MANAGEMENT OF NEMATODES ASSOCIATED WITH CARDAMOM

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(2011-11-157)

Thesis submitted in partial fulfilment of the requirement for the degree of

MASTER OF SCIENCE IN AGRICULTURE

Faculty of Agriculture

Kerala Agricultural University, Thrissur

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COLLEGE OF AGRICULTURE

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2013

DECLARATION

I hereby declare that this thesis entitled '**Management of nematodes associated with cardamom'** 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 **"Management of nematodes associated with cardamom"** is a record of research work done independently by **Miss. Angela Cyriac (2011-11-157)** 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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ACKNOWLEDGEMENT

With utmost reverence and deep sense of admiration, I express my heartfelt gratitude and indebtedness to God almighty for the help rendered during the my MSc programme and giving me the courage and strength to pursue this endeavor to completion

Dr. R. Narayana, Assistant Professor, Department of Agricultural Entomology and Chairperson of the Advisory committee for his valuable guidance, constant encouragement, timely advice, overwhelming support and care rendered during the research period without which this piece of work would not have materialized.

Dr. M.S Sheela, Professor and Head, Department of Agricultural Entomology, member of Advisory committee who inspite of her busy schedule she managed to suggest suitable ideas and was always responsive to my difficulties for clearing the bottle necks encountered during my thesis work. Her inspiring words, whole hearted technical and emotional help and unfailing support at critical stages have made this attempt a reality. Dr. Nisha M.S, Assistant Professor, Department of Agricultural Entomology and member of the Advisory committee for the help rendered during my research period and constructive suggestions and valuable advice.

Dr. Dhanya M.K, Assistant Professor (Plant pathology) Cardamom Research Station, Pampadumpara, Idukki and member of the Advisory committee for her sincere help and valuable guidance during my research programme and thesis preparation.

Dr. Gokulapalan. C, Professor, Department of Plant pathology for the help rendered during my research period.

Dr. Hebsybai, Dr. C. Nandakumar, Dr. S. Devanesan, Dr. Krishnakumar, Dr. K. D. Prathapan, Dr. Faizal, Dr. Arthur Jacob, Dr. Thomas Biju Mathew, Dr. Ambily Paul, Dr. Naseema, Dr. Anitha, Dr. Pramila, Dr. Sudharma, Dr. Jiji, Dr. Rejirani and Dr, Amritha V.S

Department of Agricultural Entomology for extending all possible help rendered during my research period.

Mr. C.E. Ajithkumar Junior programmer, Department of Agricultural Statistics for the statistical analysis for my study.

Kerala Agricultural University for giving me opportunity to complete the MSc programme.

I extend my sincere gratitude to Annie, Revu, Jayalekshmi, Arya, Pintu, Anis chechi, Malini chechi, Merlin, Kiran, Remya chechi, Raji chechi, Asha chechi, Vijayakumar chettan, Jayakumar chettan, Beena chechi, Sijini chechi and Vinitha chechi.

My greatest appreciation and friendship goes to my dearest Pallavi chechi, Aswini, Vineeth. V. Varma and Divya who was always a great support in all my struggles and frustrations I faced during my research programme. Cheers for being the most reliable persons to whom I could always talk about my problems and excitements.

My colleagues, Raviboli, Ravi G.B, Sudhakar, Robitha, Vineetha, Sruthi, Ashish, Meera have all extended their support in a very Special way, and I gained a lot from them, through their personal and scholarly interactions, their suggestions at various points of my research programme. I also acknowledge my old pals, Krishna, Sandeep, Anand, Sangeetha, Manasa, Mavi, Ahi, Remya, Hridya, Jiji, Sreya and Jisha for their well wishes.

I owe a lot to my achachan (Cyriac John) and amma (Molly) who encouraged and helped me at every stage of my research work, and longed to see this achievement come true. I deeply miss my grandpa who is not here to share my joy.

I am very much indebted to my family, akkaka, mummy, chikku, Jintu chachan, tony, malu, Jibichan, Joyel, siji, thanku, ambily chettayi and achu chettayi who supported me in every possible way to see the completion of this work.

Angela Cyriac

(2011-11-157)

Dedicated to my

Late grandpa (John)

&

Achachan, Amma

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LIST OF ABBREVATIONS

%	Per Cent
m^{-2}	Per square metre
a.i.	Active Ingredient
cm	Centimeter(s)
^{0}C	Degree Celsius
EC	Emulsifiable Concentrate
et al	And others
Fig.	Figure
g^{-1}	per gram
h	Hour
ha^{-1}	Per hectre
Kg	Kilogram
ml	milli litre
µl	micro litre
l^{-1}	per litre
m	metre
Ppm	Parts per million
sp.	Species
Viz.	Namely

INTRODUCTION

1. INTRODUCTION

India has been acclaimed as the “Land of spices” from time immemorial. The diverse agro climatic conditions prevailing in different parts of country offer an enormous scope for the production of a variety of spices. Small cardamom “The Queen of spices” occupies an important position among the foreign exchange earning commodities. The cardamom commodity is the dried capsule of *Elettaria cardamomum* Maton belonging to Zingiberaceae family. In India the natural habitat of small cardamom is the evergreen forest of Western Ghats on the Malabar cost of South West India. This area is commonly known as the Cardamom Hills. The crop is cultivated in an area of 73,795 ha, out of this Kerala occupies 60% followed by Karnataka (30%) and TamilNadu (10%). In Kerala the major cardamom growing zones are Udumbanchola, Peerumedu and Devikulam taluks of Idukki district. India accounts for the largest area under cardamom at global level, but the productivity is very low compared to that of other major producing countries like Gautemala, Tanzania, Sri Lanka, Papua New Guinea, Honduras, Costa Rica, EI Salvador, Thailand and Vietnam.

Cardamom cultivation in our country is adversely affected by the incidence of pests and diseases caused by an array of organisms. The humid and shaded condition under which the crop is grown creates favorable conditions for the multiplication and infection. Although diseases and pests have long been recognized as important constraints in cardamom production, extensive research on plant parasitic nematodes is lacking.

In cardamom, plant parasitic nematodes belonging to 28 species and 19 genera are reported (Ali and Koshy, 1982). Among them, the most important nematode problem is caused by the root knot nematodes, *Meloidogyne spp*., although the lesion nematode *Pratylenchus coffeae* and the burrowing nematode *R.similis* are also known to cause root rotting (D’Souza *et al*., 1970). In cardamom nurseries they cause significant reduction (more than 50%) in seed germination and the infested seedlings fail to establish on transplantation (Ramana and Eapen, 1995).Young seedlings were more susceptible to root knot nematode attack than mature plants. However, galling was reported to be prominent in seedlings. Reniform nematode, *R. reniformis* was also recorded in cardamom (Eapen, 1995a). The heavily shaded hot, humid atmosphere and continuous availability of soil moisture prevalent in cardamom plantations were found to be congenial condition for multiplication of root knot nematodes.

Biological agents were gaining importance in the field of nematode management. Several pre and post sowing chemical control measures were recommended against these nematodes. However, high cost and the risk of nematicide residues necessitate a safer, economic and effective means of management. Since carbofuran and phorate are banned in Kerala, there is a need for alternative methods of nematode management.

In this context the present study was taken up with following objectives.

1. To study nematode population associated with cardamom in Idukki district
2. To evaluate the reaction of different cardamom cultivars to nematodes
3. To manage nematodes using nematicides, soil amendments and bioagents

Review of literature

2. REVIEW OF LITERATURE

A number of plant parasitic nematodes were found associated with cardamom. They were found to cause severe damage to growth and yield of the crop. Several pre and post sowing chemical measures are recommended for the control of these nematodes. But the high cost and the risk of nematicide residues necessitate a safer, economic and effective means of management. In the recent years non- chemical methods for managing plant parasitic nematodes is gaining importance. The important literatures relevant to these aspects are reviewed.

2.1 Nematode association in cardamom

In cardamom plant parasitic nematodes belonging to 28 species and 19 genera were reported. Among them root knot nematode (*Meloidogyne* spp.) pose serious problem in nurseries and plantations (Ali and Koshy 1982). Eapen (1991) reported about 20 genera of plant parasitic nematodes in cardamom. However, an exhaustive survey conducted during 1979-1982 revealed the wide occurrence and distribution of root knot nematodes in cardamom plantations and nurseries. Three species of root knot nematodes *viz*., *M. incognita, M. javanica* and *M. arenaria* were observed in this survey (Ali, 1984; 1986a). D'Souza *et al*., (1970) reported high population of *R. reniformis* in rhizosphere of cardamom (58-68/100g soil). Eapen (1995a) reported the occurrence of females of reniform nematodes in the roots of cardamom. The number of mature females varied from 7 to 16 /g roots. Moderately thick and brown cortical thickening were observed on the roots at the point of nematode entry. Occasionally eggs were also seen inside the gelatinous matrix produced by the females. In a survey conducted by Eapen (1993) in Coorg district of Karnataka revealed the occurrence of *M. incognita*, *M. javanica*, *Helicotylenchus* spp., *Rotylenchus* spp. and *Pratylenchu*s spp. in the rhizosphere of rainfed cardamom.

2.2 Symptoms of damage, yield loss, survival and means of dissemination.

Stunting, narrowing of leaves and poor tillering were the major aerial symptoms of root knot nematode infestation in cardamom, galling was noticed only in young seedlings. However, it was not noticed on the roots of mature plants in the plantation (Eapen, 1992). Heavy root knot nematode infestation in mature plants caused stunting, reduced tillering, yellowing, pre-mature drying of leaf tips and margins, narrowing of leaf blades, delay in flowering, immature fruit drop and reduction in yield. Unlike several other plant species, galling of root was not a conspicuous symptom on mature plants. The infested roots, exhibited a 'witch's broom' type of excessive branching. In the primary nurseries, more than 50 per cent of the germinated seeds did not emerge as a consequence of infection of the radicles and plumule by second stage juveniles of the root knot nematode. The infested seedlings at the two leaf stage showed marginal yellowing and drying of leaves and severe galling of roots. On transplantation to a secondary nursery, they exhibited curling of unopened leaves. These leaves mostly emerged after the breaking open of the pseudostem. Up to 40 per cent of such seedlings did not establish in the secondary nursery. In the secondary nurseries, the infested plants showed stunting and yellowing with poor tillering, drying of leaf tips and margins and heavy galling of roots (Ali and Koshy, 1982; Eapen, 1995b). An yield loss of 32 to 47 per cent due to root knot nematode has been reported from the results of a nematicide experiment (Ali, 1985, 1986a). Investigations conducted in microplots to study the relationship between initial densities (Pi) of *M. incognita* (0-400 nematodes/100cm^3 soil) and growth as well as yield of susceptible accession of small cardamom revealed maximum growth suppression and yield loss (46.1%) at Pi = 4 nematodes followed by Pi = 0.4/ 100cm^3 soil. The earliest visible damage due to nematode infestation was noticed as reduction in number of tillers, six months after inoculation. However, stunting and narrowing of leaves were also observed at the fag end of the trial. Damage caused at the early part of the growth phase of cardamom plants was critical to the final yield and crop stand (Eapen 1987, 1994).

2.3 Association of these nematodes with other microorganisms

Ali and Venugopal (1992) reported that *M.incognita* pre disposed cardamom seedlings to damping off or rhizome rot disease caused by *Rhizoctonia solani*. Plants were killed when both pathogens were present but not by either nematode or fungus alone. Ali (1989) reported that cardamom plants infected with 'Kattae' mosaic virus supported five to ten times more *M. incognita* than healthy plants.

2.4 Community analysis of nematodes

In a survey conducted by Sapna *et al*., (2009) for studying the plant parasitic nematode associated with rhizosphere of *Pinus roxburghii* and *P. wallichian* in natural forests in six districts of Himachal Pradesh revealed association of twenty one species of nematodes belonging to fifteen genera.

Xiphenima americanum was found to be the most predominant species based on prominence value.

A survey conducted by Devi, (2007) for studying the community behaviour of nematodes in pineapple revealed that the major nematodes associated with pineapple were *Helicotylenchus* spp., *M. incognita*, *Tylenchorhynchus* spp. and *R. reniformis*. Among these nematodes, *Helicotylenchus* spp. was found to be the dominant species followed by *M. incognita*.

Twenty one soil samples collected from lentil yielded 5 species of plant parasites of which *T. mashhoodi* , had highest absolute frequency (85.71), density (231.42) and prominence value (21.42%) (Ali *et al*., 2006).

An extensive survey was conducted in Junagadh district of Gujarat and Diu an Union Territory, in onion, garlic, wheat, brinjal, castor, cotton, coconut and flowering plants to access the community behaviour of nematodes. Five plant parasitic nematodes *viz*., *Rotylenchulus reniformis*, *Helicotylenchus* spp., *Tylenchorhynchus* spp., *Meloidogyne* spp., and *Pratylenchus* spp. were isolated and identified from soil and root samples collected from rhizosphere of host plants (Patel *et al*., 2008).

Community analysis of plant parasitic nematodes associated with medicinal and aromatic plants revealed that *Helicotylenchus dihystera* recorded the highest prominence value (624.73) followed by *Tylenchorhynchus leviterminalis* (331.08). *Meloidogyne incognita* (84.88) and *Macroposthonia onoensis* (84.28) (Deuri and Das, 2012).

Patel *et al*., (2007) encountered of few plant parasitic nematodes *viz. R. reniformis*, *Helicotylenchus* sp., *Tylenchorhynchus* sp., *Meloidogyne* sp. and *Pratylenchus* sp. in certain medicinal plants from Gujarat. *Helicotylenchus* sp. recorded the highest frequency of occurrence of 40.9% followed by *Tylenchorhynchus* sp. with 36.3%

Community analysis of nematodes in sugarcane ecosystem in Bundi district of Rajasthan revealed that *H. dihystera* and *H. indicus* were the dominant nematodes having the highest absolute frequency of 94 per cent (Nandwana *et al*., 2005).

Rao *et al*., (2007) reported the presence of eight genera of plant-parasitic nematodes and one predatory nematode from the community analysis of plant parasitic nematodes associated with vegetable crops in selected districts of Andhra Pradesh. The species identified were *M. incognita*, *R. reniformis*, *H. dihystera* and *H. incises.*

Community analysis of nematodes associated with the rhizosphere of groundnut in Erode district of Tamil Nadu, revealed the presence of eleven species of plant parasitic nematodes. *P. brachyurus* and *R. reniformis* frequently encountered and were present in more than 50 per cent of the samples (Senthamizhi *et al*., 2005).

A two year survey of ginger in twenty four plantation in Darjeeling district of West Bengal revealed the presence of eight genera and ten species of plant parasitic nematodes. *R. reniformis*, *P. coffeae* and *H. multicinctus* were found to be the most prominent nematodes (Ramana and Dasgupta, 1998).

A study on nematode communities associated with rhizosphere of cardamom in Kerala revealed three trophic groups of nematodes, plant parasites consists of *Helicotylenchus* sp. and *Meloidogyne* sp., fungal feeders which include Aphelenchids and Enoplids, bacterial feeders include Rhabditids, Omnivorous which include Dorylaimids and predators which include Mononchids (Narayana, 2012).

Community analysis of nematodes associated with cardamom grown in Cardamom Research Station Pampadumpara revealed that *Helicotylenchus* sp and *Meloidogyne* sp were the most frequent and abundant nematodes (Sreeja, 2011).

2.5 Studies to evaluate the reaction of different cultivars/accessions of crop plants to nematodes

Kakati and Mahanta (2013) screened cucumber varieties against *M. incognita* and out of eighteen cultivars, none of the cultivars ranked as resistant. Only one was found to be moderately resistant (EC 641913), eleven were susceptible (EC641908, EC641912, EC641920, EC641927, EC641934, cucumber green long special, Malini, Bankim, Cucumber No 243, Nandini, Cucumber No-786) and six cultivars were found to be highly susceptible (EC 641925, Kalyan, Cucumber NS- 408, Debstar, Alisa, Improve Noori).

Yadav *et al*., (2007) studied the reaction of sixty three chick pea cultivars/accessions against root-knot nematode, *M. incognita.* Among the cultivars/accessions studied none of them was found to be immune, eleven were resistant, thirty varieties were moderately resistant and thirtynine varieties were susceptible and the rest two were highly susceptible.

In an experiment to evaluate groundnut germplasm (71 Nos) for resistance against root-knot nematode, none of them were found to be either immune or highly susceptible (Ravindra *et al*., 2013).

Sharma *et al*., (2006) screened field pea (*Pisum sativum*) selections for their reaction to root knot nematode. Out of 23 selections three were resistant, three were tolerant and nine were moderately resistant, and selection Ambika was found susceptible to *M.incognita*.

About five hundred and twenty five black pepper accessions were screened against *R.similis* for studying host resistance. Out of these twenty four accessions showed resistance to *R.similis*. Four hundred and thirty one accessions were inoculated with *M.incognita*. Sustainable resistance was observed only in twenty seven black pepper accessions (Eapen *et al*., 2011).

Eapen (1990) studied the methodology for evaluation of resistance in cardamom to root knot nematode. Vegetative suckers of a susceptible line of cardamom were inoculated with 100, 500, 1000 and 5000 root knot nematodes. The multiplication of root knot nematode and gall formation was assessed at 2, 3, 4, 5 and 6 months after inoculation. Nematode multiplication was inversely proportional to the initial inoculum level. Initial population of 100 and 500 nematodes consistently produced susceptible reaction. An initial inoculum of 500 nematodes and an exposure period of 3 months are recommended for evaluation of resistance in cardamom.

2.6 Management of nematodes

2.6.1 Bioagents

Among the non- chemical methods of controlling nematodes, use of biological control agents appears to be the recent strategy gaining more importance (Sharma and Pandey, 2009). The relevant literature on important bioagents were reviewed and presented.

2.6.1.1 Bacteria

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

2.6.1.2 *Bacillus* spp.

Bacteria are numerically the most abundant organisms in soil and some of them, for example members of the genera *Pseudomonas* and *Bacillus* were reported to posses nematicidal properties (Meyer, 2003).

Numerous *Bacillus* strains can suppress pests and pathogens of plants and promote plant growth and some of them were pathogens of nematodes (Li *et al*., 2005). *Bacillus macerans* was found effective against root-knot nematode in okra and pepper (Sheela and Venkitesan, 1992).

Study conducted by Racke and Sikora (1992) revealed that the plant growth promoting rhizobacteria, *Agrobacterium radiobacter* and *Bacillus sphaeriacus* increased the tuber yield of potato by suppressing the population of *Globodera pallida.* Roots from the plants infested with the nematode and bacteria have lower root indices and fewer *Meloidogyne* larvae and eggs than those infested with the nematode alone (Vargas *et al.*, 1992). Oka *et al.*, (1993) reported that exposure of *Meloidogyne* juveniles to *Bacillus cereus* inhibited the penetration of the nematodes in the roots.

The various formulations of *Bacillus thuringiensis* found toxic to eggs and larvae of *Meloidogyne* sp. Zuckeman *et al.*, (1993) found that application of an isolate of *B. thuringiensis* (CR- 371) resulted in reduced population of *M. incognita* in tomato and *P. penetrans* in strawberry.

Sharma (1994) reported that bacterial nematicides, *B. thuringiensis* var . *thuringiensis* (Btt) and *B. thuringiensis* var. *israelensis* (Bti) were effective in controlling *M.incognita* on barley. Sheela *et al.*, (1993) reported that the number of galls and root knot indices were reduced significantly with *B. macerans* in black pepper.

Meyer and Roberts (2002) reported that the bacterium *B. subtilis* and the fungus *P. lilacinus* when tested for *M. incognita* suppressed root galls, females, eggs and second-stage juveniles. Siddiqui and Mahmood (1993) reported that combined application of *B. subtilis* and *P. lilacinus* improved the plant growth and reduced the nematode population in chickpea.

B. subtilis was found effective in reducing nematode reproduction and galling in tomato (Gautam *et al.*, 1995). It was found that there is reduced multiplication of pigeonpea cyst nematode in the presence of bacteria *B. subtilis* (Siddiqui and Mahmood 1995). Application of *Bacillus* spp. showed significant reduction in hatching of larvae of *M. javanica* in cowpea and mashbean whereas as *B. subtilis* showed maximum inhibition of root galls (Dawan *et al.*, 2008).

Sheela (1991) reported that *B. pumilis*, *B. subtilis*, *B. coagulans*. *B. circulans*, *B .macerans* and *B. licheniformis* have ovicidal and larvicidal effect on *M. incognita*.

Moity *et al.*, (1998) reported that application of *Bacillus* sp. (B-15) twice to root-knot nematode infested soil significantly reduced the number of egg masses, eggs per plant and second stage larvae in soil and increased the fresh weight of root and shoot in tomato.

Niknam and Dhawan (2002) reported that *B.subtilis* isolate (Bs*t*) inhibited hatching and caused mortality of immature females and males *of R.reniformis*. Sirohi *et al.*, (2000) reported that culture filtrates of *Bacillus* sp. and *Pseudomonas* sp. could cause 80.00 to 90.00 per cent mortality in *Meloidogyne* juveniles.

Sheela *et al.*, (2004) reported the potential of *B. macerans* (two per cent solution) as dipping of cuttings + drenching in soil seven days after planting in managing *M. incognita* in coleus.

2.6.1.3 Fungi

The fungal parasites provide a promising management option against plant parasitic nematodes (Sankaranarayanan *et al.*, 1997).

2.6.1.3.1 *Paecilomyces lilacinus*

Paecilomyces lilacinus is a soil inhabiting fungus that is capable of parasitizing nematode eggs, juveniles and females and reducing soil population of nematodes. It was first discovered in soil and observed to control root-knot nematode in Peru by Jatala *et al.*, (1979). It was a potentially important biocontrol agent that was capable of parasitizing nematode eggs, juveniles and females and reported to control a range of nematode species on a number of crops worldwide (Ashraf and Khan 2005).

Khan and Khan (1992) reported that besides oviparasitism, the culture filtrates of the fungi, *P. lilacinus* showed mortality of second stage juveniles of *M. incognita*. Zaki (1994) reported that the fungal filtrates of *P. lilacinus* inhibited the hatching of *M. javanica.*

Application of *P. lilacinus* in brinjal recorded highest plant growth, yield and reduced soil and root nematode population (Krishnamoorthi and Kumar, 2007).

Ramakrishnan and Nagesh (2011) reported that *P.lilacinus* in combination with organic amendments reduced the root – knot nematode population in tobacco nurseries.

Sundraraju and Krithika (2009) reported that all the treatments involving *P. lilacinus* alone and in combination with neemcake and botanicals increased the plant growth and significantly reduced the nematode populations.

Khan and Goswami (1999) reported that the culture filtrates of *P. lilacinus* possessed nematicidal action on *M. incognita* (J_2). Nagesh *et al.*, 2003 reported that *M. incognita* in chrysanthemum was controlled using *P.lilacinus* in combination with neem cake.

