PATHOGENICITY, YIELD LOSS ASSESSMENT AND MANAGEMENT OF ROOT-KNOT NEMATODE, *Meloidogyne incognita* (Kofoid and White) Chitwood ON CHILLI (*Capsicum annuum* L.)

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DECLARATION

I hereby declare that this thesis entitled "**Pathogenicity, yield loss assessment and management of root-knot nematode, *Meloidogyne incognita* (Kofoid and White) Chitwood on chilli (*Capsicum annuum* L.)**" 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 "**Pathogenicity, yield loss assessment and management of root-knot nematode, *Meloidogyne incognita* (Kofoid and White) Chitwood on chilli (*Capsicum annuum* L.)**" is a record of research work done independently by Ms. Rajitha. R. (2001-11-43) 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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CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

cm	Centimetre(s)
g	Gram
mm	Millimetre
viz.	Namely
ml	Millilitre
kg	Kilogram
spp.	Species
et al.	And others
Fig.	Figure
CD	Critical difference
DAT	Days after transplanting
ai	Active ingredient
ha^{-1}	Per hectare
@	At the rate of
IARI	Indian Agricultural Research Institute
KAU	Kerala Agricultural University
cfu	colony forming unit

INTRODUCTION

1. INTRODUCTION

Nematodes constitute an important group of animals on earth whose existence is intricately woven with man and his activities. In an undisturbed ecosystem, they remain in harmony with the environment dynamics and attain equilibrium in population density. Contrarily, agro-ecosystems tend to favour a few species which attain pest status, necessitating management decisions. Knowledge of pathogenic threshold of the nematode pest thus becomes imperative as it is the keystone in any management programme. Economic threshold of any pest is dependent on the host plant and the environment in which it exists. Soil being the habitat of most of the plant parasitic nematodes, its characteristics profoundly influence the population dynamics of the phytophages. Since soil environment varies from place to place, effective management of nematode pests is possible only if the damage potential of the pest under specific agro-climatic conditions is known.

One of the important condiment crops of Kerala possessing immense commercial and therapeutic value is chilli (*Capsicum annuum* L.). The indispensable position occupied by chilli in the day to day life of Keralites is indisputable. It is consumed as spices, pickles and salad and is used in a number of other ways. It is cultivated in an area of 610 ha (FIB, 1999). One of the important group of pests infesting chilli is the nematodes. Sophistication of agriculture has aggravated nematode problems in the crop adding to the constraints in its production. Among nematodes, *Meloidogyne* spp. is the only genera of importance in the crop (Cho *et al.*, 1986). Its potential threat to the crop through direct damage (Saxena, 1986; Ahmad and Khan, 1991; Khan, 2000) and association with disease complex (Karthikeyan *et al.*, 2000) is well documented. Prevalence of *Meloidogyne incognita*

(Kofoid and White, 1919) Chitwood. 1949 in chilli is known in Kerala. Although considerable work has been done on the association. distribution and pathogenicity of the nematode in chilli in other countries (Varela *et al.*. 1986; Ahmad *et al.*, 1998) and parts of India (Rajagopalan *et al.*. 1969: Yadav and Mathur, 1993a) negligible information is available about its potency to cause damage to this important crop in the state. Considering the fact that damage threshold of a pest is location specific. the above mentioned reports cannot serve as a reliable source of information for formulating effective management strategies.

Hitherto, chemical nematicides have been the mainstay of nematode control programmes. However, ecological backlash to this 'miracle' tactic has created an unprecedented awareness of the hazards lurking behind this method of control. Ecofriendly methods are being increasingly sought after to ameliorate the adverse effects of nematodes. With organic farming fast becoming the cynosure of all agricultural concepts biomanagement has become the watchword in pest management. Attention has been focused on the cultivation of resistant varieties and use of biopesticides for tackling nematode problems.

Several varieties of chilli like Malagachi Yellow, Jalandhari and Laichi -2 (Kaur and Mahajan, 1990), Pusa Jwala (Khan and Khan, 1991) have been identified as resistant to *M. incognita*. Efficacy of bioagents like arbuscular mycorrhizal fungi (Sharma *et al.*, 1994; Asha, 1996; Sundarababu *et al.*, 2001), fluorescent pseudomonads (Verma *et al.*, 1998; Mani *et al.*, 1998; Sheela *et al.*, 1999) and *Trichoderma* sp. (Khan and Saxena, 1997; Karthikeyan *et al.*, 2000) has been tested and found suitable for nematode management. Similarly. efficacy of organic amendments in managing nematode in chilli is sufficiently documented (Mishra *et al.*. 1989; Jain and Gupta 1997). No such attempts have been made in the crop in Kerala.

This backdrop necessitated the present study and the investigation was taken up with the following objectives.

1. To determine the pathogenicity of *M. incognita* in chilli.

2. To assess the yield loss at different population densities of *M. incognita*

3. To evaluate local and high yielding accessions of chilli for their relative resistance/tolerance to *M. incognita*

4. To identify potential bioagents and suitable oilcakes for managing the nematode in chilli.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Pathogenicity of the root-knot nematode, *Meloidogyne incognita* in chilli and relative susceptibility /resistance of different varieties to the nematode and the efficacy of bioagents and oil cakes in suppressing the pest were studied in the present investigation . While the relevant literature pertaining to pathogenicity and management of the nematode in solanaceous vegetables is reviewed. literature seen on varietal resistance is restricted to chilli.

2.1 PATHOGENICITY AND YIELD LOSS ASSESSMENT

A large number of plant parasitic nematodes are reported to be associated with chilli, an important vegetable and spice crop grown in tropical and subtropical areas of the world (Chaturvedi and Kansal, 1984; Singh and Khera, 1984; Saxena, 1986). *M. incognita* is the only important nematode damaging the crop (Cho *et al.*, 1986). Chilli was observed to be a good host for *M. incognita* (Khan *et al.*, 2000), but non-host for *Meloidogyne javanica* (Taylor and Sasser, 1978; Khan *et al.*, 2000).

2.1.1 Pathogenicity of Root-knot Nematode in Chilli

Considerable reduction in length and weight of shoot and root in plants inoculated with varying levels of *M. incognita* was reported (Chidambaranathan and Rangaswami, 1965). The plant growth parameters were perceptibly reduced when 1000 larvae of *M. incognita* were inoculated in 45 days old chilli seedlings (Rajagopalan *et al.*, 1969). Significant difference in plant growth and dry weight of shoots and roots between control plants and inoculated plants of *C. annuum* infected by *M. incognita* was observed at varying inoculum levels (Varela *et al.*, 1986). The extent of damage caused by *M. incognita* race 1 on chilli seedlings inoculated with 50, 500 or 5000 juveniles was directly proportional to nematode density with the reproduction factor, gall index and egg mass index increasing with increasing nematode density (Ahmad and Khan, 1991) .A similar trend was observed when *C. annuum* variety Jaipur was inoculated with 10,100,1000 or 10000 J_2 of *M. incognita* per pot (Yadav and Mathur, 1993a). A study on the effect of *M. javanica* at 0, 1000, 2000 and 3000 J_2 (second stage juveniles) inoculum levels on six chilli varieties indicated a general trend of decrease in shoot parameters and an increase in root parameters with increase in inoculum levels (Ahmad *et al.*, 1998). The percentage yield loss ranged from 19.7-33.0 when infested with *M. javanica* (Bhatti and Jain, 1977).

2.1.2 Pathogenicity of *M. incognita* in other Solanaceous Vegetables

Serious yield loss was observed in brinjal due to root-knot nematode infestation (Darekar and Mhase, 1988; Khan and Khan, 1990). Solanaceous vegetables like tomato and egg plant are also good host plants of root-knot nematode (Khan *et al.,* 1993; Khan and Khan, 1990,1996). Besides cyst nematode, the root-knot nematode was identified as major pests of potato both in India and abroad (Gill, 1974). *M. incognita* population density of 1 J_2 /g soil can be considered as the damage threshold level in potato (Nagesh, 1996)

Yield loss in tomato and brinjal to the tune of 46.2 and 27.3 per cent respectively was reported in a field infested with *M. incognita* @ 2800 to 3460 larvae per kg soil (Bhatti and Jain, 1977). In another investigation the yield loss due to *M. incognita* varied from 28 to 43 per cent between brinjal and ladies finger. An inoculum level of 500 per plant of root-knot or 1000 numbers of reniform nematode alone or in combination resulted in 29 to 48 per cent yield reduction in brinjal (Jiji and Venkitesan, 1989), while an initial population of 248 *M. incognita* larvae per 250 g soil sample resulted in an avoidable loss of 20 and 22 per cent in weight and number of fruits respectively (Kerala Agricultural University, 1993). Avoidable yield loss in tomato to the extent of 71.9 per cent due to *M. incognita* and 47.3 per cent due to *M. javanica* have been reported (Jain *et al.*, 1994) and yield loss of 42.05 to 54.42 due to *M. incognita* in tomato(Subramaniyan *et al.*.1990).

2.2 VARIETAL SCREENING

2.2.1 Screening for Resistance to Root-knot Nematode

Resistant varieties offer the cheapest and most convenient method of pest management .Several varieties of chilli resistant / tolerant to root-knot nematodes have been identified.

Among the 19 varieties of chilli screened in Coimbatore, five varieties *viz*., 17-1-1, Bombay 760, Bombay 759, Ceylon and Annevum proved to be tolerant to *M. arenaria* infestation (Rajagopalan *et al*., 1970). Pusa Jwala (Mohanty *et al*., 1988; Pandey and Trivedi, 1990), SL-1 and Pusa Sadabahar were also identified as resistant sources against *M. incognita* (Mohanty *et al*.,1988). An initial inoculum level of 4 second stage juveniles (J_2) per gram soil significantly reduced the growth of chilli cultivar Mathani i-c, but the nematode did not have any significant adverse effect on the plant growth of cultivar Pusa Jwala indicating the relative susceptibility and tolerance of the nematode (Rama and Gill, 1989). Of 31 chilli cultivars tested against *M. incognita*, Malagachi yellow 12-3-3, Jalandhari and Laichi -2 were resistant while 10 cultivars were moderately resistant (Kaur and Mahajan, 1990), Mandore local 1 and 2 were assessed as moderately resistant to *M. incognita* (Pandey and Trivedi, 1990), Jwala was found resistant to races 1,2 and 4 of *M. incognita* and immune to 3, Suryamukhi green and chilli P.C.1 were susceptible to *M. javanica* (Khan and Khan, 1991). Pusa Jwala was also rated as resistant to races 1 and 3 of *M. javanica* (Khan and Khan, 1991). Out of 79 genotypes of *C. annuum* screened for their reaction to *M. incognita*, only K-2 was resistant while 14 genotypes were moderately resistant (Yadav and Mathur, 1993b). The chilli cultivars Ch-19, Ch-21 and LCH -206 were found to be moderately resistant to *M.* incognita (Sharma *et al*., 1994). Besides, the cultivar Khandari (Hussain *et al.*, 1998) and Red Hot Short were also reported to be resistant to *M. incognita*. *C. annuum* hybrid AF 2638 and AF 2640 were found to be resistant in an investigation to evaluate the reproduction of *M. incognita* race 2 on different sweet peppers (Santos *et al*., 2002). Among chilli cultivars screened, Patna Red, NP -34, Yolo Wonder, Suryamukhi, G-4 and

Capsicum F-1- Bharat were susceptible to *M. incognita* races with gall index ranging between 3.0 and 5.0 .The cultivars Chilli J-218 and Ruby King were resistant to all the races of *M. incognita* (Khan *et al.*, 2002) .

2.2.2 Screening for Resistance to Insect Pests

The major constraint in chilli production is the damage caused by insect pests like aphids (*Myzus persicae* S.), whitefly (*Bemisia tabaci* G.),thrips (*Scirtothrips dorsalis* Hood.).

The yield loss due to thrips and mite (*Hemitarsonemus latus* B.) was estimated to a tune of 50 per cent (Ahmad *et al.*, 1987; Kandasamy *et al.*, 1990): The losses in yield of green chillies due to thrips varied from 60.50 to 74.30 per cent due to insect pest attack (Patel and Gupta, 1998). In a study to screen out varieties resistant to pest infestation Pusa Sadabahar, Pant C-2 and Jawahar Mirch-2 were found promising recording less aphid, whitefly, thrips population, virus infection and in turn registered high yield (Singh *et al.,* 1998). Variety Pusa Sadabahar was found to be outstanding amongst all other varieties .In another experiment the cultivars ACS-92-4 and G-4 were found susceptible to thrips whereas both the local cultivars Jwala and S-49 were found to be most susceptible among all the genotypes tested (Panickar and Patel, 2001).However, both the local chilli cultivars, Jwala and S-49 proved to have higher yield potential.

2.3 BIOAGENTS FOR THE MANAGEMENT OF ROOT-KNOT NEMATODE

Biohazards associated with the use of chemical pesticides have been instrumental in the identification and development of biocontrol methods for integrated management of plant parasitic nematodes with various types of antagonistic organisms.

2.3.1 Arbuscular Mycorrhizal Fungi (AMF)

Symbiotic association of AMF increase host plant resistance to several soil borne fungal plant pathogens and many plant parasitic nematodes (Schenck and Kellam,1978; Schonbeck,1979).They are reported to affect the root exudation which in turn alter the chemotactic attractant on nematodes to roots

(Gerdmann,1968; Hayman,1982; Harley and Smith,1983). Besides, they also compete for space with other semi-endo and endo-parasitic nematodes, which may account for reduced nematode infection on root systems. Their association is also found to suppress the root-knot nematode infestation in crop plants (Sitaramaiah and Sikora, 1982; Hussey and Roncadori, 1982; Grandison and Cooper, 1986). It has been demonstrated that there are inter-relationships between endomycorrhizal fungi, rhizosphere microflora and nematodes and the association can markedly alter host reaction in increased levels of resistance to pathogens (Francl, 1993).

In field experiments to determine the effectiveness of the AMF, *Glomus mosseae* against *M. incognita* in chilli cv. K-2, in comparison with carbofuran 2 per cent at 1.0 kg ha^{-1}, it was found that although carbofuran caused a sudden and large reduction in the soil nematode population immediately after application, it did not give sustained suppression of nematodes as did *G. mosseae*. Further, seedlings treated with mycorrhiza produced significantly higher yield than carbofuran and untreated control (Sundarababu *et al.*, 2001).

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). *G. fasciculatum* promoted the maximum growth of tomato plants compared to other mycorrhizae species producing highest yield while minimum nematode population of 368 was observed on *G. versiforme* inoculated plants which recorded the next best yield (Sundarababu *et al.*, 1993). Colonisation of the AMF, *G. fasciculatum* was found to reduce the root-knot infestation in tomato and application of AMF first followed by nematodes resulted in greater reduction in nematode infestation than the simultaneous inoculation or inoculation of nematode first followed by mycorrhiza (Sharma *et al.*, 1994). Study on the effect of *G. fasciculatum* on the penetration, survival and development of *M. incognita* in tomato revealed that mycorrhizal seedlings produced less number of galls, egg masses per plant, eggs and juveniles per egg mass. The symbiont caused a reduction of 30 per cent in galls and egg masses per plant (Sharma *et al.*, 1995). *G. fasciculatum* inoculated 15 days earlier than nematode inoculation enhanced the growth of tomato cv.Co-3 and suppressed *M. incognita* multiplication (Sundarababu *et al.*, 1996) and brinjal (Asha,1996). Application of *G. fasciculatum* @ 10g kg^{-1} soil was sufficient for the effective management of root-knot nematode infecting tomato (Sundarababu *et al.*, 1998). The development of nematode stages in the roots of tomato plants and the nematode numbers in soil were differently suppressed by AMF with most pronounced effect with *G. fasciculatum*, comparatively less with *G. macrocarpum* and *G. margarita* (Labeena *et al.*, 2002).

The effect of AMF, *G. fasciculatum* and *M. incognita* on brinjal variety Pusa Purple Long indicated that mycorrhizal plants had the longest shoots than non-mycorrhizal plants with the longest shoots observed in plants inoculated with AMF at 300 spores per plant followed by those treated with 150 spores per plant and the control and application of AMF prior to nematode inoculation was more effective in reducing nematode infestation than the simultaneous application of AMF and nematode or nematode inoculation before AMF treatment (Borah and Phukan,2000).Plant growth was improved significantly over control with application of *G. mosseae* irrespective of dosage in brinjal infected with *M. incognita*. AMF colonization was greatest in 10g kg^{-1} followed by 5 g kg^{-1} (Jothi and Sundarababu, 2001).

2.3.2 Fluorescent pseudomonads

The biocontrol potential of fluorescent pseudomonads against root-knot nematode on tomato has been reported (Santhi and Sivakumar, 1995). *P.aeruginosa* and *Paecilomyces lilacinus* used alone or together significantly reduced infection of *M.javanica* and root infecting fungi on chilli. *P. aeruginosa* being more effective than *P. lilacinus* in reducing nematode infection (Perveen *et al.*, 1998). Root dip treatment with *P. aeruginosa* with or without *Trichoderma harzianum, T. koningii* and *T. hamatum* significantly controlled infection of roots by *M. javanica* on *C. annuum*. Combined use of *T. harzianum* and *P. aeruginosa* caused greatest reduction in gall formation (Siddiqui *et al.*,1999). All the three

P. aeruginosa strains (IE-6, Pa-7 and Pa-5) significantly reduced nematode population in soil, invasion, multiplication and gall formation due to *M. javanica* on chilli (Siddiqui *et al.* ,2001) .

Application of *P. fluorescens* at 10 g kg^{-1} seed was effective in reducing the menace of root-knot nematode, *M. incognita* in tomato (Verma *et al.*, 1998). The effectiveness of pf (1) strain of *P. fluorescens* against *M. incognita*, has also been reported (Mani *et al.*,1998). The bio control efficency of this bacteria has also been reported in brinjal (Sheela *et al.*, 1999).

2.3.3 *Trichoderma* spp.

It has been claimed that fungal filtrates of *Trichoderma* spp. has nematicidal effect against root-knot nematode. An increase in dry shoot and root weight of chilli cv.Co.2 was seen when *T. viride* was used as seed treatment followed by *P. lilacinus* and *T. harzianum* (Karthikeyan *et al.*, 2000).

Fungal filtrates of *T. harzianum* against root-knot nematode in tomato has been reported to have nematicidal activity (Sankaranarayanan *et al.*, 1997). Root dip treatment with cultural filtrate of *T. viride* was particularly beneficial in reducing *M. incognita* damage on tomato (Khan and Saxena, 1997).

2.4 ORGANIC AMENDMENTS

The damage caused by plant parasitic nematodes can be reduced by soil incorporation of organic amendments and reports have demonstrated that various organic matter like farmyard manure, green manures, crop residues, oil cakes etc. reduced the population of plant parasitic nematodes and hence the disease caused by them (Goswami and Vijayalakshmi, 1981). The reduction in nematode population is either promoted through promotion of natural enemies or release of toxic compounds (Bhattacharya and Goswami, 1987). The evaluation of available non- edible oil cakes such as neem and mustard alone or in combination with other chemicals has invariably shown an improvement in plant growth with corresponding reduction in nematode population.

Oil cake of neem was capable of reducing root – knot galls caused by root-knot nematode when incorporated into infested soil (Singh and Sitaramaiah, 1966). They reported that when applied at about 1600 Lbs acre^{-1}, was most effective against *M. javanica* in tomato and brinjal. The effectiveness of oil cakes in suppressing the population of many plant parasitic nematodes on field scale was highlighted by Singh and Sitaramaiah (1970). Neem cake was also found to possess residual effect in increasing the plant growth and reducing the nematode population in the next crop. *M. incognita* infesting tomato was very effectively controlled by neem cake. Extracts of neem seed cake used against *M. incognita* not only reduced the hatching ability of eggs but also reduced penetration ability of J_2 (Mishra *et al.*, 1989). Neem products (neem kernel, neem cake, neem leaf extract, neem bark etc.) for management of plant parasitic nematodes have gained importance because of being economical as well as eco-friendly. They are known to possess nematicidal activity against nematode population (Zaki and Bhatti, 1989; Darekar *et al.*, 1990) and mustard cake contain components that inhibit fungal growth and cause high mortalities to root-knot larvae (Rahman *et al.*, 2000 - 2001).

