the soil of root system was cleaned by water. Before weighing the banana plant, it was air dried for 30 minutes. Then the weight of total plant, corm, stem and leaves was recorded by balance.

### 3.15.2.4 Root length (cm) and root weight (kg):

The roots were separated from the banana plant corm, washed in tap water to remove the soil. Then ten roots were randomly selected and total length of the ten roots was determined. It was averaged to find out one root length. After that total root length was determined by counting the roots and multiplying. Separated roots were collected and weighted in an electric balance.

### 3.15.2.5 Galls / 100 cm root and number of nematodes / 10 cm root:

For counting the galls / 100 cm root, roots were randomly selected and collected from corm. Gall was counted by hand lens. Nematodes were counted from 10 cm banana roots. The roots were randomly selected and nematodes

were counted by piercing the total 10 cm roots while observing under stereoscopic microscope of each treatment.

### 3.15.2.6 % Necrosis of roots and Gall index (0-10):

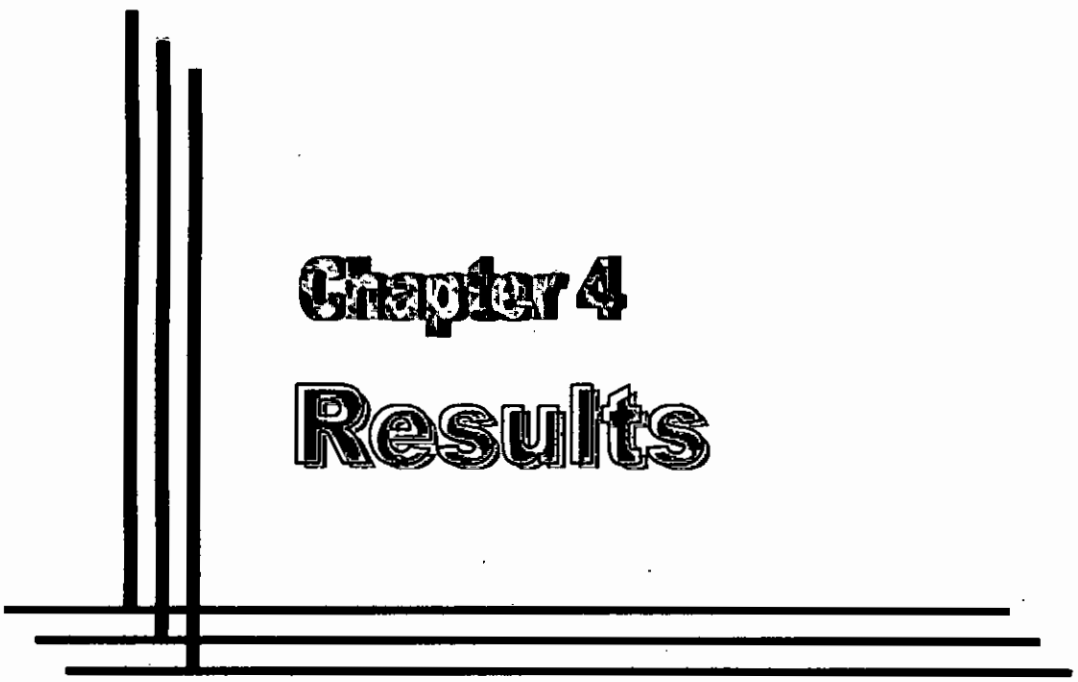
Necrosis (%) was determined by observing ten roots, which were separated from the corm. The black or dark portions of the roots, other than creamy white color were considered as necrosis. The necrotic portion of roots was averaged and % necrosis was determined and recorded. Gall index of five plants of each treatment was determined from randomly selected ten roots. The gall index was calculated following a 0-10 scale, where 0 represented no gall and 10 means highest number of galls (Zeck, 1971).

### 3.16 Data analysis:

Data on length and breadth of shoot, weight of plant and root, gall index, % necrosis etc for each treatment was analyzed statistically to find out the level of significance. The means for the treatment were counted and the analysis of variance was studied by F-test for the treatment mean and replication means. The mean differences were evaluated at p=0.05 levels of Duncan New Multiple Range Test (DMRT). Linear correlation co-efficient and regression equations were calculated with a standard statistical method.

### 3.17 Isolation and identification of the root knot nematode:

For the primary data collection nematodes were isolated following Baermann Funnel Method. And for the final data collection, the nematodes were isolated by piercing from the randomly selected banana roots. After piercing the roots, pear shaped female nematodes were observed under stereoscopic microscope.



# Chapter 4

# Results

# RESULTS

## 4.1 Final data:

### 4.1.1 Stem height (cm):

From the Table 2 it was observed that the highest stem height (110.0 cm) was recorded from the $T_7$, which received chemical nematicide Furadan 5G and Poultry refuse. The second highest stem height (98.00 cm) was resulted from the treatment $T_6$, where Rugby 10G and Poultry refuse were added. The 3rd highest stem height (95.00 cm) was stemmed from the treatment $T_8$, which received only Poultry refuse and Neembicidin. The stem height of $T_8$ treatment was statistically similar with $T_5$ and $T_9$. The lowest stem height (61.00 cm) was resulted from the treatment $T_1$, which received only Rugby 10G. However, it was statistically similar with the treatment $T_{11}$ (control) and $T_2$ (Furadan 5G). Stem heights of different plants of different treatments are shown in the Picture 1.

### 4.1.2 Stem diameter:

From the Table 2 it was observed that like stem height, there was similarity in the stem diameter (cm) (Picture 1). The highest stem diameter (32.22 cm) was resulted from the treatment $T_7$, which received nematicide Furadan 5G and Poultry refuse. The second highest stem diameter (27.92 cm) was resulted from the treatment $T_6$, which received Rugby 10G and Poultry refuse. The statistically similar stem diameter of 27.18 and 27.12 cm were found under the treatments $T_{10}$ and $T_3$, respectively. The lowest stem diameter (20.57 cm) was obtained under the treatment $T_1$, which received only Rugby 10G.

### 4.1.3 Leaf length (cm):

The highest leaf length (113.2 cm) was resulted from the $T_7$ treatment followed by $T_9$ (100.1 cm). The leaf length of $T_9$ was statistically similar with the treatments $T_3$, $T_5$, $T_6$, $T_8$ and $T_{10}$ which were 98.04, 94.66, 95.42, 97.06 and

96.66 cm, respectively. The lowest leaf length of 84.23 cm resulted from the treatment $T_2$, which received only Furadan 5G. The treatment $T_1$ which received only Rugby 10G and control treatment ($T_{11}$) gave statistically similar leaf length of 85.42 and 84.50 cm, respectively, with $T_2$.