Rao (2007) tested the efficacy of *P. lilacinus* for the management of nematodes in different horticultural crops like tomato, okra, capsicum etc. and recorded *P. lilacinus* as one of the best treatment for the management of nematodes. Khan and saxena (1996) reported that *P. lilacinus* was found to be most effective against root knot when compared to other nematodes.

Reddy *et al.*, (2008) reported that culture filtrates of *P. lilacinus* was found to be very effective in increasing the mortality and hatching of root knot nematode, *M. incognita*. The percentage mortality and egg hatching inhibition of *M. incognita* were directly propotional to the culture filtrates and exposure period.

Ramana (1994) reported that even though *P. lilacinus* could not effect absolute control of nematodes, it significantly suppressed nematode infestation and increased the total root mass production of pepper.

Sosamma and Koshy (1995) reported that *P.lilacinus* was most effective in the management of *M. incognita* in black pepper. The application of *P.lilacinus* significantly suppressed population of root knot and burrowing nematodes in black pepper and increased total root mass production. (Ramana and sharma, 1993).

Midha *et al.*, (2001) reported that *P. lilacinus* grown on wheat bran applied @ 2g/ kg resulted in good plant growth parameters and reduced the number of galls and egg masses per plant in coriander inoculated with 100J_2 *M.incognita* per pot.

Nisha, (2005) reported that the combination of solarization in the nursery and application *P. lilacinus* + neem cake in main field significantly reduced the nematode population in soil of vegetable coleus.

Efficacy of oviparasitic fungus *P. lilacinus* was studied against root knot nematode *M.incognita* on okra. The results showed that the application of *P.lilacinus* as seed treatment @ 10.15 and 20g/kg seed and soil application @1.5 and 3 per cent w/w significantly increased plant growth characters of okra suppressed galls and eggs per eggmass (Dhawan *et al.*, 2004).

Devarajan and Rajendran (2001) reported that application of *P.lilacinus* at the time of planting was very effective for the control of *R. similis* in banana. Vyas *et al.*, (2011) reported that in brinjal *P. lilacinus* @ 6g/kg soil reduced nematode population of *R. reniformis*.

Cardamom nurseries are ideal for biological control. There are reports that *Gigaspora margarita* and *Glomus fasciculatum* reduced *M.incognita* infestation and enhanced growth and vigour of seedlings (Thomas *et al.*, 1989). *P.lilacinus* reduced root knot nematodes by 48.5-57 per cent in pot culture studies and by 19.7 per cent in field studies (Eapen 1995b; Eapen and Venugopal 1995).

2.6.2 Botanicals

Various plants have been shown to be effective in controlling nematodes on agricultural crops when grown in rotation, inter-planted with susceptible crops, or used as a soil amendment (Wang *et al.*, 2002). The role of botanicals for the management of nematodes is well documented (Sitaramaiah, 1990).

The aqueous extracts prepared from different plant parts of *Tagetes erecta* inhibited the egg hatching and larval penetration of *M. javanica* (Dhangar *et al.*,1996).

Study conducted by Sosamma *et al.*, (1998) revealed that leaf extracts of *Moringa pterigosperma*, *Momordica charantia* and *Leucas aspera* have nematicidal and nematostatic properties against the root-knot nematode, *M.incognita*.

Sundararaju *et al.*, (1999) reported that the leaf extracts of *Chromolaena odorata* exhibited a high degree of nematicidal action against the adults and larvae of *R. similis*. Haseeb *et al.*, (1982) identified the nematicidal properties of *Mentha viridis*, *Cassia fistula*, *Cordia myxa*, *Carissa carandas*, *Colocasia arniquorum* against *R. reniformis*.

A study conducted by Khanna and Sharma (1998) revealed that application of leaves of *Azadirachata indica* and *Tagetes patula* improved plant growth of tomato and reduced nematode count as well as gall index which were at par with that of nematicides.

Root dip treatment of egg plant seedlings in margosa and marigold leaf extracts considerably reduced root-knot development compared to treatment with piperazine citrate, chinapodium oil and ground nut cake (Hussain *et al.*, 1984).

Adegbite and Adesiyan (2005) reported that plants like *Chromalaena odorata*, *Azadirachta indica* and *T. erecta* has some nematicidal property and were found to be effective in controlling plant parasitic nematodes. The aqueous extracts prepared from different parts of *T. erecta* inhibited the egg hatching and larval penetration of *M. javanica* (Dhangar *et al.*, 1996).

Yen *et al.*, (1998) reported that marigolds to be antagonistic to root knot nematodes. Saravanapriya *et al.*, (2004) reported that seed extract of *Areaca catechu*, leaf extracts of *T. erecta*, *A. indica* and *Calotropis gigantea* caused significant inhibition of egg hatch at lower concentration of 0.1per cent.

Jain and Gupta, (1995) also reported that leaf extracts of *Tagetes* spp. and *A. indica* significantly inhibited the egg hatch of *M.incognita* at various concentrations.

Harinath *et al.*, (2007) reported that the aqueous extract of marigold has some inhibitory properties on hatching of *M. incognita* infesting tomato. Compounds present in plants such as *Crotalaria juncea* and *T. minuta* are toxic to root knot nematodes (Guertal *et al.*, 1998).

Sundararaju and Krithika (2009), reported that *P. lilacinus* + *T. erecta* flower extracts followed by *P. lilacinus* + *T. erecta* (leaf extracts) was found to be effective treatment against *M. incognita* in banana. Sankari *et al.*, (2010) reported that acetone extract of *T. erecta* c.v. Indian Yellow was found highly effective in suppressing *M. incognita*.

Adoyo *et al.*, (1997) reported that extracts of *Tithionia diversifolia* can be used for controlling termites. Dutta *et al.*, (1993) reported that the extracts of *T. diversifolia* contain some chemicals that inhibit the insect attack in plants.

Devi, (2010) reported that the extracts of *T. diversifolia* leaf (chopped shade.– dried and ground) and stem (crushed fresh) adversely affected the egg hatching of *M.incognita.*

Olabiyi *et al.*, (2013) reported that wild sunflower (*T. diversifolia*) compost significantly reduced the infection potential of *Pratylenchus brachyurus* on maize.

2.6.3 Chemicals

The effects of chemicals for managing nematodes were reviewed here.

Mohanty and Mahapatra (2009) reported that soaking of paddy seeds for 12h in carbosulfan 0.1per cent reduced the multiplication of root- knot nematodes by 60.07 per cent in soil.

For the management of root knot nematodes in cowpea the lowest population of nematodes was observed in plants treated with carbofuran @2Kg ai/ha followed by carbosulfan 25 DS (Vinodkumar *et al.*, 2010).

Sharma *et al.*, (2008) reported that in tomato for controlling nematodes carbosulfan was found to the best. Carbosulfan 25EC (seed soaking) + carbosulfan (spray) was found to be the best treatment in reducing the galls and nematode population in soil infecting round melon (Rajvanshi *et al.*, 2008).

For reducing the populations of cereal cyst nematode, *Heterodera avenae* and increasing the grain yield in wheat and barley, carbosulfan was found to be the best treatment (Rajvanshi *et al.*, 2012) .

Integration of soil solarization, seed treatment with carbosulfan (25 ST) @ 3% w/w and application of neem cake @ 200 kg ha^{-1} at sowing significantly reduced nematode population (71.80 per cent reduction) and root knot index resulting high yield in okra (Jain and Dabur, 2000).

Seed soaking with carbosulfan 25 STD at 50, 100,200 and 400μg/ml significantly affected penetration and development of *M.incognita* race1 in sunflower(Narayana, 1997).

Jain and Gupta (1990) reported that okra seeds treated with carbosulfan had a significantly lower root knot index than untreated seeds. Mishra and Prasad (1991) found seeds pelleted with carbosulfan 25 STD had best plant growth and nematode control in cowpea crop infected with root knot nematode.

Kathirvel *et al.*, (1992) reported that carbosulfan 6 per cent seed dressing was the most effective treatment for reducing the *M. incognita* populations in okra pot experiments. Meena and Mishra (1993) found that seed soaking and seed dressing with carbosulfan gave the greatest suppression of root knot nematodes infesting soyabean.

Barman and Das (1994) found seed dressing of *Vigna radiata* with carbosulfan at 3 per cent W/W followed by single or double spray with carbosulfan and triazophos were most effective in reducing the galls, egg masses and final population of *M.incognita*.

Prasad and Chawla (1991) found that seed dressing with carbosulfan at 1, 2, 3 and 4 per cent in pot experiments reduced nematodes of groundnut. Seedling emergence was suppressed up to 50 per cent due to phytotoxicity with seed dressing at 4 per cent a.i. w/w. While developing options for the management of disease complex caused by root knot nematode and *Fusarium solani* gypsum based formulations of *Chaetomium abuense* and neem cake at half their orginal doses was found at par with the treatment involving *C. abuence*, neem cake and carbosulfan at quarter at their orginal doses (Narayana, 2002).

Das and Choudary (2012) reported that cartap hydrochloride in nursery bed @1kg a.i./ha 7 days prior to up-rooting of seedlings plus main field application at 45 days after transplanting reduced the nematode population of rice root nematode.

2.7 Management of nematodes in cardamom

P.lilacinus suppressed *Meloidogyne spp.* population by 58.3 % to 86.00% in cardamom nursery. The number of quality seedlings for transplanting was greater in beds treated with this biocontrol agent (Eapen and Venugopal, 1995). *Gigaspora margarita* and *Glomus fasciculatum* reduced *M. incognita* infestation and enhanced growth and vigour of seedlings (Thomas *et al.*, 1989). Narayana (2011) preparations using jeevamrutha + Azospirillum 10g/ clump + *Trichoderma* 10g/ clump as the best treatment followed by jeevamrutha in increasing the yield of cardamom and reducing nematode population. *P. lilacinus* reduced root knot nematodes by 48.5 to 57 per cent in pot culture studies and by 19.7 per cent in field studies in cardamom (Eapen, 1995b; Eapen and Venugopal 1995)

Some isolates of *T. harzianum* and other *Trichoderma* spp. are potential antagonists of root knot nematodes. Reduction of these fungus has been clearly shown in laboratory, green house and also in cardamom nurseries (Eapen *et al.*, 2005).

Application of aldicarb at 5kg a.i./ha three times once in, every three months, results in increased growth and vigour of seedlings in both primary and secondary nurseries of cardamom. Drenching of nursery beds with fenamiphos also significantly reduced root knot nematodes (Ali, 1986b).

Aldicarb, carbofuran and phorate at 5, 10 and 15 kg a.i/ha, respectively, have been applied in primary nurseries of cardamom for the control of *M. incognita*. None of these nematicide treatments totally prevented the nematode infestation, but there was significant reduction in the root knot densities. Aldicarb at the very high level of 15 kg a.i./ha reduced nematode numbers by 90% (Ali,1987).

Application of aldicarb, carbofuran, phorate at 5 and 10g a.i./plant and neem oil cake at 500g and 1000g/plant twice a year increases the yield of cardamom plants infested with *M. incogita* from 47 to 88 per cent. Maximum yield was obtained from the plants receiving neem oil cake at a rate of 1000g /plant twice a year followed by 500g/plant (Ali, 1984). However in another study, application of phorate at 2.5-5.0 g a.i/plant reduced the nematode population and increased the yield by more than 40 per cent (Eapen, 1995b).

Materials and Methods

3. MATERIALS AND METHODS

Studies were conducted in Idukki district to document the association of various plant pathogenic nematodes in cardamom plantations, to study the community behavior of nematodes and to evaluate the reaction of different cardamom cultivars to nematodes and management using nematicides, soil amendments and bioagents.

3.1 Survey of nematodes associated with rhizosphere of cardamom

A survey was carried out in fifteen panchayaths of Idukki district, following purposive sampling technique in nematode infested cardamom plantations. Twenty five soil and root samples were collected from different plantations of the following panchayaths: Elappara, Kattappana, Pampadumpara, Vazhathope, Nedumkandam, Chinnakkanal, Santhampara, Rajakumari, Karunapuram, Vathikudy, Senapathy, Udumbanchola, Rajakkad, Bison valley and Kumily.

3.1.1 Sampling methods

Soil samples were collected from the rhizosphere of cardamom at a depth of 15-30cm with a soil augar. Samples were taken around the plant from three spots, at each horizontal distance of 30 and 45 cm away from the base of the plant.

3.1.2 Processing of samples

The samples were bulked and 200g composite sample was processed for extraction of nematodes by Cobb’s sieving and decanting method followed by modified Baerman’s funnel technique.

3.1.3 Estimation of nematode population in roots

Approximately 25g of younger feeder roots (white in colour) were collected from the rhizosphere of cardamom plants. Roots were thoroughly washed in tap water and cut into smaller pieces (2 to 3cm in length). Five gram root sub-samples were then stained in Acid fuschin – lactophenol (Daykin and Hussey, 1985). Stained roots were washed several times in tap water to remove the excess stain and then macerated in electric blender with 10 to 15ml of water to dislodge the nematodes. Three 1ml samples were removed from the suspension to obtain the population count (Marks and Mckenna, 1981). The nematodes extracted were counted under a 300m stereo microscope.

3.1.4 Killing and fixing of nematodes for permenant mounts

The fixative used was TAF. The composition for making this fixative was as follows.

Formalin (40% formaldehyde)	: 7ml
Triethylamine	: 2ml
Distilled water	: 91ml.

Double strength fixative was prepared. Live nematodes were transferred to a small glass vial and allow them to settle at the bottom. Drain off surplus water and then they are left in about 2ml water. Nematodes were killed by stirring the vial 20-30 second in a 70-90^{0}Cwater bath, then add an equal volume of 65-70^{0}C fixative. Vial was then kept for a day to allow the fixative to penetrate and act on all tissues. Nematodes were then transferred from TAF filled vial to a cavity block. Then fill the block / vial with a solution of 5% glycerine in distilled water. Place the block or vial in an incubator at 35-40^{0}C and cover it completely leaving a narrow slit for slow evaporation. Refill with 5% glycerine, and then leave at least two or three days in the incubator until all the water has evaporated.

For identification up to species level permanent slides were prepared. For that place a drop of dehydrated glycerine in the centre of a glass slide, transfer two or three nematodes to the droplet bottom. Then three pieces of glass fibers were arranged at the bottom of the droplet. Glass fibers should be approximately 1mm long and thickness should be according to the nematode diameter. Apply a cover slip with a pair of foreceps. Redundant glycerine can be removed with filter paper first, and then with ethanol. Fix the cover slip at three points with glyceel. Photographs of the slides were taken using compound microscope at 1000x magnification.

3.2 Estimating the community analysis and yield of nematodes in the rhizosphere of cardamom: Soil samples were collected from the rhizosphere of infested cardamom plants and estimated the population of nematodes. The data thus obtained were used to study the community analysis of nematodes. Absolute frequency, relative frequency, absolute density, relative density and prominence value of each nematode genus were determined using the formula of Norton, (1978).

$$\text{Absolute frequency} = \frac{\text{Number of samples containing a species} \times 100}{\text{Total no. of samples collected}}$$

$$\text{Relative frequency} = \frac{\text{Frequency of species} \times 100}{\text{Sum of frequency of all species}}$$

$$\text{Absolute density} = \frac{\text{No. of individuals of a species in sample} \times 100}{\text{Volume of sample}}$$

$$\text{Relative density} = \frac{\text{No. of individuals in a sample} \times 100}{\text{Total of all individual in a sample}}$$

$$\text{Prominence value} = \text{Density} \times \sqrt{\text{Frequency}}$$

3.3 Evaluate the reaction of different cardamom cultivars to nematodes

Thirteen cultivars/accessions maintained in Cardamom Research Station, Pampadumpara were evaluated to study its reaction towards economically important plant parasitic nematodes.

Experiment was laid out in randomized block design with thirteen treatments, three replications and five plants were maintained in each replication.

Thirteen cultivars/accessions selected for this study were Green gold (Njallani), $PV_{2,}$ CRSP6, PL-14, MCC346, CL691, CL726, SKP164, IC547167, IC349651, IC547185, SKP104, 1C349545

3.3.1 Estimation of plant growth parameters and yield of different cultivars

Data on growth and yield contributing characters such as tiller height, tillers/ clump, length of leaf, width of leaf, fresh yield and the incidence of pests like shoot and fruit borer were recorded at harvesting stage.

3.3.2 Estimation of nematode population in soil and roots

Soil and root samples of different cultivars were collected and processed for analyzing the nematode population at three different stages of crop *viz*. tillering stage, flowering stage and harvesting stage. The collected soil samples were processed using the Cobb's sieving and decanting technique followed by modified Baermann's technique. The nematodes extracted were counted under a zoom stereo microscope having 100X magnification. Root samples processed as described in para 3.1.3. The nematode suspension was counted under a stereo microscope. For identification permanent mounts were prepared as described in para 3.1.4.

3.4 Management of Plant parasitic nematodes in cardamom

3.4.1 Testing the efficacy of chemicals and botanical *in vitro*

Wild sunflower leaves (*Tithonia diversifolia*), cartap hydrochloride 4G, thiamethoxam 50 WG, carbosulfan 6G were studied for testing their efficacy against plant parasitic nematodes. The experiment was laid out in completely randomized design with five treatments for botanical *viz*., S (2g leaf in 5ml water), S/2 (5mlS + 5mlwater), S/3 (2.5ml S+7.5ml water), S/4 (1.25 ml S + 8.75 ml water) and untreated control (water 10ml). For testing the efficacy of chemicals the experiment was laid out in completely randomized design with with five treatments 50µg/ml, 100µg/ml, 200µg/ml, 300µg/ml and untreated control.

3.4.2 Testing the efficacy of botanical *Tithonia diversifolia* against mortality of nematodes

Materials required

1. Nematode culture
2. Sterilized Petriplates
3. 0.1% $HgCl_2$
4. Ethanol 95%
5. Distilled water
6. Whatman No.1 filter paper
7. Blender

3.4.2.1 Culturing of nematodes

Root knot nematode, *Meloidogyne* sp was selected as the test organism. Second stage juveniles (J_2), hatched out from egg mass collected from culture plants mainatained in Nematology glass house were inoculated on roots of young tomato

Plate 1: *Tithonia diversifolia* (wild sunflower leaves)

plants grown in 15cm diameter earthen pots containing denematizied sandy loam soil. These plants were maintained as source of inoculum for subsequent inoculations after identification of the nematode. The egg masses of *M.incognita* were hand picked from galled roots of tomato grown in culture pots. These were surface sterilized with 0.1 per cent $HgCl_2$, followed by ethanol (95%) for one minute each. The treated egg masses were rinsed three times with sterile distilled water to remove the surface sterilizing agents. These surface sterilized egg masses were then used directly or as a source of juveniles (J_2) for *in vitro* tests.

3.4.2.2 Preparation of extract

Fourty gram of fresh leaves from wild sunflower leaves (plate 1) were crushed in twenty ml water with a blender for three minutes, the suspension was then allowed to stand for twentyfour hours and filtered through a Whatman No.1 filter paper. The filtrate was considered as standard and assayed against juveniles.

3.4.2.3 *In vitro* experiments for larval mortality

3.4.2.3.1 Plant extract

For studying the juvenile mortality, 100 second stage juvenile of *M.incognita* were suspended in 10 ml of extract in clean Petri dish. The experiment was carried out in 4 concentrations Stock solution (2g leaf in 5ml water), S/2 (5mlS + 5ml water), S/3 (2.5 ml S+7.5ml water), S/4 (1.25mlS + 8.75 ml water) and untreatedcontrol (water) with three replication each. All the Petri dishes were kept at ambient temperature. After 24, 48 and 72 h all dead and alive second stage juveniles were counted with the aid of a stereo microscope. The dead juveniles attained the shape of straight line and the mortality was ensured by touching the juvenile with a fine needle. The mortality percentage was worked out after counting the dead nematodes at 24, 48 and 72 h.

3.4.2.3.2 Chemicals

The experiment was carried out at four concentrations viz., 50, 100, 20 and 300µg/ml of the three chemicals *viz.,* carbosulfan, cartaphydrochloride, thiamethoxam. For studying the juvenile mortality, 100 numbers of nematode were suspended in 10 ml of the chemical solution with three replications. Observations were taken at 24 h, 48h, and 72h. The dead juveniles attained the shape of straight line and the mortality was ensured by touching the juvenile with a fine needle. The ratio of dead nematodes/ total number of nematodes was expressed in percentage mortality.

3.4.3 Field experiment

For the management of nematodes a field trial was conducted in two year old cardamom plants. The variety used for field experiment was Njallani. The experiment was laid out in randomized block design with seven treatments and three replications.

T_{1} – Cartap hydrochloride 4 G 1kg a.i /ha

T_2 - Thiomethoxam 25 WG 50 g a.i /ha

T_3 - Wild sunflower 5kg/plant

T_4 - *Paecilomyces lilacinus* (1x 10^7 cfu 50g/plant)

T_5 – *Bacillus macerans* (1x 10^7 cfu 50g/plant)

T_6 – Carbosulfan 6 G 1kg a.i /ha

T_7 – Untreated

The efficacy of bioagents, chemicals and leaf mulch were assessed for the management of nematodes in cardamom with carbosulfan as check. The required quantities were applied to each plant.

3.4.4 Observations made

3.4.4.1 Estimation of nematode population in soil

Soil sample from the rhizosphere of plants were collected before the application of bioagents, chemicals and leaf mulch for estimating the pre – treatment population. They were processed for nematode extraction following the Cobb's sieving and decanting technique followed by Modified Baermann's technique. The nematodes thus extracted were counted under a stereo zoom microscope. The population of nematodes in soil were estimated at the tillering stage, flowering stage and harvesting stage of the plant after treatment.

3.4.4.2 Estimation of nematode population in roots

The population of nematodes in roots were estimated at the tillering stage, flowering stage and harvesting stage of the plant after treatment. Root samples were processed according to the technique described in para 3.1.3

Various biometric characters like number of leaves and tiller, panicle and yield were recorded at tillering, flowering and harvesting stages respectively.

3.4.5 Statistical Analysis

The data generated from the experiments (3.3 to 3.4) were subjected to analysis of variance (ANOVA) technique (Cochran and Cox, 1965). The variables which do not satisfy the basic assumption of ANOVA were subjected to logarithmic, angular and square root transformations.

Results

4. RESULT

The salient results of the study "Management of nematodes associated with cardamom" is presented below.

4.1 **Association of nematodes in cardamom**

Twenty five soil and root samples were collected from fifteen panchayaths of Idukki district and analyzed for studying association and the community behaviour of nematodes. The analysis of soil samples from the rhizoshere of cardamom revealed four trophic groups 1) Plant parasites: Tylenchids 2) Bacterial feeders: Rhabditids 3) Omnivorous: Dorylaimids 4) Predatory forms : Mononchids. The results of community analysis was presented in Table 1 to Table 27.

