MANAGEMENT OF ROOT KNOT NEMATODE IN RICE

By

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THESIS

submitted in partial fulfilment of the requirements for the degree of

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DECLARATION

I, Renitha Govind (2003-11-11) hereby declare that this thesis entitled **'Management of root knot nematode in rice'** is a bonafide record of research work done by me during the course of research and this thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

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CERTIFICATE

Certified that this thesis, entitled **'Management of root knot nematode in rice'** is a record of research work done independently by **Ms. Renitha Govind** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

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Dedicated to
My Parents

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INTRODUCTION

1. INTRODUCTION

Rice cultivation dates back to antiquity and rice is the principal food of nearly half of mankind. Rice crop *Oryza sativa* L., is cultivated in lowlands under flooded conditions and well drained upland fields. Rice is cultivated over an area of about 140 million hectares with a production of about 300 million tonnes globally. It is cultivated in almost all states of India. In Kerala, rice occupies an area of 3.9 lakh hectares with an annual production of 7.7 lakh tones (Government of India, 2002)

A large number of pests attack rice and some of these cause serious damage to the crop. The nematodes are considered as one of the important pest of rice. Nematodes are worm like microscopic organisms, which inhabit the soil around the plant roots and play a vital role in yield reduction. They are associated with rice crop grown in all agro ecological situations. Root knot nematode incidence is seen in the rice grown in well drained, upland soils in Orissa and West Bengal (Rao *et al.*1986), and deepwater rice fields in Assam (Prasad and Rahman, 2001).

The root knot nematode, *Meloidogyne graminicola* Golden and Birchfield is a sedentary endoparasitic nematode attacking rice. Root knot nematode cause aerial symptoms like chlorosis, wilting, delay in flowering, reduction in growth, reduction in number of tillers and underground symptom like root gall formation. The galls are seen at the growing tip of the root and may contain many nematodes. As a result the growth of the roots are arrested. The occurrence of gall in the root is the main symptom by which the presence of root knot nematode can be diagnosed.

Among the different *Meloidogyne* spp., *M. graminicola* is widely distributed in various parts of India and it has been reported from Kerala, Madhya Pradesh, Assam, West Bengal and Tripura. The rice root nematode, *M. graminicola* is well

distributed in tropical and subtropical zones. This nematode had been reported earlier from traditional rice growing regions of eastern, north eastern and southern India (Taya and Dabur, 2004)

Prasad and Gubbaiah (2001) reported a sudden outbreak of *M. graminicola* infestation in Karnataka during Kharif and cited that the nonrelease of irrigation water in summer was the cause for high build up of the nematode population. A survey conducted in different districts of Haryana revealed that the crop loss in the fields infested by *M. graminicola* ranged between 60 to 100 per cent. The major factor for such heavy infestation in the areas is attributed to presence of light textured soil and availability of ample irrigation water (Dabur and Jain, 2004)

In Kerala, nematode has not been reported as a serious problem in rice. Recently, a severe out break of root knot nematode infestation is observed in a few rice growing tracts of Palakkad district. Nematodes are important pest elements in the rapidly changing rice production systems and the pest potential of many nematodes is under estimated.

Bioagents and organic amendments substantially suppress nematode population but presently adopted practices are mainly based on synthetic chemicals. Apart from the prohibitive cost, environmental pollution and health hazards are serious problems with the use of broad-spectrum pesticides. In this backdrop, an assessment was made on the effect of some safer management practices using bioagents on root knot nematode in rice and its efficacy compared with carbofuran, the commonly used pesticide for nematode management. The objectives of the present study were

1. To identify the species of root knot nematode infesting rice

2. To evaluate the effect of different bioagents (*Psuedomonas fluorescens* (Trevisan) Migula, *Trichoderma viride* Persoon: Fries. *Bacillus subtilis* (Erhenberg) and AMF, chemicals (carbofuran and carbosulfan) and a neem formulation (Amrith guard) for the management of root knot nematode infesting rice.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

The *Meloidogyne graminicola* Golden and Birchfield, 1965 or root knot nematode species are obligate endoparasites having a wide range of hosts. Infestations of *M. graminicola* have been reported in a range of rice production systems in South East Asia, including upland, lowland and deepwater rice (Prot and Matias, 1995; Sharma *et al,* 2001). In India it has been reported from Kerala, Madhya Pradesh, Orissa, Assam, West Bengal and Tripura. In addition it has also been reported as an important pest of rice from Bangladesh, Thailand, U.S.A. and Vietnam (Jairajpuri and Baqri, 1991)

2.1 PEST STATUS

The root knot nematode *M. graminicola* has been recognized as one of the obnoxious pest of rice in uplands, nurseries medium lands (Rao and Biswas, 1973) and deep water (Bridge and Page, 1982). Losses in grain yield were estimated to range from 16 to 32 per cent due to this nematode (Rao and Biswas, 1973). The rice root knot nematode, *M. graminicola* is well distributed in a wide variety of ecological environments, particularly in tropical and subtropical zones. This nematode had been reported earlier from traditional rice growing regions of eastern, north eastern and southern India (Taya and Dabur, 2004).

A survey conducted in different districts of Haryana revealed that the crop loss in the fields infested by *M. graminicola* ranged between 60 to 100 per cent. The major factor for such heavy infestation in the areas is attributed to presence of light textured soil and availability of ample irrigation water (Dabur and Jain, 2004)

The crop infested with *M. graminicola* had poor stand, less tillering and number of effective tillers were very few. There were typical yellowing and stunting symptoms. Hook shaped galls were terminal in position (Dabur and Jain, 2004)

2.2 DIAGNOSTIC FEATURES

M. graminicola was described and illustrated by Zhao *et al.* (2001). Female perineal pattern is dorsoventrally ovoid or rounded. Striae are usually fine and smooth, occasionally broken by short and irregular striae. Phasmids are small but distinct and closely spaced. Male head region is low and wide. It may be smooth or may contain distinct annules. Second stage juveniles tail with a long and narrow hyaline terminus. The terminus is clavate.

2.3 OTHER SPECIES OF *Meloidogyne* IN RICE

Meloidogyne incognita (Kofoid and White) Chitwood, *Meloidogyne javanica* (Treub) Chitwood and *Meloidogyne arenaria* (Neal) Chitwood are major pests of rice in temperate and warm tropical areas. *Meloidogyne oryzae* Maas, Sanders and Dede, 1978 and *Meloidogyne solasi* are seen in South America.

2.4 MANAGEMENT

2.4.1 Using Bioagents

2.4.1.1 In Rice

A study by Pathak and Kumar (1995) proved that maximum (more than 96 per cent) *M. graminicola* mortality was recorded at 100 and 50 per cent

concentrations of *Trichoderma harzianum* Rifai. The root dip of rice (cv. Rajshree) seedlings in the culture filtrate of *T. harzianum* and *Glomus virens* for different durations and concentrations had significant effect on the penetration ability of *M. graminicola* (Pathak and Kumar, 2003)

2.4.1.2 In Other Crops

Sikora and Schonbeck (1975) in their study established that there is reduction in root penetration and development of *M. incognita* by vesicular arbuscular mycorrhizae (VAM) in tomato. A report by Suresh *et al.* (1985) showed that number of giant cells formed in mycorrhizal tomato when infected with root knot nematode was significantly low when compared with non mycorrhizal plants. Development and reproduction of nematodes are often inhibited by mycorrhizal association (Cooper and Grandison, 1986; Jain and Sethi, 1988).

Jain and Sethi (1988) concluded that the gall formation by *M. incognita* and their multiplication were hampered by early establishment of *Glomus fasciculatum* on cowpea. Gokte and Swarup (1988) stressed the larvicidal effect of *Bacillus subtilis, Bacillus pumilis* and two species of *Psuedomonas* on *Anguina tritici*. Seed treatment of the above isolates in wheat individually as well as in combination caused reduction in percentage of penetration of juveniles to the roots of wheat seedlings and the viability of the larvae. Recently the flourescent *Pseudomonas* spp. associated with plant rhizosphere emerged as the largest and most promising biocontrol agents of plant parasitic nematodes (Oostendrop and Sikora, 1989)

Oostendrop and Sikora (1990) elaborated the effectiveness of *P. flourescens* as a potential biocontrol agent against *M. incognita* due to their ability to envelop or bind the root surface with carbohydrate and lectin there by interfering with normal host recognition.

Sivaprasad *et al.* (1990) observed that deleterious effect of nematodes was made insignificant due to arbuscular mycorrhizal associations in cowpea. The effect of the bacteria *B. subtilis, B. pumilis, B. coagulans, B. macerans and B. ciculans* was studied on related genera like *Heterodera oryzicola* which revealed that at 1.2×10^8 cells per ml of these bacteria caused 70 to 80 per cent larval mortality (Sheela, 1990)

Studies conducted by Sharma *et al.* (1994) indicated that VAM colonization reduced the root knot infestation in tomato. Mycorrhizal tomato seedlings had lesser number of galls, egg masses per plant, eggs and juveniles per egg mass. They studied the effect of arbuscular mycorrhizal fungus *G. fasciculatum* in the survival, penetration and development of root knot nematode *M. incognita* in tomato under glass house condition and found that the symbiont caused a reduction of 30 per cent in galls and egg masses per plant.

Santhi and Sivakumar (1995) reported the biocontrol potential of *P. flourescens* (Migula) against root knot nematode on tomato. A report by Sundarababu *et al.* (1996) showed that when *G. fasciculatum* was inoculated 15 days earlier than nematode inoculation, it enhanced the growth of tomato cv. Co-3 and suppressed *M. incognita* multiplication in pot experiments. *G. fasciculatum* was very effective in controlling root knot nematode in brinjal (Asha, 1996) and in spices like ginger, turmeric, cardamom, pepper (Sivaprasad and Sheela, 1998) and kacholam (Rajani *et al.* 1998).

Study conducted by Nageswari and Sundarababu (1998) revealed that *G. fasciculatum* could be effectively used as a biocontrol agent for *H. cajani* in cowpea. Sundarababu *et al.* (1998) proved that application of *G. fasciculatum* @10gkg^{-1} was sufficient for effective management of root knot nematode infesting tomato and okra

A talc formulation of *P. fluorescens* containing 15X108 $cfug^{-1}$ was prepared and applied to soil around root-knot infested grape vines at 15 cm depth in the basin, at the time of pruning. The bacterial formulation was applied at dosages of 1, 2 and 4 g per vine and compared with application of carbofuran at 1.8 g a.i. per vine and an untreated control. Application of *P. fluorescens* at all the three dosage levels significantly reduced the severity of root knot infection in roots. The extent of root colonization by *P. fluorescens* was dosage dependent but not directly proportional to it. The root colonization was significantly better at all dosage levels of *P. fluorescens* (Shanthi *et al*, 1998).

As reported by Ramakrishna *et al.* (1998) application of *P.flourescens* as seed treatment at a dosage of $10gkg^{-1}$ seed was effective in reducing the infestation of *Hirschmaniella gracilis.* Research findings of Verma *et al.* (1998) revealed that application of *P. flourescens* @ 10g kg^{-1} seed was effective in reducing the menace of root knot nematode, *M. incognita* in tomato.

A study conducted by Spiegel and Chet (1998) indicated that improved growth of nematode infected plants and decrease 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* preparations. Sankaranarayanan *et al.* (1999) in their study in *T. harzianum* isolates against *Meloidogyne incognita* established that *T. harzianum* was found most effective with respect to treated plants having the least number of galls and egg masses on root systems and nematode populations in soil. Khan (1999) conducted a study on the toxic effects of culture filtrates of fungi, i.e. *Alternaria alternata, Aspergillus clavatus, Rhizoctonia solani, Fusarium solani, Rhizopus stolonifer* and *Trichoderma viride,* on *Meloidogyne incognita* larvae.

Complete larval mortality was also observed in *F. solani, T. viride, Rhizoctonia solani* filtrates after 24 h.

B. thuringiensis, B. subtilis and *P. fluorescens* were evaluated for the control of *M. incognita* on tomato plants using bioassays and greenhouse tests. *P. fluorescens* isolates showed the most nematicidal activity against hatched juveniles and adults of *M. incognita* (Hanna *et al*, 1999). Sheela *et al.* (1999) also reported the biocontrol efficiency of *B. subtilis* against *M. incognita* in brinjal.

The effects of biological treatments on root-knot nematode (*M. incognita*) and fruit yield of tomato were evaluated by Reddy *et al,* 1999. *B. subtilis* strain GB03 plus one additional PGPR and a flaked chitosan was used as treatments. Across all categories of fruit, greater yields occurred with biological treatments especially in *B. subtilis* treated plots.

Khan *et al.* (2000) carried out a study by comparing chemicals and biological control treatments against *M. incognita,* on the basis of the number of galls formed on roots per tomato plant. *T. harzianum* and *Paecilomyces lilacinus* were amended with organic substrate, which resulted in the minimum number of galls per plant that was 70.61 per cent less as compared with the control.