M. incognita infected tomato plants when treated with mustard cake showed minimum number of galls per plant (Hameed,1968). Application of organic amendments *viz.*, neem cake, castor cake and mahua cake each at 500kg ha^{-1} were effective in increasing the plant growth parameters and reducing root-knot and reniform nematode populations in brinjal (Kumar and Vadivelu, 1996). Nematode population was minimum (63.7 J_2 / 250 g soil) 15 days after addition of neem cake used @ 80 q ha^{-1} leading to 63.9 per cent reduction in nematode population over initial level in tomato (Jain and Gupta, 1997). Neem cake and neem dust were found effective in the suppression of root-knot nematode, *M. incognita* in tomato (Jacob and Haq, 1998). Neem cake (@ 25q ha^{-1}) is the best non-chemical alternative for management of nematode in tomato, however, carbofuran 3G @ 1 kg *a.i* ha^{-1} remained effective against root-knot nematode in tomato (Khan and Rathi, 2000).

2.5 CHEMICALS

Vydate oxamyl, Vc-13 and Dazomet when mixed in soil and used as bare root dip or as foliar spray were found to reduce significantly the population of plant parasitic nematodes around roots of chilli plants, *C. frutescens* (Saxena *et al.*, 1974). In a study aimed at the control of root-knot nematode of chilli with nematicides, Temik 10 g at five doses ranging from 3-5 g per pot containing 1.5 kg soil and Furadan 3G at 0.5-2.5 g per pot, results indicated that for Furadan the gall numbers were 43-83 per plant, for Temik 61-103 per plant and for untreated control 216 per plant (Trivedi *et al.*, 1983). All the doses of pesticides except the lowest dose of phorate or diazinon suppressed gall and egg mass development in a study to manage root- knot of chilli in nursery applied with carbofuran, aldicarb, phorate or diazinon at 0.2, 0.1, 0.6 and 0.8 gm^{-2} (Yadav and Mathur, 1990).

Aldicarb and aldicarb based chemicals were most effective in increasing tomato yield in *M. javanica* infested plots (Jain *et al.*, 1988). High percentage of increase in tomato growth occurred with aldicarb (77.30 per cent) where as trifluralin showed the least percentage of increase (12.50 per cent) and aldicarb and oxamyl effectively reduced nematode population within tomato roots as well as number of galls and egg masses (Amin *et al.*, 1992).

Carbofuran (0.60 *a.i* $m^{-2)}$ was most effective in reducing the number of galls per 25 seedlings in nursery as well as resulted in minimum gall index (2.41) in brinjal (Mohanty *et al.*, 1995). Bare root dip treatment of brinjal seedlings with monocrotophos, triazophos or carbofuran @ 0.05 per cent is beneficial in reducing the root-knot nematode population significantly and increasing the yield between 34-80 per cent over check (Reddy *et al.*, 1997).

MATERIALS AND METHODS

3. MATERIALS AND METHODS

Pot culture experiments were conducted in the College of Agriculture, Vellayani during 2002-2003 to determine the pathogenic level of the root-knot nematode, *Meloidogyne incognita* in chilli and to identify tolerant varieties and effective biopesticides to manage the pest.

3.1. DETERMINATION OF PATHOGENICITY

3.1.1 Preparation of Denematized Potting Mixture

Sieved field soil, sand and well decomposed farmyard manure were mixed in the ratio 2 : 1 : 1 and the mixture was spread on the ground in the form of beds of 15 cm thickness. The beds were divided into blocks of one square feet and drenched uniformly with 10 per cent formaldehyde solution and then covered with polythene sheet. The sheets were removed and the mixture raked well and exposed after two weeks. This denematized potting mixture was used for pot culture studies.

3.1.2 Raising of Nematode Culture

Pure culture of *M. incognita* was raised from a single egg mass collected from infested chilli roots and multiplied on chilli maintained in sterilized soil. Subculturing was done periodically to ensure availability of sufficient larval population for inoculation following standard procedures.

Viable egg masses were handpicked from the infested roots of culture plants and kept on two layers of tissue paper supported by aluminium wire gauge in 10 cm sized petri dishes filled with fresh water for obtaining required number of J_2 (second stage juveniles). The population of J_2 of *M. incognita* in the suspension was determined by counting J_2 in 1ml aliquot. Three such counts were made and the average of 3 counts was taken as population in 1ml suspension. The larval concentration was adjusted to required number of juveniles per ml of suspension by adding required quantity of sterile water.

3.1.3 Raising of Chilli Seedlings

Chilli seedlings were raised by sowing seeds of the local accession Vellayani local 1 in pots containing sterilized soil. Three weeks after sowing, two seedlings of uniform size and growth were transplanted in 30 cm diameter earthen pots filled with denematized soil. The seedlings were thinned to one per pot after establishment of the plants.

3.1.4 *Evaluation of Pathogenicity*

Fifteen days after transplanting (DAT), chilli plants were inoculated with freshly hatched J_2 of *M. incognita* at the following densities.

T_1	-	50 J_2 / 100 g soil
T_2	-	100 J_2 /100 g soil
T_3	-	200 J_2 /100 g soil
T_4	-	300 J_2 /100 g soil
T_5	-	Control (without nematode)

Inoculation was done by boring five holes in the soil about 4 cm deep with a glass rod, 1.5 cm away from the base of the plant. The required suspension was pipetted out equally into five holes which were closed immediately. The pots were irrigated to keep the soil moist. The plants were maintained giving all the recommended agronomic practices (Kerala Agricultural University, 2002). The experiment was laid out in completely randomised design with five replications. Ten additional plants were maintained for each treatment for destructive sampling at 30 and 60 DAT.

Yield was recorded during the experiment. When yield was reduced the plants were uprooted. Observations on height of plant, number of leaves and nematode population in soil and root were recorded.

3.2 SCREENING OF ACCESSIONS

Thirteen accessions as detailed below were screened for comparing the relative susceptibility/tolerance to root-knot nematode. The trial was laid out in Completely Randomised Design with three replications.

	Accessions	Source
1	Moru Mulagu	Local collections
2	Khandari	Local collections
3	Ettumanoor Local	Local collections
4	Kolla mulagu	Local collections
5	Vellayani local 1	Local collections
6	Vellayani local 2	Local collections
7	G-4	SPIC, Bangalore
8	Indam Jwala	SPIC, Bangalore
9	Fire	SPIC, Bangalore
10	Byadagi	SPIC, Bangalore
11	Pusa Jwala	IARI, New Delhi
12	Pusa Sadabahar	IARI, New Delhi
13	Pant C-1	IARI, New Delhi
14	Jwalasakhi	KAU, Vellayani
15	Jwalamukhi	KAU, Vellayani

Seedlings of the accessions were raised and transplanted as described in 3.1.3. The J_2 of *M. incognita* were inoculated at the pathogenic level determined in 3.1.4. Sixty days after transplanting the plants were uprooted and observations on nematode population in soil and root and number of galls were recorded. Damage caused by the insect pests *viz.*, *Scirtothrips dorsalis* and *Polyphagotarsonemus latus* was scored.

3.3 EVALUATION OF BIOAGENTS AND OIL CAKES

An experiment was conducted in 30 cm diameter pots to evaluate the efficacy of bioagents and oil cakes in controlling *M. incognita* in chilli in comparison with carbofuran.

3.3.1 Pot culture trial

The experiment was laid out in completely randomized design with seven treatments and three replications. The treatments were:

T_1–Native AMF @ 250 spores per plant at planting

T_2–Fluorescent pseudomonads two per cent as root dip and soil drenching 30 days after transplanting

T_3–*Trichoderma* sp. (organic matter enriched with *Trichoderma* sp. at five per cent level) at planting

T_4–Neem cake @ 1 t ha^{-1} 15 days before planting

T_5–Mustard cake @ 1 t ha^{-1} 15 days before planting

T_6–Carbofuran @ 1 kg *ai* ha^{-1} two days after inoculation of J_2

T_7–Control (untreated)

The chilli plants were raised as in 3.1.3 and inoculated with J_2 of *M. incognita* at the pathogenic level determined in 3.1.4. 15 days after transplanting. The observations recorded included height of the plants, number of leaves, shoot weight, root weight and nematode population in soil and root.

3.3.2 Preparation and Application of AMF Inoculum

Perlite–vermiculite based Arbuscular mycorrhizal inoculum containing mixed cultures of *Glomus fasciculatum* and native isolates, *G. monosporum* and *Glomus* sp. (GI.1) having an infective propagule count of 250 spores per 50 g obtained from the Department of Plant Pathology, College of Agriculture, Vellayani was used for the experiment. Fifty gram of inoculum was applied per pot, mixed with top soil and seeds were sown over it. Three weeks after sowing the mycorrhizal seedlings were transplanted to pots containing 50g of vermiculite based AMF formulation.

3.3.3 Preparation and Application of fluorescent pseudomonads

The talc based formulation of fluorescent pseudomonads from the Department of Plant Pathology, College of Agriculture, Vellayani was used for soil drenching. Drenching was done with two per cent suspension of the formulation in water 30 days after transplanting.

3.3.4 Preparation and Application of *Trichoderma* sp.

Dry cow dung and neem cake were taken in 9 : 1 ratio and powdered to a coarse texture and mixed well to use as food base for multiplication of *Trichoderma* sp. Talc based formulation of *Trichoderma* sp. 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 newspaper. Care was taken to maintain the moisture by sprinkling water as and when required. The food base was mixed on eighth and twelfth day to achieve uniform growth. On the fifteenth day the inoculum so developed recorded *Trichoderma* sp. population 10^6 per gram (Sivaprasad, 1998). This inoculum was used for treatment at the time of planting.

3.3.5 Application of oilcakes

The neem cake and mustard cake were applied fifteen days prior to planting for decomposition. These oilcakes were applied at the rate of 1 t ha^{-1}.

3.3. 6 Mycorrhizal Colonization Percentage

The percentage of mycorrhizal colonization in root was estimated following the procedure of Phillips and Hayman (1970). Cleaned root samples free of soil. particles were cut into 1 cm sized bits and fixed in FAA (formalin : acetic acid : ethanol, 5 : 5 : 90) for three hours. Softening of the root bits was done by simmering in ten per cent potassium hydroxide at 90°C for one hour. After cooling, the root bits were repeatedly rinsed in tap water to remove the excess of alkali and then acidified with two per cent hydrochloric acid. The root bits were then stained by keeping it 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°C for three minutes. The excess stain from the root tissue was removed by clearing overnight 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 0 to 4 were given depending on the extent of mycorrhizal infection. The average value thus obtained from 100 root bits examined was taken as mycorrhizal index.

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

3.3.7 Estimation of Population of fluorescent pseudomonads and *Trichoderma* sp.

Population of fluorescent pseudomonads and *Trichoderma* sp. in the rhizosphere soil was estimated by the dilution plate technique (Timonin, 1940). One gram of rhizosphere soil was taken along with root material and transferred to 100 ml sterile water blank and shaken for five to ten minutes on a shaker. Different dilutions of 10^{-2}, 10^{-3}, 10^{-4}, 10^{-5} and 10^{-6}

were prepared from this stock suspension. The population of fungi and bacteria were estimated at 10^{-3} and 10^{-5} dilutions respectively. King's B medium, Martins Rose Bengal agar medium and potato dextrose agar medium were used for plating fluorescent pseudomonads and *Trichoderma* sp. respectively. The composition of the media used were as follows :

King's B medium

1)Peptone 20 grams

2)Dipotassium hydrogen phosphate 1.5 grams

3)Magnesium sulphate 1.5 grams

4) Glycerol 10 ml

5)Agar agar 20 mg

6)Distilled water 1 litre

7)PH – 7.2

Martin's Rose Bengal Agar Medium

1)Peptone 5 g

2)Potassium dihydrogen phosphate 1 g

3)Magnesium sulphate 0.5 g

4)Dextrose 10 g

5)Rose Bengal 33 mg

6)Agar agar 15 g

7)Distilled water 1 litre

8)pH 6 – 6.5

After sterilization 3ml of one per cent streptomycin sulphate solution per litre was added. One ml aliquots from the dilutions 10^{-3} and 10^{-6} were transferred to sterile petri plates. Melted and cooled media at 45°C was poured at 20 ml per dish and rotated gently for thorough mixing. The petri dishes were then incubated at 28 ± 1°C for 96 hours. Observations were recorded as number of colony forming units (cfu) per gram of soil.

3.4 ASSESSMENT OF RESULTS

3.4.1 Height of Plants

The height of plants was assessed at 30 DAT, 60 DAT and at harvest. Height was measured from the first node to the base of the terminal bud and the average height was calculated.

3.4.2 Number of Leaves

Total number of leaves on every plant was recorded at 30 DAT, 60DAT and at final harvest and number of leaves per plant was calculated.

3.4.3 Shoot Weight

Shoot weight of the plants at the time of harvest was assessed by cutting off the roots and weighing the shoots separately for each plant and mean shoot weight per plant was determined.

3.4.4 Root Weight

The root system of each plant after proper washing and drying was weighed at final harvest and the mean per plant was ascertained.

3.4.5 Nematode Population in Soil

Soil samples were collected from each pot 30 and 60 days after transplanting and at final harvest and nematode was extracted from the respective soil samples following the method of Cobb's sieving and decanting technique (Cobb, 1918) and modified Baermann's method. The population of the nematode thus extracted was counted under a stereoscopic microscope.

3.4.6 Nematode Population in Roots

Root samples collected were washed thoroughly in water under a tap. Five gram of the root was weighed and cut into small bits and placed on tissue paper supported by the wire net placed on a petri plate. Emerging nematodes were collected at regular intervals of 24 hours up to four days. The nematode suspension thus collected were pooled and counted under a stereoscopic microscope.

3.4.7 Root-knot Index in Pathogenicity and Management Studies

The number of galls per plant was counted and the root-knot indexing was done as detailed below :

Number of galls per plant	Root knot index
0 – 25 galls	1
26 – 50 galls	2
51-75 galls	3
76 – 100 galls	4
>100 galls	5

3.4.8 Root-knot Index in Varietal Screening

The root-knot indexing in varietal screening was done as follows:

No. of galls per plant	Root-knot index	Reaction
0	1	Highly resistant
1-10	2	Resistant
11-30	3	Moderately resistant
31-100	4	Susceptible
>100	5	Highly susceptible

3.4.9 Damage Score of Pest Infestation

Pest infestation was graded using the following damage score

Damage score	Percentage damage	Reaction
1	0 – 10	Resistant
2	11 – 25	Moderately Resistant
3	26 – 50	Susceptible

RESULTS

4. RESULTS

4.1 PATHOGENICITY AND YIELD LOSS ASSESSMENT

The effect of varying population densities of *M. incognita* on growth parameters of chilli at different intervals are presented in Tables 1 and 2.

4.1.1 Effect of Different Inoculum Levels on Plant Growth at 30 and 60 Days After Transplanting (DAT)

4.1.1.1 Plant Height

Significant decrease was seen in the height of chilli plants with increasing inoculum levels of *M. incognita* at 30 DAT (Table1). While the mean height of uninoculated plants was 23.90 cm, it was 19.42 cm in plants inoculated with 50 J_2/ 100g soil and the treatment differed significantly from all other treatments. At 100 and 200 J_2/ 100 g soil, the mean height of the plants was 17. .02 cm and 15.78 cm respectively and the treatments were on par. Maximum reduction in height was seen in plants inoculated with 300 J_2 /100 g soil, the mean height of the plants being 13.42cm. The treatment differed significantly from all other treatments.

At 60 DAT too, significant decrease was noticed in the height of plants at all inoculum levels when compared to the nematode uninfested plants (41.92cm). While the mean height of plants receiving 50 J_2/100 g soil was 35.86 cm, it was 29.52, 23.38 and 19.88 cm in plants inoculated with 100, 200 and 300 J_2 /100 g soil. All the treatments differed significantly from each other. Again, maximum reduction in height was observed in plants treated with 300J_2/100g soil.

4.1.1.2 Number of Leaves

Inoculation of *M. incognita* in varying inoculum levels resulted in a corresponding decrease in the mean number of leaves at 30 DAT too. However, there was no significant difference between the number of leaves in plants inoculated with 50 J_2/100 g soil and nematode uninfested

Table 1 Influence of population densities of *M. incognita* on plant growth parameters of *C. annuum* at different intervals (mean of five replications)

Inoculum density (J_2/100 g soil)	Plant height (cm)		Number of leaves	
	30 DAT	60 DAT	30 DAT	60 DAT
50	19.42^{c}	35.86^{d}	25.00^{bcd}	50.20^{cd}
100	17.02^{b}	29.52^{c}	20.60^{abc}	48.40^{bc}
200	15.78^{b}	23.38^{b}	18.80^{ab}	44.00^{ab}
300	13.42^{a}	19.88^{a}	16.40^{a}	40.60^{a}
Control (without nematode)	23.90^{d}	41.92^{e}	29.20^{d}	55.40^{d}
CD (0.05)	1.664*	2.074*	6.503*	5.677*

DAT – Days after transplanting
*Significant at 5 per cent level

plants the mean number being 25.00 and 29.20 per plant respectively. At 100 J_2/100 g soil, the mean number of leaves per plant was 20.60 which was on par with plants inoculated with 50 J_2/100 g soil. Statistically, the treatment was also on par with plants inoculated with 200 J_2/100 g soil, the mean number of leaves in the treatment being 18.80. Inoculation of 300 J_2/100 g soil resulted in the lowest number of leaves per plant (16.40).

A similar trend was seen at 60 DAT too. The average number of leaves in uninoculated plants was 55.40 which was on par with plants inoculated with 50 J_2/100 g soil (50.20 per plant) which in turn was statistically on par with plants inoculated with 100 J_2/100 g soil (48.40). The mean number of leaves in plants inoculated with 200 J_2/100 g soil was 44.00 and the treatment was on par with plants inoculated with 300 J_2 and 100 J_2/100g soil, the number of leaves being 40.60 per plant in the former treatment.

4.1.2 Effect of Different Inoculum levels of *M. incognita* on Plant Growth at Final Harvest

The results are presented in Table 2.

4.1.2.1 Plant Height

Population of *M. incognita* at all densities tested resulted in significant reduction in the height of plants at final harvest compared to the mean height of uninoculated plants (52.30 cm). The mean height of plants inoculated with 50, 100 and 200 J_2/100 g soil were 41.50, 35.60 and 32.40cm respectively. Significant difference was seen between all the treatments. A progressive reduction was seen in the height of plants with an increase in the inoculum density. Maximum reduction was seen in plants inoculated with 300 J_2/100g soil, the mean height of the plants being 28.14 cm.

4.1.2.2 Number of Leaves

There was no significant difference between the mean number of leaves in plants inoculated with 50 J_2/100 g soil (73.20) and uninoculated

Table 2 Influence of population densities of *M. incognita* on growth parameters at final harvest and yield of *C. annuum* (mean of five replications)

Inoculum density (J_2/100 g soil)	Plant height (cm)	Number of leaves	Shoot weight (g)	Root weight (g)	Number of fruits	Weight of fruits (g)
50	41.50^{d}	73.20^{cd}	50.14^{c}	10.20^{cd}	24.40^{d}	115.42^{d}
100	35.60^{c}	67.80^{bc}	41.02^{b}	7.46^{abc}	19.80^{c}	84.22^{c}
200	32.40^{b}	60.40^{b}	37.16^{ab}	5.74^{ab}	14.60^{b}	67.72^{b}
300	28.14^{a}	50.60^{a}	34.58^{a}	4.46^{a}	10.60^{a}	51.84^{a}
Control (without nematode)	52.30^{e}	78.80^{d}	57.20^{d}	12.92^{d}	35.60^{e}	140.06^{e}
CD (0.05)	1.483*	8.094*	6.303*	3.173*	2.389*	5.847*

*Significant at 5 per cent level

plants (78.80). The number of leaves was lowest in plants inoculated with 300 J_2/100 g soil, being 50.60 per plant. The treatment was statistically inferior to all other treatments. Plants inoculated with 200 J_2/100 g soil had 60.40 leaves per plant and it was on par with the plants inoculated with 100 J_2/100 g soil the number of leaves per plant being 67.80.