4.1.1 Distribution of plant parasitic nematodes associated with rhizosphere of cardamom

Analysis of soil and root samples collected from rhizosphere of cardamom revealed the occurrence of four plant parasitic nematodes *viz., Meloidogyne incognita, Rotylenchulus reniformis, Helicotylenchus pseudorobustus, Radopholus similis* (Table 1). Highest population of *M. incognita* was found in Thovalapady area of Karunapuram panchayath (957 /200g soil; 29 /200g soil) followed by Thopramkudy area of Vathikudy panchayath (795/200g soil; 25/5g roots). Lowest population was recorded in Moolathara area of Santhampara panchayath (20/200g soil; 2/5g soil). *M.incognita* was not recorded in soil samples collected from cardamom grown in Myladumpara of Udumbonchola panchayath, Santhampara of Santhampara panchayath, Pathinipara of Pampadumpara panchayath, Nedumkandam of Nedumkandam panchayath and Periyakanal of Chinnakanal panchayath. In the case of

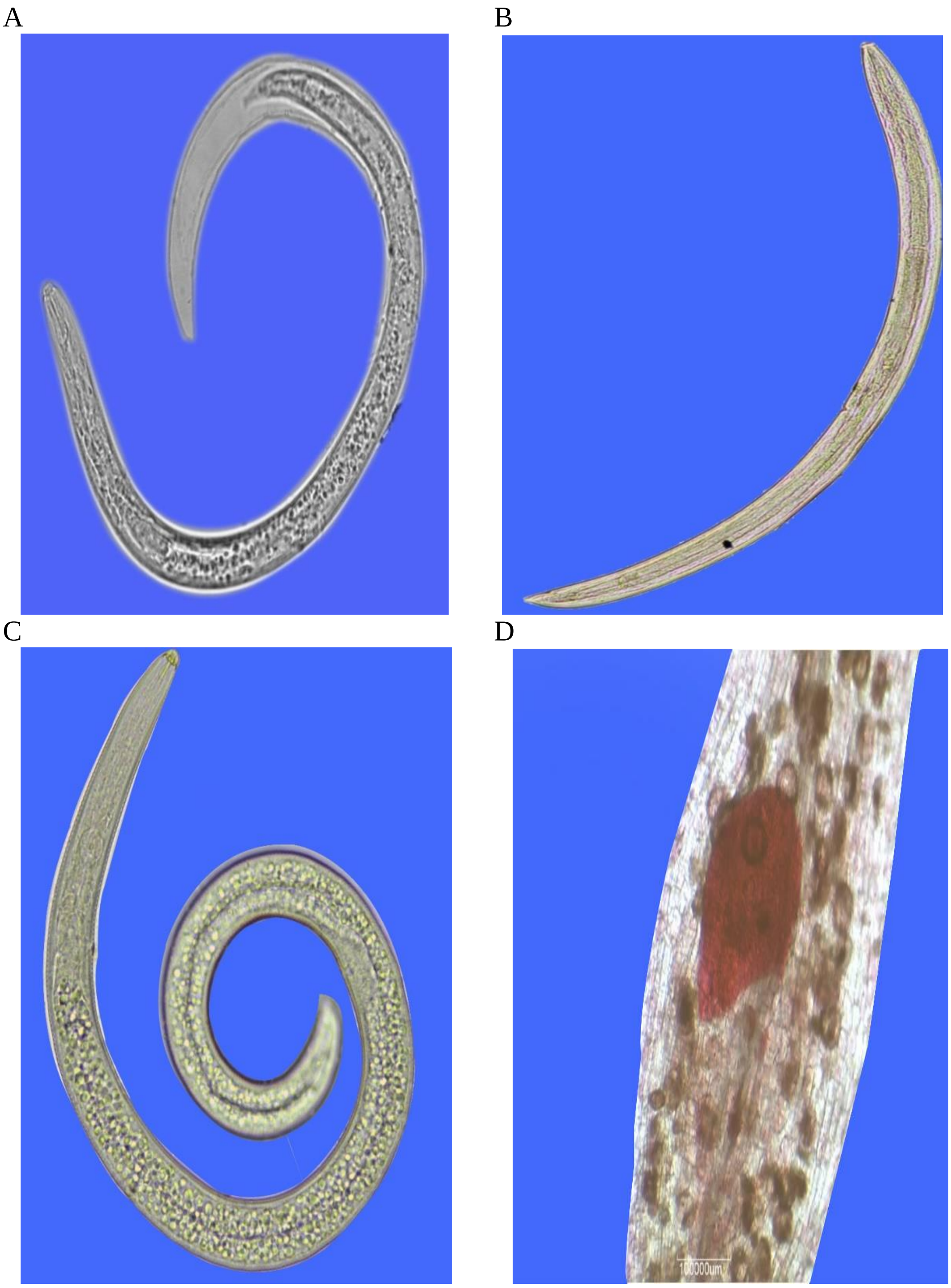


Plate 2. Nematode species identified during the survey (A): *Rotylenchulus reniformis* (B): *Eudorylaimus* sp. (C): *Helicotylenchus pseudorobustus* (D): *Meloidogyne incognita*

Table.1.Distribution of various plant parasitic nematode in the rhizosphere of cardamom

			Nematode population in soil and roots							
Sl.No	Location	Panchayath	*M. incognita*		*R. reniformis*		*H. pseudorobustus*		*R.similis*	
			Soil (200g)	Roots (5g)	Soil (200g)	Roots (5g)	Soil (200g)	Roots (5g)	Soil (200g)	Roots (5g)
1	Elappara	Elappara	192	20	225	5	557	-	-	-
2	Puliyanmala	Kattapana	161	21	-	4	589	-	223	-
3	Kattapana	Kattapana	-	-	259	7	243	-	-	-
4	Kalarickal estate	Kattapana	25	5	229	7	441	-	-	4
5	Sanyasioda	Pampadumpara	346	16	256	7	713	-	-	-
6	Pathinipara	Pampadumpara	-	8	559	8	46	-	-	-
7	Memala	Vazhathoppu	81	11	49	2	250	-	-	-
8	Kuppakal	Nedumkandam	176	14	58	5	61	-	-	-
9	Pattathimukku	Nedumkandam	-	-	90	4	220	-	-	-
10	Muruganpara	Nedumkandam	7	2	22	-	80	-	224	3
11	Nedumkandam	Nedumkandam	-	-	69	5	306	-	-	-
12	Periyakanal	Chinnakkanal	-	-	309	9	700	-	-	-
13	Cheriyar	Santhampara	557	17	169	6	314	-	-	-
14	Santhampara	Santhampara	-	-	19.75	1	261	-	-	-
15	Moolathara	Santhampara	20	2	31	4	67	-	-	-
16	Rajakumari	Rajakumari	676	19	303	7	638	-	31	2
17	Thovalapady	Karunapuram	957	29	-	-	309	-	-	-
18	Chottupara	Karunapuram	394	15	-	-	298	-	-	-
19	Thopramkudy	Vathikudy	795	25	114	6	64	-	-	-
20	Kamakshivilasam estate	Senapathy	43	3	157	6	492	-	-	
21	Myladumpara	Udumbanchola	-	-	-	2	572	-	-	-
22	Rajakkad	Rajakkad	279	9	258	7	586	-	-	-
23	Bison valley	Bison valley	65	3	34	4	249	-	-	-
24	Kumily	Kumily	158	5	13	1	86	-	-	-
25	Mannipara	Kumily	325	12	-	-	125	-	-	-

R. reniformis, the highest population was found in Pathinipara area of Pampadumpara panchayath (559/200g soil; 8/5g roots) and lowest population was recorded in Kumily area of kumily panchayath (13/200g soil; 1/5g roots). Puliayanmala area of Kattapana panchyath, Thovalapady area of Karunapuram panchayth, Chottupara area of Karunapuram panchayath, Myladumpara area of Udumbonchola panchayath and Mannipara area of Kumily Panchayath did not record any detectable levels of *R. reniformis* population in soil. *H. pseudorobustus* was distributed in all the areas surveyed. The highest population of *H. pseudorobustus* was found in Sanyasioda area of Pampadumpara panchayath (713/200g soil) and lowest population was observed in Pathinipara area of Pampadumpara Panchayath (46/200g soil). *R. similis* was recorded only in three areas in soil and root samples *viz*. Puliyanmala area of Kattapana panchayath (223/200g soil; 4/5g roots), Muruganpara area of Nedukandam panchayath (224.00/200g soil; 3/200 g soil) and Rajakumari area of Rajakumari Panchayath (31/20 g soil; 2/200 g soil)

4.1.2 Distribution of free living forms of nematodes associated with rhizosphere of cardamom

About five free living forms of nematodes were identified from the community analysis of twenty five soil samples in Idukki district *viz*., Rhabditids (bacterial feeding), *Eudorylaimus* sp., *Nygolaimus* sp., and *Aprocelaimus* sp (omnivores) and Mononchids (predatory forms). Results were presented in Table 2. Highest population of rhabditids was found in Rajakumari area of Rajakumari panchayath (1086/200g soil), followed by Muruganpara area of Nedumkandam panchayath (488/200g soil). Puliaynmala area of Kattapana panchayath recorded the lowest population of rhabditids (14/200g soil). The highest population of

Table.2.Distribution of non parasitic nematodes (free living) in the rhizosphere of cardamom

			Nematode population in 200g soil				
Sl.No	Location	Panchayath	Rhabditids	Mononchids	*Eudotylaimus* sp.	*Nygolaimus* sp.	*Aprocelaimus* sp.
1	Elappara	Elappara	23	-	20	15	24
2	Puliyanmala	Kattapana	14	-	74	28	26
3	Kattapana	Kattapana	22	-	13	70	46
4	Kalarickal estate	Senapathy	31	45	122	-	-
5	Sanyasioda	Pampadumpara	125	-	86	-	40
6	Pathinipara	Pampadumpara	-	-	6	19	31
7	Memala	Vazhathoppu	69	11	25	17	31
8	Kuppakal	Nedumkandam	81	21	53	28	19
9	Pattathimukku	Nedumkandam	392	-	60	44	45
10	Muruganpara	Nedumkandam	488	-	24	31	31
11	Nedumkandam	Nedumkandam	-	18	-	-	14
12	Periyakanal	Chinnakkanal	31	64	12	25	4
13	Cheriyar	Santhampara	-	53	9	13	17
14	Santhampara	Santhampara	17	-	17	5	-
15	Moolathara	Santhampara	133	-	75	31	39
16	Rajakumari	Rajakumari	1086	-	-	31	257
17	Thovalapady	Karunapuram	-	21	73	18	22
18	Chottupara	Karunapuram	136	36	-	-	-
19	Thopramkudy	Vathikudy	31	39	-	-	-
20	Kamakshivilasam estate	Senapathy	21	4	4	-	140
21	Myladumpara	Udumbanchola	-	42	39	30	37
22	Rajakkad	Rajakkad	17	-	86	13	-
23	Bison valley	Bison valley	25	-	33	13	-
24	Kumily	Kumily	-	-	6	-	-
25	Mannipara	Kumily	-	18	17	-	-

Mononchids was recorded in Periyakanal area of Chinnakanal panchayath with a population of 64/200g soil followed by Cheriyar area of Santhampara panchayath (53/200g soil) and the lowest population was recorded by Kamakshivilasam estate of Udumbanchola panchayath with a nematode population of 4/200g soil. Highest population of *Eudorylaimus* sp. was observed in Kalarickal estate of Kattapana panchayath (121.75/200g soil) followed by Sanyasioda area of Pampadumpara panchayath (86.25/200g soil).The lowest was found in Kamakshivilasam estate of Udumabanchola panchayath with a averge nematode population of (4/200g soil). *Nygolaimus* sp. population was found to be high in Kattapana area of Kattapana panchayath with an average population of 70.25/200g soil followed by Pattathimukku area of Nedumkandam panchayath (44/200g soil). Least nematode population was found in Santhampara area of santhampara panchayath (5/200g soil). Highest population of *Aprocelaimus* sp. was found in Rajakumari area of Rajakumari panchayath with an average of 257/200g soil followed by Kamakshivilasam estate of Udumbanchola panchayath (140/200g soil) and the lowest was observed for Periyakanal area of Chinnakanal panchayath (4/200g soil).

4.1.3 *Community analysis of nematodes in Elappara panchayath*

A total of seven nematode species were recorded in soil samples collected from Elappara panchayath. The results presented in Table 3 revealed that most prominent nematode in Elappara area of Elappara panchayath was *H. pseudorobustus* with a prominence value of 222.5, followed by *R. reniformis* (88.70). The nematode species of least prominence was *Nygolaimus* sp. (5.90). Based on the relative frequency value, *R. reniformis* (14.80), *H. pseudorobustus* (14.80), *Eudorylaimus* sp. (14.80), *Nygolaimus* sp. (14.80) and *Aprocelaimus* sp. (14.80)

Table 3. Community analysis of nematodes encountered at Elappara area in Elappara panchayath

Nematode species	Absolute frequency	Relative frequency	Absolute density	Relative density	Prominence value
M. incognita	75	11.1	770	17.2	66.7
R. reniformis	100	14.8	887	19.8	88.7
H. pseudorobustus	100	14.8	2225	49.6	222.5
Eudorylaimus sp.	100	14.8	79	1.8	7.9
Nygolaimus sp.	100	14.8	59	1.3	5.9
Aprocelaimus sp.	100	14.8	94	2.1	9.4
Rhabditids	100	14.8	375	8.4	37.5

Table 4. Community analysis of nematodes encountered at Puliyanmala area in Kattapana panchayath

Nematode species	Absolute frequency	Relative frequency	Absolute density	Relative density	Prominence value
M. incognita	100	14.3	655	14.2	65.5
H. pseudorobustus	100	14.3	2353	51.1	235.3
R. similis	100	14.3	892	19.4	89.2
Rhabditids	100	14.3	196	4.3	19.6
Eudorylaimus sp.	100	14.3	296	6.4	29.6
Nygolaimus sp.	100	14.3	112	2.4	11.2
Aprocelaimus sp.	100	14.3	104	2.3	10.4

Table 5. Community analysis of nematodes encountered at Kattapana area in Kattapana panchayath

Nematode species	Absolute frequency	Relative frequency	Absolute density	Relative density	Prominence value
R. reniformis	100	30.8	1035	44.9	103.5
H. pseudorobustus	75	23.1	972	417	84.5
Eudorylaimus sp.	25	7.7	53	2.3	2.6
Aprocelaimus sp.	75	23.1	182	7.8	15.8
Rhabditids	150	15.4	89	3.8	6.3

Table 6. Community analysis of nematodes encountered at Kalarickal estate in Kattapana panchayath

Nematode species	Absolute frequency	Relative frequency	Absolute density	Relative density	Prominence value
M. incognita	75	15	102	2.9	8.8
R. reniformis	100	20	911	25.5	91.1
H. pseudorobustus	100	20	1765	49.5	176.5
Eudorylaimus sp.	100	20	487	13.7	48.7
Rhabditids	50	10	123	3.4	15.4
Mononchids	75	15	178	5	8.7

Table 7. Community analysis of nematodes encountered at Sanyasioda area in Pampadumpara panchayath

Nematode species	Absolute frequency	Relative frequency	Absolute density	Relative density	Prominence value
M. incognita	100	11.1	800	12.7	80
H. pseudorobustus	100	11.1	2850	45.4	285
H.criconemoids	25	12.5	25	1	1.2
Rhabditids	100	11.1	500	8	50
Eudorylaimus sp.	100	11.1	345	5.5	34.5
Nygolaimus sp.	100	11.1	281	4.5	28.1
Aprocelaimus sp.	100	11.1	123	2	12.3

Table 8. Community analysis of nematodes encountered at Pathinipara area in Pampadumpara panchayath

Nematode species	Absolute frequency	Relative frequency	Absolute density	Relative density	Prominence value
R. reniformis	100	50	2234	91.5	223.4
H. pseudorobustus	75	37.5	183	7.5	15.8
Eudorylaimus sp.	25	12.5	25	1	1.2

Table 9. Community analysis of nematodes encounterd at Memala area in Vazhathoppu panchayath

Nematode species	Absolute frequency	Relative frequency	Absolute density	Relative density	Prominence value
M. incognita	100	12.5	354	16.4	35.4
R. reniformis	100	12.5	195	9.0	19.5
H. pseudorobustus	100	12.5	999	462	99.9
Rhabditids	100	12.5	276	12.8	27.6
Eudorylaimus sp.	100	12.5	98	4.5	9.8
Nygolaimus sp.	100	12.5	75	3.5	7.5
Aprocelaimus sp	100	12.5	123	5.7	12.3
Mononchids	100	12.5	43	2.0	4.3

Table10. Community analysis of nematodes encounterd at Kuppakal area in Nedumkandam

Nematode species	Absolute frequency	Relative frequency	Absolute density	Relative density	Prominence value
M. incognita	100	14.3	643	34.1	64.3
R. reniformis	100	14.3	233	12.4	24.3
H. pseudorobustus	100	14.3	243	12.9	32.3
Rhabditids	100	14.3	323	17.1	32.3
Eudorylaimus sp.	100	14.3	210	11.1	21
Nygolaimus sp.	100	14.3	111	5.9	11.1
Aprocelaimus sp.	100	14.3	123	6.5	12.3
Mononchids	100	14.3	233	12.4	23.3

Table11. Community analysis of nematodes encountered at Pattathimukku area in Nedumkandam panchayath

Nematode species	Absolute frequency	Relative frequency	Absolute density	Relative density	Prominence value
R. reniformis	100	16.7	343	10.1	34.3

H. pseudorobustus	100	16.7	880	26	88
Rhabditids	100	16.7	1567	46.3	156.7
Eudorylaimus sp.	100	16.7	240	7.1	24
Nygolaimus sp.	100	16.7	176	5.2	70.6
Aprocelaimus sp.	100	16.7	178	5.3	17.8

Table 12. Community analysis of nematodes encountered at Muruganpara area in Nedumkandam panchayath

Nematode species	Absolute frequency	Relative frequency	Absolute density	Relative density	Prominence value
R. reniformis	100	16.7	343	10.1	34.3
H. pseudorobustus	100	16.7	880	26	88
Rhabditids	100	16.7	1567	46.3	156.7
Eudorylaimus sp.	100	16.7	240	7.1	24
Nygolaimus sp.	100	16.7	176	5.2	70.6
Aprocelaimus sp.	100	16.7	178	5.3	17.8

Table 13. Community analysis of nematodes encountered at Nedumkandam area in Nedumkandam panchayath

Nematode species	Absolute frequency	Relative frequency	Absolute density	Relative density	Prominence value
R. reniformis	75	27.3	276	17	23.9
H.pseudorobustus	100	36.4	1222	75.2	122.2
Mononchids	75	27.3	73	4.5	6.3
Aprocelaimus sp.	25	9.1	55	3.4	2.8

Table 14. Community analysis of nematodes encountered at Periyakanal area in Chinnakal Panchayath

Nematode species	Absolute frequency	Relative frequency	Absolute density	Relative density	Prominence value
H. pseudorobustus	100	14.3	1234	26.7	280
R. reniformis	100	14.3	2800	60.7	123.4
Rhabditids	100	14.3	124	2.7	12.4
Eudorylaimus sp.	100	14.3	46	1.0	4.6
Nygolaimus sp.	100	14.3	98	2.1	9.8
Aprocelaimus sp.	100	14.3	56	1.2	5.6
Mononchids	100	14.3	256	5.5	25.6

Table 15. Community analysis of nematodes encountered at Cheriyar area in Santhampara panchayath

Nematode species	Absolute frequency	Relative frequency	Absolute density	Relative density	Prominence value
M. incognita	100	14.3	2267	49.7	226.7
R. reniformis	100	14.3	671	14.7	61.1
H. pseudorobustus	100	14.3	1256	27.6	125.6
Eudorylaimus sp.	100	14.3	34	0.7	3.4
Nygolaimus sp.	100	14.3	53	1.2	5.3
Aprocelaimus sp.	100	14.3	67	1.5	6.7
Mononchids	100	14.3	210	4.6	21

Table 16. Community analysis of nematodes encountered at Santhampara area in Santhampara panchayath

Nematode species	Absolute frequency	Relative frequency	Absolute density	Relative density	Prominence value
R. reniformis	50	15.4	79	15.4	5.6
H. pseudorobustus	100	30.8	1045	30.8	104.5
Eudorylaimus sp.	75	23.1	68	23.1	5.9
Nygolaimus sp.	25	7.7	22	7.7	1.1
Rhabditids	75	23.1	68	23.1	5.9

Table 17. Community analysis of nematodes encountered at Moolathara area in Santhampara panchayath

Nematode species	Absolute frequency	Relative frequency	Absolute density	Relative density	Prominence value
M. incognita	100	14.3	87	5.5	8.7
R. reniformis	100	14.3	121	7.6	12.1
H. pseudorobustus	100	14.3	267	16.8	26.7
Rhabditids	100	14.3	532	33.5	53.2
Eudorylaimus sp.	100	14.3	301	19	30.1
Nygolaimus sp.	100	14.3	123	7.8	12.3
Aprocelaimus sp.	100	14.3	156	9.8	15.6

Table 18. Community analysis of nematodes encountered at Rajakumari area in Rajakumari panchayath

Nematode species	Absolute frequency	Relative frequency	Absolute density	Relative density	Prominence value
M. incognita	100	20	2888	23.8	288.8
R. reniformis	75	20	1211	10	164.9
H. pseudorobustus	100	15	2543	21	254.3
Nygolaimus sp.	75	20	73	0.6	5.2
Aprocelaimus sp.	75	15	1036	8.7	91.5
Rhabditids	100	20	4345	35.9	434.5

Table 19. Community analysis of nematodes encountered at Thovalapadi area of Karunapuram panchayath

Nematode species	Absolute frequency	Relative frequency	Absolute density	Relative density	Prominence value
M. incognita	100	14.8	3875	65.1	387.5
H. pseudorobustus	75	11.1	1233	20.7	106.8
R. similis	100	14.8	234	3.9	23.4
Eudorylaimus sp.	100	14.8	293	4.9	29.3
Nygolaimus sp.	100	14.8	143	2.4	14.3
Aprocelaimus sp.	100	14.8	88	1.5	8.8

Table 20. Community analysis of nematodes encountered at Chottupara area in Karunapuraram panchayath

Nematode species	Absolute frequency	Relative frequency	Absolute density	Relative density	Prominence value
M. incognita	100	36.4	1653	46.7	165.3
H.pseudorobustus	100	36.4	1200	33.9	120

