ECO-FRIENDLY MANAGEMENT OF ROOT-KNOT AND BURROWING NEMATODES ASSOCIATED WITH KACHOLAM, *Kaempferia galanga* Linn.

BY

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THESIS
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Dedicated to

My

Beloved Parents

DECLARATION

I hereby declare that this thesis entitled **"Eco-friendly management of root-knot and burrowing nematodes associated with** Kacholam, ***Kaempferia galanga*** **Linn."** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award 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 **"Eco-friendly management of root-knot and burrowing nematodes associated with Kacholam, *Kaempferia galanga* Linn."** is a record of research work done independently by Ms. Nisha. M.S. under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

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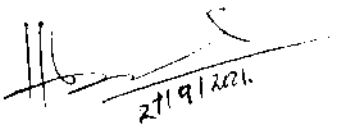

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INTRODUCTION

1. INTRODUCTION

India is a varietal emporium of medicinal plants and has one of the oldest, richest and diverse cultural tradition associated with the use of medicinal plants. In the recent years there has been an increasing interest in the cultivation of medicinal and aromatic plants to meet the requirement of essential oils for use in cosmetics, perfumes, pharmaceuticals and for earning foreign exchange. Kacholam, *Kaempferia galanga* Linn. is an economically important medicinal plant grown in tropics and subtropics of Asia and Africa.

The rhizomes are considered as stimulant, expectorant, carminative and diuretic. The leaves are used in cosmetic industry. It is commercially used for the production of about 300 common ayurvedic preparations (Pushpangadan, 1995). 'Kachuradithailam' and 'Kachuradichoornam' are some of the important ayurvedic preparations of kacholam and it is an ingredient of some of the general tonics like 'Chyavanaprasam' and 'Dasamoolarishtam'.

K. galanga was now found infested by both root-knot nematode, *Meloidogyne incognita* (Kofoid and White, 1919) Chitwood, 1949 and burrowing nematode, *Radopholus similis* (Cobb, 1893) Thorne, 1949 (Kerala Agricultural University, 1993). Root-knot nematode causes characteristic galls or root-knots on the distal end of the root resulting in decay of root and rhizome. Histopathological studies revealed that it affects the xylem vessels and tracheids blocking the translocation of food and absorption of water. In pot culture studies the reduction in yield was 18 to 64 per cent and in the field the yield loss assessed was 27 to 43 per cent (Rajani, 1998). The burrowing

nematode exhibit lesions and decay of roots and rhizomes of kacholam, but the yield loss data are not available.

The kacholam rhizomes damaged by nematodes are directly used for pharmacological preparations and will affect the quality as well as quantity of produce. Nematode management is therefore, important for high yields and quality that are required in the high-tech crop production. The hazardous chemical pesticides are to be totally avoided to ensure the quality of rhizomes used in pharmaceutical and cosmetic industry. Rajani *et al.* (1998) reported the effectiveness of neem cake and arbuscular mycorrhizal fungi for managing the root-knot nematode and for better yield.

In the non-chemical methods of management, bioagents, plant products, organic amendments and green leaves for mulching are available locally. Hence it can maximise the natural resource utilization in the context of low cost farmer friendly technology. To refine the strategy, this study was undertaken with the following objectives:

1. To evaluate the efficacy of plant products and bioagents as rhizome treatment for nematode management.
2. To test the efficiency of bioagents and organic amendments as main field treatment for managing nematodes.
3. To study the effectiveness of green leaf mulching for the management of nematodes in infested fields.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

In the recent years, non-chemical methods of control of plant parasitic nematodes is gaining importance in the light of increased awareness of environmental and human hazards associated with chemical control. The important literature relevant to these aspects are reviewed.

2.1 BOTANICAL PESTICIDES AND PLANT PRODUCTS

2.1.1 Green leaves

Several indigenous plants have been identified for their nematicidal action on root-knot nematode. Studies conducted on the use of green leaves like *Calotropis* sp., *Eupatorium* sp., mango and cashew on okra showed reduced root-knot nematode infestation and increased growth of plants (Kumar and Nair, 1976).

2.1.1.1 Chopped leaves

Kaliram and Gupta (1982) found that combined effect of various treatments like application of chopped neem and datura leaves were significant in reducing the number of galls in the case of chickpea (*Cicer arietinum* L.). Application of chopped castor leaves (40 g / kg of soil) two weeks before transplanting of tomato effectively controlled *M. javanica* (Dutt and Bhatti, 1986). Jasy *et al.* (1992) reported that chopped leaves of *Glyricidia maculata* 10 g / kg soil as green manure found to reduce the population of *R. similis* and promote the growth of black pepper under pot conditions.

Sundarababu *et al.* (1993) reported that chopped leaves of bougainvillea, ocimum, onion, prosopis, calotropis and subabul enhanced the growth of tomato and greengram and suppressed the final population of root-knot nematode in tomato and reniform nematode in greengram. Among them, prosopis was superior followed by subabul, calotropis and bougainvillea. Ajith *et al.* (1993) reported that application of chopped neem leaves @ 7.5 t/ha, 15 days prior to sowing of cowpea seeds significantly reduced the pathogenic nematodes like *M. incognita*, *R. reniformis* and *Helicotylenchus* sp.

Application of calotropis leaves @ 80 t/ha was found significantly better than neem and castor leaves which was proved as effective as carbofuran granules in reducing the nematode population in betel vine gardens (Subbarao *et al.*, 1996). Ramakrishna *et al.* (1997) reported that application of *Azadirachta indica* leaves (80 g/ pot) resulted highest reduction in root-knot index and nematode population in the case of okra.

A study conducted by Khanna and Sharma (1998) revealed that application of leaves of *Azadirachta indica* and *Tagetes patula* improved plant growth of tomato and reduced nematode count as well as gall index which were at par with that of nematicides (Phorate and carbofuran). Application of chopped leaves of *Prosopis juliflora, Catharanthus roseus, Leucaena leucocephala, Calotropis procera* and *Azadirachta indica* gave better biomass production than chemical treatment in the case of cowpea. The chopped leaves increased the VAM spore production and colonization and reduced nematode population (Santhi and Sundarababu, 1998).

Application of chopped green leaves of neem and *Chromolaena odorata* on soil before sowing significantly reduced the nematode population

and improved the yield in the case of okra and cowpea (Sheela *et al.*, 1999). In the case of tomato. plant materials like lemongrass, neem leaves and nafatia significantly improved plant growth and reduced root-knot disease, producing significantly more number of transplantable and total seedlings over control (Patel *et al.*, 2000).

2.1.1.2 Chopped shoots

Mansoor *et al.* (1987) reported that incorporation of chopped shoots of latex bearing plants like *Ficus elastica* gave greatest reduction in nematode population, root-knot development and showed significant improvement in plant growth. Soil amendment with chopped shoots of latex bearing plants viz., *Carica papaya, Artocarpus heterophyllus, Ficus carica, F. elastica, F. glomerata, Ipomea fistulosa, Nerium odorum* and *Tabarnaemontana coronaria* were effective in reducing the populations of *H. indicus, R. reniformis, T. brassicae* and *Tylenchus filiformis* infecting tomato and egg plant. *F. glomerata* and *F. elastica* significantly improved the growth of plants also (Siddiqui *et al.*, 1992).

2.1.1.3 Leaf extracts

The role of botanicals for the management of nematodes is well documented (Sitaramaiah, 1990). Root dip treatment of egg plant seedlings in margosa and marigold leaf extracts considerably reduced root-knot development compared to treatment with piperazine citrate, chinopodium oil and groundnut cake (Hussain *et al.*, 1984). The extract of *Argemone mexicana* acted as a nematicide to *M. javanica* in okra raised in micro plots (Nath *et al.*, 1982). Similarly Haseeb *et al.* (1982) identified the nematicidal

properties of *Mentha viridis, Cassia fistula, Cordia myxa, Carissa carandas, Colocasia arniquorum* against *R. reniformis*.

Extracts of *Andrographis paniculata, Calendula officianalis, Enhydra fluctuam* and *Solanum khasianum* reduced root galling by *M. incognita* on tomato transplants (Goswamy and Vijayalakshmi, 1986 a). Leaf extracts (10 to 0.1 per cent dilution) of *Euphorbia caducifolia* and *C. procera* were highly effective against *M. javanica* on tomato and brinjal showing improved growth (Maqbool *et al.*, 1987).

Aqueous leaf extracts of *Erythrina indica* at 1.1 x 1.5 concentration proved highly toxic to *M. incognita* and *Tylenchorhynchus mashhoodi* and per cent mortality of both the nematodes increased with exposure periods (Mohanty and Das, 1988). Extracts of leaves of citronella (*Cymbopogan winterianus)* reduced root galls and populations of *M. incognita* in soil and roots at concentrations of S/20, S/10 and S/5 on tomato (Mahapatra and Swain, 1993). Fresh leaf extracts of eucalyptus and neem plants (40 per cent w/v) with a dip duration of six hours were found to be highly effective in improving the growth parameters and suppressing the population of *M. javanica* on tomato (Vats and Nandal, 1994). Gupta and Sharma (1995) reported the nematicidal activity of aqueous extracts of *A. sativum* L. against the juveniles of *M. incognita*.

The aqueous extracts prepared from different plant parts of *T. erecta* (cv. Crackjack) inhibited the egg hatching and larval penetration of *M. javanica* (Dhangar *et al.*, 1996). Study conducted by Sosamma *et al.* (1998) revealed that leaf extracts of *Moringa pterigosperma, Momordica charantia*

and *Leucas aspera* have nematicidal and nematostatic properties against the root-knot nematode, *M. incognita*.

Sundararaju *et al.* (1999) reported that the leaf extracts of *Chromolaena odorata* exhibited a high degree of nematicidal action against the adults and larvae of *R. similis*. Exposure of larvae of *P. thornei* to aqueous rhizome extract of *Acorus calamus* L. resulted in 100 per cent mortality (Romabati *et al.*, 1999). Walia and Dalal (2000) observed an inhibition in the emergence of larvae from *Heterodera avenae* cysts in treatments with the extracts of two *Chenopodium* spp., *C. album* and *C. murale*. The effect decreased with dilution of the extract but increased with exposure time.

2.1.1.4 Dry leaf powder

Minimum galling and increase in growth of okra after the application of *Clerodendrone inerme* @ 1.5 per cent w/w was observed by Patel *et al.* (1985). Soil amendment with dried flowers, leaves, stems and roots of *Calotropis procera* significantly improved plant growth by reducing the root-knot nematode population in the case of egg plant (Ahmad *et al.*, 1996). Organic amendment with powdered leaves of the plants like Curry leaf, *Murraya koenigii;* Jasmine, *Jasminum sambac;* sour orange, *Citrus aurantifolia;* Patal garuda, *Rauwolfia serpentina;* Ber, *Zizyphus jujuba;* China rose, *Hibiscus rosachinensis;* and Justicia, *Justicia gandurusa;* were effective in reducing *M. incognita* population (Padhi and Behera, 2000).

2.1.2 Oil dipping

Pradhan *et al.* (1989) showed that seedling root dip in oils of chalmogra, neem and karanj at half to one eighth dilution was highly effective

in preventing larval penetration and gall production by root-knot nematode in the roots of tomato. Significant reduction of root-knot nematode on tomato by seed coating with Achook and neem oil was reported by Akhtar and Mahmood (1995).

Abid *et al.* (1995) studied the effect of essential oils of some medicinal plants on phytonematodes and found that oils from *Mentha spicata, Thymus vulgaris, Marjona hortensis* and *M. longifolia* inhibited nematode mobility. Higher concentration of organic oils of karanj, neem, mahua and castor proved effective on preventing larval penetration and gall production in the roots of tomato (Poornima and Vadivelu, 1997).

2.1.3 Botanical pesticides

Seed treatment with neem products (nimbecidine, achook etc.) have been recorded as effective as well as economical for nematode management in chickpea and other pulse crops (Mojumder and Raman, 1996). Naik *et al.* (1998) reported that the extracts of neem products had no adverse effect on the growth of tomato plants, but significantly decreased the nematode development and reproduction. Maximum reduction in galls, egg masses and egg production was recorded in nimbecidine treated plants and found superior over seed kernel and cake extracts. Among neem based formulations (achook, neemark, nimbecidine), achook was found to be the most effective in reducing the penetration, number of root-knot galls and final soil population (Mojumder and Basu, 1999).

2.2 ORGANIC AMENDMENTS

The beneficial effects of organic amendments and plant residues in reducing the plant parasitic nematodes have long been known.

2.2.1 Neem cake

Neem oil cake applied @ 1 t/ha in drenches near the root zone of betel vine at the time of planting of vines was most effective in controlling the root-knot and increased the yield of betel vine (Acharya and Padhi, 1988). Sundararaju and Sudha (1993) reported the effectiveness of neem oil cake @ 1 kg/palm/year in reducing the nematode population and increasing the yield significantly in arecanut, banana and black pepper under arecanut based farming system.

Soil amendment with neem cake at 0.1, 0.5 and 1 per cent w/w reduced infection of *M. incognita* on mung bean *Vigna radiata* and significantly improved the plant height, but reduced root nodulation (Abid *et al.*, 1995). Acid extracts of neem cake at different dilutions also enhanced the growth of *V. unguiculata* and reduced the population build up of nematode (Alagumalai *et al.*, 1995). Neem cake application reduced the population of *M. incognita* and improved the plant growth characters of Japanese mint (Pandey, 1995). Soil amendment with neem cake and datura powder were effective for the control of root-knot and root-knot disease complex of okra (Haque *et al.*, 1996).

Rao *et al.* (1997) reported that use of aqueous extract of neem cake for seed treatment and soil drenching under field conditions found effective as application of carbofuran at 2 kg ai/ha or neem cake at 2 t/ha for the

management of *M. incognita* on okra. Neem cake and neem dust were found effective in the suppression of root-knot nematode, *M. incognita* in tomato (Jacob and Haque,1998). Rajani (1998) reported the effectiveness of neem cake (@ 200 g/m^2) for managing root-knot nematode in kacholam.

2.2.2 Other oil cakes

Coconut oil cake reduced the infestation of root-knot nematode on okra and increased the growth of plants (Kumar and Nair, 1976). Soil amended with cakes of *Shorea robusta* and *C. inophyllum* resulted in slow hatching of *M. incognita* from egg masses (Goswamy and Vijayalakshmi, 1986b). Bhattacharya and Goswamy (1987) studied the role of micro organisms in the decomposition of neem and ground nut cakes and their effect on nematode build up and penetration and established that oil cakes have significant role in reducing nematode population. Alam (1989) reported that soil amendment with horn meal, bone meal and oil cakes of mahua, castor, mustard, neem and pea nut were effective in inhibiting the root-knot development and population build up of *T. brassicae* on egg plant, chilli, okra, cabbage and cauliflower and improving the plant growth.

The effectiveness of organic amendments (oil seed cakes of neem, castor, mustard and linseed) for the management of root-knot nematodes in *Hyoscyamus albus* was reported by Haseeb and Butool (1994). Kumar and Vadivelu (1996) reported that application of organic amendments viz., neem cake, castor cake and mahua cake each at 500 kg / ha were effective in increasing plant growth parameters and reducing root-knot and reniform nematode population in brinjal.

2.2.3 Organic wastes and soil conditioners

Organic wastes like sawdust, coconut husk powder, paddy husk, lemon grass waste, cashew shell powder etc. @ 2500 kg/ha significantly reduced root-knot nematode population and increased the yield of brinjal (Kamalakshiamma, 1987). Application of poultry manure at higher dose reduced the infestation of root-knot nematode and increased fruit yield of tomato (Chindo and Khan, 1990).

Organic amendments like sawdust, neem cake and poultry manure each @ 1000 kg/ha have been reported to be effective against *M. incognita* in reducing the galls and increasing the yield of carrot (Devi and Das, 1998). Considering the efficacy of different organic matters in managing the root-knot nematodes and subsequently increasing the yield, neem cake, press mud and mustard cake were superior for bottlegourd crop under field conditions (Patel *et al.*, 1998).

A study conducted by Vats *et al.* (1998) revealed that application of organic manures like neem cake, poultry manure, spent compost, FYM and biogas slurry improved plant growth of cotton and led to reduction in root-knot nematode populations. Neem cake was the best in improving growth parameters and in reducing nematode infection and multiplication. Amendment of soil with mustard cake was found superior and effective than poultry manure with regard to shoot length and root weight in okra and bottle gourd (Dahiya *et al.*, 1998).

Patel and Patel (1998) found soil application of organic amendments viz., press mud (3 t/ha), poultry manure (3 t/ha), mustard cake (1 t/ha) and

neem cake (1 t/ha) significantly improved plant growth attributes and increased grain and fodder yields with reduction in nematode population in chick pea. Of the various organic amendments used neem and mustard cakes were most effective followed by press mud and poultry manure for the management of root-knot nematode.

Vemana *et al.* (1999) observed that among the organic amendments, the highest reduction in the nematode population was in sawdust (25 q/ha) treatment supplemented with nitrogen (30 kg/ha), phosphorus (40 kg/ha) and potassium (50 kg/ha) followed by neem cake (10 q/ha), poultry manure (50 q/ha), farmyard manure (100 q/ha), press mud (25 q/ha) and castor cake (10 q/ha) in groundnut.

2.3 BIOAGENTS

Among the non-chemical methods of controlling nematodes, use of biological control agents appears to be the recent strategy gaining more importance. The relevant literature on important bioagents are reviewed and presented.

2.3.1 Bacteria

There are two groups of bacteria one which release metabolites that have a killing or inhibitory effect on phytonematodes (species of *Bacillus*, *Clostridium*, *Pseudomonas*, *Azotobacter* etc.) and the second group include bacteria which parasitize directly on nematodes, thereby affecting the entry, penetration, reproduction, egg hatching and larval mortality of nematodes (*Pasteuria penetrans*).

2.3.1.1 *Pseudomonas fluorescens*

Recently the fluorescent *Pseudomonas* spp. associated with the plant rhizosphere emerged as the largest and most promising biocontrol agent of plant parasitic nematodes (Oostendrop and Sikora, 1989). *Pseudomonas* sp. 1 and 2 were most effective against the nematodes viz., *H. cajani, H. zeae, H. avenae* and *M. incognita* under *in vitro* condition (Gokte and Swarup, 1988). The effectiveness of *P. fluorescens* as a potential biocontrol agent against *M. incognita* due to their ability to envelop or bind the root surface with carbohydrate and lectin thereby interfering with normal host recognition (Oostendrop and Sikora, 1990). Santhi and Sivakumar (1995) reported the biocontrol potential of *P. fluorescens* (Migula) against root-knot nematode on tomato.