**4.1.4 Leaf breadth (cm):**

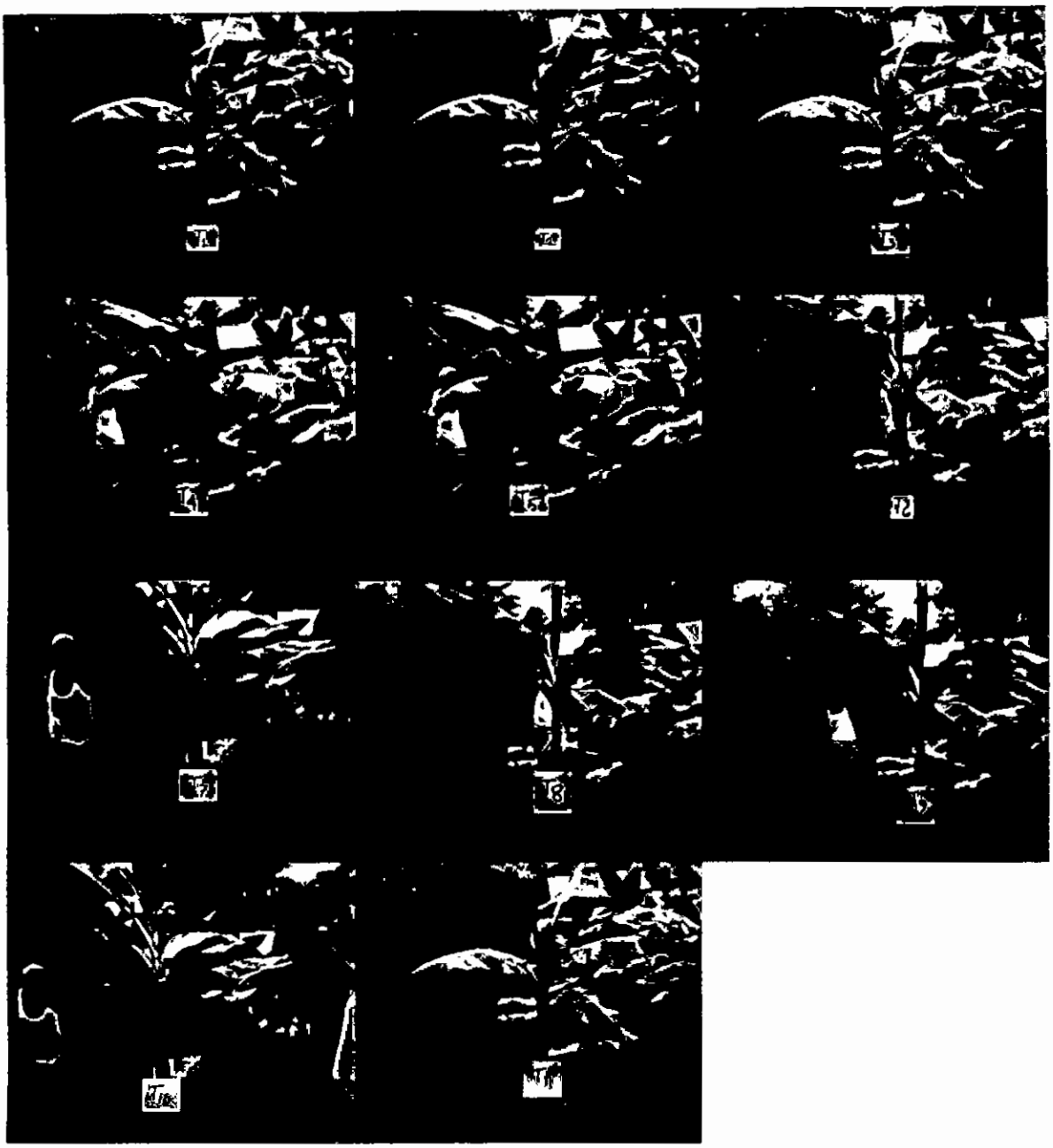
The maximum leaf breadth (44.45cm) was obtained from the treatment $T_7$, which was followed by $T_3$, $T_6$ and $T_2$ i.e. the treatment received only Neembicidin, only Furadan 5G, Rugby 10G and Poultry refuse, respectively. There were no significant differences among the treatments ($T_3$, $T_6$ and $T_2$) regarding leaf breadth. The lowest leaf breadth (31.96 cm) was resulted from the treatment $T_1$, which received only Rugby 10G and it was followed by control treatment $T_{11}$.

Table 2. Effect of different treatments on the plant growth characteristics of banana plants grown in earthen pot at six months after application of the treatments .

| Treatments | Stem height (cm) | Radius of stem (cm) | Leaf length (cm) | Leaf breadth (cm) | Root length (cm) | Root weight (kg) | Plant weight (kg) |
|---|---|---|---|---|---|---|---|
| $T_1$ | 61.00 e | 20.57e | 85.42 c | 31.96 d | 23.60 g | 0.82 e | 3.94 e |
| $T_2$ | 62.80 e | 22.89 de | 84.23 c | 36.04 bc | 27.80 ef | 0.98 de | 5.12 cd |
| $T_3$ | 81.60 d | 27.12 b | 98.04 b | 37.64 b | 30.60 cdef | 1.08 de | 6.56 a |
| $T_4$ | 81.40 d | 25.48 bcd | 92.28 bc | 34.02 bcd | 33.20 bc | 1.22 cde | 6.06 ab |
| $T_5$ | 94.80 bc | 25.18 bcd | 94.66 b | 33.91 bcd | 31.60 cd | 1.38 cd | 5.74 bc |
| $T_6$ | 98.80 b | 27.92 b | 95.42 b | 36.70 b | 36.20 ab | 2.20 a | 6.16 ab |
| $T_7$ | 110.0 a | 32.22 a | 113.2 a | 44.45 a | 37.40 a | 2.46 a | 6.72 a |
| $T_8$ | 95.0 bc | 26.12 bc | 97.06 b | 35.10 bcd | 31.20 cde | 1.60 bc | 5.20 cd |
| $T_9$ | 94.80 bc | 26.48 bc | 100.1 b | 35.50 bcd | 29.00 def | 2.00 ab | 5.52 bcd |
| $T_{10}$ | 85.40 cd | 27.18 b | 96.66 b | 32.24 cd | 27.40 f | 1.06 de | 5.04 d |
| $T_{11}$ | 64.00 e | 23.59 cde | 84.50 c | 34.34 bcd | 23.00 g | 0.96 de | 4.04 e |
| LSD | 9.864 | 3.023 | 8.583 | 4.017 | 3.793 | 0.5050 | 0.6817 |
| CV (%) | 9.16 | 9.16 | 7.11 | 8.84 | 9.89 | 27.63 | 9.79 |

$T_1$: Rugby 10G @ 30 kg/ha, $T_2$: Furadan 5G @ 60 kg/ha, $T_3$: Neembicidin @ 5 ml/L water, $T_4$: *Pasteuria penetrans*, $T_5$: Poultry refuse @ 10 ton /ha, $T_6$: Rugby 10G + Poultry refuse, $T_7$: Furadan 5G + Poultry refuse, $T_8$: Poultry refuse + Neembicidin, $T_9$: Neembicidin + Poultry refuse + Rugby 10G, $T_{10}$: Furadan 5G + Poultry refuse + Neembicidin, $T_{11}$: Control

Each value is an average of five replications. Means bearing the same letter within the same column do not differ significantly at 5% level by DMRT.