Rhabditids	50	18.2	543	15.3	38.4
Mononchids.	25	9.1	145	4.1	7.2

Table 21.Community analysis of nematodes encountered at Thopramkudy area in Vathikudy panchayath

Nematode species	Absolute frequency	Relative frequency	Absolute density	Relative density	Prominence value
M. incognita	100	23.5	3090	68.9	309
R. reniformis	100	23.5	456	10.2	22.3
H. pseudorobustus	75	17.6	258	5.8	45.6
Eudorylaimus sp.	50	11.8	546	12.2	5.5
Mononchids	50	11.8	58	1.3	38.6
Rhabditids	50	11.8	78	1.7	4.1

Table 22. Community analysis of nematodes encountered at Kamakshivilasam estate in Senapathy panchayath

Nematode species	Absolute frequency	Relative frequency	Absolute density	Relative density	Prominence value
M. incognita	50	10.5	176	3.7	12.4
R. reniformis	75	15.8	624	13.1	54
H. pseudorobustus	100	21.1	1989	41.7	198.9
Eudorylaimus sp.	100	21.1	1322	27.7	132.2
Nygolaimus sp.	75	15.8	558	11.7	48.3
Rhabditids	50	10.5	83	1.7	5.9

Table 23. Community analysis of nematodes encountered at Myladumpara area in Udumbonchola panchayath

Nematode species	Absolute frequency	Relative frequency	Absolute density	Relative density	Prominence value
H. pseudorobustus	100	16.7	2343	77.7	234.3
Rhabditids	100	16.7	79	2.6	7.9
Eudorylaimus sp.	100	16.7	157	5.2	15.7
Nygolaimus sp.	100	16.7	121	4.0	12.1
Aprocelaimus sp.	100	16.7	146	4.8	14.6
Mononchids	100	16.7	168	5.6	16.8

Table 24. Community analysis of nematodes encountered at Rajakkad area in Rajakkad Panchayath

Nematode species	Absolute frequency	Relative frequency	Absolute density	Relative density	Prominence value
M. incognita	160	23.5	1076	21.9	107.6
R. reniformis	75	17.6	1032	21	89.4
H. pseudorobustus	100	23.5	2343	47.7	234.3
Eudorylaimus sp.	75	17.6	343	7.0	29.7
Nygolaimus sp.	25	5.9	55	1.1	2.8
Rhabditids	50	11.8	67	1.4	4.7

Table 25. Community analysis of nematodes encountered at Bison Valley area in Bison valley panchayath

Nematode species	Absolute frequency	Relative frequency	Absolute density	Relative density	Prominence value
M. incognita	50	14.3	268	7.4	19.0

R. reniformis	50	14.3	131	3.8	9.30
H. pseudorobustus	100	28.6	987	27.4	98.7
Eudorylaimus sp.	25	7.1	133	3.7	6.6
Nygolaimus sp.	25	7.1	52	1.4	2.6
Rhabditids	100	28.6	2032	56.4	203.2

Table 26. Community analysis of nematodes encountered at Kumily area in Kumily panchayath

Nematode species	Absolute frequency	Relative frequency	Absolute density	Relative density	Prominence value
M. incognita	100	44.4	62,3	59.6	62.3
R. reniformis	25	11.1	53	5.1	2.6
H. pseudorobustus	75	33.3	345	33	29.9
Eudorylaimus sp.	25	11.1	25	2.4	1.2

Table 27. Community analysis of nematodes encountered at Mannipara area in Kumily panchayath

Nematode species	Absolute frequency	Relative frequency	Absolute density	Relative density	Prominence value
M. incognita	100	40	1298	64.6	129.8
H. pseudorobustus	75	30	451	22.4	39.1
Eudorylaimus sp.	50	20	234	11.6	16.5
Mononchids	25	10	27	1.3	1.4

were the most frequently occurring nematodes followed by *M. incognita* (11.10). *H. pseudorobustus* was the most abundant species with a relative density of 49.60 and *Nygolaimus* sp. (1.30) was the least abundant.

4.1.4 *Community analysis of nematodes in Kattapana panchayat*

The results from Table 4 and 5 revealed that *M. incognita, H. pseudorobustus, R. similis, Eudorylaimus sp., Nygolaimus sp.,* Rhabditids *and Aprocelaimus sp.* were the nematodes identified in Kattapana panchayath. The most prominent nematode in Puliyanmala area of Kattapana panchayath was *H. pseudorobustus* with a prominence value of (235.30) followed by *R similis* (89.20) and the nematode of least prominence was *Aprocelaimus* (10.40). Maximum relative density was recorded for *H. pseudorobustus* 51.10 per cent followed by *R. similis* (19.40).

The results of Kattapana area in Kattapana panchayath (Table 5) revealed that highest prominence value was observed in *R. reniformis* (103.50) followed by *H. pseudorobustus* (84.50) and the least was found in *Eudorylaimus* sp. (2.60). *R. reniformis* was the most frequently occurring nematode with highest relative frequency (30.80), followed by *H. pseudorobustus* and *Aprocelaimus sp*. with a relative frequency of (23.10). Maximum relative density was observed in *R. reniformis* (44.90) followed by *H. pseudorobustus* (41.70).

Results of Kalarickal estate of Senapathy panchayth were presented in Table 6. The most frequently occuring nematodes in Kalarickal area was found to be *H.pseudorobustus*, *R. reniformis* and *Eudorylaimus* sp. having a relative frequency of 20. Nematode species having high prominence value is *H. pseudorobustus* with a prominence value of (176.5) followed by *R. reniformis* (91.1). Maximum relative density was recorded for *H. pseudorobustus* 49.5 followed by *R. reniformis* 25.5.

4.1.5 Community analysis of nematodes in Pampadumpara panchayath

A total of seven nematodes were recorded in soil samples collected from Sanyasioda area of Pampadumpara panchayath (Table 7). Nematode species of high prominence value was *H. pseudorobustus* with a prominence value of 285.00 followed by *M. incognita* with a prominence value of 80. Relative frequency value for all the nematodes in that area was found to be 11.10. The nematode species having high relative density was observed for *H. pseudorobustus* (45.40) followed by *M. incognita* (12.70).

The results presented in Table 8 showed that *R. reniformis, H. pseudorobustus and Eudorylaimus* were the nematode sp. identified from the Pathinipara area of Pampadumpara panchayath. *R. reniformis* was the most prominent nematode with a prominence value of 223.40, followed by *H. pseudorobustus* 15.80 and the least prominent nematode was *Eudorylaimus* sp. (1.20). The most frequently occurring nematode was *R. reniformis* with a relative frequency of 50.00, followed by *H. pseudorobustus* (37.50). Maximum relative density was recorded by *R. reniformis* (91.50) followed by *H. pseudorobustus* (7.50).

4.1.6 Community analysis of nematodes in Vazhathoppu panchayath

High prominence value was recorded by *H. pseudorobustus* (99.90) followed by Rhabditids (27.60) and the least was recorded by *Mononchids* (4.30) (Table 9). Highest relative density was recorded by *H pseudorobustus* (46.20) followed by *M.incognita* (16.40). Relative frequency was same for all the nematode species (12.50) identified from Memala area of Vazhathoppu panchayath.

4.1.7 *Community analysis of nematodes in Nedumkandam panchayath*

The results presented in Table 10 revealed that *M.incognita* was found to be the most prominent nematode with a prominence value of 64.30 in Kuppakal area of Nedumkandam panchayath followed by *H. pseudorobustus* and Rhabditids with a prominence value of 32.30. All the nematodes found in that area were found to have a relative frequency of 12.50. Relative density was found to be high by *H. pseudorobustus* (34.10) followed by Rhabditids (17.10) and the species with least relative density (5.90) was found to be *Nygolaimus* sp.

Community analysis of Pattathimukku area (Table 11) revealed that the most prominent nematode was Rhabditids (156.70) followed by *H. pseudorobustus* (88.00) and the least was *Aprocelaimus* sp. (17.80). All the nematode species identified from that area was found to have a relative frequency of 16.70. Most abundant nematode was Rhabditids (156.70) followed by *Nygolaimus* sp. (70.62).

Rhabditids have the highest prominence value (156.70) in Muruganpara area of Pampadumpara panchayath followed by *Nygolaimus* sp. (70.60). All the nematode species recorded the same relative frequency (16.70) (Table 12). Nematode species having lowest prominence value was *Aprocelaimus* sp. (17.80). Rhabditids (46.30) was the most abundant nematode followed by *H. pseudorobustus* (10.10).

From the results (Table 13) nematode species having highest prominence value in Nedumkandam area was *H. pseudorobustus* (122.20) followed by *R. reniformis* (23.90) and Mononchids recorded the lowest prominence value (6.30). The most frequently occurring nematode in that area was *H. pseudorobustus* with a relative frequency of 36.40 followed by *R. reniformis* and *Mononchids* having a relative frequency of 27.30.

4.1.8 *Community analysis of nematodes in Chinnakanal panchayath*

A total of seven nematodes were recorded in soil samples collected from Periyakanal area of Chinnakanal panchayath (Table 14) Highest prominence value was recorded for *H. pseudorobustus* (280.00), followed by *R. similis* (123.40). The most abundant nematode was *R. reniformis* with a relative density of 60.70 followed by *H. pseudorobustus* (26.70). Frequency of occurrence was found to be 100 for all the nematode species found in that area.

4.1.9 *Community analysis of nematodes in Santhampara panchayath*

M.incognita, *R. reniformis*, *H. pseudorobustus*, *Eudorylaimus* sp., *Nygolaimus* sp., *Aprocelaimus* sp., Mononchids and Rhabditids were the major nematodes found in Santhampara panchayath. From the table 15 presented it is clear that the most prominent nematode in Cheriyar area was *M. incognita* (226.70) followed by *H. pseudorobustus* and the nematode species of least prominence in that area was recorded as *Eudorylaimus* sp (3.40). Abundant nematode was found to be *M.incognita* with a relative density of (49.70) followed by *H. pseudorobustus* having a relative density of (27.60). The frequency of occurrence was found to be 100 for all the nematode species found in this area.

The most prominent nematode in Santhampara area was found to be *H. pseudorobustus* with a prominence value of (104.50) followed by *Eudorylaimus* sp. and Rhabditids (5.90). The most dominant nematode was found to be *H. pseudorobustus.* The most frequently occurring nematode in Santhampara area was *H. pseudorobustus* with a relative frequency of (100), followed by *Eudorylaimus* sp and Rhabditids with a relative frequency of (75). The results were presented in Table 16.

Results presented in Table 17 revealed that in Moolathara area the most dominant nematode group was rhabditids followed by Eudorylaimus (301) and *Helicotylenchus pseudorobustus* (267). *M.incognita* recorded the lowest density (87).The absolute frequency value for all the nematodes in this area were found to be same (100). Among the plant parasitic nematodes *H. pseudorobustus* recorded highest prominence value (254.3).

4.1.10 *Community analysis of nematodes in Rajakumari panchayath*

Community analysis of Rajakumari area in Rajakumari panchayath revealed that (Table18) the most frequently occurring nematode species were *M.incognita*, *R.reniformis*, *Nygolaimus* sp and rhabditids with a relative frequency of (20). Rhabditids were the most abundant group with a prominence value of (434.50). *Nygolaimus* sp. recorded the lowest prominence value (5.20) Among the plant parasitic nematodes *M. incognita* was the most frequent and abundant nematode with a prominence value of (288.80).

4.1.11 *Community analysis of nematodes in Karunapuram panchayath*

M.incognita, *H.pseudorobustus*, *R.similis*, *Eudorylaimus* sp., *Nygolaimus* sp., *Aprocelaimus* sp., rhabditids and mononchids were the nematodes identified and recorded from karunapuram panchayath. *M. incognita* was found to be the most abundant nematode in

Thovalapadi area of Karunapuram panchayath with a prominence value of 387.50 and relative density of 65.10 followed by *H. pseudorobustus* with a prominence value of 106.80 and relative density of 20.70 (Table 19). *M. incognita*, *R. similis*, *Eudorylaimus* sp., *Nygolaimus* sp. and *Aprocelaimus* sp were the most frequently occurring nematode species with a relative frequency of 14.80.

Community analysis of Chottupara area of Karunapuram panchayath was presented in Table 20. Highest frequency of occurrence was recorded by *M. incognita* and *H. pseudorobustus* with a relative frequency of 36.40, followed by Rhabditids (18.20). The most abundant nematode in this area was found to be *M. incognita* with a prominence value of (165.30) and a relative density of 46.70 followed by *H. pseudorobustus* with a prominence value of 120 and relative density (33.90).

4.1.12 *Community analysis of nematodes in Vathikudy panchayath*

The results of community analysis of nematodes associated with rhizosphere of cardamom grown in Thopramkudy area of Vathikudy panchayath were presented in Table 21. *M. incognita*, *R. reniformis*, *H. pseudorobustus* were the plant parasitic nematodes recorded. *Eudorylaimus* sp., mononchids and rhabditis were the free living forms. *M.incognita* and *R. reniformis* was found to be the most frequently occurring nematode with a relative frequency of 123.50. Prominence value was found to be high in *M. incognita* (309), followed by *H.pseudorobustus* (45.6) and lowest prominence value was recorded by the rhabditids group (4.10). Relative density of *M.incognita* was highest 68.90 and that of *Eudorylaimus* sp. was the lowest 12.20.

4.1.13 *Community analysis of nematodes in Senapathy panchayath*

Analysis of soil samples collected from kamakshivilasam estate of Senapathy panchayth revealed that *H.pseudorobustus* and *Eudorylaimus* sp were the most frequently occurring nematode with a relative frequency of 21.10 (Table 22). *M.incognita* and rhabditids recorded the lowest relative frequency (10.5). *H.pseudorobustus* was found to be the most abundant nematode with a relative density of 41.70 and prominence value of 198.9 among plant parasites. *Eudorylaimus* sp. was the most prominent nematode among the free living forms (132.2). Bacterial feeding rhabditids recorded the lowest relative frequency and lowest prominence value (5.9).

4.1.14 *Community analysis of nematodes in Udumbonchola panchayath*

The results presented in Table 23, revealed the occurrence of following nematodes in Myladumpara area of the panchayath. *H. pseudorobustus* was the only plant parasitic nematode recorded with a relative frequency of 16.9 and relative density of 77.7, it was the most prominent nematode in the rhizosphere of cardamom (prominence value 234.3). *Eudorylaimus* sp., *Nygolaimus* sp., *Aprocelaimus* sp., rhabditids and mononchids were the other nematodes recorded with a relative frequency of 16.7 each. *Eudorylaimus* sp. was the most abundant nematode among free living forms with a relative density of 5.2 and prominence value of 15.7. Lowest prominence value was recorded by bacterial feeding rhabditids group.

4.1.15 *Community analysis of nematodes in Rajakkad panchayath*

M. incognita and *H. pseudorobustus* were the most frequently occurring plant parasitic nematodes found associated with cardamom grown in Rajakkad area with a relative frequency of 23.5 (Table24). *H. pseudorobustus* was the most abundant nematode with a relative density of 47.7 and prominence value of 234.30. *R. reniformis* recorded the lowest relative frequency (17.6), relative density (21) and prominence value 89.4.Among the free living form *Eudorylaimus* sp., recorded the highest relative frequency 17.6, relative density 7.0 and prominence value 29.7. *Nygolaimus* sp., recorded the lowest relative frequency (5.9), relative density (1.1) and prominence value (2.8).

4.1.16 *Community analysis of nematodes in Bison Valley panchayath*

Results presented in the Table 25 revealed that *M. incognita*, *R. reniformis*, *H. pseudorobustus*, *Eudorylaimus* sp., *Nygolaimus* sp., and rhabditids were the major nematodes found associated with cardamom in Bison valley area. The frequently occurring nematode in that area was found to be *H.pseudorobustus* and rhabditids with a relative frequency of 28.60 followed by *M.incognita* and *R. reniformis*. The most abundant nematode in that area was found to be rhabditids with a relative density of 56.40 and a prominence value of 203.2 followed by *H. pseudorobustus* 27.40 and a prominence value of 98.7 and the lowest relative density was recorded by *Nygolaimus* sp (1.40) and prominence value (2.6).

4.1.17 *Community analysis of nematods in Kumily panchayath*

M. incognita, *R. reniformis*, *H.pseudorobustus*, *Eudorylaimus* and mononchids were the nematodes associated with rhizosphere of cardamom cultivated in Kumily panchayath. The most frequently occurring nematode in Kumily area of this panchayath was found to be *M. incognita* with a relative frequency of 44.40 followed by *H. pseudorobustus* with a relative frequency of 33.30 (Table 26). *M. incognita* was the most abundant nematode species with a relative density of 59.60 and prominence value of 62.30 followed by *H. pseudorobustus* with relative density of 33.00 and prominence value of 29.90. *Eudorylaimus* sp. recorded the lowest relative density of 2.4 and prominence value (1.2).

M.incognita and *H.pseudorobustus* were the plant parasitic nematodes and *Eudorylaimus* sp. and mononchids were the free living forms found associated with rhizosphere of cardamom in Mannipara area of Kumily panchayath (Table 27). Frequency of occurrence was found to be high for *M. incognita* with a relative frequency of 40 followed by *H. pseudorobustus* (30). Mononchids recorded the lowest relative frequency (10). *M.incognita* was the most abundant nematode with a relative density of 64.6 and prominence value of 129.8 followed by *H.pseudorobustus* with 22.4 and 39.1 respectively. Mononchids recorded the lowest prominence value 1.4.

4.2. The reaction of different cardamom cultivars to nematodes.

Observations on growth and yield contributing characters of cardamom such as tiller height, tiller/clump, length and width of leaf, fresh yield and incidence of fruit and shoot borer, thrips and root grub were recorded and analyzed statistically for evaluating the reaction of different cardamom cultivars to nematodes

4.2.1. Reaction of different cardamom accessions in terms of their biometric characters.

Data pertaining to the reaction of different cardamom accessions in terms of their biometric characters are presented in Table 28.

Table 28. Biometric characters of cardamom accessions

Accessions	Tiller height (cms)	Tiller/clump	Length of leaf (cms)	Width of leaf (cms)
Green gold (Njallani)	6.83	216.00	54.33	10.17
PV_2	10.00	183.17	43.83	11.33
CRSP-6	12.33	163.00	46.67	9.83
PL-14	12.17	253.00	53.17	10.67
MCC346	10.17	155.33	45.67	9.33
CL691	10.17	120.33	47.17	7.33
CL726	9.83	115.67	45.00	8.17
SKP164	13.00	141.33	43.17	7.17
IC547167	14.17	138.33	45.33	8.33
IC349651	14.33	102.50	48.00	8.33
IC547185	15.00	172.33	52.00	8.83
SKP104	15.83	115.17	42.00	8.00
IC349545	23.17	115.50	45.67	8.00
CD (0.05%)	5.79	57.97	4.3	1.30

4.2.1.1 Tiller height

The results revealed that tiller height of the cardamom accessions was higher in IC 349545 (23.17 cm). The tiller height of different cardamom accessions in the decreasing order were SKP 104 (15.83 cm), IC 547185 (15.00 cm), IC 349651 (14.33 cm), IC 547167 (14.17 cm), SKP 164 (13.00 cm), CRSP 6 (12.33 cm), PL 14 (12.17 cm), CL 691 (10.17 cm) = MCC 346 (10.17 cm), PV 2 (10.00 cm), CL 726 (9.83 cm) and Green Gold (6.83 cm). No significant difference could be observed between the cardamom accessions for tiller height except for IC 349545.

4.2.1.2 Tiller/clump

The highest number of tiller/clump was observed in the accession PL 14 (253.00) which was significantly superior to all other accessions except Green Gold which was in turn at par with accessions PV 2 and CRSP 6 and the lowest number of tillers /clump was recorded by IC 349651 (102. 50). The accessions in the decreasing order for number of tillers per clump were Green gold (216.00), PV 2 (183.17), IC 547185 (172.03), CRSP 6 (163.00), MCC 346 (155.33), SKP 164 (141.33), IC 547167 (138.33), CL 691 (120.33), CL 726 (115.67), IC 349545 (115.50), SKP 104 (115.17) and IC 349651 (102.50).

4.2.1.3 Leaf length

Analysis of data showed that the accession Green gold exhibited the highest leaf length (54.33 cm) which was statistically superior to all other accessions however, it was found to be at par with accessions PL 14 (53.17) and IC 547185 (52.00). The accession SKP 104 recorded the lowest leaf length (42.00 cm). The accessions in the decreasing order of their leaf length was PL 14 (53.17 cm), IC 547185 (52.00 cm), IC 349651 (48.00 cm), CL 691 (47.17 cm), CRSP 6 (46.67 cm), MCC 346 (45.67 cm), IC 349545 (45.67 cm), IC 547167 (45.33 cm),

Table 29. Yield and incidence of pests (%) on cardamom accessions/varieties

Accessions	Fresh yield (kg/ plant)	Incidence of shoot and fruit borer (%)	Incidence of thrips (%)
Green gold (Njallani)	1.99	2.21	3.92
PV_2	1.47	1.38	2.00
CRSP-6	1.09	1.35	3.22
PL-14	1.73	1.38	2.12
MCC346	1.29	1.82	4.59
CL691	1.00	1.49	3.00
CL726	1.32	1.72	7.20
SKP164	1.05	2.09	4.21
IC547167	1.65	1.80	4.83
IC349651	1.00	1.20	3.53
IC547185	1.43	1.23	3.30
SKP104	1.13	2.04	5.58
IC349545	1.47	1.53	7.21
CD (0.05%)	0.05	0.67	0.84

CL 726 (45.00 cm), PV 2 (43.83 cm), SKP 164 (43.17 cm) and SKP 104 (42.00 cm).

4.2.1.4 Leaf width

The highest leaf width was recorded in accession PV 2 (11.33 cm) which was superior to all other accessions except with PL 14 (10.67) and Green Gold (10.17) which were statistically at par. The lowest leaf width was recorded in the accession SKP164 (7.17 cm). The leaf width of different cardamom accessions when arranged in decreasing order were PL 14 (10.67 cm), Green gold (10.17 cm), CRSP 6 (9.83 cm), MCC 346 (9.33 cm), IC 547185 (8.83 cm), IC 547167 (8.33 cm) = IC 349651 (8.33 cm), CL 726 (8.17 cm), SKP 104 (8.00 cm) = IC 349545 (8.00 cm), CL 691 (7.33 cm), SKP 164 (7.17 cm). The accession PV 2 was found to be on par with PL 14 and Green gold.

4.2.2. Reaction of different cardamom accessions in terms of their yield attributing characters.

The reaction of different cardamom accessions in terms of their yield character are presented in Table 29.

