MORPHOLOGICAL VARIATIONS OF ROOT KNOT NEMATODE IN VEGETABLES AND BANANA

by

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(2015-11-082)

THESIS

Submitted in partial fulfilment of the

requirements for the degree of

MASTER OF SCIENCE IN AGRICULTURE

Faculty of Agriculture

Kerala Agricultural University

KERALA AGRICULTURAL UNIVERSITY CENTRAL LIBRARY P.O. (P.O.), THRISSUR

DEPARTMENT OF AGRICULTURAL ENTOMOLOGY

COLLEGE OF AGRICULTURE

VELLAYANI, THIRUVANANTHAPURAM-695522

KERALA, INDIA

2017

DECLARATION

I, hereby declare that this thesis entitled **"MORPHOLOGICAL VARIATIONS OF ROOT KNOT NEMATODE IN VEGETABLES AND BANANA"** is a bonafide record of research work done by me during the course of research and 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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Certified that this thesis entitled **"MORPHOLOGICAL VARIATIONS OF ROOT KNOT NEMATODE IN VEGETABLES AND BANANA"** is a record of research work done independently by Ms. Chinchu P. Babu under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

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Acknowledgement

First of all I am bound to bow my head before The God for he has uplifted me and led me to this endeavour.

With immense pleasure, I would like to express my sincere gratitude to ***Dr. R. Narayana.*** *Assistant Professor, Department of Agricultural Entomology, esteemed chairman of the advisory committee, for the constructive guidance, constant inspiration, critical scrutiny of the manuscript and valuable suggestions which rendered me to accomplish the research work successfully.*

I convey my heartfelt thanks to ***Dr. N. Anitha,*** *Professor & Head, Department of Agricultural Entomology for the unceasing encouragement, valuable advices and whole hearted approach during the course of study.*

I extend my sincere gratefulness to ***Dr. Gavas Ragesh,*** *Assistant Professor (Agricultural Entomology), Banana Research Station, Kannara for the valuable suggestions, technical advice and incessant motivation throughout the research work.*

I would like to express my gratitude to ***Dr. Biju Joseph,*** *Asst. Professor, Soil Science and Agricultural Chemistry for the unstinting support, suggestions and passionate approach rendered during the period of research work.*

I wish to register here my deepest and utmost gratitude to ***Achan, Amma, Chechi*** *and* ***Dinkan*** *for standing beside me throughout all the tumultuous times I have been through and for all the immense emotional strength they gave to me to face all my fears and chase my dreams. I am truly debted to them for all that I am today.*

I wish to place on record of my deep sense of gratitude to my beloved ***teachers*** *for their support and advice at all stages of research work.*

Thanks to ***Nadi*** *for being such a good companion throughout these years.*

I was fortunate to have the best batchmates who supported me with their caring manner. Thanks to ***Nimisha, Ann, Mitrechi, Archana, Varsha, Gayatri, Liz*** *and* ***Hari.*** *I also extend my sincere thanks to* ***Dhanesh, Vishnu*** *and* ***Arjun*** *for their invaluable support.*

It's my pleasure to express my special thanks to ***Sunil chetan, Mridul chetan, Anju chechi, Amrithechi, Sangamesh chetan, Sunu Chechi, Renjini chechi, Sindhu chechi, Vipin chetan, Sarath*** *and also to my juniors* ***Jyothis, Binseena, Raiza, Priyatha, Remya, Shoba, Fasseh, Kishore, Hampi, and Niranjan*** *for their help and support throughout the study period.*

Words are inadequate to express my thanks to my beloved friends ***Nadi, Nimisha, Limu, Asok, Bash, Thumbi, Ann, Pachu and Sethu*** *for their constant support, love, care and for the happiest moments we cherished together.*

Chinchu P. Babu

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LIST OF ABBREVIATIONS AND SYMBOLS USED

%	Per cent
µm	Micro metre
et al.	And others
KAU	Kerala Agricultural University
No.	Number
Sl.	Serial
sp. or spp.	Species (Singular and Plural)
viz	Namely
i.e.	That is
ml	Milli metre
CV	Coefficient of variability
^{0}C	Degree Celsius
>	Greater than
<	Less than

Introduction

1. INTRODUCTION

Crop plants are of great importance for a country, and when these plants suffer from diseases they cause serious losses and adversely affect the agricultural economy of a country. Root knot nematodes (*Meloidogyne* spp.) are considered to be the most wide spread and destructive plant parasites which cause a yield loss of 25 to 50 per cent over large areas of cultivated land (Taylor and Sasser, 1978).