Saravanapriya and Sivakumar (2003) reported that culture filtrates of *Bacillus* and *Pseudomonas* can cause 80 to 90 per cent mortality in *M. incognita* juveniles. The efficacy of 2 strains of *Pseudomonas aeruginosa,* i.e. Pa-5 (3.5 x 108) cfu per ml and IE-2 (2.9 x 108 cfu per ml) and *B. subtilis* (3.0 x 108) isolate alone or in combination with neem cake or *Datura fastuosa* at 0.5 and 1.0 per cent (w/w) was tested for the management of 3 soilborne root-infecting fungi, i.e. *Macrophomina phaseolina, Fusarium solani and Rhizoctonia solani,* and the root-knot nematode, *M.*

javanica, on urdbean (*Vigna mungo*). *B. subtilis* in combination with either neem cake or *D. fastuosa* gave better control of the root-rot and root-knot infection with the enhancement of growth of urdbean compared to the use of either component alone (Siddiqui *et al*, 2001).

Sharon *et al.* (2001) carried out a study on the fungal biological control agent, *T. harzianum*, for its potential to control the root-knot nematode *M. javanica*. In greenhouse experiments, root galling was reduced and top fresh weight increased in nematode infected tomatoes.

Khan *et al.* (2002) proved that treatment with *B. subtilis* or *Beijerinckia indica* reduced galling by 33-34 per cent and increased the dry weight of shoots by 22-24 per cent in green gram. Egg mass production and soil populations of *M. incognita* were more adversely affected. Field trials were performed in Florida, USA during 1998-99 to evaluate tomato and pepper transplants amended with formulations of several plant growth-promoting rhizobacteria (PGPR). *B. subtilis* was found to reduce root knot nematode *M. incognita* infesting tomato and pepper (Burelle *et al*, 2002)

Devi and Dutta (2002) studied the effect of *P. fluorescens* on root-knot nematode (*Meloidogyne incognita*) of okra plant. They found that *P. fluorescens* improved shoot and root lengths and weights, and reduced root gall number.

A study conducted by Faruk *et al.* (2002) indicated that different isolates of *T. harzianum* (W-108, W-120, TG, TK, T33, and TV-1) reduced severity of root knot and increased plant growth and fruit yield over the control. Pant and Pandey (2002) carried out a pot culture experiment to determine the effect of using *T. harzianum* and neem cake alone and in combination to manage *M. incognita* in chickpea. The study revealed that the organic amendment and *T. harzianum* increased the chickpea growth

over the control. Reduction of root-knot nematode was maximum with neem cake + *T. harzianum*, followed by neem cake and *T. harzianum* alone.

While analyzing the culture filtrates of *P. striata* (strain 303), *Aspergillus awamori*, *T. harzianum* and *T. viride* for their effects on egg-hatch in laboratory experiments Ansari *et al.* (2002) found that *T. harzianum* and *T. viride* reduced egg hatch by 13 to 69 per cent. Devi and Sharma (2002) carried out a study on the effect of *Trichoderma* spp. against root knot nematode *M. incognita* on tomato. Plant growth and nematode population were evaluated 90 days after nematode inoculation. Treatment with *Trichoderma* improved plant height, shoot weight, and root length and weight, and reduced nematode population.

Devi and Hassan (2002) carried out a study on the effects of *T. viride* and organic manures (farmyard and poultry manures) on *M. incognita* on soybean in Allahabad, Uttar Pradesh, India, during the kharif season of 2000. Soybean seeds were treated with *T. viride* at 50 gkg^{-1} seeds. The seeds were sown 12 h after treatment with *T. viride*. Germination percentage was recorded 7 days after sowing (DAS), and plant growth and root knot formation were recorded at 30, 60, and 90 DAS. *T. viride* improved plant growth (measured in terms of shoot height, and number of branches, leaves, and nodules) and reduced nematode gall formation. Seed germination and plant growth were most pronounced with the application of *T. viride*

Nursery and field experiments were conducted by (Mahapatra *et al*, 2003) to determine the efficacy of *P. fluorescens* against *M. incognita* infesting aubergine. *P. fluorescens* at 20 g m^{-2} had the highest reduction (46.4 per cent) in root-knot index at transplanting. Exposure of root-knot nematode to culture filtrates of *P. fluorescens* under in vitro conditions significantly reduced egg hatch and caused substantial mortality of *M. javanica* juveniles (Siddiqui and Shaukat, 2003)

Pot and field trials were conducted by Pandey *et al.* (2003) to study the efficacy of different levels of *T. viride* (1000, 2000, 3000 and 4000 spores per plant) against root-knot nematode (*M. incognita*) in chickpea. All the treatments of *T. viride* showed significantly higher plant growth parameters over control. The gall development and final nematode population of *M. incognita* decreased with the increasing level of *T. viride* under pot and field conditions. While analyzing the plant growth parameters and nematode population 30 days after inoculation of *T. viride* at 5 x 10^6 Singh *et al.* (2003) found that the treatment significantly reduced *M. incognita* population in okra. The treatments significantly improved plant growth characteristics also. Studies conducted by Chaitali *et al.* (2003) indicated that *T. viride* treatments reduced *M. incognita* population 30 days after inoculation.

A field experiment was conducted by Jothi *et al.* (2003) to evaluate the efficacy of commercially formulated *P. fluorescens* against root-knot nematode, *M. incognita*, race 3 infesting tomato. *P. fluorescens* treated plants gave the maximum yield (64.3 per cent) and minimum M. incognita soil population (56 per cent). The efficacy of *P. fluorescens* strain CHA0 against *M. javanica* was evaluated in the repeated experiments conducted in sandy loam soils under glasshouse conditions by Siddiqui *et al.* (2004). Biological control inoculants significantly reduced nematode population densities and subsequent root-knot infection in two different legumes i.e. mung bean and soyabean.

According to Siddiqui and Shaukat (2004) *P. fluorescens* and *T. harzianum* applied together in unsterilized sandy loam soil caused greater reduction in nematode population densities in tomato roots. They also found that *T. harzianum* improves biocontrol by the antagonistic rhizobacterium *P. fluorescens* both in vitro and under glasshouse conditions.

2.4.2 Using Chemicals

2.4.2.1 In Rice

Carbofuran, aldicarb, ethoprophos and fenamiphos at one, three and five kg ai per ha per plant respectively were evaluated for control of *M. graminicola* in deep water rice in field and pot experiments by Rahman (1991). The nematode population in the soil, percentage of plant infestation and number of galls and mature females in the root were significantly reduced in treated plots. Carbofuran, phorate, isazophos, cartap, cabosulfan or quinalphos were applied to rice variety Jaya, infested with *M. graminicola* in a pot experiment. All tested pesticides significantly reduced galling at one kg per ha or above (Panigrahi and Mishra, 1995).

Das *et al.* (1999) evaluated the efficacy of *Polygonum hydropiper*, neem seed, *Ageratum* sp., *Mikania* sp., rice straw and water hyacinth, and two antagonistic fungi, *Paecilomyces lilacinus* and *Gliocladium virens* and carbofuran against *M. graminicola* under field conditions. Carbofuran (Furadan 3G) @ 1.5 $kgha^{-1}$ was the most efficient amongst all the treatments. While analysing different chemicals against root knot nematode *M. graminicola* (Mohanty *et al*, 2000) found that carbosulfan 25 EC at 0.1 per cent was effective amongst all treatments having lowest number of egg masses per 5g of root and highest yield.

Tiwari *et al* (2002) found that the rice nursery bed treated with 0.6 g carbofuran significantly decreased gall index and increased crop yield. Compared to other plots the maximum yield (362 q per ha) was recorded in carbofuran treated nursery beds.

2.4.2.2 In Other Crops

A study conducted by Bhagavathi and Phukan (1990) indicated that carbofuran reduced the galls and egg masses in roots of pea and increased the yield. Borah and Phukan (1990) tried carbofuran 3 G, phorate 10 G, Mocap10 G and Diazinon10G each at one, two and three per cent as seed treatment for the control of *M. incognita* on green gram and found that increase in concentration of chemicals resulted in the decrease in number of galls and egg masses and increase in plant growth characters and yield.

Research findings of Mohan and Mishra (1993) revealed that carbofuran was effective in suppressing *M. incognita* activity and improving plant growth of French bean. Soil application of carbofuran @ 2kg ai per ha and seed dressing 22g ai per kg seed were highly effective in controlling *M. incognita* larvae and reduced root knot galls in pea compared to control plants. These treatments also improved the plant growth parameters and yield (Devi, 1993).

Singh and Kumar (1995) concluded that carbofuran 2kg ai per ha was effective in reducing the population of *M. incognita* and increasing the growth parameters like root length, shoot dry weight, root fresh weight and number of leaves in Japanese mint. Faruk *et al.* (2001) conducted two separate experiments in Bangladesh to evaluate the efficacy of pre-plant soil treatment with poultry refuse, neem leaf powder, and Furadan 3G [carbofuran] for the management of root-knot nematodes *(Meloidogyne* spp.) of tomato. They found that among the treatments, poultry refuse alone and mixed with Furadan 3G reduced root-knot disease and improved the growth and fruit yield of tomato. Phorate 10 G, triazophos 40 EC, carbofuran 3 G at 0.5-1.0 kg a.i. per ha, achook @ 5 $Kgha^{-1}$ and neem seed powder (NSP) @ 50 $Kgha^{-1}$, were used alone or in various combinations for the control of root-knot nematode (*M. incognita*) on spinach cv. Local, in a field experiment in New

Delhi, India during September 1999. Application of carbofuran resulted in the highest yield and the highest reduction of nematode population (Sharma *et al*, 2001)

Khan and Rathi (2001) investigated the effect of available organic amendments, along with carbofuran, on root-knot nematode infesting tomato cv. Pusa Ruby in a field experiment conducted during 1997 and 1998, in Solan, India. All the treatments improved plant growth and yield in comparison to the untreated control and the soil amendments matched well with carbofuran treatment.

2.4.3 Neem Based formulations

2.4.3.1 In Rice

Das and Deka (2002) studied the effects of Neem Azal 5 per cent, Neem Azal F 1 per cent, Multineem, Econeem and Neemstar at 4 per cent on *M. graminicola*. The neem based products effectively reduced gall number, egg mass and soil nematode population.

2.4.3.2 In Other Crops

The effects of neem products in comparison with carbofuran (4 kg ai. per ha) were studied on *M. incognita* in pot experiments. In comparison with control, all treatments were effective and maximum fruit weight per plant and minimum number of root knots and egg masses were recorded in carbofuran treated pots (Jacob *et al*, 1998).

Nanjegowda *et al*. (1998) evaluated the efficacy of various neem (*Azadirachta indica*) products: neem seed kernel, neem leaf, neem cake, Nimbecidine

and a nematicide (carbofuran) against *M. incognita* in a tomato nursery. They concluded that the neem products significantly reduced the nematode population and increased the plant growth compared to control. A neem pesticide Achook was tested as soil treatment @ 0.5, 1.0, 2.0, 4.0, and 8.0 gkg $^{-1}$ soil in pots against *M. javanica* on okra. Data recorded 35 days after nematode inoculation indicated that plant growth parameters were improved significantly at 1.0 and 2.0g kg^{-1}doses over control (Kaushal, 1999)

Sharma (2000) reported significant reduction in the number of galls of *M. incognita* in vegetables, with soaking of seeds in 5 per cent neemark and nimbecidine. Five neem based formulations: Neem Jeevan, Neemark, Neem Gold, Achook and Kranti were tested at 1.0, 0.5 and 0.25 per cent concentrations by Sharma (2000) against *M. incognita*. Their findings indicated that these formulations were effective in controlling the nematode population.

Javed *et al.* (2001) reported the lowest number of galls when tomato was treated with nimbokil (*A. indica* product extract) compared to control. Randhawa *et al.* (2002) in a pot experiment proved that the growth of okra cv. Punjab 7 was enhanced and the *M. incognita* population was reduced when the botanical extracts and Rakshak Gold (neem based preparation) were applied to seeds at 0.5, 1.0, and 1.5 per cent.

A pot experiment was conducted by Mittal and Prasad (2003) to determine the effect of neem formulations and triazophos on soyabean against the root-knot nematode *M. incognita*. The treatments comprised azadirachtin (0.15 EC), neem gold 0.03 EC, Bioneem 0.15 EC, Rakshak 0.03 EC, Linanool 0.15 EC, Sukrina at 10 and 20 litres per ha and triazophos at 2 litres per ha. The highest shoot length, fresh shoot weight, and fresh root weight were obtained with 20 litres azadirachtin 0.15 EC and

10 litres Neem gold. The lowest number of root-knot galls was observed in Bioneem and Linanool treatments.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The objectives of the study entitled 'Management of root knot nematode in rice' include identification of species of rice root knot nematode and management of this nematode by different bioagents and chemical pesticides. The experiments were carried out in the Department of Agricultural Entomology, College of Horticulture, Vellanikkara during February 2004 to July 2005

3.1 COLLECTION OF ROOT AND SOIL SAMPLES

A survey was conducted for the collection of soil and root samples from the rice growing tracts, already infected with root knot nematodes, from two blocks of Palghat district namely Nenmara and Alathoor. Samples were also collected from infested plots of Agriculture Research Station, Mannuthy. Root and soil samples were taken in polythene bags and labelled. Sufficient numbers of root and soil samples were collected from each location, labelled and kept in polythene bags for maintaining a pure culture of nematodes and further studies.