4.1.2.3 Shoot Weight

Significant reduction was also observed in the shoot weight of plants at different inoculum levels of *M. incognita* compared to uninoculated plants. While the shoot weight of nematode uninfested plants was 57.20g, it was 50.14g in plants inoculated with 50 J_2/100g soil which differed statistically from other treatments. The mean shoot weight of 100 J_2/100 g soil inoculated plants was 41.02 g which was on par with the shoot weight of plants in 200 J_2/100 g soil (37.16 g). Minimum shoot weight was observed in 300 J_2/100 g soil inoculated plants (34.58 g) which in turn was on par with 200 J_2/100 g soil inoculated plants.

4.1.2.4 Root Weight

A progressive decrease in the weight of roots was also noted with increase in the inoculum levels of *M. incognita*. Plants inoculated with 300 J_2/100 g soil recorded the lowest mean root weight (4.46 g). It was followed by 200 and 100 J_2/100 g soil levels (5.74 and 7.46 g respectively) which were statistically different from the uninoculated plants but on par with each other. Plants inoculated with 50 J_2/100 g soil with the mean root weight of 10.20 g differed statistically from all other treatments but was on par with uninoculated control plants (12.92g).

4.1.2.5 Yield (per plant)

The various levels of nematode population showed significant reduction in the yield of chilli plants compared to uninoculated plants.

The yield in terms of number of fruits was reduced significantly in all the inoculum levels studied. The number of fruits was minimum in plants treated with 300 J_2/100 g soil, being 10.60 per plant. When inoculated with 200 J_2/100 g soil, the plants yielded 14.60 chillies per plant. Inoculation of the plants with lower population levels of *M. incognita viz.*, 100 and 50J_2/100g soil yielded significantly higher number of fruits when compared to the plants receiving higher levels of the nematode inoculum. The number of fruits in the treatments were 19.80 and 24.40 per plant respectively as against 35.60 fruits per plant in uninoculated chilli plants. All the treatments differed significantly.

Considering the weight of fruits again a significant difference was seen in the different inoculum levels of *M. incognita*. Lowest yield was recorded in plants inoculated with 300 J_2/100 g soil (51.84 g) followed by plants inoculated with 200 J_2/100 g soil (67.72 g per plant). The weight of fruits obtained from plants inoculated with 100 J_2/100 g soil was 84.22 g per plant and 115.42 g per plant in 50J_2/100g soil. Weight of fruits was maximum in control plants being140.06 g and it differed significantly from all other treatments. In addition, all the treatments exhibited significant variation among themselves.

4.1.3 Multiplication of Root-knot Nematode

Multiplication of *M. incognita* in chilli in relation to initial inoculum levels assessed in terms of nematode population in soil and root and reproduction rate at different levels is presented in Tables 3 and 4.

4.1.3.1 Nematode Multiplication at 30 DAT

4.1.3.1.1 Population in Soil (No. per 100 g soil)

Statistical analysis of the data indicated significant difference in the population of *M. incognita* in the soil at different inoculum densities. Maximum number of nematodes (334.60) was observed in soil samples collected from pots inoculated with 300 J_2/100g soil, while the mean number of nematodes seen in the rhizosphere of plants inoculated with 200 J_2/100 g soil was 245.00. It was 114.80 in 100 J_2/100 g soil and 61.80

Table 3 Influence of initial population densities of *M. incognita* on population of the nematode in *C. annuum* at different intervals

Initial population density (J_2/ 100 g soil)	Nematode population					
	30 DAT			(60 DAT		
	Soil (100 g)	Root (5 g)	Reproduction rate (Rf = Pf / Pi)	Soil (100 g)	Root (5 g)	Reproduction rate (Rf = Pf / Pi)
50	61.80^{a}	28.40^{a}	1.80^{b}	79.80^{a}	57.40^{a}	2.74^{d}
100	114.80^{b}	72.00^{b}	1.87^{d}	138.60^{b}	100.20^{b}	2.39^{c}
200	245.00^{c}	106.80^{c}	1.76^{a}	242.60^{c}	152.80^{c}	1.98^{b}
300	334.60^{d}	216.60^{d}	1.84^{c}	342.60^{d}	228.00^{d}	1.90^{a}
Control (without nematode)	-	-	-	-	-	-
CD (0.05)	6.022*	5.606*	0.067*	4.196*	5.267*	0.062*

Rf = Reproduction rate
Pi = Initial nematode population
Pf = Final nematode population (soil + root)
DAT = Days after transplanting

*Significant at 5 per cent level

Table 4. Influence of initial population densities of *M. incognita* on population of the nematode in *C. annuum* at harvest (mean of five replications)

Initial population density (J_2/ 100 g soil)	Nematode population			Root-knot index
	Soil (100 g)	Root (5 g)	Reproduction rate (Rf = Pf / Pi)	
50	32.60^{a}	45.20^{a}	1.56^{ab}	1.00
100	73.20^{b}	81.40^{b}	1.55^{a}	1.80
200	191.00^{c}	144.40^{c}	1.68^{c}	3.00
300	267.40^{d}	211.00^{d}	1.59^{ab}	3.60
Control (without nematode)	-	-	-	
CD (0.05)	6.025*	5.923*	0.062*	

Rf = Reproduction rate
Pi = Initial nematode population
Pf = Final nematode population (soil + root)

*Significant at 5 per cent level

in 50 J_2/100 g soil. Significant difference was seen between all the treatments.

4.1.3.1.2 Population in Root (No. per 5 g root)

The larval population estimated from the roots too varied significantly in the different treatments with the highest number of larvae being recovered from plants treated with 300 J_2/100 g soil (216.60). The mean number of *M. incognita* obtained from the roots of chilli plants treated with 200 J_2/100 g soil was 106.80, 72.00 in 100 J_2/100 g soil and 28.40 in 50 J_2/100 g soil. Statistically the treatments differed significantly.

4.1.3.1.3 Reproduction Rate

Statistical analysis of the data pertaining to the reproduction rate of nematodes revealed that all the treatments were significantly different. The highest reproduction rate was noted for the 100 J_2/100 g soil inoculum level (1.87) followed by 300 J_2/100 g soil (1.84), 50 J_2/100 g soil (1.80) and 200 J_2/100 g soil (1.76).

4.1.3.2 Nematode Multiplication at 60 DAT

4.1.3.2.1 Population in Soil (No. per 100 g soil)

Assessment of population of *M. incognita* in the soil showed that the treatments were significantly different from each other with the maximum number of nematode recovered from 300 J_2/100 g soil treated pots (342.60). An increase in nematode population was observed in 300 J_2/100 g soil, 100 J_2/100 g soil (138.60) and 50 J_2/100 g soil (79.80) inoculated soil samples in contradiction to 200 J_2/100 g soil inoculated ones (242.60) which decreased to this number from 245.00 recorded at 30 DAT.

4.1.3.2.2 Population in Root (No. per 5 g root)

Maximum number of *M. incognita* larvae (228.00) was recovered from the root sample of plants inoculated with 300 J_2/100 g soil. A progressive decrease was observed in the population of the nematode extracted from the roots of chilli plants with decreasing inoculum levels. While the mean number of J_2 obtained from roots of plants receiving 200 J_2/100 g soil was 152.80, it was 100.20 in 100 J_2/100 g soil and 57.40 in 50 J_2/100 g soil . Significant difference was manifested between all the inoculum levels.

4.1.3.2.3 Reproduction Rate

Highest reproduction rate of 2.74 was found in the inoculum level 50 J_2/100 g soil which was statistically different from the treatment 100 J_2/100 g soil (2.39). This treatment in turn also differed from the treatment 200 J_2/100 g soil (1.98). An initial inoculum level of 300 J_2/100 g soil recorded the lowest reproduction rate, being 1.90 and it differed significantly from all other treatments.

4.1.3.3 Nematode Multiplication at Final Harvest

4.1.3.3.1 Population in Soil (No. per 100 g soil)

The number of second stage larvae of *M. incognita* extracted from the soil samples was significantly different in all the inoculum levels. Highest population of the nematode was present in soil samples collected from pots inoculated with 300 J_2/100 g soil (267.40), followed by 200 J_2/100 g soil (191.00), 100 J_2/100 g soil (73.20) and 50 J_2/100 g soil (32.60).

4.1.3.3.2 Population in Root (No. per 5 g of roots)

Estimation of the larval population in the roots also showed significant variation in different treatments. Again maximum number of *M. incognita* larvae was recovered from plants inoculated with 300 J_2/100 g soil (211.00). Following it were the treatments 200 J_2/100 g soil with mean nematode population of 144.40, 100 J_2/100 g soil (81.40) and 50 J_2/100 g soil (45.20).

4.1.3.3.3 Reproduction Rate

The reproduction rate of the nematode was highest when the initial population density was 200 J_2/100 g soil, being 1.68. This was statistically superior to all other inoculum levels . The other treatments were on par with each other, the reproduction rate being 1.56 for 50 J_2/100 g soil, 1.55 for 100 J_2/100 g and 1.59 for 300 J_2/100 g soil inoculum levels.

4.1.4 Root-knot Index

Root-knot index ranged from 1.00 to 3.60 (Table 4). The highest root-knot index was registered in the treatment 300 J_2 / 100 g soil (3.60) followed by 200 J_2 (3.00), 100 J_2 (1.80) and 50 J_2/ 100 g soil (1.00).

4.2 SCREENING FOR RESISTANCE

Results on the preference of *M. incognita* for different local and improved accessions of chilli assessed in terms of nematode population characteristics are presented in Table 5.

4.2.1 Nematode Population in Soil (No. per 100 g soil)

Significant difference was observed in the population of the second stage juveniles recovered from the rhizosphere of the accessions tested, 60 days after inoculation. Among the varieties screened lowest population of *M incognita* was recorded from the rhizosphere of Pusa Sadabahar, the mean population being 85.67.It differed significantly from the resistant check, Pusa Jwala which had a mean nematode population of 70.67. The cultivars released from Kerala Agricultural University viz., Jwalamukhi and Jwalasakhi supported a soil population of 140.33 and 151.00 and differed significantly from each other and the resistant and susceptible checks *viz.*, Vellayani local 1 which recorded a population of 261.33. A mean population of 151.00 was seen in the rhizosphere of accession Vellayani local 2. A significantly higher population of the nematode was observed in Khandari (168.67) and its effect was statistically different

Table 5 Reaction of local and high yielding accessions of *C. annuum* to *M. incognita* (mean of three replications)

Accessions	Nematode population		Reproduction rate (Rf = Pf / Pi)	Root –knot index (1-5 scale)		Reaction
	Soil (100 g)	Root (5 g)		Range	Mean score	
Local Khandari	168.67^{c}	131.67^{e}	1.54^{cd}	3-4	3.30	Moderately resistant
Moru mulagu	221.00^{f}	107.67^{cd}	1.64^{e}	4-4	4.00	Susceptible
Ettumanoor local	235.33^{gh}	154.00^{f}	1.95^{ghi}	4-4	4.00	Susceptible
Kolla mulagu	231.00^{g}	106.33^{cd}	1.69^{e}	4-4	4.00	Susceptible
Vellayani local 2	151.00^{d}	121.00^{e}	1.35^{c}	5-5	5.00	Highly susceptible
High Yielding Jwalamukhi	140.33^{c}	70.67^{b}	1.06^{b}	4-4	4.00	Susceptible
Jwalasakhi	151.00^{d}	121.00^{e}	1.36^{cd}	4-4	4.00	Susceptible
Pusa Sadabahar	85.67^{b}	101.33^{c}	0.66^{a}	3-3	3.00	Moderately resistant
Pant C-1	241.33^{hijk}	155.00^{f}	1.98^{ghi}	4-4	4.00	Susceptible
Indam jwala	239.33^{ghi}	128.33^{e}	1.84^{eg}	4-4	4.00	Susceptible
Fire	248.33^{ijk}	177.70^{g}	2.14^{j}	4-4	4.00	Susceptible
G-4	240.33^{ghij}	228.00^{h}	2.33^{k}	4-5	4.30	Susceptible
Byadagi	221.67^{f}	152.33^{f}	1.87^{gh}	4-4	4.00	Susceptible
Vellayani local 1 (susceptible check)	261.33^{l}	234.70^{h}	2.48^{k}	4-5	4.60	Susceptible
Pusa Jwala (resistant check)	70.67^{a}	24.00^{a}	0.47^{a}	2-2	2.00	Resistant
CD (0.05)	9.299*	11.359*	0.212*			

Rf = Reproduction rate, Pi = Initial nematode population, Pf = Final nematode population (soil + root)
*Significant at 5 per cent level

from the susceptible check and other local accessions. Moru mulagu (221.00) and Byadagi (221.67) supported a large population of the nematode and were on par. Maximum nematode population (248.33) was found in the variety Fire which differed significantly from the susceptible check Vellayani local 1, but was on par with Pant C-1 (241.33), G-4 (240.33) and Indam Jwala (239.33). The nematode population in local accessions Ettumanoor local (235.33) and Kolla mulagu (231.00) were on par with each other but differed significantly from the susceptible and resistant checks.

4.2.2 Nematode Population in Root (No. per 5 g of roots)

Significant variation was also seen in the nematode population obtained from the roots of the different accessions. The cultivar Jwalamukhi had the lowest population (70.67). However, statistically it was inferior to the resistant check,Pusa Jwala (24.00). The mean root population obtained from the accessions Pusa Sadabahar. Kolla mulagu and Moru mulagu were 101.33,106.33 and 107.67 respectively which were on par, but differed significantly from both the resistant and susceptible checks. A similar trend was displayed by the accessions Khandari, Indam Jwala, Jwalasakhi and Vellayani local 2 where the population in roots was 131.67, 128.33, 121.00 and 121.00 respectively. A significantly higher population was recovered from the root samples of the variety Fire (177.70) which differed significantly from all other accessions. The population of the nematode in the roots of Ettumanoor local, Pant C-1 and Byadagi were154.00, 155.00 and 152.33 and statistically they were on par. Similarly. the susceptible check. Vellayani local 1 and G-4 with a population of 234.70 and 228.00 were statistically on par in their preference for the nematode.

4.2.3 Reproduction Rate

Significant variation was seen in the reproduction rate of *M. incognita* in the different accessions. Reproduction rate of the nematode was significantly low in Pusa Sadabahar, being 0.66 and it was on par with the resistant check, Pusa Jwala where the reproduction rate was 0.47 .In Jwalamukhi the nematode had a reproduction rate of 1.06 and differed significantly from all other accessions. Reproduction rate of *M. incognita* in Vellayani local 2 was 1.35 which was on par with Jwalasakhi (1.36).Accessions Khandari (1.54), Moru mulagu (1.64), Kolla mulagu (1.69), Indam Jwala (1.84), Byadagi (1.87), Ettumanoor local (1.95), Pant C-1 (1.98) and Fire (2.14) were on par with each other . Similarly, the accession G-4 which recorded a reproduction rate of 2.33 was on par with the susceptible check (2.48) in their effect on the reproduction of the nematode.

4.2.4 Root-knot Index

The improved accession Pusa Sadabahar and the local accession Khandari registered a mean root-knot index of 3.00 and 3.30 respectively with the range of index being 3-3 for Pusa Sadabahar and 3-4 for Khandari. Highest root-knot index of 5.00 (5-5) was recorded in Vellayani local 2 and it was followed by the susceptible check .All other accessions viz., Moru mulagu, Ettumanoor local, Kolla mulagu, Jwalamukhi, Jwalasakhi, Pant C-1,Indam Jwala, Byadagi and Fire had a root-knot index of 4.00,the range being 4-4.G-4 possessed a root-knot index 4.30 while the susceptible check Vellayani local 1 had a root-knot index,4.60. Resistant check Pusa Jwala registered a root-knot index of 2.00 with the range of index being 2-2.

4.2.5 Reaction of Chilli Accessions to Nematode Infestation

Considering the reaction of the accessions to root-knot nematode, *M. incognita*, based on the root-knot index, Khandari and Pusa Sadabahar were seen to be moderately resistant. The local accessions *viz*., Moru mulagu, Ettumanoor local and Kolla mulagu were susceptible. The improved varieties Pant C-1, Fire, Indam Jwala, Byadagi and G-4 together with the KAU released varieties Jwalamukhi and Jwalasakhi also showed a

Table 6 Reaction of local and high yielding accessions of *C. annuum* to *Scirtothrips dorsalis* and *Polyphagotarsonemus latus* (mean of three replications)

Accessions	Damage score (1-4)			Reaction
	15 DAT	30 DAT	45 DAT	
Local				
Moru mulagu	1.00	2.30	3.30	Susceptible
Khandari	1.00	2.70	3.70	Susceptible
Ettumanoor local	1.30	2.30	3.70	Susceptible
Vellayani local 2	1.00	2.70	3.30	Susceptible
Kolla mulagu	1.30	2.70	3.30	Susceptible
High yielding				
Jwalamukhi	1.00	2.00	2.00	Moderately resistant
Jwalasakhi	1.00	1.70	2.30	Moderately resistant
Pusa Sadabahar	1.00	2.00	2.00	Moderately resistant
Pant C-1	1.00	1.00	2.00	Moderately resistant
Indam Jwala	1.00	2.70	3.00	Susceptible
Fire	1.00	2.30	3.00	Susceptible
G-4	1.00	2.00	3.00	Susceptible
Byadagi	1.00	3.00	3.00	Susceptible
Vellayani local 1 (susceptible check)	1.30	2.30	3.30	Susceptible
Pusa Jwala (resistant check)	1.00	1.30	2.00	Moderately resistant

susceptible reaction whereas the local accession Vellayani local 2 showed a highly susceptible reaction.

4.2.6 Reaction of Chilli Accessions to Pest Infestation

The score of the extent of damage caused by chilli thrips, *Scirtothrips dorsalis* and mite, *Polyphagotarsonemus latus* presented in Table 6 indicated a mean damage score ranging from 1.00 to 1.30 when observed at 15DAT. An increase in the damage was seen at 30DAT. The accessions Pant C-1 (1.00), Pusa Jwala (1.3) and Jwalasakhi (1.70) had a lower damage score when compared to the other varieties. While the damage score of G-4, Pusa Sadabahar and Jwalamukhi were 2.00, it was 2.30 in Moru mulagu, Ettumanoor local, Fire and Vellayani local 1 and 2.70 in Khandari, Vellayani local 2, Kolla mulagu and Indam Jwala. At 45 DAT, Pusa Jwala, Pant C-1, Pusa Sadabahar and Jwalamukhi had a damage score of 2.00 and registered a moderately resistant reaction. Jwalasakhi with a damage score of 2.30 showed a moderately resistant reaction. All the other accessions *viz.*, Byadagi, Fire, G-4 and Indam Jwala (3.00) Vellayani local 1, Kolla mulagu, Vellayani local 2 and Moru mulagu (3.30) and Khandari and Ettumanoor local (3.70) were susceptible to pest attack.

4.3 EFFECT OF BIOAGENTS AND OILCAKES

4.3.1 Plant Growth Parameters

4.3.1.1 Plant Height

The results are presented in Table 7.

There was no statistically significant variation in height of chilli plants due to application of different management treatments at 30 DAT. The mean height of plants in the different treatments ranged from 15.03 cm to 19.33 cm as compared to 13.70 cm in nematode infested plants.

