Nematode Association in Cabbage, *Brassica oleracea* L. var. *capitata* and its Management Using Botanicals.

by

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THESIS

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2015

DECLARATION

I, hereby declare that this thesis entitled "**Nematode association in cabbage, *Brassica oleracea* L. var. *capitata* and its management using botanicals**" 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 to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

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CERTIFICATE

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LIST OF ABBREVIATIONS

cm	-	Centimeter
et al.	-	Co-workers/ Co-authors
CD (0.05)	-	Critical difference at 5per cent level
Fig.	-	Figure
g		Gram
g(kg soil)$^{-1}$	-	Gram per kilogram soil
gm^{-2}	-	Gram per meter square
g plant^{-1}	-	Gram per plant
hrs		Hours
ml plant^{-1}	-	Milliliter per plant
viz.	-	Namely
sp.		Species
i.e.	-	that is

LIST OF SYMBOLS

%	-	per cent
@		At the rate of

INTRODUCTION

1. INTRODUCTION

Cabbage, *Brassica oleracea* L. var. *capitata* is an important vegetable crop grown throughout the country and is consumed by majority of the people. India is the second largest cabbage grower in the world with an area of 412 ha and production of 9126 MT (2013-2014). It is a rich source of vitamins and minerals. In Kerala, cultivation was confined to high ranges of Idukki and Wayanad districts. With the development of tropical cabbage varieties the cultivation has spread to the non-traditional areas in South India including Karnataka, Tamil Nadu and Kerala. At present with the active intervention of Vegetable and Fruit Promotion Council Kerala (VFPCK) cultivation of cabbage is made possible throughout Kerala. More farmers in the plains are interested in cabbage cultivation as it is remunerative.

Cultivation of a crop becomes profitable only when the effect of losses incurred could be made minimum. Plant parasitic nematodes remain a major challenge in cool season vegetable production especially in developing countries. The root-knot nematode, *Meloidogyne incognita* (Kofoid & White) Chitwood. is one of the limiting factors in commercial production of vegetables and is responsible for 15 to 60 per cent yield loss (Krishnappa *et al.*, 1992). In India, estimates showed that this nematode is responsible for both quantitative and qualitative yield losses amounting about Rs. 21 billion every year (Jain *et al.*, 2007). In Kerala, *M. incognita* problem in cabbage was observed in Thiruvanthapuram district resulting 50 per cent reduction in size of cabbage head (Narayana *et al.*, 2012). The juveniles move intercellular towards the region of vascular differentiation where they induce the formation of giant cells (Niyaz *et al.*, 2011). Besides direct damage, plant parasitic nematodes serve as predisposing agents in development of disease complexes with fungi, bacteria and viruses.

In Kerala, because of environmental pollution due to endosulfan aerial spraying and its social impacts, the commonly used extremely toxic insecticides with nematicidal property such as carbofuran and phorate have been banned.

Cabbage being a short duration crop, in the search for more benign acceptable alternatives to chemicals, the possibilities of exploiting nematode-antagonistic plants for the management of plant parasitic nematodes is to be investigated. Kerala being a hot spot of biodiversity, there is immense scope for utilizing the rich floral diversity. A number of plants including weeds with pesticidal property have not been exploited in an effective way. Unlike synthetic pesticides which are mostly based on a single active ingredient, bio pesticides have several bio active components which work together and thus prevent the development of resistant strains and undergo fast dissipation.

As cabbage is being consumed raw or with little cooking, it must be free of pesticide residues. Hence phytochemical based nematode management strategy using various plant based products is gaining momentum. In Kerala reports available on nematode association with cabbage and eco-friendly management strategies are scanty whereas presence of number of plant parasitic nematodes have been documented in neighbouring states and other parts of the country.

Considering the above fact, the present study was undertaken with the following objectives:

- To study the nematode fauna in rhizosphere of cabbage in cabbage growing tracts of Idukki, Kollam and Thiruvananthapuram districts.
- To evaluate the ovicidal and larvicidal effect of weed plant extracts against *M. incognita* under laboratory condition
- To standardize appropriate preparation and method of application of botanicals
- Field evaluation of promising botanical in comparison with bioagent and chemical

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Literature survey pertaining to investigation on nematodes associated with cabbage, and their eco-friendly management strategies using plant products as alternative to synthetic chemicals, is arranged as follows.

2.1. NEMATODE ASSOCIATION IN CABBAGE

Olthof and Potter (1973) reported that the root lesion nematode, *Pratylenchus penetrans* (Cobb), Filipjev and Stekhoven has the potential to reduce market yield of cabbage by 19-33 %. The spiral nematode, *Helicotylenchus multicinctus* (Cobb), Golden has been reported in Kenya, Uganda and other parts of the world to be associated with cabbage (Bafokuzara, 1996).

A survey conducted in Samsun (Middle Black Sea Region), Turkey on cabbage varieties revealed that lesion (*Pratylenchus thornei* Sher and Allen), spiral (*Helicotylenchus* sp.), and cyst forming (*Heterodera cruciferae* Sher and Allen, and *H. mediterranea* Volvas, Inserra and Stone) nematodes were the most frequently encountered nematodes. Root-knot nematode (*Meloidogyne incognita* (Kofoid & White), Chitwood) was also observed from the region. Association of *H. mediterranea* and two lesion nematodes (*P. thornei* and *Pratylenchus neglectus* (Rensch), Filipjev and Stekhoven) was reported for the first time in red and white cabbages (Mennan and Handoo, 2006).

Maina (2011) reported that a survey in cabbage based cropping system in selected agro-ecological zones of Kenya revealed cabbage as a preferable host to lesion nematodes (*Pratylenchus*) with 87 and 58 % frequency of occurrence in soil and roots respectively. *Helicotylenchus* spp. were recovered at a frequency of occurrence of 82 % in rhizosphere and 27 % in roots. *Meloidogyne* spp. were present at a frequency of 42 and 23 % in soil and roots. *Tylenchorhynchus* spp. occurred in

67 % of the soil samples while *Paratrichodorus*, *Trichodorus* and *Paratylenchus* spp. were present in 78 %, 57 % and 58 % frequency of occurrence. Other PPN (plant parasitic nematodes) detected in low frequencies of occurrence include *Tylenchus, Scutellonema* and *Xiphinema* spp. In addition to *H. multicinctus* and *P. penetrans, Rotylenchulus reniformis* Linford and Oliveira was also identified to be a major PPN on cabbage (Osei *et al.*, 2014)

In India, 12-15 per cent losses in vegetables are incurred as a result of infestation due to *M. incognita* (Khan and Khan, 1990). Many cruciferous plants serve as host to common species of root knot nematodes. Soil and root samples collected from cabbage in Kashmir valley revealed that the species of nematodes associated with cabbage were *Tylenchorhynchus mashhoodi* Siddiqi and Basir, *T. filiforms, T. brassicae, Basirolaimus indicus* (Sher) Shamsi, *Hoplolaimus* spp., *H. indicus, H. silvaticus, Helicotylenchus* spp., *M. incognita, A. saprophillus, Longidorus* sp. and *Trichodorus* sp. (Waliullah, 1992). The stunt nematode, *T. mashhoodi* reduced the yield of cabbage and cauliflower in IARI farm, New Delhi (Khan and Khan, 1999). Khan *et al.* (2002) found *M. javanica, M. incognita* race 1 and 2 and *M. areneria* infection in cabbage. Ravichandra and Krishnappa (2004) reported predominance of *M. incognita* in cabbage, carrot, raddish in Mandhya District of Karnataka. Waceke (2007) also reported of the root knot nematode infestation in cabbage. Anwar and Mc kenry (2012) reported that *Belonolaimus longicaudatus* Rau, *Paratrichodorus minor* (Colbran.) Siddiqi, *Helicotylenchus* spp., *Hoplolaimus columbus* Sher, *Pratylenchus* spp. and *M. incognita* were associated with cabbage in Punjab. Narayana *et al.* (2012) reported occurrence of *M. incognita* in cabbage from Thiruvanathapuram district of Kerala.

2.2 ASSOCIATION WITH OTHER MICRO ORGANISMS

Besides direct damage, nematodes serve as predisposing agents in development of disease complexes with fungi, bacteria and viruses. Interactions between *Meloidogyne* spp. and fusarium wilt pathogens has been studied and documented in tomatoes (Abawi and Barker, 1984); alfalfa (Griffin, 1986); chickpeas (Kumar *et al.*, 1988; Maheswari *et al.*,1997); beans (France and Abawi, 1994); cotton (De Vay *et al.*, 1997); bananas (Jonathan and Rajendran,1998); peas (Siddiqui and Mahmood, 1999); coffee (Bertrand *et al.*, 2000) and lentils (De *et al.*, 2001). Pathak and Keshari (2004) reported that high wilting was observed in cauliflower plants inoculated with both *M. incognita* and *Fusarium oxysporum* Schlecht especially when nematode was present fourteen days prior to fungus. *M. incognita* and *F. oxysporum* together cause disease complex in cabbage in Karnataka (Rajinikanth, 2011).

2.3. COMMUNITY ANALYSIS

Pathogenic potential of plant parasitic nematodes in a particular region and identification of hot spots of nematode attack could be assessed by community analysis of nematodes. A two year survey of ginger in twenty four plantations in Darjeeling district of West Bengal revealed the presence of eight genera and ten species of plant parasitic nematodes. The most prominent nematodes in this area were *R. reniformis*, *P. coffeae* and *H. multicinctus* (Ramana and Dasgupta, 1998).

Community analysis of nematodes in sugarcane ecosystem in Bundi district of Rajasthan revealed *Helicotylenchus* sp. *(H. dihystera* and *H. indicus*) as the prominent nematode with the highest prominence value (1163.4) and an absolute frequency of 94 per cent followed by *Tylenchorhynchus* spp., *Pratylenchus* spp. and lastly *M. incognita* with a prominence value of 28.0 (Nandwana *et al.*, 2005).

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 (Senthamizh *et al.*, 2005).

Twenty one soil samples collected from lentil yielded five 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).

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*.

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. incisus*.

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 assess the community behaviour of nematodes. Five plant parasitic nematodes *viz.*, *R. 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. The highest frequency of occurrence was recorded in *Helicotylenchus* spp. (40.91) followed by *Tylenchorhynchus* spp. (36.36) in Junagadh district. While in Diu, the highest

frequency recorded (70.0) was of *Meloidogyne* spp. followed by *Pratylenchus* spp. (Patel *et al.*, 2008).

Kadela (2008) reported that community analysis of nematodes in village Khawas of Barmer district, Rajasthan in areas under pearl millet and gram crops revealed *Tylenchorhynchus* sp. as the most dominant plant parasitic nematode with the highest relative prominence value (46.81) followed by *Acrobeles* sp. a saprozoic nematode with relative prominence value (18.92).

In a survey conducted by Sapna *et al.* (2009) for studying the plant parasitic nematode associated with rhizosphere of *Pinus roxburghii* Sarg. and *P. wallichian* in natural forests in six districts of Himachal Pradesh revealed twenty one species of nematodes belonging to fifteen genera. *Xiphenima americanum* Cobb. was found to be the most predominant species based on prominence value.

On the basis of investigation carried out at IIVR (Indian Institute of Vegetable Research) research farm area on vegetables *viz.*, tomato, pea, brinjal, chilli, cauliflower, broccoli and bean, *M. incognita* was identified to infest almost all the crops. High mean population (472), population percentage (10.73 %), absolute (90.91) and relative (19.42) frequency, absolute (188.65) and relative (16.14) density and prominence value (1798.75) was recorded by *M. incognita,* followed by *R. reniformis, H. indicus, Dorylaimus* sp., *T. vulgaris* and *Helicotylenchus* sp. (Singh *et al.*, 2009). The degree of damage done depends upon the pathogenic potential and population growth of nematodes which are greatly influenced by their initial population densities (Chandra *et al.*, 2010; Udo and Ugwuoke, 2010).

A survey conducted in Nyandarua and Embu Agro-ecological Zones of Kenya revealed highest frequency of occurrence (87 %) of lesion nematodes in soil followed by *Helicotylenchus* spp. (82 %) and *Tylenchorhynchus* spp. (67 %) in cabbage.

Lesion nematodes (*Pratylenchus* spp.) were detected in 58% of the root samples, followed by *Helicotylenchus* spp. (27 %) and *Meloidogyne* spp. (23 %) Maina (2011).

A study of community structure of phytonematodes associated with the vegetable crops viz., tomato, egg plant, cowpea, beans and bottle gourd in the district Durg of Chhattisgarh revealed *M. incognita, M. javanica,* and *Meloidogyne* spp. as predominant species associated with tomato, egg plant, cowpea and bottle gourd. Others were *R. reniformis*, *T. indicus*, *Pratylenchus* spp., and *Helicotylenchus* spp. (Sahu *et al.*, 2011).

Sreeja (2011) reported that in cardamom grown in Cardamom Research Station Pampadumpara, *Helicotylenchus* sp. and *Meloidogyne* sp. were the most frequent and abundant nematodes.

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

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

Soil and root samples collected from nematode infested cardamom plantations in fifteen panchayats of Idukki district revealed that *H. pseudorobustus* was the most frequently occuring (absolute frequency of 100%) nematode followed by *R. reniformis*. Other non parasitic nematodes recorded were rhabditids (bacterial

feeding), *Nygolaimus* sp., *Aprocelaimus* sp., *Eudorylaimus* sp. and mononchids (predatory nematodes) with varying frequencies (Cyriac, 2013).

2.4. PLANT PRODUCTS IN MANAGEMENT OF NEMATODES

Plant extracts have the advantages of cheapness, and ready availability over the conventional nematicides. Strategies that are environmentally sound and economically feasible for sustainable agriculture are now preferred.

2.4.1. Effect on Egg Hatching

Vijayalekshmi and Goswami (1985) reported that aqueous extract of *Calotropis gigantea* (L.) W.T.Aiton. could completely inhibit egg hatch of root knot nematode at high concentration. Chattopadhyay and Mukhopadhyaya (1989) reported nematicidal effect of Kathal champa (*Artabotrys odoratissimus* (R.Br. ex Ker Gawl. (Pier) (Grin)) leaves against *M. incognita*. Extracts of 15, 30 and 45 leaves of *A. odoratissimus* gave significant reduction in larval hatch of 83.40, 36.00 and 16.80 per cent respectively when exposed in the extract for 72 hours. A higher hatch was observed in 24 hours when compared to 48 and 72 hours.

Ajayi (1990) reported that extracts of bitter leaf at 25 and 50% concentration inhibited *M. incognita* egg hatch and juvenile survival to the extent of 100% after 48 hours of exposure. Dhangar *et al.* (1996) reported that the aqueous extracts prepared from different parts of *Tagetes erecta* L. inhibited the egg hatching and larval penetration of *M. javanica*. Guertal *et al.* (1998) reported nematicidal action of *Crotalaria juncea* L. and *T. minuta* L. against root knot nematodes. Yen *et al.* (1998) reported marigolds to be antagonistic to root knot nematodes.

Olabiyi and Oyedunmade (2003) reported that marigold, basil, nitta and rattle weed completely prevented hatching of root-knot nematode eggs and destroyed the

root-knot nematode juveniles at concentrations of 10% and above. Patel *et al.* (2004) reported that leaf extract of argemone (*Argemone maxicana*, L.), lantana (*Lantana camara* L.) and neem seed kernel suspension (*Azadirachta indica* A.Juss) in 1:10 dilution caused complete inhibition of root-knot nematode egg hatching 48, 96 and 144 hrs, indicating ovicidal effect. Lantana leaves at 5% reduced the hatching by 98.2 per cent.

Saravanapriya *et al.* (2004) reported effect of seed extract of *Areca catechu* L., latex of *Carica papaya* L. and *Calotropis gigantea* (L.) W.T.Aiton on hatching percentage of root knot nematode. The seed extract of *A. catechu* recorded the high inhibition rate of 87.7 per cent at 0.1 % concentration. Latex of *C. papaya* caused 98.22 and cent per cent inhibition of hatching at one and 10.0 % concentration respectively while *C. gigantea* latex caused cent per cent inhibition at 10.0 % concentration. Harinath *et al.* (2007) reported hatching inhibitory property of marigold aqueous extract on *M. incognita* infesting tomato.

Among ten leaf extracts of *Parkia javanika* Lam., *Clerodendrum indicum* L., *Tectona grandis* L.f., *Mussenda glabra* (Hook.f.) Hutch. ex Gamble, *Clerodendrum serratum* (L.) Moon, *Melia azedarach* L., *Xylosoma longifolia* Clos, *Vitex trifolia* L., *Plumeria rubra* L. and *Andrographis paniculata* (Burm.f.) Wall. ex Nees, chloroform methanol extracts of *A. paniculata* in 1000, 100 and 10 ppm concentration showed cent per cent hatching inhibition of *M. incognita* (Devi , 2008).

Nimbalkar and Rajurkar (2009) reported that siam weed, neem, castor bean and lemon grass root extracts exhibited 93 to cent per cent egg hatch inhibition at one hundred per cent concentration. They reported that the chemicals present in siam weed, neem, lemon grass and castor were found to be very effective as they either affected the embryonic development or killed the eggs or dissolved the egg masses.

In *in vitro* studies, water extracts of *Ocimum gratissimum* L., *A. indica, Vernonia amygdalina* Delile and *Moringa oleifera* Lam. at two concentrations of 10,000 and 20,000 mg/kg revealed that bitter leaf (*V. amygdalina*) at 20,000 mg/kg inhibited egg hatch the most (50%) followed by moringa at 20,000 mg/kg (40%). The least effective extract was moringa at 10,000 mg/kg (Claudius-cole, 2010). Katooli *et al.* (2010) reported that alcoholic extracts and oils of chinaberry and castor bean were highly effective in causing immobility of second stage juveniles and unhatching of nematode eggs in laboratory conditions.

Adegbite (2011) reported egg hatch inhibiting property of *Chromalaena odorata* L. (Siam weed), *Nicotiana tabacum* L. (Tobacco), *C. papaya* (Pawpaw), *Cannabis sativa* L.(Hemp), *Cassia alata* L. (Asunwon) and *V. amygdalina* (Bitter leaf) extracts against *M. incognita.*

Odeyemi and Adewale (2011) reported that *Tithonia diversifolia* (Hemsl.)Gray water extract significantly inhibited *M. incognita* egg hatch by 98 and 100 per cent *in vitro* two and nine days after incubation (DAI) respectively. Akpheokhai *et al.* (2012) reported that water extracts of *T. diversifolia, A. indica, Zanthoxylum zanthoxyloides*(Lam.) Zepern. and Timler, and *Datura metel* L. at 25,000 and 50,000 $mgkg^{-1}$ concentrations were very effective in inhibiting egg hatch of *M. incognita* by over 70% within ten days. *L. camara* extract showed 90.0 and 94.1 per cent hatching inhibition at one and three per cent concentration respectively (Taye *et al.*, 2013).

2.4.2. Effect on Larval Mortality

Haseeb *et al.* (1982) identified the nematicidal properties of *Mentha viridis* L., *Cassia fistula* L., *Cordia myxa* L., *Carissa carandas* L., *Colocasia arniquorum* Schott. against *R. reniformis.*

Among leaf extracts of six plant species viz. *Ricinus communis* L., *Leucaena leucocephala* (Lam.)de Wit, *Populus deltoids* Bartram, *A. indica, L. camara* and *Eucalyptus* hybrid (*Eucalyptus tereticornis* Sm.) tested for their toxicity to *M. incognita, R. communis* leaf extract was most toxic followed by *L. leucocephala, P. deltoids, A. indica, L. camara* and *Eucalyptus* hybrid (Chhabra *et al.*, 1988).

Use of PA (1, 2-dehydropyrrolizidine alkaloids) plants found to be valuable element for integrated nematode management. Hartmann *et al.* (1989) reported that as in other PA plants, the PAs of *C. odorata* are located in the root bark or epidermis. The plant material has to be ground as finely as possible to release as much of the PAs stored in the vacuoles (Hartmann and Witte, 1995).

Hussaini *et al.* (1996) reported total mortality of *M. incognita* juvenile at 1:2 dilution of *Argemone mexicana* L. leaf extract. A study conducted by Sundararaju *et al.* (1999) revealed the effectiveness of *C. odorata* as a promising nematicide against adults and larvae of *Radopholus similis* (Cobb) Thorne. *C. odorata* has been shown to contain nematoxic compounds such as flavinoids, tannins, alkaloids and saponins (Fatoki and Fawole, 2000).

Compounds lantanoside, linaroside and camarinic acid isolated from *L. camara* were tested for nematicidal activity against *M. incognita* and showed 90, 85, and 100 per cent mortality respectively at 1.0 % concentration (Begum *et al.*, 2000).

Adegbite and Adesiyan (2005) reported that siam weed and neem root extracts exhibited cent per cent larval mortality at one hundred per cent concentration while castor bean and lemon grass root at 100 % concentration exhibited 62.1 and 75 per cent larval mortality. Shaukat *et al.* (2004) demonstrated that certain weed extracts caused substantial mortality of plant parasitic nematodes and improved plant

growth and yield. Aqueous extracts of basil leaves (*Ocimum basilicum* L.), marigold leaves (*Tagetes* spp.), neem seed (*A. indica*) and china berry leaves (*Melia azedarach* (L.) affected the survival of root knot nematode juveniles *in vitro* and reduced second stage juveniles in soils and roots of egg plant under field conditions. (Hasabo and Noweer, 2005)

Qamar *et al.* (2005) reported that lantanilic acid, camaric acid and oleanolic acid possessing nematicidal activity were isolated from the methanolic extract of *L. camara* aerial parts through bio-assay guided fractionation. These compounds at 0.5% concentration exhibited 98, 95 and 70 per cent mortality against *M. incognita* respectively.

Saxena and Lalitha (2005) reported that 250 ppm of *Catharanthus roseus* (L.) G. Don, 440 ppm of *C. lanceolatus*, 860 ppm of *Dandelion* sp. and 1550 ppm of *Chrysanthemum* sp. were found effective against J_2 of *M. incognita* after 24h.

Thoden *et al.* (2007) reported that pure pyrrolizidine alkaloids from *C. odorata* roots showed nematicidal effect on *M. incognita* at 70-330 ppm concentration in lettuce. Nazli *et al.* (2008) reported that leaf extract of *Gliricidia sepium* (Jacq.) Kunth ex Walp. caused a mortality of 60% in second stage juvenile of *M. incognita*.

L. camara leaf extract at standard concentration 'S' was found to be highly nematostatic, where nematodes were completely paralyzed (100 %) after 12 and 48 h of exposure and 96% of juveniles were killed at same concentration *in vitro*. The mortality of second stage juveniles (J_2) of *M. incognita* was 75% in S/2 dilution at 48 h (Ahmad *et al.*, 2010).

Akpheokhai *et al.* (2012) reported juvenile mortality of 93, 92, 89 and 75% at 50,000 $mgkg^{-1}$ concentration extract of *A. indica*, *D. metel*, *T. diversifolia* and

Z. zanthoxyloides. Water hyacinth leaf crude extract (100% conc.) showed cent per cent mortality of *M. incognita* larvae at exposure periods of 24, 48, 72 and 96 hours while diluted extract (crude extract diluted with 10ml of distilled water) gave juvenile mortality of 56.1 % at 24 hrs exposure and increased up to 80.7% at 96 hrs exposure. (Umar and Mohammed, 2013)

2.5. NEMATODE MANAGEMENT

2.5.1. Botanicals

2.5.1.1. Soil Application

2.5.1.1.1. Fresh and Dry Plant Material

Kumar and Nair (1976) reported soil incorporation of leaves of *Calotropis* sp., *Eupatorium* sp., mango and cashew @ 5000 kg/ha, at a depth of 25 cm three weeks before sowing seeds, reduced number of root galls incited by *M. incognita* and increased plant height and root weight in okra, cv. Pusa Sawani.

Castillo (1985) reported reduction in *R. reniformis* population in pots where fresh leaves of *Asystacia gangetica* (L.)T. Anderson, *Polytrias amaura* (Buse) Kuntze, *G. sepium* and *L. leucocephala* were added. Alam (1987) reported that chopped leaves of many weeds successfully suppressed the population of plant parasitic nematodes and improved plant growth. Mulching of green leaves of pongamia and neem in soil significantly reduced the incidence of root-knot nematodes and increased the plant growth as well as leaf yield in mulberry (Govindaiah *et al.*, 1989). Osman *et al.* (1989) reported that green and dry manuring of plant parts has been practiced as a method for the control of plant parasitic nematodes. Chopped leaves of *Glyricidia maculata* (H.B.K.) Steud. as green manure

was found to reduce the population of *R. similis* and promote growth of black pepper under pot conditions (Jasy and Koshy, 1992).

Root knot nematode can be controlled by application of green leaf manures to the infected soil (Wang and Chao 1995). Soil amendment with dried flowers, leaves, stems and roots of *Calotropis procera* (Aiton) W.T.Aiton. significantly improved plant growth by reducing the root-knot nematode population in the case of egg plant (Ahmad *et al.*, 1996). Ajith and Sheela (1996) reported addition of chopped green leaves of neem and eupatorium @ 15t/ha effectively reduced plant parasitic nematodes of okra and cowpea and subsequently increased crop yield during rainy and summer seasons. A study conducted by Khanna and Sharma (1998) revealed that application of leaves of *A. indica* and *T. patula* improved plant growth of tomato and reduced nematode count as well as gall index which were at par with that of nematicides.

Das *et al.*(1999) reported a significant increase in plant growth parameters of rice var. Jaya and a reduction in *M. graminicola* infestation in plots amended with chopped botanicals of *Polygonum hydropiper* (L.)Delabre, neem seed, *Ageratum* sp, *Mikania* sp., rice straw and water hyacinth (*Eichhornia crassipes* (Mart.) Solms). Ramakrishnan *et al.* (1999) reported that cassava leaf and tuber rind applied as soil amendments at 100 and 50 g/plot significantly reduced *M. incognita* population and improved growth parameters of okra in pot experiments.

L. camara soil-amendment caused significant suppression of *M. javanica* in mungbean (Syed and Imran, 2001). Nisha and Sheela (2002) reported that green leaf mulching with neem, chromolaena and glyricidia leaves @5 kgm^{-2} reduced nematode population and increased yield of kacholam.

Adediran *et al.* (2005) reported that either fallow dominated by *C. odorata* or the direct application of plant material as mulch reduced the population density of

plant parasitic nematodes. Application of green leaves of *C. odorata* and *A. indica* was found effective for managing nematodes associated with bhindi and cowpea (Sheela *et al.,* 2008). Wachira *et al.* (2009) reported that application of organic amendments (green leaf manure) to the soil acts as a stimulant of nematode-destroying fungi which arrest the nematode population increase.

Saba and Khan (2009) reported amendment of leaves of *C. procera, A. indica, T. erecta* L. and *Juglans regea* L. significantly improved plant growth parameter (length, dry weight and number of flowers) and reduced reproduction factor, number of galls and intensity of root-knot as compared to untreated in balsam plants. Pakeerathan *et al.* (2009) reported that extent of galling (35.87), gall index (0.327), yield (17.87 Mt/ha), reproductive factor (0.411) and plant growth parameters viz. height and dry matter (22.47 cm and 45.08 g) were significantly best in tomato plants treated with green leaf manures of *G. maculata* compared to *Thespesia populnea* (L.)Sol. ex Correa, *C. gigantea, A. indica, Glycosmis pentaphylla* (Retz.)DC. and control while *T. populnea* and *A. indica* ranked second and third, respectively in managing *M. incognita.* Olabiyi *et al.* (2013) reported that wild sunflower (*T. diversifolia*) compost significantly reduced the infection potential of *P. brachyurus* on maize. Wild sunflower leaves (*T. diversifolia*) @ 5kg /plant in the rhizosphere of cardamon reduced the population of PPN (Cyriac, 2013).

2.5.1.1.2. Powder Form

Patel *et al.* (1985) reported that the application of *Clerodendron inerme* (L.)Gaertn. in okra at 1.5 per cent w/w caused minimum galling and increase in growth of okra .

Organic amendment with powdered leaves of the plants like curry leaf, (*Murray koenigii* (L.)Sprengel), Jasmine (*Jasminum sambac* (L.)Aiton), sour orange (*Citrus aurantifolia* (Christm.) Swingle), Patal garuda (*Rauwolfia serpentina*

(L.)Benth. ex Kurz), Ber (*Zizyphus jujuba* Mill.), China rose (*Hibiscus rosa-sinensis* L.) and Justicia (*Justicia gendarussa* Burm.f.) were effective in reducing *M. incognita* population (Padhi and Behera, 2000). Siji *et al.* (2010) reported application of dried powder of *Cleome viscosa* L. @ 250g powder/plot reduced gall formation and increased the fruit weight (61.76% increase over untreated) of okra.

2.5.1.1.3. Plant Extracts

Aqueous crude extracts of *C. odorata* showed nematicidal properties (Subaramaniyan, 1985). Soil application of leaf extracts (5, 10 and 20 ml) of *Cymbopogon citratus* (DC.) Stapf, *E. crassipes* and *Ipomoea carnea* Jace. improved plant growth of chickpea (*Cicer arietinum* L.) var. P-256 seedlings (Siddiqui and Husain, 1990). Patel *et al.* (1993) reported that water hyacinch (*E. crassipes*) and congress grass (*Parthenium hysterophorus* L.) were moderately effective in reducing root-knot nematode numbers (25.1 and 28.9% resp.) in tomato.

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

The root leachate of *L. camara* was found to contain phenolic compounds, including *p*-hydroxybenzoic acid, vanillic acid, caffeic acid, ferulic acid and a quercetin glycoside, 7-glucoside (Shaukat *et al.*, 2003). Campbell *et al.* (2005)

reported that root extracts of spurge, poinsettia and lantana provided 69, 70 and 57% mortality of sting nematodes by 96 hrs. Shoot portions of poinsettia and spurge provided 95 to 98% mortality while goldenrod, tall lettuce and lantana shoot extracts recorded 64, 40 and 25% mortality respectively. Ahmad *et al.* (2010) reported that addition of freeze-dried aqueous extract of *L. camara* to sterile sandy substrate at three and five per cent concentration significantly decreased the root-knot infection (85 per cent reduction in root-knot count over untreated) to susceptible eggplants whereas second stage juveniles (J_2) that penetrated roots of eggplant were able to complete development in sterile sandy substrate without treatment of freeze-dried aqueous extract.

Botanicals such as *Azadirachta, Eucalyptus, Chromolaena, Sida acuta* Burm.f. and *Tagetes* have been found to be effective in the control of nematodes in cowpea, tomato and egg plant fields (Umar *et al.*, 2010).

Organic extract of *C. viscosa* at 500 ppm showed moderate toxicity to *M. incognita* larvae (Williams *et al.*, 2003) .Compounds present in *Crotalaria juncea* L. and *T. minuta* found to be toxic to root knot nematodes (Guertal *et al.*, 1998). Sundararaju and Kiruthika (2009) reported that combination treatment of *P. lilacinus* and *T. erecta* flower extracts followed by combination treatment of *P. lilacinus* and *T. erecta* leaf extracts was found to be effective against *M. incognita* in banana.

2.5.1.2. Bare Root Dip

Bare root dip in leaf or root extract of nematicidal plants is effective in managing root knot nematode in susceptible crops. Root dip treatment of egg plant seedlings in margosa and marigold leaf extracts considerably reduced root-knot development compared to treatment with piperazine citrane, chinopodium oil and groundnut cake (Hussain *et al.*, 1984).

Water extracts of *O. gratissimum, A. indica, V. amygdalina* and *M. oleifera* caused juvenile mortality of *M. incognita* (82%-93.8%) (Claudius-Cole *et al.*, 2010).