Application of *P. fluorescens* @ 10 g/kg seed was effective in reducing the menace of root-knot nematode, *M. incognita* in tomato (Verma *et al.*, 1998) and grape vine (Santhi *et al.*, 1998). Mani *et al.* (1998) reported the effectiveness of pf (1) strain of *P. fluorescens* against *M. incognita*, *Tylenchulus semipenetrans* and potato cyst nematode. Application of *P. fluorescens* as seed treatment at a dosage of 10 g/kg seed was effective in reducing the infestation of *Hirschmaniella gracilis* (Ramakrishna *et al.*, 1998). Sheela *et al.* (1999) also reported the biocontrol efficiency of this bacteria in brinjal.

Seenivasan *et al.* (2000) found that the culture filtrate of *P. fluorescens* have toxic effect on *H. oryzae* population. Sirohi *et al.* (2000) reported that culture filtrates of *Bacillus* and *Pseudomonas* can cause 80 to 90 per cent mortality in *M. incognita* juveniles.

2.3.1.2 *Bacillus* spp.

Bacillus macerans was found effective against root-knot nematode in bhindi and pepper (Sheela and Venkitesan, 1992). Study conducted by Racke and Sikora (1992) revealed that the plant growth promoting rhizobacteria, *Agrobacterium radiobacter* and *Bacillus sphaeriacus* increased the tuber yield of potato by suppressing the population of *Globodera pallida*. Roots from the plants infested with the nematode and bacteria had lower root indices and fewer *Meloidogyne* larvae and eggs than those infested with the nematode only (Vargas, 1992). Oka and Chet (1993) opined that exposure of *Meloidogyne* juveniles to *Bacillus cereus* inhibited the penetration of the nematodes into the tomato roots.

The various formulations of *Bacillus thuringiensis* found toxic to eggs and larvae of *Meloidogyne* sp. Zuckerman *et al.* (1993) found that application of an isolate of *Bacillus thuringiensis* (CR-371) resulted in smaller population of *M. incognita* in tomato and *P. penetrans* in strawberry. Sharma (1994) reported that bacterial nematicides, *Bacillus thuringiensis* var. *thuringiensis* (Btt) and *B. thuringiensis* var. *israelensis* (Bti) were effective in controlling *M. incognita* on barley.

2.3.1.3 *Pasteuria penetrans*

P. penetrans, a mycelial endospore forming bacterium, is an obligate parasite of large number of nematodes and it completes its life cycle in second stage juveniles. Ahmad *et al.* (1994) reported that *P. penetrans* applied at 2.5 cm soil depth was the most effective method for the control of *M. incognita* on tomato. *P. penetrans* application significantly reduced the

population of root-knot nematode and gall index in okra (Walia and Mehta, 2000).

2.3.2 Fungi

2.3.2.1 Arbuscular mycorrhizal fungi

AMF have potential in reducing plant diseases caused by plant parasitic nematodes. AMF association is reported to induce tolerance to root pathogens (Sharma and Trivedi, 1994). The interaction between AMF and plant parasitic nematodes have been studied by several workers (Bagyaraj *et al.*, 1979; Suresh *et al.*, 1985). Development and reproduction of nematodes are often inhibited by mycorrhizal association (Cooper and Grandison, 1986; Jain and Sethi, 1988).

Bagyaraj *et al.* (1979) reported that tomato roots colonized by *G. fasciculatum* exhibited fewer and small galls than nematodes (*M. incognita* and *M. hapla*) infested non-mycorrhizal plants. The number of giant cells formed in mycorrhizal tomato when infected with the root-knot nematode was significantly low when compared with non-mycorrhizal plants (Suresh *et al.*, 1985).

Increased resistance against nematodes and suppression of nematode population have been observed in mycorrhizal soybean (Franil and Dropkin, 1985), tomato and white clover (Cooper and Grandison, 1986). The gall formation by *M. incognita* and their multiplication were hampered by the early establishment of *G. fasciculatum* on cowpea (Jain and Sethi, 1988).

Sivaprasad *et al.* (1990) observed that deleterious effect of nematodes was made insignificant due to arbuscular mycorrhizal associations in cowpea.

The root-knot index and nematode population were reduced considerably. In pepper there was reduction in nematode population in root and soil, root-knot index and increased growth of vines when plants were inoculated with *G. fasciculatum* and *G. etunicatum* (Sivaprasad *et al.*, 1990). Cowpea plants inoculated with *M. incognita* in association with *G. fasciculatum*, *G. mosseae* and *A. morroweae* recorded a root-knot index of 1, 3.16 and 3.43 respectively as against 4.89 observed for control plants (Deepthi, 1993).

Sharma *et al.* (1994) reported 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 glasshouse condition and found that the symbiont caused a reduction of 30 per cent in galls and egg masses per plant.

Sundarababu *et al.* (1996) reported that when *G. fasciculatum* was inoculated 15 days earlier than nematode inoculation, enhanced the growth of tomato cv. Co-3 and suppress *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). *G. mosseae* was found effective in reducing burrowing nematode population in coconut (Koshy *et al.*, 1998) and banana (Sosamma *et al.*, 1998).

Study conducted by Nageswari *et al.* (1998) revealed that *G. fasciculatum* can be effectively used as a biocontrol agent for *H. cajani* in

cowpea. Ray and Dalei (1998) reported that in the case of greengram all plant growth parameters including pod yield, leaf chlorophyll content, bacterial nodulation, leg haemoglobin content of nodules and NPK contents of plants showed significant improvement in mycorrhiza inoculated plants. Application of *G. fasciculatum* @ 10 g/kg soil was sufficient for the effective management of root-knot nematode infesting tomato and okra (Sundarababu *et al.*, 1998).

Mycorrhizal inoculation enhanced significantly oil yield in *Mentha arvensis* cv. Himalaya (Pandey *et al.*, 1998), flower yield in *Crossandra undulaefolia* (Nagesh *et al.*, 1999) and growth parameters in white clover (Habte *et al.*, 1999).

2.3.2.2 *Trichoderma viride*

Trichoderma and *Gliocladium* has been reported as potential fungal biocontrol agents against several plant pathogens and plant parasitic nematodes (Papavizas, 1985; Sankaranarayanan *et al.*, 1997). *T. harzianum* is a saprophytic fungus often found in the soil rich in organic matter. The parasitic fungus, *T. harzianum* Rifari has been reported to be one of the promising biocontrol agent against plant parasitic nematodes (Reddy *et al.*, 1996 and Rao *et al.*, 1998). Exposure of second stage juveniles of rice root nematode to the *T. harzianum* culture filtrate also caused significant nematode mortality.

The synergistic effect of fungi *T. viride* along with the organic amendment for the enhancement of plant growth by increasing the population of nematode trapping fungus was reported by Reddy *et al.* (1996) and

Sundarababu *et al.* (1997). Sankaranarayanan *et al.* (1997) reported the nematicidal effect of fungal filtrates (*T. harzianum*) against root-knot nematode in tomato. Khan and Saxena (1997b) reported that root dip treatment with culture filtrates of *A. niger*, *P. lilacinus* and *T. viride* was particularly beneficial in reducing *M. incognita* damage on tomato in pot experiments.

Sanakranarayanan *et al.* (1998) studied the antagonistic effect of *Trichoderma* and *Gliocladium* sp. against the root-knot nematode (*M. incognita*) on sunflower and found that these fungi were effective in reducing the number of galls and egg masses on the root system and nematode population in soil. Application of plant based formulations of *T. harzianum* to nursery beds of aubergine was effective in producing vigorous seedlings with least root galling, increased root colonization and parasitization of *M. incognita* females by *T. harzianum* (Rao *et al.*, 1998).

Acharya *et al.* (2000) reported good control of root-knot nematode in betel vine by field application of *T. viride*. The fungus showing saprophytic habit when inoculated with suitable oil cake (mustard cake as substrate) proved to be an effective parasite of root-knot nematode, thus resulted in reducing the nematode population in soil and thereby increasing the yield (both number and weight of leaves).

2.4 CHEMICALS

The effect of chemicals for managing root-knot nematode in various crops are reviewed here. Mahajan (1978) observed reduced root-knot index after four weeks by the application of carbofuran flowable paste at different

concentrations in okra seeds. Spot application of chemical was superior than row or broadcast in reducing root-knot incidence (Sitaramaiah and Vishwakarma, 1978).

Carbofuran at 2 kg ai/ha effectively controlled *M. incognita* on ginger and improved plant growth in pot culture experiments (Parihar and Yadav, 1986). Jain *et al.* (1988) reported that aldicarb and aldicarb based chemicals were most effective in increasing tomato yield in *M. javanica* infested plots. Carbofuran reduced the galls and egg mass in roots of pea and increased the yield (Bhagavati and Phukan, 1990). Borah and Phukan (1990) tried carbofuran 3 G, phorate 10 G, Mocap 10 G and diazinon 10 G each at one, two and three per cent as seed treatment for the control of *M. incognita* on greengram and revealed 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. In another study carbofuran was found effective in suppressing *M. incognita* activity and improving plant growth of French bean (Mohan and Mishra, 1993).

Soil application of carbofuran @ 2 kg ai/ha and seed dressing @ 2 g ai/kg were highly effective in controlling *M. incognita* larvae and reduced root-knot galls in pea compared to control plants. This treatments also improved the plant growth parameters and yield (Devi, 1993). Carbofuran 2 kg 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 (Singh and Kumar, 1995).

Joshy and Patel (1996) reported that seed treatment and soil application of nematicides for management of *M. javanica* on groundnut revealed that soil

application of Phorate was found most effective followed by carbofuran in improving plant growth, while phenamiphos was found most effective in reducing host infection.

Bare root dip treatment of brinjal seedlings with monocrotophos, triazophos or carbosulfan @ 0.05 per cent is beneficial in reducing the root-knot nematode population significantly and increasing the yield between 34 to 80 per cent over the check (Reddy *et al.*, 1997).

Pareek *et al.* (1998) reported that in gram, application of carbofuran @ 2 kg ai/ha was better in improving the plant growth characters like shoot-root weight and length and in reducing number of galls, egg/egg mass and final soil population in comparison to other chemicals like sebufos and phorate.

Patel *et al.* (1998) reported that soil application of carbofuran @ 3 kg ai/ha increased dry pod yield by 42.8 per cent and dry fodder yield by 28.8 per cent and reduced root-knot disease by 45.2 over control in the case of groundnut.

Vadhera *et al.* (2000) reported that carbofuran @ 0.6 g ai/m^2 in nursery bed treatment improved the germination, seedling vigour, weight and significantly reduced the gall index from 5 to 3.6 and increased the yield by 36 per cent.

2.5 Combination of bioagents and organic amendments

In the case of tomato there was significant reduction in root-knot index and final population of root-knot nematode and significant increase in plant growth in mycorrhizal seedlings transplanted in neem cake (Rao *et al.*, 1995) and castor cake (Rao *et al.*, 1996) amended soils. *V. lecani* in combination with the oilcakes viz., castor, karanj and neem at 200 g/plant was effective in

increasing the plant growth and reducing the citrus nematode population in soil and root (Reddy *et al.*, 1996) in the case of acid lime.

Rao *et al.* (1997) reported integration of *G. fasciculatum* (500 g/m^2) with castor cake (400 g/m^2) resulted significant reduction in root galling and fecundity of *M. incognita* and an increase in root colonization by endomycorrhiza in tomato plants.

Reddy *et al.* (1997) reported that by integrating eco-friendly components like endomycorrhiza *G. mosseae* along with oil cakes like karanj or neem cake, *R. similis* population in banana can be effectively managed.

Investigations on interaction of endomycorrhiza with organic amendments revealed that neem cake and castor cake encourage the multiplication of *G. mosseae* and *G. fasciculatum* respectively. Integration of these oil cakes with endomycorrhiza in the nursery protected the seedlings of tomato from the attack of *M. incognita* (Reddy *et al.*, 1998).

2.6 Combination of bioagents and plant products

G. mosseae in combination with neem leaf or neem leaf extract proved very effective in increasing the plant growth parameters of egg plant seedlings in the nursery beds and reducing nematode infestation, indicating combined and complimentary interacting effect of both components on the management of root-knot nematode due to their synergistic actions (Rao *et al.*, 1993).

2.7 Combination of bioagents and chemicals

Treatment with a combination of either *Trichoderma* – Vydate (oxamil) or *Trichoderma*-Nemacur (fenamiphos) significantly decreased disease and

root-gall index and improved plant height and shoot dry weight on tomato plants (Stephan *et al.*, 1996).

The application of *P. fluorescens* and carbofuran in combination enhanced the yield and improved the vigour of plants in the case of tomato by suppressing the root-knot nematode (Khan, 2000) and cyst nematode, *Heterodera cajani* in soil and root system (Sujatha *et al.*, 2000)

2.8 Combination of organic amendments and chemicals

Singh *et al.* (1980) recommended combined application of oil cakes and nematicides for effective control of nematode population, since it was found superior to oil cakes alone and only a low concentration of nematicide is required when mixed with oil cakes. Gaur and Mishra (1990) reported combined application of organic amendment (neem cake 1 t/ha) and phorate 10 G @ 1 per cent (w/w) as seed treatment and basal application of aldicarb 10 G @ 40 kg/ha significantly reduced the plant parasitic nematodes and increased the yield of greengram. Neem cake followed by carbofuran treated plots showed minimum gall index in ginger (Mohanty *et al.*, 1992).

In a field study Kaul and Bhatt (1995) revealed that neem cake both spot application 30 g / plant and general application 1 t/ha and also carbofuran alone and in combination with neem cake were most effective in reducing the larval population of *M. incognita* in 30 and 60 days of transplantation in the case of tomato. In ginger neem cake @ 2.5 t/ha at the time of planting and carbofuran 1 kg ai/ha forty five days after planting were effective in reducing *M. incognita* populatin in soil and root and also the root-knot index and increasing the yield (Sheila *et al.*, 1995).

Seed treatment with carbofuran 3 G @ three per cent (w/w) and organic amendments viz., neem cake, poultry manure and mustard oil cake each at two t/ha alone and combined application of seed dressing followed by organic amendments @ 1 t/ha each were found effective in improving plant growth characters and yield of greengram (Barman and Das, 1996).

Neem cake and carbofuran treated plants supported minimum nematode population and root-knot index in papaya plants (Mohanty *et al.*, 2000). Keshari and Pathak (2000) reported neem cake, mustard cake, press mud @ 25 g/kg soil and carbofuran 20 and 10 mg ai/kg soil reduced root-gall formation and increased the yield (root-weight) and shoot length of red beet.

2.9 Others

Integration of calotropis leaf and *G. fasciculatum* (Rao *et al.*, 1996) and oil cakes, bone and horn meals with *P. lilacinus* (Khan and Saxena, 1997a) resulted increased plant growth and reduced population build up of nematodes and root gallings in the case of tomato. The combined effect of the mycorrhizal fungi and *P. lilacinus* gave maximum reduction of nematode galls in okra (Sharma and Trivedi, 1997).

The combination of endomycorrhizal fungus *G. deserticola* and *P. penetrans* was beneficial for sustainable management of *M. incognita* in tomato (Rao and Gowen, 1998). The combination significantly reduced the number of egg masses in root system and increased the parasitization of females by *P. penetrans*. Root colonization by *G. deserticola* was not affected by *P. penetrans*.

Integration of *P. penetrans, T. viride* and neem cake in nursery and rotation of tomato with marigold in the field gave significant reduction in root galling, egg mass production and final nematode population in soil which resulted in increased tomato yield (Reddy *et al.*, 2000).

MATERIALS AND METHODS

3. MATERIALS AND METHODS

Studies were conducted to evolve an eco-friendly management strategy for controlling nematodes associated with the medicinal plant kacholam, *Kaempferia galanga* L. The experiments were conducted in microplots at College of Agriculture, Vellayani. The efficacy of botanical pesticides, plant products, bioagents and organic amendments in suppressing the nematode population was evaluated by rhizome treatment, main field treatment and also by mulching in infested microplots.

3.1 Experiment on rhizome treatment

3.1.1 Preparation of rhizomes for planting

Whole or split rhizomes having one healthy sprout was used as planting material. Well developed mature healthy disease free rhizomes were selected and washed in running water to remove the soil particles before treatment. Dry roots were also removed from the selected rhizomes. Five gram rhizome with one or two healthy sprout per pit was used as planting material. Starch was coated on the surface of the cleaned seed rhizomes for easy adherence of the plant products and bioagents. The treated rhizomes were planted at a spacing of 20 x 15 cm at a depth of 4-5 cm in microplots containing nematode infested garden soil (sick plots). Plants were maintained as per the package of practices recommendations of Kerala Agricultural University (1996).

3.1.2 Preparation of neem oil emulsion

Five gram soap flakes were dissolved in 30 ml of lukewarm water and mixed well to get soap solution. To this added 20 ml of neem oil and agitated thoroughly to make an emulsion. The emulsion was further diluted with water by constant stirring and made upto one litre to get two per cent neem oil emulsion.

3.1.3 Preparation of neem leaf extract

The leaves of *Azadirachta indica* plants were collected from Instructional Farm, Vellayani for extraction. Crude extract was prepared by crushing 50 g neem leaf in minimum quantity of water. The extract was filtered using a fine muslin cloth and was made upto one litre to get five per cent neem leaf extract.

3.1.4 Preparation of neem leaf extract + garlic solution

Crude extract of neem leaf was prepared by crushing 40 g neem leaf in minimum quantity of water. To this garlic extract obtained by grinding 10 g garlic was added and made upto 1 litre to get neem leaf (4 %) + garlic (1 %) extract.

3.1.5 Preparation of neem oil garlic emulsion

Five gram of ordinary washing soap was dissolved in 30 ml of lukewarm water to get soap solution. Twenty ml of neem oil was added to the soap solution with constant stirring to get neem oil emulsion. Twenty gram garlic was grinded in 50 ml of water and mixed it with neem oil emulsion to get 100 ml stock solution. This was made upto one litre to get two per cent neem oil garlic emulsion.

3.1.6 Preparation of nimbecidine solution

A commercial botanical pesticide containing azadirachtin 0.03 per cent supplied by T. Stanes and Company Ltd., Coimbatore was used for the experiment. Nimbecidine 0.2 per cent was obtained by dissolving two ml nimbecidine in one litre of water.