**Picture 1 Banana plants at six months after the application of different treatments.**

### 4.1.5 Root length:

The highest length of a single root (37.40 cm) was obtained from the treatment $T_7$ followed by $T_6$ (36.20 cm) and $T_4$ (33.20 cm). The lowest root length (23.00 cm) was obtained under the treatment $T_1$.

### 4.1.6 Root weight (kg):

The highest root weight of a single plant (2.46 kg) was obtained from the treatment $T_7$ followed by the treatments $T_6$ (2.2 kg) and $T_9$ (2.00 kg/plant). The lowest root weight (0.82 kg/plant) was resulted from $T_1$, which received only Rugby 10G.

### 4.1.7 Plant weight (kg):

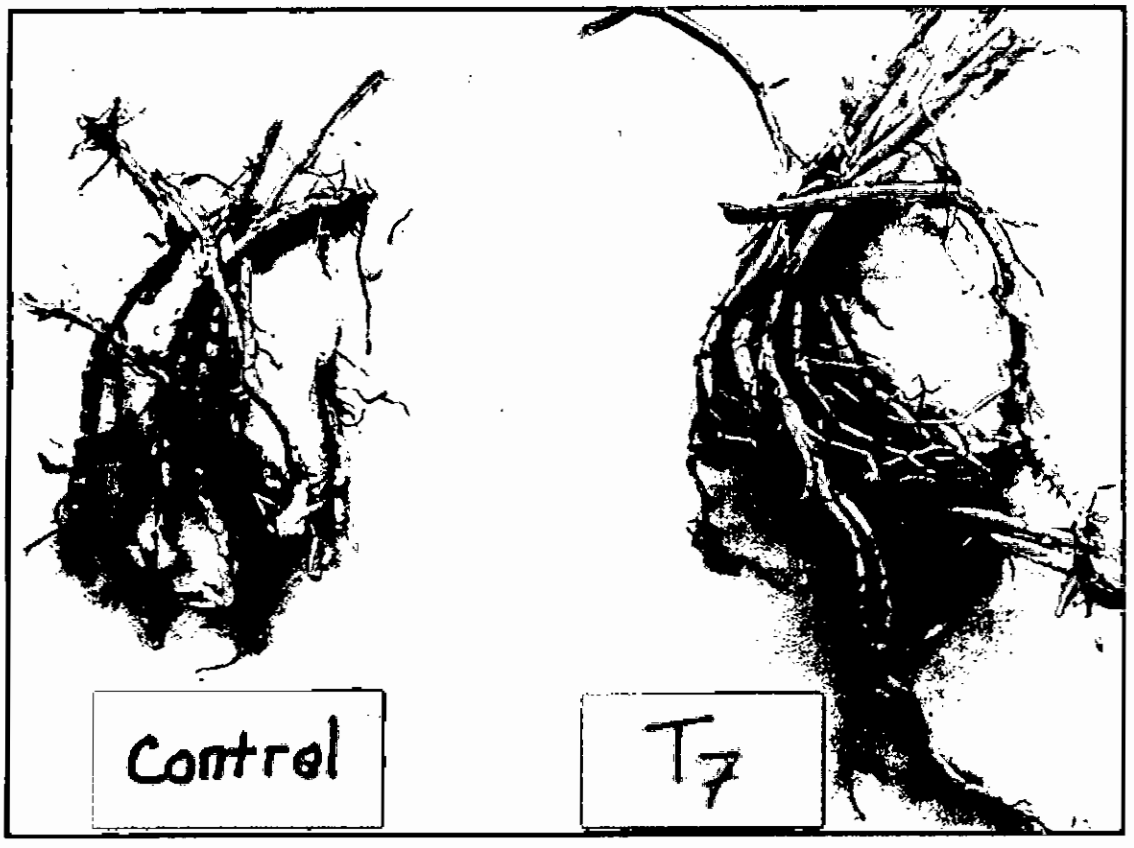
Significantly highest plant weight (6.72 kg/plant) was obtained from the treatment $T_7$, where chemical nematicides Furadan 5G and Poultry refuse were applied. Statistically similar with $T_7$ but the 2nd highest plant weight of 6.56 kg/plant was resulted from the treatment $T_3$, which received Neembicidin only. The 3rd highest plant weight of 6.16 kg/plant was resulted from the treatment $T_6$, where Rugby 10G and Poultry refuse added together. Statistically similar plant weight with $T_6$, 6.06 kg/plant was given by $T_4$, where *Pasteuria penetrans* was applied. The lowest plant weight (3.94 kg/plant) was resulted from the treatment $T_1$, which was statistically similar to the treatment $T_{11}$ (control).

### 4.1.8 Number of galls / 100 cm root:

Number of galls/ 100 cm roots differed significantly in respect of different treatments (table 3). The highest reduction of number of galls/100 cm roots was 13.20, which was obtained from the $T_7$, which received chemical nematicide Furadan 5G and Poultry refuse. The second highest reduction was obtained from the treatment $T_3$, where only Neembicidin was applied. The third highest reduction of galls/100 cm roots were resulted from the treatment $T_6$ and $T_{10}$, where Rugby 10G + Poultry refuse and Furadan 5G + Poultry refuse + Neembicidin were added, respectively. The highest number of galls /100 cm roots was 30.40 which were recovered from the control treatment ($T_{11}$). Application of Poultry refuse alone ($T_5$) resulted 29.20 number of galls /100 cm roots, which was followed by $T_4$ (24.20 galls/100 cm roots). Galls free healthy roots are shown in the Picture 2 and roots with numerous galls are shown in the picture 3.