2.5.2. Bioagent

2.5.2.1. Fungi

2.5.2.1.1. Paecilomyces lilacinus

The action of fungal parasite *Paecilomyces lilacinus* (Thom) Samson. in reducing nematode population is a promising form of crop protection against *Meloidogyne* spp. The biocontrol potential of this parasitic fungus was reported against *Meloidogyne* spp. (Jatala *et al.*, 1980). Besides oviparasitism, the mortality of second stage juveniles of *M. incognita* by the action of culture filtrates of *P. lilacinus* was reported by Khan and Khan (1992). Khan *et al.* (1997) reported *P. lilacinus* as a potentially important fungal biocontrol agent 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) reported that 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. Kumar *et al.* (2008) reported that culture filtrates of *P. lilacinus* was found to be very effective in increasing the mortality and decreasing the hatching of root knot nematode, *M. incognita.*

2.5.2.1.1.1. Cool Season Vegetables (Potato, Carrot and Coriander)

P. lilacinus has been successfully used to manage root-knot nematode in potato (Jatala *et al.*, 1979) and carrot (Sivakumar, 1998). Midha *et al.* (2001) reported that *P. lilacinus* grown on wheat bran applied @ 2 g/ kg resulted in good plant growth

parameters and reduced the number of galls and egg masses per plant in coriander inoculated with 100 J_2 *M. incognita* per pot.

2.5.2.1.1.2. Brinjal

Sharma and Trivedi (1989) reported that *P. lilacinus* increased growth of brinjal plants and reduced root galling, egg masses and number of eggs per egg mass of *M. incognita.* Root dip treatment of egg plant seedlings in formulation of *P. lilacinus* resulted in drastic reduction of *M. incognita* population (Rao *et al.*, 1998). Khanna (2000) reported that an inoculum level of 3.6 g fungus per 600 g soil was the optimum level for keeping the root-knot nematode under check and enhancing the growth of brinjal plants. Application of *P. lilacinus* @ 10 g per pot improved the plant growth (length and weight of shoot and root) of brinjal and tomato by reducing the multiplication of *M. incognita.* (Verma *et al.*, 2004). Krishnamoorthi and Kumar (2007) reported that application of *P. lilacinus* in brinjal recorded highest plant growth, yield and reduced soil and root nematode population. Vyas *et al.* (2011) reported the reduction of *R. reniformis* population in soil by the application of *P. lilacinus* @ 6 g/kg in brinjal.

2.5.2.1.1.3. Okra

P. lilacinus at an inoculum level of four g fungus culture (on rice grain medium) per kg soil reduced *M. incognita* attack in okra (Saikia and Roy, 1994). Dhawan *et al.* (2004) reported that the application of *P. lilacinus* in okra as seed treatment @ 10, 15 and 20 g/kg seed and soil application @ 1.5 and 3 per cent w/w significantly increased plant growth characters and suppressed galls and eggs per egg masses in okra.

2.5.2.1.1.4. Tomato

P. lilacinus application reduced multiplication of *M. incognita* and increased plant growth and fruit yield in tomato (Khan and Saxena (1995) and Goswami *et al.*, 1998). Khan and Goswami (2000) reported that 8 g (57.92 x 10^8 spores) *P. lilacinus* inoculated rice grain kg^{-1} soil was considered to be optimum for suppression of *M. incognita* in tomato. They also reported that *P. lilacinus* isolate 6 showed highest percentage (75) of egg parasitism of *M. incognita*. Inoculation of *P. lilacinus* in the second season of tomato cv. Pusa Ruby reduced *M. incognita* in soil by 68.00 per cent (Khan and Goswami, 2002). Cannayane *et al.* (2004) reported that *P. lilacinus* introduced through seed treatment and seedling bare root dip in cowpea, tomato and chilli protected the root surfaces from the invasion of *M. incognita* juveniles by forming hyphal networks through profuse colonization. Soil application of talc based formulation of *P. lilacinus* @ 4.0 g per 3 kg was found to be highly effective in reducing the population of *M. incognita* and increasing the biometric characters and yield of tomato (Priya and Kumar, 2006). 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.

2.5.3. Organic Amendments

Alam *et al.* (1980) recorded less penetration of *M. incognita* juveniles in tomato grown in oil-cakes amended soil. In a study by Mian and Rodriguez-Kabana (1982) soil amendments with cotton seed, peanut oil-cakes and chicken litter effectively controlled *M. arenaria* in *Cucurbita pepo* L. and stimulated plant growth but a higher dosage (more than 0.4% w/w) caused phtotoxicity.

Neem cake applied at the rate of 1g nitrogen per kg soil in pots caused no galling in tomato, chilli and okra (Alam 1989).

Prasad and Chawla (1994) reported that cotton seed oil cake water extract at 0.05% concentration caused *M. incognita* larval mortality of 100% while 17% larval mortality was observed in *M. incognita* juveniles 24hours after exposure. Larval mortality of 45.7% was observed in alcohol extract at lowest concentration of 0.01%.

Neem has been found to be highly effective in the management of nematodes from time immemorial. Abid *et al.* (1995) reported that soil amendment with neem cake at 0.1, 0.5 and 1 per cent w/w reduced infection of *M.incognita* on mung bean *Vigna radiata* (L.) R. Wilczek and significantly improved the plant height, but reduced root nodulation. Alagumalai *et al.* (1995) reported that acid extracts of neem cake at different dilutions enhanced the growth of *Vigna ungiculata* (L.) Walp. and reduced the population build up of nematode. Neem cake application reduced the population of *M. incognita* and improved the plant growth characters of Japanese mint (Pandey, 1995). Soil ammendment with neem cake and datura powder were effective for the control of root-knot and root-knot disease complex of okra (Haque *et al.*, 1996). Patel *et al.* (1996) reported that application of castor cake @ 2 t/ha followed by soil solarization reduced root-knot disease (22.8%) and thereby produced higher numbers (16.8%) of tomato transplants.

Rao *et al.* (1997) reported that use of aqueous extract of neem cake for seed treatment and soil drenching under field conditions found effective as application of carbofuran @ 2 kg a.i/ha or neem cake @ 2 t/ha for the management of *M. incognita* on okra. Neem cake and neem dust were found effective in the suppression of *M. incognita* in tomato (Jacob and Haque, 1998). Neem cake application @ 200g/m^2 was very effective in reducing the nematode population in kacholam rhizosphere (Rajani 1998; Nisha and Sheela, 2003). Organic amendments such as neem cake, groundnut cake @ 50 g/1.5 kg soil and chopped cauliflower leaves @ 100 g/1.5 kg soil suppressed the reproduction and population build up of *M. incognita* on *Phaseolus mungo* L. and improved plant growth (Vaitheeswaran *et al.*, 2005).

2.5.3.1. Combination of Bioagent with Organic Amendment

Neem cake suspension (five per cent) mixed with spores of *P. lilacinus* was also effective as seed treatment in okra for the management of *M. incognita* under field conditions (Rao *et al.*, 1997). Rao *et al.* (1998) reported that root dip treatment of aubergine seedlings in the formulations of *P. lilacinus* cultured on neem cake extract resulted in significant increase in plant growth parameters and drastic reduction in root-knot index and final population of *M. incognita*. In tube rose, split application of *P. lilacinus* in combination with oil cakes *viz.* castor, pongamia or neem (at planting and 45 days later) under field conditions significantly reduced root knot index, root and soil populations of *M. incognita* and its multiplication compared to single application of *P. lilacinus* and oil cakes at planting (Nagesh *et al.*, 1998). Nagesh *et al.* (2001) found that supplementation of castor and neem oil cake with nitrogen, phosphorus and potassium in the form of inorganic fertilizers had an additive effect on the mycelial growth and sporulation of *P. lilacinus* enhancing the antagonistic potential of *P. lilacinus* against root-knot nematode in tomato nursery. Anver and Alam (2001) reported that integration of *P. lilacinus* with neem cake in the field was highly effective in reducing multiplication of *M. incognita* in soil and increasing the plant growth and oil content of linseed significantly. Nagesh *et al.* (2003) reported that *M. incognita* in chrysanthemum was controlled using *P. lilacinus* in combination with neem cake.

P. lilacinus in combination with neem cake was highly effective in reducing the multiplication of soil nematodes and subsequently increasing the plant growth in chickpea (Tiyagi and Ajaz, 2004). Nisha (2005) reported that combination of solarization in the nursery and application *P. lilacinus* @ 15g/m^2 + neem cake @ 100 g/m^2 in main field significantly reduced *M. incognita* population and increased the yield of coleus.

Combination treatment of *P. lilacinus* and neemcake was found to be effective in the management of plant parasitic nematodes. Sundraraju and Krithika (2009) reported that treatments involving *P. lilacinus* alone and in combination with neem cake and botanicals increased the plant growth and significantly reduced the population of *R. similis* in banana. Ramakrishnan and Nagesh (2011) reported that *P. lilacinus* in combination with organic amendments reduced the root knot nematode population in tobacco nurseries. Nisha *et al.* (2015) reported nursery application of *P. lilacinus* @ 50g/m^2 + main field application of *P. lilacinus* @ 5kg along with 2.5 t FYM/ha reduced the nematode population (97-99%) and increased the yield of brinjal (98% increase over untreated).

2.5.4. Chemicals

The effect of chemicals for managing nematodes were reviewed here. Hong and Sethi (1988) reported that triazophos at 0.5, 1.0 and 2.0 per cent reduced the final population of *M. incognita* in french beans from 72 to 92 per cent.

Jain and Gupta (1990) reported that okra seeds treated with carbosulfan had a significantly lower root knot index than untreated seeds. Seeds pelleted with carbosulfan 25 STD reduced *M. incognita* population and improved plant growth in cowpea (Mishra and Prasad, 1991). Prasad and Chawla (1991) found that seed dressing with carbosulfan at 1, 2, 3 and 4 per cent reduced nematodes of groundnut in pot experiments. Patel and Patel (1992) reported that carbofuran and HOE 388 each @ 2kg a.i/ha and benfurocarb @ 1kg a.i/ha significantly improved plant height, fresh shoot and root weight and effectively reduced *R. reniformis* on pigeonpea cv. T15-15. Carbosulfan 6 per cent seed dressing was highly effective in reducing population of *M. incognita* in okra under pot culture condition (Kathirvel *et al.*, 1992). Meena and Mishra (1993) reported that seed soaking and seed dressing with carbosulfan gave the greatest suppression of root knot nematodes infesting soyabean. Seed dressing of

V. radiata with carbosulfan @ 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* (Barman and Das, 1994). (Narayana, 1997) reported that seed soaking with carbosulfan 25 STD at 50, 100, 200 and 400 µg/ml significantly affected penetration and development of *M. incognita* race1 in sunflower.

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).

Seedling emergence was suppressed up to 50 per cent due to phytotoxicity with seed dressing @4% a.i. w/w. While developing options for the management of disease complex caused by root knot nematode and *Fusarium solani* (Mart.) Sacc. gypsum based formulations of *Chaetomium abuense* Lodha 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).

According to Rajvanshi and Bishnoj (2008) carbosulfan 25 EC seed soaking coupled with carbosulfan (spray) was found to be the best treatment in reducing the galls and nematode population in soil infecting round melon. Sharma *et al.* (2008) reported that in tomato for controlling nematodes carbosulfan was found to the best. Mohanty and Mahapatra (2009) reported that soaking of paddy seeds for 12h in carbosulfan at 0.1 per cent reduced the multiplication of root- knot nematodes by 60.07 per cent in soil. Vinodkumar *et al.* (2010) reported that for the management of root knot nematodes in cowpea, the lowest population of nematodes was observed in plants treated with carbofuran @ 2 kg a.i/ha followed by carbosulfan 25 DS. Das and Choudary (2012) reported that cartap hydrochloride @1kg a.i./ha in nursery bed 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.

Rajvanshi *et al.* (2012) reported that in order to reduce the populations of cereal cyst nematode, *Heterodera avenae* Wollenweber and increasing the grain yield in wheat and barley, carbosulfan was found to be the best treatment. Cyriac (2013) reported that thiamethoxam @ 300 µg/ml exhibited 63.33 per cent, 69.12 per cent and 73.34 per cent mortality of *M. incognita* juveniles after 24, 48 and 72h of exposure respectively.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The study entitled "Nematode association in cabbage, *Brassica oleracea* L. var. *capitata* and its management using botanicals" was conducted at the Department of Agricultural Entomology, College of Agriculture, Vellayani, Thiruvananthapuram during 2012-2014. Details regarding the experimental materials used and the methodology adopted for the study are presented in this chapter.

3.1. COLLECTION AND ESTIMATION OF NEMATODES ASSOCIATED WITH CABBAGE

A survey was conducted in the cabbage growing tracts of Idukki, Kollam, and Thiruvananthapuram districts to document the nematode fauna associated with cabbage.

As part of the survey, one hundred soil and root samples were collected from different locations across the above mentioned areas.

3.1.1. Sampling Methods

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

3.1.2. Processing of Samples

The samples were bulked and 200 cc composite sample was processed for extraction of nematodes by Cobb's sieving and decanting method followed by modified Baermann's funnel technique (Schindler, 1961).

3.1.2.1. Counting of Nematodes

The suspension was shaken well and one ml of the suspension was taken and transferred to a counting slide by means of a pipette. The population of each species were counted under a stereozoom microscope and separately recorded.

3.1.3. Estimation of Nematode Population in Roots

Approximately 25 g of younger feeder roots were collected from the rhizosphere of cabbage plants. Roots were thoroughly washed under tap water and cut into smaller pieces (2 to 3 cm 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 an electric blender with 10 to 15 ml of water to dislodge the nematodes. Samples were taken from this suspension in order to obtain the population count (Marks and Mc kenna, 1981). The nematodes extracted were then counted under a stereo microscope.

3.1.4. Killing and Fixing and Processing of Nematodes

Fixative TAF (Triethanolamine formalin) was used for fixing nematodes. The composition of the fixative was as follows.

Formalin (40% formaldehyde)	7 ml
Triethanolamine	2 ml
Distilled water	91 ml

Double strength fixative was prepared. Live nematodes were transferred to a small glass vial and allowed to settle at the bottom of the container. Excess water was

drained off carefully so that nematodes were left in about 2 ml of water. The killing of the nematode was facilitated by stirring the nematode containing vial for about 20-30 seconds in a water bath at 70-90^{0}C followed by addition of equal volumes of 65-70^{0}C hot fixative to it. The vial was then kept for a day to allow the fixative to penetrate and act on tissues of the nematode.

The fixed nematodes were processed by slow method to glycerine (Seinhorst, 1965).

3.1.5. Permanent Mount

Permanent slides were prepared for the identification of nematodes up to species level. A drop of dehydrated glycerine was initially placed at the centre of a glass slide .Two to three processed nematodes were placed on this droplet in a way that the nematodes settled at the bottom of the droplet. This was followed by the placement of three pieces of glass fibers around the nematodes, at the bottom of the droplet. Glass fibers were approximately one mm long and thickness (according to the nematode diameter). A cover slip was then placed over the drop in such a way that no air bubble was trapped in between. Redundant glycerine on the slide was first removed using filter paper and then by ethanol. The cover slip was then fixed at three points with glyceel. Photo micrographs of the slides were taken with the aid of compound microscope at 1000x magnification.

3.1.6. Community Analysis of Nematodes in the Rhizosphere of Cabbage

Soil samples were collected from the rhizosphere of infested cabbage plants and the population of nematodes was estimated. The data thus obtained were subjected to community analysis. Absolute frequency, relative frequency, absolute density, relative density and prominence value of each nematode genus were determined using the formula of Norton (1978).

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

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

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

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

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

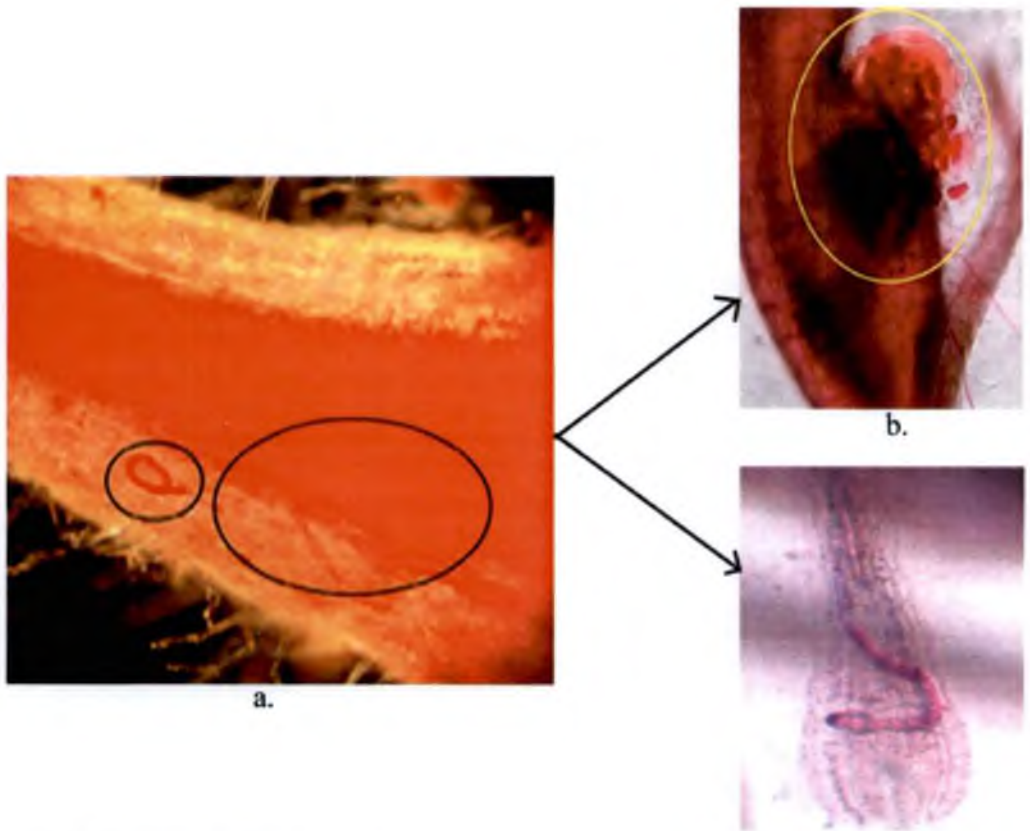
3. 2. *IN VITRO* SCREENING OF PLANT EXTRACTS FOR NEMATICIDAL PROPERTY

3.2.1. Preparation of Denematized Potting Mixture

Denematized potting mixture was prepared by mixing sieved field soil, sand and well decomposed farmyard manure in the proportion of 2:1:1 .The mixture was then packed in polypropylene covers and autoclaved at 15psi pressure and 121°C for 20 minutes. The denematized potting mixture was then used for pot culture studies.

3.2.2. Raising Pure Culture of Root-Knot Nematodes

Root knot nematode, *Meloidogyne* sp., was selected as the test organism (Plate 1). The second stage juveniles (J_2) required for pure culture was obtained from infested tomato plants maintained in nematology glass house. Roots with conspicuous



a- J2 after penetration into roots
b-Female nematode with egg mass
c-Male nematode after fourth moult

A. Microscopic view of nematodes in roots

B. Symptom in root

C. Infested area

Plate 1(A, B & C). *M.incognita* infestation in cabbage

galls were selected, washed gently in water and examined for the presence of egg mass under a stereo zoom microscope.

The egg masses with gelatinous matrix were separated from the roots and transferred to a beaker with sterile distilled water for incubation. After 3-5 days, the hatched out second stage juveniles were ready for inoculation. The identity of *M. incognita* race 3 was confirmed by using taxonomic key and host differentials.

3.2.3. Inoculation of Nematodes

Newly hatched second stage juveniles were inoculated at a depth of 5cm in the rhizosphere of twenty five day old tomato seedling variety Vellayani Vijay. The nematodes were inoculated into seedling raised in steam sterilized potting mixture @ one J_2/g of soil. The culture of *M.incognita* was ready after 30 days from the date of inoculation. The egg masses on the galled roots were hand picked and surface sterilized with 0.1 per cent $HgCl_2$, followed by ethanol (95%) for one minute each. The treated egg masses were then 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 proceeding with the experiment. The number of larvae per ml of suspension was determined with the help of a stereozoom microscope using hand tally counter. The larval concentration was adjusted to required number of larvae per ml of suspension by adding required quantity of sterile water.

3.2.4. Plants Screened

Wild sunflower leaves (*Tithonia diversifolia*), water hyacinth leaves (*Eichhornia crassipes*), siam weed roots (*Chromolaena odorata*) and lantana leaves (*Lantana camara*) were tested for their efficacy against root knot nematodes in laboratory.

3.2.4.1. Preparation of Extracts

Crude extracts of the plants were prepared by grinding 150 g of the plant part with 150 ml of distilled water in a blender for 3 minutes. The extracts were centrifuged at 3000 rpm for 10 minutes and filtered through Whatman no 1 filter paper. The filtered extract served as the stock solution for preparing different dilutions.

3.2.4.2. Preparation of Concentration

Different concentrations of water extracts of the samples *viz.* S/2, S/3 and S/4 were prepared from the stock solution as follows:

100%	-	(S) -	100 ml of stock solution
50%	-	(S/2) -	50ml of stock solution + 50 ml water
33.3%	-	(S/3) -	33.3ml of stock solution+ 66.7 ml water
25%	-	(S/4) -	25ml of stock solution + 75 ml water

3.2.5. Evaluation of the Efficacy of Plant Extracts Against *M. incognita*

3.2.5.1. Effect on Egg Hatching

The effect of different plant extracts on hatching of eggs was studied by taking viable egg masses from infested tomato plants maintained in glass houses as mentioned in para 3.2.2. Four concentrations *viz.* 25, 33.3, 50 and 100 per cent of plant extracts were prepared as mentioned in 3.2.4.2. Five ml of each concentration of plant extract was taken, in sterile vials and three uniformly sized egg masses were transferred to this. Egg masses kept in distilled water served as control. The number of eggs hatched at 1, 2, 3, 4, 5, 6, 7 and 8 days was noted.

Design-CRD Treatments -17 Replications-2

T_{1}-	*C. odorata* root extract extract	(S)
T_{2}-	*C. odorata* root extract extract	(S/2)
T_{3}-	*C. odorata* root extract extract	(S/3)
T_{4}-	*C. odorata* root extract extract	(S/4)
T_{5}-	*T. diversifolia* leaf extract	(S)
T_{6}-	*T. diversifolia* leaf extract	(S/2)
T_{7}-	*T. diversifolia* leaf extract	(S/3)
T_{8}-	*T. diversifolia* leaf extract	(S/4)
T_{9}-	*L. camara* leaf extract	(S)
T_{10}	*L. camara* leaf extract	(S/2)
T_{11}-	*L. camara* leaf extract	(S/3)
T_{12}-	*L. camara* leaf extract	(S/4)
T_{13}-	*E. crassipes* leaf extract	(S)
T_{14}-	*E. crassipes* leaf extract	(S/2)
T_{15}-	*E. crassipes* leaf extract	(S/3)
T_{16}-	*E. crassipes* leaf extract	(S/4)
T_{17}-	Control (Distilled water)	

3.2.5.2. Effect on Larval Mortality

Stock solution and different concentrations of plant extracts were prepared as mentioned in 3.2.4.1. Hundred freshly emerged second stage juveniles of *M. incognita* larvae were suspended in 5 ml of each concentration of plant extract in sterile vials. All vials were kept in BOD incubator at a temperature of 30°C. Larval mortality was estimated by counting the number of dead juveniles at 24, 48 and 72 hours after treatment (Plate 2).

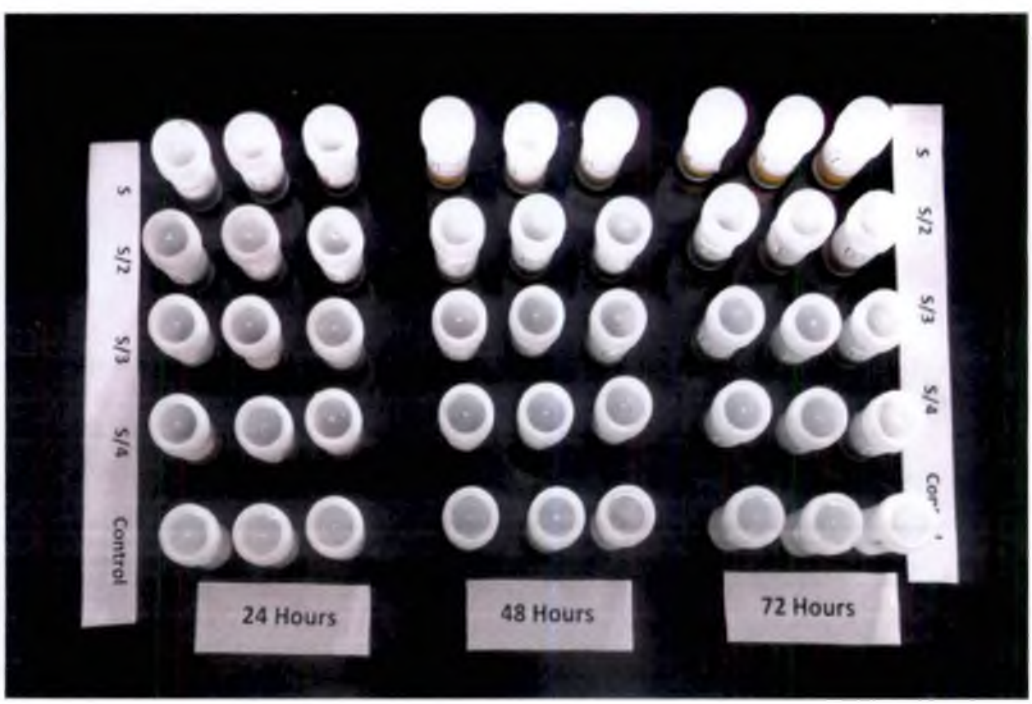
Design-CRD Treatments-17 Replications-2

T_1 - -*C. odorata* root extract extract (S)
T_2 - -*C. odorata* root extract extract (S/2)
T_3 - -*C. odorata* root extract extract (S/3)
T_4 - -*C. odorata* root extract extract (S/4)
T_5 - -*T diversifolia* leaf extract (S)
T_6 - -*T. diversifolia* leaf extract (S/2)
T_7 - -*T. diversifolia* leaf extract (S/3)
T_8 - -*T. diversifolia* leaf extract (S/4)
T_9 - -*L. camara* leaf extract (S)
T_{10}- -*L. camara* leaf extract (S/2)
T_{11}- -*L. camara* leaf extract (S/3)
T_{12}- *L. camara* leaf extract (S/4)
T_{13}- -*E. crassipes* leaf extract (S)
T_{14}- *E. crassipes* leaf extract (S/2)
T_{15}- -*E. crassipes* leaf extract (S/3)
T_{16}- -*E. crassipes* leaf extract (S/4)
T_{17}- -Control (distilled water)

3.3. POT CULTURE STUDIES TO EVALUATE THE EFFECTIVE BOTANICAL

A pot culture study was conducted to find out appropriate formulation and delivery system of the effective botanical identified from 3.2 *viz.* soil application in the form of granules (suspended in charcoal), dry leaf powder, soil drench and seedling root dip. The experiment was conducted at College of Agriculture, Vellayani by raising cabbage plants as mentioned in 3.3.1

A. Wild sunflower (*Tithonia diversifolia*)



B. *In vitro* condition

Plate 2(A &B). Screening of *T.diversifolia* extract for nematicidal property under *in vitro* conditions (Effect on larval mortality)

3.3.1 Raising of Cabbage Seedlings

Cabbage seeds (variety NS 183) were sown in pot trays filled with denematised peatmoss and coirpith. The plants were maintained as per Package of Practices Reccomendations of Kerala Agricultural University (KAU, 2011).

3.3.2. Formulation of Botanical

3.3.2.1 Granules

Most effective plant extract selected from *in vitro* studies was mixed with charcoal powder (1:1 ratio) and applied in the form of granules.

3.3.2.2 Dry Powder

Effective plant was selected, dried and applied in the form of powder

3.3.2.3 Seedling Root Dip

One month old healthy cabbage seedlings were uprooted for the experiment. The seedlings were washed well and dipped in the effective botanical prepared as described in para 3.2.4.1 for 30 minutes. These seedlings were then planted in pots containing denematized potting mixture.

3.3.2.4. Soil Drench

Crude extract of the effective botanical was applied in the root zone of cabbage seedlings as drench @ 25, 50 and 100 ml per plant.

3.3.3. Transplanting in Pots

One month old cabbage seedlings were selected for pot culture study. The seedlings were transplanted in 1 kg capacity pots with denematised potting mixture prepared as described in 3.2.1. Nematode culture was maintained as mentioned in para 3.2.2. After establishment of seedlings, newly hatched second stage larvae of *M. incognita* were inoculated to the root zone of the transplanted seedlings @ one J_2 /g of soil. Incoculation was done as per the method suggested by Venkitesan and Sethi (1977). Simultaneously, the effective botanical was delivered in the form of charcoal adsorbed granules, dry powder, seedling root dip and soil drench. The experiment was laid out in a Completely Randomized Design with eleven treatments and three replications. Plants were maintained as per the Package of Practices Recommendations of Kerala Agricultural University (KAU, 2011).

The treatments were given as follows.

T_1 -Extract adsorbed on charcoal (25g/kg soil)

T_2 -Extract adsorbed on charcoal (50g/kg soil)

T_3 -Extract adsorbed on charcoal (100g/kg soil)

T_4 -Dried powder (25g/kg soil)

T_5 -Dried powder (50g/kg soil)

T_6 -Dried powder (100g/kg soil)

T_7 -Seedling root dip for 30 minutes

T_8 -Soil drenching of crude extract (25ml/plant)

T_9 -Soil drenching of crude extract (50ml/plant)

T_{10} -Soil drenching of crude extract (100ml/plant)

T_{11} -Untreated

3.3.4. Recording Observations

Biometric characters of five observational plants *viz.* plant height, gross plant weight, leaf length, leaf breadth and root weight were taken 45 days after inoculation. After uprooting, observations on nematode population characteristics *viz.* number of galls, number of females, number of egg masses, nematode population in soil and root were taken.

The number of egg masses per five g root was estimated by following the method of Southey (1986). Five g root was placed in a phloxine B solution (0.15 g per litre water) for 15 minutes. Stained egg masses from the entire root system were counted under a stereo microscope. Care was taken to reduce the loss of egg masses but where there were mature females which had egg masses, these were also counted.

For estimating the number of females, five g cabbage root was cut into small bits of 2-3 cm length and stained by differential staining method using acid fuschin-lactophenol mixture .The processed roots were pressed between glass slides and then teased with a needle and examined under a microscope to count the number of females.

Nematode population in soil was estimated by collecting 200 g of soil sample from cabbage rhizosphere. Nematodes were extracted from the soil samples adopting Cobb's sieving and decanting method (Cobb, 1918) followed by modified Baermann's funnel technique (Schindler, 1961). The nematodes thus extracted were counted under a stereo zoom microscope. The nematode population in root was estimated by processing root samples according to the technique described in 3.1.3

3.4. FIELD EXPERIMENT TO EVALUATE THE PROMISING BOTANICAL COMPARED TO BIOAGENT ENRICHED ORGANIC AMENDMENT AND CHEMICAL

A field experiment was conducted to evaluate efficacy of botanical selected from pot culture studies in comparison with recommended bio control agent and chemical. The experiment was conducted in Instructional farm, Vellayani in an area naturally infested with root knot nematodes.

The experimental details were as follows.