3.1.7 Preparation of dimethoate solution

Three ml of the insecticide, dimethoate (Rogar 30 per cent EC) was dissolved in one litre of water to get 0.1 per cent dimethoate solution required for rhizome treatment.

3.1.8 Bioagents

3.1.8.1 Preparation of *Pseudomonas fluorescens*

Talc based formulation of *P. fluorescens* obtained from the Department of Plant Pathology, College of Agriculture, Vellayani was used for rhizome treatment. The seed rhizome was treated with a thick suspension of *P. fluorescens* formulation (10^{6} spores per g) in water @ three per cent weight by weight (w/w) of seed rhizome.

3.1.8.2 Preparation of *Trichoderma viride*

Dry cowdung and neem cake were taken in 9 : 1 ratio and powdered well to a coarse texture. This mixture was used as food base for multiplication of *Trichoderma* for field application. Talc based formulation of *T. viride* obtained from the Department of Plant Pathology, College of Agriculture, Vellayani was incorporated in the food base. The mixture was moistened by sprinkling water and covered with gunny bag. Care was taken to maintain the moisture by sprinkling water. The food base was mixed on

eighth and twelfth day to achieve uniform growth. On the 15th day the inoculum so developed recorded *Trichoderma* population 10^6 per gram (Sivaprasad, 1998). This inoculum was used for rhizome treatment @ 3 per cent w/w of seed rhizome.

3.1.8.3 AMF inoculum and inoculation

AMF inoculation technique developed for ginger rhizomes, followed in the present study (Sivaprasad, 1998). Perlite–vermiculite based arbuscular mycorrhizal inoculum containing mixed cultures of *Glomus fasciculatum* and native isolates *G. monosporum* and *Glomus* sp. (GI.1) obtained with an infective propagule count of 100 per gram from the Department of Plant Pathology, College of Agriculture, Vellayani was used for the experiment. First the rhizomes were treated with starch suspension and then the wet rhizomes were rolled in AMF inoculum so as to get a coating of rhizome with the inoculum. Rhizomes treated with the inoculum were partially dried before planting.

3.1.8.4 Establishment of bioagents in the root and rhizosphere

3.1.8.4.1 Mycorrhizal colonization percentage and intensity

The percentage of mycorrhizal colonization in root was estimated following the procedure of Phillips and Hayman (1970). Cleaned root samples which are free of soil particles were cut into one cm sized bits, fixed in FAA (formalin : acetic acid : ethanol 5 : 5 : 90) for three hours. The root bits were softened by simmering in ten per cent potassium hydroxide at 90^0 C for one hour. After cooling, the excess of alkali was removed by repeated rinsing in tap water and then acidified with two per cent hydrochloric acid. Staining was done by keeping the root bits in 0.05 per cent Trypan blue solution

(Trypan blue (Romali) – 50 mg, Lactophenol – 100 ml) in lactophenol reagent (lactic acid - 20 ml, phenol- 20 ml, glycerol – 40 ml, distilled water – 40 ml) at 90^0 C for three minutes. The excess stain from the root tissue was removed by clearing over night in fresh lactophenol. Ten root bits were examined at a time for the typical arbuscular mycorrhizal infection under a light microscope. Each root bit was divided into four equal segments for recording the presence or absence of mycorrhiza and based on this, different grades from zero to four were given depending on the extent of mycorrhizal infection. The average value thus obtained for 100 root bits examined was taken as mycorrhizal index.

$$\text{Percentage of mycorrhizal infection} = \frac{\text{Number of root bits having infection}}{\text{Number of root bits subjected for observation}} \times 100$$

3.1.8.4.2 Estimation of mycorrhizal spore count

The number of spores in the soil was estimated by adopting wet sieving and decanting technique of Gerdemann and Nicolson (1963). For this, 50 g of kacholam rhizosphere soil was initially suspended in 100 ml of tap water in a measuring cylinder and after the heavier particles had settled, the supernatant was passed through a set of sieves of B.S.S. No. 60 (250 microns), 150 (150 microns) and 350 (45 microns). The residue left behind in the measuring cylinder was resuspended in 100 ml of fresh tap water and passed through the same set of sieves. The procedure was repeated three to four times in order to collect maximum number of spores from the soil. Finally, the material present on each sieve was transferred to 100 ml beakers in small volume of

water and spread over Whatman no. 1 filter paper. The contents of each filter paper were carefully examined under a stereomicroscope for Arbuscular Mycorrhizal Fungal (AMF) spores and recorded the spore count.

3.1.8.4.3 Estimation of population of *P. fluorescens* and *T. viride*

The population of *P. fluorescens* and *T. viride* in the rhizosphere soil was estimated by the dilution plate technique (Timonin, 1940).

One gram of rhizosphere soil was taken along with root materials and transferred to 100 ml sterile water blank and shaken for 5-10 minutes on a shaker. From this stock suspension different dilutions of 10^{-2}, 10^{-3}, 10^{-4}, 10^{-5}, 10^{-6} were prepared. The population of fungi and bacteria were estimated at 10^{-3} and 10^{-6} dilutions respectively. Kings' B medium; Martins Rose Bengal Agar medium and potato dextrose agar medium were used for plating *P. fluorescens* and *T. viride* respectively. The composition of media used were as follows :

Kings' B media

1) Peptone – 20 g
2) Dipotassium hydrogen phosphate – 1.5 g
3) Magnesium sulphate – 1.5 g
4) Glycerol – 10 ml
5) Agar agar – 20 g
6) Distilled water – 1 litre
7) pH – 7.2

Martin's Rosebengal Agar medium

1) Peptone – 5 g
2)Potassium di hydrogen phosphate – 1 g
3) Magnesium sulphate – 0.5 g
4) Dextrose – 10 g
5) Rosebengal – 33 mg
6) Agar agar – 15 g

7) Distilled water – 1 litre 8) PH – 6-6.5

After sterilization one per cent streptomycin sulphate solution 3 ml/l was added.

One ml aliquots from the dilutions 10^{-3} and 10^{-6} were transferred to sterile petriplates. Melted and cooled media at 45^{0}C was poured at the rate of 20 ml per dish and rotated gently for thorough mixing. The petridishes were incubated at 28 ± 1^{0}C for 96 hours. Observations were recorded as number of colony forming units (cfu) per g of soil.

The details of rhizome treatment experiment are given as follows :

Plot size – 2 x 2 m Design – RBD

Treatments – 11 Replication – 3

T_1 – Neem oil (2 per cent)

T_2 – Neem leaf extract (5 per cent)

T_3 – Neem oil + garlic (1 : 1) (2 per cent)

T_4 – Neem leaf extract (4 per cent) + garlic (1 per cent)

T_5 – Nimbecidine (0.2 per cent)

T_6 – Arbuscular mycorrhizal fungi (3 per cent w/w)

T_7 – *P. fluorescens* (3 per cent w/w)

T_8 – *T. viride* (3 per cent w/w)

T_9 – Hot water treatment (55^{0}C)

T_{10} – Dimethoate (0.1 per cent)

T_{11} – Untreated

The main items of observations recorded were

1. Population of nematodes in 250 g soil at bimonthly intervals by Cobb's sieving and decanting technique and cleared by modified Baermann funnel technique.
2. Biometric characters of the plant like number of leaves, weight of roots and shoots at the time of harvest.
3. Yield in terms of weight of rhizomes.
4. Root-knot count per g of root.
5. Population of nematode in 5 g root was estimated by modified Baermann funnel technique.
6. Estimation of bioagents in the rhizosphere

3.2 Experiment on mainfield treatment

The efficacy of bioagents and soil conditioners were assessed by applying them as main field treatment for the management of nematodes in kacholam along with carbofuran as check. The required quantities of soil conditioners were applied to each plot at a depth of 25 cm from the soil surface and the plants were maintained as mentioned in 3.1.1.

3.2.1 Preparation of bioagents

3.2.1.1 Preparation of *P. fluorescens*

The talc based formulation of *P. fluorescens* (10^{11} cells g^{-1}) obtained from the Department of Plant Pathology, College of Agriculture, Vellayani was used for soil drenching. Soil drenching was done with two per cent suspension of *Pseudomonas* formulation in water before planting the rhizomes.

3.2.1.2 Preparation of *T. viride*

T. viride inoculum was prepared as described earlier. Twenty five gram of the inoculum per m^2 was applied in the field in furrows before planting the rhizomes.

3.2.1.3 AMF inoculum and inoculation

The mycorrhizal inoculum obtained from the Department of Plant Pathology, College of Agriculture, Vellayani was inoculated to seed rhizome as described earlier.

3.2.2 Establishment of bioagents in the root and rhizosphere

3.2.2.1 Mycorrhizal colonization percentage and intensity

Mycorrhizal colonization percentage and intensity were estimated as mentioned in para 3.1.7.4.1.

3.2.2.2 Estimation of mycorrhizal spore count

The mycorrhizal spore count was estimated as mentioned in para 3.1.7.4.2.

3.2.2.3 Estimation of population of *P. fluorescens* and *T. viride*

The recovery of *P. fluorescens* and *T. viride* were estimated as mentioned in para 3.1.7.4.3.

Field trial was conducted as detailed below.

Net plot size :	1 x 1 m	Design :	RBD
Treatments :	9	Replication :	3

T_1 – Neem cake (200 g per m^2)

T_2 – Coir pith (500 g per m^2)

T_3 – Sawdust (500 g per m^2)

T_4 – Neem leaf (750 g per m^2)

T_5 – AMF (300 g inoculum per m^2)

T_6 – *P. fluorescens* (10 g per m^2)

T_7 – *T. viride* (10 g per m^2)

T_8 – Carbofuran (1 g a.i. per m^2 i.e., 3.33 g per m^2)

T_9 – Untreated

Nematode population in soil was estimated at 2, 4, 6, 8 and 10 months after treatment. Biometric characters of plant viz., number of leaves, weight of roots and shoots as well as yield and nematode population characteristics (root-knot count per g of root, number of females in 5 g root, nematode population in 5 g root sample) were recorded at the time of harvest (uprooting the plant 10 months after planting). Ten g of soil sample was taken for estimation of bioagents in the rhizosphere as mentioned in 3.1.8.4.

3.3 Experiment on effect of mulching

The micro plots were filled with nematode infested garden soil which was made into good tilth. The required quantities of green leaves (5 kg/m^2) were applied into the soil up to a depth of 30 cm, at the time of planting of rhizomes. Five shallow furrows were taken for planting the rhizomes and they were maintained as per the package of practices recommendations of Kerala Agricultural University (1996).

The experimental details are as follows :

Net plot size - 2 x 2 m Design - RBD

Treatments - 7 Replication - 3

T_1 – Neem (5 kg/m^2) T_5 – Calotropis (5 kg/m^2)

T_2 – Glyricidia (5 kg/m^2) T_6 – Chromolaena (5 kg/m^2)

T_3 – Mangium (5 kg/m^2) T_7 – Untreated (without mulching)

T_4 – Clerodendron (5 kg/m^2)

The following observations were recorded.

1. Population of nematodes in soil at bimonthly intervals.
2. Biometric characters of the plant like number of leaves, weight of roots and shoots at the time of harvest.
3. Yield in terms of weight of rhizome.
4. Root-knot count per g of root and indexing.
5. Population of nematode in five g root sample.
6. Population of nematode in soil sample.

3.4 Assessment of results

3.4.1 Estimation of nematode population in soil

Soil samples from each plot were collected before planting of rhizomes for estimating the pre-treatment population. Soil samples were collected 2, 4, 6, 8 and 10 months after planting and nematodes were extracted from the representative soil samples following the method of Cobb's sieving and decanting technique (Cobb, 1918) and modified Baermann's method. The nematodes thus extracted were counted under a stereoscopic microscope.

3.4.2 Estimation of nematode population in roots

Nematode population in root samples was estimated by modified Baermann funnel technique as follows. Root samples collected were washed thoroughly in a stream of tap water. Five gram of root was weighed and cut into small bits of 2-3 cm length and placed above the tissue paper supported by the wire guaze placed on petri plate. After 24 hours the nematode suspension were collected, pooled and counted under a stereoscopic microscope. These were moistened and kept in 200 gauge polythene cover and incubated for 24 hours.

3.4.3 Root-knot index

The number of galls per g of root were counted and the root-knot indexing was done as detailed below.

Number of galls/g of root	Root-knot index
1-5 galls	1
6-10 "	2
11-15 "	3
16-20 "	4
Above 20 "	5

3.4.4 Number of females

Five g root sample from the root system of kacholam was cut into small bits of 2-3 cm length and stained by differential staining method using acid fuschsin-lactophenol mixture. The processed roots were pressed between glass slides and then teased with a needle and examined under a microscope to count the number of females.

RESULTS

4. RESULTS

4.1 EXPERIMENT ON RHIZOME TREATMENT

4.1.1 Number of leaves

The results presented in Table 1 showed that there was significant variation in leaf production in kacholam plants by different rhizome treatments. Maximum leaf production was recorded in *P. fluorescens* (3 per cent w/w) treated plants giving more than cent per cent increase over the untreated. This treatment was on par with arbuscular mycorrhizal fungi (AMF) (3 per cent w/w) and neem leaf extract (4 per cent) + garlic (one per cent) (NLE + G) treatment giving more than 96 per cent increase over untreated. Next best treatment was hot water treatment of rhizome (55^0C), which also improved the leaf production to a tune of 91 per cent over the untreated. Statistically, effect of this treatment was on par with *T. viride* (3 per cent w/w). Rhizome treatment with nimbecidine (0.2 per cent) and dimethoate (0.1 per cent) were on par giving more than 60 per cent increase in leaf production over untreated though they were inferior to bioagents, NLE + G and hot water treatment. Effect of neem leaf extract (5 per cent) as rhizome treatment was on par with dimethoate and significantly superior to the untreated giving 36 per cent increase in leaf production.

4.1.2 Shoot weight

There was statistically significant variation in shoot weight of the kacholam plants due to treatment of rhizomes (seed material) with bioagents, botanicals etc. The results are presented in Table 1. The mean shoot weight of

Table 1 Effect of rhizome treatments on the biometric characters of kacholam ten months after treatment (mean of three replications)

Treatments	Mean no. of leaves	% increase over untreated	Mean shoot weight (g)	% increase over untreated	Mean root weight (g)	% increase over untreated	Mean fresh plant weight (g)	% increase over untreated
Neem oil (NO)-2%	27.40	8.73	1.67	3.73	49	2.08	145	10.13
Neem leaf extract (NLE)-5%	34.27	35.99	2.17	34.78	63	31.58	160	21.53
NO + Garlic (1:1)–2%	28.70	13.89	1.78	10.56	52	8.42	155	17.73
NLE (4%) + Garlic (1%)	49.50	96.43	3.31	105.59	83	73.68	175	32.92
Nimbecidine -0.2%	40.77	61.79	2.57	59.63	75	57.89	185	40.51
Arbuscular mycorrhizal fungi (AMF) -3% w/w	50.30	99.60	3.20	98.76	93	94.74	250	89.88
Pseudomonas fluorescens-3 % w/w	55.30	119.44	3.44	113.66	111	133.68	295	124.06
Trichoderma viride - 3% w/w	43.20	71.43	2.83	75.78	83	73.68	195	48.11
Hot water treatment –55^{0}C	48.13	90.99	2.83	75.78	87	84.21	210	59.50
Dimethoate –0.1%	40.20	59.52	2.71	68.32	79	67.37	165	25.32
Untreated	25.20	-	1.61	-	48	-	131.66	-
CD (0.05)	6.44	-	0.67	-	12.97	-	41.89	-

treated plants ranged from 1.67 to 3.44 g as against the mean weight of 1.61 g in untreated. The maximum shoot weight was obtained in *P. fluorescens* treatment (3.44 g) followed by neem leaf extract + garlic (3.31 g) and AMF (3.20 g). The percentage increase in shoot weight of above treatments ranged from 99 to cent per cent. Both the hot water treatment and *T. viride* recorded the same shoot weight of 2.83 g and the effect of all the above five treatments were statistically on par and superior to the botanical pesticide, nimbecidine and the chemical, dimethoate.

4.1.3 Root weight

Analysis of the data on root weight at the time of harvest revealed that there was statistically significant variation (Table 1). The highest root weight of 111 g was recorded in plants treated with *P. fluorescens* which was significantly superior to next best treatment AMF (93 g). The effect of AMF, hot water treatment, NLE + G and *T. viride* were statistically on par and the latter two treatments recorded the same root weight (83 g). The effect of nimbecidine was on par with dimethoate (79 g) and neem leaf extract (63 g). Neem oil (49 g) and neem oil + garlic treated plants (52 g) did not significantly improve the root weight of kacholam plants.

4.1.4 Fresh weight of plant

The fresh weight of plants under various rhizome treatments showed statistically significant variation. All the treatments except neem oil, neem oil + garlic, neem leaf extract and dimethoate significantly improved the fresh weight of shoot. The fresh plant weight under various treatments varied from 145 to 295 g. The highest fresh weight was recorded in *P. fluorescens*

treated plants (295 g). This treatment was significantly superior to next best treatment AMF. The percentage increase in fresh plant weight in the above treatments were cent percent and 90 per cent respectively. Effect of rhizome treatments with hot water (210 g), *T. viride* (195 g), nimbecidine (185 g) and NLE + G (175 g) were statistically on par giving more than 33 per cent increase in fresh weight of plant. The effect of dimethoate (165 g), neem leaf extract (160 g), neem oil + garlic (155 g) and neem oil (145 g) did not vary significantly (Table 1). The improvement in biometric characters due to rhizome treatment with *P. fluorescens* and AMF are shown in Plate 1.

4.1.5 Yield

The yield assessed in terms of weight of rhizomes was presented in Table 2. The effect showed statistically significant variation between treatments. The *P. fluorescens* treated plants recorded highest rhizome yield (per plant) giving cent percent increase over the untreated. This treatment was on par with AMF with an yield increase of 93 per cent. The hot water treatment was significantly inferior to *P. fluorescens* (180 g / plant) but was on par with AMF, *T. viride*, neem leaf extract + garlic, nimbecidine and dimethoate treatments giving more than 53 per cent increase in rhizome yield over untreated.