However, a significant difference was noted in the height of plants in the different treatments at 60 DAT. Maximum height was produced by

Table 7 Effect of bioagents and oil cakes on the growth parameters of *C. annuum* infested with *M. incognita* (mean of three replications)

Treatments	Plant height (cm)			Number of leaves			Shoot weight (g)	Root weight (g)
	30 DAT	60 DAT	Final harvest	30 DAT	60 DAT	Final harvest		
Native AMF @ 250 spores per plant at planting	19.23	32.70^{abcd}	41.23^{b}	16.00	46.67^{abc}	74.67^{c}	40.40^{c}	9.33^{c}
Fluorescent pseudomonads (2 per cent root dip and soil drenching) 30 DAT	15.03	32.03^{abc}	36.50^{a}	14.00	38.00^{ab}	58.00^{b}	34.47^{b}	6.90^{ab}
Trichoderma sp. 5 per cent at planting	18.80	31.23^{ab}	45.00^{c}	23.00	66.67^{d}	80.00^{c}	44.83^{d}	10.13^{cd}
Neem cake @ 1 t ha^{-1} 15 days before planting	19.33	41.27^{c}	50.63^{d}	20.67	87.67^{e}	101.00^{e}	49.30^{e}	11.30^{de}
Mustard cake @ 1 t ha^{-1} 15 days before planting	19.07	39.40^{c}	47.43^{c}	20.33	71.00^{d}	93.00^{d}	45.33^{d}	10.36^{cde}
Carbofuran @ 1 kg *ai* ha^{-1} 2 days after inoculation of J_2	17.37	32.07^{abcd}	40.50^{b}	14.33	41.67^{abc}	56.00^{b}	35.92^{b}	7.70^{b}
Control (untreated)	13.70	28.67^{a}	35.83^{a}	13.67	34.33^{a}	48.33^{a}	30.67^{a}	5.57^{a}
CD (0.05)	NS	5.671*	2.604*	NS	13.911*	6.162*	3.340*	1.360*

DAT = Days after transplanting, * Significant at 5 per cent level plants in neem cake@ 1 t ha^{-1} treated soil (41.27 cm) which was on par with plants treated with mustard cake @ 1 t ha^{-1} (39.40 cm) and superior to all other treatments. The height of plants treated with bioagents *viz*., AMF @ 250 spores per plant (32.70 cm), fluorescent pseudomonads 2per cent (32.03 cm) and *Trichoderma* sp.5 per cent (31.23 cm) did not differ significantly from the nematode affected plants and were on par with carbofuran @ 1 kg *ai* ha^{-1} (32.07 cm) and untreated control (28.67 cm).

At final harvest, again neem cake @ 1 t ha^{-1} treated plants had the maximum height (50.63cm) which was significantly superior to all other treatments. Application of mustard cake @ 1 t ha^{-1} also increased the height of plants (47.43cm) and was on par with *Trichoderma* sp.5 per cent treated plants (45.00 cm) but differed from nematode uninfested plants (35.83). A significant difference was seen in the treatments AMF @250 spores per plant (41.23cm) and carbofuran @ 1 kg *ai* ha^{-1} (40.50cm). Treatment with fluorescent pseudomonads 2 per cent (36.50cm) was on par with untreated control but differed significantly from other treatments.

4.3.1.2 Number of Leaves

There was no significant variation in leaf production in chilli plants at 30 DAT when treated with bioagents and oilcakes. The number of leaves produced in the different treatments ranged from 14.00 to 23.00 compared to 13.67 leaves in nematode uninfested plants.

At 60 DAT the treatments showed significantly different variation in the production of leaves. The number of leaves produced was maximum in plants treated with neem cake @ 1 t ha^{-1} (87.67) which differed significantly from all other treatments. Treatment with mustard cake @ 1 t ha^{-1} also instigated more leaf production (71.00) and was statistically on par with *Trichoderma* sp.5 per cent (66.67) which in turn manifested a significantly different reaction in relation to other treatments. The mean number of leaves in plants receiving AMF @ 250 spores per plant was 46.67 and it was on par with plants treated with carbofuran @ 1 kg *ai* ha^{-1} (41.67), fluorescent pseudomonads (38.00) and control (34.33).

The number of leaves produced per plant showed statistically significant variation at final harvest too. Again the neem cake @ 1 t ha^{-1} treated plants produced maximum leaves (101.00) followed by mustard cake @ 1 t ha^{-1} (93.00) and these two were statistically different and superior to other treatments and untreated control. The average number of leaves in untreated plants (48.33) was statistically different from other treatments. Fluorescent pseudomonads 2 per cent was on par with carbofuran @ 1 *ai* ha^{-1} treated plants (58.00 and 56.00 respectively). AMF @250 spores per plant (74.67) and *Trichoderma* sp. 5 per cent (80.00) treatments were on par and superior to control.

4.3.1.3 Shoot Weight

There was statistically significant variation in shoot weight of chilli plants . Treatment with bioagents and oilcakes also exerted a significant influence on the shoot weight of chilli plants.The mean shoot weight of the treated plants ranged from 34.47g to 49.30g as against the mean weight of 30.67g in untreated plants. The shoot weight was maximum in neem cake treatment @ 1 t ha^{-1} (49.30g) which was significantly superior to other treatments. It was followed by mustard cake treatment @ 1 t ha^{-1} (45.33g) which was statistically on par with soil application of *Trichoderma* sp.5per cent (44.83g). Significantly higher shoot weight was also seen in plants treated with AMF@250 spores per plant (40.40g). When compared to the control plants effect of carbofuran @ 1kg *ai* ha^{-1} and fluorescent pseudomonads 2 per cent on shoot weight was on par the weight of shoot in the treatments being 35.92 and 34.47g respectively and was significantly superior to untreated.

4.3.1.4 Root Weight

Statistical analysis of the data pertaining to the root weight of chilli plants under various treatments revealed significant difference between control and other treatments. Maximum root weight was recorded in plants treated with neem cake@ 1 t ha^{-1} the mean root weight being 11.30g which was on par with root weight of plants treated with mustard cake@ 1 t ha^{-1} (10.36 g) and *Trichoderma* sp. 5 per cent (10.13 g) treatments. Mustard cake @ 1 t ha^{-1} on the other hand statistically differed from carbofuran @ 1 kg *ai* ha^{-1} (7.70 g). Effect of application of AMF@250 spores per plant was superior to treatment with carbofuran @ 1 kg *ai* ha^{-1},fluorescent pseudomonads 2 per cent (6.90 g) and untreated control (5.57 g) while it was on par with mustard cake @ 1 t ha^{-1}. Similarly, root weight of plants treated with fluorescent pseudomonads 2per cent was on par with carbofuran @ 1kg *ai* ha^{-1}.

4.3.2 Nematode Population

4.3.2.1 Nematode Population in Soil (No. per 100 g soil)

The results relating to the effect of bioagents and oilcakes on the population of the root-knot nematode in chilli rhizosphere at 30,60DAT and final harvest are presented in Table 8.

Imposition of management practices showed a significant decrease in the population of the nematode at 30 DAT. Analysis of the data revealed that the mean population of nematode was lowest in carbofuran @ 1kg *ai* ha^{-1} treated pots (120.67) and the treatment was superior to all other treatments. This was followed by application of mustard cake @ 1 t ha^{-1} and treatment with vermiculite based AMF @250 spores per plant .The population of the nematodes in these treatments were 138.33and 140.33 respectively and they were on par. Amendment of the soil with neem cake @ 1 t ha^{-1} also reduced the nematode population significantly (149.67) when compared to control. These treatments were statistically different from untreated control (189.67). Effect of fluorescent pseudomonads 2 per cent (174.67) and *Trichoderma* sp. 5 per cent (166.33) was statistically on par and significantly superior to untreated

Table 8 Effect of bioagents and oil cakes on the population of *M. incognita* infesting *C. annuum* (mean of three replications)

Treatments	Nematode population						Root-knot index
	Soil (100 g)			Root (5 g)			
	30 DAT	60 DAT	Final harvest	30 DAT	60 DAT	Final harvest	
Native AMF @ 250 spores per plant at planting	140.33^{b}	98.33^{ab}	80.67^{abc}	133.00^{c}	98.00^{b}	67.67^{b}	1.30
Fluorescent pseudomonads (2 per cent root dip and soil drenching) 30 DAT	174.67^{d}	192.00^{d}	105.00^{e}	156.67^{d}	122.33^{c}	88.00^{c}	2.30
Trichoderma sp. 5 per cent at planting	166.33^{d}	128.00^{c}	93.00^{d}	121.00^{b}	77.67^{a}	51.67^{a}	2.00
Neem cake @ 1 t ha^{-1} 15 days before planting	149.67^{c}	124.00^{c}	88.30^{abcd}	161.00^{d}	138.00^{d}	111.00^{d}	2.00
Mustard cake @ 1 t ha^{-1} 15 days before planting	138.33^{b}	107.67^{b}	78.80^{ab}	141.00^{c}	116.33^{c}	80.33^{c}	2.00
Carbofuran @ 1 kg *ai* ha^{-1} 2 days after inoculation of J_2	120.67^{a}	90.67^{a}	76.70^{a}	104.00^{a}	70.67^{a}	52.33^{a}	2.00
Control (untreated)	189.67^{e}	260.70^{e}	295.67^{f}	173.67^{e}	217.33^{e}	250.33^{e}	3.00
CD (0.05)	9.035*	11.958*	11.853*	11.497*	8.016*	9.608*	-

DAT = Days after transplanting, *Significant at 5 per cent level plants as was AMF @ 250 spores per plant with mustard cake @ 1 t ha^{-1}, but these treatments were inferior to carbofuran @ 1 kg *ai* ha^{-1} as far as reducing nematode population was concerned.

Analysis of the data relating to the number of larvae in the root zone of chilli plants at 60 DAT showed significant reduction when compared to untreated check (260.70). Reduction in population was maximum in carbofuran @ 1 kg *ai* ha^{-1} treated plants (90.67) followed by AMF (98.33) and both the treatments were on par .In the pots amended with mustard cake @ 1 t ha^{-1} the population of the nematode was 107.67 which was on par with AMF treatment. Significantly lower population of the nematode was also seen in the pots treated with neem cake (124.00) and *Trichoderma* sp. 5 per cent (128.00). Similarly, though inferior to all other treatments application of fluorescent pseudomonads 2 per cent (192.00) also reduced nematode population significantly when compared to control.

At final harvest, too the lowest population of *M. incognita* was recorded in carbofuran @1 kg *ai* ha^{-1} treatment (76.70). This was followed by application of mustard cake @ 1 t ha^{-1} (78.80) and AMF (80.67). All the three treatments were on par in the effect in reducing the nematode population. Fluorescent pseudomonads differed significantly from other treatments in reducing nematode population and was inferior to all. Application of neem cake @ 1 t ha^{-1} and *Trichoderma* sp. 5 per cent also reduced the population of the nematode in soil significantly, the number of nematodes per 100g soil being 88.30 and 93.00 respectively. Both the treatments were on par and *Trichoderma* sp. 5 per cent differed significantly from AMF @ 250 spores per plant and mustard cake @ 1 t ha^{-1} treatments. Root dip and soil drenching with fluorescent pseudomonads 2 per cent, though inferior to other treatments, reduced population of *M. incognita* significantly (105.00) when compared to untreated control.

4.3.2.2 Nematode Population in Root (No. per 5 g of roots)

Significant reduction was also observed in the population of the nematode in the root in all the treatments compared to untreated plants when observed at 30DAT.The mean population of J_2 in the root samples ranged from 104.00 to 161.00 in various treatments as against 173.67 in untreated control. Minimum number of nematode was seen in the root samples of carbofuran @ 1kg *ai* ha^{-1} treated plants (104.00) which thus established its superiority in reducing root-knot nematode over other treatments. It was followed by *Trichoderma* sp. 5 per cent (121.00) which was also significantly superior to all other treatments in reducing nematode population in root. Mustard cake @ 1 t ha^{-1} and treatment with AMF @ 250 spores per plant application also reduced the root population of the nematode, the population being, 141.00 and 133.00 respectively and the treatments were on par. Compared to other treatments, population of the nematode was higher in the roots of neem cake treated plants (161.00). However it was on par with the effect of fluorescent pseudomonads (156.67) and was superior to untreated control.

Application of all the management treatments significantly reduced the number of root-knot nematode in root samples at 60 DAT too. The mean population of the larvae ranged from 70.67 to 138.00 in the treatments as against 217.33 in untreated control. Again lowest number of the nematode was seen in the roots of carbofuran @ 1 kg *ai* ha^{-1} treated plants (70.67) followed by *Trichoderma* sp.5 per cent (77.67) treated plants and both the treatments were on par. Roots of plants treated with AMF @ 250 spores per plant also had significantly low population of root-knot nematode (98.00). Similarly, root dip and soil drenching with fluorescent pseudomonads 2 per cent (122.33) and mustard cake @ 1 t ha^{-1} (116.33) supported significantly lower population of the nematode and the treatments were on par. Comparatively, population of the nematode was high in plants treated with neem cake @ 1 t ha^{-1} (138.00) in root, but it was superior to untreated control.

All the management practices significantly reduced the nematode population in root at final harvest also. Contrary to the observations recorded at 30 and 60DAT maximum reduction in the population of the nematode was seen in the roots of plants treated with *Trichoderma* sp.5per cent (51.67). However the treatment was on par with carbofuran @ 1 kg *ai* ha^{-1} (52.33) treatment. Treatment with AMF @ 250 spores per plant also reduced the nematode population in the roots of chilli plants significantly, the population being 67.67 per 5g root. Application of mustard cake @ 1 t ha^{-1} and treatment with fluorescent pseudomonads 2per cent were on par in their effect in reducing root infestation by the nematode, the population recorded in the treatments being 80.33 and 88.00 respectively. Again application of neem cake @ 1 t ha^{-1} (111. 00) was inferior to all other treatments but superior to untreated control.

4.3.3 Root-knot Index

The number of galls produced in the different treatments differed as indicated by the root-knot index. Lowest number of galls was seen in plants treated with AMF @ 250 spores per plant (1.30). While the gall index in treatments *Trichoderma* sp. 5 per cent, neem cake @ 1 t ha^{-1}, mustard cake @ 1 t ha^{-1} and carbofuran @ 1 kg *ai* ha^{-1} was 2.00 it was 2.30 in fluorescent pseudomonads compared to 3.00 in untreated control.

4.3.4 Yield (per plant)

Consequent to the treatments, a significant increase was observed in the yield of chilli plants (Table 9). Maximum number of fruits was obtained from plants treated with AMF @ 250 spores per plant, the number of fruits being 44.00 per plant and the treatment was on par with soil application of *Trichoderma* sp.5 per cent (41.67) which in turn was on par with the effect of plants treated with fluorescent pseudomonads 2 per cent (36.67) and mustard cake @ 1 t ha^{-1} (37.33). Both these treatments were on par with carbofuran @ 1kg *ai* ha^{-1} (35.33) and

Table 9 Effect of bioagents and oil cakes on the yield of *C. annuum* (mean of three replications)

Treatments	Number of fruits	Weight of fruits (g)
Native AMF @ 250 spores per plant at planting	44.00^{ef}	167.57^{f}
Fluorescent pseudomonads (2 per cent root dip and soil drenching) 30 DAT	36.67^{bcd}	155.17^{cd}
Trichoderma sp. 5 per cent at planting	41.67^{def}	160.93^{def}
Neem cake @ 1 t ha^{-1} 15 days before planting	34.00^{b}	149.57^{bc}
Mustard cake @ 1 t ha^{-1} 15 days before planting	37.33^{bcde}	156.50^{de}
Carbofuran @ 1 kg *ai* ha^{-1} 2 days after inoculation of J_2	35.33^{bc}	144.97^{b}
Control (untreated)	24.67^{a}	121.17^{a}
CD (0.05)	6.126*	6.714*

*Significant at 5 per cent level

neem cake @ 1 t ha^{-1} (34.00) treated plants. The untreated control plants yielded the lowest number of fruits, being 24.67.

Considering the weight of fruits, maximum weight was recorded in AMF @ 250 spores per plant treated plants which was on par with soil treatment with *Trichoderma* sp.5per cent, the weight of fruits in the treatments being 167.57g and 160.93 g respectively. The weight of fruits obtained from plants treated with mustard cake @ 1 t ha^{-1} was 156.50 g and it was on par with weight of fruits obtained from *Trichoderma* sp.5 per cent and fluorescent pseudomonads 2per cent treated plants being 155.17 g. The weight of fruits obtained from plants treated with neem cake 1 t ha^{-1} and carbofuran @ 1 kg *ai* ha^{-1} was on par and comparatively lower being 149.57 g and 144.97 g though superior to control (121.17 g).

4.3.5 Estimation of bioagents from the roots and rhizosphere of chilli plants

Re-isolation of fluorescent pseudomonads from the rhizosphere recorded 13 colonies in 10^{-5} dilution .In the case of *Trichoderma* sp. , at 10^{-3} dilution there was 8 colony forming units (cfu). The colonization percentage of AMF in the root was 74 per cent.

DISCUSSION

5. DISCUSSION

The ubiquitous root-knot nematode, *M. incognita* is an important pest of solanaceous crops like tomato, brinjal and chilli. Besides the direct damage caused, the nematode is associated with damping off and wilt disease of chilli resulting in substantial loss of the plants. Though occurrence of the nematode in chilli is known, its pathogenic potential has not been adequately. documented in Kerala. Information on the damage threshold and yield loss at different population densities is essential for cost effective management of the pest. Considering the role of the nematode in disease complexes, identification of resistant / tolerant varieties would be highly desirable for widespread cultivation. Potential biopesticides too if available and adoptable might be an effective nematode management decision in chilli.

5.1 DAMAGE THRESHOLD

The need for determining the damage threshold of plant parasitic nematodes in each and every crop and under different agro- climatic conditions is widely accepted as it is greatly dependent on the host plant /species and the soil environment in which it exists.

The trial conducted on the pathogenicity of *M. incognita* on *C. annuum* revealed significant reduction in the growth parameters of chilli plants inoculated with different inoculum levels. A progressive decrease was observed in the plant growth characters with increasing population densities. Both the stature of plants and number of leaves were significantly reduced at 30 and 60 DAT and at final harvest .The percentage reduction in the height of plants ranged from 18.74 to 43.84 at 30 DAT, 40.45 to 52.57 at 60 DAT and 20.65 to 46.19 at final harvest at the different population densities (Fig.1). Similarly, the percentage reduction in the number of leaves ranged from 14.38 to 43.83 at 30 DAT,

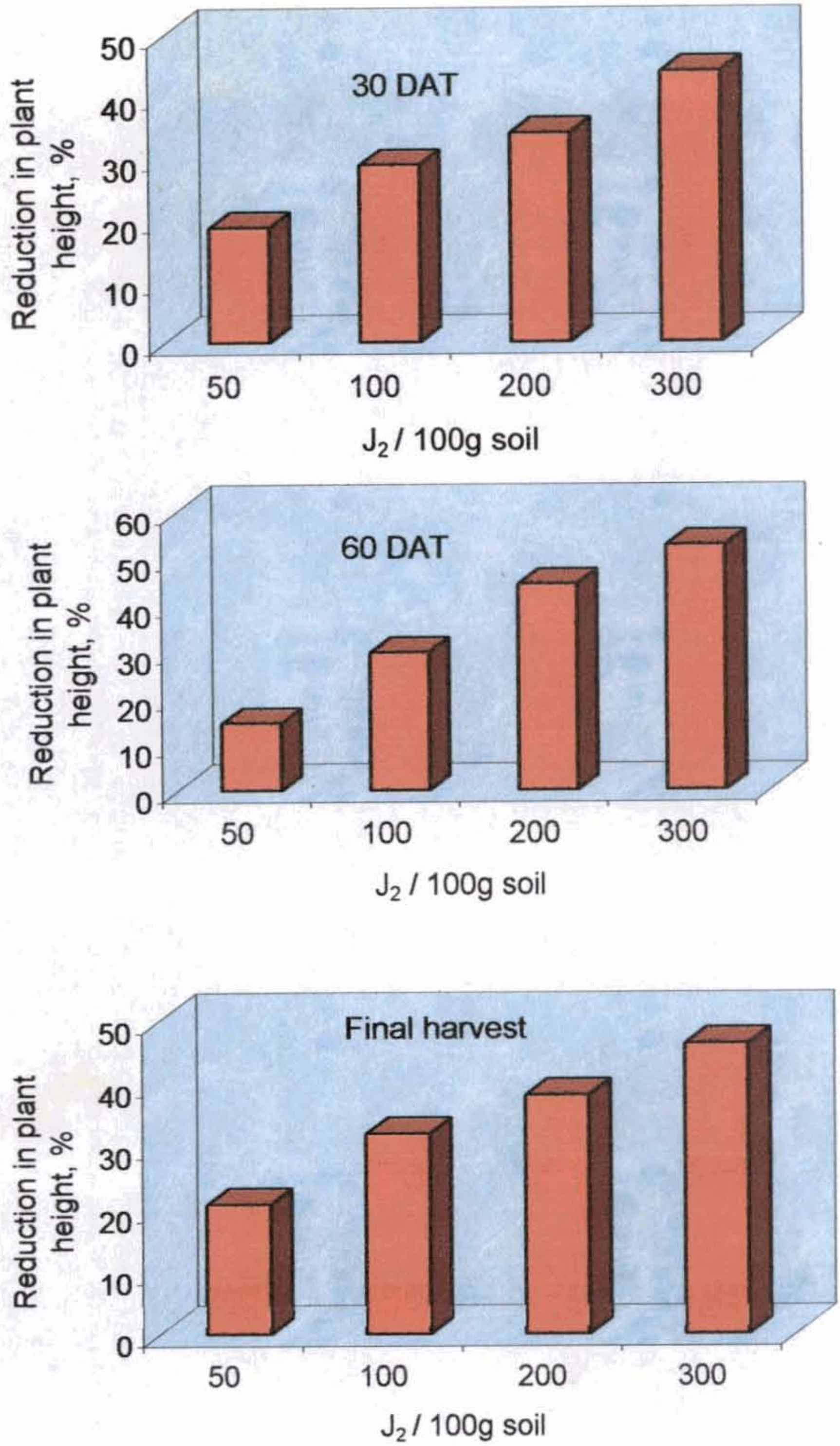

Fig. 1 Percentage reduction in the height of *C. annuum* at different population densities of *M. incognita*

9.38 to 26.71 at 60 DAT and 7.1 to 35.78 at final harvest (Fig.2). Shoot weight also showed a progressive decrease being 12.34, 28.29, 35.03 and 39.55 per cent at 50,100,200 and 300 J_2 /100 g soil respectively (Fig.3). The decrease in root weight ranged from 21.05 to 65.48 per cent in the different inoculum densities (Fig.3). Similar influence of varying population densities of *M. incognita* on the growth parameters of chilli has been made earlier. Considerable reduction in the length and weight of shoot and root in plants inoculated with varying levels of *M. incognita* was observed by Chidambaranathan and Rangaswami (1965) and Varela *et al.* (1986). The extent of damage was observed to be directly proportional to nematode density when inoculated with 50, 500 and 5000 J_2/pot and 10, 100 and 1000 J_2 per pot (Ahmad and Khan, 1991) and 10, 100, 1000 or 10000 J_2 per pot (Yadav and Mathur, 1993a). Reduction in root weight was noted in chilli by Rajagopalan *et al.* (1969). Contrarily, an increase in the weight of roots with increase in inoculum levels was reported by Ahmad *et al.* (1998).