4.2.2.1 Fresh yield of capsules/ plant

The data on fresh yield of capsules per plant showed statistically significant variation among different cardamom accessions (Table 29). The highest fresh yield of capsules (1.99 kg/plant) was observed in Green gold which was statistically superior to all other accessions followed by PL 14 (1.73 kg/plant) and IC 547167 (1.65 kg/plant) and the lowest yield was observed in IC 349651 and CL 691 (1.00 kg/plant). The accessions in the decreasing order of fresh yield of capsules per plant in the decreasing order was as follows Green gold (1.99), PL 14 (1.73), IC 547167 (1.65), IC 349545 (1.47) = PV 2 (1.47), IC 547185 (1.43), CL 726 (1.32), MCC 346 (1.29), SKP 104

(1.13), CRSP 6 (1.09), SKP 164 (1.05), IC 349651 (1.00) = CL 691 (1.00).

4.2.3 Reaction of different cardamom accessions to insect pest incidence.

The reaction of different cardamom accessions in terms of insect pest incidence were presented in Table 29.

4.2.3.1 Incidence of shoot and capsule borer

The results of incidence of shoot and capsule borer in cardamom accessions were recorded in Table 29. The lowest incidence of shoot and capsule borer was observed in accession IC 349651 (1.20 %) which was found to be on par with IC 547185 (1.23 %), CRSP 6 (1.35 %), PV 2 (1.38 %), PL 14 (1.38 %), CL 691 (1.49 %), IC 349545 (1.53 %) and CL 726 (1.72 %). The highest incidence of shoot and fruit borer was observed in cultivar Green gold (2.21 %) and it was found to be statistically on par with accessions like SKP 164 (2.09 %), SKP 104 (2.04 %), MCC 346 (1.82 %), IC 547167 (1.80 %), and CL 726 (1.72 %).

4.2.3.2 Incidence of thrips

The percentage incidence of thrips in different cardamom accessions showed that the damage of capsules by thrips were less in accession PV 2 (2.00 %) and was found to be statistically on par with the cultivar PL 14 (2.12 %). The percentage incidence of thrips in different cardamom cultivars in increasing order was as follows: CL 691 (3.00 %), CRSP 6 (3.22 %), IC 547185 (3.30 %), IC 349651 (3.53 %), Green gold (3.92 %) and SKP 164 (4.21 %). The highest percentage incidence was found in the accession IC 349545 (7.21 %) which was on par with CL 726 (7.20 %).

4.2.3.3 Incidence of root grub

Incidence of root grub was not observed in any of the

Table 30. Nematode population in rhizosphere of cardamom accessions/varieties at tillering stage

Name of accessions/varieties	Mean population of nematode/200g soil		
	M.incognita	*R.reniformis*	*H.pseudorobustus*
Green gold (Njallani)	204.30 (2.31)	96.67 (1.98)	176.67 (2.24)
PV_2	1675.33 (3.22)	279.33 (2.44)	474.00 (2.67)
CRSP-6	0.00 (0.00)	107.33 (2.03)	417.33 (2.62)
PL-14	1754.00 (3.24)	84.33 (1.93)	283.00 (2.45)
MCC 346	20.67 (1.33)	57.67 (1.76)	470.33 (2.67)
CL691	20.00 (1.32)	82.67 (1.92)	1097.00 (3.04)
CL726	27.00 (1.44)	106.00 (2.02)	435.33 (2.63)
SKP164	117.00 (2.07)	124.33 (2.09)	695.67 (2.84)
IC547167	100.00 (2.00)	184.00 (2.26)	911.67 (2.96)
IC349651	17.33 (1.26)	95.33 (1.98)	643.33 (2.80)
IC547185	0.00 (0.00)	72.67 (1.86)	461.33 (2.66)
SKP104	184.67 (2.26)	83.00 (1.92)	1340.00 (3.12)
IC349545	0.00 (0.00)	112.33 (2.05)	304.33 (2.48)
CD (0.05 %)	(0.035)	(0.023)	(0.006)

Figures in parentheses are logarithmic transformed value cardamom cultivars studied.

4.3 Estimation of nematode population in soil and roots of different cardamom cultivars

Soil and root samples of different cardamom accessions/cultivars were collected and processed for analyzing nematode population at different stages.

4.3.1 Nematode population in cardamom before planting (initial nematode population)

The initial nematode population in the experimental plot is as follows. The population range of root knot nematode was 20.33 - 23.00/200g soil: spiral nematode 58.67 - 60.67/200g soil and reniform nematode 40.33 - 43.00/200g soil.

4.3.2. Population of root knot nematode in rhizosphere ocardamom accessions/ varieties at the tillering stage

The root knot nematode population varied significantly among the different cardamom accessions (Table 30). The most susceptible accession to root knot nematode was PL 14 (1754.00/200g soil) and it was closely followed by the accession PV 2 (1675.33/200g soil) and these two accessions were found to be statistically at par. The accessions with no detectable level of root knot nematode was CRSP 6 (0.00/200g soil), 1C 547185 (0.00/200g soil), IC 349545 (0.00/200g soil). Nematode population recorded in MCC 346 (20.67/200 g soil) and CL 691 (20.00/200 g soil) were found to be statistically on par. The nematode populations in soil from the rhizosphere cardamom accessions at tillering stages from other accessions were CL 726 (27/200 g soil), IC 547167 (100/200 g soil), SKP 164 (117.00/200 g soil), SKP 104 (184.67/200 g soil) and Green gold (204.30/200 g soil).

4.3.3 Population of reniform nematode in rhizosphere of cardamom accessions/ varieties at the tillering stage

The results in the Table 30 showed that there was significant variation in the reniform nematode population among the various cardamom accessions. Lowest nematode population was recorded in MCC 346 (57.67/200 g soil) which was significantly superior to all other accessions which was closely followed by the accession IC 547185 (72.67/200g soil).Highest nematode population was found in PV 2 (279.33/200 g soil) which was closely followed by IC 547167 (184.00/200 g soil). The population of nematodes in accession PL 14 (84.33/200 g soil) was found statistically on par with the accessions SKP 104 (83.00/200 g soil) and CL 691 (82.67 /200 g soil). The nematode population of accession IC 349545 (112.33/200 g soil) was found on par with the accession CRSP 6 (107.33/200 g soil) which is in turn statistically on par with the accession CL 726 (106.00/200 g soil). The accession Green gold with nematode population of 96.67/200 g soil was found statistically on par with the accession IC 349651 (95.33/200 g soil).

4.3.4 Population of spiral nematode in rhizosphere of cardamom accessions / varieties at the tillering stage

The spiral nematode population showed significant variation among different cardamom accessions (Table 30). The nematode population in the rhizosphere of cardamom in different accessions ranged from 176.67 – 1340.00/200 g soil. The lowest nematode population was recorded in accession Green gold (176.67/200 g soil) which was significantly different from other acessions. The highest nematode population was recorded in the accession SKP 104 (1340.00/200 g soil) which was found to be statistically on par with accession CL 691 (1097.00/200g soil). The accessions PV 2 (474.00/200 g soil) and MCC 346 (470.33/200 g soil) were found statistically on par. The nematode population of the 13 cultivars/accessions of cardamom in increasing order of the population was as follows Green gold (176.67/200 g soil), PL 14 (283.00/200 g soil), IC 349545 (304.33/200 g soil), CRSP 6 (417.33/200 g soil), CL 726 (435.33/200 g soil), IC 547185 (461.33/200 g soil), MCC 346 (470.33/200 g soil), PV 2 (474.00/200 g soil), IC 349651 (643.33/200 g soil), SKP 164 (695.67/200 g soil), IC 547167 (911.67/200 g soil), CL 691 (1097.00 /200 g soil), SKP 104 (1340.00/200 g soil).

4.3.5 Population of root knot nematode in rhizosphere of cardamom accessions/varieties at flowering stage

Analysis on the population of root knot nematodes in the soil at flowering stage revealed that there was significant variation in the nematode population among different accessions (Table 31). The accessions with no detectable level of root knot nematode populations was found in CRSP 6 (0.00/200 g soil), 1C 547185 (0.00/200 g soil) and, IC 349545 (0.00/200 g soil). The lowest nematode population was recorded by MCC 346 (28.33/200g soil) which was found to be significantly different from other accessions, followed by CL 691(31.33/200g soil) which is statistically at par with the accession IC 349651 (31.67/200g soil). The highest root knot nematode population was observed as PV 2 (2315.33/200g soil) and it was closely followed by the accession PL 14 (1910.67/200 g soil) and these two accessions were found to be statistically different.

4.3.6 Population of reniform nematode in rhizosphere of cardamom accessions/ varieties at flowering stage

The results presented in Table 31 showed that there was significant variation in reniform nematode population among the various accessions. The lowest nematode population was found in the accession MCC 346 (74.00/200g soil) which significantly varied from

Table 31. Nematode population in rhizosphere of cardamom accessions/varieties at flowering stage

Name of accessions/varieties	Mean population of nematode/200g soil		
	M.incognita	*R.reniformis*	*H.pseudorobustus*
Green gold (Njallani)	215.5 (2.33*)	153.33 (2.18)	71.00 (2.43)
PV_2	2315.33 (3.36)	316.33 (2.50)	695.33 (2.84)
CRSP-6	0.00 (0.00)	293.33 (2.46)	681.00 (2.83)
PL-14	1910.67 (3.28)	127.67 (2.10)	319.67 (2.50)
MCC 346	28.33 (1.46)	74.0 (1.87)	494.00 (2.69)
CL691	31.33 (1.50)	125.33 (2.10)	1055.33 (3.02)
CL726	34.67 (1.55)	184.00 (2.26)	680.33 (2.83)
SKP164	196.00 (2.29)	145.33 (2.16)	1021.67 (3.00)
IC547167	161.00 (2.20)	259.67 (2.41)	1355.33 (3.13)
IC349651	31.67 (1.51)	120.67 (2.08)	826.33 (2.91)
IC547185	0.00 (0.00)	121.0 (2.08)	612.67 (2.78)
SKP104	223.33 (2.35)	122.00 (2.08)	1687.00 (3.22)
IC349545	0.00 (0.00)	138.00 (2.13)	483.33 (2.68)
CD (0.05%)	(0.037)	(0.052)	(0.005)

Figures in parentheses are logarithmic transformed values the other accessions. Highest nematode population was observed in the accession PV 2 (316.33/200g soil) which was closely followed by CRSP 6 (293.33/200g soil) which was in turn on par with the accession IC 547167 (259.67). The nematode population of the accessions in the increasing order was as follows MCC 346 (74.00/200g soil), IC 349651 (120.67/200g soil), SKP 104 (122.00/200g soil), CL 691 (125.33/200g soil), PL 14 (127.67/200g soil), IC 34, 9545 (138.00/200g soil), SKP 164 (145.33/200g soil), CL 726 (184.00/200g soil), IC 547167 (259.67/200g soil), CRSP 6 (293.33/200g soil), PV 2 (316.33/200g soil).

4.3.7 Population of spiral nematodes in rhizosphere of cardamom accessions/ varieties at flowering stage

Data on the spiral nematode population (Table 31) showed significant variation among different accessions. The least nematode population was found in the accession Green gold (71.00/200g soil) which was found to be significantly superior among the other accessions. The highest spiral nematode population was observed in the accession SKP 104 (1687.00/200 g soil). The population of spiral nematodes of 13 cultivars in increasing order was as follows Green gold (71.00/200 g soil), PL 14 (319.67/200 g soil), IC 349545 (483.330/200 g soil), MCC 346 (494.00/200 g soil), IC 547185 (612.67/200 g soil), CL 726 (680.33/200 g soil), CRSP 6 (681.00/200 g soil), PV 2 (695.33/200 g soil), IC 349651 (826.00/200 g soil), SKP 164 (1021.67/200 g soil), CL 691 (1055.33/200 g soil), IC 547167(1355.33/200g soil), SKP 104 (1687.00/200g soil). The accession CL 726 was found statistically on par with the accession CRSP 6. All the other accessions showed statistically significant variation.

Table 32.Nematode population in rhizosphere of cardamom accessions/varieties at harvest

Name of accessions/varieties	Mean population of nematode/200 g soil		
	M.incognita	*R.reniformis*	*H.pseudorobustus*
Green gold (Njallani)	219.67 (2.34)	181.33 (2.26)	324 (2.51)
PV_2	2682.33 (3.42)	480.67 (2.68)	873 (2.94)
CRSP-6	0.00 (0.00)	308.00 (2.48)	861 (2.93)
PL-14	2127.00 (3.32)	191.33 (2.28)	354.66 (2.55)
MCC346	42.67 (1.63)	97.67 (1.99)	579.33 (2.76)
CL691	40.33 (1.61)	148.00 (2.17)	2016.33 (3.30)
CL726	50.33 (1.71)	221.67 (2.34)	890.33 (2.95)
SKP164	288.00 (2.46)	293.33 (2.46)	1419.66 (3.15)
IC547167	202.67 (2.30)	316.00 (2.50)	1895.6 (3.27)
IC349651	51.00 (1.71)	159.00 (2.20)	1287.00 (3.11)
IC547185	00 (0.00)	151.33 (2.18)	892.00 (2.95)
SKP104	362.33 (2.56)	167.33 (2.22)	2680.33 (3.42)
IC349545	0.00 (0.00)	227.33 (2.35)	620 (2.79)
CD (0.05 %)	(0.019)	(0.012)	(0.002)

Figures in parentheses are logarithmic transformed values

4.3.8 Population of root knot nematodes in rhizosphere of cardamom accessions/ varieties at harvesting stage

Root knot nematode population at harvest showed significant variation among various accessions and the results were presented in Table 32. The population of root knot nematodes was not recorded in accessions CRSP 6, 1C 547185, IC 349545. The accession with lowest number of nematodes was found to be CL691 (40.33/200g soil) followed by the accession MCC 346 (42.67/200g soil). The accession with highest population of root knot nematode was observed as PV 2 (2682.33), and it was closely followed by the accession PL 14 (2127.00/200 g soil) and these two were found to be statistically different. The accessions IC 349651 (51.00/200 g soil) was found to be statistically on par with the accession CL 726 (50.33/200 g soil). The acessions PV 2 (2682.33/200 g soil), PL 14 (2127.00/200 g soil), SKP 104 (362.33/200 g soil), SKP 164 (288.00/200 g soil), Green gold (219.67/200 g soil) were found to be statistically different among other acessions.

4.3.9 Population of reniform nematodes in rhizosphere of cardamom accessions/ varieties at harvesting stage

Data pertaining to nematode population in the rhizosphere of cardamom at the harvesting stage showed that there was significant variation among the various accessions. The nematode population was recorded in MCC 346 (97.67/200 g soil) followed by CL 691 (148.00). Highest nematode population was found in the accession PV 2 (480.67/200 g soil) followed by CRSP 6 (308.6/200 g soil) where both the accessions were significantly different. The nematode population of the accessions in the increasing order of their population was as follows MCC 346 (97.67/200 g soil), CL 691(148.00/200 g soil), IC 547185 (151.33/200 g soil), IC 349651 (159.00/200 g soil), SKP 104

(167.33/200 g soil), PL 14 (191.33/200 g soil), Green gold (181.33/200 g soil), CL 726 (221.67/200 g soil), IC 349545 (227.33/200 g soil), SKP 164 (293.33/200 g soil), CRSP 6 (308.00/200 g soil), IC 547167 (316.00/200 g soil) and PV 2 (480.67/200 g soil). The nematode population recorded in accessions IC 349545 and CL 726, SKP 164 and IC 349651 were found statistically on par.

4.3.10 Population of spiral nematodes in rhizosphere of cardamom accessions/ varieties at harvesting stage

The spiral nematode population (Table 32) showed significant variation among the accessions. Nematode population ranged from 324 to 2680.33/200 g soil. The lowest population of nematodes was found in the accession Green gold (324.00/200 g soil) followed by PL 14(354.66/200g soil).The highest spiral nematode population was observed in the accession SKP 104 (2680.33/200 g soil). The nematode population recorded in the accessions IC 547185 (892.00/200 g soil), CL 726 (890.33/200 g soil) and PV 2 (873.00/200 g soil) were found statistically on par. The spiral nematode population of the 13 cultivars in increasing order was as follows Green gold (324.00/200 g soil), PL 14 (354.66/200 g soil), MCC 346 (579.00/200 g soil), IC 349545 (620.00/200 g soil), CRSP 6(861.00/200 g soil), PV 2 (873.00/200 g soil), CL 726 (890.33/200 g soil), IC 547185 (892.00/200 g soil), IC 349651 (1287.00/200 g soil), SKP 164 (1419.60/200 g soil), IC 547167 (1895.60/200 g soil) , CL 691 (2016.33/200 g soil), SKP 104 (2680.33/200 g soil).

4.3.11 Population of nematodes in root samples of various accessions of cardamom

Root samples of different cardamom accessions (5g/plant) were collected and processed for analysing nematode population at different stages

4.3.11.1 Root knot nematode population

Data pertaining to the root knot nematode population in roots at the tillering stage were given in Table 33. The accessions CRSP 6, CL 691, IC 349651, 1C 547185, IC 349545 were free of nematodes. The accession with least number of nematodes was found to be MCC 346 (2.31/5 g roots) followed by CL 726 (4.65) and was found to be statistically different. PV 2 (101.66/5 g root) and PL 14 (98.99/5 g root)) were found in higher population of nematodes, which was found to be statistically on par. Population at the flowering stage also showed similar pattern as at tillering stage. IC 547185 (0.00), CRSP 6 (0.00), IC 349545 (0.00) recorded no detectable level of nematodes in root samples. Highest population of nematodes was recorded PV 2 (120.00/5 g root). At the harvesting stage the highest nematode population was recorded in pl-14 (121.66/5 g root)) followed by PV 2 (107.99/5 g root) and were found to be statistically on par.

4.3.11.2 Reniform nematode population

At the tillering stage, the lowest population of nematodes was recorded in the accession MCC 346 (2.33/5g roots) followed by the accession IC 547185(3.67/5 g roots) and was found to be statistically different. Nematode population was found to be highest in the accession PV 2 (34.33/5g roots) which is closely followed by the accession SKP 164 (28.67/5g roots), where both the accessions are significantly different at the tillering stage. Same trend in the population of *R. reniformis* was noticed in samples taken at flowering and harvesting stage of the crop.

Table 33. Nematode population in 5g of root sample at different stages

Name of accessions/ varieties	Tillering stage		Flowering stage		Harvesting stage	
	M.incognita	*R.reniformis*	*M.incognita*	*R.reniformis*	*M.incognita*	*R.reniformis*
Green gold (Njallani)	10.38 (3.36)	17.00 (4.12)	13.32 (3.78)	21.00 (4.58)	15.99 (4.12)	26.00 (5.10)
PV_2	101.66 (10.13)	34.33 (5.86)	120.99 (11.04)	43.00 (6.56)	107.99 (10.44)	58.33 (7.64)
CRSP-6	0.00 (1.00)	22.00 (4.69)	0.00 (1.00)	26.00 (5.10)	0.00 (1.00)	34.67 (5.89)
PL-14	98.99 (9.99)	8.00 (2.82)	104.99 (10.29)	16.33 (4.04)	121.66 (11.07)	21.67 (4.65)
MCC346	2.31 (1.82)	2.33 (1.52)	7.98 (2.99)	7.00 (2.64)	13.96 (3.86)	13.00 (3.60)
CL691	0.00 (1.00)	8.67 (2.94)	1.64 (1.62)	13.33 (3.65)	6.97 (2.82)	20.00 (4.47)
CL726	4.65 (2.37)	25.00 (5.00)	5.97 (2.64)	33.33 (5.77)	12.98 (3.74)	45.67 (6.76)
SKP164	20.99 (4.68)	28.67 (5.35)	25.99 (5.19)	37.00 (6.08)	34.99 (5.99)	52.33 (7.23)
IC547167	13.98 (3.87)	21.00 (4.58)	20.99 (4.68)	30.00 (5.48)	28.99 (5.47)	57.00 (7.55)

Table 33. Continued.