3.2 MAINTENANCE OF CULTURE OF RICE ROOT KNOT NEMATODE

The paddy variety, *Kunjukunju Varna* obtained from Rice Research Station, Pattambi was used for the maintenance of nematode culture. The seeds were sown in pots filled with denematized potting mixture. Second stage juveniles of root knot nematodes were extracted from infested soil and root samples collected from the paddy fields. Cobbs decanting and sieving technique was followed for extracting the nematodes from soil samples (Cobb, 1918). Galls were separated from root samples after cleaning thoroughly with tap water and nematodes were extracted from roots by Modified Baermann funnel method or Petri plate method (Schindler, 1961). The second stage juveniles of the nematodes obtained were inoculated to the potted plants. Repotting and inoculation was repeated periodically for maintaining the pure culture of root knot nematode for different experiments.

Plate 1. Lay out of the experiment.

3.3 IDENTIFICATION OF NEMATODES

The species of root knot nematodes are identified by the perineal pattern of the white females. So white females were collected from the root knots for the identification of the species of nematodes.

3.3.1 Collection of White Females by Staining Technique

Root samples collected from the culture plants were used for extracting white females. Root samples were washed in a stream of tap water to remove any soil particles adhering to it. Root knots were separated from the roots with the help of a scissor. It was then placed in small piece of muslin cloth and was wrapped in it. This small bag containing root knots were plunged into boiling lacto phenol containing 0.1 per cent cotton blue for 3 minutes. The root knots were removed from muslin cloth and were kept in a Petri plate. It was washed in water to remove excess stain. The root knots were transferred to a microscopic slide containing a drop of lactophenol. It was then placed under a stereomicroscope and was dissected using a needle. The white females, which was stained light blue, came out of the root knots in large numbers, were collected and transferred to a glass vial containing lactophenol. It was then closed tightly and was sent to the Department of Nematology, Indian Agricultural Research Institute, New Delhi for identification.

3.4 POT CULTURE STUDIES

Pot culture studies were conducted to determine the efficacy of different bioagents and chemical pesticides in the management of rice root nematode under flooded and non flooded conditions.

Design

The experiments were laid out in Complete Randomized Design with nine treatments and three replications. The treatments were

T1- Seed treatment (10g kg^{-1} seed) and soil application (2.5kgha^{-1}) of *Pseudomonas fluorescens*

T2 - Seed treatment (4gkg^{-1} seed) and soil application (2.5kgha^{-1}) of *Trichoderma viride*

T3 - T1 + T2

T4 - Seed treatment (10gkg^{-1} seed) and soil application (2.5kgha^{-1}) of *Bacillus subtilis*

T5 - Soil application of neem granules (Amrith guard @ 25 kgha^{-1})

T6 - Soil application of AM Fungi (10gkg^{-1} soil)

T7 - Soil application of carbofuran (18kgha^{-1})

T8 - Foliar spray of carbosulfan (0.05%)

T9 - Control

3.4.1 Preparation of Denematized Potting Mixture

Sieved soil, sand and well-decomposed farmyard manure was mixed in the ratio 1:1:1 and the mixture was spread on a concrete floor in the form of beds of 15cm thickness. The beds were divided into blocks of one square feet. The potting mixture in each block was covered with transparent polythene sheets and was exposed to sun for solarization. After two weeks, the polythene sheets were removed and the mixture was raked well. Soil samples were taken from each

block to test the presence of nematodes. This sterilized potting mixture was used for pot culture studies.

3.4.2 Raising of Nursery

Paddy variety *Kunjukunju Varna* was used for raising nursery.

P. fluorescens (10gkg^{-1} seed), *T. viride* (4gkg^{-1} seed) and *B. subtilis* (10gkg^{-1} seed) were used for treating the seeds. *P. fluorescens* and *T. viride* were used individually and in combination. Fifty grams of paddy seeds were taken in separate beaker and poured 100ml of distilled water to soak the seeds. To this the required quantity of bioagents were mixed thoroughly and kept overnight.

Amrith guard @ 25 kgha^{-1}, AMF (10 gkg^{-1} soil), carbofuran @ 18 kgha^{-1}and carbosulfan (0.05%) were applied only at the time of transplanting. Seeds were soaked in distilled water and kept over night for these treatments and control.

Nursery was raised in earthern pots of 25cm diameter filled with denematized potting mixture. The treated seeds were sown in each pot and labelled accordingly.

3.4.3 Transplanting of Seedlings

Earthern pots of size 25cm diameter were used for transplanting the seedlings. The experiment was conducted under flooded and non flooded conditions. All treatments were included for flooded and nonflooded condition. For maintaining flooded condition, drainage holes of pots were closed with cement.

Pots were filled with denematized potting mixture. Plants were irrigated periodically to maintain wet condition of soil in non flooded and standing water for flooded ones. Three numbers of 25 day old seedlings were transplanted in each pot from respective treatments.

3.4.4 Treatments at the Time of Transplanting

P. fluorescens, *T. viride* , *P. fluorescens* + *T. viride*, *B. subtilis*, neem granules (Amrith guard), AMF and carbofuran were applied to the soil in the required quantity at transplanting stage. Carbosulfan was given as foliar spray. AMF was mixed thoroughly with 5cm upper layer of denematized potting mixture.

3.4.5 Extraction of Second Stage Juveniles for Inoculation

Second stage juveniles of root knot nematode were extracted from the galls collected from the culture plants. Procedure of Modified Baermann funnel method (Petri plate method) was followed for extraction. Roots were gently cleaned free of soil particles by holding them in a stream of tap water. After cleaning the roots were cut into small pieces. It was then spread on the surface of tissue paper kept over the wire mesh placed on a Petri dish, containing sterile water. Care was taken to see that the wire mesh was just in contact with water in the Petri plate. After 24h, the nematode suspension was drawn out from the Petri dish. This was continued till no nematode was obtained.

3.4.6 Inoculation of Nematodes

Nematode population in the nematode suspension was assessed. Each pot was inoculated with 10ml of suspension containing 2000 second stage juveniles of root knot nematodes after seventh day of transplanting. At the time of inoculation the suspension was thoroughly mixed by blowing air with a pipette, to get uniform

distribution of nematodes. This suspension was then poured to the root zone of plants, by making holes of about 5cm depth in soil using a glass rod.

The crop was given all agronomic operations as recommended in Package of Practice of crops - Recommendations 2002 (Kerala Agricultural University, 2002)

3.5 OBSERVATIONS

The following observations were taken during the course of the experiments

1. Shoot characters

a) Number of leaves.

b) Height of the plant.

c) Number of tillers.

2. Yield

a) Date of flowering.

b) Number of days to harvest.

c) Number of panicles.

d) Number of grains per panicle.

e) Wet weight of grains.

f) Dry weight of grains.

g) Weight of straw.

3. Root characters

a) Length of root.

b) Weight of root.

4. Nematode population

a) Nematode population in 200g soil.

b) Number of nematodes in 10g of root.

c) Number of root knots in 10g of root.

3.5.1 Estimation of Nematode Population from Soil

A composite sample of 200g soil was collected from the root zone of plants from each pot and processed for extracting nematodes by Cobbs decanting and sieving technique (Cobb, 1918). The nematode suspension drawn out after 24h was counted using counting dish.

3.5.2 Estimation of Galls from Roots

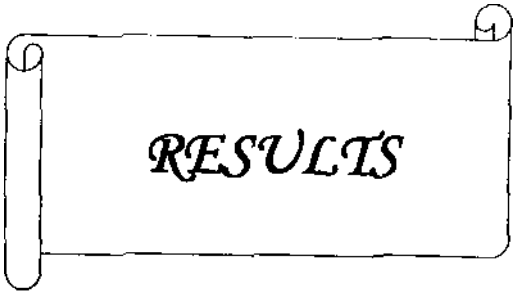
Root samples were taken from the uprooted plants, of each treatment of flooded and non flooded pots in a polythene cover and labelled. It was cleaned free of soil particles and 10g of root was taken to count the number of galls.

3.5.3 Estimation of Nematode Population from Root

After counting the number of galls, the root samples were used for extracting nematodes. The Modified Baermann funnel technique was used for extracting nematodes from roots (Schindler, 1961).

3.6 STATISTICAL ANALYSIS

Analysis of variance was performed on the data collected in the experiments using statistical package of MSTAT. Multiple comparison of the means was done using DMRT.


RESULTS

4. RESULT

The results of the study 'Management of root knot nematode in rice' are presented in this chapter

4.1 IDENTIFICATION OF NEMATODES

The white females collected from root knot nematode infested rice root were sent to the Department of Nematology, Indian Agricultural Research Institute, New Delhi. The species of root knot nematode attacking rice plant was identified as *Meloidogyne graminicola.*

4.2 POT CULTURE EXPERIMENTS

Pot culture experiments were conducted to study the effect of different bioagents, chemicals and a neem formulation on management rice root knot nematode under flooded and non flooded conditions. Treatments were given as mentioned in 3.4. The effect of the treatments on the shoot characters, yield, root characters and nematode population are presented.

4.3 FLOODED CONDITION

4.3.1 Shoot Characters

4.3.1.1 Number of Leaves

The data related to the number of leaves of the seedlings on the day of transplanting and harvest was statistically significant. The result is presented in Table1. There was significant variation in the number of leaves of seedlings raised from seeds treated with *P. fluorescens, T. viride, P.fluorescens* + *T. viride* and *B. subtilis.* At the time of transplanting T4 was found to be superior with 15.67

Plate 4. Root knots produced by *Meloidogyne graminicola*

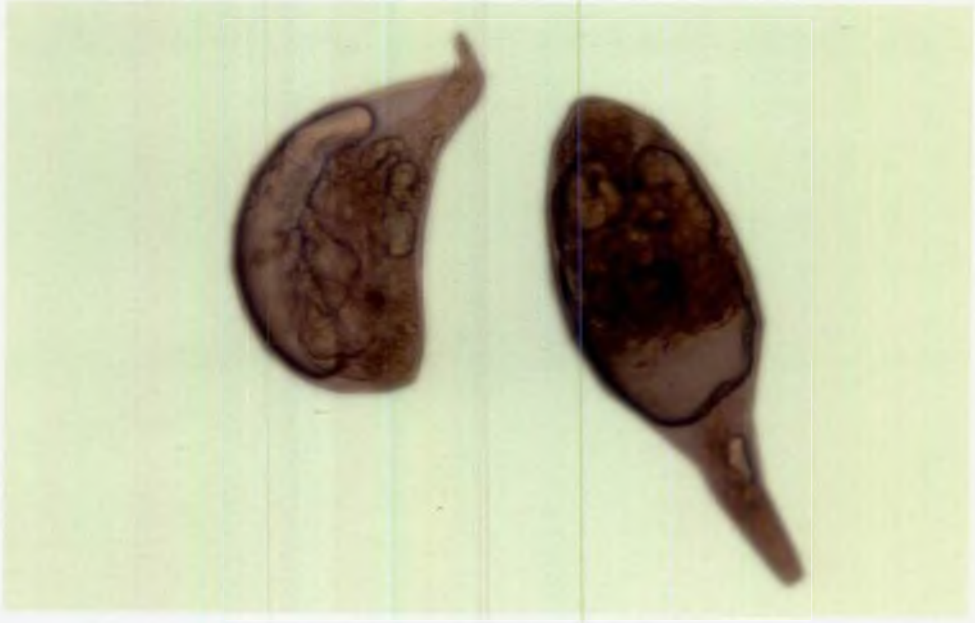


Plate 5. White females of *Meloidogyne graminicola* (400x).

Table1. Effect of different treatments on the shoot characters of rice plants
(Mean of three replications).