The reduction in the different growth characters, led to an overall reduction of 15.28, 29.11, 38.00 and 46.75 per cent in the total growth of chilli plants when infested with 50,100,200 and 300 J_2 /100 g soil (Fig. 4). This growth reduction was reflected in the yield of the crop. While 50 and 100 J_2 /100 g soil resulted in 17.59 and 39.87 per cent reduction in yield respectively, 200 and 300 J_2 /100 g soil contributed to 51.65 per cent and 62.99 per cent reduction in yield of chilli .An average yield loss of 26.00 per cent has been reported in chilli due to infestation of *M. incognita* by Bhargava and Sharma (2001) and 39.76 to 53.36 per cent by Yadav and Mathur (1993a). *M. incognita* is known to disrupt the vascular tissue of roots, causing reduced uptake and translocation of nutrient elements and water within a plant system which directly or indirectly affect plant host physiology (Melakeberhan *et al.*, 1985; Been and Shomaker, 1986). Added to this, the photosynthetic pigments (chlorophyll and carotenoids) are reduced leading to reduced photosynthesis (Ashaq *et al.*,

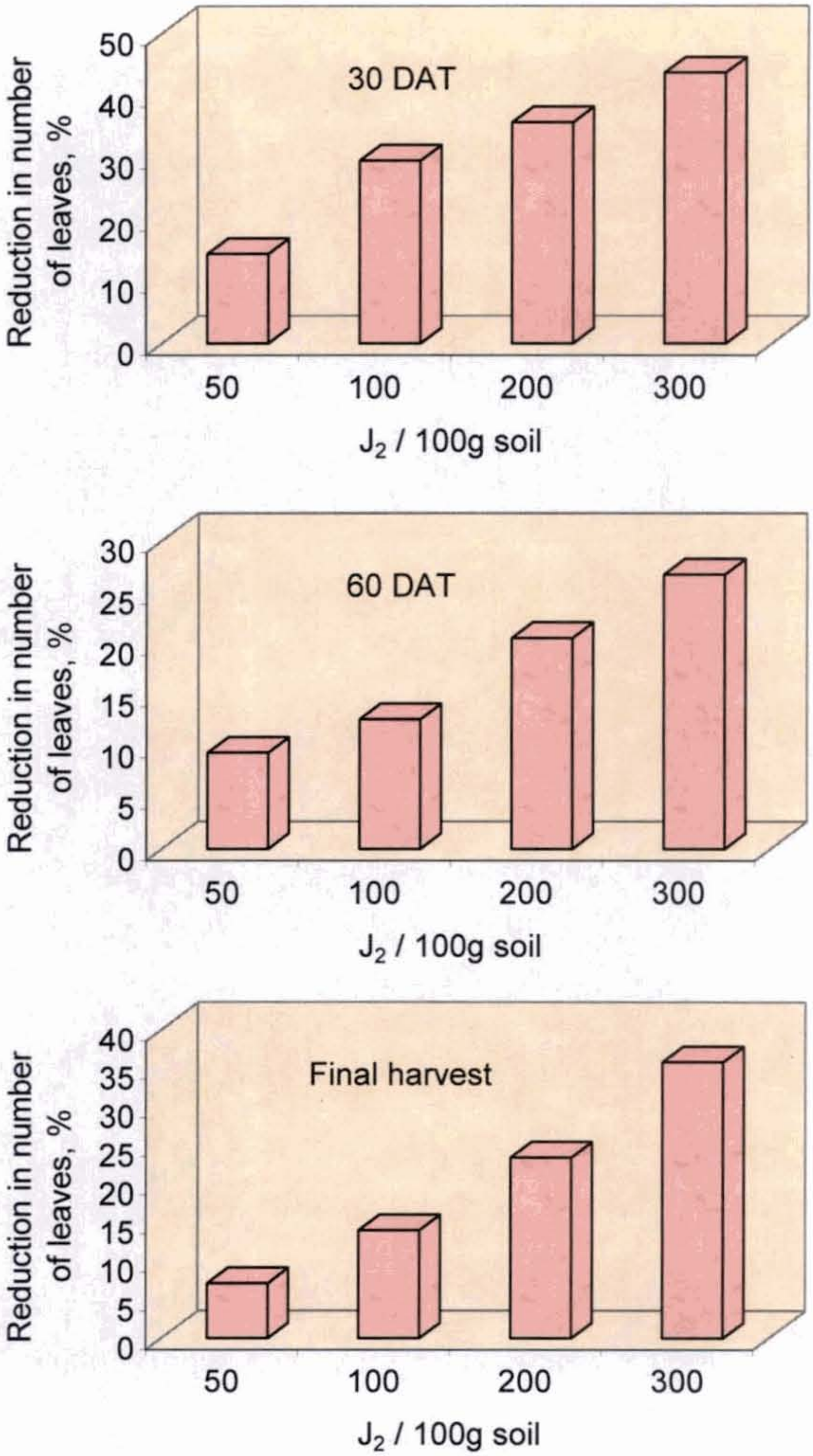

Fig. 2 Percentage reduction in number of leaves of *C. annuum* at different population densities of *M. incognita*

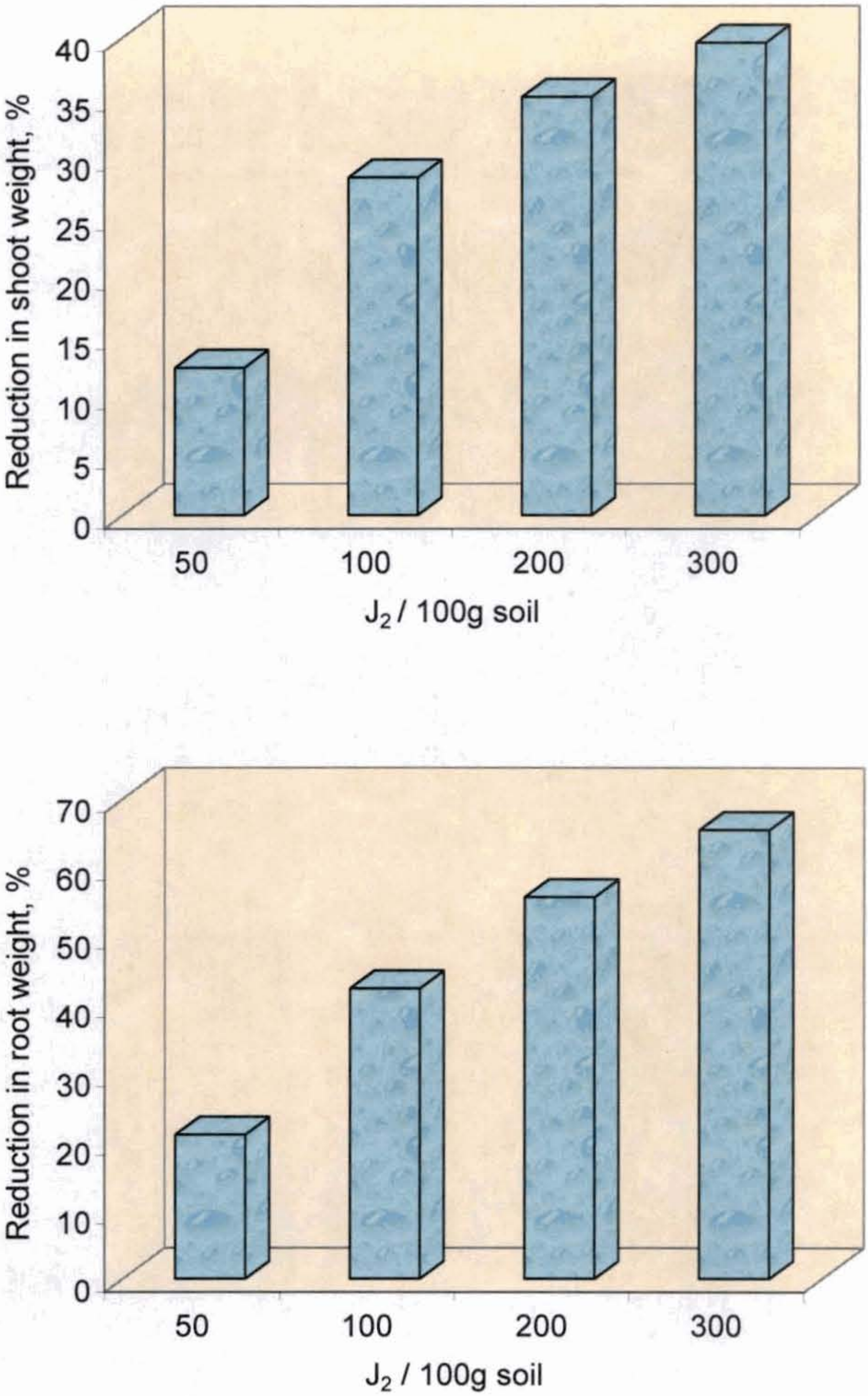

Fig. 3 Percentage reduction in shoot and root weight of *C. annuum* at different population densities of *M. incognita*

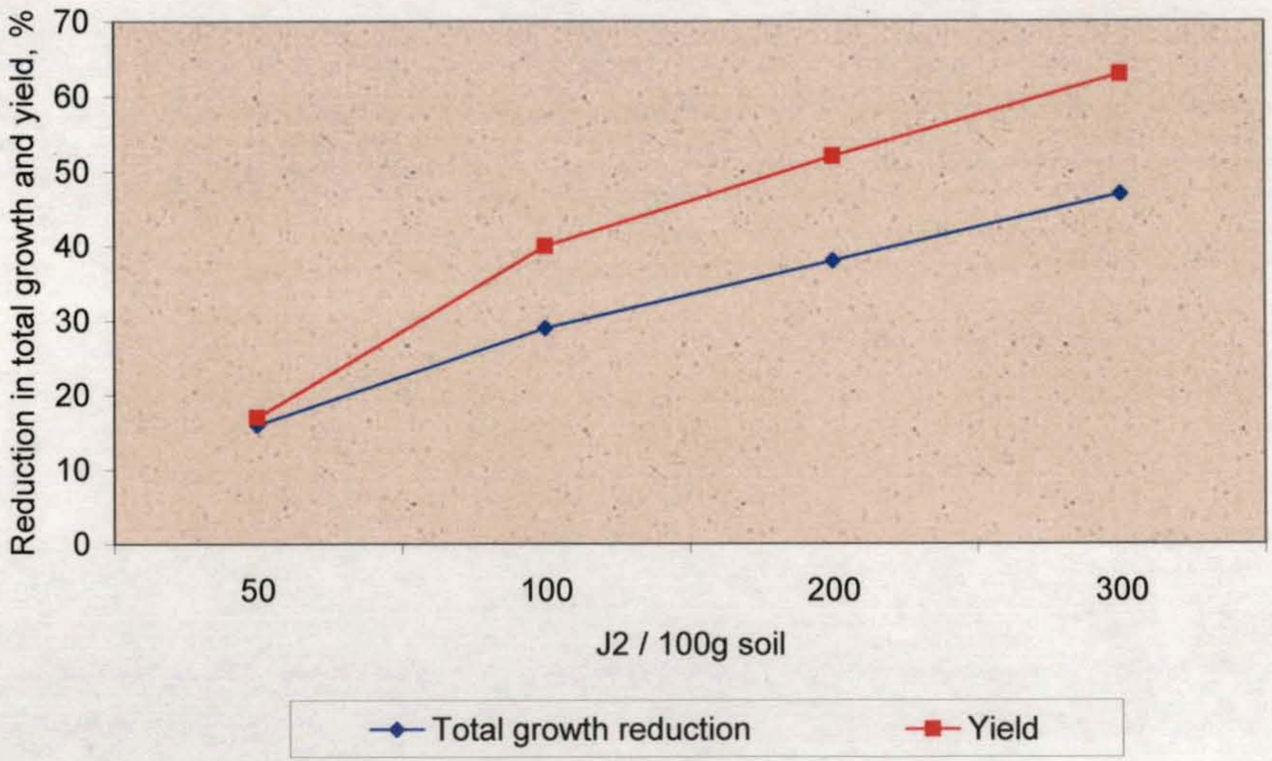

Fig. 4 Percentage reduction in total growth and yield of *C.annuum* at different population densities of *M. incognita*

1999). Thus these sequence of events may have led to the reduced yield observed in the chilli plants inoculated with varying levels of population densities.

The initial population level of nematodes in the soil is crucial since the build up of the population is density dependent. Results presented in para 4.1.3 indicated a general increase in the reproduction rate, root-knot index and final nematode population in relation to initial densities conforming to earlier findings (Yadav and Mathur, 1993a). A critical analysis of the multiplication of the nematode in the study showed an increasing trend up to 60 DAT followed by a decline at final harvest (Fig.5). While the increase in the population at 30 DAT ranged from 75.90 to 86.80 per cent in the different inoculum levels, it ranged from 3.50 to 52.10 per cent at 60 DAT. At final harvest, the decline in population ranged from 16.16 to 43.30 per cent. Evidently at 30 DAT there was not much difference in the rate of increase in the nematode population at 50, 100, 200 and 300 J_2/100g soil. This may be due to the availability of congenial conditions (nutrition and space) for the normal growth and development of nematodes at all population densities which did not hamper the normal reproduction as indicated by the reproduction rate presented in para 4.1.3.1.3. At 60 DAT nematodes in 50 and 100 J_2 inoculated per 100g soil treatments had better conditions for multiplication as indicated by the higher reproduction rates (2.74 and 2.39 respectively) than in the higher inoculum densities where the reproduction rate was significantly lower. The increase in population at the two inoculum levels was 52.10 and 27.80 per cent respectively. The decrease in population observed at final harvest (16.16 to 43.32 per cent) at all inoculum levels may be due to the non-availability of nutrition as it was the fag end of the crop.

While determining the pathogenic level of a plant parasitic nematode several factors have to be taken into account. The value of the host plant is

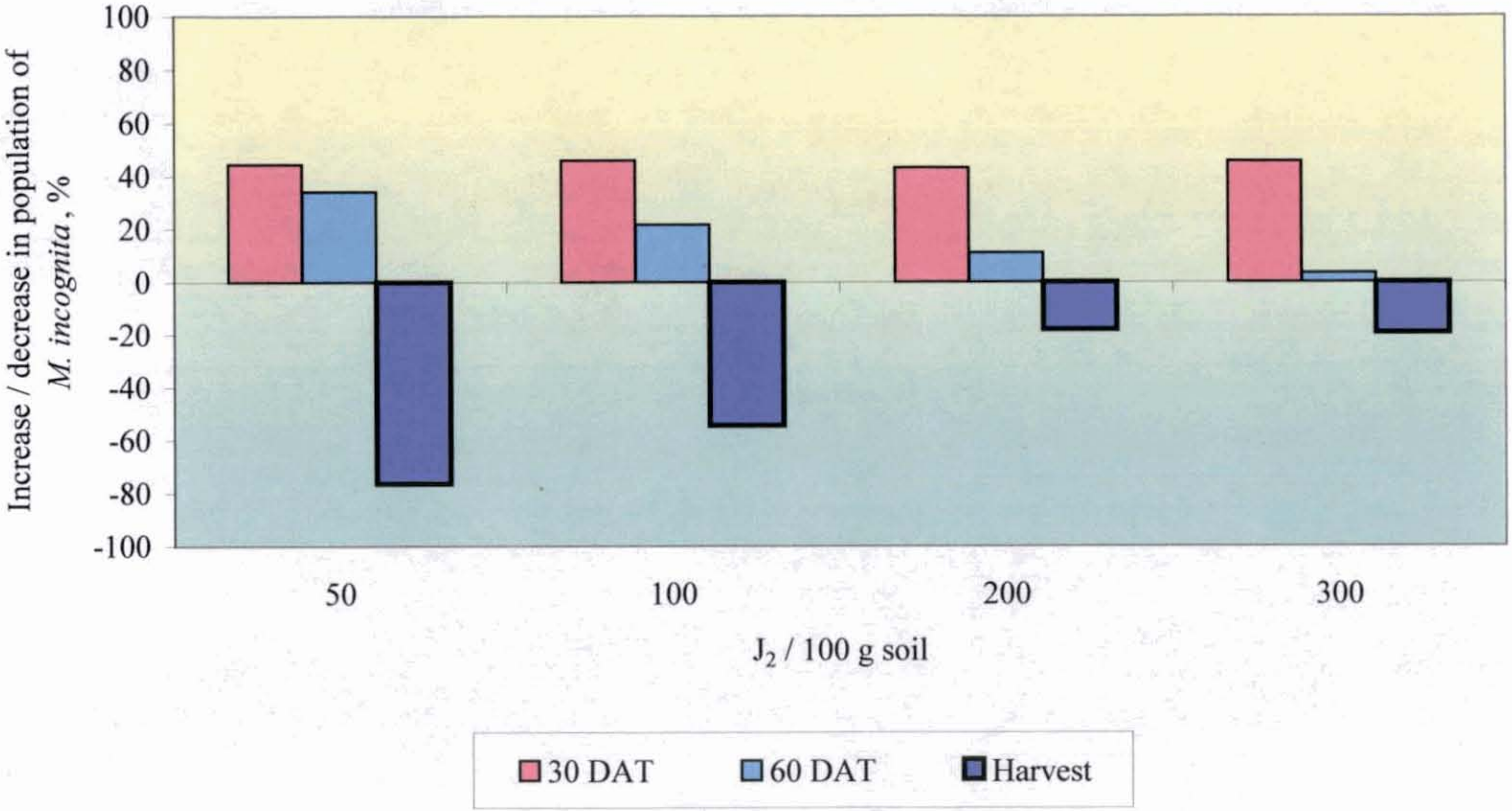

Fig. 5 Multiplication of *M. incognita* in relation to its population density at previous growth interval of *C. annuum*

of prime importance. Considering the commercial value and rate of consumption of chilli in the state, 40 per cent loss in yield seen at an initial population density of 100 J_2/100g soil is quite substantial. As the nematode plays a significant role in the incidence of wilt and damping off disease in chilli, significant aggravation of disease can be expected at this population density leading to sizeable loss in plant density. Moreover, the population build up during the reproductive phase of the crop was quite high (1.87) compared to that at the higher inoculum levels of 200 and 300 J_2/100 g soil implying that this initial population density is optimal for increase of the nematode to destructive levels at the crucial stage of the crop. Considering these factors the pathogenic level of *M. incognita* in chilli may be fixed at 100 J_2/100g soil.