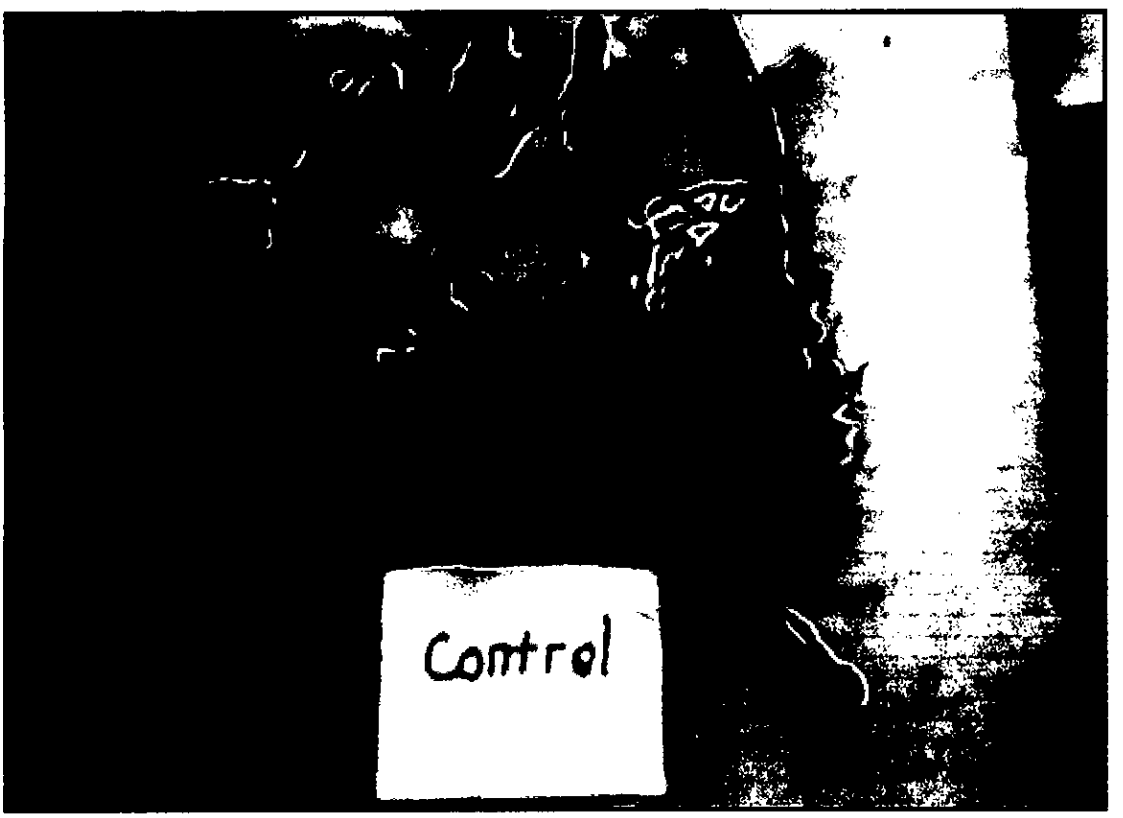
### 4.1.9 Number of nematodes / 10 cm root:

The root knot nematode (*Meloidogyne ssp*) was isolated from banana roots and identified. From the Table 3 it was observed that all the treatments significantly reduced the number of root-knot nematodes/ 10 cm banana roots except the $T_1$ treatment, which received only Rugby 10G. The highest reductions of nematodes (10.40/10 cm roots) were achieved in the treatment $T_7$, where Furadan 5G and Poultry refuse were added. The second highest suppression of number of nematodes/10 cm roots was resulted from $T_5$ treatment, which received only poultry refuse. However, $T_5$ was statistically similar with that of $T_3$ and $T_8$. The highest number of nematodes (18.6/10 cm roots) was counted under the treatment $T_{11}$ (control). Nematodes present in the root of $T_{11}$ treatment are shown in the Picture 6.




**Picture 2 Heavily galled, short and necrotic roots of control plant ($T_{11}$) & healthy & long roots of $T_7$ (Furadan + Poultry refuse) plants**

**Picture 3 Galls present in the roots of banana plant in control treatment ($T_{11}$).**




**Picture 4 Root shortening, %necrosis and profuse branching banana roots in the control ($T_{11}$) at six months after the application of the treatments.**

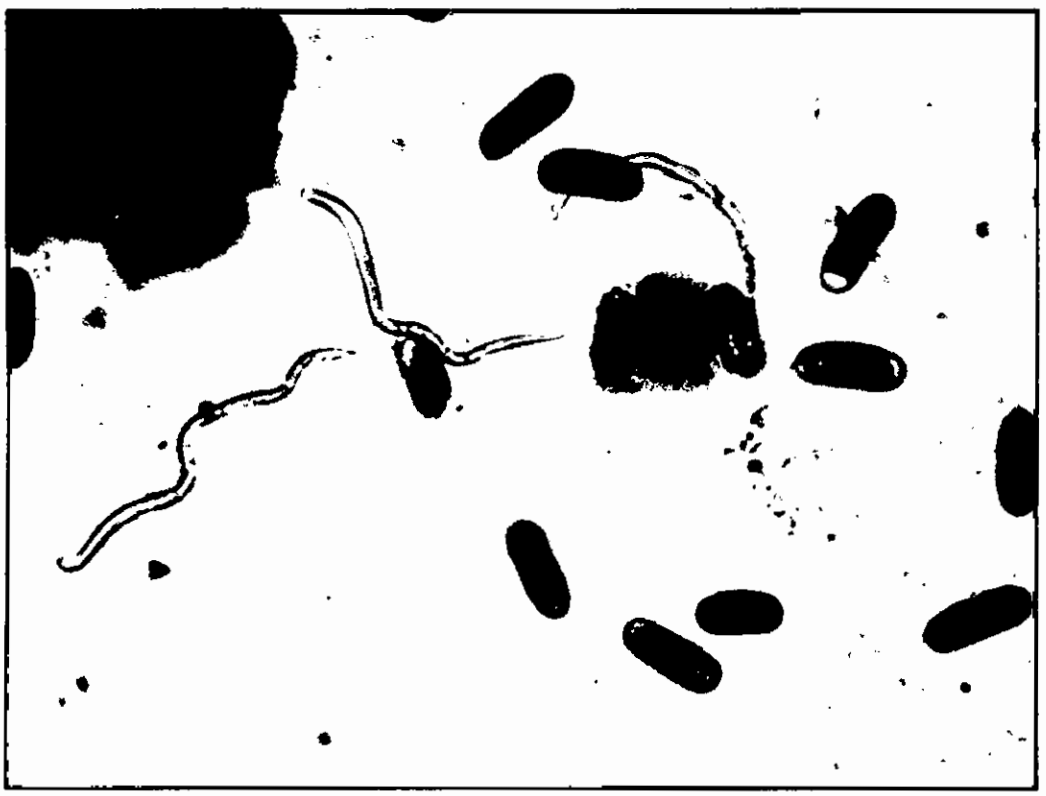
### 4.1.10 Root necrosis (%):

From the Table 3 it was observed that all treatments reduced necrosis % of the roots over control. The minimum % necrotic roots (22%) were achieved by $T_7$ treatment, which was statistically similar with the treatment $T_6$ (26% necrosis) where Rugby 10G and Poultry refuse were used. The second highest % necrotis root of banana plants were given by the treatments $T_3$ and $T_4$, which produced 28% and 29% necrotic lesion on the roots after receiving Neembicidin and *Pasteuria penetrans*, respectively. The highest 62% root necrosis or black roots were found under the control treatment. The second highest 48% of root necrosis was resulted from the treatments $T_5$ and $T_9$ where only poultry refuse and Neembicidin + Poultry refuse + Rugby 10G were applied, respectively.

### 4.1.11 Gall Index (0-10 scale):

From the present study it has been found that all the treatments reduced gall indices significantly over control treatment. The highest reduction of gall index in the banana plants (2.2) was calculated in the treatment $T_7$ where Furadan 5G and Poultry refuse were added. The second highest suppression of gall index (2.8) but statistically similar with $T_7$ was given by the treatments $T_1$ and $T_6$ which received Rugby 10G + Poultry refuse and Rugby 10G, respectively. The third highest reduction of gall indices 3.00, but statistically similar with $T_7$, was resulted by the treatments $T_2$ and $T_3$, which received Furadan 5G and Neembicidin, respectively. The highest gall index (4.6) was resulted under the control treatment ($T_{11}$). The second highest gall index 3.4 was given by the treatments $T_4$ and $T_8$ where *Pasteuria penetrans* and Poultry refuse + Neembicidin were applied, respectively. Heavily galled roots are shown in the picture 2.