Design -RBD Net plot size - 2X2 m

Treatments-5 Replications - 4

T_1 & T_2 -Effective treatments from 3.3

T_3 -*P. lilacinus* enriched neem cake (20 gm^{-2})

T_4 -Thiamethoxam 25% WG (0.04 g/plot)

T_5 -Untreated

One month old cabbage seedlings (Variety- NS 183) with uniform growth were transplanted in nematode infested micro plots at a spacing of 45x45 cm. After establishment of seedlings, soil application of the treatments viz. effective botanical identified from pot culture studies, *P. lilacinus* enriched neem cake and chemical thiamethoxam were done. The plants were maintained as per the Package of Practices of Kerala Agricultural University (KAU, 2011). Observations on biometric characters (plant height, leaf length, leaf breadth, non wrapper leaves per plant, gross plant weight), yield (head depth, head diameter, gross head weight and net head weight)

and nematode population characteristics (no. of galls, no. of egg masses, nematode population in soil and root) were taken as described in para 3.3.4.

3.5. STATISTICAL ANALYSIS

The data generated from the experiments (3.1 to 3.4) were subjected to analysis of variance (ANOVA) technique (Cochran and Cox, 1965). The variables which did not satisfy the basic assumption of ANOVA were subjected to logarithmic, angular and square root transformations.

RESULTS

4. RESULTS

The salient results of the study "Nematode association in cabbage, *Brassica oleracea* L. var. *capitata* and its management using botanicals" are presented below.

4.1. COLLECTION AND ESTIMATION OF NEMATODES ASSOCIATED WITH CABBAGE

4.1.1. Association of Nematodes in Cabbage

A total of two hundred and eight soil and root samples were collected from cabbage growing tracts of Idukki, Kollam and Thiruvananthapuram districts. The samples were analyzed for studying association and the community behavior of nematodes in the root zone of cabbage. The analysis of soil samples from the rhizosphere of cabbage revealed the presence of both plant parasitic and free living forms of nematodes. The plant parasities included Tylenchids and the free living forms included Rhabditids, Dorylaimids and Mononchids. The results of community analysis are presented in Table 1. to 57.

4.1.2. Distribution of Plant Parasitic Nematodes Associated with Rhizosphere of Cabbage

Analysis of soil and root samples collected from the rhizosphere of cabbage revealed the occurrence of *M. incognita, Rotylenchulus reniformis, Helicotylenchus* sp., *Radopholus similis, Xiphinema* sp. and *Tylenchorhynchus* sp. (Table 1. and Fig. 1). The population of root knot nematode from cabbage growing areas of Kerala *viz.* Idukki, Kollam and Thiruvananthapuram districts were observed in the range 0-310. Distribution

Fig. 1 Distribution of plant parasitic nematodes in cabbage growing tracts of Thiruvanathapuram, Kollam and Idukki Districts

Table 1: Distribution of nematodes in cabbage in major cabbage growing tracts of Kerala

Location		Nematode species	Population range/ 200 cc	Mean	Frequency of occurrence (%)
Idukki (District)	Vattavada (Panchayath)	*M. incognita*	0-118	29	38.5
		Helicotylenchus sp.	39-728	329	100
		Rotylenchulus sp.	0-310	97	76.9
		Tylenchorhynchus sp.	0-234	69	76.9
	Kanthalloor (Panchayath)	*M. incognita*	0-247	84	61.5
		Helicotylenchus sp.	16-752	334	100
		Rotylenchulus sp.	0-374	130	76.9
		Tylenchorhynchus sp.	0-238	41	38.5
Kollam (District)		*M. incognita*	0-310	104	53.9
		Helicotylenchus sp.	0-240	107	69.2
		Rotylenchulus sp.	0-170	66	53.9
		Xiphinema sp.	0-15	2	15.4
Thiruvanathapuram (District)		*M. incognita*	0-262	77	61.5
		Helicotylenchus sp.	56-432	197	100
		Rotylenchulus sp.	0-212	83	61.5
		Tylenchorhynchus sp.	0-150	25	30.8
		R. similis	0-45	35	7.7

of nematodes in Kanthalloor and Vattavada panchayath are individually found out as not only are they the important cabbage growing tracts of Idukki district but also in the state as well. In Vattavada panchayath (Idukki district), the population of *M. incognita* ranged from 0-118 with an average of 29 and frequency of occurrence of 38.5. *R. reniformis* ranged from 0–310 with an average of 97 and frequency of occurrence of 76.9. In Kanthalloor panchayath (Idukki district) population of *M. incognita* was in the range 0-247 per 200 cc soil with an average of 84 and a frequency of occurrence of 61.5%. Other tylenchids observed were in the population range of 0-752 per 200 cc soil with an average of 168 and a frequency of occurrence of 71.8 %. In Kollam district the population of *M. incognita* ranged from 0-310 with an average of 104 and a frequency of occurrence of 53.9 %. The population of other plant parasitic nematodes ranged from 0-240 per 200 cc soil samples with an average of 58 and frequency of occurrence of 46.2 %. In Thiruvananthapuram district the population of *M. incognita* was observed in the range 0-262 with an average of 77 and a frequency of occurrence of 61.5 %.The population of other plant parasitic nematodes per 200 cc soil was observed in the range 0-432.

Location wise detailed separate community analysis was worked out for Kanthalloor and Vattavada panchayaths of Idukki district because of the relevance of these cabbage growing tracts in the state. *M. incognita* was recorded from five locations out of thirteen locations from Vattavada panchayath (Idukki district). Free living nematodes and *Helicotylenchus* sp. was recorded from all the thirteen locations in Vattavada panchayath. *R. reniformis* was not recorded from Location 1, 8, 10 similarly *Tylenchorhynchus* sp. was not recorded from Location1, 2 and 10 (Table 2.). In Kanthalloor panchayath (Idukki district), *M. incognita* was recorded from eight locations out of the thirteen locations surveyed *viz.*, Location 2 of

Table 2.Distribution of plant parasitic nematodes in Vattavada panchayath, Idukki district

Sl.No	Location	Population of nematodes					
		M. incognita		*R. reniformis*	*Helicotylenchus* sp.	*Tylenchorhynchus* sp.	Free living
		Soil (200 cc)	Root(5g)				
1	Loc 1	-	-	-	74	-	359
2	Loc 2	52	15	54	365	-	125
3	Loc 3	-	-	102	172	21	604
4	Loc 4	44	20	299	473	153	432
5	Loc 5	67	23	44	355	68	87
6	Loc 6	118	42	20	39	234	951
7	Loc 7	-	-	193	271	123	51
8	Loc 8	-	-	-	538	74	1032
9	Loc 9	-	-	15	160	63	375
10	Loc 10	-	-	-	54	-	190
11	Loc 11	95	52	310	399	48	838
12	Loc 12	-	-	126	728	15	132
13	Loc 13	-	-	99	654	100	93

Table 3. Distribution of plant parasitic nematodes in Kanthalloor panchayath, Idukki District

Sl. No	Village	Location	Population of nematodes					
			M. incognita		*R. reniformis*	*Helicotylenchus* sp.	*Tylenchorhynchus* sp.	Free living
			Soil (200 cc)	Root (5g)				
1	Kheezhanthoor	Loc 1	-		-	714	-	44
2	"	Loc 2	104	79	58	538	-	140
3	"	Loc 3	-	-	261	165	27	208
4	Kanthalloor	Loc1	-	-	298	752	160	527
5	Puthoor	Loc 1	80	53	-	341	-	757
6	"	Loc 2	32	11	81	194	-	104
7	"	Loc 3	-	-	-	57	-	224
8	"	Loc 4	-	-	374	246	52	497
9	Perumala	Loc 1	146	78	155	198	50	162
10	"	Loc 2	168	97	25	16	238	114
11	"	Loc 3	190	118	240	621	-	242
12	"	Loc 4	247	153	88	143	-	208
13	"	Loc 5	118	79	105	350	-	158

Table 4. Distribution of plant parasitic nematodes in Kollam district

Sl.No	Village	Panchayath	Population of nematodes					
			M. incognita		*R. reniformis*	*Helicotylenchus* sp.	*Xiphinema* sp.	Free living
			Soil (200 cc)	Root (5g)				
1	Anchal	Anchal	-	-	100	96	-	523
2	Chemmakkad	"	-	-	120	-	-	784
3	Panayamcherry	"	-	-	180	-	-	200
4	Kottukkal	"	240	130	120	-	-	132
5	Thazhamel	"	130	87	-	170	-	558
6	Vazhakkal	"	87	24	53	134	-	147
7	Eroor	Eroor	-	-	-	60	10	667
8	Alancherry	"	-	-	240	-	-	149
9	Vilakkupara	"	310	168	188	150	15	239
10	Aylara	"	169	86	-	-	-	891
11	Alayamon	Alayamon	169	91	-	-	-	936
12	Karavaloor	Karavaloor	-	-	240	150	-	200
13	Edamulackal	Edamulackal	240	123	150	100		416

Table 5. Distribution of plant parasitic nematodes in Thiruvanathapuram district

Sl. No	Village	Panchayath	Population of nematodes						
			M. incognita		*R. reniformis*	*Helicotylenchus* sp.	*Tylenchorhynchus* sp.	*R. similis*	Free living
			Soil (200 cc)	*Root* (5g)					
1	Uzhamalaical	Uzhamalaical	-	-	48	56	-	-	292
2	Kulathoor	Kulathoor	-	-	-	69	-	-	239
3	Athiyanoor	Athiyanoor	-	-	-	141	42	-	105
4	Thembamuttam	Balaramapuram	39	8	-	173	-	-	323
5	Aralumoodu	Athiyanoor	-	-	212	179	91	-	529
6	Nellimoodu	Athiyanoor	52	13	195	158	-	-	627
7	Kuttichal	Kuttichal	179	109	-	325	-	-	729
8	Kanjiramkulam	Kanjiramkulam	92	63	188	432	-	-	925
9	Eanikkara	Karakulam	82	41	150	210	-	-	350
10	Kottukal	Kottukal	262	147	56	93	42	-	163
11	Vellanadu	Vellanadu	40	19	76	79	-	-	244
12	Kalliyoor	Kalliyoor	-	-	-	315	-	-	243
13	Vellayani	Kalliyoor	256	139	159	333	150	45	661

Kheezhanthoor village, Location 1 and 2 of Puthoor village and five locations of Perumala village. *Helicotylenchus* sp. and free living nematodes was recorded from all the thirteen locations in Kanthalloor panchayath. *R. reniformis* was found in ten locations *viz.* Location 2 and 3 of Kheezhanthoor village, Location1 of Kanthalloor village, Location 2 and 4 of Puthoor village and Location 1-5 of Perumala village .*Tylenchorhynchus* sp. were recorded from five locations *viz.* Location 3 of Kheezhanthoor village, Location1 of Kanthalloor village, Location 4 of Puthoor village and Location 1 and 2 of Perumala village (Table 3.).

M. incognita was obtained from soil samples collected from seven locations out of thirteen locations in Kollam district *viz.* Kottukal, Thazhamel, Vazhakkal, Vilakkupara, Aylara, Alayamon, and Edamulackal. *Helicotylenchus* sp. was recorded from seven locations of Kollam district *viz.*, Anchal, Thazhamel, Vazhaykkal, Eroor, Vilakkupara, Karavaloor and Edamulackal. *R. reniformis*, was found in nine locations viz., Anchal, Chemmakkad, Panayamcherry, Kottukkal, Vazhakkal, Alancherry, Vilakkupara, Karavaloor and Edamulackal. *Xiphinema* sp. was obtained from two locations Vilakkupara and Eroor of Kollam district. Free living nematodes were reported from all the thirteen locations (Table 4.).

The survey of cabbage growing areas in Thiruvananthapuram district (Table 5.) showed the presence of *M. incognita* at Thembamuttam, Nellimoodu, Kuttichal, Kanjiramkulam, Eanikkara, Kottukal, Vellanadu and Vellayani locations out of the soil samples collected from thirteen locations. *Helicotylenchus* sp. was observed from all the thirteen locations in Thiruvananthapuram region. *R. reniformis* was recorded from eight locations *viz.* Uzhamalaikal, Aralumoodu, Nellimoodu, Kanjiramkulam, Eanikkara, Kottukal, Vellanadu and Vellayani. *Tylenchorhynchus* sp. was found in four

locations *viz.* Athiyanoor, Aralumoodu, Kottukal and Vellayani. Vellayani region reported the presence of *R. similis*. Free living nematodes were reported from all the thirteen locations.

4.1.3. Community Analysis of Nematodes of Cabbage in Idukki District (Vattavada Panchayath)

4.1.3.1. Community Analysis of Nematodes in Location 1

Helicotylenchus sp. was the important nematode species obtained from Location 1 of Vattavada panchayath (Table 6.). Highest prominence value was recorded by free living nematodes (143.6) followed by *Helicotylenchus* sp. (29.6). The free living nematodes were observed with a relative density of 82.9 followed by *Helicotylenchus* sp. (17.1). Frequency of occurrence was found to be 50.0 for all the nematode species found in that area.

4.1.3.2. Community Analysis of Nematodes in Location 2

M. incognita, *R. reniformis*, *Helicotylenchus* sp. and free living nematodes were found in Location 2 of Vattavada Panchayath. Table 7. clearly shows that the most prominent nematode in Location 2 was *Helicotylenchus* sp. (146.0) followed by free living nematode (50.0) and *R. reniformis* (21.6). Prominence *value of M. incognita* was 20.8. The frequency of occurrence was found to be 25.0 for all the nematode species found in this area. *Helicotylenchus* sp. was the most abundant species with a relative density of 62.1.

Table 6. Community analysis of nematodes in Location 1 of Vattavada Panchayath at Idukki District

Nematode species	Absolute frequency	Relative frequency	Absolute density	Relative density	Prominence value
Helicotylenchus sp.	100	50.0	296.0	17.1	29.6
Free living	100	50.0	1436.0	82.9	143.6

Table 7. Community analysis of nematodes in Location 2 of Vattavada Panchayath at Idukki District

Nematode species	Absolute frequency	Relative frequency	Absolute density	Relative density	Prominence value
M. incognita	100	25.0	208.0	8.7	20.8
Helicotylenchus sp.	100	25.0	1460.0	62.1	146.0
R. reniformis	100	25.0	216.0	9.1	21.6
Free living	100	25.0	500.0	21.0	50.0

Table 8. Community analysis of nematodes in Location 3 of Vattavada Panchayath at Idukki District

Nematode species	Absolute frequency	Relative frequency	Absolute density	Relative density	Prominence value
Helicotylenchus sp.	100	26.7	688.0	19.1	68.8
R. reniformis	100	26.7	408.0	11.3	40.8
Tylenchorhynchus sp.	75	20.0	84.0	2.3	7.3
Free living	100	26.7	2416.0	67.2	241.6

4.1.3.3. Community Analysis of Nematodes in Location 3

The most prominent nematode in Location 3 was free living nematodes with a prominence value of (241.6) followed by *Helicotylenchus* sp. (68.8), *R. reniformis* (40.8) and *Tylenchorhynchus* sp. (7.3). The most dominant nematode was found to be free living nematodes with a relative density of 67.2 and the least abundant nematode was *Tylenchorhynchus* sp. with a relative density of 2.3. The most frequently occurring nematode in Location 3 was *Helicotylenchus* sp., *R. reniformis* and free living nematodes with a relative frequency of (26.7), followed by *Tylenchorhynchus* sp. with a relative frequency of (20.0) (Table 8.).

4.1.3.4. Community Analysis of Nematodes in Location 4

Results presented in Table 9. revealed that in Location 4 the most prominent nematode group was *Helicotylenchus* sp. (189.2) followed by free living (172.8), *R. reniformis* (119.6). *M. incognita* was observed with a prominence value of 17.6. The relative frequency of the nematodes *viz. M. incognita, R. reniformis, Helicotylenchus* sp. and free living nematodes was observed as 21.1. *Tylenchorhynchus* sp. recorded a lowest relative frequency of 15.8.

4.1.3.5. Community Analysis of Nematodes in Location 5

Community analysis of nematodes in Location 5 of Vattavada panchayath (Table 10.) revealed that *Helicotylenchus* sp. was the most frequently occurring nematode with a prominence value of 142.0 followed by free living nematodes (34.8), *M. incognita* (26.8), *Tylenchorhynchus* sp. (19.2) and *R. reniformis* (12.4). *Helicotylenchus* sp. was the most abundant nematode with a relative density of 57.2 followed by free living nematodes

Table 9. Community analysis of nematodes in Location 4 of Vattavada Panchayath at Idukki District

Nematode species	Absolute frequency	Relative frequency	Absolute density	Relative density	Prominence value
M. incognita	100	21.1	176.0	3.1	17.6
Helicotylenchus sp.	100	21.1	1892.0	33.8	189.2
R. reniformis	100	21.1	1196.0	21.3	119.6
Tylenchorhynchus sp.	75	15.8	612.0	10.9	53.0
Free living	100	21.1	1728.0	30.8	172.8

Table 10.Community analysis of nematodes in Location 5 of Vattavada Panchayath at Idukki District

Nematode species	Absolute frequency	Relative frequency	Absolute density	Relative density	Prominence value
M. incognita	100	25.0	268.0	10.8	26.8
Helicotylenchus sp.	100	25.0	1420.0	57.2	142.0
R.reniformis	50	12.5	176.0	7.1	12.4
Tylenchorhynchus sp.	50	12.5	272.0	11.0	19.2
Free living	100	25.0	348.0	14.0	34.8

(14.0), *Tylenchorhynchus* sp. (11.0), *M. incognita* (10.8) and *R. reniformis* (7.1). Relative frequency of nematodes *viz. M. incognita, Helicotylenchus* sp., and free living nematodes were observed to be 25.0. The relative frequency of *R.reniformis* and *Tylenchorhynchus* sp. was observed as 12.5.

4.1.3.6. Community Analysis of Nematodes in Location 6

The nematode species identified from Location 6 of Vattavada panchayath (Table 11.) was *M. incognita, Helicotylenchus* sp., *Tylenchorhynchus* sp., *R. reniformis* and free living forms. Highest prominence value was observed for free living nematodes (380.4) followed by *Tylenchorhynchus* sp. (93.6), *Helicotylenchus* sp. (47.2), *M. incognita* (15.6) and the lowest by *R. reniformis* (8.0). The most abundant nematodes were free living nematodes with a relative density of 69.8. The relative density recorded by *Tylenchorhynchus* sp., *M. incognita, Helicotylenchus* sp. and *R. reniformis* were 17.2, 8.7, 2.9 and 1.5 respectively. The relative frequency values of all the nematodes were observed as 20.0.

4.1.3.7. Community Analysis of Nematodes in Location 7

The results of Community analysis of nematodes in Location 7 of Vattavada panchayath was presented in Table 12. Free living nematodes showed the highest prominence value of 206.4. *Helicotylenchus* sp, *R. reniformis* and *Tylenchorhynchus* sp. recorded a prominence value of 108.0, 77.2 and 42.6 respectively. Highest frequency of occurrence was recorded by *Helicotylenchus* sp. (26.7), *R. reniformis* (26.7) and free living nematodes (26.7) followed by *Tylenchorhynchus* sp. with a relative frequency of 20.0. The most abundant nematode in this area was free living nematodes with a relative density of 46.8.The relative density value of

Table 11.Community analysis of nematodes in Location 6 of Vattavada Panchayath at Idukki District

Nematode species	Absolute frequency	Relative frequency	Absolute density	Relative density	Prominence value
M.incognita	100	20.0	472.0	8.7	47.2
Helicotylenchus sp.	100	20.0	156.0	2.9	15.6
R. reniformis	100	20.0	80.0	1.5	8.0
Tylenchorhynchus sp.	100	20.0	936.0	17.2	93.6
Free living	100	20.0	3804.0	69.8	380.4

Table 12.Community analysis of nematodes in Location 7 of Vattavada Panchayath at Idukki District

Nematode species	Absolute frequency	Relative frequency	Absolute density	Relative density	Prominence value
R. reniformis	100	26.7	772.0	17.5	77.2
Helicotylenchus sp.	100	26.7	1080.0	24.5	108.0
Tylenchorhynchus sp.	75	20.0	492.0	11.2	42.6
Free living	100	26.7	2062.0	46.8	206.4

Helicotylenchus sp., *R. reniformis* and *Tylenchorhynchus* sp. were observed as 24.5, 17.5 and 11.2 respectively.

4.1.3.8. Community Analysis of Nematodes in Location 8

The results of community analysis of nematodes associated with rhizosphere of cabbage growing area in Location 8 of Vattavada panchayath showed the prominence of *Helicotylenchus* sp., *Tylenchorhynchus* sp. and free living nematodes. The prominence value of free living nematodes, *Helicotylenchus* sp. and *Tylenchorhynchus* sp. were observed as 412.8, 215.2 and 29.6 respectively. All the nematodes possessed the same relative frequency of 33.3. Free living forms were the most abundant nematodes recorded with a relative density of 62.8. The relative density of *Helicotylenchus* sp. and *Tylenchorhynchus* sp. were observed as 32.7 and 4.5 respectively. (Table 13.)

4.1.3.9. Community Analysis of Nematodes in Location 9

Analysis of soil samples collected from Location 9 of Vattavada panchayath recorded *Helicotylenchus* sp., *R. reniformis*, *Tylenchorhynchus* sp. and free living nematodes. The prominence value was found to be the highest (150.0) in free living nematodes followed by *Helicotylenchus* sp. (55.4), *Tylenchorhynchus* sp. (17.8) and *R. reniformis* (4.2) (Table 14.). Free living nematodes showed the highest relative frequency of 36.4 followed by *Helicotylenchus* sp. (27.3), *R. reniformis* (18.2) and *Tylenchorhynchus* sp. (18.2). Highest relative density (61.2) was observed in free living nematodes. The nematodes *Helicotylenchus* sp., *Tylenchorhynchus* sp. and *R. reniformis* recorded a relative density of 26.1, 10.3 and 2.4 respectively.

Table 13.Community analysis of nematodes in Location 8 of Vattavada Panchayath at Idukki District

Nematode species	Absolute frequency	Relative frequency	Absolute density	Relative density	Prominence value
Helicotylenchus sp.	100	33.3	2152.0	32.7	215.2
Tylenchorhynchus sp.	100	33.3	296.0	4.5	29.6
Free living	100	33.3	4128.0	62.8	412.8

Table 14.Community analysis of nematodes in Location 9 of Vattavada Panchayath at Idukki District

Nematode species	Absolute frequency	Relative frequency	Absolute density	Relative density	Prominence value
Helicotylenchus sp.	75	27.3	640.0	26.1	55.4
R. reniformis	50	18.2	60.0	2.4	4.2
Tylenchorhynchus sp.	50	18.2	252.0	10.3	17.8
Free living	100	36.4	1500.0	61.2	150

Table 15.Community analysis of nematodes in Location 10 of Vattavada Panchayath at Idukki District

Nematode species	Absolute frequency	Relative frequency	Absolute density	Relative density	Prominence value
Helicotylenchus sp.	100	50.0	216.0	22.1	21.6
Free living	100	50.0	760.0	77.9	76.0

4.1.3.10. Community Analysis of Nematodes in Location 10

The results presented in Table 15. revealed that free living nematodes to be the most prominent plant parasitic nematode in Location 10 of Vattavada panchayath. The prominence value of free living nematodes was 76.0 and that of *Helicotylenchus* sp. was 21.6. Based on the abundance of nematodes, the highest relative density (77.9) was observed in free living nematodes followed by *Helicotylenchus* sp. (22.1). The relative frequency of *Helicotylenchus* sp. and free living nematodes was found to be 50.0

4.1.3.11. Community Analysis of Nematodes in Location 11

The results of community analysis of nematodes associated with rhizosphere of cabbage in location 11 of Vattavada panchayath were presented in Table 16. Prominence value was found to be highest in free living nematodes (335.2) followed by *Helicotylenchus* sp. (138.2), *R. reniformis* (107.4), *M. incognita* (38.0) and *Tylenchorhynchus* sp. (13.6). The highest relative frequency was recorded by *M. incognita* and free living nematodes (25.0). *Helicotylenchus* sp. and *R. reniformis* showed a relative frequency of 18.8. *Tylenchorhynchus* sp. recorded the lowest relative frequency of 12.5. *M. incognita* exhibited the maximum relative density of 56.0, followed by free living nematodes, *Helicotylenchus* sp., *R. reniformis* and *Tylenchorhynchus* sp. with a relative density of 49.6, 23.6, 18.3 and 2.8 respectively.

4.1.3.12. Community Analysis of Nematodes in Location 12

Results presented in the Table 17. showed that *R. reniformis*, *Helicotylenchus* sp., *Tylenchorhynchus* sp. and free living nematodes were the nematodes found associated with cabbage in Location 12 of Vattavada

Table 16.Community analysis of nematodes in Location 11 of Vattavada Panchayath at Idukki District

Nematode species	Absolute frequency	Relative frequency	Absolute density	Relative density	Prominence value
M.incognita	100	25.0	380.0	56.0	38.0
Helicotylenchus sp.	75	18.8	1596.0	23.6	138.2
R.reniformis	75	18.8	1240.0	18.3	107.4
Tylenchorhynchus sp.	50	12.5	192.0	2.8	13.6
Free living	100	25.0	3352.0	49.6	335.2

Table 17. Community analysis of nematodes in Location 12 of Vattavada Panchayath at Idukki District

Nematode species	Absolute frequency	Relative frequency	Absolute density	Relative density	Prominence value
Helicotylenchus sp.	75	23.1	2912.0	72.7	252.2
R. reniformis	75	23.1	504.0	12.6	43.6
Tylenchorhynchus sp.	75	23.1	60.0	1.5	5.2
Free living	100	30.8	528.0	13.2	52.8

Panchayath. The frequently occurring nematode in that area was found to be free living nematodes with a relative frequency of (30.8) followed by *Helicotylenchus* sp. (23.1), *R. reniformis* (23.1) and *Tylenchorhynchus* sp. (23.1). *Helicotylenchus* sp. was the most abundant nematode in that area with a relative density of 72.7 followed by free living nematodes, *R. reniformis* and *Tylenchorhynchus* sp. with values 13.2, 12.6 and 1.5 respectively.

4.1.3.13. Community Analysis of Nematodes in Location 13

Community analysis of nematodes in Location 13 of Vattavada panchayath showed the prominence of *Helicotylenchus* sp. (261.6). The prominence value of free living nematodes, *Tylenchorhynchus* sp. and *R. reniformis* were observed as 37.2, 34.6 and 28.0 respectively (Table 18). Highest frequency of occurrence was recorded by *Helicotylenchus* sp. and free living nematodes (30.8) followed by *Tylenchorhynchus* sp. (23.1) and *R. reniformis* (15.4). *Helicotylenchus* sp. was found to be the abundant nematode in Location 13 of Vattavada Panchayath with a relative density of 69.1 followed by *Tylenchorhynchus* sp., *R. reniformis* and free living nematode with relative density values of 10.6, 10.5 and 9.8 respectively (Table 18.).

4.1.4. Community Analysis of Nematodes of Cabbage in Idukki District (Kanthallor Panchayath)

4.1.4.1. Community Analysis of Nematodes in Kheezhanthoor Village

The main species of nematode obtained from Location 1 of Kheezanthoor village was *Helicotylenchus* sp. followed by free living nematodes, which includes Rhabditids, Dorylaimids and Mononchids. *Helicotylenchus* sp. recorded as a prominent nematode with a prominence

Table 18. Community analysis of nematodes in Location 13 of Vattavada Panchayath at Idukki District

Nematode species	Absolute frequency	Relative frequency	Absolute density	Relative density	Prominence value
Helicotylenchus sp.	100	30.8	2616.0	69.1	261.6
R. reniformis	50	15.4	396.0	10.5	28.0
Tylenchorhynchus sp.	75	23.1	400.0	10.6	34.6
Free living	100	30.8	372.0	9.8	37.2

Table 19. Community analysis of nematodes in Kheezhanthoor Village (Location 1) of Kanthalloor Panchayath at Idukki District

Nematode species	Absolute frequency	Relative frequency	Absolute density	Relative density	Prominence value
Helicotylenchus sp.	100	50.0	2836.0	94.2	285.6
Free living	100	50.0	176.0	58.0	17.6

Table 20.Community analysis of nematodes in Kheezhanthoor Village (Location 2) of Kanthalloor Panchayath at Idukki District

Nematode species	Absolute frequency	Relative frequency	Absolute density	Relative density	Prominence value
M. incognita	50	18.2	416.0	12.4	29.4
Helicotylenchus sp.	75	27.3	2152.0	64.0	186.4
R. reniformis	50	18.2	232.0	6.9	16.4
Free living	100	36.4	560.0	16.7	56.0

value of 285.6 followed by free living nematodes (17.6). Based on the relative frequency value, *Helicotylenchus* sp. (50.0) was the most frequently occurring nematode followed by free living nematodes (50.0). *Helicotylenchus* sp. was the most abundant species with a relative density of 94.2 whereas, free living nematodes recorded a relative density of 58.0 (Table 19.).

The survey from Location 2 of Kheezhanthoor Panchayath revealed the presence *M. incognita, Helicotylenchus* sp., *R. reniformis* and free living nematodes (Table 20.). The results showed that *Helicotylenchus* sp. to be the most prominent nematode in the area, with a prominence value of 186.4 followed by free living nematodes (56.0), *M. incognita* (29.4) and the lowest by *R. reniformis* (16.4). Based on the relative frequency, the most frequently occurring nematode was free living nematodes (36.4) followed by *Helicotylenchus* sp. (27.3) and the lowest by *M. incognita* (18.2) and *R. reniformis* (18.2). *Helicotylenchus* sp. was the most abundant species with a relative density of (64.0) followed by free living nematodes (16.7), *M. incognita* (12.4) and *R. reniformis* (6.9).

Tylenchorhynchus sp., *Helicotylenchus* sp., *R. reniformis* and free living nematodes were recorded from Location 3 of Kheezhanthoor Village. The results presented in Table 21. showed that *R. reniformis* to be the most prominent nematodes in the area, with a prominence value of 90.4, followed by, free living forms (83.2), *Helicotylenchus* sp. (66.0) and *Tylenchorhynchus* sp. (9.4). Free living nematodes and *Helicotylenchus* sp. (28.6) were the most frequently occurring nematodes followed by *Tylenchorhynchus* sp. and *R. reniformis* (21.4). The relative density value of *R. reniformis* was found to be the highest (39.5) followed by free living nematodes (31.5), *Helicotylenchus* sp. (25.3) and *Tylenchorhynchus* sp. (4.1)

Table 21. Community analysis of nematodes in Kheezhanthoor Village (Loctaion 3) of Kanthalloor Panchayath at Idukki District

Nematode species	Absolute frequency	Relative frequency	Absolute density	Relative density	Prominence value
Helicotylenchus sp.	100	28.6	660.0	25.3	66.0
R. reniformis	75	21.4	1004.0	39.5	90.4
Tylenchorhynchus sp.	75	21.4	108.0	4.1	9.4
Free living	100	28.6	832.0	31.5	83.2

Table 22.Community analysis of nematodes in Kanthalloor Village (Location 1) of Kanthalloor Panchayath at Idukki District

Nematode species	Absolute frequency	Relative frequency	Absolute density	Relative density	Prominence value
Helicotylenchus sp.	100	26.7	3008.0	43.3	300.8
R.reniformis	75	20.0	1160.0	17.2	103.2
Tylenchorhynchus sp.	100	26.7	640.0	9.2	64.0
Free living	100	26.7	2108.0	30.3	210.8

Table 23. Community analysis of nematodes in Puthoor Village (Location 1) of Kanthalloor Panchayath at Idukki District

Nematode species	Absolute frequency	Relative frequency	Absolute density	Relative density	Prominence value
M. incognita	50	20.0	320.0	6.8	22.6
Helicotylenchus sp.	100	40.0	1364.0	29.0	136.4
Free living	100	40.0	3024.0	64.3	302.4

4.1.4.2. Community Analysis of Nematodes of Kanthalloor Village

The results from Table 22. showed that *Helicotylenchus* sp., *R. reniformis* and *Tylenchorhynchus* sp. were the plant parasitic nematodes identified from Kanthalloor Panchayath. The most prominent nematode from Location 1 of Kanthalloor Panchayath was *Helicotylenchus* sp. with a prominence value of 300.8 followed by free living nematodes (210.8), *R. reniformis* (103.2) and *Tylenchorhynchus* sp. (64.0). *Helicotylenchus* sp., *Tylenchorhynchus* sp. and free living nematodes exhibited the highest relative frequency of 26.7. Relative density value of *Helicotylenchus* sp. was the highest (43.3) followed by free living nematodes (30.3), *R. reniformis* (17.2) and *Tylenchorhynchus* sp. (9.2).