5.2 SOURCES OF RESISTANCE

Cultivation of a resistant cultivar is more effective in managing nematodes especially in monocultures as it is simple and involves no additional cost over normal production practices. With this objective 13 accessions including local and high yielding ones of chilli were screened for their relative resistance/tolerance to *M. incognita*.

Of the 13 accessions evaluated, the local accession Khandari and the high yielding variety Pusa Sadabahar with a root-knot index of 3.0 were observed to be moderately resistant to *M. incognita*. Both the accessions had already been reported as resistant to *M. incognita* (Mohanty *et al.*, 1988; Hussain *et al.*, 1998) The local accessions Moru mulagu, Ettumanoor local and Kolla mulagu and the improved varieties Pant C-1, Indam Jwala, Fire, G-4 and Byadagi with a root-knot index of 4.0 registered a susceptible reaction to the nematode. The two high yielding accessions released from Kerala Agricultural University with a root-knot index of 4.0 were also susceptible. A local accession commonly cultivated by farmers of the state *viz.*, Vellayani local 2 was seen to be highly susceptible, the root-knot index being 5.0. However, the reproduction factor of the nematode in the different varieties showed inconsistent relation with the root-knot index in certain accessions. While the reproduction factor was comparatively low, being 1.06 to 1.36 in the accessions Jwalamukhi, Jwalasakhi and Vellayani local 2, appreciable number of galls were seen in these accessions and hence these were rated as susceptible. On the other hand, in the accession Khandari rated as moderately resistant, the reproduction factor of the nematode was high being 1.54. Evidently, number of galls per plant cannot be solely relied on for rating resistance behaviour of a cultivar. The peroxidase activity, potassium and phenolic content of the root should also be considered side by side with the number of galls /plant before categorizing a cultivar as resistant or susceptible (Chakrabarti and Mishra, 2002). Hence biochemical studies need to be conducted for confirmatory results.

Often, cultivation of varieties rated as resistant to nematodes do not give the desired yield. This is because, a variety resistant to a nematode may be susceptible to insect pests which are a major limiting factor in the cultivation of crops. In the course of selection of a resistant cultivar, the factor is often over-looked. Hence in the present study the extent of pest damage in the accessions too were recorded. While all the local accessions were susceptible to infestation of chilli mite and chilli thrips, two major pests of chilli in the state, the high yielding varieties Pant C-1 and Pusa Sadabahar were moderately resistant. The nematode resistant check Pusa Jwala was also seen to be moderately resistant to pest attack. The varieties released by Kerala Agricultural University *viz*., Jwalamukhi and Jwalasakhi and Pant C-1 though susceptible to nematode were moderately resistant to pest infestation. Among the accessions only Pusa Sadabahar and Pusa Jwala showed tolerance to both *M. incognita* and mites and thrips of chilli. These two varieties may be preferred for cultivation in areas where both the nematode and thrips and mites are important pests. Thus the study indicated the need for evaluating nematode resistant varieties for tolerance to major insect pests too and also the need for selecting and cultivating varieties based on overall assessment of the pest situation in a locality.

5.3 MANAGEMENT

Soil amendments and bioagents offer alternate strategy to the prevalent use of nematicides for nematode management due to their selective toxicity to target pests and safety to non-target organisms and environment. Sufficient information is available in literature on the efficacy of oil cakes in nematode suppression (Alam *et al.*, 1979; Mojumder and Mishra, 1994). Similarly, the remarkable potential of AMF (Schonbeck, 1979;Grandison and Cooper, 1986; Sharma *et al.*, 1994; Sundarababu *et al.*, 2001), *Trichoderma* spp. (Sankaranarayanan, 1997) and *Pseudomonas* spp. (Santhi and Sivakumar, 1995; Verma *et al.*, 1998, Sheela *et al.*, 1999) in reducing root pathogens is also well documented. In view of the changing concept of pest management strategies, an attempt was made to identify potential bio management practices for managing root knot nematode in chilli.

Application of the bioagents vermiculite based AMF, fluorescent pseudomonads and *Trichoderma* sp. and amendment of soil with oilcakes reduced the population of root-knot nematode significantly. The percentage reduction in the population of *M. incognita* ranged from 7.91 to 36.38 per cent at 30 DAT, 26.34 to 65.22 per cent at 60 DAT and 64.49 to 74.06 per cent at final harvest in soil and 7.29 to 40.12 per cent at 30 DAT, 36.50 to 67.48 at 60 DAT and 55.66 to 79.36 per cent at final harvest in root (Fig.6).

Among the bioagents, AMF colonization drastically reduced nematode infestation as seen by the poor galling of roots. Similar effect had been observed earlier in chilli (Sundarababu *et al.*, 2001) and the result is in conformity with the report. Mycorrhizal association is reported to alter root physiology of plants by increasing amino acids and reducing sugar content in the root and wall thickness of cortical root cells

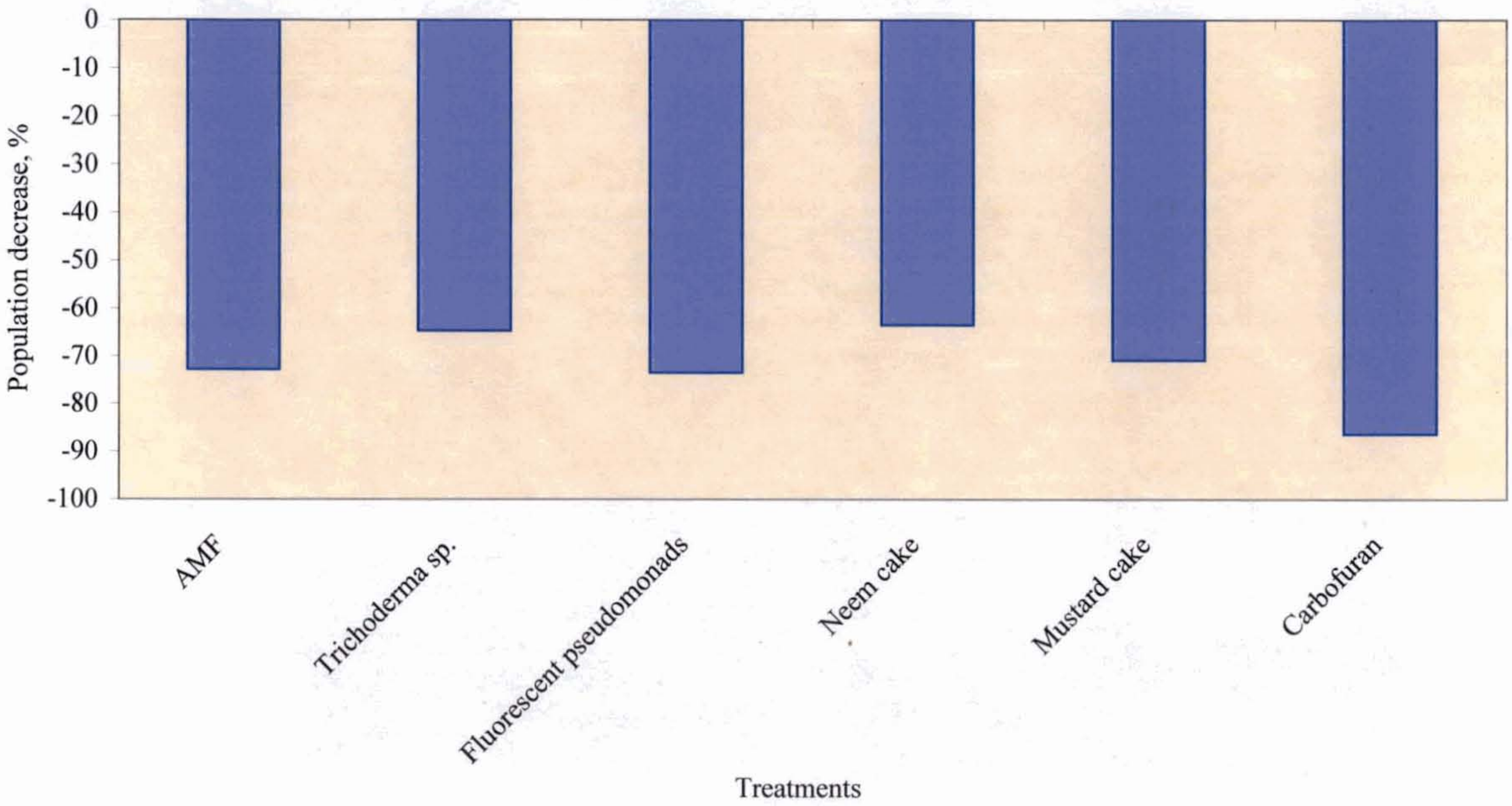

Fig. 6 Percentage decrease in total population (soil and root) of *M. incognita* in *C. annuum* treated with bioagents, oil cakes and carbofuran

(Schenck and Kellam, 1978). This altered root physiology may not be favourable for the penetration and multiplication of root-knot nematode larvae. It has been suggested that lignins and phenols get increased in mycorrhizal plants and thus may be responsible for expressing resistance against nematode invasion.Thus the mycorrizha induced resistance to root-knot nematode observed in the study could be linked to decreased penetration and slower development of the J_2's in mycorrhizal root of chilli (Singh *et al.*, 1990).

Trichoderma sp. too exerted a distinct influence in restricting the growth and development of the nematode. The antagonistic ability of *Trichoderma* sp. against root-knot nematodes have also been recorded. (Sankaranarayanan *et al.*, 1997).The percentage reduction in the nematode population was 12.31, 50.89, 68.55 per cent at 30 DAT, 60 DAT and at final harvest in soil. Among the bioagents, fluorescent pseudomonads was less effective compared to AMF and *Trichoderma* sp. Nevertheless its effect was superior to untreated control. Similar biological activities were already reported by several workers. The potential of fluorescent pseudomonads as nursery and seed treatment was reported in various crops by several workers. Santhi and Sivakumar (1995) and Sheela *et al.* (1999) reported the effectiveness of fluorescent pseudomonads as nursery treatment against *M. incognita* in tomato and brinjal respectively. The mechanism responsible for the reduction of nematode population may be due to the ability of this bacterium to envelope or bind the root surface with carbohydrate-lectin thereby interfering with the normal host recognition process as reported by Oostendrop and Sikora (1990). Competition for space and nutrients, production of antibiotics, volatile and anti-microbial substances and compounds such as iron chelating siderophores and HCN were also reported as activities of fluorescent pseudomonads responsible for regulating root pathogens (Siddiqui *et al.*, 1999). Any one of these factors might have contributed to the reduction in the population of *M. incognita*.

The reduction in total nematode population (soil + root) in pots amended with oilcakes, *viz.*, neem cake and mustard cake, was 14.49 and 23.12 per cent at 30 DAT, 45.19 and 53.14 per cent at 60 DAT and 63.49 and 70.87 per cent at final harvest (Fig.6). The result agreed with the findings of Singh and Sitaramaiah (1966) and Goswami and Vijayalakshmi (1981). Anti-nematode effect of oilcake may be attributed to ammonia, phenol, aldehydes, amino acids and fatty acids released during its degradation (Reddy *et al.*, 1997) apart from its stimulating effect on predaceous fungi. The nematicidal effect of neem cake was also due to the release of nimbidine and azadirachtin after dissolution of the neem cake in water. Azadirachtin is well recognized for its strong growth regulatory, antifeedant and reproduction inhibitory effect besides its direct toxicity. The antifeedant property affects the physiological process of nematode (Parmar, 1997).

Both the bioagents and oilcakes had a significant effect on the growth parameters of chilli .All the treated plants were taller and had more number of leaves than nematode infested plants. While plant stature increased from 9.71 to 41.09 per cent in the different treatments at 30 DAT, it ranged from 8.93 to 43.95 per cent at 60 DAT and 1.87 to 41.31 per cent at final harvest (Fig.7). Similarly 2.41 to 68.25, 10.70 to 155.37 and 15.87 to 108.97 per cent increase in the number of leaves was noted at 30 DAT, 60 DAT and final harvest (Fig.8). The per cent increase in shoot and root weight ranged from 12.39 to 60.74 per cent and 23.88 to 102.87 per cent respectively (Fig.9). This level of vegetative growth implied that the rate of photosynthesis and hence accumulation of organic matter was higher for the treated plants.

Among the bioagents, AMF and *Trichoderma* sp. showed good vegetative growth, the per cent increase in plant height ranging from 14.06 to 40.36 from 30 DAT to harvest in AMF and 8.92 to 37.23 in *Trichoderma* sp. Fluorescent pseudomonads was on par with carbofuran.

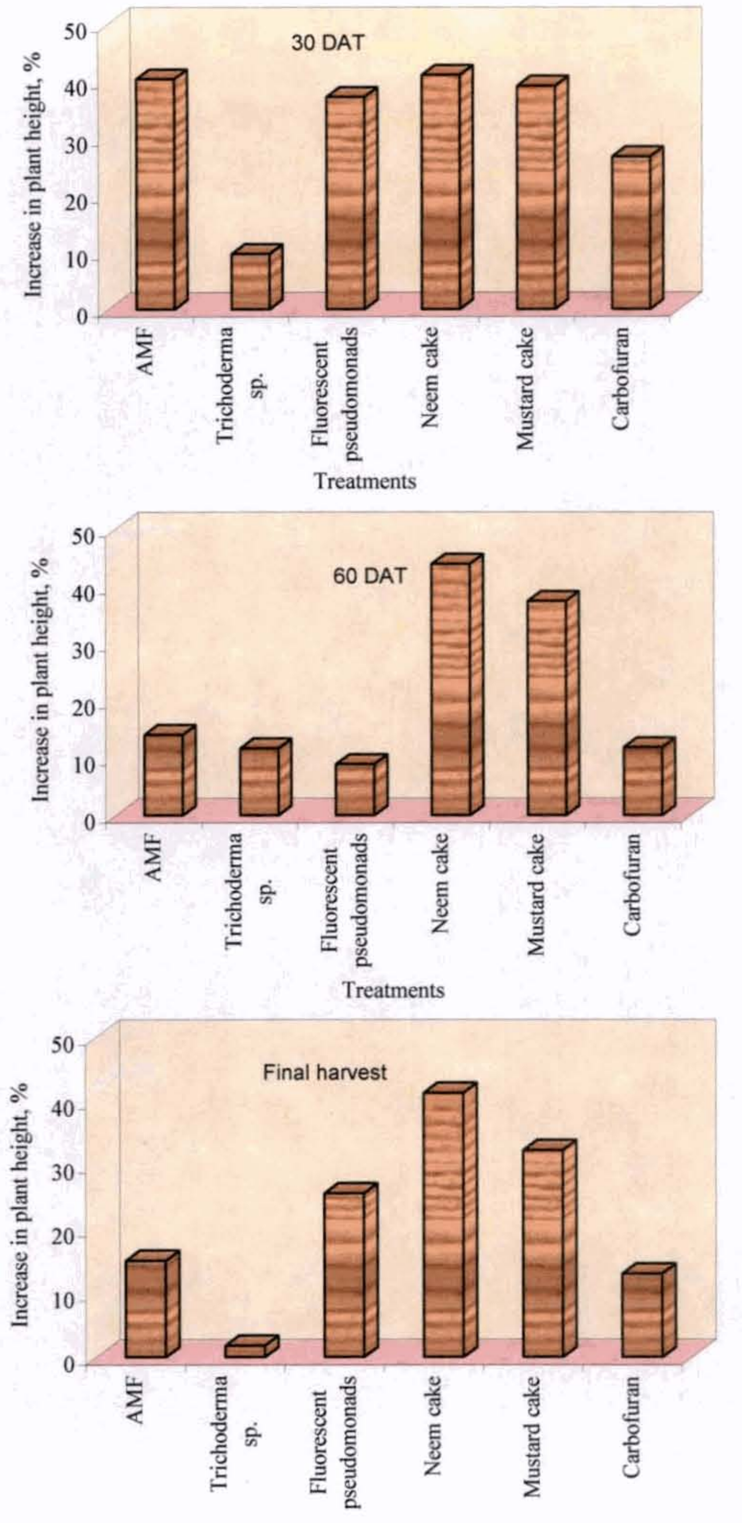

Fig. 7 Percentage increase in plant height of *C. annuum* treated with bioagents, oil cakes and carbofuran at different intervals

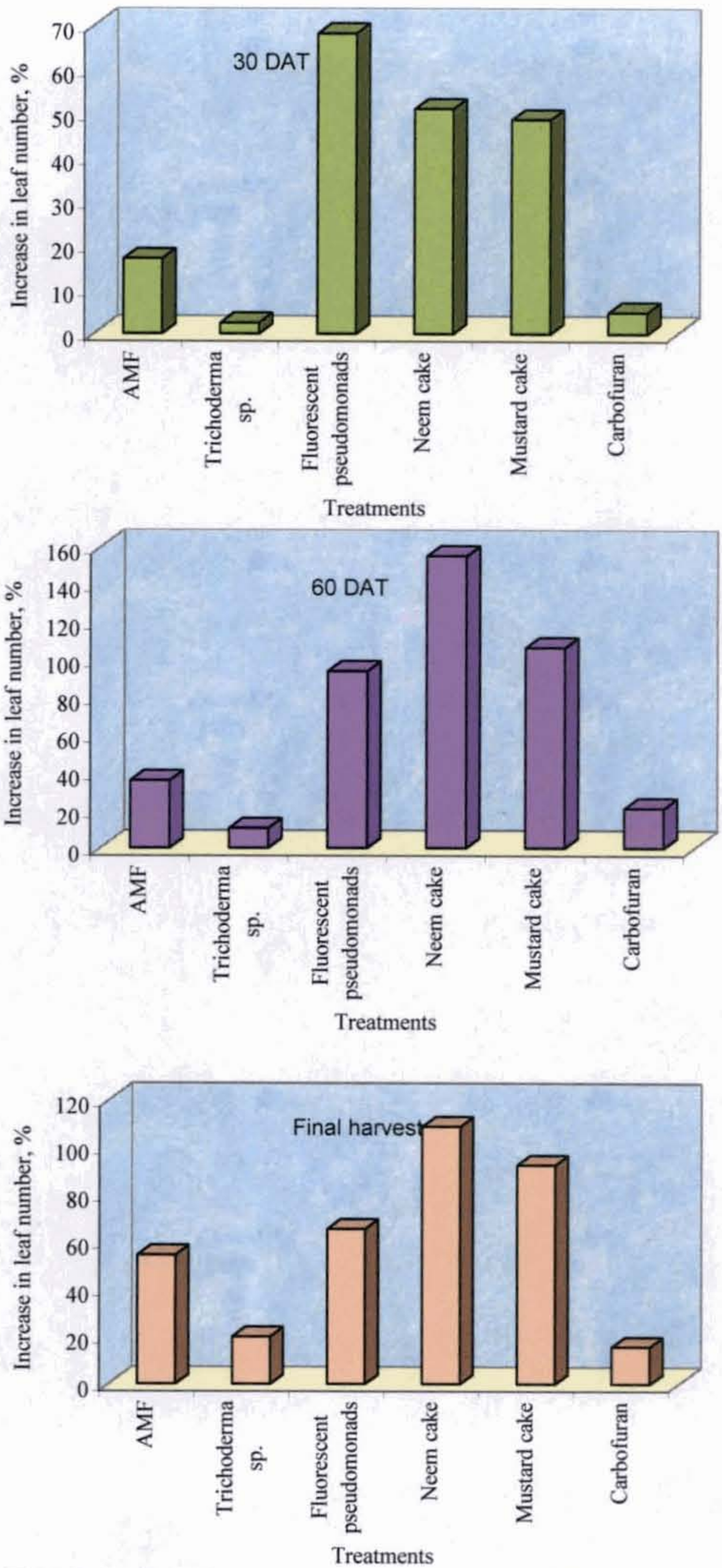

Fig. 8 Percentage increase in number of leaves of *C. annuum* treated with bioagents, oil cakes and carbofuran at different intervals