Treatments	Flooded condition					Non flooded condition				
	Number of leaves at Transplanting	Number of leaves at harvesting	Height of plants at transplanting	Height of plants at harvesting	Number of tillers at harvesting	Number of leaves at transplanting	Number of leaves at harvesting	Height of plants at transplanting	Height of plants at harvesting	Number of tillers at harvesting
T1	11.00^{b} (3.39)	50.67^{de} (7.15)	30.33^{cd}	82.00^{d}	18.33^{e} (4.34)	10.67^{b} (3.36)	53.67^{d} (7.36)	31.33^{c}	82.33^{d}	22.00^{cd} (4.74)
T2	10.67^{b} (3.36)	31.67^{ij} (5.67)	27.00^{defgh}	66.00^{h}	13.00^{g} (3.67)	9.67^{bcd} (3.18)	34.67^{ij} (5.93)	29.67^{cde}	63.67^{h}	17.33^{ef} (4.22)
T3	10.33^{b} (3.29)	36.67^{hi} (6.09)	28.33^{cdef}	72.33^{fg}	14.00^{g} (3.81)	9.67^{bcd} (3.18)	39.00^{hi} (6.29)	27.00^{defgh}	70.33^{g}	13.00^{g} (3.67)
T4	15.67^{a} (4.02)	74.00^{b} (8.62)	41.67^{a}	107.67^{a}	29.67^{a} (5.49)	15.00^{a} (3.93)	69.67^{b} (8.38)	38.33^{b}	105.00^{a}	28.67^{a} (5.39)
T5	9.00^{bcde} (3.08)	46.33^{ef} (6.84)	27.67^{defg}	78.00^{e}	15.00^{fg} (3.93)	9.00^{bcde} (3.07)	48.33^{ef} (6.98)	30.33^{cd}	77.00^{e}	21.67^{cd} (4.71)
T6	9.00^{bcde} (3.08)	67.33^{c} (8.24)	26.67^{efgh}	93.33^{b}	23.33^{bc} (4.88)	10.00^{bc} (3.23)	60.33^{c} (7.79)	26.00^{fgh}	88.00^{c}	25.33^{b} (5.08)
T7	9.33^{bcd} (3.12)	58.67^{g} (7.69)	27.00^{defgh}	86.67^{c}	20.00^{de} (4.53)	8.00^{cde} (2.91)	43.67^{g} (6.64)	30.33^{cd}	75.00^{ef}	18.67^{e} (4.38)
T8	7.00^{e} (2.74)	24.33^{k} (4.98)	24.33^{gh}	41.67^{j}	7.00^{i} (2.74)	7.67^{de} (2.85)	23.67^{k} (4.92)	26.00^{fgh}	45.67^{j}	10.33^{h} (3.29)
T9	7.67^{de} (2.86)	19.67^{l} (4.49)	24.00^{h}	37.33^{k}	5.33^{j} (2.41)	7.33^{de} (2.79)	17.33^{l} (4.22)	27.33^{defgh}	39.00^{ik}	8.33^{i} (2.96)
Mean	9.96 (3.21)	45.48 (6.64)	28.56	73.89	16.19 (3.98)	9.67 (3.17)	43.37 (6.50)	29.59	71.78	18.37 (4.27)

Values in parenthesis are $\sqrt{x}$ +0.5 transformed values

number of leaves. T1, T2 and T3 were significantly on par with each other producing 11.00, 10.67 and 10.33 leaves respectively.

The number of leaves at the time of harvesting was also more in T4 (74.00) and was statistically superior to other treatments. Next superior treatment was AMF (67.33). The effects of T7 (58.67), T1 (50.67), T5 (46.33) showed a decreasing trend in the production of leaves. Effect of T3 (36.67) was statistically on par with T2 (31.67). T8 was observed to be the inferior treatment with 24.33 leaves, but more than control (T9), which produced only 19.67 leaves.

4.3.1.2 Height of Plants

The height of seedlings raised from seeds treated with *B. subtilis* produced the tallest plants (41.67) at the time of transplanting. T1 was ranked next superior to T4 with 30.33cm of height. The height of the plants in other treatments ranged between 24.00 to 28.33cm. At the time of harvesting maximum height was seen in T4 (107.67). T6 was the next best treatment with 93.33cm height. Its effect was followed by T7 (86.67), T1 (82.00), T5 (78.00), T3 (72.33) and T2 (66.00). Plant height was found to be statistically inferior in T8 (41.67). Control plants showed poor growth with only 37.33cm height (Table 1.)

4.3.1.3 Number of Tillers.

The effect of different treatments on the number of tillers are presented in Table1. At the time of harvesting T4 was superior with highest number of tillers (29.67). Next best treatment was AMF (23.33). Effect of T7 (20.00) was on par with T1 (18.33). The number of tillers produced by T5 (15.00), T3 (14.00) and T2 (13.00)

were statistically on par with each other. T8 was ranked inferior to other treatments (7.00). The control plants produced only 5.33 numbers of tillers.

4.3.2 Yield

4.3.2.1 Number of Days to Flower

The number of days taken to flower from the date of transplanting under various treatments showed statistically significant variation (Table 2). The number of days taken for flowering was least in T4 (22 days) and was the best treatment. T7 (24.67 days) was ranked as the next superior treatment and was statistically on par with T4. This was followed by T6 (32.33 days). The effect of T5 (43.67 days) was on par with T1 (40.33 days). Plants treated with *P. fluorescens* + *T. viride* (52.00 days) and *T. viride* (63.00 days) took more days for flowering. The treatment T8 showed least effect taking 66.67 days to flower and its effect was on par with T2. Control plants showed late flowering and some plants in control did not flower.

4.3.2.2 Number of Days to Harvest

The results presented in Table 2. showed that there was significant variation in the days to harvest by different treatments. Minimum number of days to harvest was taken by plants in T4 (74.33) and was the statistically superior treatment. Effect of T6 (74.33), T7 (74.33), T1 (79.00) and T5 (83.67) were statistically on par with T4. Both T2 and T3 took 88.33 days to harvest and was found statistically on par with each other. Plants treated with carbosulfan (T8) took maximum days to harvest (93.00). Its effect was on par with control

Table 2. Effect of different treatments on the yield characters under flooded condition
(Mean of three replications)

Treatments	Number of days to flower	Number of days to harvest	Number of panicles	Number of grains per panicle	Wet weight of grains (g)	Dry weight of grains (g)	Straw weight (g)
T1	40.33^{ef} (6.39)	79.00^{ab} (8.91)	11.00^{cd} (3.39)	133.33^{bc} (11.56)	46.20^{de}	20.80^{dc}	56.40^{d}
T2	63.00^{bc} (7.96)	88.33^{a} (9.42)	5.33^{efgh} (2.40)	115.00^{d} (10.74)	29.40^{i}	14.57^{f}	34.70^{g}
T3	52.00^{d} (7.24)	88.33^{a} (9.42)	6.67^{def} (2.66)	122.67^{cd} (11.09)	31.70^{ig}	14.80^{f}	44.33^{f}
T4	22.00^{h} (4.74)	74.33^{b} (8.65)	16.67^{a} (4.14)	140.67^{ab} (11.87)	79.53^{b}	36.90^{a}	83.13^{a}
T5	43.67^{e} (6.65)	83.67^{ab} (9.17)	10.67^{de} (3.33)	133.00^{bc} (11.54)	40.83^{ef}	18.40^{e}	50.30^{e}
T6	32.33^{f} (5.73)	74.33^{b} (8.65)	12.00^{bc} (3.50)	128.67^{bc} (11.36)	55.37^{cd}	26.20^{c}	74.63^{b}
T7	24.67^{gh} (5.01)	74.33^{b} (8.65)	15.67^{b} (4.02)	140.00^{ab} (11.85)	77.83^{c}	34.97^{a}	64.96^{c}
T8	66.67^{bc} (8.19)	93.00^{a} (9.67)	3.67^{ghi} (2.03)	100.33^{e} (10.03)	13.27^{k}	6.60^{g}	14.10^{h}
T9	77.00^{b} (8.80)	93.00^{a} (9.67)	2.00^{i} (1.56)	85.00^{f} (9.24)	3.83^{k}	2.13^{h}	5.30^{i}
Mean	46.85 (6.75)	83.15 (9.36)	9.29 (3.01)	122.07 (11.03)	41.99	19.48	47.54

Values in parenthesis are $\sqrt{x}$ +0.5 transformed values

Table 3. Effect of different treatments on the yield characters under non flooded condition (Mean of three replications)

Treatments	Number of days to flower	Number of days to harvest	Number of panicles	Number of grains per panicle	Wet weight of grains (g)	Dry weight of grains (g)	Straw weight (g)
T1	31.33^{fg} (5.64)	79.00^{cd} (8.92)	9.00^{cd} (3.08)	129.00^{bc} (11.37)	49.96^{de}	23.50^{cd}	62.77^{c}
T2	66.00^{bc} (8.15)	88.33^{ab} (9.42)	4.67^{efgh} (2.26)	129.67^{bc} (11.41)	18.77^{i}	9.10^{g}	36.57^{g}
T3	56.67^{d} (7.56)	88.33^{ab} (9.42)	6.33^{def} (2.61)	128.33^{bc} (11.35)	43.17^{fg}	19.10^{e}	44.77^{f}
T4	22.33^{h} (4.77)	72.00^{d} (8.52)	15.67^{a} (4.02)	148.67^{a} (12.21)	72.43^{b}	31.93^{b}	80.60^{a}
T5	42.00^{e} (6.52)	83.67^{bc} (9.17)	7.33^{de} (2.79)	121.67^{cd} (11.05)	47.37^{ef}	20.73^{de}	56.47^{d}
T6	32.33^{f} (5.73)	74.33^{d} (8.65)	10.00^{bc} (3.24)	136.33^{b} (11.69)	54.13^{cd}	25.83^{c}	74.00^{b}
T7	27.00^{gh} (5.24)	72.00^{d} (8.52)	12.33^{b} (3.58)	136.33^{b} (11.69)	57.27^{c}	25.67^{c}	50.80^{e}
T8	67.67^{bc} (8.26)	88.33^{ab} (9.42)	3.00^{ghi} (1.86)	83.00^{j} (9.13)	6.80^{k}	2.80^{h}	14.23^{h}
T9	70.00^{b} (8.39)	93.00^{a} (9.67)	1.50^{i} (1.41)	79.67^{j} (8.95)	3.00^{k}	1.33^{h}	5.67^{i}
Mean	46.15 (6.69)	82.11 (9.07)	7.76 (2.76)	121.40 (10.98)	39.21	17.78	47.32

Values in parenthesis are $\sqrt{x}$ +0.5 transformed values

4.3.2.3 Number of Panicles

Analysis of data given in Table 2. on the number of panicles revealed that there was significant variation. The mean number of panicles varied between 3.67 and 16.67 in treated plants, while it was 2.00 in control. Maximum number of panicles was recorded in T4 (16.67), which was closely followed by T7 (15.67). The effect of T6 (12.00), T1 (11.00) and T5 (10.67) were statistically on par. The effect of T3 (6.67) was on par with T2 (5.33). Carbosulfan was the inferior treatment, which produced only less number of panicles (3.67). Its effect was on par with T2.

4.3.2.4 Number of Grains per Panicle

Maximum number of grains per panicle was recorded in T4 (140.67). It was closely followed by carbofuran (140.00) treated plants. The effects of T1 (133.33), T5 (133.00) and T6 (128.67) were statistically on par giving similar results. *P. fluorescens* + *T. viride* (122.67) was on par with T2 (115.00). Carbosulfan was the inferior treatment (100.33). The result is presented in Table 2.

4.3.2.5 Wet Weight of Grains

The yield assessed in terms of wet weight of grains are presented in Table 2. *B. subtilis* treated plants recorded highest yield (79.53g) and was the superior treatment. Carbofuran was the next best treatment (77.83g). This was followed by T6 (55.37g), T1 (46.20g), T5 (40.83), T3 (31.70g) and T2 (29.40g) and all the treatments were found to be on par with each other. Carbosulfan (T8) was least effective (13.27g), which was equally ranked with control.

4.3.2.6 Dry Weight of Grains

The dry weight of grains per plant under different treatments revealed significant variation. The result is presented in Table 2. Maximum yield (dry weight of grains) was recorded for T4 (36.90g). T7 was found equally superior to T4 (34.97g). This was followed by T6 (26.20g). The effect of T1 (20.80g) was on par with T5 (18.40g). Grain weight was very low in T8 (6.60g) and was statistically inferior.

4.3.2.7 Straw Weight

The straw weight of rice plants showed statistically significant variation due to various treatments and the results are presented in Table 2. T4 recorded highest straw weight (83.13g). Next best treatment was T6 (74.63g). There was a descending trend in the straw weight of plants in T7 (64.96g), T1 (56.40g), T5 (50.30g), T3 (44.33g) and T2 (34.70g). Carbosulfan foliar spray (T8) was the inferior treatment and recorded a mean straw weight of 14.10g.

4.3.3 Root Characters

4.3.3.1 Length of Root

Root length of rice plants showed statistically significant variation due to application of different treatments. There was marked difference in the length of the root in *B. subtilis* treated plants. The average length of the root recorded was 33.77cm. Next best treatment was T6 (30.33cm). This was followed by T7 (26.0cm). The inferior treatment was T8 (11.50cm), which recorded the minimum root length compared to other treated plants. Control plant showed only very short roots (Table 4).