**Picture 5 *Meloidogoine ssp* (pear shaped female) present in the root of control banana plant ($T_{11}$), observed under stereoscopic microscope (X 40).**



**Picture 6 Eggs and larvae of *Meloidogoine ssp* in root of control ($T_{11}$) plants observed under stereoscopic microscope (X 400).**

Table 3. Effect of different treatments on the suppression of root-knot nematode development in the banana roots, six months after the application of treatments in the pot soils.

| Treatments | Number of galls/ 100 cm root | Number of nematodes/ 10 cm root | % Necrosis | Gall Index (0-10) |
|---|---|---|---|---|
| $T_1$ | 21.60 cd | 18.20 ab | 32.00 cde | 2.80 b |
| $T_2$ | 19.40 cde | 13.80 cd | 41.00 bcd | 3.00 b |
| $T_3$ | 15.60 ef | 12.80 cd | 28.00 de | 3.00 b |
| $T_4$ | 24.20 bc | 15.00 abc | 29.00 de | 3.40 ab |
| $T_5$ | 29.20 ab | 13.20 cd | 44.00 bc | 3.40 ab |
| $T_6$ | 18.40 def | 14.60 abc | 26.00 e | 2.80 b |
| $T_7$ | 13.20 f | 10.40 d | 22.00 e | 2.20 b |
| $T_8$ | 23.20 cd | 13.80 cd | 48.00 b | 3.40 ab |
| $T_9$ | 22.60 cd | 14.20 bcd | 43.00 bc | 3.20 b |
| $T_{10}$ | 18.40def | 16.20 abc | 31.00 cde | 3.20 b |
| $T_{11}$ | 30.40 a | 18.60 a | 62.00 a | 4.60 a |
| LSD | 5.310 | 4.189 | 13.29 | 1.315 |
| CV (%) | 19.40 | 22.48 | 28.24 | 32.41 |

$T_1$: Rugby 10G @ 30 kg/ha, $T_2$: Furadan 5G @ 60 kg/ha, $T_3$: Neembicidin @ 5 ml/L water, $T_4$: *Pasteuria penetrans*, $T_5$: Poultry refuse @ 10 ton /ha, $T_6$: Rugby 10G + Poultry refuse, $T_7$: Furadan 5G + Poultry refuse, $T_8$: Poultry refuse + Neembicidin, $T_9$: Neembicidin + Poultry refuse + Rugby 10G, $T_{10}$: Furadan 5G + Poultry refuse + Neembicidin, $T_{11}$: Control

Each value is an average of five replications. Means bearing same letter with in the same column do not differ significantly at 5% by DMRT

### 4.1.12 Relationship between plant growth of banana with number of galls / 100 cm root.

#### 4.1.12.1 Stem height with number of galls / 100 cm root.

The stem height of banana was inversely related with no. of galls/100 cm root (Fig.1). The relationship between stem height and no. of galls was expressed as Y= 32.883-0.3258X (r = -0.56859) where Y= stem height and X= gall number. It indicated that increase of one gall may cause decrease in stem height by 0.3258 cm.

#### 4.1.12.2 Leaf length with number of galls / 100 cm root.

The relationship between leaf length and no. of galls were significant, which was observed in Fig. 2. The relationship was expressed as Y= 113.91- 0.8952X and r = -0.56413 (Y= leaf length, X= gall number). This indicated that 0.8952 cm leaf length may be reduced for increasing one gall of banana roots.

#### 4.1.12.3 Root length with number of galls / 100 cm root.

Root length of banana plants was significant and negatively correlated with no. of galls / 100 cm root (r = 0.46601). The relationship between them was expressed as Y = 38.806 – 0.4059X, which was shown in Fig. 3. Root length was decreased by 0.4059 cm with the increase of one gall.

#### 4.1.12.4 Plant weight with number of galls / 100 cm root.

The plants weight of banana plants was negatively correlated with no. of galls in the banana roots. The relationship between plant weights with gall number was expressed as Y = 7.5155 – 0.0956X and r = -0.54844, where Y = plant weights and X = gall number. This indicated that 0.0956 kg banana plant weight was reduced by increasing of one gall of banana root (Fig. 4).

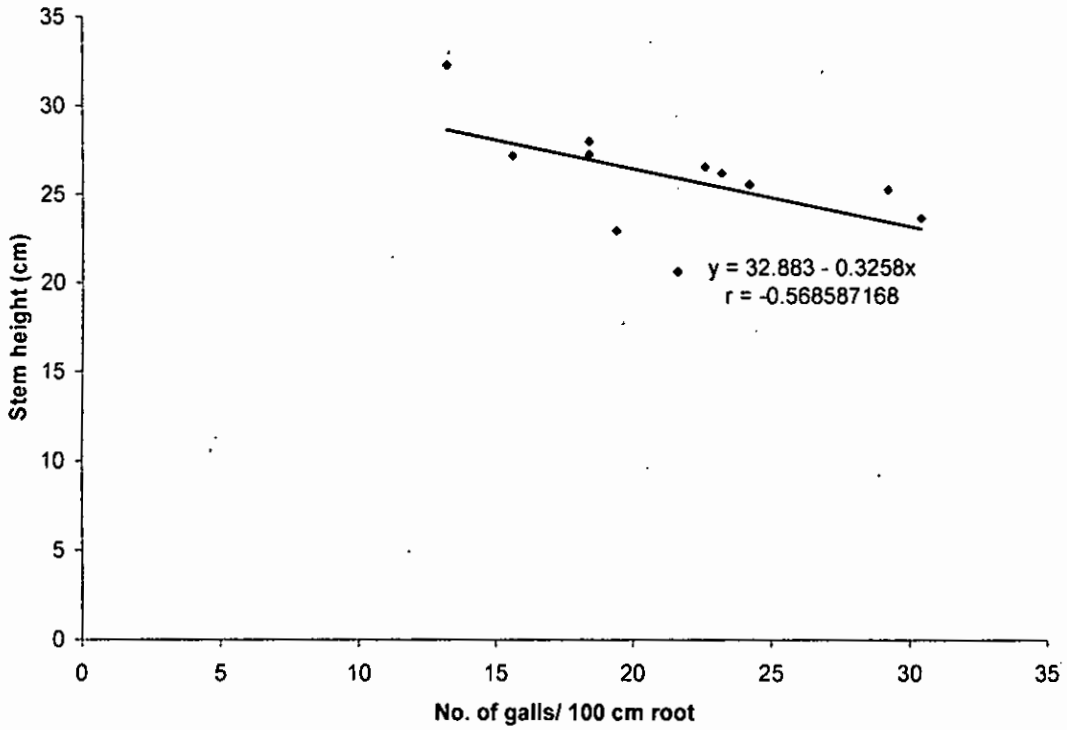



Fig. 1 Relationship between stem height with No. of galls/ 100 cm root (Y = Stem height, X = No. of galls)