When the rhizome yield was computed in per plot basis, yield per plot (2 m x 2 m) ranged from 2.23 kg to 4.37 kg (Table 2). Maximum yield was obtained from plots, planted with *P. fluorescens* treated rhizomes resulting an yield increase of more than cent per cent over the untreated and in terms of per hectare yield also it showed the same trend. Next best treatments were AMF and hot water treatment giving 86 and 81 per cent yield increase respectively over the

Plate 1 Effect of rhizome treatment with *P. fluorescens* and AMF on kacholam

A

B

C

A - *Pseudomonas fluorescens*
B- Arbuscular Mycorrhizal Fungi
C - Untreated

Table 2 Effect of rhizome treatments on the yield of kacholam ten months after treatment (mean of three replications)

Treatments	Per plant weight (g)	% increase over untreated	Per plot weight (kg)	% increase over untreated	Yield in t ha^{-1} (fresh weight)
Neem oil (NO)-2%	95	26.67	2.45	25.64	6.13
Neem leaf extract (NLE)-5%	105	40.00	2.62	34.36	6.55
NO + Garlic (1:1)–2%	90	20.00	2.23	14.36	5.58
NLE (4%) + Garlic (1%)	135	80.00	3.37	72.82	8.43
Nimbecidine -0.2%	125	66.67	3.12	60.00	7.80
Arbuscular mycorrhizal fungi (AMF) -3% w/w	145	93.33	3.62	85.64	9.05
Pseudomonas fluorescens-3 % w/w	180	140.00	4.37	124.10	10.93
Trichoderma viride - 3% w/w	135	80.00	3.37	72.82	8.43
Hot water treatment –55^{0}C	140	86.67	3.52	80.51	8.80
Dimethoate –0.1%	115	53.33	2.87	47.18	7.18
Untreated	75	-	1.95	-	4.88
CD (0.05)	37.39	-	0.87	-	-

untreated and statistically effect of these treatment were on par. The per plot yield of rhizome, obtained from plots planted with *T. viride* and NLE + garlic treated rhizomes showed an yield increase of 73 per cent. Statistically effect of these treatments were on par with nimbecidine. The per hectare yield under various treatments ranged from 6 to 11 t as against 5 t in untreated plots.

4.1.6 Root-knot count

The data relating to root-knot count showed the effectiveness of various rhizome treatments in reducing the gall formation which ranged from 1 to 27 in treated plants as against 33 in untreated plants. Root-knot count was lowest in *P. fluorescens* treatment (1.21 per 5 g root), followed by the AMF treatment (1.94 per 5 g root) and these two treatments were on par and significantly superior to other treatments with 94 to 96 percent reduction in root-knot count. Next best treatment was *T. viride* which was on par with hot water treatment and NLE + garlic and nimbecidine giving more than 62 per cent reduction. The effect of the chemical, dimethoate as rhizome treatment was inferior to above treatment but on par with neem leaf extract (Table 3).

4.1.7 Number of females

It is apparent from the results that the different treatments had significant impact on the number of females per 5 g root sample. The mean number of females varied between seven and 42 in various treatments while it was 68 in untreated. The mean number of females was minimum in *P. fluorescens* treatment (7) which was closely followed by AMF (9.7) and both were on par. The percentage reduction in female number in the above treatments were 90 percent and 86 percent respectively. Next best treatment was hot water

Table 3. Effect of rhizome treatment on the population characteristics of *M. incognita* (mean of three replications)

Treatments	Root-knot count/g of root (5g)	% decrease over untreated	Gall index	No. of females / 5g root sample	% decrease over untreated	Nematode population on 5g root	% decrease over untreated
Neem oil (NO)-2%	26.81 (5.27)*	17.89	5	41.69 (6.53)	38.52	36.28 (6.05)	48.92
Neem leaf extract (NLE)-5%	21.90 (4.79)	32.92	5	37.65 (6.22)	44.48	34.16 (5.92)	51.91
NO + Garlic (1:1)–2%	23.50 (4.96)	27.75	5	39.30 (6.65)	42.04	33.38 (5.86)	53.01
NLE (4%) + Garlic (1%)	11.95 (3.59)	63.39	3	24.04 (5.07)	64.55	14.87 (3.98)	79.07
Nimbecidine -0.2%	12.27 (3.64)	62.42	3	19.64 (4.54)	71.04	19.37 (4.51)	72.73
Arbuscular mycorrhizal fungi (AMF) -3% w/w	1.94 (1.72)	94.06	1	9.66 (3.27)	85.75	12.30 (3.65)	82.68
Pseudomonas fluorescens-3 % w/w	1.21 (1.49)	96.29	1	6.93 (2.82)	89.78	10.47 (3.39)	85.26
Trichoderma viride - 3% w/w	7.69 (2.95)	76.45	2	16.79 (4.22)	75.24	18.32 (4.39)	74.21
Hot water treatment –55^{0}C	8.29 (3.05)	74.61	2	12.69 (3.70)	81.29	16.47 (4.18)	76.81
Dimethoate –0.1%	16.17 (4.14)	50.47	4	24.94 (5.09)	63.22	25.06 (5.11)	64.72
Untreated	32.65 (5.80)	-	5	67.81 (8.29)	-	71.03 (8.49)	-
CD (0.05)	(0.85)	-	-	(0.82)	-	(1.58)	-

* Figures given in the parenthesis are values after square root transformation.

treatment and was on par with *T. viride* giving 81 and 75 per cent decrease respectively over the untreated. The effect of rhizome treatment with nimbecidine, neem leaf extract + garlic and dimethoate were on par giving more than 63 per cent reduction in female number though they were inferior to the bioagents. Effect of rhizome treatment with neem leaf extract, neem oil + garlic and neem oil were on par and significantly superior to the untreated giving 45, 42 and 39 per cent decrease in number of females respectively (Table 3).

4.1.8 Nematode population in root

The results presented in Table 3 revealed that various rhizome treatments significantly reduced the nematode population in root at harvest. In treated plants the mean population of nematodes in the root were appreciably low compared to untreated. The population ranged between 10.47 to 36.28 per 5 g root sample in treated plants as against 71.03 in untreated. Maximum reduction in population was observed in *P. fluorescens* treated plants (85 per cent). The effect of this was on par with treatments viz., AMF, neem leaf extract + garlic, hot water treatment and *T. viride* giving more than 74 per cent reduction in nematode population over the untreated plants. Rhizome treatment with nimbecidine, dimethoate, neem oil + garlic, neem leaf extract and neem oil were also effective and on par in reducing the nematode population giving more than 49 per cent reduction over the untreated.

4.1.9 Nematode population in soil

The results relating to the effect of rhizome treatment on the population build up of nematodes in kacholam rhizosphere examined at 2, 4, 6

and 8 months after planting and at the time of harvest were presented in Table 4. The initial population level in different plots (before planting the treated rhizomes) showed no significant variation, the nematode population ranged between 100 to 160 *M. incognita* and 45 to 65 *R. similis* per 100 g soil. All the rhizome treatments significantly reduced the *M. incognita* population in soil. The effect of *P. fluorescens* was found superior in reducing the population of nematodes in soil through out the crop period (78 to 83 per cent reduction over control). Two months after planting, the effect of AMF, hot water, *T. viride*, nimbecidine, NLE + G and dimethoate were statistically on par with more than 58 per cent reduction in *M. incognita* population over untreated. The effect of neem leaf extract and neem oil + garlic were statistically on par giving 54 and 48 per cent reduction in population respectively. Analysis of the data on the population of *R. similis* two months after planting recorded no significant difference between treatments (Table 4).

Nematode population estimated at four months after planting (MAP) of kacholam rhizomes revealed that the minimum nematode population was recovered from *P. fluorescens* treated plants which was on par with AMF, hot water treatment, nimbecidine, *T. viride* and neem leaf extract + garlic treatments. The percentage reduction in nematode population of above treatments ranged from 69 to 78. The effect of dimethoate treatment was on par with neem leaf extract and neem leaf extract + garlic treatment giving more than 54 per cent reduction in population over the untreated. The population of *R. similis* recorded four MAP was very low and between treatments there was no significant variation also.

Table 4 Effect of rhizome treatments on the population build up of nematodes in soil at different intervals (Mean of three replications)

Treatments	Population observed at different intervals after planting (days)											
	2 MAP			4 MAP			6 MAP		8 MAP		At harvest	
	M. *incognita*	% decrease over untreated	R. *similis*	M. *incognita*	% decrease over untreated	R. *similis*	M. *incognita*	% decrease over untreated	M. *incognita*	% decrease over untreated	M. *incognita*	% decrease over untreated
Neem oil (NO)	73.84 (8.65)*	35.67	13.85 (3.85) **	79.32 (8.96)*	31.64	7.66 (2.77)**	95.21 (9.80)*	31.25	77.23 (8.84)*	50.91	74.92 (8.66)*	49.48
Neem leaf extract (NLE)	52.94 (7.34)	53.88	12.59 (3.69)	53.07 (7.35)	54.26	3.25 (2.06)	73.25 (8.61)	47.11	85.20 (9.28)	45.85	79.24 (8.90)	46.57
NO + Garlic	59.16 (7.76)	48.46	14.65 (3.96)	65.04 (8.13)	43.95	8.41 (2.9)	83.94 (9.21)	39.39	103.25 (10.21)	34.37	84.85 (9.21)	42.79
NLE + Garlic	43.00 (6.63)	62.54	11.96 (3.60)	36.07 (6.09)	68.91	1.94 (1.72)	55.10 (7.49)	60.21	86.86 (9.37)	44.79	38.29 (6.19)	74.18
Nimbecidine	42.76 (6.61)	62.75	15.42 (4.05)	33.23 (5.85)	71.36	1.21 (1.49)	59.03 (7.75)	57.38	73.74 (8.65)	53.13	68.59 (8.28)	53.75
AMF	36.89 (6.16)	67.86	15.56 (4.07)	26.65 (5.26)	77.03	2.55 (1.88)	30.66 (5.63)	77.86	40.64 (6.45)	74.17	55.20 (7.43)	62.78
P. fluorescens	19.63 (4.54)	82.89	17.11 (4.26)	25.81 (5.18)	77.76	3.39 (2.09)	30.59 (5.62)	77.91	33.89 (5.91)	78.46	32.23 (5.68)	78.27
T. viride	42.58 (6.60)	62.90	11.13 (3.48)	35.26 (6.02)	69.61	1.21 (1.49)	50.53 (7.18)	63.51	68.29 (8.32)	56.59	65.13 (8.07)	56.09
Hot water treatment	39.92 (6.39)	65.22	11.69 (3.56)	31.64 (5.71)	72.73	0 (1)	43.81 (6.69)	68.37	55.08 (7.49)	64.99	48.51 (6.96)	67.29
Dimethoate	47.80 (6.99)	58.36	11.94 (3.59)	42.57 (6.60)	63.31	2.32 (1.82)	62.91 (7.99)	54.57	78.34 (8.91)	50.21	65.38 (8.09)	55.92
Untreated	114.78 (10.76)	-	17.65 (4.32)	116.03 (10.82)	-	9.38 (3.06)	138.49 (11.81)	-	157.33 (12.58)	-	148.31 (12.18)	-
CD (0.05)	(1.26)	-	NS	(1.06)	-	NS	(1.00)	-	(0.85)	-	(0.74)	-

Figures given in the parentheses are values after square root transformation.

*Figures given in the parentheses are values after $\sqrt{x+1}$ transformation.

The population of root-knot nematode in soil estimated at 6 MAP indicated that rhizome treatment with *P. fluorescens* was found to be the best in reducing the nematode population in soil followed by AMF which were statistically on par. Next best treatment was the hot water treatment of rhizome and was on par with *T. viride* and NLE + G. The percentage reduction in nematode population in the above 5 treatments ranged from 60 to 78 per cent. Rhizome treatment with nimbecidine, dimethoate and NLE were on par giving 57, 55 and 47 per cent reduction in nematode population respectively. Effect of neem oil + garlic and neem oil were on par and significantly superior to untreated giving a percentage reduction of 39 and 31 per cent respectively (Table 4).

At 8 MAP *P. fluorescens* rhizome treatment was the best one in reducing the nematode population in soil followed by AMF. The effect of these treatments were statistically on par giving a percentage reduction of 78 and 74 per cent respectively. Next best treatment was hot water treatment and it was on par with *T. viride* treatment giving more than 57 per cent reduction of nematode population in soil. The effect of *T. viride* treatment was on par with nimbecidine, neem oil and dimethoate giving more than 50 per cent reduction in population. The NLE + G treatment was on par with NLE and neem oil + garlic giving 45, 46 and 34 per cent reduction respectively. All the above treatments were significantly superior to untreated in reducing the nematode population in soil.

The population of nematodes in soil (100 g soil sample) at the time of harvest are given in Table 4. All the treatments were very effective in reducing the nematode population. The *P. fluorescens* treatment gave

maximum reduction in nematode population (78 per cent) and it was on par with neem leaf extract + garlic treatment. Next best treatments were hot water treatment of rhizome and AMF giving 67 and 63 per cent reduction in nematode population respectively and these were statistically on par. The effect of *T. viride* was on par with AMF and dimethoate treatments giving 56 to 63 per cent reduction over the untreated. Next comes the botanical pesticide, nimbecidine which was on par with neem oil and neem leaf extract. They were statistically on par giving 54, 49 and 47 per cent reduction respectively.

4.1.10 Estimation of bioagents from the root and rhizosphere

Re-isolation of *P. fluorescens* from the rhizosphere recorded 17 colonies in 10^{-6} dilution. In the case of *T. viride* at 10^{-3} dilution there was 50 colony forming units (cfu) in Rose bengal agar and 26 cfu in potato dextrose agar. In the case of AMF application as rhizome treatment the colonization percentage in the root was 74 with a spore count of 65 per 25 g soil.

4.2 EXPERIMENT ON MAIN FIELD TREATMENT

4.2.1 Number of leaves

The total leaf production at the time of harvest under different treatments are given in Table 5. All the treatments were significantly superior to untreated in the production of leaves. The leaf production was maximum in carbofuran treated plants which was on par with neem cake and AMF treatments. The percentage increase in leaf production in kacholam plants due to these treatments in main field ranged from 98 to cent percent when compared to untreated. The main field treatment with sawdust,

Table 5 Effect of main field treatments on the biometric characters of kacholam ten months after treatment (Mean of three replications)

Treatments	Mean number of leaves	% increase over untreated	Mean shoot weight (g)	% increase over untreated	Mean root weight (g)	% increase over untreated	Mean fresh plant weight (g)	% increase over untreated
Neem cake (200g/m^2)	53.97	111.9	6.55	212.0	121.67	102.7	290	100
Coir pith (500g/m^2)	41.20	61.76	3.26	55.2	96.67	61.1	245	69.5
Sawdust (500g/m^2)	45.60	79.03	4.29	104.0	100.00	66.7	255	75.9
Neem leaf (750 g/m^2)	40.07	57.32	5.27	151.0	95.00	58.3	225	55.2
AMF (300g inoculum per m^2)	50.47	98.15	4.43	111.0	115.00	91.7	275	89.7
P. fluorescens (10g /m^2)	41.40	62.54	3.95	88.0	100.00	66.7	220	51.7
T. viride (10g/m^2)	39.27	54.18	3.20	52.4	86.67	44.5	218	50.3
Carbofuran (1g a.i./m^2)	55.00	115.94	5.11	143.5	106.67	81.12	275	89.7
Untreated	25.47	-	2.10	-	60.00	-	145	-
CD (0.05)	6.22	-	0.93	-	33.85	-	52.19	-

P. fluorescens, coir pith and neem leaf closely followed the above three treatments and were statistically on par giving an increase of 57 to 79 per cent over the untreated. The *T. viride* treatment also showed significant increase in leaf production (54 per cent) compared to untreated.

4.2.2 Shoot weight

The shoot weight of kacholam plants showed statistically significant variation due to various main field treatments. All the treatments except coirpith, *P. fluorescens* and *T. viride* showed more than cent percent increase in shoot weight compared to the untreated. The highest shoot weight was recorded by the neem cake treated plants (7 g) which was significantly superior to all other treatments. The next best treatment was neem leaf (5.3 g) and was statistically on par with carbofuran (5 g) and AMF treatments (4.4 g). But the effect of AMF treatment was on par with sawdust (4.3 g) and *P. fluorescens* (3.95 g) treatments. Effect of coir pith and *T. viride* treatments were on par and significantly superior to untreated giving an increase in shoot weight of 55 and 52 per cent respectively (Table 5).

4.2.3 Root weight

There was statistically significant variation in the root weight of kacholam plants and the results are presented in Table 5. Neem cake treated plants recorded the highest root weight (122 g) which was statistically on par with all treatments except *T. viride* (87 g). Next best treatment was application of AMF in the main field (115 g) which resulted in 92 per cent increase in root weight over untreated which was closely followed by carbofuran (107 g). The effect of treatments AMF, carbofuran

P. fluorescens, sawdust, coir pith, neem leaf and *T. viride* were statistically on par and the *P. fluorescens* and saw dust treatments recorded the same root weight (100 g). The percentage increase in root weight in these treatments ranged from 45 to 90 per cent.

4.2.4 Fresh weight of plant

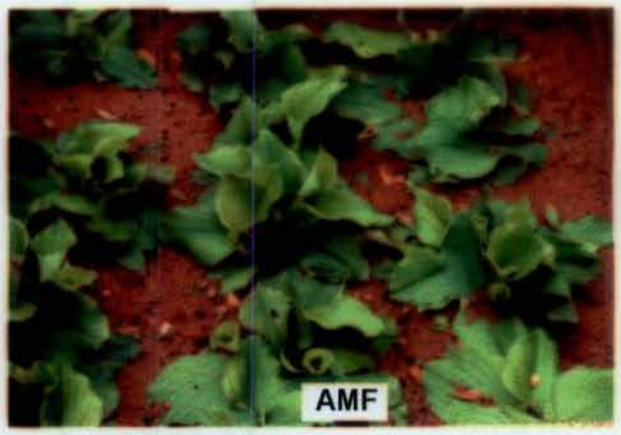
There was statistically significant variation in fresh weight of plants in different treatments (Table 5). Plants grown in neem cake treated plots recorded the highest fresh plant weight (290 g) with more than cent percent increase over the untreated plots. Neem cake application was on par with AMF, carbofuran, sawdust and coir pith giving 70 to 90 per cent increase over the untreated. The main field treatments with neem leaf, *P. fluorescens* and *T. viride* were statistically on par and significantly improved the growth giving 50 to 55 per cent increase. The improvement in biometric characters due to main field treatments with neem cake, AMF, carbofuran and untreated are shown in Plate 2.