Table 4. Effect different treatments on the root characters of rice plants (Mean of three replications)

Treatment	Flooded condition		Non flooded condition	
	Length of root (cm)	Weight of root (g)	Length of root (cm)	Weight of root (g)
T1	23.07^{de}	74.53^{g}	22.13^{e}	89.10^{e}
T2	15.53^{g}	44.53^{k}	14.13^{gh}	48.13^{k}
T3	18.27^{f}	53.30^{j}	15.60^{g}	59.76^{i}
T4	33.77^{a}	122.23^{b}	31.80^{ab}	127.97^{a}
T5	19.90^{f}	67.33^{h}	18.06^{f}	77.33^{g}
T6	30.33^{b}	96.13^{c}	24.93^{cd}	105.43^{c}
T7	26.40^{c}	82.53^{f}	17.67^{f}	68.43^{h}
T8	11.50^{i}	20.03^{l}	12.50^{hi}	13.57^{m}
T9	8.13^{j}	11.57^{m}	7.90^{j}	10.73^{m}
Mean	20.77	63.58	18.31	66.72

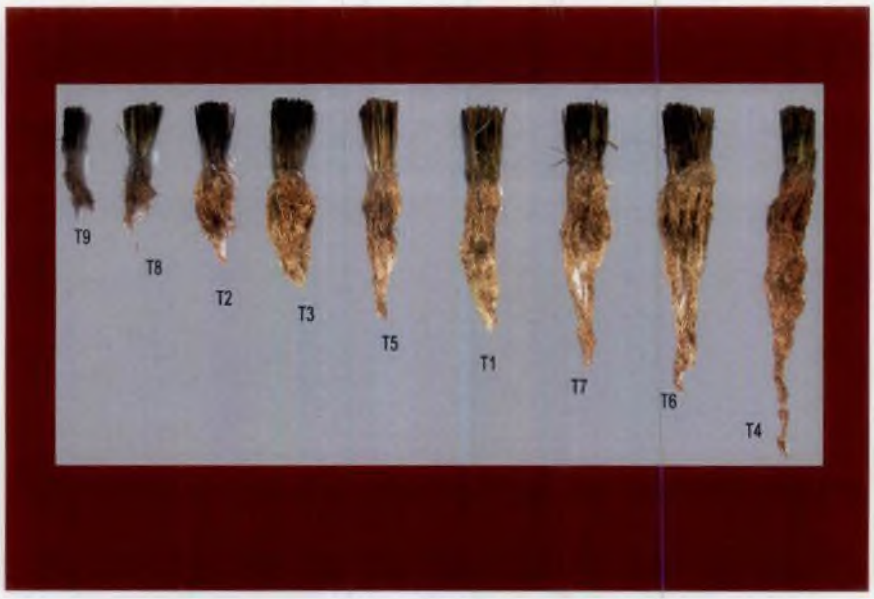


Plate 2. Effect of various treatments on the length of roots under flooded condition.

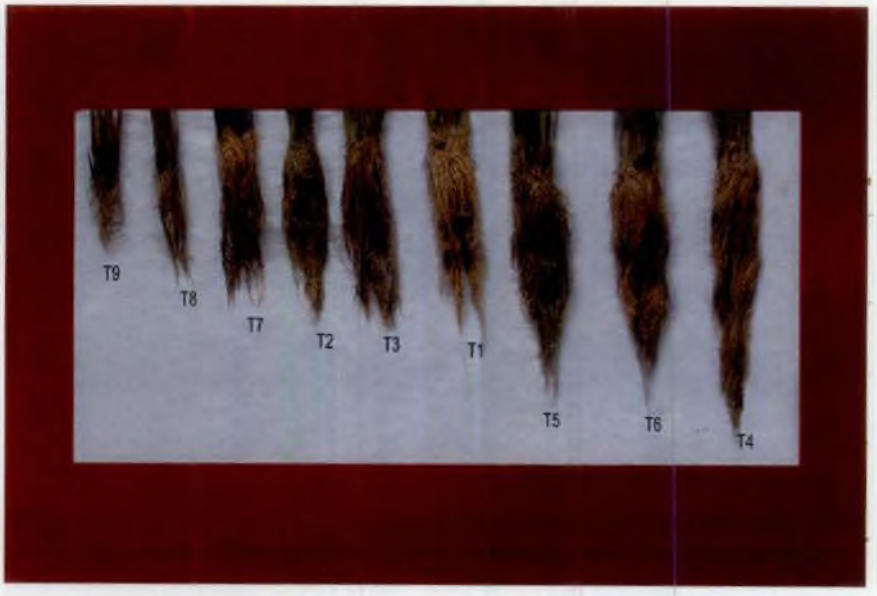


Plate 3. Effect of various treatments on the length of roots under non flooded condition.

4.3.3.2 Weight of Root

There was statistically significant variation in root weight and the results are presented in Table 4. It was observed that there was vigorous root growth in T4 and recorded the highest root weight (122.23g). This was followed by T6 (96.13g). There was a decreasing trend in the root weight in T7 (82.53g), T1 (74.53g), T5 (67.33g), T3 (53.30g), and T2 (44.53g). Carbosulfan treated plants (T8) recorded the lowest root weight (20.03g) but was superior to control, where the root weight obtained was only11.57g.

4.3.4 Nematode Population

4.3.4.1 Nematode Population in Soil

The mean nematode population estimated from 200g of soil varied significantly in different treatments (Table 5). There was drastic reduction in the mean nematode population in treated pots. The population ranged from 2.00 to 92.00 in treated pots against 122 in control. The best treatment was T4 (2.00) giving about 98.36 percent reduction in nematode population over control. T7, T6 and T1 were equally good in reducing the nematode population and were found to be on par with T4. The respective number of nematodes and percentage reduction over control in T7, T6 and T7 were 4.33 (96.45), 6.00 (95.08) and 8.67 (92.89). T5 (14.00) was statistically on par with T1. A decreasing trend in nematode population over control was observed in T3 (20.67) and T2 (27.00). Carbosulfan (T8) was inferior to all treatments but had a superior effect over control by 24.59 per cent.

Table 5. Effect of different treatments on the population of nematodes
(Mean of three replications)

Treatment	Flooded condition						Non flooded condition					
	Nematode count in soil	Percent decrease over control	Nematode count in root	Percent decrease over control	Number of galls in 10g of root	Per cent decrease over control	Nematode count in soil	Percent decrease over control	Nematode count in root	Percent decrease over control	Number of galls in 10g of root	Percent decrease over control
T1	8.67^{g} (3.02)	92.89	13.67^{gh} (3.76)	94.51	6.33^{fg} (2.60)	57.78	13.67^{f} (3.76)	92.46	16.33^{fg} (4.06)	93.97	3.00^{gh} (1.86)	88.75
T2	27.00^{d} (5.24)	77.87	39.33^{d} (6.30)	84.20	10.00^{cde} (3.24)	33.33	26.00^{d} (5.14)	85.66	37.33^{d} (6.15)	86.22	15.00^{b} (3.93)	43.76
T3	20.67^{e} (4.59)	83.06	25.33^{e} (5.06)	89.83	8.00^{def} (2.91)	46.67	20.00^{e} (4.52)	88.97	27.00^{e} (5.24)	90.04	10.33^{cd} (3.29)	61.26
T4	2.00^{i} (1.56)	98.36	3.00^{lm} (1.86)	98.79	0.67^{i} (0.99)	95.56	5.00^{h} (1.44)	97.25	6.33^{jk} (1.42)	97.66	1.00^{h} (1.17)	96.25
T5	14.00^{f} (3.80)	88.52	18.33^{fg} (4.34)	92.64	7.00^{ef} (2.72)	53.33	15.67^{f} (4.01)	91.36	22.00^{ef} (4.74)	91.88	7.00^{e} (2.74)	73.75
T6	6.00^{gh} (2.53)	95.08	8.67^{ij} (3.02)	96.51	4.00^{gh} (2.11)	73.33	8.67^{g} (3.02)	95.21	11.00^{hi} (3.37)	95.94	2.33^{gh} (1.68)	91.25
T7	4.33^{h} (2.19)	96.45	4.67^{kl} (2.26)	98.12	1.00^{i} (1.17)	93.33	1.67^{i} (2.33)	99.08	2.00^{m} (2.60)	99.26	0.67^{h} (1.05)	97.50
T8	92.00^{c} (11.08)	24.59	206.00^{b} (15.02)	17.27	12.67^{bc} (3.62)	15.56	122.33^{b} (9.62)	32.54	225.00^{c} (14.37)	16.97	24.33^{a} (4.98)	8.76
T9	122.00^{b} (13.48)	Nil	249.00^{a} (16.47)	Nil	15.00^{b} (3.93)	Nil	181.33^{a} (11.07)	Nil	271.00^{a} (15.79)	Nil	26.67^{a} (5.21)	Nil
Mean	32.96 (5.28)	82.10	68.67 (6.45)	83.98	7.19 (2.59)	58.61	43.81 (4.99)	85.32	68.67 (6.42)	83.99	10.03 (2.88)	70.16

Values in parenthesis are $\sqrt{x}$ +0.5 transformed values

4.3.4.2 Nematode Population in Root

Treating with bioagents, neem granules and chemicals significantly reduced the population of nematodes in the roots at harvest. The results are presented in Table 5. The mean number of nematode ranged from 3.00 to 206.00 per 10g of root in various treatments as against 249 in control. Maximum reduction in population was recorded in T4 (3.00) giving 98.79 per cent reduction over control. It was found that T7, T6 and T1 gave 98.12, 96.51 and 94.51 per cent reduction in nematode population over control. Effect of T5 (18.33) was on par with T3 (25.33). The population of nematodes was very high in T8 (206.00) and was inferior to all other treatments.

4.3.4.3 Number of Root Galls

The mean number of galls on the roots of rice plants at the time of harvest showed drastic reduction due to various treatments (Table 5). The mean number of galls ranged from 0.67 to 12.67 per 10g root in various treatments as against 15.00 in control. T4 (0.67) gave maximum reduction in number of galls giving 95.56 per cent reduction over the control. The next best treatment was T7 (1.00), which was on par with T4 giving 93.33 per cent reduction in gall formation. This was followed by T6 (4.00) and T1 (6.33). These treatments were statistically on par giving 73.33 and 57.78 per cent reduction in gall number over control. The number of galls in T1 was found to be on par with T5 giving 57.78 and 53.33 percent reduction in gall count over the control. T3 (8.00) and T2 (10.00) were on par. The effect of T8 was very poor in reducing the gall formation. It was observed that T8 and T9 were on par with 12.67 and 15.00 number of galls.

4.4 NONFLOODED CONDITION

4.4.1 Shoot Characters

4.4.1.1 Number of Leaves

The effect of different treatments on the number of leaves in rice at the time of transplanting and harvest are presented in Table 1. The average number of leaves at the time of planting was observed to be more in the seedlings raised from seeds treated with *B. subtilis* (15.00). Effects of T1, T3 and T2 were on par. At the time of harvesting also T4 was superior with highest number of leaves (69.67). This was followed by T6 (60.33), T1 (53.67) and T7 (43.67). T8 was ranked inferior to other treatments (23.67). The control plants produced only 17.33 number of leaves.

4.4.1.2 Height of Plants

The variation in height of rice plants at the time of transplanting and harvesting ranged between 26.00 to 38.33cm and 39.00 to 105.00cm respectively (Table 1.). At the time of transplanting tallest plants were obtained with *B. subtilis* seed treatment (38.33cm). The height of the seedlings raised from seeds treated with *P. flourscens, T. viride and P. flourscens + T. viride* did not differ much from seedlings raised from untreated seeds.

At harvest T4 plants attained maximum height (105.00cm) and was statistically superior to other treatments. AMF was the next superior treatment (88.00). There was a decreasing trend in height of the plants in T1 (82.33), T5 (77.00), T7 (75.00), T3 (70.33) and T2 (63.67). Carbosulfan (T8) continued to be the least effective treatment (45.67).

4.4.1.3 Number of Tillers

The average numbers of tillers in different treatments are presented in Table 1. There was statistically significant variation in different treatments. T4 produced more number of tillers compared to other treatments. The next superior treatments were T6 (25.33) and T1 (22.00). T5 was found to be equally superior to T1 with 21.67 number of tillers. The number of tillers in T2 and T7 were found to be on par. Carbosulfan (T8) recorded the lowest number of tillers (10.33). When compared to carbofuran T4 and T6 were superior in production of tillers.

4.4.2 Yield

4.4.2.1 Number of Days to Flower

The data presented in Table 3. revealed that T4 was found to be the best treatment with early flowering (22.33 days). The effect of T4 was statistically on par with carbofuran (27 days). This was followed by T1 (31.33 days), T6 (32.33 days), T5 (42 days), T3 (56.57 days), T2 (66 days), and T8 (67.67 days), The control plants showed late flowering (70 days). A few plants in control did not flower. It was observed that the days taken for flowering in T8 and control were statistically on par.