Name of accessions/ varieties	Tillering stage		Flowering stage		Harvesting stage	
	M.incognita	*R.reniformis*	*M.incognita*	*R.reniformis*	*M.incognita*	*R.reniformis*
IC349651	0.00 (1.00)	5.33 (2.31)	2.25 (1.80)	8.00 (2.82)	2.95 (1.98)	54.00 (7.34)
IC547185	0.00 (1.00)	3.67 (1.91)	0.00 (1.00)	10.33 (3.21)	0.00 (1.00)	18.67 (4.32)
SKP104	17.99 (4.35)	6.33 (2.51)	30.99 (5.65)	13.67 (3.69)	40.99 (6.48)	26.00 (5.10)
IC349545	0.00 (1.00)	27.33 (5.23)	0.00 (1.00)	36.00 (3.69)	0.00 (1.00)	43.33 (6.58)
CD (0.05%)	(0.142)	(0.102)	(0.235)	(0.144)	(0.200)	(0.110)

Figures in parentheses are square root transformed values

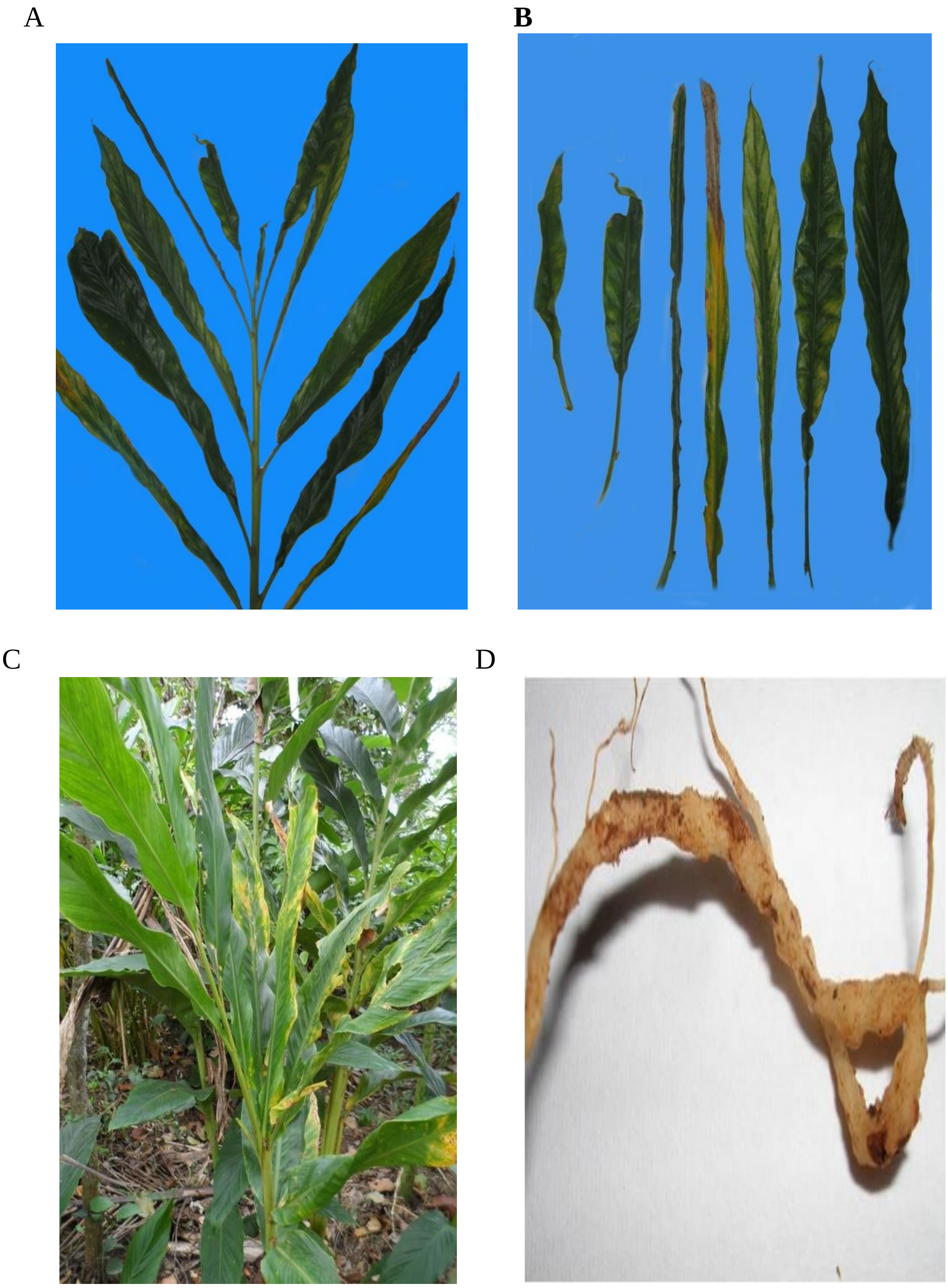


Plate 3. Symptoms of *M. Incognita* infestation in cardamom (A), (B) & (C): Infested shoot (D): gall formation in roots

4.4 MANAGEMENT OF PLANT PARASITIC NEMATODES IN CARDAMOM

4.4.1 Evaluation of efficacy of chemicals and botanical under *in vitro* conditions.

4.4.1.1 Efficacy of fresh leaf extracts of *Tithonia diversifolia* on the mortality of M. incognita juveniles (J_2)

The results presented in Table 34 revealed that all the concentrations tested (S, S/2, S/3, S/4) were found effective in increasing the mortality of *M. incognita* juveniles at all time intervals. The concentration S at 24h showed the highest percentage mortality of J_2 (95.34%) which was statistically superior to other concentration (S, S/2, S/3, S/4).The percentage mortality of J_2 exposed to S/3 was 83.03 which was on par with mortality of J_2 recorded in S/4(81.00). Observation after 48 h of exposure of J_2 of *M.incognita* to S and S/2 concentrations recorded the highest percentage mortality (99.99%) followed by S/3 (97.05) and S/4(94.02). After 72 h of exposure, all the concentration showed higher mortality percentage. The concentrations S, S/2 and S/3 recorded 99 % mortality followed by S/4 with a percentage mortality of 98.37 per cent (fig.2).

4.4.1.2 Mortality of *M. incognita* juveniles treated with different chemicals

The results presented in the table 35 revealed that all the chemicals showed statistically significant variation between their respective concentrations. Carbosulfan 6G at 300 µg/ml after 72 h of exposure showed the highest J_2 mortality 95.03 percentage. After 24 h of exposure the concentration 300µg/ml showed highest mortality of 63.33 per cent which was significantly superior to untreated control.

Table 34. Effect of *Tithonia diversifolia* leaf extracts on *M.incognita* juveniles

Concentration	Percentage mortality		
	24h	48h	72h
S	95.34 (77.50)	99.99 (90)	99.99 (90)
S/2	91.06 (72.52)	99.99 (90)	99.99 (90)
S/3	83.03 (65.64)	97.05(80.08)	99.99 (90)
S/4	81.00 (64.13)	94.02(75.82)	98.37 (82.63)
Control	0.00(0)	0.00(0)	0.00 (0)
CD (0.05%)	(1.99)	(1.96)	(1.29)

Figures given in parentheses are angular transformed value

S - 2g leaf in 5ml water

S/2 – 5ml S + 5ml water

S/3 – 2.5ml S + 7.5 ml water

S/4 – 1.25 ml S + 8.75 ml water

Control- water 10ml.

Table 35. Effect of different chemicals on the mortality of *M. incognita* juveniles

Concentration	Mortality of juveniles at different treatments in various period of exposure								
	Carbosulfan			Thiamethoxam			Cartap hydrochloride		
	24 h	48h	72h	24 h	48h	72h	24 h	48h	72h
50 µg/ml	2.64 (9.35)	4.96 (12.83)	18.39 (10.32)	0 (0)	4.96 (12.87)	16.40 (7.98)	0 (0)	0 (0)	4.32 (11.99)
100 µg/ml	8.98 (17.43)	20.66 (27.02)	30.99 (33.81)	4.32 (11.99)	13.30 (21.38)	27.02 (20.66)	4.96 (12.87)	10.62 (19.05)	14.99 (22.76)
200 µg/ml	45.33 (42.30)	69.00 56.14	80.00 (63.41)	23.99 (29.31)	53.66 (47.08)	56.55 (69.66)	21.99 (27.95)	47.99 (43.83)	65.00 (53.70)
300 µg/ml	63.33 (52.71)	84.00 (66.40)	95.03 (77.09)	51.00 (45.55)	73.34 (58.89)	69.12 (87.33)	47.66 (43.64)	68.66 (55.93)	78.00 (62.00)
Control	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)
CD (0.05%)	(1.447)	(1.605)	(1.612)	(1.120)	(2.133)	(1.214)	(1.437)	(0.831)	(1.371)

Figures given in parentheses are angular transformed values

After 48h of exposure, carbosulfan at 300µg/ml showed highest J_2 mortality (84.00%) which was significantly superior to other concentrations *viz*. 50 µg/ml, 100 µg/ml and 200 µg/ml. After 24 h, 48h and 72h of exposure, thiomethoxam @ 300 µg/ml exhibited 63.33 per cent, 69.12 per cent and 73.34 per cent J_2 mortality respectively. After 72h of exposure to cartap hydrochloride the mortality of J_2 was found to be 78.00 per cent and it was found to be superior to other treatments.

4.5.2 Effect of treatments on plant growth parameters and yield

4.5.2.1. Number of tillers

The perusal of data presented in Table 36 revealed that treatments $T_{6,}$ carbosulfan 6 G @ 1Kg a.i/ha (19.66), $T_{1,}$ cartap hydrochloride 4 G@ 1Kg a.i/ha (19.33) and T_3, thiamethoxam 50 WG @50 g a.i./ha (18.66) were found to be effective in increasing the number of tillers per plant when compared to untreated control. These treatments were found to be statistically superior to all other treatments. However, they were found to be on par with each other. The treatments T_3 (wild sunflower leaves 5Kg/plant), T_4 (*Paecilomyces lilacinus* @ 1x 10^7cfu 50g/plant) and T5 (*B.macerans* @ 1x 10^7cfu 50g/plant) were also found to be effective in increasing number of tillers per plant. However, they were not found statistically significant when compared to untreated control. T_6 recorded the highest percentage increase in number of tillers (20.39). However, the lowest percentage increase was recorded by $T_{4.}$

4.5.2.2. Number of leaves per tiller

The total number of leaves per tiller at the time of harvest under different treatments are given in Table 36. Data revealed that the treatments T_6, T_1, T_2 and T_3 were significantly superior to untreated

Table 36. Effect of treatments on the growth and yield attributing characters of cardamom (Var: Njallani)

Treatments	No. of tillers	% increase	No. of leaves/ tiller	% increase	No. of panicles	% increase	No. of capsules/ panicle	% increase
Cartap hydrochloride 4G (1kg ai/ha)	19.33	18.37	15.66	42.36	30.00	38.50	30.66	55.95
Thiamethoxam 50 WG (50 gai/ha)	18.66	14.26	14.00	27.27	28.66	32.59	28.33	40.09
Wild sunflower leaves (5 kg/plant)	18.33	12.24	13.66	24.18	27.66	27.70	25.66	30.51
Paecilomyces lilacinus (1x10^7cfu 50g/plant)	17.00	4.10	12.66	15.00	26.33	21.56	24.00	22.07
Bacillus macerans (1x10^7cfu 50g/plant)	18.33	12.24	13.66	24.18	27.00	24.65	25.33	28.84
Carbosulfan 6G (1 kg ai/ha)	19.66	20.39	16.33	48.45	30.33	40.02	31.66	61.10
Untreated	16.33	-	11.00	-	21.66	-	19.66	-
CD (0.05%)	2.01	-	2.13	-	1.63	-	2.41	-

control in the production of leaves. The leaf production was maximum in carbosulfan 6G treated plants (16.33) which was on par with cartap hydrochloride 4G (15.66). The latter was on par with thiamethoxam 50 WG (14.00). The percentage increase in leaf production ranged from 15 to 48 per cent in the main field when compared to untreated control. The effect of field treatment with *B. macerans* (13.66), *P. lilacinus* (12.66) and wild sunflower leaves (13.66) were statistically on par.

4.5.2.3 Number of panicles

There was statistically significant variation in number of panicles per plant between treatments and untreated control (Table 36). All the treatments were found superior when compared to untreated. Highest number of panicle (31.66) was recorded in carbosulfan 6G treated plants followed by cartap hydrochloride (30.66) and are statistically on par. All other treatments followed the above treatments and cartap hydrochloride statistically on par with thiamethoxam (28.66) which is on par with wild sunflower leaf treatment (26.66). Treatment with bioagents like *P. lilacinus* (26.33) was found on par with *B. macerans* (27.00)

4.5.2.4 Number of capsules/panicle

All the treatments were found to be effective in increasing the number of capsules per panicle when compared to untreated control. They were also found statistically superior (Table 36). Carbosulfan treated plants showed the highest number of capsules (31.66) with 61 per cent increase over untreated followed by treatment with cartap hydrochloride (30.66), which recorded 55 per cent increase over the untreated. Treatment with cartap hydrochloride was found on par with plants treated with thiamethoxam (28.33) which was in turn significantly different from treatment involving wild sunflower leaves

(25.66). Treatment with *B. macerans* (25.33) and *P. lilacinus* (24.00) were found to be on par with treatment involving wild sunflower leaves.

4.5.2.5. Fresh weight of capsules

In general all the treatments were found to be effective in increasing the fresh weight of capsules when compared to untreated and were found to be statistically superior over untreated (Table 37). The fresh weight of the capsule ranged from 1.98 to 5.29 kg/plant as against the weight of 1.32 kg/plant in untreated. The maximum fresh weight was recorded in carbosulfan 6G treated plants (5.29 kg/plant) followed by the treatment involving cartap hydrochloride (4.46 kg/plant). The effect of thiamethoxam (2.21 kg/plant) was statistically on par with the three treatments *viz., B. macerans* (2.10 kg/plant), *P. lilacinus* (2.02 kg/plant) and wild sunflower leaves (1.98 kg/plant).

4.5.2.6. Dry weight of capsules

The effect of treatments on dry weight of capsules showed that there was significant difference among treatments. The treatments carbosulfan and cartap hydrochloride were found to be superior to all other treatments when compared to untreated. Maximum dry weight of the capsule was observed in carbosulfan 6 G (0.68 kg/plant) treated plants with more than cent per cent yield over the untreated. This treatment was on par with cartap hydrochloride 4 G (0.66 kg/plant) with 78 per cent increase over untreated. Next best treatment was *B. macerans* (0.39 kg/plant) which increased the dry weight to a tune of 30 per cent over the untreated. This treatment was on par with wild sunflower leaves (0.38 kg/plant). Treatment with *P. lilacinus* (0.37 kg/plant) was on par with wild sunflower leaves (0.38 kg/plant) with

Table 37. Effect of treatments on the yield of cardamom

Treatments	Fresh weight of capsules (kg/plant)	Dry weight of capsules (kg/plant)	Yield (t/ha)
Cartap hydrochloride 4G (1kg ai/ha)	4.46	0.66	1.65
Thiamethoxam 50 WG (50 g ai/ha)	2.21	0.54	1.35
Wild sunflower leaves (5 kg/plant)	1.98	0.38	0.95
Paecilomyces lilacinus (1x10^7cfu 50g/plant)	2.02	0.37	0.92
Bacillus macerans (1x10^7cfu 50g/plant)	2.10	0.39	0.97
Carbosulfan 6G (1 kg ai/ha)	5.29	0.68	1.70
Untreated	1.32	0.30	0.75
CD (0.05%)	0.277	0.309	NA

25 per cent increase in dry weight of the capsules. Treatment with thiamethoxam was significantly superior to untreated with 77 per cent increased dry weight of capsules (Fig.3).

4.5.3 Nematode population in soil and root after treatment

4.5.3.1 Pre-treatment nematode population

The analysis of soil and root samples collected from the rhizosphere of cardamom before the start of the experiment showed that the root knot nematode population ranged from 200 - 207.66/ 200g of soil, spiral nematode population ranged from 317.33 - 321/ 200g soil and root knot nematode ranged from 92.67 - 95.33/5 g root before applying the various treatments.

4.5.3.2 Root knot nematode population in soil

The results presented in Table 38 clearly indicated that application of different treatments resulted in significant reduction in nematode population compared to untreated at two intervals i.e. three and six months after treatment (MAT). All the six treatments were statistically superior over untreated. Among the treatments, the percentage reduction of nematodes was significantly higher in plants treated with carbosulfan 6G (1kg a.i/ha). Percentage reduction in nematode population was to a tune of 94.56 and 94.69 after three and six months of treatment respectively. This was followed by cartap hydrochloride 4G (1kg ai/ha) which reduced the nematode population to a tune of 93.51 (3 MAT) and 94.02 per cent (6 MAT) respectively at the two intervals. The treatments involving *P.lilacinus* with a nematode population of 177.00/200g soil at 3MAT and wild sunflower leaves (166.66/200g 3 MAT) were found to be on par.

Table 38. Effect of treatments on the nematode population in cardamom

Nematode population in 200g soil								
Treatments	*M.incognita*				*H.pseudorobustus*			
	3 months after treatment	% decrease	6 months after treatment	% decrease	3months after treatment	% decrease	6 months after treatment	% decrease
Cartap hydrochloride 4G (1kg ai/ha)	39.00 (6.39)	93.51	45.00 (6.71)	94.02	50.00 (7.07)	91.80	57.67 (7.59)	92.16
Thiamethoxam 50 WG (50 g ai/ha)	51.66 (7.16)	91.40	66.00 (8.12)	91.23	49.33 (7.02)	91.92	58.33 (7.64)	92.07
Wild sunflower leaves (5 kg/plant)	166.66 (12.91)	72.28	202.67 (14.24)	73.00	71.00 (8.43)	88.33	323.33 (17.98)	56.08
Paecilomyces lilacinus (1x10^7 cfu 50g/plant)	177.00 (13.30)	70.50	180.00 (13.42)	76.10	70.33 (8.39)	88.48	76.00 (8.72)	89.67
Bacillus macerans (1x10^7 cfu 50g/plant)	78.33 (8.85)	86.91	81.33 (9.02)	89.20	58.00 (7.62)	90.50	63.67 (7.98)	91.35
Carbosulfan 6G (1 kg ai/ha)	32.66 (5.71)	94.56	40.00 (6.32)	94.69	42.00 (6.48)	93.12	49.00 (7.00)	93.34
Untreated	601.33 (24.52)	-	753.33 (27.45)	-	610.77 (24.17)	-	736.33 (27.14)	-
CD (0.05%)	(0.581)	-	(0.056)	-	(0.226)	-	(0.045)	-

Figures given in parentheses are square root transformed values

4.5.3.3. Spiral nematode population in soil

Data pertaining to the percentage reduction of nematode population at 3 and 6MAT revealed that all the treatments were found to be superior to the untreated (Table 38). The highest percentage reduction over control was recorded in plants treated with carbosulfan 6G @1 kg ai/ha which was about 93.12 and 93.34 per cent at 3MAT and 6MAT respectively. The percentage reduction of nematodes when subjected to different treatments, at 3 and 6MAT were 92.07 and 91.92 per cent for thiamethoxam 50 WG @ 50 gai/ha, 91.80 and 92.16 per cent for cartap hydrochloride 4G @ 1kg ai/ha, 90.50 and 91.35 per cent for *B.macerans* @ $1x10^{7}$ cfu 50g/plant, 88.48 and 89.67 per cent for *P. lilacinus* @ $1x10^{7}$ cfu 50g/plant and 88.33 and 56.08 per cent for wild sunflower leaves @ 5 kg/plant. The treatments involving carbosulfan and cartap hydrochloride were found to be on par. Treatment with *P. lilacinus* was found statistically on par with wild sunflower leaves in reducing the population of nematodes by 80 per cent over the untreated control.

4.5.3.4. Root knot nematode population in roots.

The population of nematodes estimated from the roots varied significantly among different treatments at 3 and 6MAT. All the treatments were found superior to untreated (Table 39). The population of nematodes in the roots ranged from 72 - 89 per 5g of roots in various treatments when compared to 137 in untreated after three months of treatments. Treatment with carbosulfan 6G @ 1 kg ai/ha recorded the lowest number of nematodes (47 and 94.69 % reduction). Next best treatment was cartap hydrochloride 4G @ 1kg ai/ha which had given a per cent reduction of 44.79 and 94.02 per cent, followed

Table 39. Effect of treatments on the juveniles of root knot nematode population in 5g root

Treatments	3 months after treatment	% decrease	6 months after treatment	% decrease
Cartap hydrochloride 4G (1kg ai/ha)	76.00 (8.72)	44.79	45.00 (6.71)	94.02
Thiamethoxam 5 0 WG (50 gai/ha)	79.00 (8.89)	42.61	66.00 (8.12)	91.23
Wild sunflower leaves (5 kg/plant)	89.66 (9.47)	34.86	202.67 (14.24)	73.09
Paecilomyces lilacinus (1x10^7 cfu 50g/plant)	86.66 (9.31)	37.04	180.00 (13.42)	76.10
Bacillus macerans (1x10^7 cfu 50g/plant)	82.00 (9.06)	40.43	81.33 (9.02)	89.20
Carbosulfan 6G (1 kg ai/ha)	72.66 (8.52)	47.21	40.00 (6.32)	94.69
Untreated	137.66 (11.73)	-	753.33 (27.45)	-
CD (0.05%)	(0.159)	-	(0.091)	-

by thiamethoxam 50 WG @ 50 g ai/ha (42.61 and 91.23 %), *B. macerans* @ 1x10^7cfu 50g/plant (40.43 and 89.20 %), *P.lilacinus* @ 1x10^7cfu 50g/plant (37.04 and 76.10 %), wild sunflower leaves @ 5 kg/plant (34.86 and 73. 09 %).

Discussion

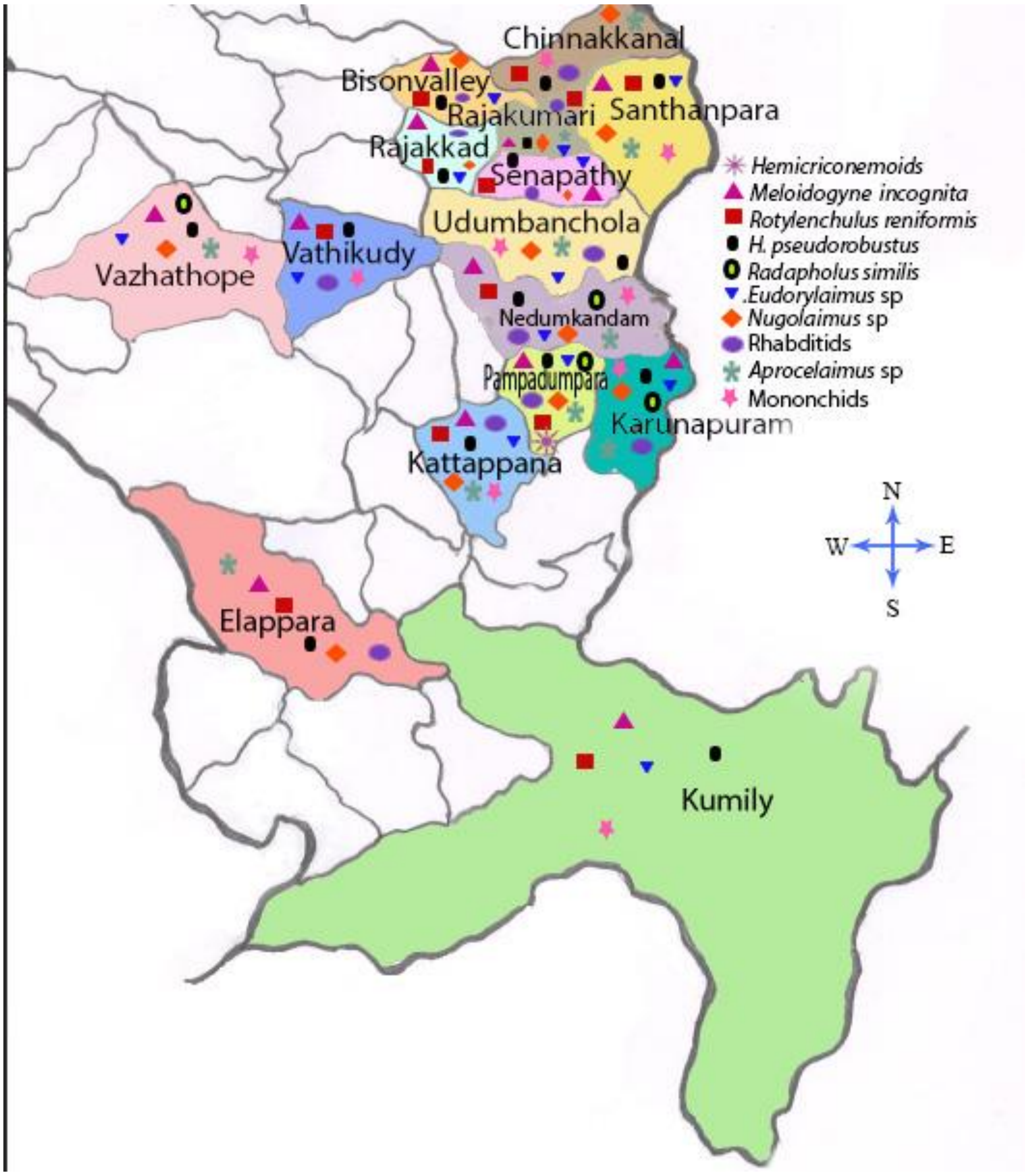
5. DISCUSSION

Cardamom (*Elettaria cardamom* Maton) referred as "Queen of Spices" belonging to the ginger family Zingiberaceae is one of the world's ancient spice known to mankind. It is the significant and most valuable spice in the world. It is the highly expensive spice after vanilla and saffron. Kerala is the highest cardamom producing state in India. In Kerala the major cardamom growing zones are (a) Udumbanchola taluk (b) Peeremedu taluk and (c) Devikulam taluk of Idukki district. One of the major constraints in cardamom cultivation is the infestation by nematodes, contributing 32-47percent loss in yield. Plant parasitic nematodes *viz., M. incognita, R. reniformis, H. pseudorobustus,* and *Pratylenchus* spp. cause economic loss to this crop. However, the information available on the nematodes in cardamom and the methods of managing them is very meagre. Hence a study has been carried out to access the association of nematodes in cardamom.Banning of nematicides like carbofuran and phorate in Kerala necessitate the need for an alternate method for management of nematodes. With this backdrop, an attempt was made to study nematodes associated with cardamom in Idukki district, to evaluate the reaction of different cardamom cultivars to nematodes, and to manage nematodes using nematicides, soil amendments and bioagents. The results of the above aspects are discussed below in following heads.