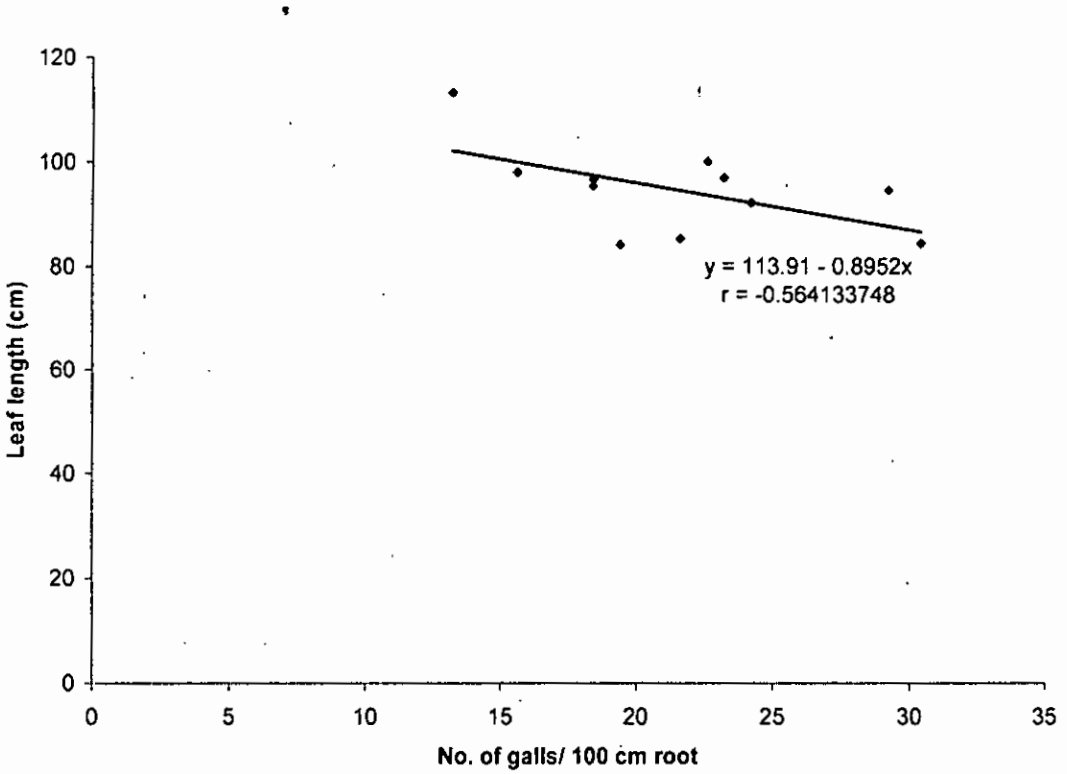



Fig. 2 Relationship between leaf length with No. of galls/ 100 cm root (Y = leaf length, X = No. of galls)

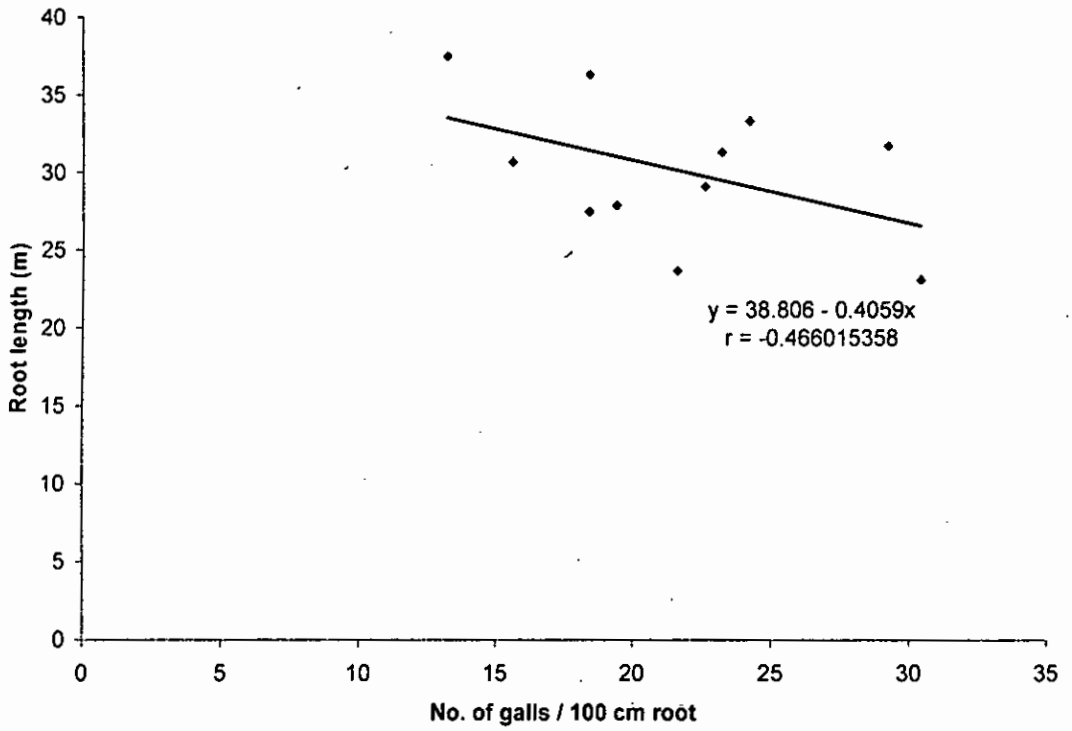



Fig. 3 Relationship between root length with No. of galls/ 100 cm root (Y = root length, X = No. of galls)