4.1.4.3. Community Analysis of Nematodes in Puthoor Village

Helicotylenchus sp, *M. incognita* and free living nematodes were recorded in soil samples collected from four locations of Puthoor village (Table 23.). In Location 1, free living forms were the most prominent nematodes followed by *Helicotylenchus* sp. and *M. incognita* with a prominence value of 302.4, 136.4 and 22.6 respectively. Relative frequency values of *Helicotylenchus* sp. and free living nematodes were 40.0 followed by *M. incognita* (20.0). Free living nematodes showed the highest relative density (64.3) while the lowest was recorded by *M. incognita* (6.8).

The results of Location 2 in Puthoor village (Table 24.) revealed that highest prominence value was observed in *Helicotylenchus* sp. (77.6) followed by free living nematodes (41.6) and *R. reniformis* (28.1). *M. incognita* was observed with a prominence value of 12.8. *M. incognita, Helicotylenchus* sp. and free living nematode were the more frequently occurring nematodes with highest relative frequency (26.7), followed by

Table 24.Community analysis of nematodes in Puthoor Village (Location 2) of Kanthalloor Panchayath at Idukki District

Nematode species	Absolute frequency	Relative frequency	Absolute density	Relative density	Prominence value
M. incognita	100	26.7	128.0	7.8	12.8
Helicotylenchus sp.	100	26.7	776.0	47.2	77.6
R. reniformis	75	20.0	324.0	19.7	28.1
Free living	100	26.7	416.0	25.3	41.6

Table 25. Community analysis of nematodes in Puthoor Village(Location 3) of Kanthalloor Panchayath at Idukki District

Nematode species	Absolute frequency	Relative frequency	Absolute density	Relative density	Prominence value
Helicotylenchus sp.	100	50.0	228.0	20.3	22.8
Free living	100	50.0	896.0	79.7	89.6

Table 26. Community analysis of nematodes in Puthoor Village (Location 4) of Kanthalloor Panchayath at Idukki District

Nematode species	Absolute frequency	Relative frequency	Absolute density	Relative density	Prominence value
Helicotylenchus sp.	75	23.1	984.0	21.2	85.2
R.reniformis	75	23.1	1496.0	32.0	125.6
Tylenchorhynchus sp.	75	23.1	208.0	4.5	18.0
Free living	100	30.8	1988.0	42.5	198.8

reniform nematode with a relative frequency of 20.0. Highest relative density was observed in *Helicotylenchus* sp. (47.2) followed by free living nematodes (25.3) and lowest by *M. incognita* (7.8).

Free living nematodes recorded the highest prominence value of 89.6 followed by *Helicotylenchus* sp. (22.8) in Location 3 of Puthoor village (Table 25.). Highest relative density was recorded by free living nematodes (79.7) followed by *Helicotylenchus* sp. (20.3).

The results presented in Table 26. showed that *R. reniformis, Helicotylenchus* sp. *and Tylenchorhynchus* sp. were the plant parasitic nematode species identified from Location 4 of Puthoor village. Free living nematodes were observed with the highest prominence value of 198.8, followed by *R. reniformis* (125.6), *Helicotylenchus* sp. (85.2) and the lowest by *Tylenchorhynchus* sp. (18.0). Free living nematodes were the most frequently occurring nematodes with highest relative frequency (30.8) followed by *Helicotylenchus* sp. (23.1), *R. reniformis* (23.1) and *Tylenchorhynchus* sp. (23.1). Highest relative density was recorded by free living nematodes (42.5) followed by *R. reniformis* (32.0), *Helicotylenchus* sp. (21.2) and *Tylenchorhynchus* sp. (4.5).

4.1.4.4. Community Analysis of Nematodes in Perumala Village

In Location 1 of Perumala village *Helicotylenchus* sp. recorded the highest prominence value (68.6) followed by free living nematodes (64.8). *M. incognita* showed a prominence value of 58.4 (Table 27.). Highest relative frequency was recorded by *M. incognita* (22.5) followed by *R. reniformis* (22.22), free living nematodes (22.2), *Helicotylenchus* sp. (16.67) and *Tylenchorhynchus* sp. (16.7). *Helicotylenchus* sp. was the most abundant

Table 27. Community analysis of nematodes in Perumala Village (Location 1) of Kanthalloor Panchayath at Idukki District

Nematode species	Absolute frequency	Relative frequency	Absolute density	Relative density	Prominence value
M. incognita	100	22.5	584.0	20.5	58.4
Helicotylenchus sp.	75	16.67	792.0	27.9	68.6
R. reniformis	100	22.22	620.0	21.8	62.0
Tylenchorhynchus sp.	75	16.7	200.0	7.0	17.3
Free living nematodes	100	22.2	648.0	22.8	64.8

Table 28. Community analysis of nematodes in Perumala Village (Location 2) of Kanthalloor Panchayath at Idukki District

Nematode species	Absolute frequency	Relative frequency	Absolute density	Relative density	Prominence value
M. incognita	100	22.2	672.0	30.0	64.2
Helicotylenchus sp.	100	22.2	64.0	2.9	6.4
R. reniformis	100	22.2	100.0	4.5	10.0
Tylenchorhynchus sp.	50	11.1	952.0	42.4	67.3
Free living	100	22.2	456.0	29.0	45.6

species with a relative density of 27.9. *Tylenchorhynchus* sp. recorded the lowest relative density of 7.0.

The results presented in Table 28. revealed that *Tylenchorhynchus* sp. to be the most prominent nematode with a prominence value of 67.3 followed by *M. incognita* (64.2), free living nematodes (45.6) and *R. reniformis* (10.0) in location 2 in Perumala area. The lowest prominence value (6.4) was found in *Helicotylenchus* sp. The highest relative frequency of 22.2 was observed for *M. incognita, Helicotylenchus* sp., *R. reniformis* and free living nematodes. Relative density was found to be high in *Tylenchorhynchus* sp. (42.4) followed by *M.incognita* (30.0). The least relative density (2.9) was recorded by *Helicotylenchus* sp.

Community analysis of nematodes in Location 3 in Perumala area (Table 29.) revealed that the most prominent nematode was *Helicotylenchus* sp. (248.4) followed by free living nematodes (96.8) and *R. reniformis* (83.1). The highest relative frequency was recorded by *M. incognita, Helicotylenchus* sp. and free living nematodes (26.7). *R. reniformis* showed the lowest frequency of 20.0. Most abundant nematode was *Helicotylenchus* sp. with a relative density of 48.0 followed by free living nematodes (18.7) and *R. reniformis* (18.6).

Data on community analysis of nematodes in Location 4 in Perumala area (Table 30.) showed the presence of *Helicotylenchus* sp., *M. incognita, R. reniformis* and free living nematodes. The highest prominence value was recorded by *M. incognita* (85.6) followed by free living nematodes (83.2). *Helicotylenchus* sp. (49.5) and *R. reniformis* (35.2). Maximum relative frequency (28.6) was observed in free living nematodes and *R. reniformis* followed by *Helicotylenchus* sp. and *M. incognita* with a relative frequency of

Table 29. Community analysis of nematodes in Perumala Village (Location 3) of Kanthalloor Panchayath at Idukki District

Nematode species	Absolute frequency	Relative frequency	Absolute density	Relative density	Prominence value
M. incognita	100	26.7	760.0	14.7	76.0
Helicotylenchus sp.	100	26.7	2484.0	48.0	248.4
R. reniformis	75	20.0	960.0	18.6	83.1
Free living	100	26.7	968.0	18.7	96.8

Table 30. Community analysis of nematodes in Perumala Village (Location 4) of Kanthalloor Panchayath at Idukki District

Nematode species	Absolute frequency	Relative frequency	Absolute density	Relative density	Prominence value
M. incognita	75	21.4	988.0	36.0	85.6
Helicotylenchus sp.	75	21.4	572.0	20.9	49.5
R.reniformis	100	28.6	352.0	12.8	35.2
Free living	100	28.6	832.0	30.3	83.2

21.4. The most abundant nematodes were *M. incognita* (36.0) followed by free living forms (30.3) *Helicotylenchus* sp. (20.9) and the lowest relative density was observed in *R. reniformis* (12.8).

In Location 5 of Perumala area (Table 31.) *Helicotylenchus* sp. showed the highest prominence value (140.0) followed by free living nematodes (63.2) *M. incognita* (47.2) and *R. reniformis* (42.0). All the nematodes showed the relative frequency value 25.0.The most abundant nematodes were *Helicotylenchus* sp. with a relative density of 47.9 and the least prominent nematode was *R. reniformis* (14.4).

4.1.5. Community Analysis of Nematodes on Cabbage in Kollam District

4.1.5.1. Community Analysis of Nematodes in Anchal Panchayath

The results presented in Table 32. revealed that the prominent nematodes in Anchal village of Anchal panchayath was free living nematodes with a prominence value of 190.7 followed by *R. reniformis* and *Helicotylenchus* sp. (36.4). Relative frequency value for all the nematodes in that area was found to be 33.3. Maximum relative density was recorded by free living nematodes (72.3) followed by *R. reniformis* (13.8) and *Helicotylenchus* sp. (13.8).

The survey from Chemmakkad village of Anchal panchayath revealed the presence of free living nematodes and *R. reniformis*. Free living forms recorded highest prominence value of 285.1 followed by *R. reniformis* (31.5). Highest relative frequency was observed in free living forms (57.1) followed by *R. reniformis* (42.9). Maximum relative density was recorded by *R. reniformis* (113.0) followed by free living nematodes (88.7) (Table 33.)

Table 31. Community analysis of nematodes in Perumala Village (Location 5) of Kanthalloor Panchayath at Idukki District

Nematode species	Absolute frequency	Relative frequency	Absolute density	Relative density	Prominence value
M. incognita	100	25.0	472.0	16.14	47.2
Helicotylenchus sp.	100	25.0	1400.0	47.9	140.0
R.reniformis	100	25.0	420.0	14.4	42.0
Free living	100	25.0	632.0	21.6	63.2

Table 32. Community analysis of nematodes in Anchal Village of Anchal Panchayath at Kollam District

Nematode species	Absolute frequency	Relative frequency	Absolute density	Relative density	Prominence value
R.reniformis	100	33.3	363.6	13.8	36.4
Helicotylenchus sp.	100	33.3	363.6	13.8	36.4
Free living	100	33.3	1907.8	72.3	190.7

Table 33. Community analysis of nematodes in Chemmakkad Village of Anchal Panchayath at Kollam District

Nematode species	Absolute frequency	Relative frequency	Absolute density	Relative density	Prominence value
R. reniformis	75	42.9	363.6	113	31.5
Free living	100	57.1	2850.9	88.7	285.1

Free living nematodes showed the highest prominence value (59.6) followed by *R. reniformis* (53.3) in Panayamcherry village of Anchal panchayath (Table 34). All the nematode species recorded the same relative frequency (50.0). Free living nematodes were the most abundant nematodes (52.6) in the soil followed by *R. reniformis* (47.4).

The results of Kottukkal village of Anchal panchayath (Table 35.) revealed that the highest prominence value was observed in *M. incognita* (63.9) followed by free living nematodes (40.6) and *R. reniformis* (32.0). Free living nematodes were the most frequently occurring nematode with the highest relative frequency (40.0), followed by *M. incognita* and *R. reniformis* (30.0). Highest relative density was observed in *M. incognita* (48.8) followed by free living nematodes (26.8) and *R. reniformis* (24.4).

The data showing the community analysis of nematodes associated with cabbage grown in Thazhamel village of Anchal panchayath, revealed the occurrence of *M. incognita, Helicotylenchus* sp. and free living nematodes (Table 36.). The most abundant nematode was free living nematodes with a prominence value of 223.2 followed by *M. incognita* and *Helicotylenchus* sp. (45.0).The most frequently occurring nematode was free living nematode with highest relative frequency of 40.0 followed by *M. incognita* and *Helicotylenchus* sp. (30.0).Relative density was found to be high for free living nematodes (65.0) followed by *Helicotylenchus* sp. (19.8). Lowest relative density was recorded by *M. incognita* (15.2).

The results of community analysis of nematodes associated cabbage grown in Vazhakkal village of Anchal panchayath were presented in Table 37. *Helicotylenchus* sp, free living nematodes, *M. incognita* and *R. reniformis* were the plant parasitic nematodes recorded. Prominence value was found to

Table 34. Community analysis of nematodes in Panayamcherry Village of Anchal Panchayath at Kollam District

Nematode species	Absolute frequency	Relative frequency	Absolute density	Relative density	Prominence value
R. reniformis	100	50.0	533.3	47.4	53.3
Free living	100	50.0	595.6	52.6	59.6

Table 35. Community analysis of nematodes in Kottukkal Village of Anchal Panchayath at Kollam District

Nematode species	Absolute frequency	Relative frequency	Absolute density	Relative density	Prominence value
M. incognita	75	30.0	738.5	48.8	63.9
R. reniformis	75	30.0	369.2	24.4	32.0
Free living	100	40.0	406.2	26.8	40.6

Table 36. Community analysis of nematodes in Thazhamel Village of Anchal Panchayath at Kollam District

Nematode species	Absolute frequency	Relative frequency	Absolute density	Relative density	Prominence value
M.incognita	75	30.0	520.0	15.2	45.0
Helicotylenchus sp.	75	30.0	680.0	19.8	45.0
Free living	100	40.0	2232.0	65.0	223.2

be highest in free living nematodes (56.0) followed by *Helicotylenchus* sp. (51.1) *M. incognita* (33.1) and *R. reniformis* (20.2). Relative frequency values of all the nematodes were the same (25.0). Relative density of free living nematodes was highest (34.9) followed by *Helicotylenchus* sp. (31.8), *M. incognita* (20.7) and *R. reniformis* (12.6).

4.1.5.2. Community Analysis of Nematodes in Eroor Panchayath

The results presented in Table 38. revealed that the highest relative frequency was shown by free living nematodes and *Helicotylenchus* sp (40.0) followed by *Xiphinema* sp. (20.0) in Eroor village of Eroor panchayath. The free living nematodes were found to be most abundant forms (242.5) followed by *Helicotylenchus* sp. (167.3) and *Xiphinema* sp. (2.6). Free living nematodes showed highest relative density (58.7) followed by *Helicotylenchus* sp. (40.5) and *Xiphinema* sp. (0.9).

Community analysis of nematodes associated with cabbage in Alancherry village in Eroor Panchayath (Table 39.) revealed that the most prominent nematode was *R. reniformis* (96.0) followed by free living forms (59.6). All the nematode species identified showed a relative frequency of 50.0. Most abundant nematode was *R. reniformis* (61.7) followed by free living forms (38.3).

In Vilakkupara village of Eroor panchayath, highest prominence value was recorded by *M. incognita* (124.0) followed by free living nematodes (67.6), *R. reniformis* (65.1) and the lowest was recorded by *Xiphinema* sp. (6.0) (Table 40). The highest relative frequency was recorded by *M. incognita* and *Xiphinema* sp. (25.0), followed by *Helicotylenchus* sp. and *R. reniformis* (18.8). Highest relative density was recorded by *M. incognita* (34.4) followed

Table 37. Community analysis of nematodes in Vazhakkal Village of Anchal Panchayath at Kollam District

Nematode species	Absolute frequency	Relative frequency	Absolute density	Relative density	Prominence value
M. incognita	100	25.0	331.4	20.7	33.1
R.reniformis	100	25.0	201.9	12.6	20.2
Helicotylenchus sp.	100	25.0	510.5	31.8	51.1
Free living	100	25.0	560.0	34.9	56.0

Table 38. Community analysis of nematodes in Eroor Village in Eroor Panchayath at Kollam District

Nematode species	Absolute frequency	Relative frequency	Absolute density	Relative density	Prominence value
Helicotylenchus sp.	100	40.0	1672.7	40.5	167.3
Xiphinema sp.	50	20.0	36.4	0.9	2.6
Free living	100	40.0	2425.5	58.7	242.5

Table 39. Community analysis of nematodes in Alancherry Village of Eroor Panchayath at Kollam District

Nematode species	Absolute frequency	Relative frequency	Absolute density	Relative density	Prominence value
R.reniformis	100	50.0	960.0	61.7	96.0
Free living	100	50.0	590.0	38.3	59.6

by free living nematodes (26.4). *Xiphinema* sp. recorded the lowest relative density (1.7).

The survey from Aylara village of Eroor panchayath revealed the presence of *M. incognita* and free living nematodes (Table 41.). Relative frequency values of all the nematode species in the area was recorded as 50.0 Free living nematodes was found to be the most abundant nematode with a relative density of 84.1 and prominence value of 285.2 followed by *M. incognita* with a relative density of 15.9 and prominence value of 54.1.

4.1.5.3. Community Analysis of Nematodes in Alayamon Panchayath

M. incognita and free living nematodes were the most frequently occurring nematodes found associated with cabbage grown in Alayamon village of Eroor (Table 42.). Free living nematode was found to be the most prominent nematode with a prominence value of 183.5 followed by *M. incognita* (71.2). The relative frequency values of both the nematodes were 50.0. Free living nematode was the most abundant nematode with a relative density of 72.1.

4.1.5.4. Community Analysis of Nematodes in Karavaloor Panchayath

R. reniformis, Helicotylenchus sp. and free living nematodes were recorded from rhizosphere of cabbage grown in Karavaloor village of Karavaloor panchayath (Table 43). *R. reniformis* was found to be the most abundant nematode in the area with a prominence value of 80.0 and relative density of 40.7 followed by free living nematodes with a prominence value of 66.7 and relative density of 33.9. All the nematodes showed the same relative frequency (33.3).

Table 40. Community analysis of nematodes in Vilakkupara Village of Eroor Panchayath at Kollam District

Nematode species	Absolute frequency	Relative frequency	Absolute density	Relative density	Prominence value
M.incognita	100	25.0	1240.0	34.4	124.0
R.reniformis	75	18.8	752.0	20.8	65.1
Helicotylenchus sp.	75	18.8	600.0	16.6	52.0
Xiphinema sp.	100	25.0	60.0	1.7	6.0
Free living	50	12.5	956.0	26.4	67.6

Table 41. Community analysis of nematodes in Aylara Village of Eroor Panchayath at Kollam District

Nematode species	Absolute frequency	Relative frequency	Absolute density	Relative density	Prominence value
M.incognita	100	50.0	540.8	15.9	54.1
Free living	100	50.0	2851.2	84.1	285.2

Table 42. Community analysis of nematodes in Alayamon Village of Alayamon Panchayath at Kollam District

Nematode species	Absolute frequency	Relative frequency	Absolute density	Relative density	Prominence value
M.incognita	100	50.0	711.6	27.9	71.2
Free living	100	50.0	1835.8	72.1	183.5

4.1.5.5. Community Analysis of Nematodes in Edamulackal Panchayath

Four different species of nematodes were recorded in soil samples collected from rhizosphere of cabbage in Edamulackal village of Edamulackal panchayath (Table 44.). Free living forms recorded the highest prominence value of 138.7 followed by *R. reniformis* (43.3) and *M. incognita* (42.5). *Helicotylenchus* sp. showed lowest prominence value (33.3). *Helicotylenchus* sp. and free living nematodes exhibited highest relative frequency (30.8) followed by *R. reniformis* (23.1) and the lowest was by *M.incognita* (15.4). Free living nematodes showed highest relative density (49.2) followed by *M. incognita* (21.3), *R. reniformis* (17.7) and *Helicotylenchus* sp. (11.8).

4.1.6. Community Analysis of Nematodes on Cabbage in Thiruvananthapuram District

4.1.6.1. Community Analysis of Nematodes in Uzhamalaikal Panchayath

The results presented in Table 45. revealed that prominent nematodes in Uzhamalaikal village in Uzhamalaikal panchayath was free living nematodes (116.8) followed by *Helicotylenchus* sp. and *R. reniformis* with a prominence value of 22.4 and 16.6 respectively. The highest relative frequency was recorded by *Helicotylenchus* sp. and free living nematodes (36.4). The most abundant nematodes in Uzhamalaikal village was free living nematodes with a relative density of 73.7. The relative density of *Helicotylenchus* sp. was 14.1 followed by and *R. reniformis* (12.1).

Table 43.Community analysis of nematodes in Karavaloor Village of Karavaloor Panchayath at Kollam District

Nematode species	Absolute frequency	Relative frequency	Absolute density	Relative density	Prominence value
R. reniformis	100	33.3	800.0	40.7	80.0
Helicotylenchus sp.	100	33.3	500.0	25.4	50.0
Free living	100	33.3	666.7	33.9	66.7

Table 44. Community analysis of nematodes in Edamulackal Village of Edamulackal Panchayath at Kollam District

Nematode species	Absolute frequency	Relative frequency	Absolute density	Relative density	Prominence value
M.incognita	50	15.4	600.8	21.3	42.5
R. reniformis	75	23.1	500.0	17.7	43.3
Helicotylenchus sp.	100	30.8	333.3	11.8	33.3
Free living	100	30.8	1386.7	49.2	138.7

Table 45. Community analysis of nematodes in Uzhamalaical Village of Uzhamalaical Panchayath at Thiruvananthapuram District

Nematode species	Absolute frequency	Relative frequency	Absolute density	Relative density	Prominence value
Helicotylenchus sp.	100	36.4	224.0	14.1	22.4
R.reniformis	75	27.3	192.0	12.1	16.6
Free living	100	36.4	1168.0	73.7	116.8

4.1.6.2. Community Analysis of Nematodes in Kulathoor Panchayath

Helicotylenchus sp. was the prominent plant parasitic nematode in Kulathoor village of Kulathoor panchayath with a prominence value of 27.6 (Table 46.). However free living nematodes recorded the prominence value of 95.6. The relative density of free living nematodes was higher (77.6) followed by *Helicotylenchus* sp. (22.4). The relative frequency for both these nematodes were found to be the same (50.0).

4.1.6.3. Community analysis of nematodes in Athiyanoor Panchayath

Two plant parasitic nematodes were recorded in soil samples collected from Athiyanoor village (Table 47.). *Helicotylenchus* sp. (70.5) was the most prominent nematode followed by *Tylenchorhynchus* sp. (63.0) and free living nematodes (29.7). *Helicotylenchus* sp. and *Tylenchorhynchus* sp. exhibited highest relative frequency (40.0) followed by free living nematodes (20.0). The most abundant nematodes were *Helicotylenchus* sp. followed by *Tylenchorhynchus* sp. and free living nematodes with relative density values of 40.2, 35.9 and 23.9 respectively.

4.1.6.4. Community Analysis of Nematodes in Balaramapuram Panchayath

Community analysis of nematodes associated with cabbage in Thembamuttam village of Balaramapuram (Table 48.) showed that free living forms to be the most prominent nematodes (129.2) followed by *Helicotylenchus* sp. and *M. incognita* with a prominence value of 69.2 and 15.6 respectively. All the nematode species identified from that area was found to have a relative frequency of 33.3. The relative density of *Helicotylenchus* sp. and *M. incognita* was found to be 32.3 and 7.3 respectively

Table 46. Community analysis of nematodes in Kulathoor Village of Kulathoor Panchayath at Thiruvananthapuram District

Nematode species	Absolute frequency	Relative frequency	Absolute density	Relative density	Prominence value
Helicotylenchus sp.	100	50.0	276.0	22.4	27.6
Free living	100	50.0	956.0	77.6	95.6

Table 47. Community analysis of nematodes in Athiyanoor Village of Athiyanoor Panchayath at Thiruvananthapuram District

Nematode species	Absolute frequency	Relative frequency	Absolute density	Relative density	Prominence value
Helicotylenchus sp.	100	40.0	705.0	40.2	70.5
Tylenchorhynchus sp.	100	40.0	630.0	35.9	63.0
Free living	50	20.0	420.0	23.9	29.7

Table 48. Community analysis of nematodes in Thembamuttam Village of Balaramapuram Panchayath at Thiruvananthapuram District

Nematode species	Absolute frequency	Relative frequency	Absolute density	Relative density	Prominence value
M.incognita	100	33.3	156.0	7.3	15.6
Helicotylenchus sp.	100	33.3	692.0	32.3	69.2
Free living	100	33.3	1292.0	60.4	129.2

4.1.6.5. Community Analysis of Nematodes in Athiyanoor Panchayath

Results presented in Table 49. showed that free living forms were the most prominent nematodes in Aralumoodu village with prominence value of 211.6 followed by *Helicotylenchus* sp. (71.6), *R. reniformis* (60.0) and *Tylenchorhynchus* sp. (25.7). The highest relative frequency was recorded by *Helicotylenchus* sp. and free living nematodes (33.3) followed by *R. reniformis* and *Tylenchorhynchus* sp. (16.7).

M. incognita, Helicotylenchus sp., *R. reniformis* and free living forms were the nematodes recorded from rhizosphere of cabbage grown in Nellimood village of Athiyanoor panchayath .The free living forms were the most prominent nematodes followed by *Helicotylenchus* sp., *R. reniformis* and *M. incognita* with a prominence value of 250.8, 63.2, 55.2 and 20.8 respectively (Table 50.).The most abundant plant parasitic nematodes was *R. reniformis* with a relative density of 18.9 followed by *Helicotylenchus* sp. (15.3) and *M. incognita* (5.0).

4.1.6.6. Community Analysis of Nematodes in Kutticahl Panchayath

Free living nematodes showed highest prominence value of 291.6 followed by *Helicotylenchus* sp. (130.0) and lowest by *M. incognita* (71.6) in Kuttichal village of Kuttichal panchayath. Highest relative density was recorded by free living forms (59.1) followed by *Helicotylenchus* sp. (26.4) and *M. incognita* (14.5). All the nematodes recorded a uniform relative frequency of 33.3 (Table 51).

Table 49. Community analysis of nematodes in Aralumoodu Village of Athiyanoor Panchayath at Thiruvananthapuram District

Nematode species	Absolute frequency	Relative frequency	Absolute density	Relative density	Prominence value
Helicotylenchus sp.	100	33.3	716.0	17.7	71.6
R.reniformis	50	16.7	848.0	21.0	60.0
Tylenchorhynchus sp.	50	16.7	364.0	9.0	25.7
Free living	100	33.3	2116.0	52.3	211.6

Table 50.Community analysis of nematodes in Nellimoodu Village of Athiyanoor Panchayath at Thiruvananthapuram District

Nematode species	Absolute frequency	Relative frequency	Absolute density	Relative density	Prominence value
M. incognita	100	28.6	208.0	5.0	20.8
Helicotylenchus sp.	100	28.6	632.0	15.3	63.2
R. reniformis	50	14.3	780.0	18.9	55.2
Free living	100	28.6	2508.0	60.8	250.8

Table 51. Community analysis of nematodes in Kuttichal Village of Kuttichal Panchayath at Thiruvananthapuram District

Nematode species	Absolute frequency	Relative frequency	Absolute density	Relative density	Prominence value
M incognita	100	33.3	716.0	14.5	71.6
Helicotylenchus sp.	100	33.3	1300.0	26.4	130.0
Free living	100	33.3	2916.0	59.1	291.6

4.1.6.7. Community Analysis of Nematodes in Kanjiramkulam Panchayath

The results of community analysis of Kanjiramkulam village of Kanjiramkulam panchayath (Table 52.) revealed that the highest prominence value was recorded by free living nematodes (462.5) followed by *Helicotylenchus* sp., *R. reniformis* and *M. incognita* with a prominence value of 216, 72.8 and 46.0 respectively. The most frequently occurring nematodes were *M. incognita, Helicotylenchus* sp. and free living nematodes with a relative frequency of 27.8. *R. reniformis* recorded a relative frequency of 16.7. Maximum relative density was observed in free living nematodes (56.5) followed by *Helicotylenchus* sp., *R. reniformis* and *M. incognita* with a relative density of 26.4, 11.5 and 5.6 respectively.

4.1.6.8. Community Analysis of Nematodes in Karakulam Panchayath

M. incognita, R. reniformis and *Helicotylenchus* sp. were the plant parasitic nematodes associated with cabbage in Eanikkara area of Karakulam panchayath (Table 53.). Free living nematodes were found to be the most abundant nematode with a prominence value of 175 .The highest relative frequency was recorded by *Helicotylenchus* sp. and free living forms (31.2) followed by *R. reniformis* (25.0) and *M. incognita* (12.5). Maximum relative density was recorded by free living forms (44.2) followed by *Helicotylenchus* sp. (20.5), *R. reniformis*(18.9) and *M. incognita*(10.4).

4.1.6.9. Community Analysis of Nematodes in Kottukal Panchayath

The results of community analysis of nematodes associated with the rhizosphere of cabbage grown in Kottukal village of Kottukal panchayath were presented in Table 54. *Helicotylenchus* sp., *M.incognita, Tylenchorhynchus* sp. and *R. reniformis* were the plant parasitic nematodes

Table 52. Community analysis of nematodes in Kanjiramkulam Village of Kanjiramkulam Panchayath at Thiruvananthapuram District

Nematode species	Absolute frequency	Relative frequency	Absolute density	Relative density	Prominence value
M.incognita	100	27.8	460.0	5.6	46.0
Helicotylenchus sp.	100	27.8	2160.0	26.4	216.0
R.reniformis	60	16.7	940.0	11.5	72.8
Free living	100	27.8	4625.0	56.5	462.5

Table 53. Community analysis of nematodes in Eanikkara Village of Karakulam Panchayath at Thiruvananthapuram District

Nematode species	Absolute frequency	Relative frequency	Absolute density	Relative density	Prominence value
M. incognita	40	12.5	410.0	10.4	25.9
Helicotylenchus sp.	100	31.2	1050.0	20.5	105.0
R. reniformis	80	25.0	750.0	18.9	67.1
Free living	100	31.2	1750.0	44.2	175

recorded. Prominence value was found to be high in *M. incognita* (104.8). *M. incognita* was the most abundant nematode in Kottukal area with a relative density value of 42.5 followed by free living nematodes, *Helicotylenchus* sp., *R. reniformis* and *Tylenchorhynchus* sp. with relative density values of 26.5, 15.1, 9.1 and 6.8 respectively.

4.1.6.10. Community Analysis of Nematodes in Vellanadu Panchayath

Analysis of soil samples collected from Vellanadu village of Vellanadu panchayath revealed the occurrence *M. incognita*, *Helicotylenchus* sp., *R. reniformis* and free living nematodes. The prominence value of free living nematodes, *Helicotylenchus* sp., *R. reniformis* and *M. incognita* were recorded as 97.6, 31.6, 30.4 and 6 .0 respectively. Free living nematodes were found to be the most abundant nematode with a relative density of 56.9 followed by *Helicotylenchus* sp., *R. reniformis* and *M. incognita* with relative abundance of 18.4, 17.7 and 7.0 respectively. *Helicotylenchus* sp., *R. reniformis* and free living nematodes recorded a relative frequency of 30.8 followed by *M. incognita* with a relative frequency of 7.7. (Table 55.)