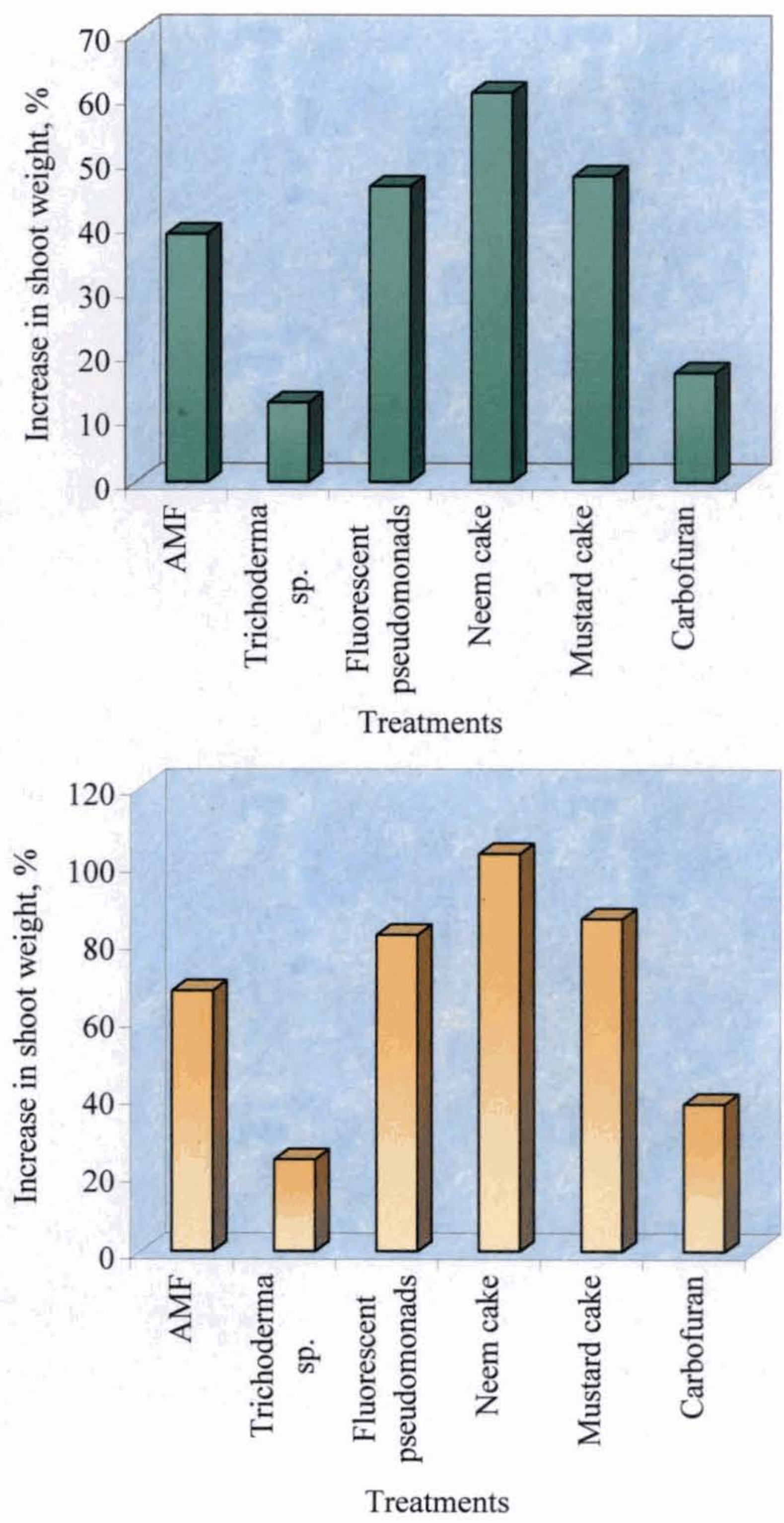

Fig. 9 Percentage increase in shoot weight and root weight of *C. annuum* treated with bioagents, oil cakes and carbofuran

Symbiotic association of AMF is known to improve plant growth through better host nutrition and improved P_2O_5 uptake (Grandison and Cooper, 1986).

Comparatively, better vegetative growth was seen in plants raised in oilcake treated soil. This could be attributed to the fact that apart from their adverse effects on *M. incognita*, oilcake treatments enriched the soil with their nutrients. Moreover, amended soil show increased microbial activity which increases conversion of nitrogen to nitrate form. This in turn stimulates nitrate reductase activity. Plants utilize the nitrate form of nitrogen in nature. However, it must be reduced to ammonia before incorporation into the nitrogenous compounds of plants. This reaction is mediated by enzymes such as nitrate reductase (Tiyagi *et al.*, 2002).

Compared to the treatments with oilcake and bioagents, the vegetative growth in carbofuran treatment was less. Though carbofuran was effective when compared to control, it was inferior to the bioagents and oilcakes in improving plant growth and yield.

The significant reduction in nematode infestation as indicated by the reduced number of galls and improvement in plant growth by the different treatments was reflected in the yield of chilli (Fig. 10). The increase in yield ranged from 19.64 to 38.29 per cent. Maximum yield was obtained from AMF (38.29 per cent) treated plants followed by *Trichoderma* sp. (32.81per cent) treatment. Fluorescent pseudomonads (28.06 per cent) though inferior to these treatments was on par with the oilcakes (23.44 and 29.16 per cent for neem cake and mustard cake respectively). The yield obtained from oilcake treated plants did not commensurate with the vegetative growth exhibited. Nevertheless, compared to the yield obtained from nematode infested plants it was significant. Though overall assessment of the results indicated that bioagents and oilcakes are effective for managing root-knot nematode in chilli, several factors favour the exploitation of bioagents. A serious constraint in the use of oil cakes is the large quantity and high cost involved. Further,

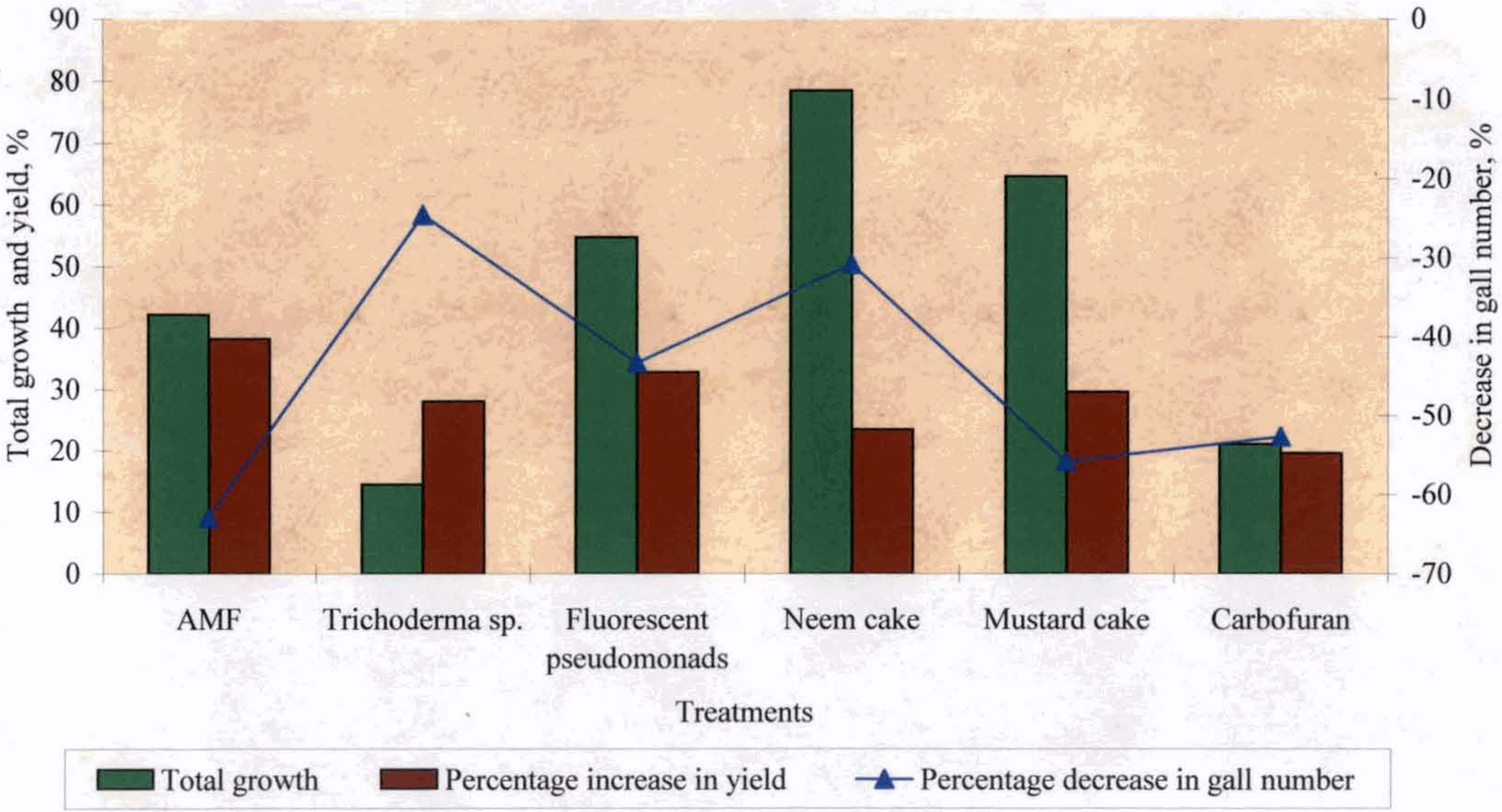

Fig. 10 Influence of bioagents, oil cakes and carbofuran on total growth and yield of *C. annuum*

incorporation in soil two to three weeks prior to planting of crops at times is not practical. Moreover use of oil cake as cattle feed takes priority over nematode management. In this context potential bioagents would be a better option for managing *M. incognita* in chilli. In addition, the ability of AMF to increase host plant resistance to soil borne root pathogens would definitely be of advantage in a crop like chilli which is highly susceptible to diseases.

Based on the findings of the study, the pathogenic level of *M. incognita* in chilli can be fixed at 100 J_2/ 100 g soil. Preference may be given to the cultivation of nematode tolerant varieties, Pusa Jwala and Pusa Sadabahar in root-knot nematode endemic areas as both the varieties are tolerant to infestation of chilli thrips and mites too. As biocontrol agents are cost effective, reliable and its efficacy can be potentiated in conjugation with resistant cultivar, application of vermiculite formulation of AMF @ 250 spores per plant or *Trichoderma* sp. 5 per cent would be ideal for raising "organic chilli".

Identification of more high yielding varieties tolerant to both the nematode and insect pests should be the future thrust in research. The susceptibility/ resistance should be confirmed through biochemical studies.

SUMMARY

6. SUMMARY

The root-knot nematode, *M. incognita* is an important pest of vegetables and is a major constraint in the cultivation of chilli. Besides the direct damage caused, association of the nematode in disease complexes enhances its damage potential in the crop. Information on the damage threshold of any pest is vital for its effective management. In view of the widespread occurrence of the nematode in chilli in the state, a pot culture study was conducted to determine the pathogenicity of the nematode. High yielding varieties and local accessions of chilli were screened to identify sources of resistance to the nematode. The efficacy of bioagents and oilcakes in controlling the nematode was also determined through a pot culture experiment.

The salient results of the study are summarized below.

Significant reduction was observed in the growth parameters of chilli plants inoculated with 50,100,200 and 300 J_2/100 g soil at 30,60 DAT and final harvest. While the reduction in total growth of the plants was 15.29, 29.11,38.00 and 46.75 per cent, the reduction in yield was 17.00,40.00,52.00 and 63.00 per cent at the different population densities of *M. incognita*.

The rate of multiplication of the nematode was high at 50,100 and 200 J_2/100 g soil. Considering the commercial importance of the crop in the state, the nematode's association in disease complexes, 40 per cent loss caused in yield and multiplication of the nematode in relation to its initial density, the damage threshold of the nematode was fixed as 100 J_2/100 g soil.

Among the high yielding varieties and local accessions screened for resistance to *M. incognita*, the high yielding varieties Pusa Sadabahar and the local accession Khandari were found to be moderately resistant to the nematode. The local accession, Vellayani local 2 commonly cultivated by farmers was highly susceptible .Infestation of the insect pest *S. dorsalis* and the acarine pest *P. latus* was low in the variety Pusa Sadabahar, Pusa Jwala and Pant C-1 and the accessions were recorded as moderately resistant to pest attack. Khandari was susceptible to the pest.

The two high yielding varieties, Jwalasakhi and Jwalamukhi released from Kerala Agricultural University were found susceptible to nematode infestation but showed tolerance to pest attack.

Application of bioagents and oil cakes reduced nematode population, improved plant growth and increased yield significantly. Though amendment of soil with oil cakes resulted in better growth of plants, treatment with bioagents afforded better protection to chilli plants from nematode infestation. Comparatively, yield was higher in plants treated with bioagents. Among the bioagents, treatment of soil with vermiculite based formulation of AMF containing 250 spores per plant at planting and application of *Trichoderma* sp. 5 per cent was equally effective in reducing nematode infestation and increasing yield.

Similarly, amendment of soil with neem cake and mustard cake @ 1 t ha^{-1} 15 days before planting were on par in their effect on *M. incognita*. Application of carbofuran @1kg *ai* ha^{-1} though reduced nematode population significantly was inferior in its effect on plant growth and yield.

Thus at 100 J_2/100 g soil *M. incognita* is a potential threat to the cultivation of chilli. Cultivation of the high yielding varieties Pusa Jwala or Pusa Sadabahar would be a viable option in nematode and insect pest prone areas, as both these varieties are moderately resistant to *M. incognita* and *S. dorsalis* and *P. latus*, two major pests of chilli. Application of the vermiculite formulation of AMF @ 250 spores per plant or *Trichoderma* sp. 5 per cent at planting can be recommended for inclusion in integrated nematode management programmes in chilli.

REFERENCES

7. REFERENCES

Ahmad, R., Khan, M.A., Hussain, S. and Inam-ul-Haq, M. 1998. Relationship of *Meloidogyne javanica* population with growth rate of chilli varieties affected with root-knot disease. *Pakist. J. Phytopathol.* 10 : 108-112

Ahmad, S. and Khan, A.A. 1991. Pathogenicity of *M. incognita* race 1 on chilli. *Curr. Nematol.* 2 (2) : 121-122

Ahmad, K., Mehmood, M.G. and Murthy, N.S.R. 1987.Losses due to various pests in pepper. *Capsicum Newsl.* 6 : 83-84

Alam, M.M., Khan, A.M. and Saxena, S.K. 1979. Mechanism of control of plant parasitic nematodes as a result of application of organic amendments to the soil (V) role of phenolic components. *Indian J. Nematol.* 9 : 136-142

Amin, W.A., Fatma, A.M. and Budai, C.S. 1992. Effect of trifluralin and certain pesticides for management of *M. incognita* on tomato. *Indian J. Nematol.* 22 (2) : 89-92

Asha, J. 1996. Phytochemicals and VAM for management of nematodes in brinjal (*Solanum melongena* L.). M.Sc. (Ag) thesis, Kerala Agricultural University, Thrissur, p. 135

Ashaq, M., Bhat, M.Y. and Naqvi, Q.A. 1999. *M. incognita*. *Rhizoctonia solani* and chilli mosaic virus interaction in chilli, *C. annuum*. *Indian J. Nematol.* 29 (2) : 185-186

Been, T.H. and Shomaker, C.H . 1986. Quantitative analysis of growth. mineral composition and ion balance of the potato cultivar Irene infested with *Globodera pallida* (Stone). *Nematologica* 32 : 339-355

Bhargava, S. and Sharma, M.K. 2001. Assessment of yield losses and varietal screening of chilli and tomato against *M. incognita. J. Mycol. and Plant Pathol.* 31 (2) : 238-239

Bhattacharya, D. and Goswami, B.K. 1987. A study in the comparative efficacy of neem and groundnut oil cakes against root-knot nematode, *M. incognita* as influenced by micro organisms in sterilized and unsterilised soil. *Indian J. Nematol.* 17 :81-83

Bhatti, D.S. and Jain, R.K. 1977. Estimation of loss in okra, tomato and brinjal yield due to *M. incognita. Indian J. Nematol.* 7 : 34-41

Borah, A. and Phukan, P.N. 2000. Effect of VAM fungus, *Glomus fasciculatum* and root-knot nematode, *M. incognita* on brinjal. *J. Agric. Soc. North-East India* 13 (2) : 212-214

Chakrabarti, U. and Mishra, S.D. 2002. Evaluation of biochemical parameters for screening resistance of chickpea cultivars against *M. incognita. Indian J. Nematol.* 32 (1) : 26-29

*Chaturvedi, Y. and Kansal, K.C. 1984. *Bull. Zool. Surv. India.*5 : 93-101

Chidambaranathan, A. and Rangaswami, G. 1965. Studies on the pathogenicity and host range of three species of root-knot nematode. *Indian Phytopathol.* 18 : 168-173

*Cho, H.O., Han, S.C. and Chol, D.R. 1986. *Plant Environ. Mycol. Farm Prod. Uti.* 28 : 94-97

Cobb, N.A. 1918. Estimating nematode population of the soil. *U.S. Department of Agriculture.* Technical Circulation 1 : 1-48

*Darekar, K.S. and Mhase, N.L. 1988. *Int. Nematol. Netw. Newsl.* 5 : 7-9

Darekar, K.S., Mhase, N.L and Shelka, S.S.1990 . Effect of placement of non-edible oilseed cakes on the control of root-knot nematode. *Int. Nematol. Netw. Newsl.* 7 : 5-7

FIB. 1999. *Farm Guide 1999.* Farm Information Bureau, Government of Kerala, Thiruvananthapuram, p. 95

Francl, L.J. 1993. Interaction of nematodes with mycorrhizae and mycorrrhizal fungi. *In.Nematode Interactions* (ed. M.W. Khan). Chapman and Hall, London 337 pp.

*Gerdmann, J.W. 1968. *Phytopathol.* 6 : 397-418

Gill, J.S. 1974. Nematology pp.175-179. Scientific Report of the CPRI, Shimla for the Triennium 1971-1973.