4.4.2.2 Number of Days to Harvest

The number of days to harvest was minimum for T4 and T7 (72days). Both the treatments were found superior to other treatments. This was followed by T6 and T1, which took 74.33 and 79 days to harvesting and was statistically on par. The effect of T1, T2, T5, T8 and T9 were found to be statistically on par, which took 79, 88.3, 83,67 and 88.3 and 93.00 days respectively for harvesting from the date of transplanting. Result is presented in Table 3.

4.4.2.3 Number of Panicles

There was statistically significant variation in the number of panicles of the rice plants due to different treatments (Table 3). The mean number of panicles varied between 3.00 and 15.67 in various treatments while it was 1.50 in control. The highest number of panicles was recorded in T4 (15.67). The next best treatment was carbofuran (12.33), which was on par with AMF with 10 number of panicles. This was followed by T1 (9.00), which was statistically on par with T6. The effect of T8 was inferior to the treatments mentioned above (3.00) which was on par with *T. viride* (4.67) and control (1.50).

4.4.2.4 Number of Grains per Panicle

The number of grains per panicle showed statistically significant variation due to various treatments (Table 3). Maximum number of grains per panicle was obtained in plants treated with *B. subtilis* (148.67), which was the best treatment among the bioagents. The next superior treatments were T6 (136.33) and T7 (136.33). The effect of T1 (129.00), T2 (129.67) and T3 (128.33) was statistically on par with T6 and T7. T8 was the inferior treatment (83.00) and its effect was on par with control (T9) with 79.67 number of grains per panicle.

4.4.2.5 Wet Weight of Grains

The wet weight of grains per plant showed significant variation in different treatments (Table 3) Highest yield was recorded in T4 (72.43g), which was ranked superior and was followed by T7 (57.27g). The weight of grains in T6 (54.13g) and T1 (49.97g) was on par. The effect of T5 and T3 was found to be on par, with 47.37g and 43.17g grain weight respectively. Statistically inferior treatment was T8 (6.80g), which was seen on par with T9 (control) with only 3.00g grain weight.

4.4.2.6 Dry Weight of Grains

The application of different treatments improved the dry weight of grains per plant (Table 3). T4 recorded highest dry weight of grains (31.93g). This was followed by T6 (25.83g), which was found to be on par with T7 (25.67g) and T1 (23.50g). The yield obtained from plants treated with neem granules (20.73g) was on par with T3 (19.10g). Dry weight of grains obtained from T8 (2.80g) was least compared to other treatments and it was on par with control (1.33g).

4.4.2.7 Straw Weight

The straw weight of rice plants showed statistically significant variation in all the treatments and the results are presented in Table 3. Plants treated with *B. subtilis* recorded highest straw weight (80.60g). Other treatments were ranked in the order T6 (74.00g), T1 (62.77g), T5 (56.47g), T7 (50.80g), T3 (44.77g), T2 (36.57g) and T8 (14.23g). Straw weight in control plants was only 5.67g because of poor growth and stunting of plants.

4.4.3 Root Characters

4.4.3.1 Length of Root

There was statistically significant variation in the root length of rice plants (Table 4). Root growth was vigorous and maximum root length (31.80cm) was recorded in T4. In this treatment a reddish brown discolouration was seen in the roots. The next best treatment was T6 (24.93cm). This was followed by T1 (22.13cm). The effect of T5 (18.07cm) was statistically on par with carbofuran (17.67cm) treated

plants. The root length of T3 (15.60cm) was found to be on par with T2 (14.13cm) treated plants. Among treated plants minimum effect was shown in T8 (12.50cm).

4.4.3.2 Weight of Root

There was statistically significant variation in the root weight of rice plants in different treatments. The result is presented in Table 4. The highest root weight was recorded by T4 (127.96g). Next best treatment was T6 recording a mean root weight of 105.43g. This was followed by T1 (89.10g), T5 (77.33g), T7 (68.43g), T3 (59.77g) and T2 (48.13g). Carbosulfan (13.57g) was the inferior treatment, which was on par with the control (10.73g).

4.4.4 Nematode Population

4.4.4.1 Nematode Population in Soil

There was significant reduction in the population of nematode in soil in all treatments (Table 5). The mean number of larvae ranged from 1.67 to 122.33 per 200 g of soil in various treatments as against 181.33 in control. Maximum reduction in population was recorded in carbofuran treated pots (1.67) giving about 99.08 per cent reduction in nematode population in soil. *B. subtilis* was ranked next superior to carbofuran with a mean nematode population of 5.00 resulting in 97.25 per cent reduction. This was followed by T6 (8.67) and T1 (13.67) giving about 95.21 and 92.46 per cent reduction in nematode population respectively. The effect of neem granules (15.67) was found to be on par with T3 (20.00) and T2 (26.00). Carbosulfan (122.33) showed the maximum population of nematodes and was inferior to all other treatments but superior to control.

4.4.4.2 Nematode Population in Root

The larval population estimated from the 10g of roots varies significantly in different treatments and there was a drastic reduction in the mean larval population. The details of results are given in Table 5. The mean population of larvae in root samples ranged from 2.00 to 225. 00 in various treatments against 271.00 in control. Minimum number of nematodes was seen in carbofuran treated plants (2.00) with 99.36 per cent reduction over the control. Here carbofuran established its superiority over the other treatments. The next superior treatments were T4 (6.33) and T6 (11.00), giving 97.66 and 95.94 per cent reduction in the nematode population in root, over the control. This was followed by T1, T5, T3 and T2 with 16.33, 22.00 27 and 37.33 number of nematodes. Also treatments T3 (27.00) and T2 (37.33) were on par. Carbosulfan (225.00) was the inferior treatment but had a superior effect over the control (271.00).

4.4.4.3 Root knot Count

The results presented in Table 5. showed drastic reduction in the mean number of galls on the roots of rice plants due to various treatments. The mean number of galls ranged from 0.67 to 24.33 per 10g of root in various treatments as against 26 in the control. T7 (0.66) gave maximum reduction in gall formation giving 97.50 per cent reduction in gall count over untreated. Next best treatments were T4 (1.00), T6 (2.33) and T1 (3.00), which was equally good and on par with carbofuran treatment giving 96.25, 91.25 and 88.75 per cent reduction in gall formation respectively over the control. This was followed by T5 (7.00), T3 (10.33) and T2 (15.00) with a percentage reduction of 73.75, 61.25 and 43.75 respectively. The effect of T8 (24.33) was inferior to the above treatments. It was on par with control (26.67).

DISCUSSION

5. DISCUSSION

The results of the study entitled 'Management of root knot nematode in rice' are discussed in this chapter.

5.1 IDENTIFICATION OF RICE ROOT KNOT NEMATODE OF RICE

The rice root knot nematode collected from the Nenmara and Alathoor blocks of Palakkad district was identified as *Meloidogyne graminicola.*

5.2 FLOODED CONDITION

5.2.1 Shoot Characters

The influence of different treatments in improving the growth of seedlings at the time of transplanting in relation to number of leaves and height of plant are indicated in Table1 and Fig. 1. The superiority of the treatments T1, T2, T3 and T4 was obvious at the time of transplanting. *B. subtilis* (T4) was the best treatment with maximum number of leaves and the height of plants, which were15.67 and 41.67cm respectively. The efficacy of *B. subtilis* as seed treatment was reported by Gokte and Swarup (1988). They reported that seed treatment with *B. subtilis* caused reduction in percentage of penetration of juveniles to the roots of wheat seedlings. The effectiveness of *P.flourescens* as seed treatment against *Hirschmaniella gracilis* and *M. incognita* was reported by Ramakrishna *et al.* (1998) and Verma *et al.* (1998). Singh *et al.* (2003) proved that the treatment with *T. viride* significantly improved plant growth characteristics in okra.

At the time of harvest *B. subtilis* was found to be the superior treatment. The number of leaves, height of plant and number of tillers in T4 was 74, 107.67 and 29.67 respectively. This was closely followed by AMF, carbofuran, *P. fluorescens* and neem granules in relation to the number of leaves, height of plant

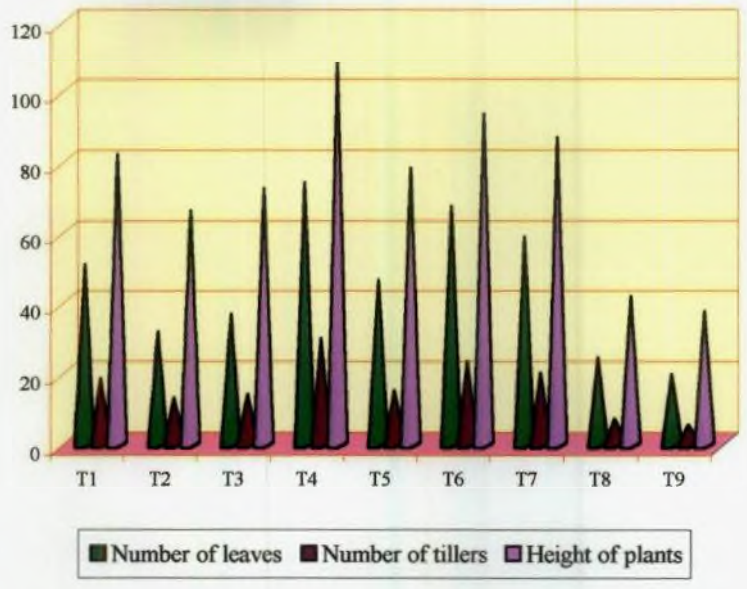


Fig. 1. Effect of various treatments on the shoot characters (Flooded condition)

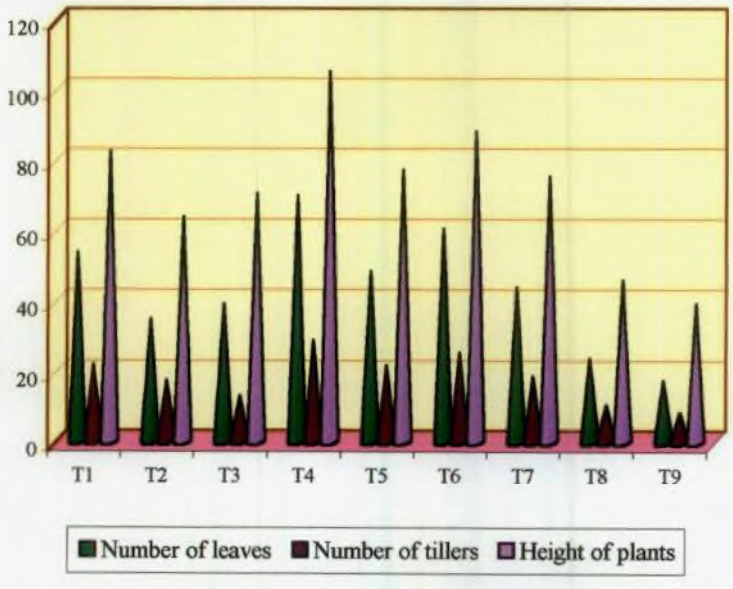


Fig. 2. Effect of various treatments on the shoot characters (Non flooded condition)

and number of tillers. The result obtained is in confirmation with those of Ray and Dalei (1998) and Sundarababu *et al* (1996). The efficacy of carbofuran in suppressing *M. incognita* activity and improving plant growth of French bean was already reported by Mohan and Mishra (1993). They described the influence of AMF in improving the shoot characters (number of leaves, number of tillers and height) in various crops. Sanhita *et al.* (2000) reported the growth promotion of tomato plants by the rhizobacteria *P. fluorescens*. Similar observations were made by Devi *et al.* (2002). There was no effect for carbosulfan in enhancing the shoot characters, which strongly indicate that foliar spraying with carbosulfan has no effect in managing the nematode in soil. Plants in control pots showed dwarfness with only less number of leaves and tillers. Reduction in the shoot characters may be attributed to nematode feeding.