4.1.6.11. Community Analysis of Nematodes in Kalliyoor Panchayath

The results of community analysis of nematodes associated with cabbage from Kalliyoor village in Kalliyoor panchayath (Table 56.) revealed *Helicotylenchus* sp., to be the important plant parasitic nematode with prominence value of 126.0. The lowest prominence value was recorded by free living nematode (97.0). *Helicotylenchus* sp. and free living species recorded relative density values of 56.5 and 43.5 respectively.

In Vellayani village of Kalliyoor panchayath free living forms were the most abundant nematodes with a relative density of 41.2 and a prominence

Table 54. Community analysis of nematodes in Kottukal Village of Kottukal Panchayath at Thiruvananthapuram District

Nematode species	Absolute frequency	Relative frequency	Absolute density	Relative density	Prominence value
M. incognita	100	23.5	1048.0	42.5	104.8
Helicotylenchus sp.	75	17.7	372.0	15.1	32.2
R.reniformis	100	23.5	224.0	9.1	22.4
Tylenchorhynchus sp.	50	11.8	168.0	6.8	11.9
Free living	100	23.5	652.0	26.5	65.2

Table 55. Community analysis of nematodes in Vellanadu Village of Vellanadu Panchayath at Thiruvananthapuram District

Nematode species	Absolute frequency	Relative frequency	Absolute density	Relative density	Prominence value
M. incognita	25	7.7	120.0	7.0	6.0
Helicotylenchus sp.	100	30.8	316.0	18.4	31.6
R.reniformis	100	30.8	304.0	17.7	30.4
Free living	100	30.8	976.0	56.9	97.6

Table 56. Community analysis of nematodes in Kalliyoor Village of Kalliyoor Panchayath at Thiruvananthapuram District

Nematode species	Absolute frequency	Relative frequency	Absolute density	Relative density	Prominence value
Helicotylenchus sp.	100	50.0	1260.0	56.5	126.0
Free living	100	50.0	970.0	43.5	97.0

Table 57.Community analysis of nematodes in Vellayani Village of Kalliyoor Panchayath at Thiruvananthapuram District

Nematode species	Absolute frequency	Relative frequency	Absolute density	Relative density	Prominence value
M. incognita	100	22.2	1024.0	16.0	102.4
Helicotylenchus sp.	100	22.2	1332.0	20.8	133.2
R.reniformis	50	11.1	636.0	9.9	44.9
Tylenchorhynchus sp.	50	11.1	600.0	9.4	42.4
R.similis	50	11.1	180.0	2.8	12.7
Free living	100	22.2	2644.0	41.2	264.4

value of 264.4 (Table 57.). *R. similis* recorded the lowest relative density of 2.8 and prominence value of 12.7. The highest relative frequency was recorded by all the three nematodes *viz. M. incognita, Helicotylenchus* sp. *and* free living nematodes (22.2).However the lowest relative frequency was recorded by *R. reniformis, R. similis* and *Tylenchorhynchus* sp. (11.1)

4.2. *IN VITRO* SCREENING OF PLANT EXTRACTS FOR NEMATICIDAL PROPERTY.

4.2.1. Effect on Egg Hatching

Effect of different extracts showed statistically significant variation in the hatching of eggs from three to eight days after treatment (Table 58.). On the first and second day there was 100 % hatching inhibition in all the treatments.

On the third day minimum hatching (1.00 %) was observed in *T. diversifolia* at 100 % concentration (conc.). The lower concentrations (50, 33.3 and 25 % conc.) of *T. diversifolia* also showed significant variation on egg hatching ranging from 3.00 to 7.49 %. The effect of these treatments was statistically significant among them and also with other plant extracts of *C. odorata, L. camara* and *E. crassipes. C. odorata* (100 % conc.) was inferior to *T. diversifolia* at all concentrations but superior to lower concentrations of *C. odorata* giving a hatching percentage of 9.49 %. Egg hatching percentage in *C. odorata* (50 % conc.) and *L. camara* (100 % conc.) was statistically on par and inferior to all concentrations of *T. diversifolia.* These treatments were inferior *C. odorata* (100 % conc.) but was superior to other treatments and control. The effect of root extract of *C. odorata* (50 % conc.) and *L. camara* (100 % conc.) was on par giving 11.50 and 11.98 % hatching of eggs respectively. The latter one was on par with *C. odorata*

Table 58. Effect of weed plant extracts on hatching of *M.incognita* egg *in vitro*

Plant species	Concentration in percentage	Percentage of egg hatching for different exposure time (in days)							
		1D	2D	3D	4D	5D	6D	7D	8D
Chromolaena odorata	T_1 (100%)	0.00	0.00	9.49(3.08)^{e}	12.49(3.54)^{e}	12.98(3.60)^{e}	14.50(3.80)^{e}	14.00(3.74)^{e}	13.98(3.74)^{e}
	T_2 (50%)	0.00	0.00	11.50(3.39)^{f}	14.98(3.87)^{f}	15.50(3.94)^{f}	16.50(4.06)^{f}	16.99(4.12)^{f}	15.50(3.94)^{e}
	T_3 (33.3%)	0.00	0.00	13.50(3.67)^{g}	17.00(4.12)^{fg}	16.99(4.12)^{f}	18.50(4.30)^{g}	19.00(4.36)^{fg}	18.99(4.36)^{f}
	T_4 (25%)	0.00	0.00	16.99(4.12)^{h}	17.50(4.18)^{g}	18.50(4.30)^{g}	19.50(4.42)^{h}	20.50(4.53)^{gh}	22.00(4.69)^{g}
Tithonia diversifolia	T_5 (100%)	0.00	0.00	1.00(1.00)^{a}	1.00(1.00)^{a}	1.00(1.00)^{a}	1.46(1.21)^{a}	1.87(1.37)^{a}	1.46(1.21)^{a}
	T_6 (50%)	0.00	0.00	3.00(1.73)^{b}	4.49(2.12)^{b}	5.49(2.34)^{b}	5.96(2.44)^{b}	6.49(2.55)^{b}	7.00(2.65)^{b}
	T_7 (33.3%)	0.00	0.00	4.95(2.22)^{c}	6.96(2.64)^{c}	7.49(2.74)^{c}	7.49(2.74)^{c}	8.49(2.91)^{c}	9.00(3.00)^{c}
	T_8 (25%)	0.00	0.00	7.49(2.74)^{d}	8.49(2.91)^{d}	9.98(3.16)^{d}	10.49(3.24)^{d}	11.00(3.32)^{d}	11.50(3.39)^{d}
Lantana camara	T_9 (100%)	0.00	0.00	11.98(3.46)^{fg}	16.50(4.06)^{f}	20.95(4.58)^{g}	22.99(4.80)^{i}	23.50(4.85)^{h}	25.00(5)^{h}
	T_{10} (50%)	0.00	0.00	17.49(4.18)^{h}	20.50(4.53)^{h}	25.50(5.05)^{h}	27.00(5.20)^{j}	26.99(5.20)^{i}	27.50(5.24)^{hi}
	T_{11} (33.3%)	0.00	0.00	19.99(4.47)^{i}	21.99(4.69)^{h}	26.50(5.15)^{h}	26.99(5.20)^{j}	27.48(5.24)^{i}	27.99(5.29)^{i}
	T_{12} (25%)	0.00	0.00	22.50(4.74)^{j}	26.99(5.20)^{i}	28.50(5.34)^{i}	29.99(5.48)^{l}	31.48(5.61)^{j}	32.48(5.70)^{j}
Eichhornia crassipes	T_{13} (100%)	0.00	0.00	21.99(4.69)^{j}	25.99(5.10)^{i}	28.50(5.34)^{i}	29.50(5.43)^{k}	31.00(5.57)^{j}	31.99(5.66)^{j}
	T_{14} (50%)	0.00	0.00	25.50(5.05)^{k}	28.50(5.34)^{i}	30.00(5.48)^{i}	31.99(5.66)^{m}	34.50(5.87)^{j}	36.00(6.00)^{k}
	T_{15} (33.3%)	0.00	0.00	31.50(5.61)^{l}	35.00(5.92)^{j}	37.50(6.12)^{j}	39.50(6.29)^{n}	40.00(6.32)^{k}	40.50(6.36)^{l}
	T_{16} (25%)	0.00	0.00	36.50(6.04)^{m}	38.50(6.21)^{k}	40.00(6.32)^{j}	40.50(6.36)^{o}	42.50(6.52)^{k}	43.99(6.63)^{m}
Control	T_{17}	0.00	0.00	78.99(8.89)^{n}	88.48(9.41)^{l}	97.99(9.90)^{k}	101.00(10.1)^{p}	101.00(10.1)^{k}	101.00(10.1)^{p}
CD(0.05)				(0.291)	(0.273)	(2.292)	(0.040)	(0.341)	(0.262)

Figures in the parenthesis are square root transformed values *D-Day

(33.3 % conc.). The percentage of egg hatching in *C. odorata* (25 % conc.) was higher than all the other concentrations of *C. odorata* (100, 50 and 33.3 %) but it was on par with *L. camara* (50 % conc.) giving 16.99 and 17.49 % egg hatching respectively. *L. camara* at 33.3 % concentration recorded 19.99 % hatching of eggs of *M. incognita* which was inferior to *L. camara* (50 %). Effect of *E. crassipes* (100 % conc.) and *L. camara* (25 % conc.) was statistically on par giving 21.99 and 22.50 % of egg hatching respectively. These treatments were inferior to *L. camara* at 33.3 % conc. Lower concentrations of *E. crassipes* (50, 33.3 and 25 % conc.) were the least effective leaf extract in the inhibition of egg hatching and the effect of these treatments was statistically significant among them giving 25.50, 31.50 and 36.50 % hatching of eggs respectively.

Maximum inhibition was observed in *T. diversifolia* (100 % conc.) fourth day after the treatment. Statistically significant variation was obtained among lower dilutions of *T. diversifolia* (50, 33.3 and 25 % conc.) which ranged from 4.49 to 8.49 % hatching of eggs. All the concentrations of *T. diversifolia* were significantly superior over all the other concentrations of plant extracts of *C. odorata, L. camara* and *E. crassipes. C. odorata* (100 % conc.) was inferior to all concentrations of *T. diversifolia* but was superior to *C. odorata* (50 % conc.), *L. camara* (100 % conc.) and *C. odorata* (33.3 % conc.). The effect of these three treatments was statistically on par giving 14.98, 16.50 and 17.00 % of hatching of eggs respectively. The latter was statistically on par with *C. odorata* at 25 % conc. *L. camara* at 50 % conc. was inferior to *C. odorata* at 25 % conc. but was on par with *L. camara* at 33.3 % conc. with a hatching percentage of 20.50, 17.50 and 21.99 % respectively. The highest concentration of *E. crassipes* (100 %) was inferior to *L. camara* (33.3 % conc.) but was on par with *L. camara* (25 % conc.) and *E. crassipes* (50 % conc.) giving a hatching percentage of 25.99, 21.99, 26.99

and 28.50 respectively. Lower concentrations of *E. crassipes* (33.3 and 25 % conc.) were observed of having least effect on the inhibition of egg hatching giving a percentage hatching of 35.00 and 38.50 % respectively. The control showed a hatching percentage of 88.48 on the fourth day after treatment.

T. diversifolia (100 % conc.) showed the maximum inhibition of hatching of eggs, five days after treatment. The egg hatching percentage observed in the above treatment was one. Statistically significant variation was observed in the lower dilutions of *T. diversifolia* (50 %, 33.3 % and 25 % conc.) with a percentage hatching of 5.49, 7.49 and 9.98 respectively. All the concentrations of *T. diversifolia* were superior to other plant extracts treated *viz. C. odorata, L. camara* and *E. crassipes. C. odorata* (100 % conc.) was statistically significant over all the other treatments with a hatching percentage of 12.98. The effect of lower concentrations of *C. odorata* (50 % and 33.3 % conc.) was statistically on par giving 15.50 and 16.99 % egg hatching respectively, but was inferior to *C. odorata* (100 % conc.). The least effect among different dilutions in *C. odorata* was observed in *C. odorata* 25 % conc., but it was on par with *L. camara (*100 % conc.) giving 18.50 and 20.95 % hatching of eggs respectively.

The inhibition of egg hatching in *L. camara* (50 % conc.) and *L. camara* (33.33 % conc.) was statistically on par and inferior to *L. camara* (100 % conc.).The percentage hatching observed in these treatments were 25.50 and 26.50% respectively. The lowest concentration of *L. camara* (25 %) was on par with higher concentrations of *E. crassipes* (100 % and 50 % conc.) giving 28.50, 28.50 and 30.00 % hatching of eggs respectively. *E. crassipes* (33.3 % and 25 % conc.) was statistically on par but was inferior or to all other concentrations of plant extract tested. The percentage hatching

observed in the above treatments were 37.50 and 40.00 respectively. The control gave a percentage hatching of 97.99 on the fifth day.

T. diversifolia at 100 % conc. recorded minimum hatching percentage (1.46 %) on the sixth day of treatment. Different dilutions of *T. diversifoia* (50, 33.3 and 25 % conc.) were statistically superior over all the other plant extracts tested and was statistically significant among them and with other extracts of plants *viz. C. odorata, E. crassipes* and *L. camara* .The hatching percentage in these treatments ranged from 5.96 to 10.49 .The inhibition of egg hatching in different dilutions (100, 50, 33.3 and 25 % conc.) of *C. odorata* showed significant variation among them and with other plant extracts. The hatching percentage was in the range 14.50 to 19.50. *L. camara* 100 % conc. was statistically significant with all the other treatments with a percentage egg hatching of 22.99. Lower concentrations of *L. camara* (50 % and 33 % conc.) were statistically on par giving 27.00 and 26.99 % respectively.

E. crassipes at 100% conc. was statistically significant with all the other treatments with egg hatching percentage of 29.50 and it was inferior to *L. camara* (33.3 % conc.).The percentage of egg hatching in *L. camara* leaf extract at 25 % concentration was 26.99 and it was inferior to *E. crassipes* (100 % conc.). The lower concentrations of *E. crassipes* (50, 33.3 and 25 % conc.) showed maximum percentage of egg hatching percentage ranging from 31.99 to 40.50 and the effect was statistically significant among them and also with the other plant extracts tested. Cent percent hatching was observed in control on the sixth day after the treatment.

One week after the treatment, *T. diversifolia* (100 % conc.) recorded maximum hatching inhibition when compared to all the other concentrations

of plant extracts viz. *L. camara*, *C. odorata* and *E. crassipes*. *T. diversifolia* (100 % conc.) gave egg hatching percentage of 1.87. Lower dilution of *T.diversifolia* (50, 33.3 and 25 % conc.) showed hatching percentage ranging from 6.49 to 11.00. Effect of these treatments was statistically superior over all the other treatments. The effect of root extract of *C. odorata* (100 % conc.) was statistically significant with all the other treatments with 14.00 % egg hatching. *C. odorata* at 50 % conc. was on par with *C. odorata* (33.3 % conc). giving hatching percentage of 16.99 and 19.00 respectively. The latter was on par with *C. odorata* at 25 %. *C. odorata* at 25 % conc. found equally effective as *L. camara* at 100 % conc. giving 20.5 and 23.5 % egg hatching respectively. The effect of hatching in *L. camara* at 50 % conc. was inferior to *L. camara* (100 % conc.) but was on par with *L. camara* at 33.3 % conc. The egg hatching percentage in these treatments ranged from 23.50 to 27.48. *E. crassipes* (100 % conc.) was inferior to *L. camara* at 33.3 % conc. but was on par with *L. camara* at 25 % conc. and *E. crassipes* (50 % conc.) giving a hatching percentage of 31.00, 27.48, 31.48 and 34.50 respectively. The inhibition of egg hatching by *E. crassipes* (33.3 % and 25 % conc.) was inferior to *E. crassipes* at 50 % conc., but the treatments were statistically on par giving 40 and 42.5 % egg hatching. In the control 100 % hatching was observed a week after treatment.

Maximum inhibition of egg hatching was caused by *T. diversifolia* (100 % conc.), eight days after exposure. Lower concentrations of *T. diversifolia* (50 %, 33.3 % and 25 % conc.) was statistically superior over all the other concentrations of plant extracts tested viz. *L. camara*, *C. odorata* and *E. crassipes*. The hatching percentage in these four treatments ranged from 1.46 to 11.50 %. *C.odorata* at 100 % conc. was on par with *C. odorata* at 50 % conc. giving 13.98 and 15.50 % egg hatching respectively. The treatments *C. odorata* at 33.3 and 25 % conc. was statistically significant

with all the other treatments giving a percentage hatching of 18.99 and 22.00 respectively. The inhibition of egg hatching in *L. camara* at 100 % conc. was statistically on par with *L. camara* at 50 % conc. giving 25.00 and 27.50 percentage of egg hatching respectively. The latter was on par with *L. camara* at 33.3 % conc. giving hatching percentage of 27.50 and 27.99 respectively. *E.crassipes* at 100% conc. was statistically on par with *L.camara* (25 %) giving 31.99 and 32.48 % egg hatching respectively. Lower dilutions of *E. crassipes* (50, 33.3 and 25 % conc.) was inferior to all other treatments and was statistically significant with one another. Cent per cent hatching of the eggs was observed eight days after treatment.

All the concentrations of *T. diversifolia* were statistically superior over all other concentrations of different plant extracts tested. *T. diversifolia* at 100 % conc. caused egg hatching of 1.00 to 1.87 % for an exposure period of three to eight days. Hatching percentage in *T. diversifolia* (50 % conc.) was within the range 3.00 to7.00 for a period three to eight days after treatment. The percentage of egg hatching in *T. diversifolia* 33.3 % conc. ranged between 4.95 to 9.00 three to eight days after the exposure of egg mass to the plant extract. *T. diversifolia* 25 % conc. gave hatching of egg masses in the range of 7.49 to 11.50 % three to eight days after treatment.

4.2.2. Effect on Larval Mortality

Effect of different extracts showed statistically significant variation in the mortality of *M.incognita* juveniles 24, 48 and72 hours after treatment (Table 59).

T. diversifolia 100 % conc. showed statistically significant variation from all other treatments. Maximum larval mortality (90.49 %) was observed in *T. diversifolia* at 100 % concentration at twenty four hours after treatment.

Table 59. Effect of weed plant extracts on mortality of *M. incognita in vitro*

PLANT SPECIES	Concentration in percentage	Percentage of larval mortality for different exposure time		
		24hrs	48hrs	72hrs
Chromolaena odorata	T_1 (100%)	56.00(7.48)^{e}	96.49(9.82)^{ab}	98.49(9.92)^{b}
	T_2 (50%)	45.99(6.78)^{f}	56.49(7.52)^{e}	86.99(9.33)^{d}
	T_3 (33.3%)	36.49(6.04)^{h}	37.49(6.12)^{i}	46.99(6.86)^{j}
	T_4 (25%)	11.49(3.39)^{k}	17.47(4.18)^{l}	25.49(5.05)^{l}
Tithonia diversifolia	T_5 (100%)	90.49(9.51)^{a}	98.25(9.91)^{a}	100.35(10.02)^{a}
	T_6 (50%)	85.49(9.25)^{b}	97.15(9.86)^{ab}	99.85(9.99)^{b}
	T_7 (33.3%)	73.99(8.60)^{c}	96.10(9.80)^{ab}	98.75(9.94)^{b}
	T_8 (25%)	63.48(7.97)^{d}	94.60(9.73)^{b}	96.10(9.80)^{c}
Lantana camara	T_9 (100%)	54.49(7.38)^{e}	70.00(8.37)^{c}	78.99(8.89)^{e}
	T_{10} (50%)	46.99(6.86)^{f}	61.50(7.84)^{d}	71.49(8.46)^{f}
	T_{11} (33.3%)	40.49(6.36)^{g}	54.00(7.35)^{f}	66.49(8.16)^{g}
	T_{12} (25%)	21.99(4.69)^{j}	48.50(6.96)^{g}	59.00(7.68)^{h}
Eichhornea crassipes	T_{13}(100%)	27.48(5.24)^{i}	43.50(6.60)^{h}	60.50(7.78)^{h}
	T_{14}(50%)	21.49(4.64)^{j}	41.50(6.44)^{h}	59.00(7.68)^{h}
	T_{15} (33.3%)	10.49(3.24)^{l}	35.50(5.96)^{j}	54.50(7.38)^{i}
	T_{16}(25%)	2.48(1.57)^{m}	21.50(4.64)^{k}	30.50(5.52)^{k}
Control	T_{17}	1.00(1)^{n}	1.00(1)^{m}	1.46(1.21)^{m}
CD(0.05)		(0.247)	(0.163)	(0.185)

Figures in the parenthesis are square root transformed values

The lower concentrations (50, 33.3 and 25 %) of *T. diversifolia* also showed significant variation in the percentage mortality of larvae, which ranged from 63.48 to 85.49 and the effect was statistically significant among them and also with the other plant extracts of *C. odorata*, *L. camara* and *E. crassipes*. The juvenile mortality in *C.odorata* and *L. camara* at 100 % conc. was statistically on par giving 56.00 and 54.49 % respectively. These two treatments were inferior to all concentrations of *T. diversifolia* but were superior to all other treatments and control. *L. camara* (50 % conc.) was inferior to *L. camara* (100 % conc.) but was statistically on par with *C. odorata* (50 % conc.) giving 45.99 % to 46.99 % larval mortality at 24hr after treatment. The larval mortality in *L. camara* (33.3 % conc.) was statistically significant from all the other treatments with a percent mortality of 40.49. *C. odorata* at 33.3 % conc. was statistically significant with all the other treatments with a percentage of larval mortality 36.49 and was inferior to *L. camara* at 33.3 % conc. Effect of larval mortality in *E. crassipes* at 100 % conc. was significantly different from all the other treatments with a percentage mortality of 27.48 but it was inferior to *C. odorata* 33.3 % conc. The effect of *L. camara* at 25 % conc. was on par with *E. crassipes* at 50% conc. giving a larval mortality of 21.99 and 21.49 % respectively. *C. odorata* at 25 % conc. was found inferior to *E. crassipes* at 50% conc. with a larval mortality of 11.49 %. Lower concentrations of *E. crassipes* (33.3 and 25 %) were the least effective plant extracts in causing larval mortality giving a mortality percentage of 10.49 and 2.48 % respectively. No mortality was observed in control with distilled water.

Maximum larval mortality was observed in *T. diversifolia* at 100 % conc. at forty eight hours after exposure. This treatment was statistically on par with three treatments *viz. T. diversifolia* 50 % conc., *C. odorata* 100 % conc. and *T. diversifolia* 33.3 % conc. giving a percentage mortality of

98.25, 97.15, 96.49 and 96.10. These three treatments were statistically on par with *T. diversifolia* (25 %) with a larval mortality of 94.60 %. Statistically significant variation was noticed among *L. camara* at 100% and 50% conc. and with all other treatments giving a larval mortality of 70.00 % and 61.50 % respectively. These treatments were inferior to *T. diversifolia* (25 % conc.). *C. odorata* at 50 % was inferior to *L. camara* at 50 % conc. and was significantly different from all other treatments giving a larval mortality of 56.49 % and 61.50 % respectively. Lower concentrations of *L. camara* (33.3 and 25 %) were observed to be inferior to *C. odorata* at 50 % conc. and was significantly different from one another and with other treatments showing a larval mortality of 54.00 and 48.50 % respectively. The effect of *E. crassipes* at 100 and 50 % conc. was statistically on par giving 43.50 and to 41.50 % larval mortality respectively. *C. odorata* at 33.3% conc. was inferior to *E. crassipes* at 50 % conc. which was significantly different from all the other treatments giving a mortality of 37.49 %. *E. crassipes* at 33.3 % conc. was found inferior to *C. odorata* 33.3 % conc. with a larval mortality of 35.50 %. The lowest concentration of *E. crassipes* at 25 % conc. was inferior to *E. crassipes* 33.3 %) giving 21.50 % larval mortality .The lowest larval mortality of 17.47 % was recorded by *C. odorata* (25 %). No mortality was observed in control.

T. diversifolia 100% conc. gave maximum mortality (100 %) at seventy two hours after the treatment. The effect of *T. diversifolia* at 50 % conc. was statistically on par with 33.3 % conc. and *C. odorata* 100 % conc. giving mortality of 99.85, 98.75 and 98.49 % respectively. Statistically significant variation was observed in the lower dilution of *T. diversifolia* 25 % conc. with a percentage mortality of 96.10. *C. odorata* 50 % conc. was inferior to *T. diversifolia* 25 % conc. giving 86.99 % larval mortality. Concentrations of *L. camara* (100, 50, 33.3 %) were statistically significant from one another

and with other treatments giving a larval mortality of 78.99, 71.49 and 66.49 % respectively. *E. crassipes* at 100 % conc. was statistically on par with the same at 50 % conc. and *L. camara* 25 % conc. giving a larval mortality of 60.50, 59.00 and 59.00 % respectively. *E. crassipes* 33.3 % conc. was inferior to these treatments and was significantly different from other treatments giving a larval mortality of 54.50 %. The percentage of larval mortality observed in *C. odorata* 33.3 % conc. was 46.99 and it was inferior to *E. crassipes* (33.3% conc.). *E. crassipes* 25 % conc. was inferior to the above treatment and gave a larval mortality of 30.50 %. The least effect on larval mortality was observed in *C. odorata* 25 % conc. giving a mortality percentage of 25.49. The larval mortality percentage in control was 1.46 at seventy two hours after treatment.

All the concentrations of *T. diversifolia* were statistically superior over all other concentrations of plant extracts tested. *T. diversifolia* 100 % conc. caused larval mortalities in the range of 90.49 to100 % at 24 to 72 hours after treatment percentage larval mortality in *T. diversifolia* 50 % conc. was within the range of 85.49 to 85.00 % at 24 to 72 hours after exposure. The larval mortality in *T. diversifolia* 33.3% conc. ranged between 73.99 to 98.75 % at 24 to 72 hours after exposure. *T. diversifolia* 25 % conc. gave a larval mortality in the range of 63.48 to 96.10 % at 24 to 72 hours after treatment.

4.3. POT CULTURE STUDIES TO EVALUATE THE EFFECTIVE BOTANICAL

4.3.1. Biometric Characters

The results presented in Table 60. showed that there was statistically significant variation among the treatments on biometric characters of cabbage plants recorded one month after treatment.

Table 60. Effect of different treatments on the biometric characters of cabbage one month after treatment under pot culture condition (Mean of three replication)

Treatments	Plant height (cm)	Leaf length(cm)	Leaf width (cm)	Leaf area (cm^2)	Root weight(g)	Gross plant weight (g)
T1- Extract of *T. diversifolia* adsorbed on charcoal (25g (kg soil)$^{-1}$)	18.67^{ef}	8.33^{e}	7.00^{bc}	58.67	8.63^{de}	105.33^{e}
T2- Extract of *T. diversifolia* adsorbed on charcoal (50g (kg soil)$^{-1}$)	20.67^{de}	9.33^{cde}	6.33^{b}	59.00^{c}	10.53^{d}	120.33^{d}
T3- Extract of *T. diversifolia* adsorbed on charcoal (100g (kg soil)$^{-1}$)	22.33^{d}	10.67^{ab}	8.00^{ab}	75.00^{ab}	11.03^{cd}	144.33^{c}
T4- Dried powder of *T. diversifolia* (25g (kg soil)$^{-1}$)	25.00^{bc}	10.00^{bc}	7.33^{ab}	74.00^{bc}	13.91^{bc}	145.66^{c}
T5- Dried powder of *T. diversifolia* (50g (kg soil)$^{-1}$)	26.67^{b}	10.67^{a}	8.00^{ab}	74.00^{ab}	15.48^{b}	170.00^{b}
T6- Dried powder of *T. diversifolia* (100 g(kg soil)$^{-1}$)	30.00^{a}	11.67^{a}	9.00^{a}	105.33^{a}	24.50^{a}	187.00^{a}
T7- Seedling root dip in *T. diversifolia* extract for 30 minutes	20.00^{ef}	6.00	4.67	28.00	5.58^{ef}	85.00^{f}
T8- Soil drenching of crude extract of *T. diversifolia* (25ml plant^{-1})	19.67^{ef}	9.67^{bcd}	5.00	48.67	6.35^{e}	84.00^{f}
T9- Soil drenching of crude extract of *T. diversifolia* (50ml plant^{-1})	22.33^{d}	9.33^{cde}	5.33	50.33	7.43^{e}	101.33^{e}
T10-Soil drenching of crude extract of *T. diversifolia* (100ml plant^{-1})	22.67^{cd}	8.67^{de}	7.00^{bc}	61.00^{c}	8.63^{de}	122.00^{d}
T11-Untreated	18.33^{f}	9.67^{bcd}	6.67^{bc}	64.33^{bc}	3.30^{f}	61.67^{g}
CD(0.05)	2.378	1.021	1.888	21.917	3.037	9.179

4.3.1.1. Plant Height (cm)

Among the treatments, maximum height (30 cm) was recorded in plants treated with *T. diversifolia* dried powder @ 100 g(kg soil)$^{-1}$ (T6) which was significantly superior to all other treatments followed by T5 (dried powder of *T. diversifolia* 50 g(kg soil)$^{-1}$) and T4 (dried powder of *T. diversifolia* @ 25 g(kg soil)$^{-1}$) which were statistically on par with a height of 26.67 and 25.00 cm respectively (Table 60.). The latter was statistically on par with soil drenching of crude extract of *T. diversifolia* 100 ml plant^{-1} (22.67 cm). Similarly, soil drenching of crude extract of *T. diversifolia* 100 mlplant^{-1} (22.67 cm) was on par with extract of *T. divsersifolia* adsorbed on charcoal @100 g(kg soil)$^{-1}$ (22.33 cm), soil drenching of crude extract of *T. divsersifolia* 50 ml plant^{-1} (22.33 cm) and extract adsorbed on charcoal @ 50 g(kg soil)$^{-1}$ (20.67 cm). No significant difference in plant height over control (18.33 cm) was recorded in T7 seedling root dip (20.00 cm), soil drenching of crude extract of *T. divsersifolia* 25 mlplant^{-1} (19.67 cm), and extract of *T. divsersifolia* adsorbed on charcoal @ 25 g(kg soil)$^{-1}$ (18.67 cm).

4.3.1.2. Length of Leaf (cm)

The leaf length of plants among various treatments showed statistically significant variation (Table 60.). The effect of *T. diversifolia* dried powder @100 g, 50 g(kg soil)$^{-1}$ and extract adsorbed on charcoal 100 g(kg soil)$^{-1}$ was statistically on par giving a leaf length of 11.67, 10.67 and 10.67 cm respectively. However, extract adsorbed on charcoal 100 g(kg soil)$^{-1}$ was statistically on par with untreated. No significant increase in leaf length over untreated control (9.67 cm) was recorded in plants treated with crude extract of leaves of *T. diversfolia* @ 50 and 100 ml plant^{-1} and those received the

treatment of dried powder @ 25 g(kg soil)$^{-1}$ (10.00 cm) and soil drenching of crude extract @ 25 mlplant^{-1}.

4.3.1.3. Width of Leaf (cm)

The highest leaf breadth was observed in treatment with dried powder of *T. diversifolia* @ 100 g(kg soil)$^{-1}$, the value being 9.00 cm. The above treatment was statistically on par with T5, (*T. diversifolia* dried powder 50 g(kg soil)$^{-1}$ (8.00 cm),T3, leaf extract adsorbed on charcoal @100 g(kg soil)$^{-1}$ (8.00 cm) and T4, dried powder 25 g(kg soil)$^{-1}$ (7.33 cm). Among these, the treatments, T5, T3, and T4 were statistically on par with other treatments including untreated control (Table 60.).