4.2.5 Yield

Assessment of yield in terms of rhizome weight per plant showed significant variation. Highest yield (rhizome weight) was recorded in carbofuran treated plants (185 g) which was closely followed by neem cake (175 g) and AMF treatments (170 g). The percentage increase in yield of above treatments ranged from 89 to cent per cent when compared to untreated plants. The effect of main field treatment with sawdust, *P. fluorescens*, coir pith, neem leaf and *T. viride* were statistically on par with 56 to 83 per cent

Plate 2 Effect of different treatments on kacholam (Main Field)

A



B

C

D

A - Neem Cake (200 g / m^2)
B - AMF (300 g inoculum / m^2)
C - Carbofuran (1 g a.i. / m^2)
D - Untreated

Table 6 Effect of main field treatments on the yield of kacholam ten months after treatment (mean of three replications)

Treatments	Per plant weight (g)	% increase over untreated	Per plot weight (kg)	% increase over untreated	Yield in t ha^{-1} (fresh weight)
Neem cake (200g/m^2)	175	94.40	1.49	170.91	14.9
Coir pith (500g/m^2)	150	66.67	1.15	109.09	11.5
Sawdust (500g/m^2)	165	83.33	1.38	150.91	13.8
Neem leaf (750 g/m^2)	145	61.11	1.08	96.36	10.8
AMF (300g inoculum per m^2)	170	88.89	1.45	163.64	14.5
P. fluorescens (10g /m^2)	165	83.30	1.38	150.91	13.8
T. viride (10g/m^2)	140	55.56	1.00	81.82	10.0
Carbofuran (1g a.i./m^2)	185	105.56	1.68	205.45	16.8
Untreated	90	-	0.55	-	5.5
CD (0.05)	42.57	-	0.57	-	-

yield increase. Except *T. viride* all the above treatments were on par with the chemical, carbofuran.

Analysis of the data on yield (rhizome weight) per plot in different treatments revealed that there was statistically significant variation (Table 6). The average yield per plot (1 m x 1 m) varied from 1 kg to 1.68 kg. The effect of application of carbofuran, neem cake, AMF, sawdust and *P. fluorescens* in the main field was statistically on par showing more than cent per cent yield increase. The per plot yield of rhizomes was maximum in carbofuran treated plots (1.68 kg) and the per ha yield in these treatments ranged from 14 t to 17 t. The neem leaf and *T. viride* treatments were also effective in improving the yield of rhizomes per plot (96 and 82 per cent increase respectively over the untreated).

4.2.6 Root-knot count

The results presented in Table 7 showed drastic reduction in the mean number of galls on the roots of kacholam plants due to various treatments. The number of galls ranged from 1 to 16 per 5 g root in various treatments as against 26 in untreated. Carbofuran application gave maximum reduction in gall formation giving 95 per cent over the untreated. The next best treatments were neem cake and AMF which was on par with carbofuran treatment giving 91 and 87 per cent reduction in gall formation respectively over the untreated. Statistically the effect of these three treatments was on par. The effect of sawdust was statistically on par with *P. fluorescens* and neem leaf treatments with a percentage reduction of 75 and 66 respectively. Effect of coir pith and *T. viride* were on par and inferior to above treatments but significantly superior to the untreated.

Table 7 Effect of main field treatments on the population characteristics of *M. incognita* (mean of three replications)

Treatments	Root-knot count/ g root (5g)	Gall index	% decrease over untreated	Number of females/5g root sample	% decrease over untreated	Nematode population in 5g root sample	% decrease over untreated
Neem cake (200g/m^2)	2.33 (1.82)	1	90.92	9	87.5	5.33 (2.48)	90.18
Coir pith (500g/m^2)	13.00 (3.72)	3	49.36	25	65.8	10.33 (3.36)	80.86
Sawdust (500g/m^2)	7.33 (2.88)	2	71.45	12	83.33	7.33 (2.87)	86.47
Neem leaf (750 g/m^2)	8.67 (3.09)	2	66.23	8	88.9	12.33 (3.62)	77.15
AMF (300g inoculum per m^2)	3.33 (2.06)	1	87.03	6	91.7	8.00 (2.99)	85.18
P. fluorescens (10g /m^2)	6.33 (2.69)	2	75.34	10	86.1	6.33 (2.68)	88.27
T. viride (10g/m^2)	15.67 (4.06)	4	35.06	30	58.3	14.33 (3.91)	73.45
Carbofuran (1g a.i./m^2)	1.33 (1.49)	1	94.82	4	94.4	1.00 (1.38)	98.15
Untreated	25.67 (5.16)	-	-	72	-	54.00 (1.36)	-
CD (0.05)	(3.75)	-	-	6.25	-	(0.97)	-

4.2.7 Number of females

There was statistically significant reduction in number of females recorded from different treatments (Table 7). Maximum reduction in the number of females was recorded in carbofuran treatment (with 94 per cent reduction) and was significantly superior to all other treatments. Next best treatments were in the order of AMF, neem leaf, neem cake, *P. fluorescens*, sawdust and were statistically on par in reducing the nematode population giving 83 to 92 per cent reduction in number of females. Coir pith and *T. viride* were also significantly superior to untreated showing 66 and 58 per cent reduction in female development but inferior to above treatments.

4.2.8 Nematode population in root

The larval population estimated from the roots vary significantly in different treatments. The details of the results are given in Table 7. The mean population of larvae in the root samples ranged from one to 14 per five g of root in various treatments as against 54 in untreated. Minimum number of nematodes was seen in carbofuran treated plants (98 per cent reduction). Here carbofuran established its superiority over other treatments. The effect of neem cake, *P. fluorescens*, sawdust, AMF and coirpith were statistically on par giving 81 to 91 per cent reduction. Neem leaf and *T. viride* treatment resulted 77 and 73 per cent reduction in nematode population which was on par and superior to the untreated but inferior to the above treatments.

4.2.9 Nematode population in soil

The results relating to the effect of different main field treatments on the population build up of nematodes in kacholam rhizosphere 2, 4, 6 and 8

months after planting and at the time of harvest were presented in Table 8. The initial nematode population in soil was uniform and in different plots it ranged between 99 to 125 *M. incognita* larvae and 40 to 50 *R. similis* per 100 g soil.

The decrease in population level in the plots showed statistically significant variation. Analysis of the data on nematode population assessed two months after planting (2 MAP) revealed that mean population of nematodes was lowest in carbofuran treated plots and the other treatments in the order of their effectiveness on reducing the nematode population were neem cake, neem leaf and AMF. The effect of all these four treatments were statistically on par and the percentage reduction in nematode population ranged from 51 to 61. The effect of other treatments like sawdust, *P. fluorescens*, coir pith and *T. viride* were statistically on par and significantly superior to the untreated but inferior to the above treatments and reduction of nematode population was below 50 per cent.

There was statistically no significant variation in the population of burrowing nematode taken two months after planting of kacholam plants. The average number of nematodes ranged from 11.17 in treated to 18.02 in the untreated plots (in 100 g soil). After that the population was very negligible.

Statistical analysis of the data related to the number of larvae in the root zone of plants four months after planting showed significant reduction. The reduction in population was maximum in carbofuran treated plots. It was followed by neem cake, AMF and neem leaf. The effect of the above four treatments in reducing the nematode population was statistically on par giving 52 to 61 per cent reduction over the untreated. Coir pith, sawdust,

P. fluorescens and *T. viride* treatments were statistically on par and effective in reducing the nematode population in soil but the percentage reduction in population was less than 50 per cent (Table 8).

Nematode population estimated six months after planting showed significant variation and the results are given in Table 8. The mean population in different treatments varied from 58 to 109 as against 125 in control. Carbofuran treatment showed maximum reduction in nematode population in soil (54 per cent). This was closely followed by application of neem leaf, neem cake and AMF and the effect of these treatments were on par (reduction in these treatments varied from 46 to 54 per cent). The treatments sawdust and *P. fluorescens* were also found to be effective in reducing the nematode population but their reduction in population was less than 50 percentage (31 and 29 per cent respectively).

Data on the soil population of nematodes 8 MAP revealed that the lowest population was recorded in carbofuran treatment and this was followed by neem cake, AMF and sawdust treatments revealing that they were as effective as the chemical. The effect of the above four treatments were statistically on par with a percentage reduction ranged from 54 to 65 per cent. The main field treatments in the descending order of effectiveness were *P. fluorescens*, neem leaf, coir pith and *T. viride*. The effect of these treatments were statistically on par and better than untreated (Table 8).

At harvest (uprooting) the population of larvae in soil treated with different organic amendments and bioagents in comparison with carbofuran showed significant variation. The lowest number of nematodes was recovered from carbofuran treated plots (37 per 100 g soil). The effect of this treatment

Table 8. Effect of main field treatments on the population build up of the nematodes in soil at different intervals (Mean of three replications)

Treatments	Population observed at different intervals after planting (days)											
	2 MAP			4 MAP			6 MAP		8 MAP		At harvest	
	M. *incognita*	% decrease over untreated	R. *similis*	M. *incognita*	% decrease over untreated	R. *similis*	M. *incognita*	% decrease over untreated	M. *incognita*	% decrease over untreated	M. *incognita*	% decrease over untreated
Neemcake	43.25 (6.65)*	56.01	11.17 (3.49)**	47.74 (6.98)*	56.05	0.80 (0.65)**	64.64 (8.10)*	48.39	37.95 (6.24)*	60.98	42.21 (6.49)*	58.86
Coirpith	58.64 (7.72)	40.35	15.72 (4.09)	58.96 (7.74)	45.70	0.91 (1.38)	97.22 (9.91)	22.37	52.59 (7.32)	45.93	60.96 (7.81)	40.58
Sawdust	54.62 (7.46)	44.44	16.47 (4.18)	63.96 (8.06)	40.16	2.19 (1.48)	85.85 (9.32)	31.45	45.07 (6.74)	53.67	57.76 (7.59)	43.69
Neem leaf	47.01 (6.93)	52.18	14.46 (3.93)	51.82 (7.21)	52.29	7.98 (2.82)	57.83 (7.67)	53.82	48.81 (7.06)	49.81	44.45 (6.67)	56.67
AMF	48.17 (7.01)	51.00	16.69 (4.21)	49.6 (7.11)	54.34	0.91 (1.38)	67.21 (8.26)	46.33	41.55 (6.52)	57.28	43.14 (6.57)	57.95
P. fluorescens	54.64 (7.46)	44.42	17.02 (4.24)	66.7 (8.23)	38.59	1.94 (1.71)	89.29 (9.50)	28.7	47.71 (6.98)	50.95	53.26 (7.29)	48.08
T. viride	69.60 (8.40)	19.20	13.19 (3.77)	82.9 (9.16)	23.69	1.31 (1.52)	109.00 (10.49)	12.97	59.65 (7.79)	38.67	71.97 (8.48)	29.85
Carbofuran	38.28 (6.27)	61.06	17.86 (4.34)	38.23 (6.26)	64.81	0 (1)	57.26 (7.63)	54.28	34.49 (5.96)	64.54	37.44 (6.12)	63.51
Untreated	98.31 (9.97)	-	18.02 (4.36)	108.63 (10.47)	-	8.29 (2.88)	125.24 (11.24)	-	97.26 (9.91)	-	102.59 (10.13)	-
CD (0.05)	(1.19)	-	NS	(1.46)	-	NS	(1.53)	-	(0.89)	-	(0.98)	-

* Figures given in the parentheses are values after square root transformation.

** Figures given in the parentheses are values after $\sqrt{x+1}$ transformation

was on par with neem cake, AMF and neem leaf with a percentage reduction ranged from 57 to 64. The next best treatments in the order of effectiveness were *P. fluorescens*, neem leaf, saw dust, coir pith and *T. viride* giving less than 50 per cent reduction (Table 8).

4.2.10 Estimation of bioagents from the root and rhizosphere

Re-isolation of *P. fluorescens* from the rhizosphere recorded 25 colonies in 10^{-6} dilution. In the case of *T. viride* there was 56 colony forming units (cfu) in Rose bengal agar and 35 cfu in potato dextrose agar at 10^{-3} dilution. In the case of AMF as main field treatment the colonization percentage in root was 70 and spore count in soil was 69 per 25 g soil.

4.3 EXPERIMENT ON MULCHING

4.3.1 Number of leaves

The results presented in Table 9 showed that there was significant variation in leaf production in kacholam plants by planting the rhizomes in plots mulched with different types of green leaves. Maximum leaf production was noticed in neem leaf (5 kg / m^2) mulched plots with cent per cent increase. This treatment was on par with the chromolaena mulching giving 92 per cent increase over the untreated. Next best treatment was glyricidia leaf mulching, which improved the leaf production to a tune of 77 per cent over the untreated. Statistically effect of this treatment was on par with calotropis and clerodendron giving 59 to 75 per cent increase in leaf production over the untreated. Minimum effect was noticed in mangium which was also superior to the control plants.

Table 9 Effect of mulching on the biometric characters of kacholam ten months after treatment (Mean of three replications)

Treatments	Mean number of leaves	% increase over untreated	Mean shoot weight (g)	% increase over untreated	Mean root weight (g)	% increase over untreated	mean fresh plant weight (g)	% increase over untreated
Neem leaf (5kg/m^2)	58.3	113	4.63	153.00	122.00	155.9	350.33	132.5
Glyricidia (5kg/m^2)	48.3	76.7	2.83	54.64	93.33	95.78	271.00	79.86
Mangium (5kg/m^2)	32.4	18.5	1.87	2.19	48.67	2.09	170.00	12.83
Clerodendron (5kg/m^2)	43.4	58.7	3.00	63.93	80.00	67.82	248.33	64.82
Calotropis (5kg/m^2)	47.73	74.58	2.90	58.47	82.67	73.42	262.00	73.89
Chromolaena (5kg/m^2)	52.4	91.67	3.57	95.08	93.67	96.49	299.00	98.45
Untreated	27.34	-	1.83	-	47.67	-	150.67	-
CD (0.05)	7.61	-	1.28	-	49.99	-	39.63	-

4.3.2 Shoot weight

The effect of mulching with different green leaves showed statistically significant variation except mangium (Table 9). The mean shoot weight of plants grown in plots mulched with green leaves of different plants ranged from 1.87 g to 4.63 g. The highest shoot weight was recorded in neem leaf mulched plants (4.63 g), this was closely followed by chromolaena (3.57 g) and these two treatments were statistically on par. The percentage increase in shoot weight of above treatments were cent percent and 95 per cent respectively. The next best effect was obtained in calotropis. It was on par with clerodendron and glyricidia giving 55 to 64 per cent increase in shoot weight.

4.3.3 Root weight

Analysis of the data on root weight at the time of harvest revealed that there was statistically significant variation. The results are presented in Table 9. The highest mean root weight (122 g) was recorded in neem leaf mulched plots giving cent per cent increase over the untreated. The effect of this treatment was on par with chromolaena, glyricidia, calotropis and clerodendron giving more than 68 per cent increase in root weight over the untreated. There was no significant increase in root weight, in plants mulched with mangium.

4.3.4 Fresh weight of plants

The data on the fresh weight of plant showed statistically significant improvement except mangium (Table 9). The fresh weight of plants in different treatments ranged from 170 g to 350 g. The neem leaf mulched

plants showed highest fresh weight (350 g) and was significantly different from all other treatments giving cent per cent increase over the untreated establishing its superiority over the other treatments. Next best treatment was chromolaena (299 g) treated plants which was on par with the glyricidia and calotropis giving 74 to 98 per cent increase in fresh plant weight over the untreated. Clerodendron mulching was found least effective but it also showed 65 per cent increase. The improvement in biometric characters due to mulching with neem, chromolaena and glyricidia leaves showed in Plate 3 and 4.

4.3.5 Yield

The yield assessed in terms of weight of rhizomes per plant was presented in Table 10. The application of different green leaves as mulch improved the yield per plant significantly except mangium. The neem leaf mulched plants recorded highest rhizome yield (225 g) followed by chromolaena (210 g) and these two were on par giving more than cent per cent increase in rhizome yield over the untreated. The effect of mulching with glyricidia, calotropis and clerodendron were statistically on par (increase in yield ranged from 59 to 82 per cent).

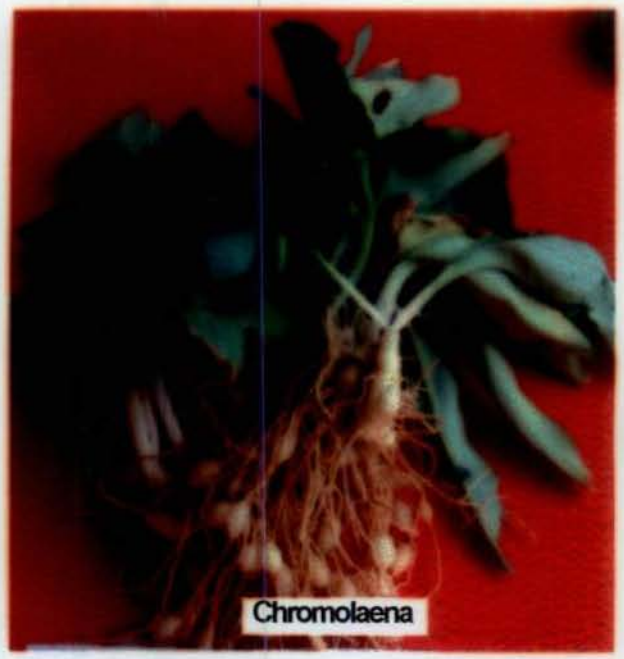
Statistical analysis of the data pertaining to the yield of kacholam per plot under different mulching treatments revealed significant variation except mangium. Per plot yield of rhizome was maximum in neem leaf mulched plots (5.63 kg) which was closely followed by the chromolaena (5.25 kg) and these two were on par. These two treatments recorded more than cent per cent yield increase compared to the untreated and per hectare yield, it was 13

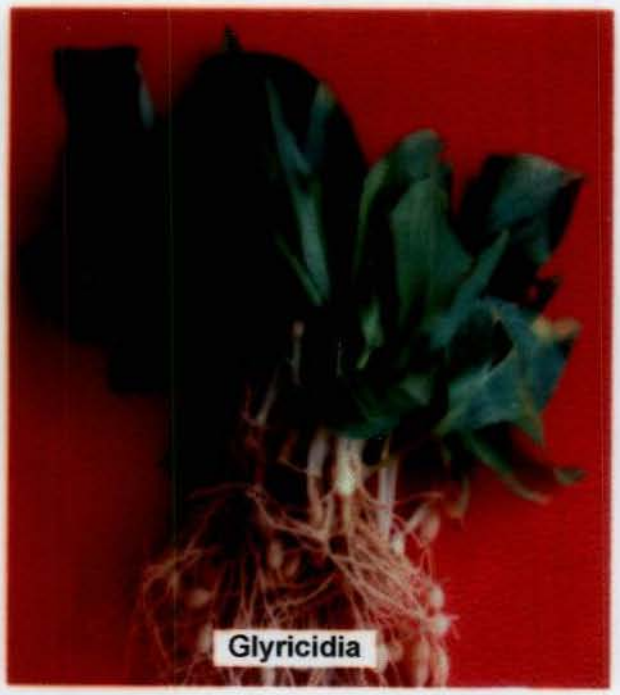
Plate 3 Effect of neem leaf mulching on kacholam

Table 10 Effect of mulching on the yield of kacholam ten months after treatment (mean of three replications)

Treatments	Per plant weight (g)	% increase over untreated	Per plot weight (kg)	% increase over untreated	Yield in t/ha (fresh weight)
Neem leaf ($5kg/m^2$)	225	164.7	5.625	160.66	14.06
Glyricidia ($5kg/m^2$)	155	82.35	3.875	79.56	9.69
Mangium ($5kg/m^2$)	105	23.53	2.625	21.64	6.56
Clerodendron ($5kg/m^2$)	135	58.82	3.375	56.39	8.44
Calotropis ($5kg/m^2$)	145	70.59	3.625	67.98	9.06
Chromolaena ($5kg/m^2$)	210	147.06	5.25	143.28	13.13
Untreated	85	-	2.158	-	5.39
CD (0.05)	24.86	-	0.60	-	-

Plate 4 Effect of mulching with different green leaves on kacholam





of 3.88 kg per plot and statistically effect of this treatment was on par with calotropis (3.63) and clerodendron (3.38) treatments. The percentage yield increase in the above treatments ranged from 56 to 80 per cent. Mangium treated plots also recorded numerical increase in yield over untreated but the effect was not enough to get statistical significance (Table 10).