Root knot nematodes are found within the roots where they feed and reproduce on modified living plant cells, inducing small to large galls or root knots. The infective stages of these nematodes are second stage juveniles which upon hatching from the egg penetrate the healthy root and initiate gall formation. The nematode infested roots are often attacked by secondary pathogens resulting in extensive damage to the root system. The above ground symptoms are not readily apparent and may be similar to those produced on any plants having a damaged or malfunctioning root system. The symptoms include yellowing, various degrees of stunting, lack of vigour and wilting under moisture stress resulting from the interference of these nematodes on water and nutrient uptake.

These nematodes are polyphagous and more than 2000 species of plants have been reported as host plants (Sohrabi *et al.*, 2015). In India, vegetables and banana are adversely affected by these nematodes and cause a yield loss of 16.675 per cent, 14.10 per cent, 27.21 per cent and 12.3per cent in brinjal, okra, tomato and banana respectively (Jain *et al.*, 2017).

There are more than 100 species of root knot nematodes in the world and 15 species in India (Khan *et al.*, 2014), among which 4 species are predominant namely, *M. incognita* (Kofoid & White, 1919) Chitwood, 1949, *M. javanica* (Treub, 1885) Chitwood, 1949, *M. arenaria* (Neal, 1889) Chitwood, 1949 and *M. hapla* Chitwood, 1949 which has been the subject of a considerable amount of research.

The lack of awareness about the existence of these nematodes and the characteristic symptom they cause, make these nematodes often neglected by the

farmers. The knowledge about the species often involves identification of the species and better species descriptions to tackle the problem of lack of awareness.

Morphological analyses including perineal patterns are considered important for differentiating *Meloidogyne* species. Morphological and morphometric studies are useful in identification of root knot nematodes from different crops and locations which in turn help in species specific management. Moreover, it will also help in documenting the root knot nematode diversity. Varietal resistance is reported in some crops and identification of nematode species in an area will help in selection of plant varieties resistant to that species for cultivation and thus, effective management practices can be developed by precise identification of nematode species and variation within a single nematode species (Eisenback, 1982).

In this context, the present study entitled "Morphological variations of root knot nematode in vegetables and banana" was undertaken with the aim to study the morphological and morphometric variations of root knot nematode in brinjal, okra, tomato and banana in Kerala.

Review of Literature

2. REVIEW OF LITERATURE

Root knot nematodes are diverse group of plant parasitic nematodes belonging to the genus *Meloidogyne*. They are economically important plant parasites with worldwide distribution and damage every species of higher plants (Perry *et al.*, 2009). Sohrabi *et al.* (2015) reported that the root knot nematodes occur on a wide host range of more than 2,000 species. Other than cultivated crops, over 226 species of weed plants also act as hosts of these nematodes (Rich *et al.*, 2008). The rapid rate of reproduction of these nematodes on its host in several generations leads to severe damage to the crops.

2.1 ROOT KNOT NEMATODES IN VEGETABLES

Sasser (1987) reported that the root knot nematodes reduce the yield of world's 40 major cash crops by an average of 12.3 per cent. Vegetables, cereals, pulses, oil seed crops, fiber yielding crops, ornamentals, fruit trees and plantation crops are affected by these nematodes, among which vegetables are the most preferred host (Khan and Khan, 1990). *Meloidogyne* species were the major nematodes infecting vegetables like tomato, bhindi, brinjal, chilly and cucurbits (Anwar *et al.*, 1991). Sharma (1997) reported that the estimated yield loss caused by root knot nematodes in brinjal, bhindi and tomato are 27-70 per cent, 28-90 per cent and 27-70 per cent respectively.