5.2.2 Yield

The yield characters with reference to days to flowering (22.00), days to harvest (74.33), number of panicles (16.67), number of grains per panicle (140.67), wet weight (79.53g), dry weight (36.90g) and straw weight (83.13g) was superior in *B. subtilis* seed treatment and soil application. This shows that *B. subtilis* as soil application can effectively influence the yield characters. *B. subtilis* is considered as plant growth promoting rhizobacterium (PGPR).Decrease in the nematode population by *B. subtilis* may be due to the effect of lytic enzymes or due to the effect of volatile organic compounds that it produced. Reddy *et al.* (1999) reported maximum fruit yield for *B. subtilis* treated tomatoes. Gokte and Swarup (1988) opined that this might be due to the larvicidal effect of *B. subtilis*. Carbofuran was ranked next to *B. subtilis* with respect to early flowering (24.67), early harvest (74.33), number of panicles (15.67) and number of grains per panicle (140.00). Khan and Rathi (2001) and Borah and Phukan (1990) reported the effectiveness of carbofuran in decreasing the number of galls and egg masses and increasing in plant growth characters and yield in tomato and green gram

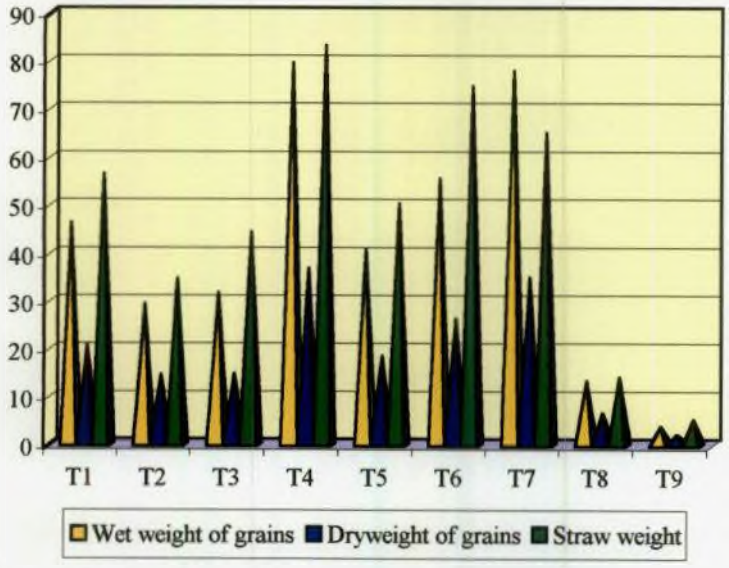


Fig. 3. Effect of various treatments on the yield (Flooded condition)

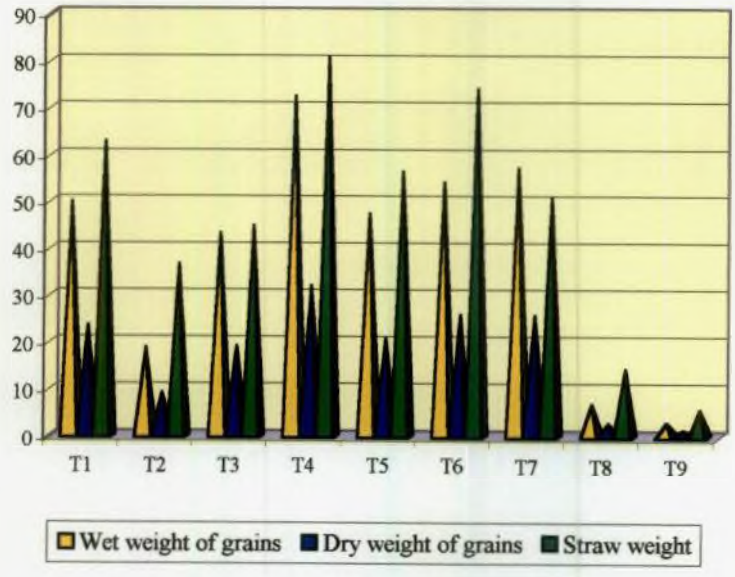


Fig. 4. Effect of various treatments on the yield (Non flooded condition)

AMF (T6) was found to be statistically on par with carbofuran. This was followed by T1 (*P. fluorescens*) and T5 (neem granules). Ray and Dalei (1998) reported importance of AMF in increasing the yield in green gram. Jothi *et al.* (2003) could obtain maximum yield (64.3%) and minimum *M. incognita* soil population (56%) in tomato by using *P. fluorescens*. However, carbosulfan as foliar spray was found to be less effective than other treatments at recommended doses and was found statistically on par with control plants. This clearly indicates that foliar spray with carbosulfan is not encouraging the yield characters by managing the nematodes (Fig 3.)

5.2.3 Root Characters

The root characters given in Table 4.indicates that *B. subtilis* (T4) was the statistically superior treatment contributing, maximum root length (33.77cm) and root weight (122.2g). The direct effect of *B. subtilis* in increasing the length and weight of root was not reported earlier but its effect on growth of the plant is reported by Siddiqui *et al.*, 2001. With regard to the length and weight of root, AMF was the next superior treatment with 30.33cm length and 96.13g weight. This was followed by carbofuran and *P. fluorescens*, which was observed to be equally superior to AMF. Similar results were obtained by Sikora and Schonpeck (1975) where they found that AMF had great influence in increasing the growth and yield of tomato. The potential of carbofuran in enhancing the root length and weight was already proved by Singh and Kumar (1995). They found that carbofuran 2kg ai/ha was effective in reducing the population of *M. incognita* and increasing the growth parameters like root length, shoot dry weight, root fresh weight and number of leaves in Japanese mint.

In the present study it was found that control (T9) plants showed poor root growth with only very short roots. Length and weight of roots were 8.13cm and 11.5g respectively. The poor root growth may be attributed to the damage by the second stage juveniles. Compared to other treatments the effect of carbosulfan

was least. Though carbosulfan has basipetal action, foliar spraying has no effect in improving the root characters.

5.2.4 Nematode Population

The data on the population characters presented in Fig 5. explains the influence of different treatments in reducing the number of nematodes in soil and root and the gall count in root. *B. subtilis* application gave maximum reduction in the number of nematodes in soil, root and gall formation giving 98.36, 98.79 and 95.56 per cent reduction over the control. This result indicates that *B. subtilis* could serve as a biopesticide and its effect was superior to all other treatments. Carbofuran treated plants were equally superior to *B. subtilis* in reducing the number of nematodes in soil, root and root galls. The inhibitory effect shown by *B. subtilis* may be due to the larvicidal effect of this bioagent as reported by Sheela (1990). The study revealed that 1.2×10^8 cells per ml of these bacteria caused 70 to 80 per cent larval mortality of *Heterodera oryzicola*. Khan *et al.* (2002) and Siddiqui *et al.* (2001) emphasized the efficacy of *B. subtilis* in reducing the root knots caused by *M. javanica* and *M. incognita* in urdbean and green gram. The potential of carbofuran in reducing the nematode population was established in this study. This finding was in agreement with Rahman (1991) and Panigrahi and Mishra (1995). They described the efficacy of carbofuran in reducing the root knots.

There was statistically significant reduction in nematode population in all the other treatments (AMF, *P. fluorescens,* neem granules, *T. viride* and *P. fluorescens* + *T. viride*) except T8 and T9. Sharma *et al.* (1994) reported that VAM colonization reduced the root knot infestation by *M. incognita* in tomato. This may be due to the suppression of the multiplication of the nematode as reported by Sundarababu *et al* (1996). The efficacy of AMF as biocontrol agent for reducing the nematode population in soil and root as reported in this study is in line with that of Asha (1996) and Sivaprasad and Sheela (2001). Compared to

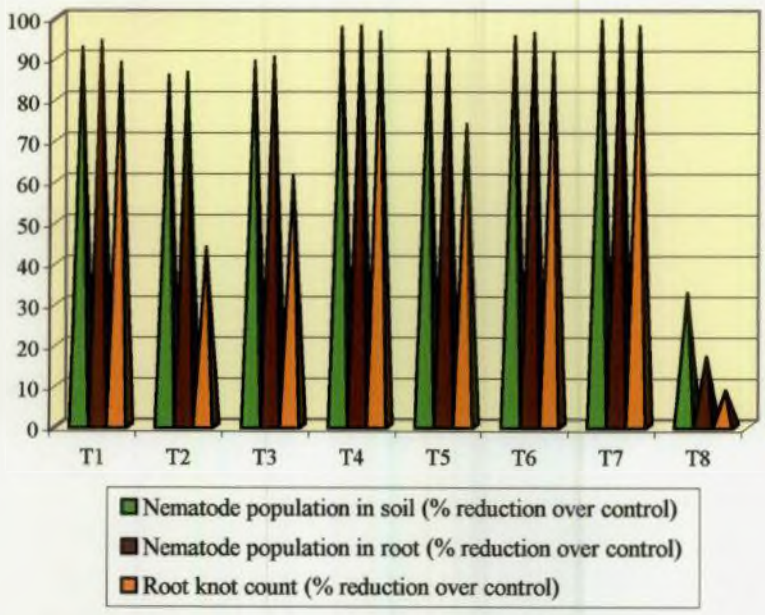


Fig. 5. Effect of various treatments on the nematode population (Flooded condition)

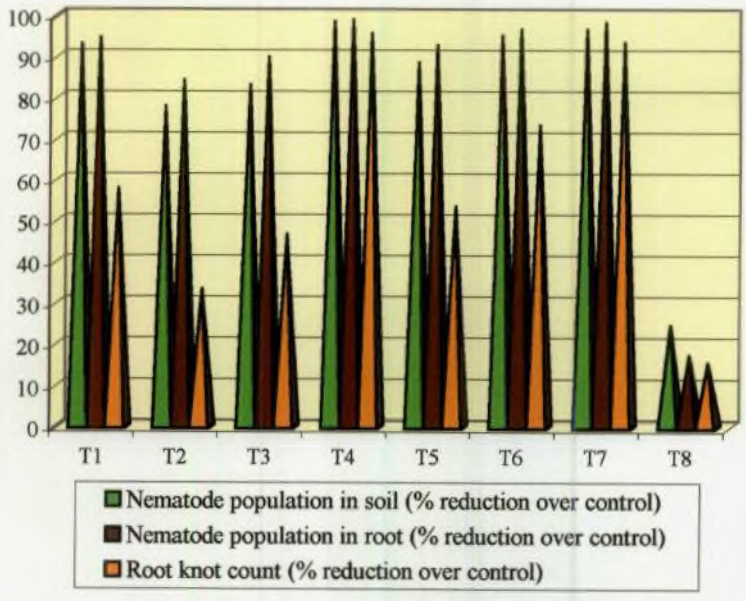


Fig. 6. Effect of various treatments on the nematode population (Non flooded condition)

all other treatments foliar spray of carbosulfan had no effect in managing the population of nematodes. T8 showed very high population of nematodes in soil, root and root knot count.

5.3 NON FLOODED CONDITION

5.3.1 Shoot Characters

The data on the shoot characters presented in Fig.2 and Table 1 explains the influence of different treatments in improving the growth of seedlings at the time of transplanting in relation to number of leaves and height of plant. Both these parameters were superior in T1, T2, T3 and T4 than seedlings raised from untreated seeds. It was found that the number of leaves and the height of plants were maximum in T4 (*B. subtilis*), which was 15 and 38.33cm respectively. The growth promotion of *B. subtilis* is in line with the study of Kloepper (2003). He reported that *B. subtilis* promoted plant growth by a blend of volatile organic compounds. This may be the attributed reason for the increase in the biometric characters of the crop. Santhi and Sivakumar (1995) and Sheela *et al.* (1999) reported the effectiveness of *P. fluorescens* against *M. incognita* in tomato and brinjal respectively. Singh *et al.* (2003) proved that the treatment with *T. viride* significantly improved plant growth characteristics in okra.

At the time of harvest also the superior effect of *B. subtilis* in the shoot characters was obvious. The number of leaves, height of plant and number of tillers in T4 was 69.67, 105 and 28.67 respectively. The result obtained was in agreement with the study conducted by Siddiqui *et al.* (2001), who revealed that *B. subtilis* gave better control of the root-rot and root-knot infection with the enhancement of growth of urdbean. This was closely followed by AMF, *P. fluorescens* and neem granules in relation to the number of leaves, height of plant and number of tillers. The improvement in biometric characters (number of leaves, number of tillers and height) by the action of AMF in various crops was

already reported by Ray and Dalei (1998) and Sundarababu *et al* (1996). Sanhita *et al.* (1995) reported the growth promotion of tomato plants by the rhizobacteria *P. fluorescens.* Similar observations were obtained by Devi and Dutta (2002). They studied the effect of *P. fluorescens* on root-knot nematode (*M. incognita*) of okra plant and found that *P. fluorescens* improved shoot and root lengths and weights, and reduced root gall number. Effect of carbofuran was superior to T2, T3 and T8 with respect to all shoot characters. There was no effect for enhancing the shoot characters by carbosulfan, which strongly indicate that foliar spraying with carbosulfan has no effect in managing the nematode in soil. Plants in control pots were dwarf with only less number of leaves and tillers. Reduction in the shoot characters may be attributed to nematode feeding.

5.3.2 Yield

The yield attributes given in Table 3 and Fig. 4 indicates that *B. subtilis* (T4) was the statistically superior treatment contributing, early flowering (22.33 days), highest number of panicles (15.67), number of grains per panicle (148.67), wet weight of grains (72.43g), dry weight of grains (31.93) and straw weight (80.60g). This shows that *B. subtilis* seed treatment and soil application can effectively influence the yield characters. The potential of *B. subtilis* for management of nematode and increasing the yield was already reported by Reddy *et al.* (1999) and Khan *et al.* (2002). This may be due to the larvicidal effect of *B. subtilis* as reported by Gokte and Swarup (1988).