4.3.6 Root-knot count

The mean number of galls on the roots of plants at the time of harvest showed drastic reduction due to mulching with different green leaves except mangium. The results are presented in Table 11. The mean root-knot count was 1.3 to 22 in various treatments as against 32 in untreated. Maximum reduction was observed in neem leaf mulching and it was statistically on par with the chromolaena. The percentage reduction in gall formation in these two treatments were 96 and 92 respectively. Mulching with calotropis (9 galls per g root), glyricidia (10 galls per g root) and clerodendron (10 galls per g root) were also highly effective in reducing gall formation (68 to 73 per cent reduction over control) and were statistically on par. The gall index was minimum (1) in neem and chromolaena leaf mulching. In the case of plants mulched with glyricidia, calotropis and clerodendron the index was two as against the index of five in mangium and untreated plants.

4.3.7 Number of females

Analysis of the data on the number of females per five gram root sample revealed that there was statistically significant variation and the results are presented in Table 11. Mulching with green leaves like neem chromolaena, glyricidia, calotropis and clerodendron gave substantial

Table 11 Effect of mulching on the population characteristics of *M. incognita* (mean of three replications)

Treatments	Root-knot count/ g of root	Gall index	% decrease over untreated	Number of females5 g root	% decrease over untreated	Nematode population in 5g root	% decrease over untreated
Neem leaf (5kg/m^2)	1.33 (1.49)*	1	95.98	5 (2.41)	91.67	7.00 (2.76)	89.61
Glyricidia (5kg/m^2)	9.67 (3.23)	2	70.09	10 (3.31)	83.33	14.67 (3.89)	78.21
Mangium (5kg/m^2)	22.33 (4.79)	5	31.02	24.67 (5.05)	53.30	33.67 (5.87)	49.99
Clerodendron (5kg/m^2)	10.33 (3.36)	2	68.14	15 (3.97)	75.00	22.67 (4.82)	66.33
Calotropis (5kg/m^2)	8.67 (3.10)	2	73.18	12 (3.58)	80.00	16.00 (4.03)	76.24
Chromolaena (5kg/m^2)	2.67 (1.88)	1	91.74	8 (2.88)	86.70	9.33 (3.18)	86.14
Untreated	32.33 (5.74)	5	-	60 (7.80)	-	67.33 (8.26)	-
CD (0.05)	(1.02)	-	-	(1.04)	-	(1.45)	-

*Figures given in the parenthesis are values after square root transformation

reduction in number of females (75 to 92 per cent). The number of females was minimum (5) in neem leaf treated plants followed by chromolaena (8) glyricidia (10) and calotropis (12) treatments which were on par. The percentage reduction in the number of females of above treatments ranged from 83 to 92 per cent. The effect of calotropis and clerodendron mulching were statistically on par giving 80 per cent and 75 per cent reduction respectively. Here mangium mulching was also effective in reducing (53 per cent) the female count significantly though it was inferior to all other treatments.

4.3.8 Nematode population in root

Mulching with green leaves of neem, glyricidia, calotropis, chromolaena and clerodendron significantly reduced the population of nematodes in the roots of kacholam at harvest. The results are presented in Table 11. The mean number of larvae ranged from 7 to 34 per five g root in various treatments as against 67 in untreated. Maximum reduction in population was recorded in neem leaf mulching. The effect of this was on par with cromolaena, glyricidia and calotropis treatment giving 76 to 90 per cent reduction in larval population over the untreated. Mulching with clerodendron and mangium also showed significant reduction in nematode population more than 50 per cent and the effect of these two treatments were statistically on par and inferior to other treatments but better than untreated.

4.3.9 Nematode population in soil

The variation of population of root-knot nematode in soil examined at 2, 4, 6, 8 and 10 months after treatment with various green leaf mulches

revealed significant reduction in nematode population. The initial population of nematodes in soil was uniform and the population of *M. incognita* and *R. similis* ranged from 100 to 265 and 45 to 52 respectively. Neem leaf treatment was found to be the best one in reducing the nematode population in the soil throughout the crop period.

The results presented in Table 12 revealed that two months after application of the treatments, neem leaf and chromolaena recorded the same population of root-knot nematode (32/100g soil sample). This was closely followed by glyricidia mulching and the effect of these three was on par. The reduction in nematode population of the above treatments ranged from 67 to 70 per cent. Next best treatment was calotropis mulching which was significantly different from clerodendron mulching giving 61 per cent and 37 per cent reduction respectively. However the effect of mangium mulching was also significantly superior to the untreated. Analysis of the data on the population of *R. similis* two months after planting recorded no significant difference between treatments (Table 12).

The population of root -knot nematode estimated 4 MAP indicated that all treatments were significantly better than untreated. The percentage reduction was maximum in neem leaf and was on par with chromolaena. Next best treatment was glyricidia mulching and was on par with chromolaena. The percentage reduction in nematode population of above treatments ranged from 71 to 78 per cent. Effect of calotropis, clerodendron and mangium mulching were significantly superior to the untreated giving 61, 52 and 14 per cent reduction in nematode population respectively. The population of *R. similis* recorded 4 MAP was very low and between treatments there was no

Table 12 Effect mulching on the population build up of nematodes in soil at different intervals (Mean of three replications)

Treatments	Population observed at different intervals after planting (days)											
	2 MAP			4 MAP			6 MAP		8 MAP		At harvest	
	M. incognita	% decrease over untreated	*R. similis*	*M. incognita*	% decrease over untreated	*R. similis*	*M. incognita*	% decrease over untreated	*M. incognita*	% decrease over untreated	*M. incognita*	% decrease over untreated
Neem leaf	31.96 (5.74)*	69.87	11.80 (3.44)**	35.99 (6.08)*	78.05	0 (1)**	40.93 (6.47)*	84.58	43.81 (6.69)*	83.49	45.44 (6.74)*	81.78
Glyricidia	34.96 (5.99)	67.02	9.22 (3.04)	46.79 (6.91)	71.47	2.55 (1.88)	56.72 (7.58)	78.63	77.94 (8.88)	70.64	52.48 (7.24)	78.95
Mangium	88.93 (9.48)	16.10	7.64 (2.76)	141.77 (11.94)	13.55	4.82 (2.41)	185.88 (13.67)	29.98	243.97 (15.65)	8.09	178.26 (13.35)	28.52
Clerodendron	66.53 (8.22)	37.24	14.52 (3.81)	78.28 (8.90)	52.27	1.21 (1.49)	106.69 (10.38)	59.81	129.96 (11.44)	51.05	98.35 (9.92)	60.56
Calotropis	40.95 (6.48)	61.37	11.37 (3.37)	63.99 (8.06)	60.98	0.80 (0.65)	100.95 (10.09)	61.97	100.95 (10.09)	61.97	85.86 (9.27)	65.57
Chromolaena	31.94 (5.74)	69.82	12.19 (3.49)	41.32 (6.51)	74.80	1.31 (1.52)	51.79 (7.27)	80.47	51.79 (7.27)	80.49	48.96 (6.99)	80.37
Untreated	106 (10.34)	-	14.14 (3.80)	164.62 (12.87)	-	9.38 (3.06)	265.46 (16.32)	-	265.47 (16.32)	-	249.37 (15.79)	-
CD (P-0.05)	(0.75)	-	(NS)	(0.58)	-	(NS)	(1.34)	-	(1.24)	-	(0.97)	-

* Figures given in the parentheses are values after square root transformation

** Figures given in the parentheses are values after $\sqrt{x + 1}$ transformation

significant variation Nematode population estimated six months after planting revealed that all treatments except mangium significantly reduced the nematode population. Neem, chromolaena and glyricidia mulching were statistically on par with 85, 81 and 79 per cent reduction in nematode population respectively. The calotropis and clerodendron leaf mulching were inferior to above treatments but it also reduced the nematode population to a tune of 60–62 per cent. Mangium mulching also showed 30 per cent reduction in nematode population which was significantly superior to the untreated.

Eight months after mulching all the treatments except mangium significantly reduced the nematode population in soil. Maximum reduction was observed in neem leaf treated plots (84 per cent) followed by chromolaena (81 per cent) and the effect of these two treatments were on par. Next effective ones were glyricidia and calotropis. They were on par showing more than 50 per cent reduction in nematode population.

At the termination of the experiment it was evident that application of green leaves as mulch was found to be effective for the management of nematodes in soil. Maximum reduction in nematode population was observed in neem leaf followed by chromolaena and glyricidia. The effect of these treatments were on par giving 79 to 82 per cent reduction of nematode population in soil. The next best treatment was calotropis which was on par with clerodendron giving more than 66 per cent reduction in nematode population. Minimum reduction (29 per cent) was observed in mangium but it was also statistically superior to untreated.

DISCUSSION

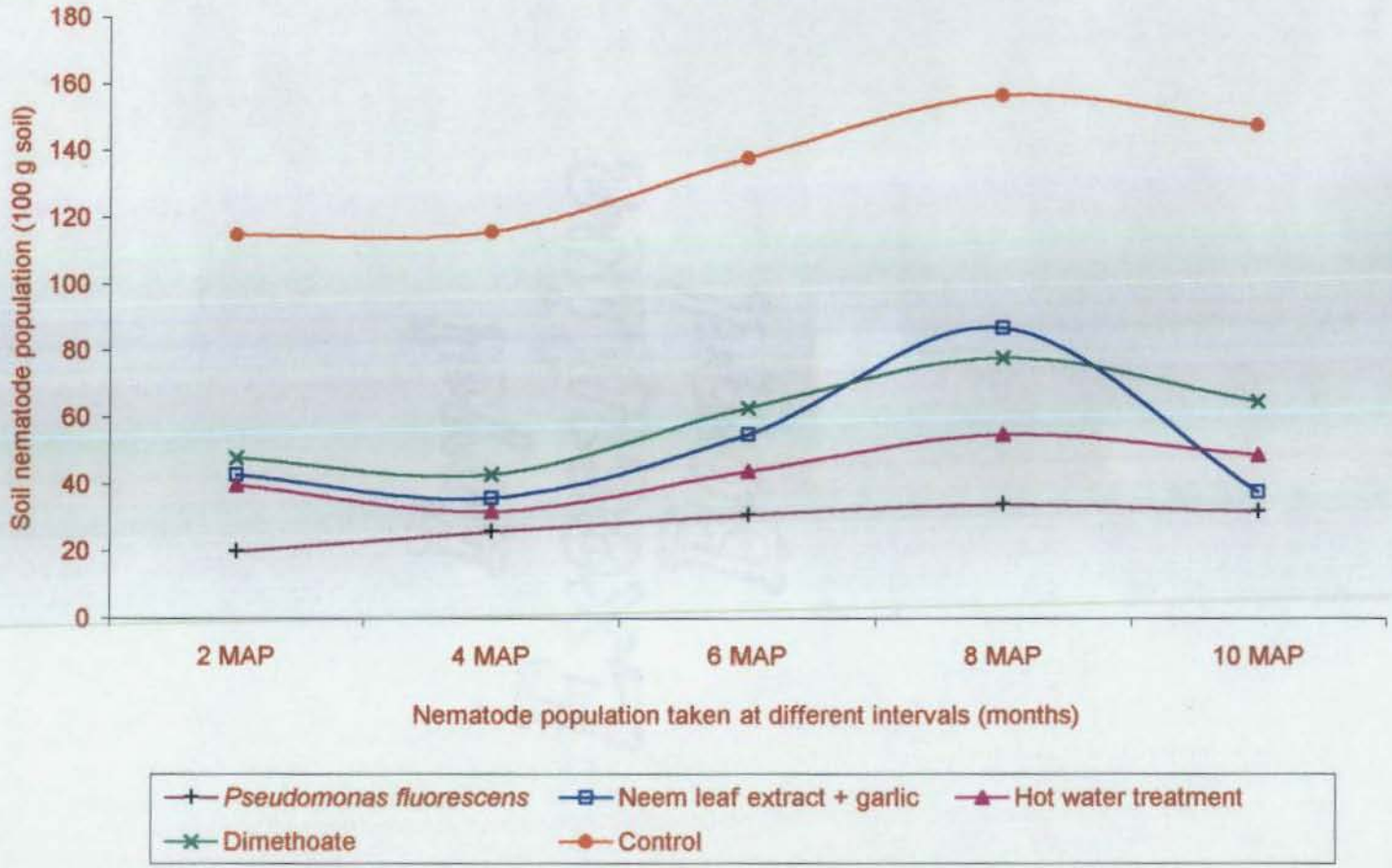
5. DISCUSSION

In the present study, bioagents (*Pseudomonas fluorescens*, Arbuscular Mycorrhizal Fungi (AMF), *Trichoderma viridae*) @ 3 per cent w/w plant products (neem oil (2 per cent), neem leaf extract (5 per cent), neem oil + garlic (1 :1) (2 per cent), neem leaf extract (4 per cent) + garlic (1 per cent)) botanical pesticide, nimbecidine (0.2 per cent), hot water treatment (55^0C) and chemical, dimethoate (0.1 per cent) were tested as rhizome treatment for the management of nematodes associated with kacholam. The efficacy of organic amendments (neem cake) (200 g / m^2), coir pith (500 g / m^2), sawdust (500 g / m^2), neem leaf (750 g / m^2) and bioagents (*P. fluorescens* (10 g / m^2), arbuscular mycorrhizal fungi (300 g inoculum / m^2), *T. viride* (10 g /m^2) were evaluated as main field treatment also. Carbofuran (1 g a.i./m^2 i.e.. 3.33 g / m^2) was tested as check in the main field. Effect of mulching with various green leaves (neem, glyricidia, mangium, clerodendron, calotropis. chromolaena) @ 5 kg / m^2 at the time of planting of the rhizomes also studied as low cost eco-friendly method utilizing natural resources. The results were assessed in terms of nematode population build up in soil at different intervals after treatment and harvest of the crop, nematode population characteristics in root (number of galls, number of females and number of larvae) growth characteristics (number of leaves, shoot weight, fresh plant weight and root weight) and yield (in terms of rhizome weight) of kacholam.