5.1 Association of nematodes in cardamom

In the present study association of nematodes in cardamom was studied by undertaking a survey in 15 panchayaths of Idukki district following purposive sampling technique covering nematode infested plantations. Nematodes in soil and root samples were analysed for studying the community analysis of nematodes in terms of nematode population in soil and roots, range of average, absolute frequency, absolute density, relative frequency, relative density and prominence value. The analysis of soil samples from the rhizosphere of cardamom revealed the presence of nematodes belonging to four trophic groups *viz*., plant parasites:

Fig: 1 Distribution of nematodes associated with cardamom in Idukki district



Tylenchids, bacterial feeders: Rhabditids, omnivorous: Dorylaimids and predatory forms: Mononchids.

The survey has shown that *M. incognita*, *R. reniformis, R. similis, H. pseudorobustus* and *Hemicriconemoides* sp. were the plant parasitic nematodes associated with the rhizosphere of cardamom plants in Idukki district. Several reports are there with the occurrence of these nematodes, Ali and Koshy (1982) reported the occurrence of *M. incognita* from Idukki, Kollam, Kozhikode and Palghat districts and *M. javanica* from Kozhikode and Palakkad districts. Root knot *Meloidogyn*e spp., lesion nematode *Pratylenchus coffea*, burrowing nematode *R. similis* were reported from cardamom plantations (Sundararaju *et al*., 1979). Eapen (1995a) reported the occurrence of reniform nematode, *R. reniformis* in cardamom. A survey in Coorg district of Karnataka revealed the occurrence of *M. incognita*, *M. javanica*, *Rotylenchulus* sp. and *Pratylenchus* sp. (Eapen, 1993).

The present study revealed the presence of other free living nematodes also *viz.* Rhabditids (bacterial feeding), *Eudorylaimus* sp., *Nygolaimus* sp., and *Aprocelaimus* sp (omnivores) and Mononchids (predatory forms) with varying frequencies. This finding was in line with the findings of Narayana (2012) who reported the occurrence of three trophic groups of nematodes, plant parasites. (*Helicotylenchus* sp. and *Meloidogyne* sp.), fungal feeders (aphelenchids and enoplids), bacterial feeders (rhabditids), omnivorous (dorylaimids) and predatory forms which include mononchids in cardamom.

Community analysis of nematodes revealed that *H. pseudorobustus* was the most frequent and most prominent species of plant parasitic nematode in the entire nematode community associated with rhizosphere of cardamom with an absolute frequency of 100 per cent (table 1 to 27). This was in line with Narayana (2012) who reported that *Helicotylenchus* sp, to be the most prominent nematode species in most of the cardamom soils. Community analysis of nematodes associated with cardamom grown in Cardamom Research Station, Pampadumpara revealed that *Helicotylenchus* sp and *Meloidogyne* sp were the most frequent and abundant nematode (Sreeja, 2011). Patel *et al*., (2007) reported the occurrence of

Helicotylenchus sp., *R reniformis*, *Tylenchorynchus* sp., *Meloidogyne* sp., *Pratylenchulus* sp. in certain medicinal plants from Gujarat. *Helicotylenchus* sp. recorded the highest frequency (40.90) followed by *Tylenchorynchus* sp. (36.30).

Thovalapadi (957nematodes/200g soil), Rajakumari (676 nematodes/200g soil) and Thopramkudy (795 nematodes/200g soil) area of Idukki district recorded highest population of *M. incognita* and these areas can be designated as hot spot area of root knot infestation.

R. reniformis occurred in all the locations surveyed except in Puliyanmala, Thovalapadi, Chottupara and Myladumpara. D'Souza *et al*., (1970) reported high population of *R. reniformis* in rhizosphere of cardamom (58 - 68/100g soil). Eapen (1995a) reported the occurrence of females of reniform nematodes (7 – 16/g of roots) in cardamom plantations of Kerala.

R. similis was recorded only in three areas in soil and root samples *viz.*, Puliyanmala area of Kattapana panchayath (223/200g soil; 4/5g roots), Muruganpara area of Nedukandam panchayath (224.00/200g soil; 3/200g soil) and Rajakumari area of Rajakumari Panchayath (31/20g soil; 2/200g soil). The present findings was in line with those of Ramana and Eapen (1995b) who reported the presence of *R. similis* in cardamom - arecanut mixed gardens.

Community analysis of nematodes in cardamom grown in various panchayaths of Idukki district in general showed a lower population of free-living forms of nematodes like omnivores and predatory mononchids. This may be due to the result of low levels of application of organic inputs and over dependence on chemical fertilizers and pesticides by the growers. It was also noticed that the leaf litter of the shade trees was also not ploughed back into the soils. Adding organic matter to soil influences diversity and important biological activities. Widmer *et al*., (2002) reported that the diversity and number of free living and plant parasitic nematodes are altered by rotational crops, cover crops, green manures and other sources of organic matter. Soil management programmes should include the use of proper organic materials to improve soil chemical, physical and biological parameters and to suppress plant parasitic nematodes and soil borne pathogens.

5.2 The reaction of different cardamom cultivars to nematodes

Observations on nematode population, growth and yield contributing characters of cardamom such as tiller height, tiller/clump, length and width of leaf, fresh yield and incidence of fruit and shoot borer, thrips and root grub were recorded and analyzed statistically for evaluating the reaction of different cardamom cultivars to nematodes (Table 28 to 33).

Root and soil samples of nematodes collected from 13 accessions/varieties of two year old cardamom plants maintained in Cardamom Research Station, Pampadumpara showed that the population of each nematode species *viz., M. incognita, R. reniformis and H. pseudorobustus* significantly differed among different cardamom accessions at three different stages (tillering, flowering and harvesting).

The results revealed that, the occurrence of *M. incognita* was not noticed in accessions *viz.*, CRSP 6, IC 547185 and IC 349545 at tillering, flowering and harvesting stage. All the other accessions supported the population of nematodes at varying levels. PV 2 and PL 14 recorded highest population of *M. incognita* (Table 30-33). A similar observation was reported by Hegde *et al*., (1993). They observed that three high yielding varieties of cardamom *viz.*, Mudigree 1, CL 683, CL 726 from Karnataka and an erect type from Kerala were susceptible to *M. incognita* supporting high population in the soil and root. Eapen *et al.*, (1998) reported that out of 48 accessions of turmeric and 116 accessions of ginger, seven turmeric and six ginger accessions were found to be resistant to root knot nematode, *M.incognita.* Among these, one ginger and two turmeric accessions were highly resistant to root knot nematode. Routary and Mohapatra (1988) reported that none of the tested cultivars of ginger exhibited resistance to *M. incognita*. However, the nematode multiplication was lowest in ‘UP’ followed by V_1K_1-3 and PGS-19. The maximum reduction in rhizome yield was recorded in V_2E_5-3.

In the present study *R. reniformis* and *H. pseudorobustus* was found infesting all the accessions/varieties of cardamom studied. Lowest population of *R. reniformis* was recorded in MCC 346 and that of *H. pseudorobustus* in Green

Table 40 Ranking of different varities/lines based on biometric characters, yield and reduction in nematode population

Cultivar/ acession	Tiller height	Tillers/ clump	Leaf length	Leaf width	Fresh yield	Incidenc e of borer	Incidence of thrips	Population of nematodes in soil								
								M.incognita			*R.reniformis*			*H.pseudorobustus*		
								At tillering	At flowering	At harvest	At tillering	At flowering	At harvest	At tillering	At flowering	At harvest
Green gold	11	2	1	3	1	12	7	8	8	6	5	6	7	1	1	1
PV 2	9	3	11	1	4	4	1	9	11	10	10	10	13	8	8	6
CRSP 6	7	5	6	4	9	3	4	1	1	1	6	9	11	4	7	5
PL 14	8	1	2	2	2	4	2	10	10	9	4	3	6	2	2	2
MCC 346	8	6	7	5	7	9	9	4	2	3	1	1	1	7	4	3
CL 691	8	9	5	10	11	5	3	3	3	2	3	3	2	11	11	12
CL 726	10	10	10	8	6	7	11	6	5	4	6	7	8	5	6	7
SKP 164	6	7	12	11	10	11	8	6	7	7	8	5	10	9	10	10
IC 547167	5	8	9	7	3	8	9	5	6	5	9	8	12	10	12	11
IC 349651	4	13	4	7	11	1	6	2	4	4	5	2	4	8	9	9
IC 547185	3	4	3	6	5	2	5	1	1	1	2	2	3	6	5	8
SKP 104	2	12	13	9	8	10	10	7	9	8	3	2	5	12	13	13
IC 349545	1	11	8	9	4	6	12	1	1	1	7	4	9	3	3	4

Table 40 continues Ranking of different varities/lines based on biometric characters, yield and reduction in nematode population

Cultivar/ acession	Population of nematodes in roots						Mean	Rank
	RKN at tillering	RKN at flowering	RKN at harvesting	Reniform at tillering	Reniform at flowering	Reniform at harvesing		
Green gold	4	6	6	7	7	4	5.18	7
PV 2	9	11	10	12	12	11	8.32	12
CRSP 6	1	1	1	9	8	5	4.91	4
PL 14	8	9	11	5	6	3	5.05	5
MCC 346	2	5	5	1	1	1	4.18	2
CL 691	1	2	3	6	4	2	5.41	8
CL 726	3	4	4	10	10	7	7.00	9
SKP 164	7	8	8	11	11	8	8.64	13
IC547167	5	7	7	8	9	10	7.86	10
IC349651	1	3	2	3	2	9	5.14	6
IC547185	1	1	1	2	3	2	3.05	1
SKP 104	6	10	9	4	5	4	7.91	11
IC349545	1	1	1	4	5	6	4.64	3

Gold (Njallani). This finding was in agreement with Eapen (1995a). He reported high population of *R. reniformis* in soil and roots of cardamom.

Regarding the biometric and yield characters, the accession PL 14 and Njallani (Green gold) performed better than the other acessions. The incidence of shoot borer and thrips, was lower in PV 2 and PL 14. But in overall ranking, the accession IC 547185 ranked first followed by MCC 346 and IC 349545 (Table 40). Based on the overall rating (biometric characters, yield characters and ability to avoid nematodes and pests) accessions *viz.*, CRSP 6, IC 547185, IC 349545 and MCC 346 can be selected as a component in integrated nematode management (INM) experiments in cardamom as the varietal selection is a major component in INM.

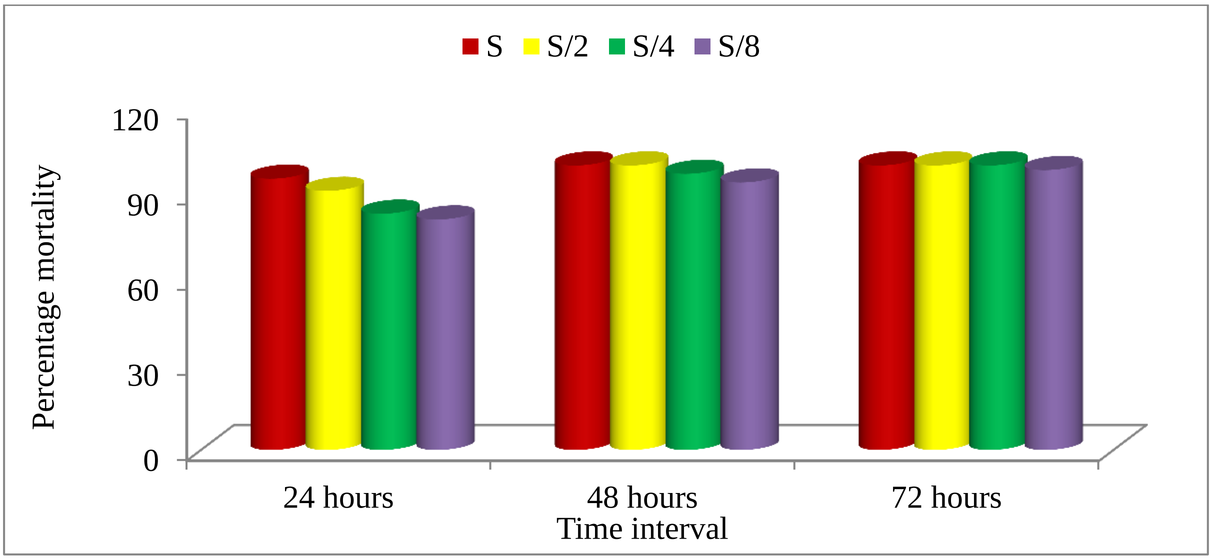
5.3 Management of plant parasitic nematodes in cardamom

5.3.1 Evaluation of bioefficacy of chemicals and botanicals under *in vitro* conditions

5.3.1.1 Bioefficacy of fresh leaf extracts of *Tithonia diversifolia* on the mortality of *M. incognita* juveniles (J_2)

A laboratory study was conducted to assess the bioefficacy of fresh leaf extracts of *Tithonia diversifolia* against *M. incognita*. All the concentrations tested *viz.*, S, S/2, S/3, S/4 were found to be effective in increasing the mortality of *M. incognita* juveniles at different time intervals (24, 48 and 72 h after treatment). The application of *T. diversifolia* extract on *M. incognita* juveniles, in the laboratory resulted in a significant increase in J_2 mortality (Table 34). The mortality of *M. incognita* J_2 increased with the concentration of plant extract and time of exposure. The inhibitory effect of the plant extracts might be due to the presence of alkaloids, flavanoids and saponins in *T. diversifolia* (Tona *et al*., 2000; Olabiyi *et al*., 2013). Greater mortality of *M. incognita* was observed at higher concentration (S) of crude plant extract where as lower concentration (S/4) recorded lesser mortality. After 72 hours of exposure, the concentrations *viz.*, S, S/2 and S/3 recorded 99 per cent mortality followed by S/4 which recorded 98 per cent mortality. This was in line with the findings of Odeyemi and Adewale (2011)

Fig.2. Mortality of *Meloidogyne incognita* juveniles treated with fresh leaf extracts of *Tithonia diversifolia*



who reported that application of *T. diversifolia* extract on *M. incognita* eggs resulted in significant reduction in egg hatching after 2nd (98 %), 5th (98 %) and 9th (100 %) day of exposure. Studies have shown *T. diversifolia* have bioactive compounds that have nematicidal properties (Prakash and Rao, 1997). Tsay *et al*., (2004) reported that out of 56 species and 45 genera of Asteraeceae plants tested for their susceptibility to *M. incognita*, *T. diversifolia* was one among the nine found to be highly resistant or immune. Since *T. diversifolia* was found to have nematicidal properties based on *in vitro* studies it has been included as one of the treatments in the further field experiments.

5.3.1.2 Mortality of M. incognita juveniles treated with different chemicals

Laboratory bioassays revealed that population of *M. incognita* had high susceptibility to carbosulfan, cartap hydrochloride and thiamethoxam for the diagnostic dose and time of exposure used (Table 35). Regarding percentage mortality of J_2 during all the testing periods (24, 48 and 72 h after exposure), carbosulfan evoked significantly high J_2 mortality (95.03 %) at 72 h, however, cartap hydrochydrochloride (78 %) and thiamethoxam (69.12 %) recorded comparatively lower mortality. The study conducted by Narayana (1997) also was in agreement with these findings. He reported that carbosulfan 25 STD was very effective in reducing penetration and development of *M. incognita* race-1 in roots of sunflower. Sharma *et al.* (2008) reported that carbosulfan was found to be the best treatment in controlling nematodes in tomato. Narayana, 2002 reported that carbosulfan was effective in reducing the population of *M.incognita* infecting soyabean. Data presented in Table 35 revealed that as the concentration of the chemical and the time of exposure increased, the mortalilty also increased. Highest mortality (95.03%) was observed in the case of carbosulfan at a concentration of 300 µg kg^{-1} at 72 h of exposure. In conclusion, the results of the study indicated that carbosulfan was more effective than cartap hydrochloride and thiamethoxam.

5.3.1.3 Management of plant parasitic nematodes in cardamom

A field trial was conducted in a two year old cardamom plantation to access the efficacy of treatments *viz.*, carbosulfan 6G at 1 kg ai/ha, cartap hydrochloride 4G @ 1 kg ai/ha, thiamethoxam 25 WG @ 1 kg ai/ha, wild sun flower leaves (*Tithonia diversifolia*) @ 5 kg/plant as mulch, *P. lilacinus* $1x10^7$ cfu 50 g/plant, and *B. macerans* $1x10^7$ cfu 50 g/plant in managing the nematodes associated with cardamom. The results were accessed in terms of nematode population build up in soil at two intervals (three and six months after treatment), growth characters like no. of tillers, no. of leaves/tillers, no. of panicles, no. of capsules/panicle and yield characters (fresh weight of capsules, dry weight of capsules and total yield).

The results on population characteristics of nematodes were presented in Table 38 and 39. The periodical estimation of the nematode population in soil and root samples (three months and six months after treatment) revealed that carbosulfan 6G @ 1 kg a.i /ha was superior to all other treatments in reducing the nematode population. Percentage reduction in *M.incognita* population in soil and root was to a tune of 94.56 at 3MAT & 94.69 per cent at 6MAT and 47.21 at 3MAT and 94.69 per cent at 6MAT respectively. However, the population of *H. pseudorobustus* was found to be 93.12 at 3MAT and 93.34 per cent at 6MAT. This findings is in conformity with the reports of Sao *et al*., (2008) reported carbosulfan to be a widely used nematicide due to its good systemic properties, low residue and long term effects. Application of carbofuran at 5 and 10 g a.i/plant twice a year increased the yield of *M. incognita* infested cardamom plants from 47 to 88 per cent (Ali, 1984). Narayana (1997) reported that carbosulfan was very effective in reducing the population of *M. incognita* race-1 in sunflower when used as a soil drench. The efficacy of carbosulfan in managing root knot nematode infesting round melon was reported by Rajavanshi *et al*. (2008). Narayana, 2002 reported that carbosulfan was effective in reducing the population of *M.incognita* infecting soyabean. Garabedian and Van Gundy (1985) reported carbosulfan as soil drench reduced root knot nematode in tomato. The reduction in nematode population as a result of carbosulfan treatment could be due to adverse influences on orientation towards root, invasion, development, reproduction and fecundity coupled with a direct poisoning effect (Di Sango, 1973; McLeod and Khair, 1975).

The better nematicidal action of carbosulfan against root knot nematode (94.56 - 94.69 %) when compared to spiral nematode (93.12 - 93.34 %) was probably due to a smaller rate of degradation of the nematicide and a greater inhibition of acetyl choline esterase in root knot than in spiral nematode. Comparing the percentage reduction of root knot nematode population in root and soil over a period of time (three months and six months after treatment), highest reduction was observed in the case of root samples. This may be attributed to the systemic action and long term effect of carbosulfan.

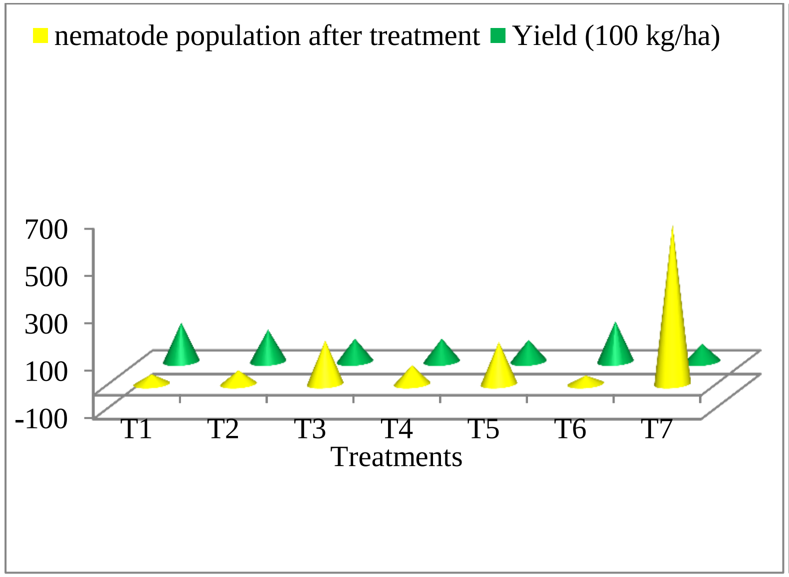
The improvement in biometric characters like no. of tillers (20.39 %), no. of leaves/tiller (48.45 %), no. of panicles (40.02 %) and no. of capsules/panicle (61.10 %) which inturn resulted in increased fresh (5.29 kg/plant) and dry weight of capsules (0.68 kg/plant) in cardamom plants treated with carbosulfan. In the case of total yield (1.70 t/ha), the treatment with carbosulfan established its superiority over all other treatments. Narayana (1997) reported that with increase in the concentration of carbosulfan 25 STD, there was an increase in various plant growth parameters including shoot and root length, dry weight of shoot and root, fresh weight of head and weight of seeds. Maximum growth was recorded @400 µg/ml in sunflower. Kumar *et al*., 2010 reported the efficiency of carbosulfan 25 DS @ 3 per cent as seed dressing in cowpea seeds in suppressing the population of *M. incognita* and thereby improving the biometric characters (shoot length, shoot weight, shoot dry weight, root length and fresh root weight). Vadhera *et al*. (1998) reported 65 per cent reduction in nematode population and 40 per cent yield increase of chickpea after soaking seeds in carbosulfan (0.01 %).