Goswami, B.K. and Vijayalakshmi, M. 1981. Effect of some indigenous plant materials and oil cakes amended soil on the growth of tomato and root –knot nematode populations. *Indian J. Nematol.* 11:121

Grandison, G.S. and Cooper, K.M. 1986. Interaction of vesicular arbuscular fungi with root-knot nematode on the cultivars of tomato and white clover susceptible to *Meloidogyne hapla. Ann. Appt. Biol.* 108 : 1-111

Hameed, S.F. 1968. Relative efficacy of different oilcakes on the incidence of root- knot nematodes. *Madras agric. J.* 55 : 168-171

Harley, J.L. and Smith, S.E. 1983. Mycorrhiza symbiosis. Academic Press

*Hayman, D.S. 1982. *Canadian J. Bot.* 61 : 944-963

Hussain, A., Ahmad, R. and Khan, M.A. 1998. Growth responses of chilli cultivars to identify resistant sources against root-knot nematode, *M. javanica. Pakist. J. Phytopathol.* 10 : 101-104

Hussey, R.S. and Roncadori, R.W.1982.Vesicular-arbuscular mycorrhizae may limit nematode activity and improve plant growth. *Plant Disease Reporter* 66 : 8-14

Jacob, A.J. and Haque, M.M. 1998. Effect of neem products on the suppression of root-knot nematode, *M. incognita* in tomato. *Proc. III. Int. Symp. AASN*, p. 226

Jain, R.K. and Gupta, D.C. 1997. Efficacy of neem (*Azadirachta indica*) cake as nursery bed treatment in the management of root-knot nematode (*M. javanica*) infecting tomato. 27 (2) : 249-250

Jain, R.K. Paruthi, I.J. and Gupta, D.C. 1988. Control of root-knot nematode, *M. javanica* in tomato through nursery bed alone and in combination with application of carbofuran at transplanting. *Indian J. Nematol.* 18 : 340-341

Jain, R.K., Dabour, K.R. and Gupta, D.C.1994. Assessment of avoidable losses in yield due to root-knot nematodes (*Meloidogyne* spp.) in few vegetable crops. *Indian J. Nematol.* 24 : 181-184

Jiji, T. and Venkitesan, T.S. 1989. Pathogenic effect caused by root-knot nematode (*M.incognita*) and reniform nematode (*Rotylenchulus reniformis)* alone and in combination on brinjal. *Indian J. Nematol.* 19 (2) : 95-99

Jothi, G. and Sundarababu,R. 2001 . Evaluation of optimum dose of *Glomus mosseae* for control of *M. incognita* in brinjal. *Indian J. Nematol.* 31(1) : 90-91

Kandasamy, C., Mohansundaram, M. and Karuppachamy, P. 1990. Evaluation of insecticides for the control of thrips, *Scirtothrips dorsalis* Hood in chillies (*Capsicum annuum* L.). *Madras agric. J.* 77 (3&4) : 169-171

Karthikeyan, G., Doraisamy, S. and Sivakumar, C.V. 2000 . Biological and chemical control of *Pythium. aphanidermatum - M .incognita* disease complex in chilli and brinjal. *Madras agric. J.* 87(1&3) : 105-108

KAU, 1993. Biennial Report of AICRP on plant parasitic nematode with integrated approach for their control, Vellayani Centre, p. 32

KAU, 2002. Package of Practices Recommendations-Crops-2002. Directorate of Extension, Kerala Agricultural University, Thrissur, p. 278

Kaur, D.J. and Mahajan, R. 1990. Reaction of some chilli cultivars to the root-knot nematode *M. incognita. Int. Nematol. Netw. Newsl.* 7 (3) : p.23

Khan, A. A. and Khan, M.W. 1996. Distribution of root-knot nematode species and races infesting vegetable crops in eastern Uttar Pradesh, India. *Indian J. Nematol.* 26 : 238-244

Khan, A.A. and Khan, M.W. 1990. Infestation, distribution: pattern and identity of root-knot nematodes associated with vegetable crops in the districts of Meerut division in Uttar Pradesh, India. *Indian J. Nematol.* 20 : 67-75

Khan, A.A. and Khan, M.W. 1991. Suitability of some cultivars of pepper as hosts for *M. javanica* and races of *M. incognita*. *Nematol. Medit.* 19 (1) : 51-53

Khan, A.A.M., Khan, W. and Khan, B.2000 . Preferential parasitism of different species of root-knot nematodes on vegetable crops. *Indian J. Nematol.* 30 (2) :186-188

Khan, B., Khan, A.A . and Khan, M.R. 2002. Response of some cultivars of pepper, egg plant and tomato to races of root-knot nematodes, *M. incognita* and *M. javanica* . *Indian J. Nematol.* 32 (2) : 147-152

Khan, M.L. and Rathi, N. 2000. Effect of organic amendments and carbofuran on *M. incognita* population and yield in tomato. *Indian J. Nematol.* 31 (1) : 83-84

Khan, M.W., Ashraf, S. S., Ansari, N. A. and Khan, A. A.1993. Incidence and intensity of root-knot on vegetables and identity of species/races of root-knot nematode in some hilly districts of Uttar Pradesh, India . *Indian J. Nematol.* 23 : 95-100

Khan, T.A. and Saxena, S.K. 1997. Effect of root dip treatment with fungal filtrates on root penetration development and reproduction of *Meloidogyne javanica* on tomato. *Int. J. Nematol.* 7 : 85-88

Kumar, S. and Vadivelu, S. 1996. Evaluation of organic amendments for the management of root-knot and reinform nematodes infecting brinjal as compared to carbofuran. *Pest Mgmnt. Hort. Ecosystem* 2 : 71-74

Labeena, P. Sreenivasa, M.N. and Lingaraja, S. 2002. Interaction effects between AMF and root-knot nematode, *M. incognita* on tomato. *Indian J. Nematol.* 32 (2) :118-120

Mani, M.P. Sundarababu, R. and Sivakumar, C.V. 1998. 'Management of the potato cyst' nematodes, *Globodera* spp. through plant rhizosphere bacteria *Pseudomonas fluorescens* Migula. *J. Biol. Control.* 12 : 131-134

Melakeberhan. H., Brooke. R.C.. Webster. J.M. and D'Auria. J.M. 1985. The influence of *M. incognita* on the growth, physiology and nutrient content of *Phaseolus vulgaris*. *Physiol. Plant Pathol.* 26 : 259-268

Mishra,S.D.,Haque,M.M., Mojumder, V. and Goswami, B.K. 1989.Effect of neem seed cake on the hatching ability of *M .incognita* . *Neem Newsl.* 6 : 6-7

Mohanty, K.C., Mahapatra, S.N. and Patnaik, P.R. 1988. Reaction of some chilli cultivars against root-knot nematode. *PMSO Newsl.* 2 : 39

Mohanty, K.C., Mahapatra, S.N., Patnaik, P.R. and Ray, S. 1995. Management of root-knot nematode, *M. incognita* through chemical nursery treatments in brinjal. *Indian J. Nematol.* 25 (1) : 6-7

Mojumder, V. and Mishra, S.D. 1994. *In nematode Pest Mgmt. in Crops*, (Eds. Bhatti, D.S. and Walia, R.K.) Delhi, U.B.S. Publishers, pp.132 – 149

Nagesh, M.1996.Relationship between the population densities of root-knot nematode, *M. incognita* (Kofoid and White,1919) Chitwood,1949 and growth of potato, *Solanum tuberosum* L. *Pest Mgmt. Hort. Ecosystems* 2(1) : 9-14

Oostendrop, M. and Sikora, R.A. 1990. In vitro relationships between rhizosphere bacteria and *Heterodera schachtii*. *Rev. Nematol.* 13 : 269-274

Pandey, R. and Trivedi, P.C. 1990. Response of chilli cultivars to *M. incognita* and its effect on morphometrics of female. *Nematol. Medit.* 18 (2) : 219-220

Panickar, B.K. and Patel, J.R. 2001.Susceptibility of some of the genotypes/cultivars of chilli to thrips, *S. dorsalis*. *Indian J. Ent.* 63 (1) : 52-54

Parmar, B.S. 1997. Industrial uses of neem and future commercialization. In : Neem in sustainable agriculture (eds. Narwàl, S.S., Taurol, P. and Bisla, B.B.), Scientific Publishers, Jodhpur, India, pp. 251-260

Patel , V.N. and Gupta ,H.C.L. 1998.Estimation of losses and management of thrips infesting chillies. In National Seminar on "Entomology in 21 st century". Biodiversity ,Sustainability , Environmental Safety and Human Health held at Udaipur, pp. 99.

Perveen, S., Ehteshamul-Haque, S. and Ghaffar, A.1998. Efficacy of *Pseudomonas aeruginosa* and *Paecilomyces lilacinus* in the control of root rot-root knot disease complex on some vegetables. *Nematol. Medit.* 26 (2) : 209-212

Phillips, J.M. and Hayman, D.S. 1970. Improved procedure for clearing roots and staining parasitic and vesicular – arbuscular mycorrhizal fungi for rapid assessment of infection. *Trans. Brit. Mycol. Soc.* 55 : 158-161

Rahman, M.H., Nahar, M.S., Rahman, M.A, Faruk, I. (BARI), Jasmine, H.S., Alam, S. (IPM CRSP/Virginia) Tech/., Black, L. (AVRDC) and Miller , S. (Ohio State). Management of soil borne pathogens of egg plant, cabbage and cucumber. Abstract from the Eighth Annual Report of the IPM Collaborative Research Support Programme. (IPM CRSP) Bangladesh. 2000-2001 (29 September – 28 September)

Rajagopalan, P., Seshadri, A.R. and Muthukrishnan, T.S. 1969. Studies on the pathogenic effects of three species of root-knot nematodes on chilli variety Sathursamba. All Indian Nematology Symposium, Aug 21-22, pp. 16-17

Rajagopalan, P., Seshadri, A.R. and Muthukrishnan, T.S. 1970. Preliminary observations on the varietal resistance of chillies to the root-knot nematode, *M. arenaria*. *Madras agric. J.* 57 : 25

Rama, D. and Gill, J.S. 1989 .Comparative pathogenicity of the root-knot nematode, *M. incognita* on susceptible and resistant chilli cultivars. *Indian J. Nematol.* 19 (2) :246-249

Reddy, B.M.R., Krishnappa, K. and Karuna, K. 1997. Seedling bare root dip with chemicals for the management of root- knot nematode in brinjal. *Indian J. Nematol.* 27 : 258-259

Reddy, P.P., Rao, M.S. and Nagesh, M. 1997. Nematode management in horticultural crops. In : Neem in sustainable agriculture (eds. Narwal, S.S., Taurol, P. and Bisla, B.B.), Scientific Publishers, Jodhpur, India, pp. 229-246

Sankaranarayanan, C., Hussaini, S.S., Sreeramakumar, P. and Prasad, R.D. 1997. Nematicidal effect of fungal filtrates against root- knot nematodes. *J. Biol. Control* 11: 37-41

Santhi, A. and Sivakumar, C.V. 1995. Biocontrol potential of *Pseudomonas fluorescens* (Migula) against root-knot nematode, *Meloidogyne incognita* (Kofoid and White, 1919). Chitwood, 1949 on tomato. *J. Biol. Control* 9 : 113-115

Santos, H.S., Wileken, S.R.S and Goto, R. 2002. Reproduction of *M. incognita* race 2 on different sweet peppers (*C. annuum* L.). *Nematologia Brasileira.* 26 (2) : 209-211

Saxena ,S.K. 1986. In "Plant Parasitic Nematodes of India – Problems and Progress" (eds. Swarup, G. and Dasgopta, D.R.) IARI, New Delhi, pp.312-317

Saxena, S.K., Alam, M.M. and Khan, A.M. 1974. Chemotherapeutic control of nematodes with Vydate oxamyl, VC-13 and Dazomet on chilli plants. *Indian J. Nematol.* 4 : 235-238

Schenck .N.C. and Kellam , M.K. 1978. The influence of vesicular – arbuscular mycorrhizae on disease development. *Bulletin 798 . Florida Agriculture Expt. Station* 16 pp.

Schonbeck ,F. 1979 .Endomycorrhiza in relation to plant diseases. *In : Soil Borne Plant Pathogens*. Eds. Schippers, B. and Gams ,W. Academic Press, pp. 271-280

Sharma, M.P., Bhargava, S. Varma, M.K. and Adholeya, A. 1995. Effect of Va- Mycorrhizal fungus *Glomus fasciculation* on survival penetration and development of root–knot nematode, *M. incognita* in tomato. *Indian J. Nematol.* 25 (1) : 4-5

Sharma, M.P., Bhargava, S., Varma, M.K. and Adholeya, A. 1994. Interaction between the endomycorrhizal fungus, *Glomus fasciculatum* and the root-knot nematode *M. incognita* on tomato. *J. Nematol.* 24 : 133-139

Sharma, S.K., Sinha, A.K. and Phukan, P.N. 1994. Reaction of chilli cultivars to *M. incognita*. *Indian J. Nematol.* 24 : 237-238

Sheela,. M.S., Jiji, T. and Premila, K.S. 1999. Management of root-knot nematode through the plant rhizosphere bacterium *Pseudomonas fluorescens* Migula. *Natl. Sem. Nematologic. Res.* India, pp.33

Siddiqui, I.A., Ehteshamul- Haque, S. and Ghaffar, A. 1999. Root dip treatment with *P. aeruginosa* and *Trichoderma* spp., in the control of root rot-root knot disease complex in chilli (*C. annuum*). *Pakist. J. Nematol.* 17 (1) : 67-75

Siddiqui, I.A., Ehteshamul- Haque, S. and Shaukat, S.S. 2001. Control of the root- rot and root- knot disease complex by *P. aeruginosa*: Impact of bacterial rhizosphere colonization. *Acta Agrobotanica* 54 (1) : 55-64

Singh, R.S. and Sitaramaiah, K. 1970. Control of plant parasitic nematodes with organic soil amendments. *Pest Artic. News Summary* 16 : 287 – 297

Singh, R.S. and Sitaramaiah, K. 1966. Incidence of root-knot of okra and tomato in oil cake amended soil. *Plant Disease Repoter*. 50 : 668-672

Singh, R.V. and Khera, S. 1984. Plant Parasitic nematodes from rhizosphere of vegetable crops around Calcutta (Nematoda : Hoplaimidae). *Indian J. Nematol.* 14 : 188-190

Singh, R.V., Sharma, H.K. and Gill, J.S. 1998. *Proc. Natl. Symp. on Rational Approaches in Nematode Mgmnt. Sustainable Agric.*, GAU, Anand (Eds. S.C. Dhawan and K.K. Kaushal) pp. 58-62

Singh, U.C., Singh, R. and Nagaich, K.N. 1998. Reaction of some promising chilli varieties against major insect pests and leaf curl disease. *Indian J. Ent.* 60 (2) : 181-183

*Singh, Y.P., Singh, R.S. and Sitaramaiah, K. 1990. Mechanism of resistance of mycorrhizal tomato against root knot nematode. In : current trends in mycorrhizal research. *Proc. Nat. Conf. Mycorrhiza*. Hisar, p. 96

Sitaramaiah, K. and Sikora, R.A. 1982. Effect of the mycorrhizal fungus *G. fasciculatum* on the host parasitic relationship of *R. reniformis* in tomato. *Nematologica* 28 : 412-419

Sivaprasad, P. 1998. Management of root diseases of important spice crops of Kerala with VA mycorrhiza. DBT project final report. Kerala Agricultural University, Thrissur

Subramaniyan, S. Rajendran, G. and Vadivelu, S. 1990. Estimation of loss in tomato due to *M. incognita* and *Rotylenchulus reniformis* . *Indian J. Nematol.* 20 (2) : 239

Sundarababu, R. Sankaranarayanan, C. and Vadivelu, S. 1993. Interaction of mycorrhiza species with *M. incognita* on tomato. *Indian J. Nematol.* 23 (1) : 121-123

Sundarababu, R., Mani, M.P. and Arulraj, P. 2001. Management of *M. incognita* in chilli nursery with *Glomus mosseae*. *Ann. Pl. Prot. Sci.* 9 (1) : 161-162

Sundarababu, R., Nageswari, S., Poornima, K. and Suguna, N. 1998. Biological control potential of *Glomus fasciculatum* against *M. incognita* on tomato and okra. *Proc. I Natl. Symp. Pest Mgmnt. Hort. Crops*, Bangalore, p. 312

Sundarababu, R., Sankaranarayanan, C. and Santhi, A. 1996. Studies on the effect of interaction of *M. incognita* with *Glomus fasciculatum*. *South Indian Horticulture* 44: 114-115

Suresh, C.K., Bagyaraj, D.J. and Reddy, D.D.R. 1985. Effect of vesicular arbuscular mycorrhizae on the survival, penetration and development of root-knot nematode in tomato. *Plant and soil* 87 : 305-308

Taylor, A.L. and Sasser, J.N. 1978. Identification of *Meloidogyne* spp. pp.101-105. *In : Biology, Identification and Control of root-knot nematode (Meloidogyne* spp.). International *Meloidogyne* Project , North Carolina State University, Graphic Press

Tiyagi, S.A., Khan, A.V. and Alam, M.M. 2002. Biodegradable effect of oil seed cakes on plant parasitic nematodes and soil inhabiting fungi infesting *Trigonella foenumgreacum* and *Phaseolus aureus*. *Indian J. Nematol.* 32 (1) : 47-57

172229

Timonin, 1940. The interaction of higher plants and soil micro organisms. Microbial population of rhizosphere seedlings of certain cultivated plants. *Canad. J.* 18 : 307-317

Trivedi, P.C. and Tiyagi, B. 1983. Control of root knot of chilli with nematicides. *J. Res.* 4 (1) : 65-66

Varela, F., Ayala, A. and Toro, J. 1986. Host parasite relationship of *M. incognita* on the pepper cultivars, Blanco del pais and Cubanelle in Puerto Rico. *Nematropica* 15 (2) : 92-93

Verma, K.K. Gupta, D.C. and Paruthi, I.J. 1998. Preliminary trial on the efficacy of *Pseudomonas fluorescens* as seed treatment against *M. incognita* in tomato. *Proc. Natl. Symp. on Rational Approaches in Nematode Mgmnt. Sustainable Agriculture*, Nematological Society of India, IARI, p. 79-81

Yadav, B.D. and Mathur, B.N. 1990. Management of root- knot of chillies in nursery with chemicals. *Int. Nematol. Netw. Newsl.* 7 (4) : 40

Yadav, B.D. and Mathur, B.N. 1993a. Effects of inoculum levels of *M. incognita* on growth and development of chilli (*C. annuum* L.). *Indian J. Mycol. and Plant Pathol.* 23 (1) : 94-96

Yadav, B.D. and Mathur, B.N. 1993b. Reaction of chilli genotypes to root-knot nematode, *M. incognita*. *Indian J. Mycol. and Plant Pathol.* 23 (1) : 92-93

Zaki, F.A. and Bhatti, D.S. 1989.Phytotherapuetic effect of some plant leaves on *M. javanica* infesting tomato plants. *Nematol. Medit.* 17(2) : 71-72

*Original not seen

PATHOGENICITY, YIELD LOSS ASSESSMENT AND MANAGEMENT OF ROOT-KNOT NEMATODE, *Meloidogyne incognita* (Kofoid and White) Chitwood ON CHILLI (*Capsicum annuum* L.)

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ABSTRACT

A study was conducted in pots to determine the pathogenicity of the root-knot nematode, *Meloidogyne incognita* (Kofoid and White, 1919) Chitwood, 1949 on chilli (*Capsicum annuum* L.). A significant reduction was seen in the growth parameters at 30, 60 DAT and final harvest when chilli plants were inoculated with 50, 100, 200 and 300 J_2/100 g soil. A progressive reduction in yield was also observed with increase in the inoculum levels, the reduction in yield ranging from 17.59 to 62.99 per cent. Multiplication of the nematode was high at 50 and 100 J_2/100 g soil. Considering the importance of the crop in the state, 40 per cent loss in yield and multiplication of the nematode in relation to its initial density at 100 J_2 /100 g soil, the damage threshold of the nematode was fixed as 100 J_2/100 g soil.

Thirteen accessions including high yielding varieties and local accessions were screened in pots for resistance to *M. incognita*. Pusa Sadabahar and Khandari were moderately resistant to the nematode. Pusa Sadabahar,Pusa Jwala and Pant C-1 were moderately resistant to infestation of chilli thrips, *Scirtothrips dorsalis* and chilli mite, *Polyphagotarsonemus latus*. The high yielding varieties, Jwalamukhi and Jwalasakhi released by Kerala Agricultural University were susceptible to the nematode but moderately resistant to pest infestation.

Three bioagents *viz*., AMF @ 250 spores per plant, fluorescent pseudomonads 2 per cent and *Trichoderma* sp. 5 per cent and oilcakes *viz*., neem cake and mustard cake @ 1 t ha^{-1} were evaluated for their efficacy in controlling *M. incognita* in comparison with carbofuran @1 kg *ai* ha^{-1} in pots. Treatment with the bioagents protected chilli plants better from the infestation of the nematode while amendment of soil with oilcakes resulted in better growth of plants. Yield was also higher in plants treated with bioagents. Among the bioagents, application of AMF @ 250 spores

per plant and *Trichoderma* sp. 5 per cent were equally effective in reducing nematode infestation and increasing yield of chilli.

Based on the results of the study, *M. incognita* can be considered as a potential threat to the cultivation of chilli at 100 J_2/100 g soil. Cultivation of the varieties Pusa Jwala or Pusa Sadabahar would be a viable option in areas where root-knot nematode and chilli mite and thrips are a major problem. Application of the vermiculite formulation of AMF @ 250 spores per plant or *Trichoderma* sp. 5 per cent at planting can be recommended for inclusion in integrated nematode management programmes in chilli.