The results on population characteristics of nematodes are presented in para 4.1.6 to 4.1.9. The periodical estimation of the nematode population in

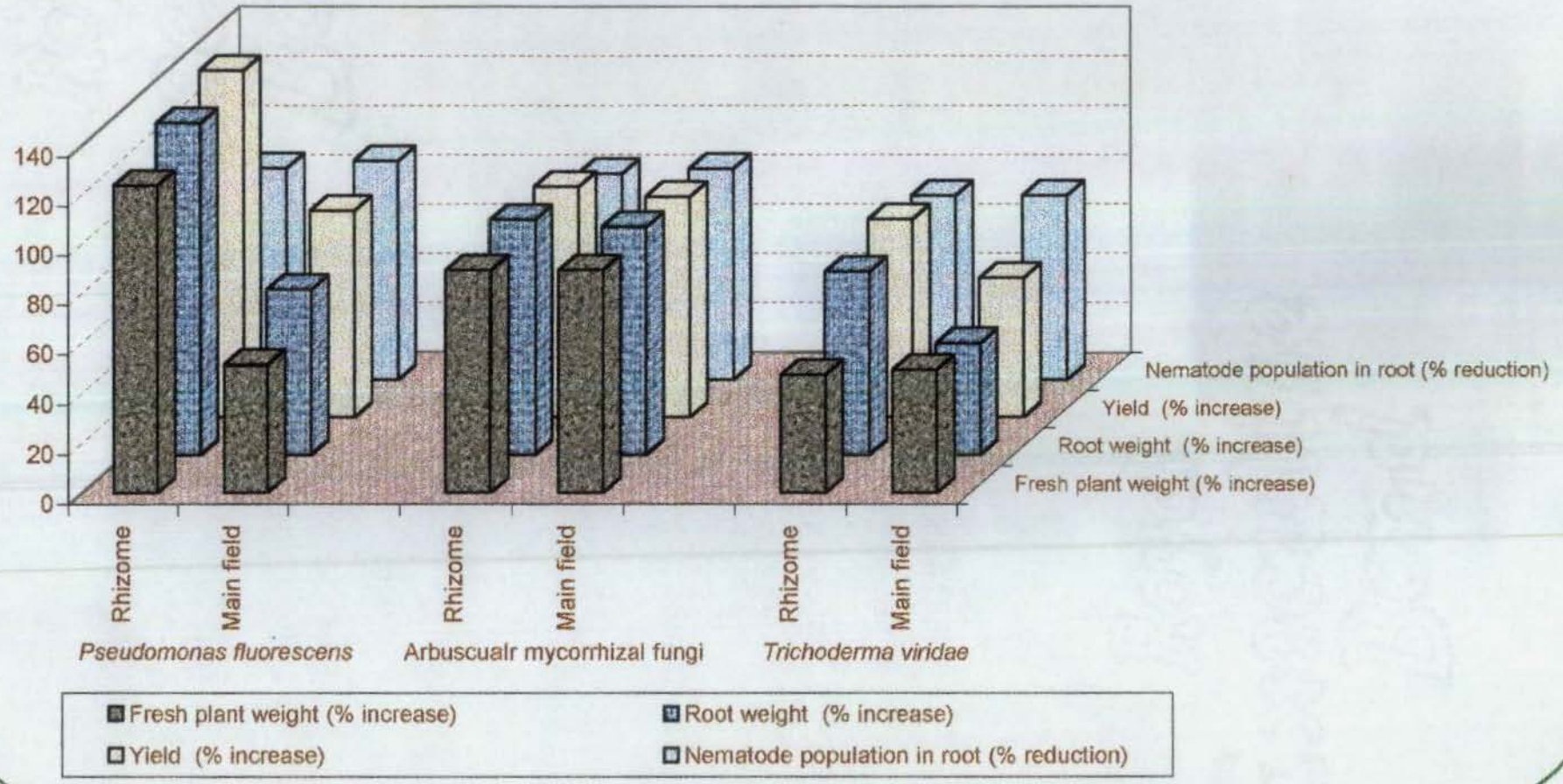
soil (2, 4, 6, 8 and 10 months after planting) and root at the time of harvest revealed that the effect of *P. fluorescens* was superior to all other treatments at 2 months after planting and was on par with AMF at six and eight months after planting. At the final stage of the crop it was on par with neem leaf extract + garlic (NLE + G) (Fig. 1). Thus the potential of *P. fluorescens* as biocontrol agent in reducing the nematode population by rhizome treatment was established in this study. The effect of AMF (mixture of *Glomus fasciculatum*, native isolates of *G. monosporum* and *Glomus* sp. (GI.1)) and NLE + garlic in reducing the nematode population was also comparable at initial and final stage of the crop respectively. This finding was in line with that of Verma *et al.* (1998) in managing root-knot nematode in tomato root zone. Nematode population in root (number of larvae) also reduced significantly by *P. fluorescens*. The effect of this was on par with AMF, NLE + G, hot water and *T. viride* (more than 74 per cent reduction). The root-knot count was reduced drastically by *P. fluorescens* and AMF treatments and these two were significantly superior to all other bioagents, botanicals, hot water treatment and chemical treatment. Similar trend was established by these two bioagents in reducing the nematode population in soil also. Thus initial protection of the rhizomes from nematodes by *P. fluorescens* and AMF will reduce the nematodes in soil and root. This may be due to inhibition of entry of the nematode into the kacholam rhizomes at the time of planting. Similar biological activities are already reported by several workers. Mondal *et al.* (2000) reported the activity of *P. fluorescens* including competition for space and nutrients, production of antibiotics, volatile and anti-microbial substances and compounds such as iron chelating sirderophores and HCN.

Fig. 1 Effect of rhizome treatment with bioagent, phytochemical, hot water treatment and dimethoate on population of *M. incognita* in soil at different intervals



The results presented in Fig. 2 revealed the reduction in nematode population due to *P. fluorescens* and AMF (as rhizome treatment @ 3 per cent w/w) and its effect was directly reflected on the biometric characters of the plant like number of leaves, root weight, fresh plant weight etc. The growth promotion of *P. fluorescens* reported in various crops is in line with this study. Sanhita *et al.* (1995) reported the growth promotion of tomato plants by the rhizobacteria *P. fluorescens*. The improvement in biometric characters (leaf number, root weight and fresh plant weight) due to reduction in root-knot and burrowing nematodes by the action of AMF in the root zone of various crops was already reported by several workers (Rajani, *et al.*, 1998; Koshy *et al.*, 1998 and Sosamma *et al.*, 1998 in kacholam, coconut and banana respectively). The improvement in biometric characters established direct impact on the yield increase in kacholam in terms of weight of rhizomes per plant, per plot and per ha basis (Para 4.1.5). Here also the *P. fluorescens* established its superiority over other treatments (including the chemical, dimethoate) except AMF at per plant basis. Hot water treatment of rhizomes (55^0C) also showed its effectiveness in increasing the yield along with *P. fluorescens* when the yield was taken at per plot basis. The potential of *P. fluorescens* as rhizome treatment for nematode management was not reported earlier but the effect of nursery and seed treatment with this bacteria was reported in various crops by several workers. Santhi and Sivakumar (1995) and Sheela *et al.* (1999) reported the effectiveness of *P. fluorescens* as nursery bed treatment against *M. incognita* in tomato and brinjal respectively. Ramakrishna *et al.* (1998) reported the potential of *P. fluorescens* as seed treatment against *H. gracilis* in rice. The mechanism responsible for the

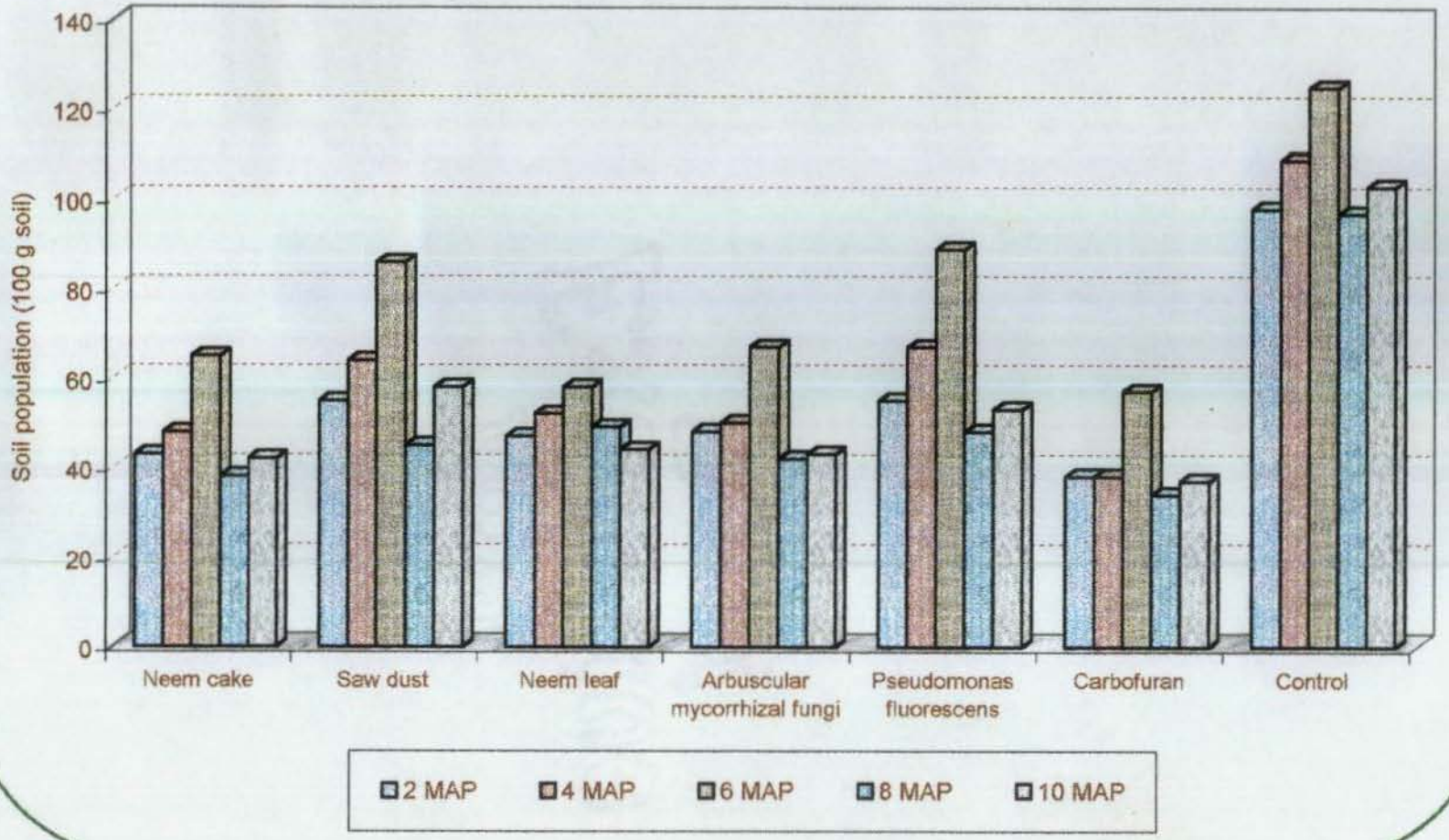
Fig. 2 Effect of bioagents treated as rhizome dip and main field application on the biometric characters, yield and population of *M. incognita* in kacholam



reduction of nematode population may be due to the ability of this bacteria to envelop or bind the root surface with carbohydrate-lectin, thereby interfering with normal host recognition process as reported by Oostendrop and Sikora (1990).

In the second trial the efficacy of organic amendments (neem cake, coir pith, sawdust, neem leaf), bioagents (*P. fluorescens*, AMF, *T. viride*) were evaluated as main field treatment before planting the rhizomes. The effect was compared with the chemical carbofuran and untreated control. The results on population characteristics of nematodes are presented in para. 4.2.6 to 4.2.9. The recovery of nematode population showed significant variation at different intervals (Fig. 3). Highest reduction in nematode population in soil was recorded in carbofuran (check) followed by neem cake, AMF and neem leaf at 2, 4, 6, 8 and 10 MAP and the effect of these treatments were statistically on par revealing that application of organic amendments like neem cake, neem leaf and the bioagent AMF were equally effective to chemical treatment. Nematode population in root (in terms of root-knot count, number of females and number of larvae), carbofuran (check) showed its superiority in number of females and larvae. In the case of reduction in root-knot count, neem cake and AMF were equally effective to chemical treatment, carbofuran. The effect of bioagents (AMF and *P. fluorescens*) and organic amendments (neem leaf, neem cake, sawdust) were statistically on par in reducing the number of females in the root. As regards the number of larvae in root, the organic amendments (neem cake, sawdust and coir pith) and bioagents (*P. fluorescens*, AMF) proved to be equally effective. The effect of these treatments were not as effective as

Fig. 3 Effect of main field treatments with bioagents, organic amendments and carbofuran on the soil population of *M. incognita*



that of carbofuran which gave 95 per cent reduction in nematode population. The reduction in nematode population in various above treatments ranged from 71 to 91 and this reduction was not enough to get statistical superiority over the chemical, carbofuran. These results are in agreement with that of Rajani *et al.* (1998); Devi and Das (1998) and Vemana *et al.* (1999). They reported the effectiveness of neem cake; sawdust, neem cake, poultry manure and sawdust in reducing root-knot nematode population in kacholam, carrot and groundnut root zone respectively. The efficacy of AMF as a biocontrol agent for reducing the nematode population in kacholam as reported in this study is in line with that of Rao *et al.* (1995), Asha (1996), Rajani *et al.* (1998), Sivaprasad and Sheela (1998), Sundarababu *et al.* (1998), Joseph *et al.* (2001) and Sivaprasad *et al.* (2001). They reported the effectiveness of AMF especially *G. fasciculatum* in reducing the population of *M. incognita* in tomato, brinjal, kacholam, pepper, okra, ginger and cardamom respectively. The capability of suppression of nematode population may be the inherent quality of AMF. The mechanism of suppression may either be due to AMF induced physiological changes in the host or mycorrhiza induced changes in the root exudates causing fewer nematodes attracted to the host (Ahmad and Alsayed, 1991).

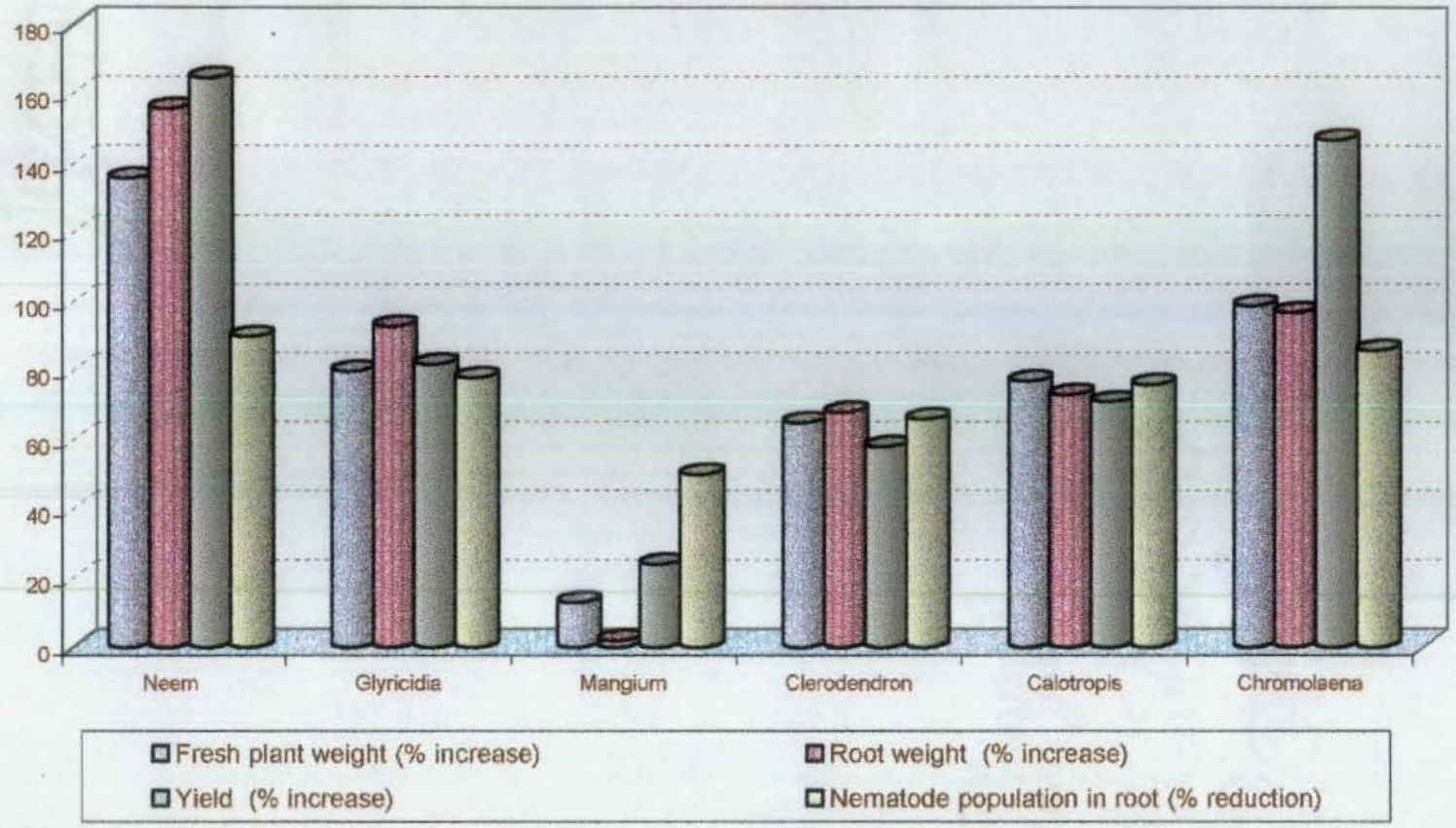
Among the biometric characters studied, the number of kacholam leaves were significantly improved by various organic amendments and bioagents and the results are presented in para 4.2.1 . Among the treatments neem cake and AMF were on par with chemical, carbofuran. But in the case of shoot weight, neem cake established its superiority over the chemical and other treatments. The effect of neem leaf and AMF treatments were inferior

to neem cake but was statistically on par with the chemical. In the case of fresh weight of plant, the effect of neem cake, AMF, sawdust and coir pith were on par with the chemical. These significant improvement in biometric characters directly contributed to the increase in yield of kacholam (Fig. 2). The effect of neem cake, AMF, sawdust, *P. fluorescens* and coir pith were on par with the chemical, carbofuran in improving the yield revealing that the above organic amendments and bioagents (AMF, *P. fluorescens*) are as effective as the chemical treatment. The beneficial effect of neem cake and AMF (*G. fasciculatum*) in kacholam was already reported (Rajani *et al.*, 1998). But the efficacy of other species of *Glomus* viz., *G. monosporum* and *Glomus* sp. (GI.1), sawdust and coir pith are reporting for the first time in this study.

Results on the study utilizing the available low cost natural resources like green leaves (neem, glyricidia, mangium, clerodendron, calotropis and chromolaena) as mulch for establishing their antihelminthic properties in kacholam rhizosphere are presented in para 4.3. The significant improvement in biometric characters, (number of leaves, shoot weight, root weight and fresh plant weight) yield (in terms of rhizome weight) and nematode population characteristics (nematode population in soil and root, root-knot count, number of females) are presented in Fig. 4 and 5.