4.3.1.4. Leaf Area (cm^2)

The highest leaf area was observed in the treatment of dried powder of *T. diversifolia* @ 100 g(kg soil)$^{-1}$ giving a leaf area of 105.33 cm^2. The above treatment was statistically on par with dried powder of *T.diversifolia* @50 g(kg soil)$^{-1}$ (74.00 cm^2) and extract absorbed in charcoal 100 g(kg soil)$^{-1}$ (75.00 cm^2). However, dried powder of *T. diversifolia* @50 g(kg soil) $^{-1}$ and 25 g(kg soil)$^{-1}$ and untreated control were statistically on par giving leaf area of 74.00 and 64.33 cm^2. (Table 60)

4.3.1.5. Root Weight (g)

Data on the root weight revealed that there was statistically significant variation among the treatments (Table 60). The highest root weight of 24.50 g was observed in plants treated with *T .divsersifolia* dried powder @ 100 g(kg soil)$^{-1}$ and it showed superiority over other treatments. Lower doses of *T. divsersifolia* dried powder @ 50 and 25 g(kg soil)$^{-1}$ were statistically on

par giving a root weight of 15.48 and 13.91 g respectively. The latter treatment was on par with extract of *T. diversifolia* adsorbed on charcoal @100 g(kg soil)$^{-1}$. The effect of different concentration of *T. diversifolia* adsorbed in charcoal *viz.* 100 g(kg soil)$^{-1}$, 50 g(kg soil)$^{-1}$ and 25 g(kg soil)$^{-1}$ did not differ significantly, the root weight being 11.03, 10.53 and 8.63 g respectively. The latter was on par with drenching of crude extract of *T. diversifolia* 100 ml plant^{-1} (8.63 g). No significant increase in root weight over the control (3.30 g) was recorded on the treatment of seedling root dip in *T. diversifolia* extract (5.58 g).

4.3.1.6. Gross Plant Weight (g)

All the treatments showed statistically significant superiority over the untreated control in improving the gross plant weight of cabbage (Table 60). The mean plant weight of treated plants ranged from 84.00 to 187.00 g against the mean weight of 61.67g in the untreated. Highest plant weight (187.00 g) was obtained in *T. divsersifolia* dried powder 100 g(kg soil)$^{-1}$ (T6) and this was significantly superior to all other treatments. *T. divsersifolia* dried powder @ 50 g(kg soil)$^{-1}$ (T5) was inferior to the above treatment but superior to all other treatments with a plant weight of 170.00 g. The effect of *T. divsersifolia* dried powder @ 25 g(kg soil)$^{-1}$ (T4) was on par with extract of *T. divsersifolia* adsorbed on charcoal 100 g(kg soil)$^{-1}$ (T3) giving a gross plant weight of 145.66 and 144.33 g respectively. Soil drenching of crude extract *T. diversifolia* 100 ml plant^{-1} (T10) was statistically on par with *T. divsersifolia* adsorbed on charcoal 50 g(kg soil)$^{-1}$ (T2) giving a plant weight of 122.00 and 120.33 g respectively. Extract of *T. divsersifolia* adsorbed on charcoal 25 g(kg soil)$^{-1}$ (T1) was found to be equally effective to soil drenching of crude extract of *T. divsersifolia* 50 ml plant^{-1} (T9) giving a plant weight of 105.33 and 101.33 g respectively.

Seedling root dip of *T. divsersifolia* for 30 minutes (T7) was statistically on par with soil drenching of crude extract of *T. divsersifolia* 25 ml plant^{-1} (T8) giving a plant weight of 85.00 and 84.00 g respectively(Plate 3.).

4.3.2. Nematode Population Characteristics

4.3.2.1. Nematode Population in Soil

The data on the effect of application of different treatments on the population build up of nematodes in cabbage rhizosphere estimated at one months after planting (MAP) are presented in Table 61. All the treatments significantly reduced the *M. incognita* population in soil. The lowest mean nematode population per 200 g soil (9.98) was observed in the treatment of dried powder of *T. diversifolia* @ 100 g(kg soil)$^{-1}$. This was followed by the treatments viz. dried powder of *T. diversifolia* @ 50 g(kg soil)$^{-1}$ (12.99) and 25 g(kg soil)$^{-1}$ (17.93), extract of *T. diversifolia* adsorbed on charcoal @ 100 g(kg soil)$^{-1}$ (44.69) and soil drenching of crude extract of *T. diversifolia* 100 ml plant^{-1} (82.91) which varied significantly among themselves. All these treatments showed statistically significant superiority over untreated control in reducing the nematode population. The effect of seedling root dip was statistically on par with extract adsorbed on charcoal 50 g(kg soil)$^{-1}$ giving a nematode population of 129.73 and 132.77 respectively. Soil drenching of crude extract of *T. diversifolia* @ 50 and 25 ml plant^{-1} and extract of *T. diversifolia* adsorbed on charcoal @ 25 g(kg soil)$^{-1}$ were statistically on par giving a mean nematode population of 222.37, 258.88, 248.13 per 200 g soil respectively.

A. B. C.

A.- T6-Dried powder of *T. diversifoila* (100g/kg soil)

B.-T5-Dried powder of *T. diversifolia* (50g/kg soil)

C.-T4-Dried powder of *T. diversifolia* (25g/kg soil)

Plate 3(A, B & C).Effect of different preparations of *T. diversifolia* against *M. incognita* in cabbage (Pot culture conditions)

Table 61. Effect of different treatments on population characteristics of *M.incognita* in cabbage one month after treatment under pot culture condition (Mean of three replications)

Treatments	Population of nematodes in		No of galls/ 5g root	Number of females in 5g root	No. of egg masses in 5g root
	Soil (200 cc)	Root (5g)			
T1- Extract of *T. diversifolia* adsorbed on charcoal (25g(kg soil)$^{-1}$)	248.13(15.75)^{g}	144.94(12.0)^{g}	47.31(6.88)^{g}	48.30(6.95)^{fg}	46.58(6.82)^{fg}
T2- Extract of *T. diversifolia* adsorbed on charcoal (50g(kg soil)$^{-1}$)	132.77(11.52)^{f}	82.26(9.08)^{e}	29.98(5.48)^{e}	32.28(5.68)^{e}	32.28(5.68)^{e}
T3- Extract of *T. diversifolia* adsorbed on charcoal (100g(kg soil)$^{-1}$)	44.69(6.69)^{d}	34.91(5.91)^{c}	19.97(4.47)^{d}	21.30(4.62)^{d}	21.30(4.62)^{d}
T4- Dried powder of *T. diversifolia* (25g (kg soil)$^{-1}$)	17.93(4.23)^{c}	9.17(3.04)^{b}	13.53(3.68)^{c}	16.00(4.00)^{c}	15.96(3.99)^{c}
T5- Dried powder of *T. diversifolia* (50g (kg soil)$^{-1}$)	12.99(3.60)^{b}	6.95(2.64)^{ab}	8.49(2.91)^{b}	10.60(3.26)^{b}	10.60(3.26)^{b}
T6- Dried powder of *T. diversifolia* (100 g (kg soil)$^{-1}$)	9.98(3.16)^{a}	4.64(2.16)^{a}	5.89(2.43)^{a}	7.28(2.70)^{a}	7.28(2.69)^{a}
T7- Seedling root dip in *T. diversifolia* extract for 30 minutes	129.73(11.39)^{f}	140.05(11.84)^{fg}	28.88(5.37)^{e}	30.24(5.50)^{e}	30.24(5.49)^{e}
T8- Soil drenching of crude extract of *T. diversifolia* (25 ml plant^{-1})	258.88(16.09)^{g}	131.58(11.47)^{fg}	49.92(7.07)^{g}	50.58(7.11)^{g}	50.23(7.09)^{g}
T9- Soil drenching of crude extract of *T. diversifolia* (50 ml plant^{-1})	222.37(14.91)^{g}	123.63(11.12)^{f}	40.64(6.37)^{f}	41.96(6.48)^{f}	41.96(6.48)^{f}
T10-Soil drenching of crude extract of *T. diversifolia* (100 ml plant^{-1})	82.91(9.11)^{e}	51.22(7.16)^{d}	27.64(5.26)^{e}	29.30(5.41)^{e}	28.62(5.35)^{e}
T11-Untreated	733.30(27.08)^{h}	627.56(25.05)^{h}	67.65(8.23)^{h}	69.00(8.30)^{h}	68.97(8.30)^{h}
CD(0.05)	(1.018)	(0.855)	(0.444)	(0.467)	(0.501)

Figures in the parenthesis are after square root transformation

4.3.2.2. Nematode Population in Root

Lowest nematode population of *M .incognita* larvae 4.64 (5 g root)$^{-1}$ was observed in treatment with *T. diversifolia* dried powder 100 g (kg soil)$^{-1}$. The effect of *T. diversifolia* dried powder @ 50 and 25 g (kg soil)$^{-1}$ was found on par in reducing the nematode population recording 6.95 and 9.17 larvae (5 g root) $^{-1}$ respectively. *T. diversifolia* extract adsorbed on charcoal @ 100 g(kg soil)$^{-1}$ and soil drenching of crude extract of the same @100 ml plant^{-1}, was superior to the extract adsorbed on charcoal @ 50 g(kg soil)$^{-1}$ in reducing the nematode population in root. The nematode population in the above three treatments ranged from 34.91 to 82.26 *M. incognita* larvae (5 g root)$^{-1}$. Effect of soil drenching of crude extract of *T. diversifolia* @ 50 and 25 ml plant^{-1} and seedling root dip in the extract was on par giving nematode population of 123.63, 131.58 and 140.05 *M. incognita* larvae (5 g root)$^{-1}$ respectively. Effect of *T. diversifolia* extract adsorbed on charcoal @ 25 g(kg soil)$^{-1}$ (144.94 *M. incognita* larvae (5 g root)$^{-1}$) found to be equally effective to soil drenching of crude extract of the same botanical @ 25 ml plant^{-1} and seedling root dip in the extract (Table 61.).

4.3.2.3. Number of Galls

The data relating to number of galls in 5 g root showed the effectiveness of various treatments of *T. diversifolia* on reducing the gall formation with mean galls ranging from 5.89 to 49.92 in treated plants as against 67.65 in untreated plants. Lowest mean galls was observed in dried powder of *T. diversifolia* 100 g(kg soil)$^{-1}$ giving a mean gall of 5.89(5 g root) $^{-1}$. Different formulations of *T. diversifolia* viz., dried powder @ 50 and 25 g(kg soil)$^{-1}$, crude extract adsorbed on charcoal @100 g(kg soil)$^{-1}$ were inferior to the above treatment giving root knot count of 8.49, 13.53 and 19.97(5 g root)$^{-1}$

respectively. Soil drenching of crude extract of *T. diversifolia* 100 ml plant^{-1}, seedling root dip in crude extract of *T. diversifolia* for 30 minutes and extract of *T. diversifolia* adsorbed on charcoal 50 g(kg soil)$^{-1}$ were statistically on par having root knot count of 27.64, 28.88 and 29.98 (5 g root)$^{-1}$ respectively. Soil drenching of crude extract of *T. diversifolia* @50 mlplant^{-1} was inferior to the above treatment with a root knot count of 40.64. Effect of extract of *T.diversifolia* adsorbed on charcoal @ 25 g(kg soil)$^{-1}$ and soil drenching of crude extract of *T. diversifolia* @ 25 ml plant^{-1} was statistically on par giving a high root-knot count of 47.31 and 49.92 (5 g root)$^{-1}$ respectively. The untreated control gave the highest galls of 67.65 (Table 61.).

4.3.2.4. Number of Females

It is apparent from the results that the different treatments had significant impact in the number of females (5 g root) $^{-1}$ sample (Table 61). The mean number of females ranged from 7.28 to 50.58 in various treatments while it was 69.0 in untreated. The lowest mean number of females in 5 g root (7.28) was observed in dried powder of *T. diversifolia* 100 g(kg soil)$^{-1}$. This treatment was superior to all the other treatments. Dried powder of *T. diversifolia* 50 and 25 g(kg soil)$^{-1}$ recorded a mean of 10.60 and 16.00 females (5 g root)$^{-1}$. The effect of these treatments was statistically independent and inferior to dried powder of *T. diversifolia* 100 g(kg soil)$^{-1}$. Extract of *T. diversifolia* adsorbed on charcoal 100 g(kg soil)$^{-1}$ was inferior to above treatments with 21.30 mean number of females (5 g root)$^{-1}$. Soil drenching of crude extract of *T. diversifolia* 100 mlplant^{-1} was statistically on par with seedling root dip of *T. diversifolia* and extract of *T. diversifolia* adsorbed on charcoal 50 g(kg soil)$^{-1}$ giving mean number of 29.30, 30.24 and 32.28 females (5 g root)$^{-1}$ respectively. Soil drenching of crude extract of *T. diversifolia* 50 ml plant^{-1} (41.96) was statistically on par with extract of

same botanical adsorbed on charcoal 25 g(kg soil)$^{-1}$ with a mean of 48.30 females (5 g root)$^{-1}$. The latter was on par with soil drenching of crude extract of *T. diversifolia* 25 ml plant^{-1} (mean of 50.58 females (5 g root)$^{-1}$).

4.3.2.5. Number of Egg Masses

All the treatments were superior over untreated. Lowest number of mean egg masses (5 g root)$^{-1}$ was seen in *T. diversifolia* dried powder 100 g(kg soil)$^{-1}$ with 7.28 (5 g root)$^{-1}$. Dried powder of *T. diversifolia* @ 50 and 25 g (kg soil)$^{-1}$ were significantly different from one another and were inferior to the above treatment giving an average no of egg masses as 10.60 and 15.96 respectively. Extract of *T. diversifolia* adsorbed on charcoal @100 g(kg soil)$^{-1}$ was inferior to above treatments giving average no of egg masses as 21.30. Soil drenching of crude extract of *T. diversifolia* 100 ml plant^{-1} was statistically on par with seedling root dip and extract of *T. diversifolia* adsorbed on charcoal @ 50 g(kg soil)$^{-1}$ giving 28.62 to 32.28 egg masses (5 g root)$^{-1}$. Soil drenching of crude extract of *T. diversifolia* 50 ml plant^{-1} was statistically on par with extract of adsorbed on charcoal @ 25 g(kg soil)$^{-1}$ giving average no of egg masses as 41.96 and 46.58 respectively. The latter was on par with soil drenching of crude extract of *T. diversifolia* 25 ml plant^{-1} giving 50.23 egg masses (5 g root)$^{-1}$ (Table 61.).

4.4. FIELD EXPERIMENT TO EVALUATE THE PROMISING BOTANICAL COMPARED TO BIOAGENT, ORGANIC AMENDMENT AND CHEMICAL

4.4.1. Biometric Characters

The treatments significantly influenced the biometric characters viz., plant height, leaf length, leaf breadth, leaf area, number of non-wrapper leaves, root weight and gross plant weight (Table 62. and Plate 4.).

A.Thiamethoxam 25% WG (0.04g/m^2)

B. *P.lilacinus* enriched neem cake (20g/m^2)

C.Dried powder of *T.diversifolia* (100g/m^2)

D. Untreated

Plate 4(A, B, C &D).Effect of different botanicals in improving the biometric characters of cabbage plants compared to bioagent and chemical

Table 62. Effect of different treatments in main field on the biometric characters of cabbage at the time of harvest (Mean of three replications)

Treatments	Plant height(cm)	Leaf length (cm)	Leaf width(cm)	Leaf area	Non wrapper leaf	Gross plant weight (g)
T1-Dried powder of *T. diversifolia*(50 g plant^{-1})	24.00^{c}	15.25^{b}	12.00	184.00^{b}	8.25^{b}	1263.00^{b}
T2-Dried powder of *T. diversifolia*(100 g plant^{-1})	24.00^{c}	16.75^{ab}	14.25^{a}	242.00^{ab}	7.50^{ab}	1367.00^{ab}
T3- *P. lilacinus* enriched neem cake (20 gm^{-2})	27.00^{b}	17.25^{ab}	14.25^{a}	247.25^{ab}	7.25^{ab}	1476.00^{a}
T4-Thiamethoxam 25% WG (0.04 gm^{-2})	30.33^{a}	18.25^{a}	15.50^{a}	284.25^{a}	6.50^{a}	1542.00^{a}
T5-Untreated	20.00	11.25	9.50	107.75	18.00	890.00
CD(0.05)	2.156	2.562	2.128	66.330	1.850	198.962

Table 63. Effect of different treatments on yield and yield attributing characters of cabbage (Mean of three replications)

Treatments	Head depth (cm)	Head diameter (cm)	Gross head weight (g)	Net head weight (g)
T1-Dried powder of *T. diversifolia* (50 g plant^{-1})	12.50^{a}	12.25^{a}	1045.00^{a}	884.75^{b}
T2- Dried powder of *T. diversifolia* (100 g plant^{-1})	13.00^{a}	12.75^{a}	1140.75^{a}	959.50^{a}
T3- *P. lilacinus* enriched neem cake (20 gm^{-2})	14.00^{a}	13.00^{a}	1146.25^{a}	962.75^{a}
T4-Thiamethoxam 25% WG (0.04g m^{-2})	15.50^{a}	13.25^{a}	1171.00^{a}	970.75^{a}
T5-Untreated	9.00^{b}	6.25^{b}	564.75^{b}	246.75^{c}
CD(0.05)	3.479	2.937	177.65	32.82

4.4.1.1. Plant Height (cm)

The plant height of cabbage plants in different treatments showed statistically significant variation over untreated control. The maximum height (30.33 cm) of plant was observed with thiamethoxam 25 WG treatment and was significantly superior to all other treatments followed by plants receiving *P. lilacinus* enriched neem cake (20 gm^{-2}) which recorded a height of 27.00 cm. Plants receiving the treatment of dried powder of *T. diversifolia* @ 100 g $plant^{-1}$ and 50 g $plant^{-1}$ were statistically on par with a height of 24.00 cm each and was significantly superior to the untreated control (Table 62).

4.4.1.2. Length of Leaf (cm)

The leaf length recorded in plants receiving the treatments of thiamethoxam 25 %WG, *P. lilacinus* enriched neem cake (20 gm^{-2}) and dried powder of *T. diversifolia* @ 100 g $plant^{-1}$ were statistically on par and the mean length of leaf being 18.25, 17.25 and 16.75 cm respectively (Table 62). Similarly, length of leaf in plants treated with *P. lilacinus* enriched neem cake (20 gm^{-2}) and dried powder of *T. diversifolia* @ 100 g $plant^{-1}$ were statistically on par with *T. diversifolia* dried powder @ 50 g $plant^{-1}$ (15.25 cm).

4.4.1.3. Breadth of Leaf (cm)

The leaf breadth recorded in plants treated with thiamethoxam 25 %WG (15.5 cm) was statistically on par with those treated with *P. lilacinus* enriched neem cake (20 gm^{-2}) and dried powder of *T. diversifolia* @ 100 g $plant^{-1}$ which gave a leaf breadth of 14.25 cm each (Table 62). Dried powder of *T. diversifolia* @ 50 g $plant^{-1}$ was inferior to the above treatments recording a leaf breadth of 12.00 cm.

4.4.1.4. Leaf Area (cm^2)

As in the case of leaf length, the leaf area recorded in plants receiving the treatments of thiamethoxam 25 %WG (0.04 g $plot^{-1}$), *P. lilacinus* enriched neem cake (20 gm^{-2}) and dried powder of *T. diversifolia* 100 g $plant^{-1}$ were statistically on par, the mean leaf area being 284.25, 247.25 and 242.00 cm^2 respectively (Table 62). Similarly, leaf area in plants treated with *P. lilacinus* enriched neem cake (20 gm^{-2}) and dried powder of *T. diversifolia* @ 100 g $plant^{-1}$ were statistically on par with *T. diversifolia* dried powder 50 g $plant^{-1}$ (184.00 cm^2).

4.4.1.5. Number of Non-Wrapper Leaves

As in the case of leaf length and the leaf area, the number of non wrapper leaves recorded in plants receiving the treatments of thiamethoxam 25%WG (0.04 gm^{-2}), *P. lilacinus* enriched neem cake (20 gm^{-2}) and dried powder of *T. diversifolia* @ 100 g $plant^{-1}$ were statistically on par the mean number of non wrapper leaves being 6.5, 7.25 and 7.50 respectively (Table 62.). Similarly, number of non-wrapper leaves in plants treated with *P. lilacinus* enriched neem cake (20 gm^{-2}) and dried powder of *T. diversifolia* 100 g $plant^{-1}$ were statistically on par with those receiving *T. diversifolia* @ 50 g $plant^{-1}$ (8.25).

4.4.1.6. Gross Plant Weight (g)

The gross plant weight was the highest in the thiamethoxam 25 WG (1542.00 g) treated plants which was statistically on par with *P. lilacinus* enriched neem cake (20 gm^{-2}) and dried powder of *T. diversifolia* @ 100 g $plant^{-1}$ which recorded a height of 1476.00 g and 1367.00 g respectively (Table 62). The gross plant weight recorded in treatment receiving dried

powder of *T. diversifolia* @ 50 g plant^{-1} (1263.00 g) was statistically on par with those received dried powder of *T. diversifolia* 100 g plant^{-1}.

4.4.2. Yield of Cabbage

The yield of cabbage in terms of head depth, head diameter, gross head weight and net head weight differed significantly over untreated control (Table 63.)

4.4.2.1. Head Depth (cm)

All the treatments were superior over control and were on par with respect to head depth (Table 63). Thus the head depth recorded in plants treated with thiamethoxam 25 WG 0.04 gm^{-2}, *P. lilacinus* enriched neem cake (20 gm^{-2}), dried powder of *T. diversifolia* @ 100 g plant^{-1} and *T. diversifolia* @ 50 g plant^{-1} were 15.5, 14.0, 13.0 and 12.5 cm respectively.

4.4.2.2. Head Diameter (cm)

As in the case of head depth, all the treatments were superior over control and were on par with respect to head diameter, the mean head diameter recorded being 13.25, 13.0, 12.75 and 12:25 cm in plants treated with thiamethoxam 25 WG 0.04 gm^{-2}, *P. lilacinus* enriched neem cake (20 gm^{-2}), dried powder of *T. diversifolia* @ 100 g and 50 g plant^{-1} respectively (Table 63.).

4.4.2.3. Gross Head Weight (g)

As in the case of head depth and head diameter, all the treatments were superior over control and were on par with respect to gross head weight, the mean head weight recorded being 1171.00, 1146.25, 1140.75 and 1045.00 g

respectively in plants treated with thiamethoxam 25 WG 0.04 gm^{-2}, *P. lilacinus* enriched neem cake (20 gm^{-2}), dried powder of *T. diversifolia* @ 100 g $plant^{-1}$ and *T. diversifolia* @ 50 g $plant^{-1}$ respectively (Table 63).

4.4.2.4. Net Head Weight (g)

Analysis of the data in yield in terms of net head weight in different treatments revealed that there was statistically significant variation (Table 63). Net head weight was the highest in Thiamethoxam 25 WG @ 0.04 gm^{-2} (970.75 g) and was statistically on par with *P. lilacinus* enriched neem cake (20 gm^{-2}) and dried powder of *T. diversifolia* 100 g $plant^{-1}$ giving a net head weight of 962.75 and 959.5 g respectively. Dried powder of *T. diversifolia* 50 g $plant^{-1}$ was inferior to above three treatments which recorded a head weight of 884.75 g (Plate 5.).

4.4.3. Nematode Population Characteristics

The results relating to the effect of different treatments in reducing the population characteristics of *M. incognita* in cabbage at the time of harvest is presented in Table.64.

4.4.3.1. Nematode Population in Soil

Nematode population estimated at the time of harvest showed significant variation (Table 64.). The mean population of *M .incognita* in soil was significantly lower (65.23 larvae (200 cc $soil)^{-1}$) in plots receiving thiamethoxam 25 WG 0.04 gm^{-2}. *P. lilacinus* enriched neem cake (20 gm^{-2}) resulted in a mean population of 77.20 which was significantly lower than those recorded in soil treated with dried powder of *T. diversifolia* @ 100 and 50 g $plant^{-1}$ which recorded a population of 85.74 and 87.23 *M. incognita*

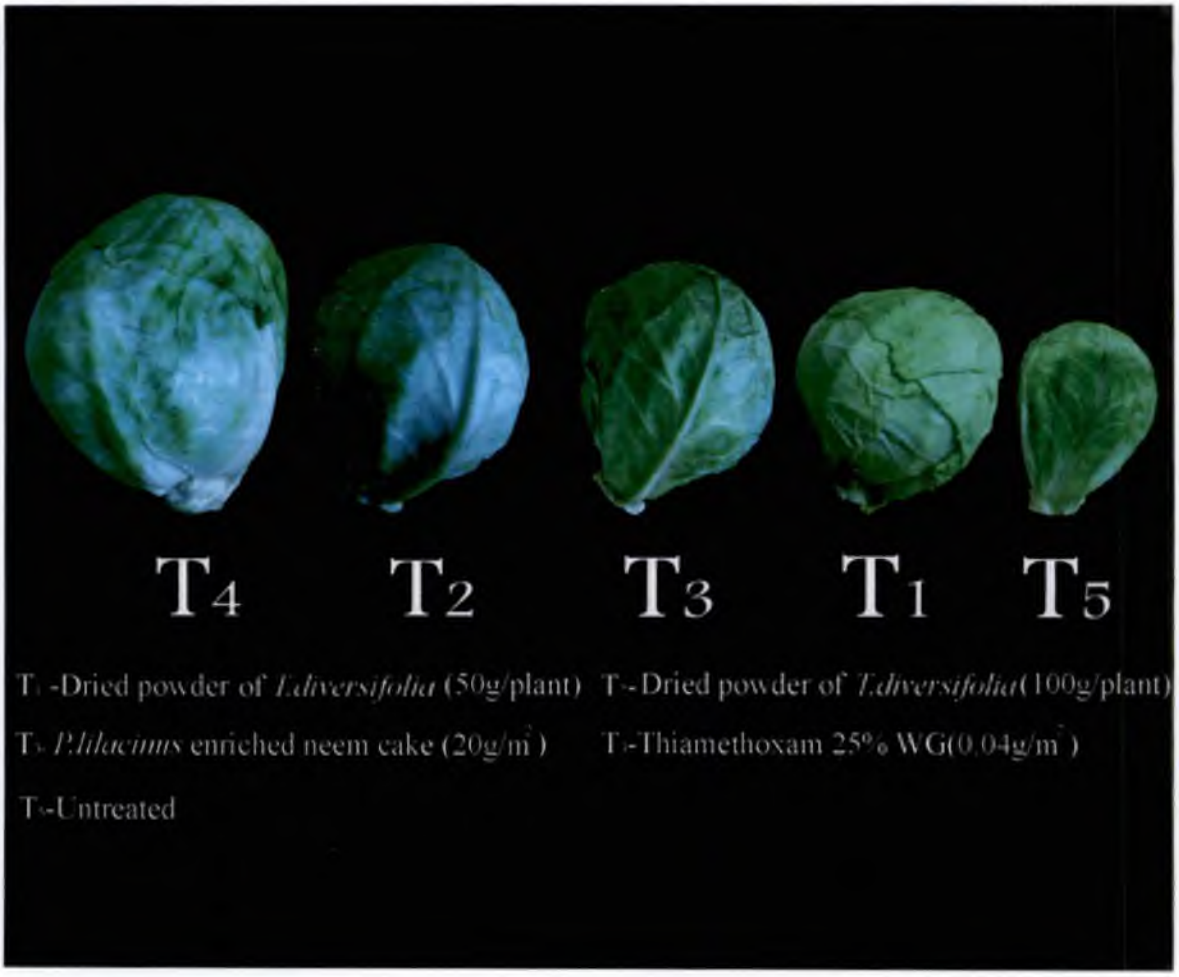


Plate 5. Effect of different treatments on the yield of cabbage

Table 64. Effect of different treatments in main field on population characteristics of *M.incognita* in cabbage at the time of harvest (Mean of three replications)

Treatments	Population of nematodes in		No. of galls in 5g root	Number of females in 5g root	No. of egg masses in 5g root
	Soil (200 cc)	Root (5g)			
T1-Dried powder of *T. diversifolia* (50 g plant^{-1})	87.23 (9.34)^{c}	39.73 (6.30)^{c}	6.88 (2.62)^{b}	16.21 (4.03)^{b}	15.28 (3.91)^{c}
T2- Dried powder of *T. diversifolia* (100 g plant^{-1})	85.74 (9.26)^{c}	31.97 (5.66)^{b}	6.41 (2.53)^{b}	7.57 (2.75)^{a}	6.72 (2.59)^{b}
T3- *P. lilacinus* enriched neem cake (20 g m^{-2})	77.20 (8.79)^{b}	29.98 (5.48)^{b}	3.97 (1.99)^{a}	7.39 (2.72)^{a}	6.16 (2.48)^{b}
T4-Thiamethoxam 25% WG (0.04 g m^{-2})	65.23 (8.08)^{a}	25.00 (5.00)^{a}	3.89 (1.97)^{a}	4.97 (2.23)^{a}	3.31 (1.81)^{a}
T5-Untreated	580.67 (24.00)^{d}	381.72 (19.54)^{d}	35.5 (5.93)^{c}	76.6 (8.75)^{c}	75.17 (8.67)^{d}
CD(0.05)	(0.358)	(0.272)	(0.533)	(0.582)	(0.611)

Figures in the parenthesis are after square root transformation

larvae (200 cc soil)$^{-1}$ respectively. The treatments dried powder of *T. diversifolia* @ 100 and 50 g plant^{-1} were statistically on par.

4.4.3.2. Nematode Population in Root

Nematode population estimated at the time of harvest in root varied significantly among the treatments (Table 64.). The mean population of *M.incognita* in root was significantly lower (25.00 *M. incognita* larvae (5 g root) $^{-1}$) in plots receiving thiamethoxam 25 WG 0.04 g plot^{-1}. *P. lilacinus* enriched neem cake (20 gm^{-2}) resulted in a mean population of 29.98 which was on par with those recorded in plots treated with dried powder of *T. diversifolia* 100 g plant^{-1} (31.97 *M. incognita* larvae 5 g root) $^{-1}$. Dried powder of *T. diversifolia* @ 50 g plant^{-1} was inferior to the above treatment which recorded a population of 39.73 *M .incognita* larvae (5 g root) $^{-1}$.

4.4.3.3. Number of Galls

The results showed drastic reduction in the mean number of galls on the roots of cabbage plants due to various treatments (Table 64.). The root knot count (5 g root)$^{-1}$ was significantly lower in thiamethoxam 25 WG and *P. lilacinus* enriched neem cake (20 gm^{-2}) the mean count being 3.89 and 3.97 respectively. Dried powder of *T.diversifolia* @ 100 and 50 g plant^{-1} were statistically on par giving a mean root knot count of 6.41 and 6.88 (5 g root)$^{-1}$ respectively (Plate 6.).

4.4.3.4. Number of Females

Data on the number of females revealed that the number of females observed in 5g root was on par in the treatments of Thiamethoxam 25 WG 0.04 gplot^{-1} *P. lilacinus* enriched neem cake (20 gm^{-2}) and dried powder of

A.Thiamethoxam 25% WG(0.04g/m^2)

B. *P.lilacinus* enriched neem cake (20g/m^2)

C. Dried powder of *T.diversifolia* (100g/plant)

D. Untreated

Plate 6(A, B, C & D). Effect of different treatments on *M.incognita* infestation in roots of cabbage

T. diversifolia @ 100 g plant^{-1}, the mean number being 4.97, 7.39 and 7.57 respectively(Table 64.). Significantly, higher population of females was observed in plots treated with dried powder of *T. diversifolia* 50 g plant^{-1}, the mean population being 16.21 as against 76.60 in the untreated control.