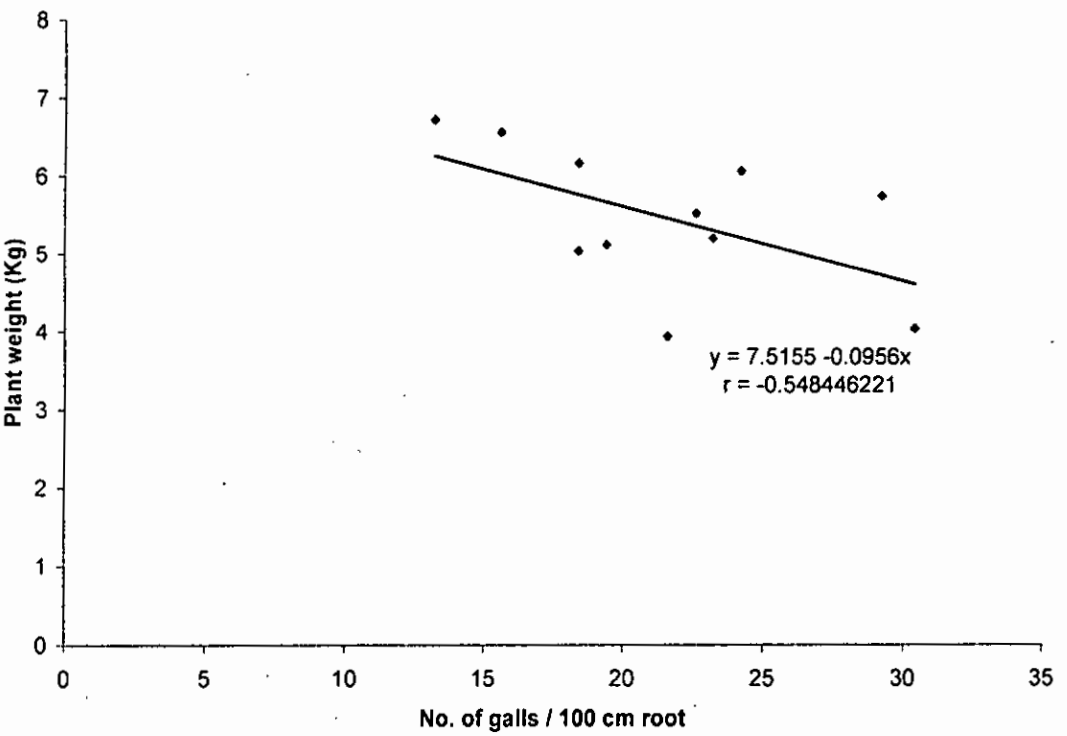



Fig. 4 Relationship between plant weight with No. of galls/ 100 cm root (Y = plant weight, X = No. of galls)

# Chapter 5
# Discussion

## DISCUSSIONS

The main objectives of this study was to find out the suitable management practices that can be adapted easily to manage root knot disease of banana caused by *Meloidogyne spp* in the farmers field to increase the quality and production of banana.

Results from the present study revealed that the chemical nematicides Rugby 10G, Furadan 5G, organic amendments, Poultry Refuse and Neembicidin, and bacterial bio-control agent *Pasteuria penetrans* caused satisfactory reduction of nematode population and gall development on root of banana plant. Chemical nematicides Rugby and Furadan when applied alone caused significant reduction of root-knot nematodes exhibited as reduced number of nematode population and galls and root necrosis. The findings of the present investigation on the root knot nematode and increased plant growth characteristics of banana with Furadan and Rugby are similar with the results of many researchers in various crops. Similar control of root-knot nematode and increased plant growth and yield were obtained with carbofuran in brinjal (Mohanty *et al.*, 2003), tomato (Zaki and Moqbool, 1995), potato (Mian *et. al.*, 1991) and papaya (Gupta and Sharma, 1988).

All the treatments gave considerable increase in plant growth characters including shoot and root characteristics of banana plant. In general, organic materials when supplemented with nematicides were comparatively better than nematicides alone to decrease nematode development and to increase plant growth characters. Among the organic amendments poultry refuse was considered to be the best amendment for nematode population and gall reduction. The present study indicated that organic amendment of soil with the combination of chemical nematicide, Furadan 5G and Rugby 10G considerably reduced the gall index and number of galls/g root and increased the total plant growth characters of banana over control. The finding of the present investigation on the root-knot nematodes and increased plant growth characters

of banana either single or combined application of nematicides and organic soil amendments, poultry refuse is agreed with the findings of many investigators in different crops. Effectiveness of poultry refuse is suppressing root-knot nematode and increased plant growth and yield in pointed gourd, tomato and jute were reported by Anon (2003), Nahar *et al.* (1996), Wahudeniya (1991), and Mishra *et al.* (1987), respectively.

However, all organic amendments were found to be promising for controlling root knot of banana plant caused by *Meloidogyne spp.* Other investigators also achieved appreciable control of root knot nematodes and increase in plant growth by treating nematode infested soil with neem leaf extract (Mishra *et al.* 1974, Nadal and Bhatti 1986, Zaiyd 1977, Alam 1990, Ahmed and Karim 1990), poultry refuse (Mian and Rodriguez-Kabana 1982, Mishra *et al.* 1987, Wahundeniya 1991, Nahar *et al.* 1996 and Marull *et al.* 1997), and oil cakes (Siddiqui *et al.* 1976, Ali and Mian 1989, Darekar *et al.*, 1990).

The available literature suggests that the increased microbiological activity during decomposition of organic substrates in the soil improves the changes in the number of micro flora and fauna that can destroy phyto nematodes. Another hypothesis says that the increased microbial activity in the amended soil leads to release of different types of chemicals some of which may kill or devitalize nematodes. Simultaneously, these chemical substances also change the osmotic concentration of the soil solutes which may play important role in reducing phytonematodes (Singh and Siteramaiah 1973, Mian and Rodriguez-Kabana 1982, Mishra *et al* 1987, Rodriguez-Kabana *et al.* 1990 and Stirling 1991).

According to Mian and Rodriguez-Kabana (1982) the organic amendment use to take part in reducing plant parasitic nematode through probably two ways, such as, release of decomposition products like formic acid, propionic acid, butyric acid, hydrogen sulphide, phenol, ammonia etc from amendments which are directly toxic to the plant pathogenic nematodes. Secondly enhanced

activities of other nonpathogenic micro-organisms which are antagonistic to the phyto-nematodes also help to suppress the pathogenic nematodes. The nematicidal activities of the organic substrates are enhanced by the presence of more nitrogenus or supplemented nitrogen, because process of decomposition is accelerated by the nitrogenus nutrients.

Results from the present study indicated that Rugby 10G and Furadan 5G were not much effective to reduce gall index, gall number, plant and root development over the control. But when Rugby 10G and Furadan 5G were applied with the combination of poultry refuse, these were more effective to reduce the gall index, gall number, and population of *Meloidogyne spp.* Their efficacy against root knot nematodes within soil application or as seed treatment has been confirmed by many workers (Maqbol *et al.* 1985, Haq and Saxena 1986, Naganathan 1984, Gichure and Ondieki 1984, Zahid *et al.* 1992, Nahar *et al.* 1996).