The results of the trial on mulching presented in para 4.3.9 showed the periodical build up of nematode population in soil at 2, 4, 6 and 8 months after planting and nematode population in soil and root at the time of harvest. The effect of neem, chromolaena and glyricidia leaf mulching was statistically on par in reducing the nematode population in soil. Many

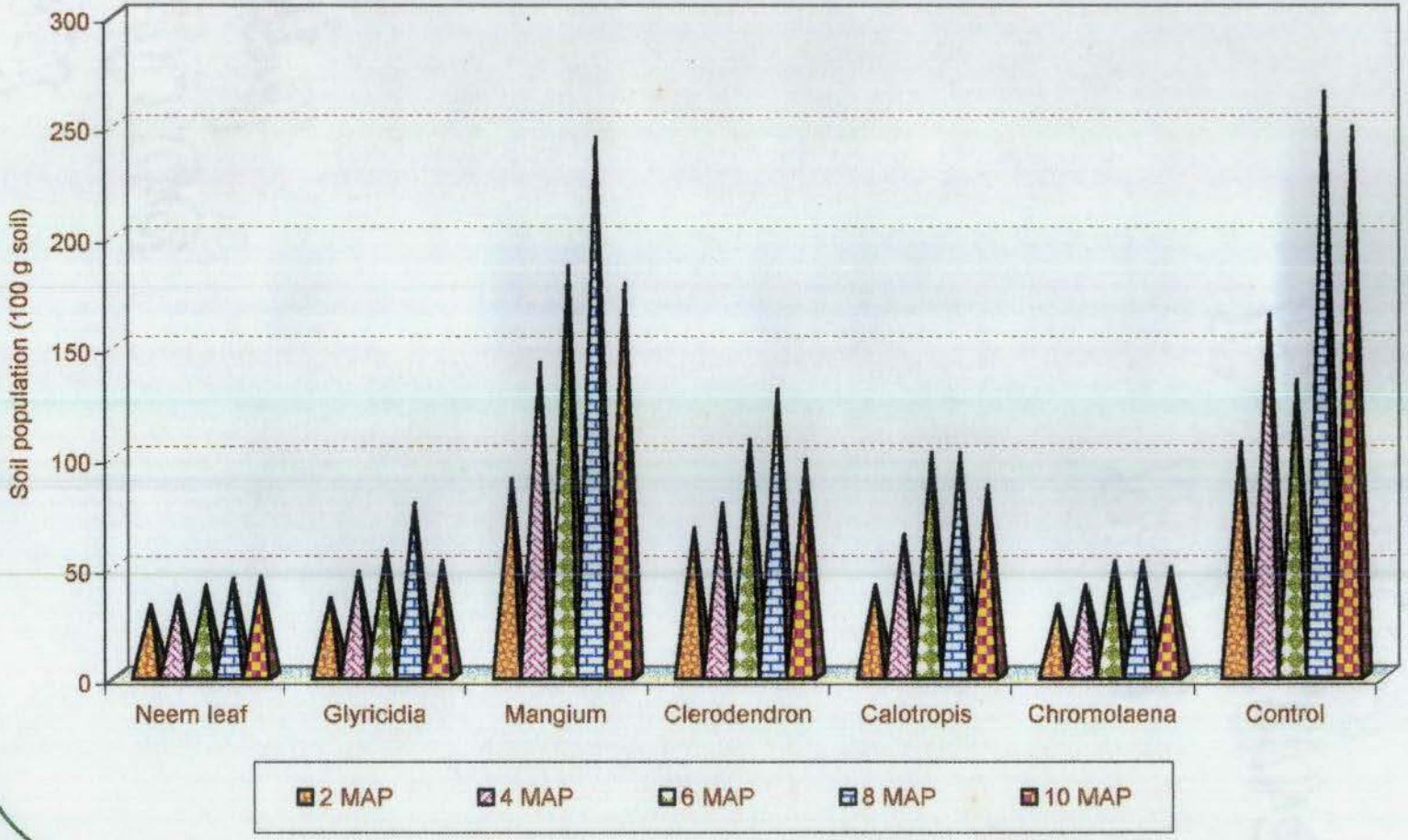
Fig.4 Effect of mulching on the biometric characters, yield and population of *M. incognita* in kacholam



workers reported the efficacy of application of green leaves for the management of nematodes associated with different crops. Jasy *et al.* (1992) reported the effectiveness of *Glyricidia maculata* leaves (10 g / kg soil) in reducing *R. similis* population and promoting the growth of black pepper. The superiority of neem leaf in managing nematode population in various crops like okra, cowpea and tomato were reported by Ajith *et al.* (1993) and Khanna and Sharma (1998). The efficacy of chromolaena leaves in managing the nematode population in okra and cowpea was already reported by Sheela *et al.* (1999). But the effect above leaves as green mulch at the time of planting of rhizomes in managing the nematode population in kacholam rhizosphere is reported for the first time in this study. The root-knot count showed drastic reduction due to mulching with different green leaves and maximum reduction was observed in neem followed by chromolaena leaves. The gall index was also minimum in neem and chromolaena green leaf mulching. Khanna and Sharma (1998) reported minimum galling in tomato roots due to incorporation of green leaves of neem and tagetes with gall index less than or equal to two. There was substantial reduction in number of females in root by various treatments like neem, chromolaena, glyricidia, calotropis and clerodendron (75 and 92 per cent reduction) and the effect of these treatments were statistically on par. Nematode population in root (number of larvae) also reduced significantly by neem and chromolaena green leaf mulching. This reduction in nematode population by neem leaf application was reported by Ramakrishna *et al.* (1997) in okra.

All the biometric characters were significantly improved by mulching with different types of green leaves. Maximum leaf production was recorded

Fig. 5 Effect of mulching on the soil population of *M. incognita*



in neem leaf mulching and the effect of this treatment was on par with chromolaena leaf. The same trend was observed in shoot weight also. The superiority of neem leaf was maintained only in fresh plant weight. In other biometric characters like number of leaves and shoot weight the effect of neem and chromolaena were on par. The effect of neem, chromolaena, glyricidia, calotropis and clerodendron leaves were on par in the case of root weight. However, mulching with neem, chromolaena and glyricidia showed 74 to 98 per cent increase in fresh weight of plants. These improvement in biometric characters directly attributed to the yield of kacholam in terms of weight of rhizome. In the case of yield, neem leaf mulching recorded significantly higher yield which was closely followed by chromolaena and these two were statistically on par. These findings are in line with that of Santhi and Sundarababu (1998) and Patel *et al.* (2000) who reported the beneficial effect of mulching in plant growth improvement, better biomass production and yield in the case of cowpea and tomato respectively.

The present studies concluded that the bioagents, *P. fluorescens* and AMF, the best rhizome treatments of promise needs more emphasis because the inoculum required in less, hence cheap method. Since the application of these bioagents is at the time of planting, it also served as a prophylatic method to ward off phytonematodes in the initial stage of growth of plants – the critical stage of nematode infestation. These are environmentally safe and also improves the vigour of plants by supplementing the phosphorus requirement (AMF only) of plants. But in the field application, neem cake and AMF were found promising indicating that potential of *P. fluorescens* as soil application was not appropriate to reduce the nematode population in soil

and also the entry of nematodes in the initial stage of the crop. In addition to the slight nematicidal and nematostatic properties neem cake improves the soil condition and subsequently the vigour of plants that also may evade infestation by nematodes. Green leaf mulching too was found effective in reducing the nematode population and increasing the yield of kacholam. Apart from the antihelminthic properties of leaves, during decomposition endothermic reaction occurs and organic acids are released it will improve the physical and chemical properties of the soil which also aid the nematode management and boost the rhizome production. Thus in the context of eco-friendly / farmer friendly low cost management strategy priority should be given for rhizome treatment with *P. fluorescens*, AMF and green leaf mulching with neem, chromolaena and glyricidia at planting. Soil application of neem cake, AMF and *P. fluorescens* and hot water treatment were not as cost effective as rhizome treatment with bioagents.

SUMMARY

6. SUMMARY

Studies were conducted to evolve an eco-friendly management strategy for controlling nematodes associated with the medicinal plant kacholam, *Kaempferia galanga* Linn. using bioagents, plant products, botanical pesticides and organic amendments as rhizome and mainfield treatments. Effect of mulching with various green leaves (neem, glyricidia, mangium, clerodendron, calotropis, chromolaena) having antihelminthic properties available in the farmer's field was also studied as a low cost method. The results were assessed in terms of biometric characters (number of leaves, shoot weight, root weight, fresh plant weight), yield (in terms of rhizome weight) and nematode population characteristics (root-knot count, number of females, number of larvae in root and soil).

Microplot (2 M x 2 M) studies were conducted to establish the efficacy of bioagents (*Pseudomonas fluorescens*, arbuscular mycorrhizal fungi (AMF) and *Trichoderma viridae*), botanicals (neem oil, neem leaf extract, neem oil + garlic, neem leaf extract + garlic, nimbecidine), hot water treatment and chemical (dimethoate) as seed rhizome treatment. The initial population level of infested plots were uniform and there was no statistically significant variation in population levels. The initial population ranged from 100 to 160 *Meloidogyne incognita* and 45-65 *Radopholus similis* per 100 g soil. The treated rhizomes were planted and observations were taken two months after planting onwards.

The effect of rhizome treatment with bioagents, botanicals, hot water treatment and chemical (dimethoate) revealed that *P. fluorescens* @ 3% w/w

significantly improved the plant growth parameters and yield more than cent per cent. Maximum leaf production, shoot weight, root weight and fresh plant weight were recorded in plants treated with *P. fluorescens* (@ 3% w/w). The effect of *P. fluorescens* was on par with AMF (@ 3% w/w) and neem leaf extract (4%) + garlic (1%) in leaf production. In the case of shoot weight *P. fluorescens* was on par with neem leaf extract + garlic, AMF, *T. viride* and hot water treatment (55^{0}C). Regarding the improvement of root weight and fresh plant weight *P. fluorescens* maintained its superiority over the other treatments. Next best treatments were AMF and hot water treatment and the effect of these treatments were statistically on par. The improvement in biometric characters of the plant resulted in higher yield in terms of weight of rhizomes. Here also the *P. fluorescens* treatment established its superiority over other treatments except AMF at per plant basis. Hot water treatment also showed its effectiveness in increasing the yield along with *P. fluorescens* and AMF when the yield was taken per plot basis. The periodical estimation of nematode population in soil (taken at 2, 4, 6, 8 and 10 months after planting) and population in root at the time of harvest revealed that rhizome treatment with *P. fluorescens* was very effective in reducing the nematode population.

The effect of *P. fluorescens* was superior to all other treatments at 2 MAP and was on par with AMF at six and eight months after planting. At the final stage of the crop it was on par with neem leaf extract + garlic. The *P. fluorescens* treatment significantly reduced the population of larvae in root (85 per cent). The effect of this was on par with AMF, neem leaf extract + garlic, hot water treatment and *T. viride* giving more than 74 per cent reduction in nematode population over the untreated plants. The root-knot

count was reduced drastically in *P. fluorescens* and AMF treatments and these two were significantly superior to all other treatments including the chemical, dimethoate (0.1 per cent). The mean number of females was minimum in *P. fluorescens* treatment which was closely followed by AMF and both were on par giving 86 to 90 per cent reduction. Estimation of bioagents in the rhizosphere at the time of harvest revealed that they survive in soil more than ten months after planting.

Second trial was conducted to find out the efficacy of above bioagents (*P. fluorescens*, AMF, *T. viride*) and organic amendments (neem cake, coirpith, sawdust, neem leaf) as main field treatment. Carbofuran was also tested as a check in main field. The trial was conducted in microplots (1 m x 1 m) having a uniform nematode population. The population ranged from 99 to 125 *M. incognita* and 40 to 50 *R. similis* per 100 g soil in different sick plots. The treatments were applied in the soil prior to planting the rhizomes. The observations were recorded and assessed in terms of biometric characters, yield and nematode population. All these treatments were found effective in reducing the nematode population and increasing the growth parameters and yield of kacholam. In the case of leaf production the treatments neem cake (200 g/m^2) and AMF (300 g inoculum/ m^2) were on par with the chemical giving 98 to cent per cent increase over the untreated. Among the treatments neem cake established its superiority over the chemical and other treatments in the case of shoot weight. Next effective treatments were neem leaf and AMF and they were on par with the chemical carbofuran (1g a.i./m^2). The neem cake treated plants recorded the highest root weight which was statistically on par with all other treatments (AMF, carbofuran,

P. fluorescens, coir pith, sawdust, neem leaf) except *T. viride*. The highest fresh plant weight was recorded in neem cake treatment which was statistically on par with AMF, carbofuran, sawdust and coir pith treatments giving more than 70 per cent increase over the untreated. These significant improvement in biometric characters directly contributed to the increase in yield of kacholam. The effect of neem cake, AMF, sawdust, *P. fluorescens* and coir pith were on par with the chemical carbofuran giving more than cent per cent increase in yield over the untreated (per plot basis). The nematode population characteristics such as root-knot count, number of females, nematode population in root and soil showed drastic reduction in various treatments along with the chemical carbofuran. Carbofuran, neem cake and AMF treatments were on par in reducing the root-knot count (87 to 95 per cent reduction over untreated). The effect of AMF, neem leaf, neem cake, *P. fluorescens* and sawdust were statistically on par in reducing the female number (83 to 92 per cent). The reduction in the number of larvae per 5 g root sample, the effect of neem cake, *P. fluorescens*, sawdust, AMF and coir pith were on par giving 81 to 90 per cent reduction over the untreated. However the effect of the above treatments in reducing the number of females and larvae were inferior to the chemical, carbofuran. The reduction in population of larvae in soil at different periods (2, 4, 6, 8 and 10 months after planting) showed that the application of bioagents, organic amendments and chemical were equally effective. Highest reduction in nematode population in soil was recorded in carbofuran followed by neem cake, AMF and neem leaf.

Third trial was conducted to evaluate the nematicidal properties of the locally available green leaves (neem, glyricidia, mangium, clerodendron,

calotropis and chromolaena) as mulch. The trial was conducted in micro plots (2 m x 2 m) having an initial population range of 265 *Meloidogyne incognita* larvae and 45 to 52 *Radopholus similis* per 100 g soil sample. There was no statistically significant variation in population in different plots. The green leaves were applied @ 5 kg / m^2 in 30 cm depth at the time of planting. At harvest, the observations on biometric characters (number of leaves, shoot weight, root weight, fresh plant weight), yield (in terms of rhizome weight) and nematode population were recorded.

All the biometric characters were improved significantly by mulching with different types of green leaves. Maximum leaf production was noticed in neem leaf mulching (cent per cent increase over untreated plants) followed by chromolaena leaf (92 percent increase). The superiority of neem leaf was maintained in fresh plant weight only. However others (chromolaena, glyricidia, calotropis) showed 74 to 98 per cent increase in fresh weight of plants. Neem leaf mulching recorded the highest yield (5.63 kg per plot) which was closely followed by chromolaena (5.25 kg per plot) and the effect was statistically on par. Maximum reduction in nematode population in soil six months after planting and at harvest was observed in neem leaf mulching followed by chromolaena and glyricidia. Even the application of mangium significantly reduced the nematode population in soil (29 per cent reduction) but the effect was inferior to other leaves but superior to untreated at different periods except eight months after planting. Maximum reduction in root-knot count was observed in neem and chromolaena leaves (92 to 96 per cent reduction). The effect of these two treatments was statistically on par and superior to other leaves as mulch. The number of females per g of root was

also minimum in the above two treatments, but it was statistically on par with glyricidia and calotropis leaves.

These investigations highlighted that *P. fluorescens* and AMF were the best rhizome treatments for managing nematodes and improving the biometric characters and yield of kacholam. But for field application neem cake and AMF were the best treatments. In green leaf mulching trial, neem leaf, chromolaena and glyricidia were equally effective in reducing the nematode population and increasing the yield. But in the context of eco-friendly low cost management strategy priority should be given for rhizome treatment with *P. fluorescens*, AMF and green leaf mulching with neem, chromolaena and glyricidia.

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ECO-FRIENDLY MANAGEMENT OF ROOT-KNOT AND BURROWING NEMATODES ASSOCIATED WITH KACHOLAM, *Kaempferia galanga* Linn.

BY

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ABSTRACT OF THE THESIS
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ABSTRACT

Field experiments were conducted to evaluate the efficacy of bioagents (*Pseudomonas fluorescens*, arbuscular mycorrhizal fungi, *Trichoderma viridae* (3 per cent w/w) plant products (neem oil (2%), neem leaf extract (5%), neem oil + garlic (2%), neem leaf extract (4%) + garlic (1%), botanical pesticide, nimbecidine (0.2%), hot water treatment (55^{0}C) and organic amendments (neem cake (200g/m^{2}), coir pith (500g /m^{2}), sawdust (500g/m^{2}), neem leaf (750 g/m^{2}) as rhizome and main field treatments for working out an eco-friendly management strategy against the nematodes (*Meloidogyne incognita* and *Radopholus similis*) in the medicinal plant, kacholam, *Kaempferia galanga* Linn. The efficacy of green leaf mulching was also tested using locally available green leaves (neem, glyricidia, mangium, clerodendron, calotropis, chromolaena) @ 5kg /m^{2} as mulch, to maximise the natural resource utilization in the context of low cost farmer friendly technology.

To establish the potential of rhizome treatment with bioagents, botanicals, plant products and hot water treatment a micro plot study (2 m x 2 m) was conducted at College of Agriculture, Vellayani in sick plots having an initial population range of 100 to 160 *M. incognita* and 45-65 *R. similis* per 100 g soil. The effect of the above treatments were compared with the chemical, dimethoate (0.1%) and untreated. The results showed that maximum improvement in biometric characters like fresh plant weight and root weight of kacholam plants was observed in rhizome treatment with *P. fluorescens*. Next best treatments were AMF and hot water treatment and the effect of these two were significantly better than the chemical, dimethoate. The improvement in biometric characters due to above three treatments increased the yield of kacholam to the tune of 87 to cent per cent. Regarding the reduction in nematode

population in root (root-knot count and number of females), *P. fluorescens* and AMF were the best treatments. Next effective ones the hot water treatment and *T. viride* were also better than the chemical, dimethoate. There was no significant variation in the *R. similis* population in soil due to rhizome treatments.

The results on the effect of application of bioagents and organic amendments in soil at the time of planting revealed that neem cake (200 g / m^2) and AMF (300 g inoculum / m^2) were on par in leaf production and neem cake established its superiority in improving the shoot weight also. Neem cake, AMF, sawdust and coir pith were statistically on par in improving the fresh weight of plant. In all these cases effect of the above treatments were on par with the chemical, carbofuran (1kg a.i./ha). Regarding the improvement in yield also the best treatments (neem cake, AMF, sawdust, *P. fluorescens* and coir pith) were on par with the chemical, carbofuran. The superiority of carbofuran was maintained in reduction of nematode population only in root (number of females and larvae). In all other cases (nematode population in soil at different periods) the effect of neem cake, AMF, neem leaf were on par with the chemical.

The results on the effect of mulching with green leaves revealed that neem and chromolaena leaves improved the fresh plant weight and yield of kacholam. Reduction in nematode population in soil was observed in glyricidia leaves also along with neem and chromolaena. The effect of neem and chromolaena @ 5kg /m^2 leaves were on par in reducing the root-knot count and number of larvae in root. There was no significant variation in population of *R. similis* due to mulching with different leaves but minimum population was recorded in neem leaf (4 MAP). Even the application of mangium @ 5 kg/m^2 significantly reduced the nematode population in soil, but the effect was inferior to other leaves, but superior to the untreated.