Carbofuran was ranked next to *B. subtilis* with respect to early flowering (27 days), number of panicles (12.33) and number of grains per panicle. The results obtained are in confirmation with that of Sharma *et al.* (2001). They proved that the application of carbofuran resulted in the highest yield and the highest reduction of root-knot nematode (*M. incognita*) on spinach. Devi (1993); Khan and Rathi (2001) and Bhagavathi and Phukan (1990) also described similar effect of carbofuran in controlling the root knot nematodes in pea and tomato. *P.*

fluorescens (T1) was found to be statistically on par with carbofuran. It is evident that *B. subtilis* and *P. fluorescens* are as good as carbofuran. The biocontrol efficiency of *P. fluorescens* was reported by many workers. Jothi *et al.* (2003) observed that *P. fluorescens* treated plants gave the maximum yield (64.3%) and minimum M. incognita soil population (56%) in tomato. Oostendrop and Sikora (1989) also described *P. fluorescens* as a promising biocontrol agent against root knot nematodes.

Considering the number of days to harvest both T4 and T7 was equally superior with early maturing of grains (72 days). This was followed by AMF (T6) and T1 (*P. fluorescens*). These treatments were statistically on par. Sundarababu *et al* (1996) reported the efficacy of VAM in enhancing the growth and yield of tomato and suppressing *M. incognita* multiplication. The number of days taken to harvest were statistically on par in T2, T3, T5 and T8. For all the characters studied under yield, carbosulfan was the inferior treatment and was found statistically on par with control plants. This clearly indicates that foliar spray with carbosulfan is not encouraging the yield characters by managing the infestation of root knot nematodes.

5.3.3 Root Characters

The improvement in root characters by various treatments given in Table 4. show that *B. subtilis* (T4) is the best treatment. The root growth was vigorous which attained a length of 31.80cm, and weight of 127.97g. In *B. subtilis* treated plants roots showed brown discolouration under non flooded condition, which was not noticed in other treatments. The browning of roots in case of *B. subtilis* treated plants may be due to the induction of phenolic compounds or may be due to the increased polyphenol oxidase activity related to induced systemic resistance (Samiyappan, 2003). The direct effect of *B. subtilis* in increasing the length and weight of root was not reported earlier but its effect on growth of the plant is reported by Siddiqui *et al.* 2001. With regard to the length and weight of root

AMF (T6) was the next superior treatment with 24.93cm length and 105.43g weight. This was followed by carbofuran with a length and weight of root of 17.67cm and 68.43g respectively. These results are in agreement with that of Panigrahi and Mishra (1995); Rahman (1991) and Das *et al.* (1999). They observed that carbofuran (Furadan 3G) was effective against *M. graminicola* in rice. The effect of AMF in increasing the growth and yield of tomato was reported by Sikora and Schonpeck (1975).

The root growth in control (T9) was very poor with only very short roots. Length and weight of roots were 7.90cm and 10.33g respectively. The poor growth of root may be due to the damage by the second stage juveniles of this nematode. The effect of carbosulfan as foliar spray on plants was statistically on par with the control plants. This may be due to the fact that foliar spray has no effect in improving the root characters with its basipetal action. The root length and weight of T1, T2, T3 and T5 was much superior to T8 and control, which also suggested that these treatments also encouraged the root characters.

5.3.4 Nematode Population

The nematode population characters with reference to reduction number of nematodes in soil, root and gall count in root was statistically significant in carbofuran treated plants (T7). It was observed that *B. subtilis* treated plants were equally superior to carbofuran in reducing the number of nematodes in soil and root and root galls. The potential of carbofuran (18kg/ha) in reducing the nematode population was established in this study. This finding was on line with that of Das *et al.* (1999) in managing the root knot nematode in rice. This may be due to the deleterious effect of the chemical on the viability of nematodes as reported by Rahman (1991). He reported reduction in nematode population in the soil, plant and number of galls in the root. Khan *et al.* (2002) and Sheela (1990) reported the effectiveness of *B. subtilis* in controlling the nematode population in green gram and black pepper. This may be due to the inhibition of entry of

nematodes in the rice roots at the time of planting and also due to the larvicidal effect. Similar biological behavior by *B. subtilis* has already been reported by Gokte and Swarup (1988). They reported the larvicidal effect of *B. subtilis* on *Anguina tritici*. This isolates in wheat caused reduction in percentage of penetration of juveniles to the roots of wheat seedlings and the viability of the larvae. Khan *et al.*, 2002 reported the effectiveness of *B. subtilis* against *M. incognita* in green gram. They reported that the treatment with *B. subtilis* reduced galling by 33-34%. There was statistically significant reduction in nematode population in all the other treatments (AMF, *P. fluorescens*, neem granules, *T. viride* and *P. fluorescens* + *T. viride*) except carbofuran and control. The efficacy of AMF as biocontrol agent in reducing the root knot formation as reported in this study agree with the investigations of Sharma *et al.* (1994) and Jain and Sethi, (1988). They observed that the gall formation and multiplication of *M. incognita* were hampered by early establishment of *G. fasciculatum* on tomato and cowpea. The mechanism of suppression may either be due to AMF induced physiological changes in the root exudates causing fewer nematodes attracted to host (Ahmad and Alsayed, 1991)

Foliar spray of carbosulfan had no effect in managing the population of nematodes. Compared to all other treatments T8 showed very high population of nematodes in soil, root and root knot count (Fig. 6).

Summing up the findings, it may be concluded that among bioagents, *B. subtilis* seed treatment and soil application at the time of transplanting effectively enhanced all the biometric characters and reduced the nematode population in root and soil under flooded condition. In non flooded condition carbofuran was found to be the effective treatment. But *B. subtilis* was found to be equally superior, which suggest that this bioagent can be even supplemented for carbofuran. It can be effectively used under flooded and non flooded conditions.

It was also noticed that nematode population was less in all the treatments under flooded condition, which indicate that flooded condition itself has got some effect in managing the nematodes. Another finding of this study is that foliar application of carbosulfan has no effect in improving the plant characters and management of nematodes with its basipetal action.

SUMMARY

6. SUMMARY

The objectives of the study entitled 'Management of root knot nematode in rice' was undertaken to identify the species of rice root knot nematode and to investigate the management of this nematode by different bio agents, chemical pesticides and a neem formulation. The work was carried out at College of Horticulture, Vellanikkara during February 2004 to July 2005

A survey was conducted for the collection of soil and root samples from the rice growing tracts, already infested with root knot nematodes, from two blocks of Palakkad district namely Nenmara and Alathoor. Samples were also collected from infested plots of Agriculture Research Station, Mannuthy. The white females collected from root knot nematode infested roots was sent to the Nematology Department of Indian Agricultural Research Institute, New Delhi. The species of root knot nematode attacking rice plant was identified as *Meloidogyne graminicola* Golden and Birchfield.

Pot culture experiments were conducted to study the management of rice root knot nematode by different bioagents, chemicals and a neem formulation under flooded and non flooded condition. The effect of the treatments on the shoot characters, yield, root characters and nematode population was tested.

6.1 FLOODED CONDITION

At the time of transplanting the number of leaves and height of seedlings ranged between 7.00cm to 15.67cm and 24.00cm to 41.67cm in various treatments but the seed treated plants were superior. At harvest *B. subtilis* (T4) was the superior treatment with maximum number of leaves, tillers and height of plants. The number of leaves, height of plant and number of tillers in T4 was 74.00, 105.67cm and 29.67 respectively. AMF, carbofuran, *P. fluorescens* and neem granules closely followed this. There was no effect for enhancing the shoot

characters by carbosulfan. Plants in control pots showed dwarfness with only less number of leaves and tillers.

The yield with reference to days to flowering, days to harvest, number of panicles, number of grains per panicle, wet weight, dry weight and straw weight was superior in *B. subtilis* (T4) treated plants. Carbofuran was ranked next to *B. subtilis*. This was followed by T6 (AMF), T1 (*P. fluorescens*) and T5 (neem granules). Carbosulfan as foliar spray was found to be less effective than other treatments.

The root characters (root length and root weight) were more in *B. subtilis* (T4) treated plants. AMF was the next superior treatment. This was followed by, carbofuran and *P. fluorescens*, which was observed to be equally superior to AMF. Compared to other treatments the effect of carbosulfan was least. It was found that control (T9) plants showed poor root growth with only very short roots.

B. subtilis application gave maximum reduction in the number of nematodes in soil, root and gall formation giving 98.36, 98.79 and 95.56 per cent reduction over the control. Carbofuran treated plants were equally superior to *B. subtilis*. There was statistically significant reduction in nematode population in all the other treatments (AMF, *P. fluorescens*, neem granules, *T. viride* and *P. fluorescens* + *T. viride*) except T8 and T9.

6.2 NON FLOODED CONDITION

At the time of transplanting number of leaves and height of seedlings raised from seeds treated with *P. fluorescens*, *T. viride*, *P. fluorescens* + *T. viride* and *B. subtilis* were superior than seedlings raised from untreated seeds. It was found that the number of leaves and the height of plants were maximum in T4 (*B. subtilis*). At the time of harvest also the superior effect of *B. subtilis* in the shoot characters was obvious. The number of leaves, height of plant and number of

tillers in T4 was 69.67, 105 and 28.67 respectively. This was closely followed by AMF, *P. fluorescens* and neem granules. Effect of carbofuran was superior to T2, T3 and T8 with respect to all shoot characters. There was no effect for enhancing the shoot characters by carbosulfan. Plants in control pots were dwarf with only less number of leaves and tillers.

The yield attributes (days to flowering, days to harvest, number of panicles, number of grains per panicle, wet weight, dry weight and straw weight) were more in plants treated with *B. subtilis*. Carbofuran was ranked next to *B. subtilis*. This was followed by T6 (AMF) and T1 (*P. fluorescens*). The number of days taken to harvest was statistically on par in T2, T3, T5 and T8. For all the characters studied under yield characters carbosulfan was the inferior treatment and was found statistically on par with control plants.

The root growth was vigorous in *B. subtilis* (T4) treated plants with a length of 72.43cm, and weight of 31.93g. This was followed by carbofuran, which was observed to be equally superior to AMF (T6). The root length and weight of T1, T2, T3 and T5 was much superior to T8 and control. The effect of carbosulfan as foliar spray on plants was statistically on par with the control plants. The root growth in control (T9) was very poor with only very short roots.

The nematode population with reference to reduction in number of nematodes in soil and root and gall count in root was superior in carbofuran treated plants (T7). *B. subtilis* treated plants were equally superior to carbofuran. There was statistically significant reduction in nematode population in all the other treatments (AMF, *P. fluorescens*, neem granules, *T. viride* and *P. fluorescens* + *T. viride*) except T8 and T9.

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* Originals not seen

MANAGEMENT OF ROOT KNOT NEMATODE IN RICE

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ABSTRACT OF THE THESIS

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ABSTRACT

The objectives of the study entitled 'Management of root knot nematode in rice' was to identify the species of rice root knot nematode and to study the management of this nematode by different bio agents, chemical pesticides and a neem formulation. A survey was conducted for the collection of soil and root samples from the rice growing tracts, already infected with root knot nematodes. The species of root knot nematode attacking rice plant was identified as *Meloidogyne graminicola* Golden and Birchfield.

Pot culture experiments were conducted to study the management of rice root knot nematode under flooded and non flooded condition by different bio agents, chemicals and a neem formulation The effect of the treatments on the shoot characters, yield, root characters and nematode population were tested.

Seed treatment with *B. subtilis*, *P. fluorescens*, *T. viride* and *P. fluorescens* + *T. viride* produced more vigorous seedlings with more number of leaves and height compared to other treatments. At the time of harvest also *B. subtilis* was superior. All other treatments except carbosulfan showed significant effect on the number of leaves, tillers and height of the plant.

In non flooded condition, *B. subtilis* followed by AMF and carbofuran showed superior effect in terms of root characters (length and weight of roots). In flooded condition also *B. subtilis* showed its superior effect. This was closely followed by AMF, carbofuran and *P. fluorescens*. Carbosulfan was the least effective treatment in both the conditions. Control plants showed poor root growth with only very short roots.

The yield attributes (days to flowering, days to harvest, number of panicles, number of grains per panicle, wet weight of grains, dry weight of grains and straw weight) in both flooded and non flooded conditions were superior in plants treated with *B. subtilis*. This was followed by carbofuran, AMF and *P. fluorescens* in non flooded condition and AMF, carbofuran, *P. fluorescens* and neem granules in flooded condition. There was no effect for enhancing the yield characters by carbosulfan. Plants in control pots were dwarf with only less number of leaves and tillers.

The nematode population characters with reference to reduction in number of nematodes in soil and root and gall count in root was superior in carbofuran treated plants in non flooded condition with 99.08, 99.26 and 97.50 percent reduction over the control respectively. *B. subtilis* treated plants showed superiority in flooded condition with 98.36, 98.79 and 95.56 per cent reduction over the control. There was statistically significant reduction in nematode population in all the other treatments (AMF, *P. fluorescens*, neem granules, *T. viride* and *P. fluorescens* + *T. viride*) except carbosulfan.