4.4.3.5. Number of Egg Masses

There was statistically significant variation in the number of egg masses recorded among the different treatments (Table 64.). The mean number of egg masses (5 g root)$^{-1}$ recorded in the case of thiamethoxam 25 WG 0.04 g plot^{-1} treatment was 3.31 which was significantly lower than all other treatments. *P. lilacinus* enriched neem cake (20 gm^{-2}) was statistically on par with dried powder of *T.diversifolia* @ 100 g plant^{-1} giving an average number of 6.16 and 6.72 egg masses (5 g root) $^{-1}$ respectively. The mean number of egg mass 5 groot^{-1} in plot treated with dried powder of *T. diversifolia* @ 50 g plant^{-1} was 15.28.

DISCUSSION

5. DISCUSSION

Cabbage, *Brassica oleracea* L. var. *capitata* is an important vegetable grown throughout the country and is consumed by majority of the people. Hitherto, in Kerala the cultivation of cabbage was possible only in the hilly tracts of Idukki and Wayanad districts. However, at present with the introduction of tropical hybrids which can grow well under high temperature conditions, cultivation of the crop could be done in plains too. Plant parasitic nematodes remain a major challenge in cool season vegetable production. Chances of presence of terminal residues in the harvested produce are more in the case of chemical interventions of nematode management especially in crop like cabbage which is of short duration. In this perspective, non chemical methods of management giving emphasis to plant products have to be undertaken. In Kerala, scanty reports are available on nematode association with cabbage and eco-friendly management strategies. Therefore the present study is under taken to document the nematodes associated with cabbage and to evolve management strategies using botanical pesticides.

As root-knot nematode, *M. incognita* is an exhausting pest causing astronomic loss to many of the vegetable crops, the present study targeted on collection and estimation of nematodes associated with the cabbage in major crop growing areas of the state, screening plant extracts for nematicidal property in laboratory and field evaluation of the promising botanicals in comparison to bioagent, organic amendment and a chemical pesticide.

The present study on "Nematode association in cabbage, *Brassica oleracea L. var. capitata* and its eco-friendly management" carried out at the College of Agriculture, Vellayani during 2012-2014 is the first of its kind in Kerala. In the present study, survey was conducted in the major cabbage growing tracts of Thiruvananthapuram, Kollam and Idukki districts of Kerala following random sampling technique. Soil samples from the rhizosphere of cabbage from 52 locations in the three districts were analysed for nematode fauna

characterization. Nematode population estimated from the soil and root samples were subjected to community analysis of nematodes in terms of absolute frequency, relative frequency, relative density and prominence value.

Analysis of 208 soil and root samples collected from the rhizosphere of cabbage revealed the presence of plant parasites and free living forms. Among the plant parasitic nematodes, species encountered were *M. incognita, Helicotylenchus* sp., *R. reniformis, Xiphinema* sp., *R. similis,* and *Tylenchorhynchus* sp., while the free living forms included Rhabditids, Dorylaimids and Mononchids. Occurrences of these nematodes in association with other different crop situations in the state were reported by several workers. Sundararaju *et al.* (1979) reported root knot nematode, *M. incognita,* lesion nematode, *Pratylenchus coffeae* Goodey and burrowing nematode, *R. similis* from cardamom plantations of Idukki district. Ali and Koshy (1982) reported the occurrence of *M. incognita* from Idukki, Kollam, Kozhikode and Palakkad districts. They also observed the occurrence of *M. javanica* from Kozhikode and Palakkad districts. The present study revealed the presence of free living nematodes (Rhabditids, Dorylaimids and Mononchids) also. Cyriac (2013) reported the presence of Rhabditids sp (bacterial feeder), *Eudorylaimus* sp., *Nygolaimus* sp., *Apocelaimus* sp. and *Mononchids* with varying frequencies from Idukki district on cardamom rhizosphere.

Vattavada and Kanthalloor Panchayaths are not only the important cabbage growing tracts of Idukki district but also in the state as well. Results on community analysis of nematodes in Idukki district (Vattavada and Kanthalloor Panchayaths) showed that *Helicotylenchus* sp. and *R. reniformis* are the key nematodes prevailing in most of the locations. In Vattavada Panchayath (Idukki district) the mean number of *Helicotylenchus* sp. ranged from 39-728 with an average of 329 nematodes per 200 cc soil followed by *R. reniformis* with a range of 0-310 and an average of 97 nematodes per 200 cc soil (Table-1). The frequency of occurrence of these nematodes was 100 and 76.9 % respectively. Highest prominence value (261.6) and relative density (72.7) was recorded by

Helicotylenchus sp. followed by *R. reniformis* with a prominence value (119.6) and relative density (21.3) in Vattavada Panchayath (Idukki district). Other Tylenchids observed were *M. incognita* and *Tylenchorhynchus* sp. which recorded population range of 0-118 and 0-234 respectively. In Kanthalloor Panchayath of Idukki district, the population of *Helicotylenchus* sp., *R. reniformis, M. incognita* and *Tylenchorhynchus* sp. were in the range of 16-752, 0-374, 0-247 and 0-238 respectively. The present findings on the predominance of different species was in agreement with those of Sreeja (2011) and Cyriac (2013) who reported *Helicotylenchus* sp. as the most prominent nematode species on cardamom soils of Idukki district. Eapen (1995) reported occurrence of females of reniform nematodes (7-16 /g of roots) in cardamom plantations of Kerala.

M. incognita and *R. reniformis* occurred in all locations surveyed in Kanthalloor Panchayath with frequency of occurrence of 61.5 and 76.9 % respectively (Table 1). Sreeja (2011) reported the occurrence of *M. incognita* from Pampadumpara. Cyriac (2013) reported Thovalapadi, Rajakumari and Thopramkudy areas of Idukki district as the hot spot areas for *M. incognita*. Highest population of *Tylenchorhynchus* sp. was observed in Puthoor area of Kanthalloor Panchayath. Hence this area can be designated as a hot spot area for stunt nematode infestation in cabbage. The occurrence of *T. mashoodi* in cabbage and cauliflower was reported earlier by Khan and Khan (1999)

In Kollam district five Panchayaths were surveyed *viz.* Anchal, Eroor, Alayamon, Karavaloor and Edamulackal. The predominant nematodes encountered were the free living ones with absolute frequency of 100 %. Among the plant parasitic nematodes, population of *M. incognita* was the highest with range of 0-310 per 200 cc soil and a mean of 104 and a frequency of 53.9 %. The highest relative frequency for root knot nematode (50) was observed in Aylara and Alayamon villages in Kollam district (Fig. 2).The population of other tylenchids (*R. reniformis, Helicotylenchus* sp.) and *Xiphinema* sp.) ranged from 0-240 per 200 cc soil sample with an average of 58 and frequency of 46.2 %. *M. incognita* recorded the highest prominence value (63.9) and relative density

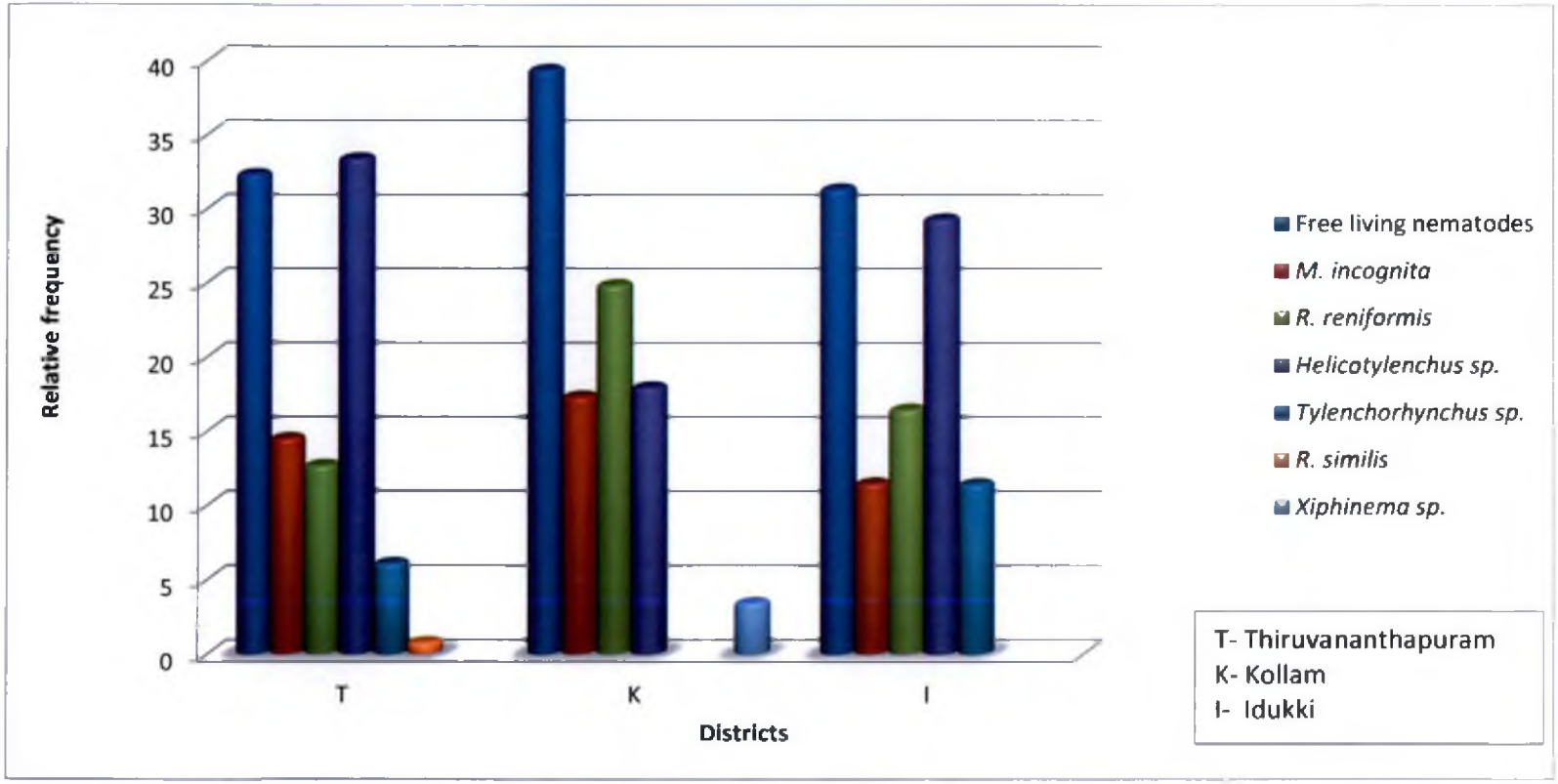


Fig. 2 Relative frequency of nematodes associated with cabbage in Thiruvananthapuram, Kollam and Idukki districts of Kerala

(48.8) in Kottukkal village of Anchal Panchayath (Fig. 3). The finding supports the report of Ravichandra and Krishnappa (2004) who observed the predominance of *M. incognita* in cabbage, carrot and raddish in Mandhya District of Karnataka.

Community analysis of nematodes in Thiruvananthapuram district (Table 45 to 57) revealed that *Helicotylenchus* sp. was the most frequent and prominent species of plant parasitic nematode associated with the rhizosphere of cabbage with frequency of occurance of cent per cent followed by *M. incognita* (61.50), *R. reniformis* (61.50), *Tylenchorhynchus* sp. (30.80) and *R. similis* (7.7). Kottukal and Vellayani villages of Thiruvananthapuram district revealed the highest population of *M. incognita* with prominence values of 104.8 and 102.4 respectively and these areas can be designated as hot spot area of root-knot nematode infestation. *R. similis* was recorded only in one area *i.e.*, Vellayani of Kalliyoor Panchayath where the previous crop grown was banana. The prominence value of *R. similis* was 42.4 in Vellayani. Narayana *et al.* (2012) and Nisha *et al.* (2012) have reported occurrence of *M. incognita* in cabbage and carrot from Thiruvanathapuram district.

The population of *M. incognita* ranged from 0-310 per 200 cc soil with 38.5 to 61.5 per cent frequency of occurrence in cabbage growing tracts surveyed. Root-knot nematode being an endoparasite reported to have very high damage potential in vegetable crops. Khan *et al.* (2002) reported *M. javanica*, *M. incognita* race 1 and 2 and *M. arenaria* infection in cabbage. In Kerala, root-knot nematode caused 26.2 to 50%, 9 to 29% and 28 to 47.5% yield loss in brinjal, bhindi and tomato respectively (Sheela *et al.*, 2005). Besides direct damage, these nematodes serve as pre disposing agents in development of disease complexes with fungi, bacteria and viruses. *M. incognita* and *F. oxysporum* together cause disease complex in cabbage in Karnataka (Rajinikanth, 2011).

Considering the above facts, *in vitro* screening studies were conducted to evaluate the ovicidal (Fig. 4) and larvicidal effects (Fig. 5) of aqueous extracts of four weed plants (leaves of *T. diversifolia, L. camara and E. crassipes* and root of

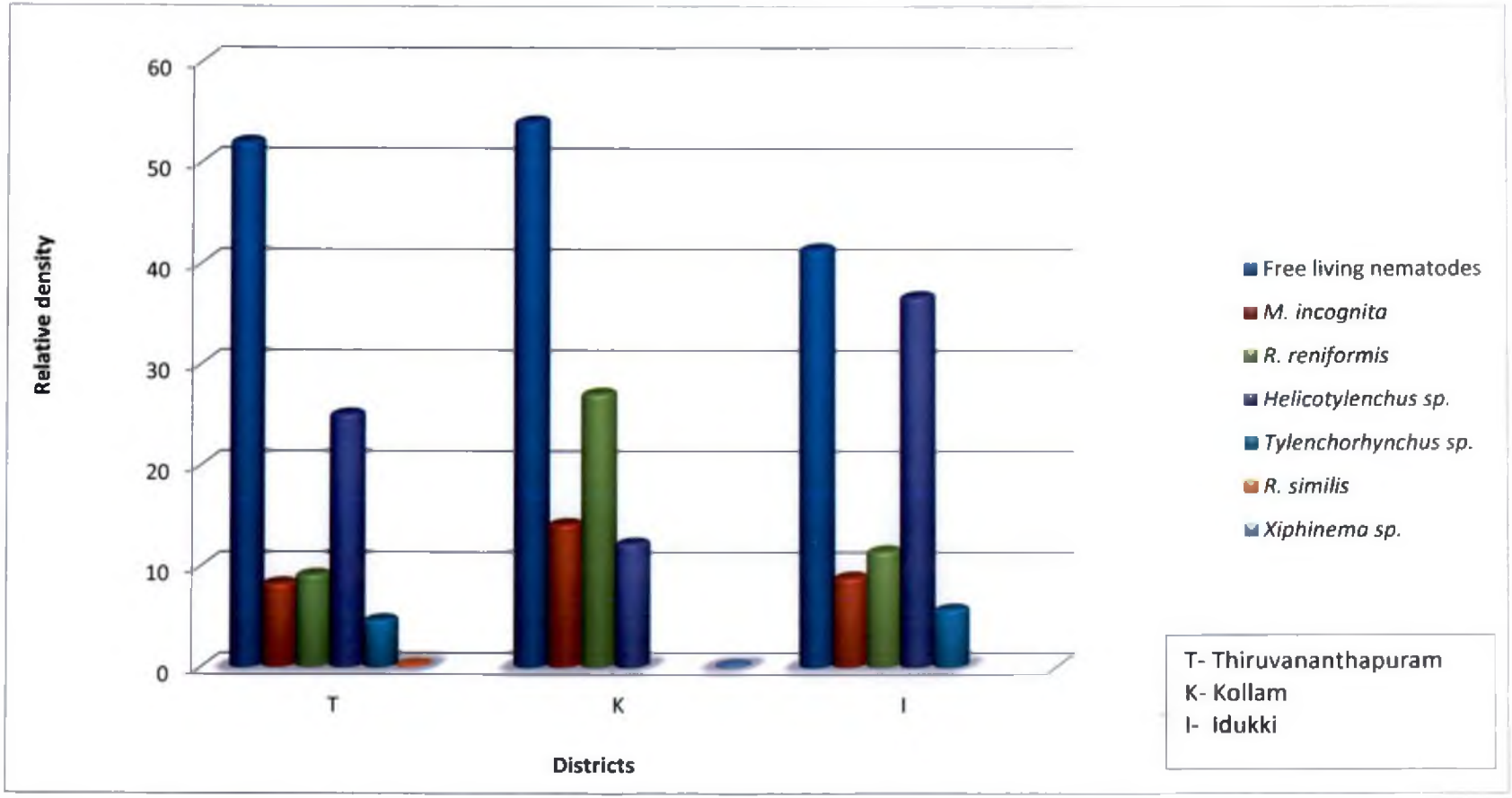


Fig.3 Relative density of nematodes associated with cabbage in Thiruvananthapuram, Kollam and Idukki districts of Kerala

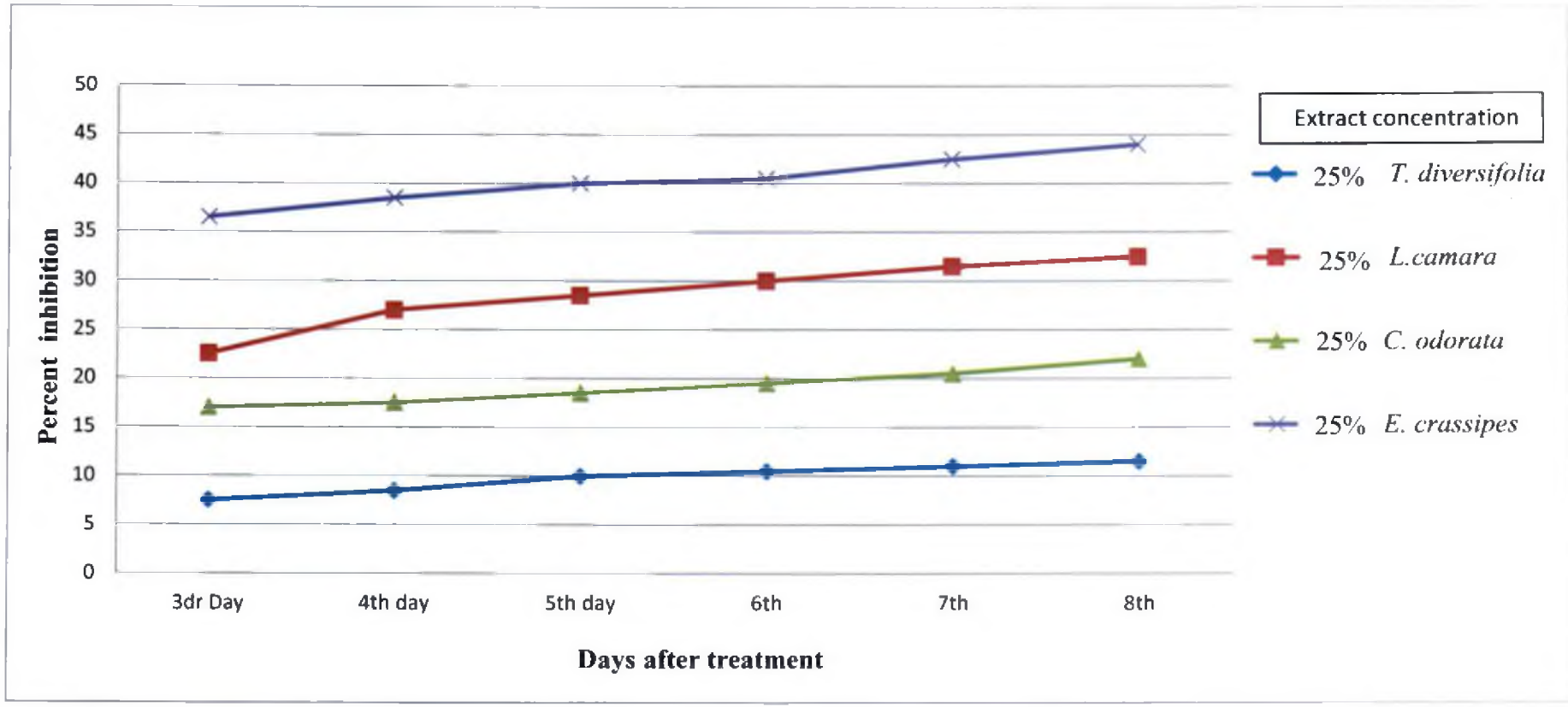


Fig. 4 Effect of plant extracts on hatching of *M. incognita* eggs *in vitro*

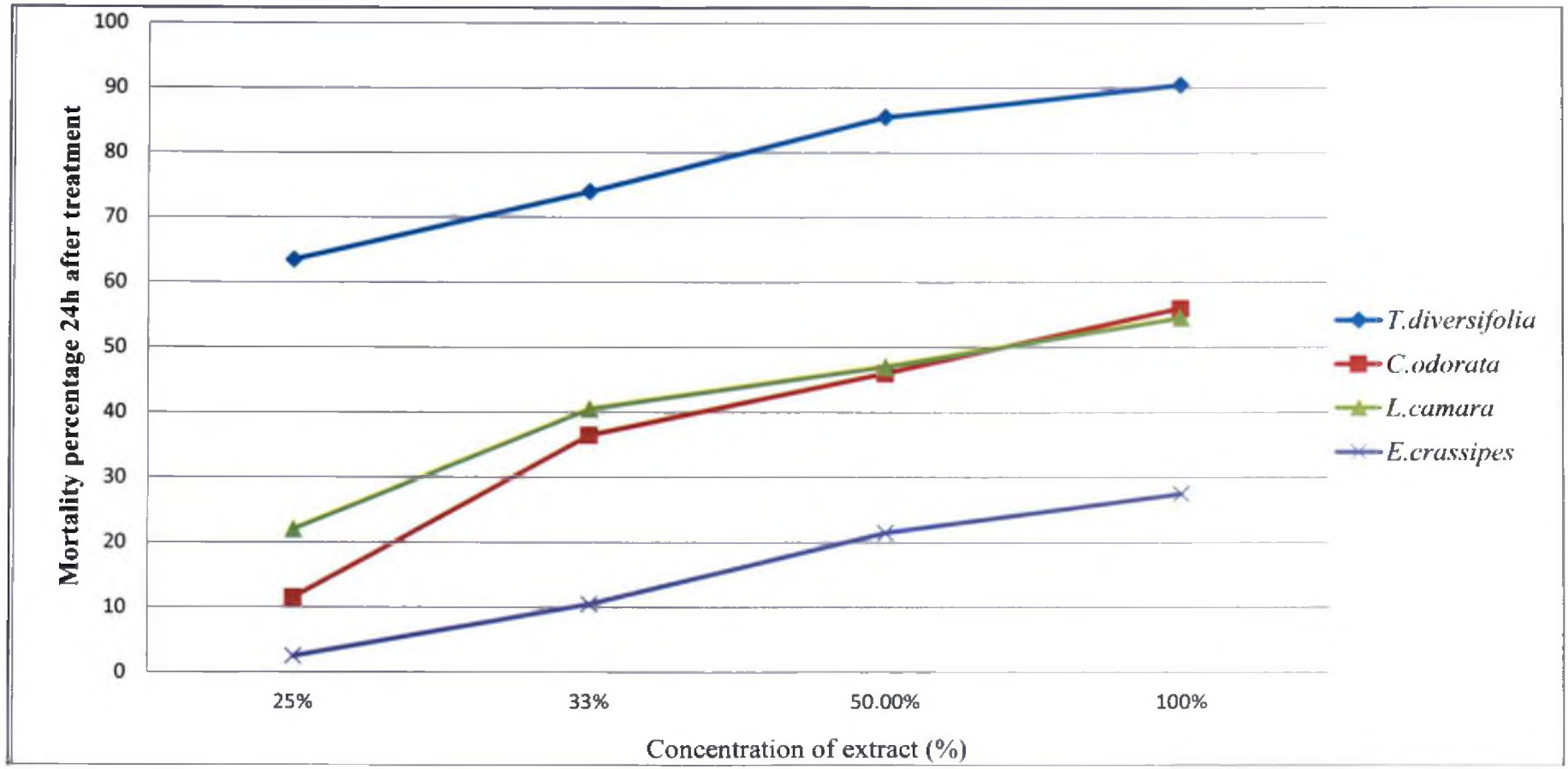


Fig.5 Effect of plant extracts on mortality of *M. incognita* juveniles *in vitro*

C. odorata) against *M. incognita.* Results presented in para 4.2 revealed that minimum egg hatching (1 to1.46 %) was observed in *T. diversifolia* leaf extract 100% concentration at three to eight days after treatment. Lower concentrations (50, 33.3 and 25%) of *T. diversifolia* also showed significant superiority over other treatments (*C. odorata, L. camara* and *E. crassipes*) giving 3.00 to 11.50% egg hatching. *C. odorata* root extract and leaf extracts of *L. camara* and *E. crassipes* also showed significant superiority in inhibiting the egg hatching at 100% concentration compared to the control. Other dilutions *viz.*50, 33.3 and 25% concentrations though significant, were less effective. The rate of hatching was directly proportional with exposure period and inversely proportional with concentration of extract as it was decreased with increase in extract concentration.

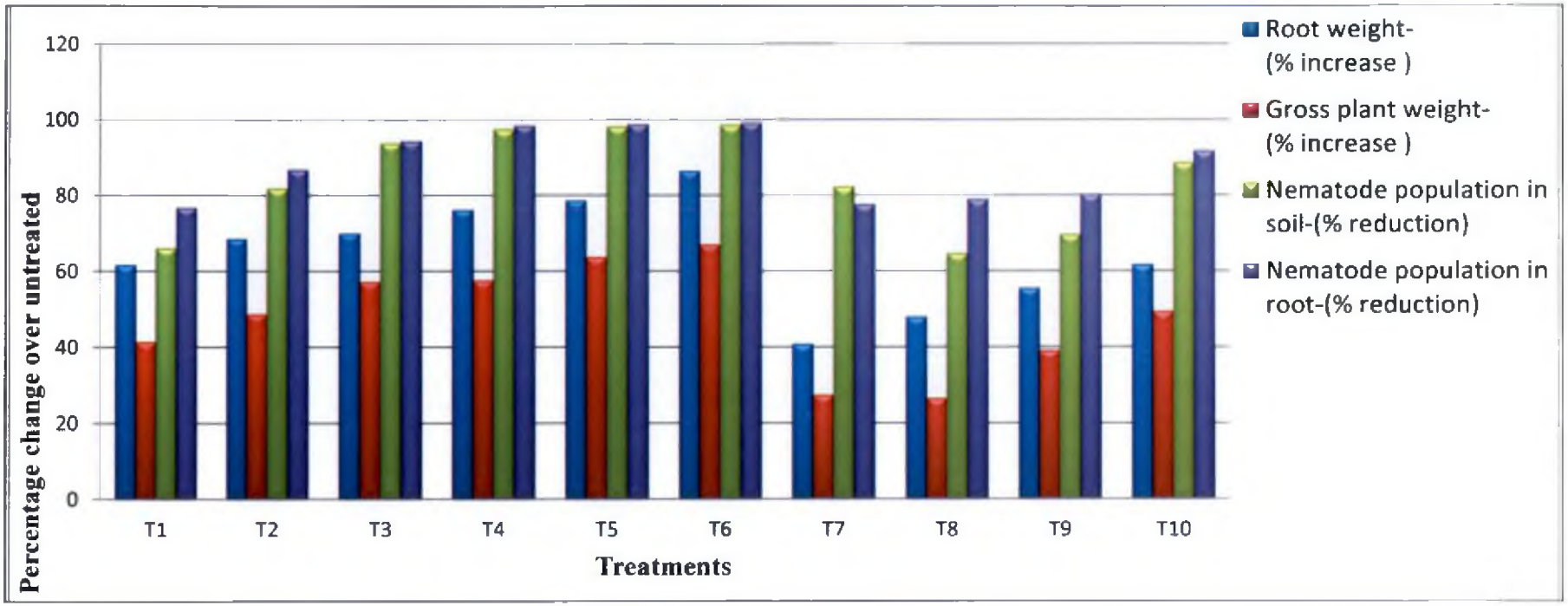
It is evident that as the extract was diluted toxicity was decreased resulting in corresponding decrease in inhibition. This observation in this study clearly highlights the ovicidal property of *T. diversifolia.* The inhibitory effect of the extract might be due to chemicals present in the *T.diversifolia* leaf extract that possess ovicidal properties. Akpheokhai *et al.* (2012) reported ovicidal effect of *T. diversifolia* on *M. incognita* to the tune of 70 per cent within 10 days and Juvenile mortality at 50,000 mg/kg concentration to the tune of 89 per cent. Odeyemi and Adewale (2011) reported application of *T. diversifolia* extract on *M. incognita* eggs resulted in significant reduction in egg hatching after second (98%), fifth (98%) and ninth (100%) day of exposure. Studies have shown that *T.diversifolia* has bioactive compounds that have nematicidal properties (Prakash and Rao, 1997). Nimbalkar and Rajurkar (2009) reported 100% inhibition of *M. incognita* egg hatching in 100% concentration of *C. odorata* root extract. Thoden *et al.* (2007) reported that pure pyrolizidine alkaloids from *C. odorata* roots have nematicidal effect on *M. incognita* at 70-350 ppm concentration on lettuce. Ovicidal effect of *L. camara* leaf extract on *M. incognita* infecting banana was reported by Patel *et al.* (2004).

The inhibitory effect of the extracts might be due to the presence of ovicidal chemicals which either affected the embryonic development or killed the

egg or dissolved the egg masses. The extracts contained alkaloids *viz.* flavinoids, saponins, amides, including benzamide and ketones that singly and in combination inhibited egg hatching (Hackney and Dickerson, 1975; Goswami and Vijayalakshmi, 1986; Adegbite, 2003).