It was apparent from the present studies that application of other synthetic pesticides *viz.,* cartap hydrochloride 4 G and thiamethoxam 25 WG significantly reduced the damage caused by root knot nematode and spiral nematode at two intervals (three and six months after treatment) and improved the biometric and yield characters (Table 36 to 39). Das *et al*., (2011) reported the efficacy of cartap hydrochloride @ 0.2 % seed soaking in managing reniform nematode *R. reniformis* in cotton. Cartap hydrochloride 4G @ 1 kg a.i/ha 45 days after transplanting was found to be effective in reducing rice root knot nematode and rice root nematode population and thereby increasing the grain yield (Das and Chowdary, 2012). A screen house study conducted by Kumar *et al*., (2010) revealed the efficiency of cartap hydrochloride 50 SP @ 1.5 per cent as seed dressing in reducing root knot nematode population in cowpea.

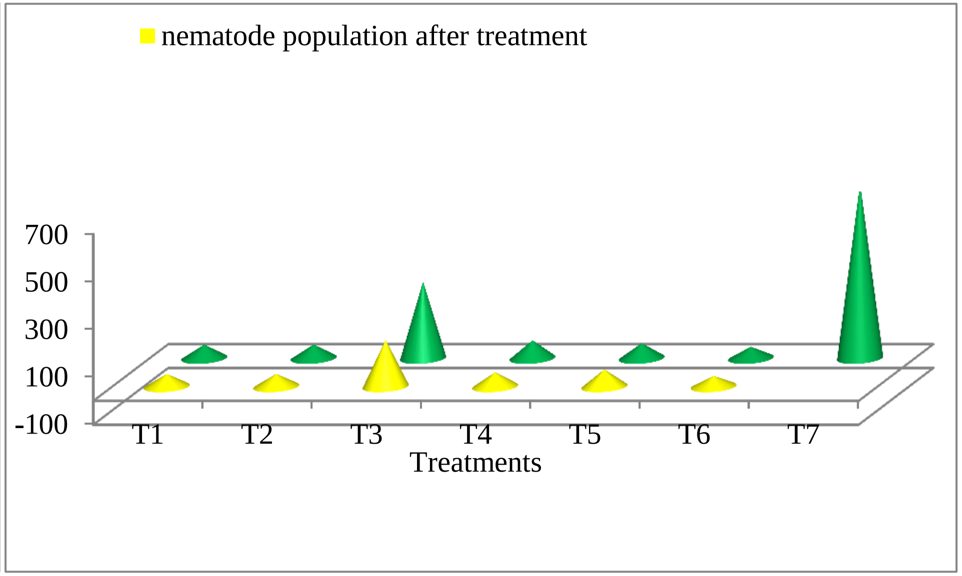
Application of thiamethoxam significantly reduced *M. incognita* population in soil by 91.40 per cent at 3MAT and 91.23 per cent at 6MAT, 42.61 at 3MAT and 91.23 per cent at 6MAT in roots. However, *H. pseudorobustus* had a per cent reduction of 91.92 per cent at 3MAT and 92.07 per cent at 6MAT in soil. In the case of biometric and yield characters, no. of tillers (14.26 %), no. of leaves/tiller (27.27 %), no. of panicles (32.59 %), no. of capsules/panicle (40.09 %), fresh weight of capsules (2.21 kg/plant), dry weight of capsules (0.54 kg/plant) and total yield (1.35 t/ha) the treatment thiamethoxam established its superiority over untreated control.

The results summarized in Table 36 to 39 clearly indicated that the biocontrol agents, *B. macerans* $1x10^7$ cfu 50 g/plant and *P. lilacinus* $1x10^7$ cfu 50 g/plant were effective in increasing the plant growth with significant reduction in nematode population. Per cent reduction of *M. incognita* population in soil was to a tune of 86.91 per cent at 3MAT and 89.20 per cent at 6MAT and in roots it was to a tune of 40.43 percent at 3MAT and 89.20 per cent at 6MAT. However, per cent reduction of *H. pseudorobustus* was 90.50 per cent at 3MAT and 91.35 per cent at 6MAT in soil. In the case of biometric and yield characters, *B. macerans* resulted in an increase of no. of tillers 12.24 per cent, no. of leaves/tiller 24.18 per cent, no. of panicles 24.67 per cent, no. of capsules/panicle (28.84 per cent), fresh weight of capsules (2.10 kg/plant), dry weight of capsules (0.39 kg/plant) and total yield (0.97 t/ha). The present findings was in line with the findings of

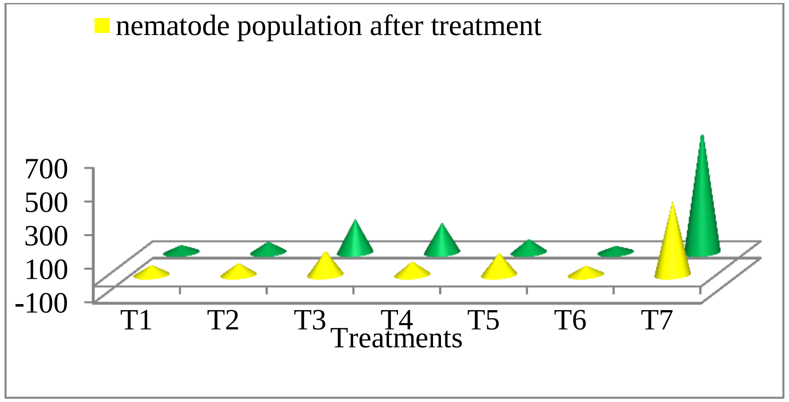
Meloidogyne incognita in soil



Helicotylenchus pseudorobustus in soil



Meloidogyne incognita in root



T1	Cartap hydrochloride 4G @ 1 kg a. i. ha^{-1}
T2	Thiamethoxam 50 WG @ 50 g a. i. ha^{-1}
T3	Wild sunflower leaves @ 5 kg $plant^{-1}$
T4	*Paecilomyces lilacinus* @ $1x10^7$ cfu 50 g $plant^{-1}$
T5	*Bacillus macerans* @ $1x10^7$ cfu 50 g plant $^{-1}$
T6	Carbosulfan 6G @ 1 kg a i. ha^{-1}
T7	Untreated

Fig:3 Nematode population and yield of cardamom at the time of harvest

Sheela and Venkatesan, 1992 who reported that *B. macerans* was found effective in increasing the length of vine, number of leaves, fresh and dry weight of shoot of pepper plants attacked by *M. incognita*. Sheela *et al*. (2004) reported the potential of *B. macerans* @ 2% as dipping of cuttings + drenching in soil seven day after planting in managing root knot nematode in coleus. Niknam and Dhawan (2002) reported the biocontrol potential of *B. subtilis* in inhibiting egg hatching and causing mortality of *R. reniformis* under *in vitro* conditions. The noncellular extracts of *B. subtilis* has been reported to cause high degree of larval mortality of root knot and cyst nematodes (Gokte and Swarup, 1988). All these findings are in line with these findings.

P. lilacinus resulted in significant reduction of *M. incognita* population to a tune of 70.50 per cent at 3MAT and 76.10 per cent at 6MAT in soil. In case of root percentage reduction of *M. incognita* was to a tune of 37.04 per cent at 3MAT and 76.10 per cent at 6MAT. However, the percent reduction of *H. pseudorobustus* in soil was to a tune of 88.48 per cent at 3MAT and 89.67 per cent at 6MAT. *P. lilacinus* was found to be superior in increasing the biometric and yield characters i.e., no. of panicles (21.56 %), no. of capsules/panicle (22.00 %), fresh weight of capsules (2.02 kg/plant), dry weight of capsules (0.37 kg/plant) and total yield (0.92 t/ha) when compared to untreated. Eapen, (1995b) Eapen and Venugopal (1995) reported that *P. lilacinus* reduced root knot population by 48.5 to 57 per cent in pot culture studies and by 19.7 per cent in field studies in cardamom. Dhawan *et al*., (2004) reported the efficacy of *P. lilacinus* against *M. incognita* on okra, the results showed that the application of *P. lilacinus* as seed treatment @ 10.15 and 20g/kg seed and soil application @ 1.5 and 3 per cent w/w significantly increased plant growth characters of okra and suppressed galls and egg masses per plant. Nisha (2005) reported that application of *P. lilacinus* with neemcake in main field significantly reduced *M. incognita* population in vegetable coleus. The efficacy of *P. lilacinus* in reducing the gall index of tomato was reported by Goswami *et al*. (1998). *P. lilacinus* was also found effective against *M. incognita* infesting potato and tomato and *R.*

reniformis infecting tomato and egg plant (Reddy and Khan, 1998 and 1999). The success of *P. lilacinus* in managing root knot nematode infecting potato was reported by Jatala *et al*., (1979). It was reported that the nematicidal action of *P. lilacinus* may be due to the action of antibiotics like leucinostatin and lilacinin together with various other proteolytic and chitinolytic fungal metabolic products (Zaki, 1994; Khan and Goswami, 1999). The egg shell and gelatinous matrix of *M. incognita* contains chitin (Spiegel and Cohn, 1985; Bird and Shelf, 1995). In addition to the above action, the ovicidal effect of *P. lilacinus* adversely affected the progeny production of nematodes. As reported by Rodriguez-Kabana *et al.*, (1984) reduction in the population of nematodes may be due to fungal attack on juveniles and or death of females before egg laying, thus reducing their fecundity and if eggs are produced, these are colonized and destroyed. *P. lilacinus*, a heavy sporulator is a strong competitor capable of successfully establishing itself in a natural soil when introduced artificially. The antibiotic, p-168, produced by *P. lilacinus* has wide antimicrobial activity against nematode (Isogai and Suzuji, 1980).

Comparing the two bioagents, bacterium *B. macerans* and fungus *P. lilacinus*, *B. macerans* was found to be statistically superior in reducing the nematode population as well as improving the biometric and yield characters. A study conducted by Khan and Taranum (1999) revealed that *B. subtilis* was more effective when compared to *P. lilacinus* in suppressing *M. incognita* infesting tomato plants.

Present study revealed the significant effect of *Tithonia diversifolia* as a nematicidal plant. This was in agreement with Odeyemi and Adwale (2011) who reported that *T. diversifolia* could be used for the management of *M. incognita* infecting yam. Tsay *et al*., (2004) reported *T. diversifolia* as a non host to *M. incognita.* It was reported that the nematicidal property of *T. diversifolia* may be due to constituents like alkaloids, flavanoids and saponins (Tona *et al*., 2000; Olabiyi *et al*., 2013). Devi (2010) reported that application of *T. diversifolia* leaf and stem significantly increased the plant growth and decreased the host infestation by root knot nematode in tomato. In the present study it was found that with the reduction in nematode population *T. diversifolia* was also found to increase the biometric and yield characters of cardamom. This may be due to the improvement of the health of the soil by application of *T. diversifolia* as a mulch. Jama *et al*. (2000) have reported that *T. diversifolia* biomass decomposes rapidly after application to soil and incorporated biomass can be an effective source of N, P, K and other nutrients for crops. Using *T. diversifolia* as a mulch around cardamom plants is a common practise among cardamom growers of Idukki district for the management of soil borne pests of cardamom. The present findings also confirm the use of *T. diversifolia* as a mulch against soil borne plant parasitic nematodes.

The present investigation on "Management of nematodes associated with cardamom" highlighted that *M. incognita, R. reniformis, R. simils, H. pseudorobustus* were the major plant parasitic nematodes found associated with cardamom. Thovalapadi, Rajakumari, Thopramkudy areas of Idukki district recorded highest population of *M. incognita* and can be considered as the hot spot area of infestation of *M. incognita*. Germplasm evaluation studies revealed that CRSP 6, IC 547185, IC 349545 and MCC 346 can be selected as a component in ensuing integrated nematode management experiments in cardamom. Mulching with *T. diversifolia* reduced *M. incognita* in cardamom plantations and could be recommended as a component in integrated nematode management in cardamom since *T. diversifolia* is a common invasive weed in cardamom plantations throughout Cardamom Reserve Hills of Idukki district. Nematicides like carbosulfan 6G, cartap hydrochloride 4G and thiamethoxam 25 WG were also found effective in reducing the nematode population and increasing the plant growth and yield of cardamom when compared to bioagents like *B. macerans, P.lilacinus* and soil mulch using *T. diversifoila*. In this context these nematicides can be recommended for the management of nematodes under intensive cultivation of cardamom. Since *B. macerans* was found to be the effective biocontrol agent this can be recommended for organic cultivation of cardamom.

Summary

6. SUMMARY

Small cardamom (*Elettaria cardamom* maton) is one of the oldest spices known to mankind. Many plant parasitic nematodes were found associated with cardamom. They were found to cause severe damage to growth and yield of the crop. Several pre and post sowing chemical measures were recommended for the control of these nematodes. The chemicals recommended for nematode management *viz.,* carbofuran and phorate were banned by the Govt. of Kerala and shift of traditional cardamom cultivation to organic production for premium price of pods necessitate a safer, economic means of management. Hence the study entitled "Management of nematodes associated with cardamom" was carried out in the Department of Entomology, College of Agriculture, Vellayani, Cardamom Research Station, Pampadumpara and Thovalapady area of Idukki district, with the objectives to study the nematodes associated with cardamom in Idukki district, to evaluate the reaction of different accessions/cultivars to nematodes and to manage nematode population using bioagents, soil amendments and nematicides"during 2011-2013

The results of the study were summarized below:

- A survey was conducted in cardamom plantations of Idukki district to study the association of nematodes in cardamom. The results revealed the presence of four trophic groups of nematodes *viz.*, plant parasites (Tylenchids), bacterial feeding (Rhabditids), omnivorous (Dorylaimids) and predatory forms (Mononchids).
- Community analysis of nematodes in the rhizosphere of cardamom revealed the occurrence of five plant parasitic nematodes *viz., Meloidogyne incognita*, *Rotylenchulus reniformis, Radopholus similis, Helicotylenchus pseudorobustus* and *Hemicriconemoides* sp.

- *H. pseudorobustus* was distributed in all the areas surveyed and was the most prominent and most frequently occuring nematode with an absolute frequency of 100 per cent followed by *R. reniformis*.
- Considering the extent of damage, *M. incognita* was the most problematic nematode in cardamom plantations. Thovalapadi, Rajakumari and Thopramkudy area of Idukki district recorded highest population of *M. incognita*.
- In the case of *R. reniformis,* highest population was found in Pathinipara area of Pampadumpara panchayath (559/200g soil; 8/5g roots) and lowest population was recorded in Kumily area of kumily panchayath (13/200g soil; 1/5g roots).
- *H. pseudorobustus* distributed in all the areas surveyed. The highest population of *H. pseudorobustus* was found in Sanyasioda area of Pampadumpara panchayath (713/200g soil) and lowest population was observed in Pathinipara area of Pampadumpara panchayath (46 $_{J2}$/200g soil).
- *R. similis* was recorded only in three areas in soil and root samples *viz*. Puliyanmala area of Kattapana panchayath (223/200g soil;4/5g roots), Muruganpara area of Nedukandam panchayath (224.00/200g soil; 3/200g soil) and Rajakumari area of Rajakumari Panchayath (31/20g soil; 2/200g soil)
- Other nematodes recorded were Rhabditids (bacterial feeding), *Eudorylaimus* sp., *Nygolaimus* sp., and *Aprocelaimus* sp (omnivores) and Mononchids (predatory forms) with varying frequencies.
- Study conducted to evaluate the reaction of 13 different cardamom accessions/varieties to nematodes with regard to biometric and yield character revealed that tiller height was highest in (IC 349545: 23. 17 cm), tiller/clump (PL 14: 253.00), Green Gold (leaf length: 54.33 cm), leaf width (PV 2: 11.33 cm), fresh yield of capsule/plant (Green gold: 1.99 kg/plant), lowest incidence of shoot

and capsule borer (IC 349651: 1.20 %) and lowest incidence of thrips (PV 2: 2.00 %)

- Periodical sampling of nematodes in 13 accessions/varieties of cardamom maintained in Cardamom Research Station, Pampadumpara at two years after planting showed that the population of each nematode species *viz., M. incognita, R. reniformis and H. pseudorobustus* significantly differed among different cardamom accessions at three different stages (tillering, flowering and harvesting).
- Occurrence of *M. incognita* was not noticed in accessions *viz.,* CRSP 6, IC 547185 and IC 349545. However, *R. reniformis* and *H. pseudorobustus* was found associated with all the accessions/varieties of cardamom studied. Lowest population of *R. reniformis* was recorded in MCC 346 and that of *H. pseudorobustus* in Green Gold (Njallani).
- Regarding the biometric and yield characters, the accession PL 14 and Njallani (Green gold) performed better than the other entries. With respect to the incidence of pests (shoot borer and thrips), PV 2 and PL 14 exhibited better performance than others. But in overall ranking, the accession IC 547185 ranked first followed by MCC 346 and IC 349545.
- Based on the biometric characters, yield characters and ability to avoid nematode and pest infestation, accessions *viz.,* IC 547185, CRSP 6, IC 349545 and MCC 346 can be selected as a component in integrated nematode management experiments in cardamom.
- The bioefficacy of fresh leaf extracts of *Tithonia diversifolia* on the mortality of *M. incognita* juveniles (J_2) revealed that all the concentrations tested (S, S/2, S/3, S/4) were effective in increasing the mortality of *M. incognita* juveniles at 24, 48 and 72 h after treatment.

- The bioefficacy of different chemicals *viz.*, carbosulfan 6 G, thiamethoxam 50 WG and cartap hydrochloride 25 WG on the mortality of *M. incognita* juveniles (J_2) revealed that carbosulfan 6G at 300 µg/ml after 24, 48 and 72 h of exposure showed the highest mortality of juveniles with 63.33, 84.00 and 95.03 per cent respectively.
- Management of nematodes in field using nematicides, soil amendments and bioagents revealed that carbosulfan 6G @ 1kg ai/ha was found to be significantly superior treatment in reducing the population of *M. incognita* and *H. pseudorobustus* in soil and root followed by cartap hydrochloride 4G @ 1kg ai/ha.
- Studies conducted to evaluate the effect of chemical treatments in biometric and yield characters of cardamom revealed that carbosulfan 6G @ 1kg a.i/ha was the most effective treatment followed by cartap hydrochloride 4G@1kg a.i/ha. The percentage increase in number of tillers, no. of leaves/tillers, no. of panicles, no.of capsules/panicles were 20.39, 48.45, 30.33, 31.66 and 18.37, 42.36, 30.00, 30.66 for carbosulfan and cartap hydrochloride respectively. Yield in terms of fresh weight and dry weight of capsules were also found higher for carbosulfan (5.29 kg/plant, 0.68 kg/plant) followed by cartap hydrochloride (4.46 kg/plant , 0.66 kg/plant).

It can be concluded that *M. incognita*, *R. reniformis, R. similis* and *H. pseudorobustus* were the major plant parasitic nematodes found associated with cardamom. Thovalapadi, Rajakumari and Thopramkudy area of Idukki district recorded highest population of *M. incognita*. There was no incidence of *M. incognita* infestation in accessions CRSP6, IC547185 and IC349545. Carbosulfan 6G @ 1kg ai/ha was found to be best treatment in reducing population of nematodes and increasing yield of cardamom. *T.diversifolia* and *B.macerans* were also found effective in reducing the nematode population and increasing the yield of cardamom. Hence these two can be recommended as a component in the organic farming or integrated nematode management of cardamom.

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MANAGEMENT OF NEMATODES ASSOCIATED WITH CARDAMOM

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(2011-11-157)

Abstract of the thesis submitted in partial fulfilment of the requirement for the degree of

MASTER OF SCIENCE IN AGRICULTURE

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2013

ABSTRACT

The present investigation on "Management of nematodes associated with cardamom" was conducted at Cardamom Research Station, Pampadumpara and Department of Entomology, College of Agriculture, Vellayani during 2012-2013. The objectives were to study nematode population associated with cardamom in Idukki district, to evaluate the reaction of different cardamom cultivars to nematodes and their management using nematicides, soil amendments and bioagents.

Soil and root samples of cardamom were collected from nematode infested plantations in Idukki district. Twenty five samples from 15 panchayats were collected and processed for studying the community analysis of nematodes. *Meloidogyne incognita*, *Rotylenchulus reniformis*, *Radopholus similis*, *Helicotylenchus pseudorobustus* and *Hemicriconemoides* sp. were the plant parasitic nematodes found associated with the rhizosphere of cardamom plants. The highest population of *M. incognita* was recorded in Thovalapady area of Karunapuram panchayat (969 J_2/200g soil) followed by Thopramkudy area of Vathikudy panchayat (773 J_2/200g soil), Rajakumari area of Rajakumari panchayat (722 J_2/200g soil). The lowest population was recorded in Moolathara area of Santhampara panchayat (22 J_2/200g soil). Highest population of *R. reniformis* was recorded in Periyakanal area of Chinnakanal panchayat (309 J_2/200g soil). *H. pseudorobustus* was the most frequently occuring (absolute frequency of 100%) nematode. *R. reniformis* was the next frequently occuring nematode. Other nematodes recorded were rhabditids (bacterial feeder), *Nygolaimus* sp, *Aprocelaimus* sp, *Eudorylaimus* sp and mononchids (predatory nematodes) with varying frequencies.

Periodical sampling of nematodes was done in 13 accessions/varieties maintained in Cardamom Research Station, Pampadumpara during the study period. Plant biometric characters and yield were recorded for two years after planting. The population of each nematode species significantly differed among different

cardamom accessions. Occurrence of *M. incognita* was not noticed in accessions *viz*. CRSP6, IC547185 and IC349545. However, *R.reniformis* and *H. pseudorobustus* was found associated with all the accessions/varieties of cardamom studied. Lowest population of *R. reniformis* was recorded in MCC346 and that of *H. pseudorobustus* in Green Gold (Njallani). Highest yield was recorded in Njallani followed by PL-14.

To assess the bioefficacy of nematicides, soil amendments and bioagents against nematodes a field trial was conducted with seven treatments *viz*., cartap hydrochloride 4G (1kg ai/ha), thiamethoxam 25WG (50g ai/ha), carbosulfan 6G (1kg ai/ha), wild sunflower, *Tithonia diversifolia* leaves (5kg/plant), *Paecilomyces lilacinus* $1x10^7$ cfu (50g/plant) *Bacillus macerans* $1x10^7$ cfu (50g/plant) and untreated control. Results indicated that among the treatments, carbosulfan 6G was the most effective treatment in reducing the population of *M. incognita* and *H. pseudorobustus* in soil and root and increasing the yield of cardamom.

It can be concluded that *M. incognita*, *R. reniformis*, *R. similis* and *H. pseudorobustus* were the major plant parasitic nematodes found associated with cardamom. Thovalapadi, Rajakumari and Thopramkudy area of Idukki district recorded highest population of *M. incognita*. There was no occurrence of *M. incognita* population in accessions CRSP6, IC547185 and IC349545. Carbosulfan 6G @ 1kg ai/ha was found to be best treatment in reducing population of nematodes and increasing yield of cardamom.