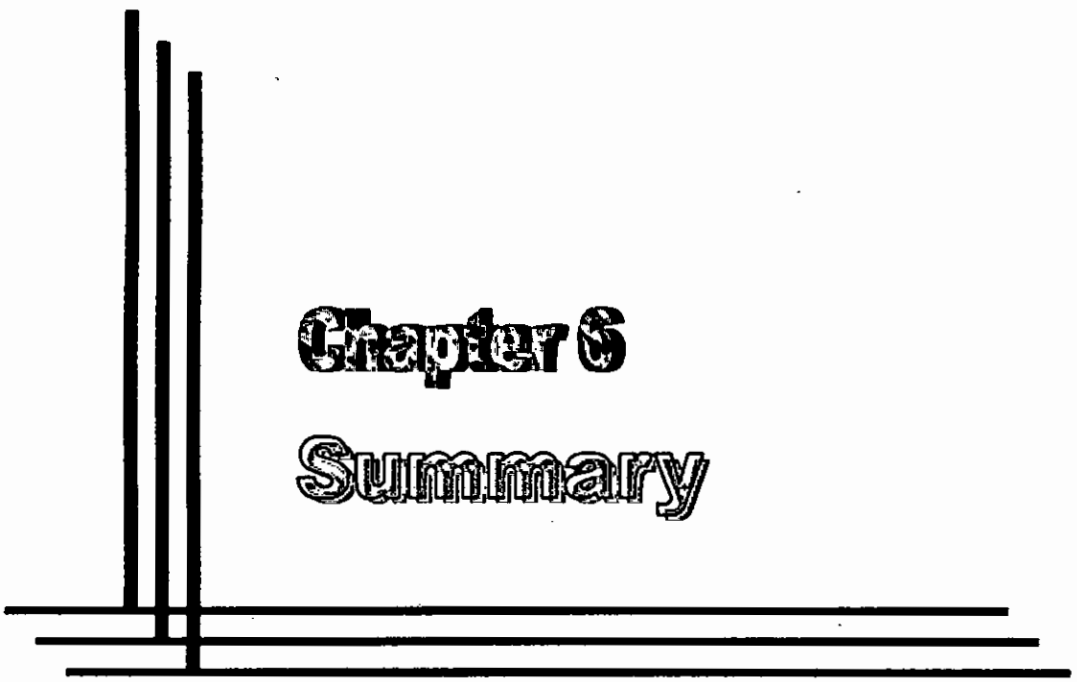
Adult female nematodes were observed under stereoscopic microscope after pinching the roots with needle while observed into microscope. Due to the attack of nematodes, roots growths were retarded and gall and % root necrosis were found highest in the control. The combination of organic amendments with chemical nematicides Furadan 5G or Rugby 10G, reduced gall index, no. of galls/100 cm root and no. of nematodes/10 cm roots. These parameters were lower than the initial values at the end of the investigation. These values were higher than the primary data in the control treatment ($T_{11}$).

In this present study, it was found that nematicides alone reduced the root knot infection of banana plant but it failed to give the satisfactory result in increasing plant growth characteristics than the combination of organic amendments with nematicides. Sometimes it was statistically similar to the control treatment ($T_{11}$), as it was observed in plant growth. But nematicides

decrease the gall/ 100 cm root, no. of nematodes / 100 cm root and % necrosis of roots.

Biological control agent *Pasteuria penetrans* (cyst forming bacterial bio-agent) gave the better performance in terms of increasing plant growth and decreasing nematode growth. But it was not showed the best performance over $T_7$ (Furadan 5G + Poultry Refuse) and $T_6$ (Rugby 10G + Poultry Refuse). Generally, the effect of the cyst forming bacteria on root-knot nematodes need long time. As the cyst infect the second stage female larvae of root-knot nematodes and multiply inside it, the female nematodes failed to produce healthy egg masses. Instead all the eggs in the infected females contained spores of the bacteria, which again infect the new healthy larvae produced by the healthy female after germination, ultimately, the reproduction of the nematodes drastically reduced. Gradually, after few generations, the population of root-knot nematodes in that field will reduce significantly.

From the present study it has been found that the application of nematicides Furadan and Rugby with or without organic substrates like poultry refuses and neembicidin and bacterial biocontrol agent *Pasteuria penetrans* may be useful in the control of root knot nematodes in the banana production.



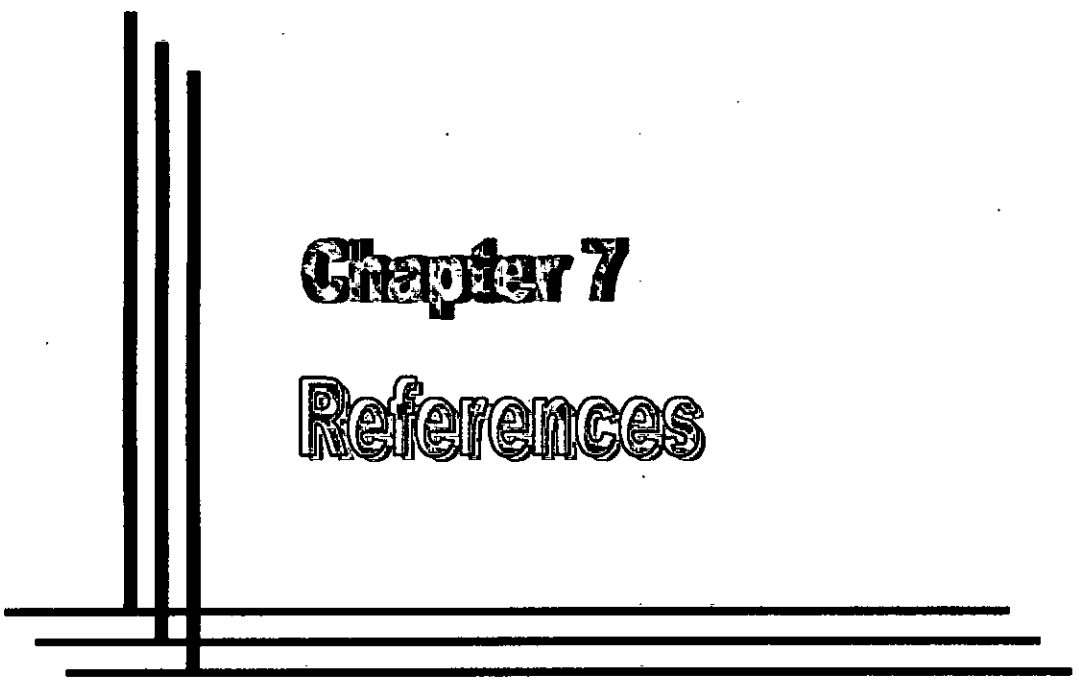
# Chapter 6

# Summary

## SUMMARY

A pot experiment was carried out to manage the root knot of banana seedlings with chemical nematicides, organic soil amendments and their combinations. The organic amendments were poultry refuse and neembicidin (a commercial product of neem, marketed by ACI, Bangladesh). The nematicides were Rugby 10G and Furadan 5G and a biological control agent *Pasteuria penetrans* (cyst forming bacterial bio-agent) was also used. Poultry refuse was applied @ 10 t/ha (2.5 kg/ plant) before 14 days of transplanting of banana seedlings. Rugby 10G, Furadan 5G, Neembicidin and *Pasteuria penetrans* were applied @ 30 kg/ ha (7.5 gm/ plant), 60 kg/ ha (15 gm/ plant) and 5 ml/ L water, respectively. Six months after the plantation of the banana plantlets and application of the treatments in the pot soils, banana plants were uprooted and washed carefully in tap water. Data on stem height, diameter of stem, leaf length, leaf breadth, root length, root weight, total plant weight, number of galls/ 100 cm root, number of nematodes / 10 cm root, % Necrosis of roots and on gall index were determined and recorded.

It was found that although the chemical nematicides alone controlled root-knot nematodes but plant growth characters were not improved satisfactory. But the combination of organic soil amendments with nematicides gave the best results in controlling root knot and improving growth parameters of banana plants. Biological control agent (*Pasteuria penetrans*) was also effective. But the results were below than the combination of organic amendments with nematicides. In general, organic amendments were more effective to induce plant growth and to reduce galls and nematode development.



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