All the concentrations of *T. diversifolia* tested (100, 50, 33.3 and 25 %) were found to be effective in increasing the mortality of *M. incognita* juveniles at 24, 48 and 72 hours after treatment (63 to 100 %). The mortality of *M. incognita* juveniles increased with the concentration of the plant extract and time of exposure. The inhibitory effect of the plant extracts might be due to the presence of alkaloids, flavinoids and saponins on *T. diversifolia* (Tona *et al.*, 2000; Olabiyi *et al.*, 2013). Greater mortality (90 to 100%) was observed at higher concentration of crude extract (100 %) whereas lower concentration (25 %) recorded lesser mortality (63 to 96%) at 24 to 72hours after treatment. *C. odorata* root extract (100 %) showed significant superiority over other treatments with 96 to 98 per cent mortality at 48 and 72 hours after treatment. This was in line with the findings of Sundararaju *et al.* (1999) who reported the effectiveness of *C. odorata* leaf extract as promising nematicide against the adults and larvae of *R. similis*. In this study *L. camara* leaf extract (100%) showed 70 and 79 per cent larval mortality of *M. incognita* at 48 and 72 hours after treatment. Lantanoside, lantanine and camanninic acid isolated from aerial parts of *L. camara* (1%) showed 90, 85 and 100% mortality against *M. incognita.* (Begum *et al.,* 2000). Quamar *et al.* (2005) reported nematicidal activity of lantanic acid, camaric acid and oleanic acid isolated from methanolic extracts of *L. camara.*

Based on the ovicidal and larvicidal activity and availability of plant biomass, *T. diversifolia* was selected for detailed study. A pot culture study was conducted to find out the form of preparation and appropriate application method of *T. diversifolia* for the management of *M. incognita* in cabbage (Fig. 6). Results presented in para 4.3 revealed that *T. diversifolia* soil application in the form of charcoal adsorbed granules at 25, 50 and 100 kg of soil, dried powder at 25, 50 and 100 g(kg soil)$^{-1}$, seedling root dip in crude extract for 30minutes, soil



T_1 –Extract absorbed on charcoal (25g/kg soil) T_4 –Dried powder(25g/kg soil) T_7-Seedling root dip for 30 minutes
T_2 –Extract absorbed on charcoal (50g/kg soil) T_5- Dried powder (50 g/kg soil) T_8-Soil drenching of crude extract (25ml/plant)
T_3.Extract absorbed on charcoal (100g/kg soil) T_6- Dried powder (100 g/kg soil) T_9- Soil drenching of crude extract (50ml/plant)
T_{10}- Soil drenching of crude extract (100ml/plant)

Fig.6 Effect of *T. diversifolia* treatments on biometric characters and nematode population in cabbage (Pot culture condition)

drenching of crude extract at 25, 50 and 100 ml plant^{-1} showed statistically significant variation in reducing the nematode population and improving the growth parameters of cabbage. Soil application of *T. diversifolia* dried powder at 100 g(kg soil)$^{-1}$ was superior to all the other treatments in reducing the nematode population in soil and root (99 % reduction over the untreated). Regarding root-knot count also minimum number of galls (5.89 galls per 5 g root) was noticed in soil application of *T. diversifolia* dried powder @ 100 g(kg soil)$^{-1}$ .Number of females and number of egg masses per root (5 g) also significantly decreased in the treatment of soil application of *T. diversifolia* dried powder @ 100 g(kg soil)$^{-1}$. Soil application of *T. diversifolia* @ 50 and 25 g(kg soil)$^{-1}$ also found effective in reducing the nematode population in soil and root (no. of larvae, no. of galls, no. of females, no. of egg masses) giving 77 to 98 % reduction over the untreated. This finding is in conformity with Odeyemi and Adwale (2011) who reported that *T. diversifolia* residue amendment was effective in suppressing number of eggs and juveniles of *M. incognita* on yam.

Tsay *et al.* (2004) reported that out of 56 species and 45 genera of Asteraceae plants tested for their susceptibility to *M. incognita*, *T. diversifolia* was the one among the nine found to be highly resistant or immune. Tona *et al.* (2000) and Olaibi *et al.* (2013) explained the nematicidal property of *T. divesifolia* to be due to the presence of alkaloids, flavinoids and saponins. Olaibi *et al.* (2007) reported reduction in number of galls and egg masses as well as increase in plant growth of nematode infected cowpea by wild sunflower compost application. The effect of application of *T. diversifolia* in dry powder form for managing root-knot nematode of cabbage is the first of its kind being reported so far.

T. diversifolia extract adsorbed on charcoal @ 50 and 100 g(kg soil)$^{-1}$ also found effective in reducing the nematode population in soil and root giving 82 to 94 % reduction over the untreated. Seedling root dip and soil drenching of crude extract also reduced nematode population to the tune of 65 to 92 %. Several authors reported the efficacy of different plant extracts in suppressing root-knot

nematode multiplication in different crops *viz.* neem leaf extract as seedling root dip against *M.incognita* in brinjal (John, 1997) *L. leucocephala* and *G. maculata* root extract against *M. incognita* in okra (Adekunle and Akinula (2007); *M. olifera* and *V. amygadalia* leaf extract against *M. incognita* in cow pea (Claudius-Cole *et al.*, 2010) and leaf extract of *Ocimum basilicum, Chrysanthemum cinerarifolium* (Trevir.), *Melia azadirach* and seed extract of *A. indica* against root-knot nematode on egg plant (Susan and Noweer, 2005). The nematicidal effect of these extracts may be attributed to their high content of certain oxygenated compounds which are characterized by their lipophilic properties that enable them to dissolve the cytoplasmic membrane of nematode cells and their functional groups interfering with the enzyme protein structure (Knoblock *et al.,* 1989). The mechanisms of plant extracts action may include denaturing and degrading proteins, inhibition of enzymes and interfering with the electron flow in respiratory chain or with ADP phosphorylation (Konstantopoulou *et al.*, 1994).

The reduction in nematode population due to application of *T. diversifolia* dried powder directly reflected in the biometric characters of cabbage plant *viz.* height, gross plant weight, root weight and leaf area. *T. diversifolia* dried powder application @ 100 g(kg soil)$^{-1}$ showed significant superiority over all other delivery systems *viz.* seedling root dip, extract adsorbed charcoal in granular form and soil drench. The result obtained in this study is in confirmation with Ramakrishnan *et al.* (1999) who reported that cassava leaf and tuber rind applied as soil amendment @ 100 and 50 g pot^{-1} significantly reduced *M. incognita* population and improved plant growth parameters of okra in pot experiments. In the present study, application of dried powder of *T. diversifolia* suppressed the multiplication of plant parasitic nematodes by nematicidal principles released during decomposition and it also indirectly managed the *M. incognita* population by stimulating the multiplication of predatory nematodes and beneficial micro flora. Increased microbial activity in the amended soil brought about increased conversion of nitrogen to nitrate form which increased the metabolic activity of

plant and resulted in improvement in growth and vigour of cabbage plants. The enhanced root growth and nutrient uptake by the cabbage plants was due to the suppression of nematode multiplication by the dried leaf powder. In this study, though all the forms of *T. diversifolia* were effective in suppressing the nematode population and in improving vigour of plants in terms of biometric characters, dried leaf powder application of *T. diversifolia* was effective in suppressing the nematode population. Hence *T. diversifolia* dried powder application @ 100 g and 50 g plant^{-1} was selected for field evaluation as there is possibility of build up of nematode population to economic injury levels subsequently in other treatments.

Based on the results of pot culture study, a field trial was conducted to assess the efficacy of treatments *viz. T. diversifolia* leaf powder @ 50 and 100 g plant^{-1}, *P. lilacinus* enriched neem cake @ 20 gm^{-2} and thiamethoxam 25 WG @ 0.04 g/m^2 for managing *M. incognita* infesting cabbage plants (Fig. 7). The results on population characteristics of nematodes were presented in para.4.4.3. Highest reduction in nematode population in soil was recorded in thiamethoxam followed by *P. lilacinus* enriched neem cake and nematode population in these treatments were significantly lower than the botanical. The effect of *T. diversifolia* dried powder @ 50 and 100 g plant^{-1} was statistically on par in reducing the nematode population in cabbage rhizosphere giving 85 % reduction over the untreated. The results are in conformity with the findings of Olabiyi *et al.* (2013) who reported bionematicidal potential wild sunflower (*T. diversifolia)* compost for the control of *P. brachyurus* infection on maize.

Cyriac (2013) reported that wild sunflower leaves @ 5 kg per cardamom plant as mulch was effective for the management of nematodes associated with cardamom. In the case of nematode population in root also Thiamethoxam 25 WG@ 0.04 gm^{-2} showed significant superiority over all other treatments giving 93 per cent reduction over the untreated. This finding is line with Cyriac (2013) who reported application of Thiamethoxam 50 WG @ 50 g a.i/ha reduced *M. incognita*

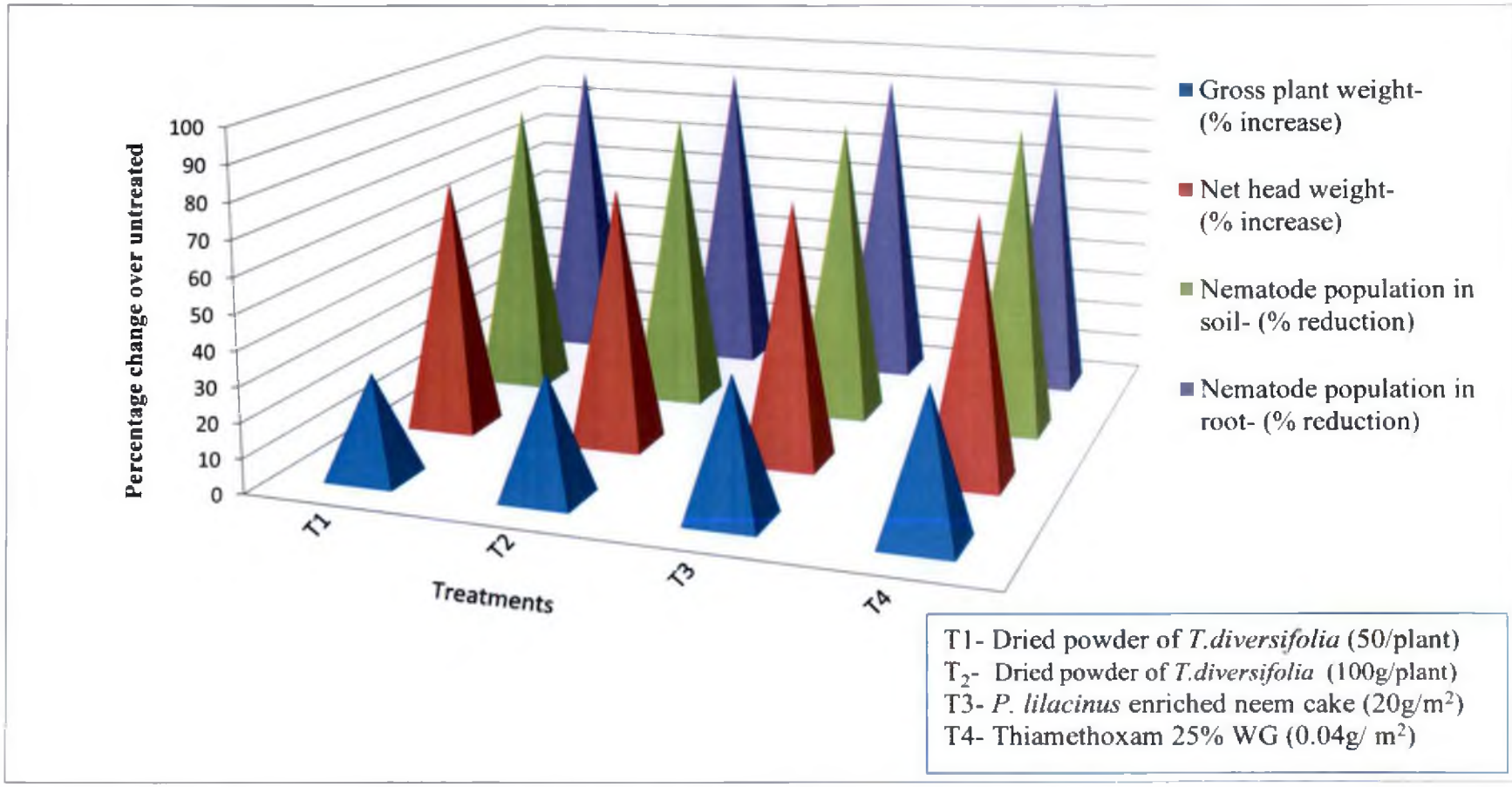


Fig. 7 Effect of treatments on yield and population of *M. incognita* in cabbage at the time of harvest (Field study)

and *H. pseudorobustus* population in cardamom roots. The efficacy of thiamethoxam 25 WG @ 0.04 gm^{-2} observed in the present study is the first report for the management of *M. incognita* in cabbage. *T. diversifolia* dried powder application @ 100 g $plant^{-1}$ was equally effective to *P. lilacinus* enriched neem cake @ 20 gm^{-2} in reducing *M. incognita* population in cabbage roots (92 % reduction over the untreated). Regarding root-knot count the effect of *P. lilacinus* enriched neem cake was equally effective to the chemical treatment, thiamethoxam 25 WG @ 0.04 gm^{-2}, giving 89 % reduction over the untreated. Several workers reported the potential of *P. lilacinus* in suppressing the population of *M. incognita* in crops *viz.* okra (Dhawan *et al.,* 2004), tomato (Priya and Kumar, 2006), and Cardamom (Cyriac, 2013). It was reported that the nematicidal action of *P. lilacinus* may be due to the action of antibiotics like leucinostatin and lilacinin together with proteolytic and chitinolytic fungal metabolic products (Zaki, 1994; Khan and Goswami, 1999). *P. lilacinus,* a heavy sporulator is a strong competitor capable of successfully establishing itself on the natural soil when introduced artificially. The antibiotic, P-168, produced by *P. lilacinus* has crude anti microbial activity against nematodes (Isogai and Suzuji, 1980).

In this study the potential of *P. lilacinus* was boosted by combining with neem cake as evidenced by the result in *M.incognita* population in soil and roots of cabbage. The beneficial effect of neem cake for boosting the potential of egg parasitic fungi, *P. lilacunus* established in this study in agreement with Nisha and Sheela (2006) and Sundararaju and Kiruthika (2009) who reported the efficacy of combined application of *P. lilacinus* and neem cake in reducing the multiplication of *M.incognita* in coleus and banana. Incorporation of neem cake with *P. lilacinus* promoted multiplication and rapid establishment of the fungus and thereby increased the availability of the fungus to nematode. In addition to the above action, the ovicidal effect of *P. lilacinus* adversely affected progeny production of *M. incognita.* Regarding the number of females and number of egg masses (5 g root) $^{-1}$, the effect of *P. lilacinus* enriched neem cake found to be

equally effective to *T. diversifolia* dried powder application @ 100 g plant^{-1} giving 90 to 92 % reduction over the untreated.

Nematicidal property of *T. diversifolia* against *T. brassicae* in cauliflower and cabbage and *M .incognita* in cowpea were reported by Tyagi and Wani (1992) and Olabiyi *et al.*, (2007) respectively. Green manures from an array of plants were reported to be effective for the management of plant parasitic nematodes. Mulching with green leaves of *C. odorata, C. infortunatum* and *A. indica* reduced nematodes in Kacholam (Nisha and Sheela, 2002) bhindi and cowpea (Sheela *et al.*, 2008). Siji *et al.* (2010) reported application of *C. viscosa* dry powder @ 250 g per plot reduced *M. incognita* multiplication in bhindi. Here, in this study the application of dried powder of *T. diversifolia* @ 100 and 50 g(kg soil)$^{-1}$ found to be effective in reducing the *M. incognita* population in soil and root of cabbage. The plant powder may acted against nematodes by means of some of the active principles absorbed by roots or by way of some chemical reaction triggered by these chemicals (Bunt, 1975) causing tolerance against the invasion and development of nematodes (Bell, 1981; Tiyagi and Alam, 1995).

Olabiyi *et al.* (2013) conducted phyto chemical screening studies and reported the presence of tannins, saponins, alkaloids and flavinoids from wild sunflower compost. Nematicidal property of flavinoids was already reported by Verma *et al.* (1978). The inference drawn from the present investigation that in *T. diversifolia,* dry powder treated plants, the root-knot nematode infestation was reduced due to the presence of flavinoids. The use of organic mulches for managing nematodes has been widely studied and there are various examples of plant debris having beneficial effects on plant growth (Jasy and Koshy, 1992) in black pepper, Khanna and Sharma (1998) in tomato and Santhi and Sundarababu (1998) in cowpea). Addition of organic matter has shown to increase soil microbial activity (Widmer and Abawi, 2000) that may have a direct effect on plant parasitic nematode population (Kloepper *et al.*, 1991).

The reduction in nematode population characteristics by the above treatments was directly reflected on the biometric characters *viz.* gross plant weight, plant height, leaf area and number of non wrapper leaves. Application of *T. diversifolia* dried powder @ 100 g per plant, *P. lilacinus* enriched neem cake and thiamethoxam was found equally effective in improving the biometric characters which was reflected in yield. In this study, the effect of *T. diversifolia* dry powder @ 100 g and 50 g per plant found to statistically on par in improving the gross head weight of cabbage. In net head weight, the dried powder of *T. diversifolia* @ 100 g/ plant was found to be equally effective to chemical, thiamethoxam and *P. lilacinus* enriched neem cake and was inferior to *T. diversifolia* dried powder @ 50 g/plant. The effect of *T. diversifolia* in enhancing plant growth parameters and yield of cowpea, tomato, yam and cardamom was already established by Olabiyi (2007), Devi (2010), Odeyemi and Adewale (2011), and Cyriac (2013) respectively. Here in this study the increase in biometric characters and yield of cabbage in *T. diversifolia* dried powder application may be due to the improvement of soil health. Jama *et al.* (2000) 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 of the crop. Cabbage needs high amount of organic matter, so incorporation of nematicidal plants like *T. diversifolia* improve soil quality, soil microbial population dynamics and also suppress the activity of soil inhabiting plant pathogens, nematodes and pests. The present finding confirms the efficacy of *T.diversifolia* dried powder @ 100 g per plant for the management of *M. incognita* in cabbage.

SUMMARY

6. SUMMARY

The study entitled "Nematode association in cabbage, *Brassica oleracea* L. var. *capitata* and its management using botanicals" was conducted at College of Agriculture, Vellayani during the period 2012-2014. The main objective was to study the nematode fauna associated with cabbage in Kerala, screening plant extracts against *M. incognita* for nematicidal property and to evolve eco-friendly management strategy using plant products.

Two hundred and eight soil and root samples were collected from cabbage growing tracts of Idukki, Kollam and Thiruvananthapuram districts. Special emphasis is given to Kanthalloor and Vattavada Panchayaths of Idukki district as they are the prominent cabbage growing tracts in the state. The samples were analyzed for studying the association and the community behavior of nematodes in the root zone of cabbage. The analysis of soil samples from the rhizosphere of cabbage revealed the presence of both plant parasitic and free living forms of nematodes. The plant parasitic included Tylenchids (*M. incognita*, *Helicotylenchus* sp., *R. reniformis*, *Tylenchorhynchus* sp., and *R. similis*), a Dorylaimid, *Xiphinema* sp. and free living forms included Rhabditids and predatory Mononchids.

The population of *M. incognita* ranged from 0-118, 0-247, 0-310, and 0-262 per 200 cc soil in Vattavada (Idukki district), Kanthalloor (Idukki district), Kollam, and Thiruvananthapuram respectively. The average and frequency of occurrence of *M. incognita* in these areas ranged from 29-104 and 38.5 to 61.5 respectively. Highest population of *M. incognita* (0-310 per 200 g soil) was observed in Vilakkupara village of Kollam district. The frequency of occurrence of *M. incognita* was highest (61.5%) in Kanthallor (Idukki district) and Thiruvananthapuram district while it was the lowest (38.5%) at Vattavada (Idukki district). The population of *Helicotylenchus* sp. ranged from 0-752 and was the dominant nematode in all cabbage growing areas surveyed. The population of *R. reniformis* ranged from 0-374 with an average of 94 and frequency occurrence of 67.3 in cabbage growing areas of Vattavada (Idukki district), Kollam, Kanthalloor (Idukki district) and Thiruvananthapuram. In the case of *Tylenchorhynchus* sp. the population ranged from 0-238 per 200 cc soil with an average of 45 and frequency occurrence of 48.73 in the above four areas. *Xiphinema* sp. was observed in two

locations of Kollam district and *R. similis* from one location of Thiruvananthapuram district. Free living nematodes were recorded from all the locations surveyed.

Location wise community analysis showed the presence of *M. incognita* in 28 locations out of 52 locations surveyed. Highest prominence value for *M. incognita* (124) was observed at Vilakkupara village of Kollam district. In the case of *R. reniformis* highest population (374 (200 cc soil)$^{-1}$) was found in Puthoor village of Idukki district with relative density of 32.0 and prominence value of 125.6. Highest population of *Helicotylenchus* sp. was recorded in Kanthalloor village (752 (200 cc soil)$^{-1}$) with prominence value of 300.8 and relative density of 43.3. The population of *Tylenchorhynchus* sp. was highest in Perumala village of Idukki district (238 (200 cc soil)$^{-1}$) with prominence value of 67.3 and relative density of 42.4. *R. similis* was observed from Vellayani village of Thiruvananthapuram with prominence value of 12.7. In Vilakkupara village of Kollam *Xiphinema* sp. was observed with absolute frequency of 100 %. Considering the distribution, *M. incognita* was the most challenging nematode in cabbage.

Laboratory studies were conducted to evaluate the ovicidal and larvicidal properties of different concentrations of *T. diversifolia, L. camara, E. crassipes* (aqueous leaf extracts) and *C. odorata* (root extract) against *M. incognita*. There was cent per cent hatching inhibition in all the treatments first and second day after treatment. Minimum egg hatching (1.00-1.46 %) was recorded by *T. diversifolia* 100 % concentration at an exposure period of three to eight days. Lower concentrations of *T. diversifolia* (50, 33.3 and 25%) also showed significant superiority over other concentrations of *C. odorata, L. camara* and *E. crassipes* giving 3.00-11.5 % egg hatching at an exposure period of three to eight days after treatment.

Regarding larval mortality, *T. diversifolia* leaf extract 100 % showed statistically significant superiority over all concentrations (50, 33.3 and 25 %) of other plant extracts (*C. odorata, L. camara* and *E. crassipes*) giving 90.49, 98.25 and 100 per cent mortality at 24, 48 and 72 hours after treatment respectively. *T. diversifolia* at 50 and 33.3 % concentration were found to be equally effective to *C. odorata* root extract 100 % giving 96.10 to 97.15 and 98.75 to 99.85 % mortality of *M. incognita* at 48 and 72 hours after treatment respectively. Lowest concentration of *T. diversifolia* (25%) recorded 63.48 % larval mortality at 24 hours after treatment and was statistically superior to all concentrations of other plant extracts tested.

As *T. diversifolia* 25% concentration being the lowest concentration of extract giving more than 50 % larval mortality (63.48 % at 24 hours after treatment) and high egg hatch inhibition (88.5 to 92.51 % at three to eight days after treatment) *T. diversifolia* was selected for further studies.

Pot culture studies were conducted to standardize appropriate preparation and method of application of selected botanical, *T. diversifolia viz.* soil application of extract adsorbed charcoal in granular form, soil application of dried powder, seedling root dip and soil drenching of leaf extract. The results were assessed in terms of biometric characters (plant height, leaf area, root weight and gross plant weight) and nematode population characteristics (root-knot count, no. of females, number of egg masses and number of larvae in root and soil). The population of *M. incognita* in the root zone of cabbage was reduced significantly by the application of *T. diversifolia* dried powder @ 100 g(kg soil)$^{-1}$. *T. diversifolia* dried powder @ 50 g(kg soil)$^{-1}$ also showed statistically significant superiority in reducing nematode population over soil application of extract adsorbed charcoal granules, seedling root dip and soil drench. The percentage reduction in nematode population in these treatments ranged from 98 to 99. The effect of *T. diversifolia* dried powder @ 100 g(kg soil)$^{-1}$ was statistically on par with *T. diversifolia* dried powder @ 50 g(kg soil)$^{-1}$ in reducing the number of larvae per 5 g root (99 % reduction over untreated). Highest reduction in root-knot count was recorded in soil application of *T. diversifolia* dried powder @ 100 g(kg soil)$^{-1}$ followed by *T. diversifolia* dried powder @ 50 g(kg soil)$^{-1}$. These two treatments showed statistically significant variation between them giving 87 to 91 % reduction over untreated. In the case of number of females and egg masses in root, highest reduction was recorded in *T. diversifolia* dried powder @ 100 g(kg soil)$^{-1}$ followed by *T. diversifolia* dried powder @ 50 g(kg soil)$^{-1}$ (85 to 89 % reduction over untreated).

Regarding the biometric characters, plants raised in pots treated with *T. diversifolia* @ 100g(kg soil)$^{-1}$ recorded maximum plant height (30.00 cm) and it was significantly superior to the next best treatment *T. diversifolia* 50 g(kg soil)$^{-1}$ (26.67 cm). In the case of leaf area also similar trend was observed. Maximum root weight (24.50 g) was recorded by *T. diversifolia* dried powder @ 100 g(kg soil)$^{-1}$ and it showed significant superiority over of *T. diversifolia* dried powder @ 50 g(kg soil)$^{-1}$ (15.48 g). Highest gross plant weight was recorded by *T. diversifolia*

dried powder soil application @ 100 g(kg soil)$^{-1}$ (187.00 g) and it showed statistically significant superiority over *T. diversifolia* dried powder @ 50 g(kg soil)$^{-1}$ (170.00 g). Results of the pot culture study revealed that application of *T. diversifolia* dried powder @ 50 and 100 g(kg soil)$^{-1}$ was effective in decreasing the population of *M. incognita* in cabbage rhizosphere and improving the growth parameters in comparison with soil application of extract adsorbed charcoal, seedling root dip and soil drench. Thus *T. diversifolia* dried powder @ 50 and 100 g(kg soil)$^{-1}$ was selected for field evaluation using cabbage variety NS 183.

Field study was conducted to evaluate the efficacy of botanical identified (*T. diversifolia* dried powder) in comparison with chemical, thiamethoxam and bio agent, *P. lilacinus* enriched neem cake for the management of *M. incognita* in the rhizosphere of cabbage as main field treatment. The results were assessed in terms of biometric characters (plant height, leaf area, non-wrapper leaves, and gross plant weight), yield attributing characters (head depth, head diameter, gross head weight, net head weight) and nematode population characteristics (root-knot count, number of females, number of egg masses, number of larvae in root and soil. The initial population levels of infested plots were uniform and there was no statistically significant variation in population levels which ranged from 259 to 283 per 200 g soil. Seedlings of cabbage were transplanted to sick plots (2 m X 2 m). Treatments were given simultaneously with planting and observations were taken at the time of harvest.

Maximum reduction in nematode population in soil was observed in chemical, thiamethoxam (89 % reduction over untreated) followed by *P. lilacinus* enriched neem cake (87 % reduction) and *T. diversifolia* dried powder @ 100 g and 50 g plant^{-1} (85 % reduction). Regarding nematode population in root, the chemical thiamethoxam showed significant superiority over *P. lilacinus* enriched neem cake and *T. diversifolia* dried powder giving 93 % reduction over untreated. Similar trend was observed in the case of number of egg masses per root also. The effect of soil application of *T. diversifolia* dried powder 100 g plant^{-1} was found to be statistically on par with *P. lilacinus* enriched neem cake in reducing the number of larvae and egg masses in root (91 to 92 %). Maximum reduction in root-knot count was observed in chemical and it was statistically on par with bio agent enriched neem cake (89 % reduction over untreated). Soil application of *T. diversifolia* @ 50 and 100 g plant^{-1} also significantly reduced the root-knot count (82 % reduction over the untreated) but the effect was inferior to the

chemical and bio agent. The number of females per g root was minimum in chemical treatment followed by *P. lilacinus* enriched neem cake and *T. diversifolia* leaf powder @ 100 g plant^{-1} and the effect of these three treatments was statistically on par giving 90 to 94 % reduction over untreated.

All the treatments showed significant superiority in improving the biometric chararacters also. Maximum plant height was recorded in chemical treatment followed by *P. lilacinus* enriched neem cake, *T. diversifolia* dried leaf powder @ 100 g and 50 g plant^{-1}. In the case of number of leaves the effect of *T. diversifolia* dried powder @ 100 g plant^{-1} was statistically on par with chemical and *P. lilacinus* enriched neem cake. Highest gross plant weight was recorded by chemical treatment followed by *P. lilacinus* enriched neemcake and *T. diversifolia* dried powder @ 100 g plant^{-1} (42 % increase over the untreated). The effect of soil application of *T. diversifolia* dried powder @ 100 g plant^{-1} was statistically on par with chemical and bio agent enriched organic amendment in improving the yield attributing characters *viz.* head depth, head diameter, gross head weight and net head weight.

These investigations highlighted that the major nematodes associated with the rhizosphere of cabbage were *M. incognita*, *R. reniformis*, *Helicotylenchus* sp., *Tylenchorhynchus* sp., *R. similis*, and free living forms (Rhabditids, Dorylaimids and Mononchids). *M. incognita* being an endoparasite was observed as the most problematic nematode in the rhizosphere of cabbage. Aqueous extract of *T. diversifolia* showed ovicidal and larvicidal property against *M. incognita in vitro* even at lower concentration of 25%. Soil application of *T. diversifolia* dried powder @ 100 g plant^{-1} can be recommended as a low cost environmentally safe method for managing root knot nematode in cabbage.

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7. REFERENCES

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Nematode Association in Cabbage, *Brassica oleracea* L. var. *capitata* and its Management Using Botanicals

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ABSTRACT

An investigation entitled 'Nematode association in cabbage, *Brassica oleracea* L. var. *capitata* and its management using botanicals' was carried out at College of Agriculture, Vellayani during 2012-2014 with an objective to study the nematode fauna in rhizosphere of cabbage and to evolve an eco-friendly management strategy using plant products.

A survey was conducted in major cabbage growing tracts of the state *viz.*, Idukki, Kollam and Thiruvananthapuram districts. Result of the survey revealed the presence of *Meloidogyne incognita* (Kofoid & White) Chitwood., *Rotylenchulus reniformis* Linford and Oliveira, *Helicotylenchus* sp., *Tylenchorhynchus* sp., *Radopholus similis* (Cobb) Thorne and *Xiphinema* sp. The population of *M. incognita* ranged from 0-118, 0-247, 0-310 and 0-262 per 200 g soil in Vattavada (Idukki district), Kanthalloor (Idukki district), Kollam and Thiruvananthapuram respectively. The average and frequency of occurrence of *M. incognita* in these areas ranged from 29 to 104 and 38.5 to 61.5 respectively. The population of *Helicotylenchus* sp. ranged from 0-752 and was the dominant nematode in cabbage growing areas surveyed. The population of *R. reniformis* ranged from 0-374 with an average of 94 and frequency of occurrence of 67.3 in these areas. In the case of *Tylenchorhynchus* sp. the population ranged from 0-238 per 200 g soil with an average of 45 and frequency of occurrence of 48.73 in the above four areas. *Xiphinema* sp. and *R. similis* was observed in soil samples collected from Kollam and Thiruvananthapuram districts respectively. Community analysis of nematodes was also done.

Aqueous leaf extracts of *Tithonia diversifolia* (Hemsl.) Gray, *Lantana camara* L., *Eichhornia crassipes* (Mart.) Solms and root extract of *Chromolaena odorata* L. were screened for ovicidal and larvicidal effect against *M. incognita* under *in vitro*

condition. *T. diversifolia* 100 % recorded minimum egg hatching (1 to 1.5 %) three to eight days after treatment.

The bio efficacy of fresh leaf extracts of *T. diversifolia*, *L. camara*, *E. crassipes* and *C. odorata* on mortality of *M. incognita* juveniles revealed that *T.diversifolia* 100, 50, 33.3 and 25 % were effective in increasing the mortality of *M. incognita* juveniles at 24, 48 and 72 hours after treatment (63 to 100 %). *C. odorata* 50 and 100% also showed significant superiority over other treatments giving a mortality of 56 to 98 % at 48 and 72 hours after treatment.

Pot culture study was conducted to find out efficacy of different preparations of *T. diversifolia* and appropriate method of application. *T. diversifolia* dried powder @100 and 50 g(kg soil)$^{-1}$ were effective in decreasing the nematode population in soil and root (98 to 99 %) and improving the plant growth (31 to 87 %).

Results of field study revealed that highest reduction of nematode population in soil was observed in thiamethoxam followed by *Paecilomyces lilacinus* (Thom)Samson enriched neem cake and nematode population in these treatments was significantly lower than *T. diversifolia* dried powder. *T. diversifolia* dried powder @ 50 and 100 g plant^{-1} was statistically on par in reducing the nematode population (85 % reduction over untreated) in cabbage rhizosphere.