2.2 SPECIES OF ROOT KNOT NEMATODE IN INDIA AND KERALA

Khan *et al.* (2014) reported that there are more than 100 species of root knot nematode in the world and 15 species in India. *M. incognita* (Kofoid & White, 1919) Chitwood, 1949, *M. javanica* (Treub, 1885) Chitwood, 1949, *M. arenaria* (Neal, 1889) Chitwood, 1949 and *M. hapla* Chitwood, 1949 were the major species and among these species the most important species worldwide was *M. incognita* (Sasser, 1980).

M. incognita, *M. javanica* and *M. arenaria* were distributed in tropical, subtropical and temperate climates, whereas *M. hapla* occurs in the cooler regions (Taylor *et al.*, 1982).

M. incognita and *M. javanica* infest a wide range of plant families including Fabaceae, Compositae, Solanaceae, Cruciferae, Bromeliaceae, Graminae, Musaceae, Vitaceae, Convolvulaceae, Caryophyllaceae, Euphorbiaceae, Chenopodiaceae and Rosaceae (Whitehead, 1968). Cofcewigz *et al.* (2005) reported that *M. arenaria* and *M. incognita* were the major species of root knot nematode infecting *Musa* spp.

In India, Chattopadhay and Sengupta (1955) reported *M. incognita* for the first time from jute in West Bengal and Sen (1959) reported *M. javanica* from vegetables. *M. arenaria* was identified from tomato in Bihar (Lall and Ansari, 1960) and *M. hapla* from tea in Assam (Mukherjee, 1960).

Other species identified from India are *M. africana* Whitehead, 1968, *M. brevicauda* Loos, 1953, *M. thamesi* Goodey, 1963, *M. exigua* Goeldi, 1887, *M. graminicola* Golden and Birchfield, 1965, *M. indica* Whitehead, 1968, *M. lucknowica* Singh, 1969, *M. graminis* (Sledge and Golden, 1964) Whitehead, 1968, *M. triticoryzae* Gaur, Saha and Khan, 1993, *M. piperi* Sahoo, Ganguly and Eapen, 2000 and *M. enterolobii* Yang & Eisenback, 1983.

In Kerala, *M. incognita* was reported from vegetables, banana, coleus, ginger, cardamom, turmeric, carrot and cabbage (Nair *et al.*, 1969; Mammen, 1973; Jacob and Kurien, 1979; Raja and Gill, 1982; Ali and Koshy, 1982; Sukumaran *et al.*, 1989; Nehru *et al.*, 1991; Sheela *et al.*, 1995; Nisha *et al.*, 2012; Narayana *et al.*, 2012). *M. javanica* was reported from banana, coleus and sugarcane (Nair *et al.*,1969; Mammen, 1974). From pepper, *M. piperi* has been reported (Sahoo *et al.*, 2000). Sheela *et al.* (2005) reported *M. graminicola* from rice.

2.3 MORPHOLOGICAL AND MORPHOMETRICAL VARIABILITY OF MAJOR MELOIDOGYNE SPECIES

The morphology of perineal pattern, head and stylet were quite stable characters used for differentiating species of *Meloidogyne* (Eisenback *et al.*, 1981; Rammah, 1989; Sahoo and Ganguly, 2000).

Nadakal (1963) reported that the size of the *Meloidogyne* spp. varied with the species of the host plant. The morphometric characters of females, perineal pattern and second stage juveniles of Indian populations *M. incognita* varied with respect to host plant and locality (Kaur and Attri, 2013a). Sahoo and Ganguly (2000) reported that the morphometric characters of *M. javanica* from different districts of Punjab showed significant variations.

2.3.1 Females

External morphological studies of female head of *M. arenaria, M. incognita, M. javanica* and *M. hapla* when compared using light and scanning electron microscopy revealed that the head morphology differed in all the species (Eisenback and Hirschmann, 1979).

Kofoid and White (1919) described *M. incognita* and found that the females were pear shaped and there was no posterior terminal protuberance. The stylet knobs were drawn out laterally (Whitehead, 1968), rounded in shape and not sharply set off from shaft (Chitwood, 1949; Eisenback, 1982).

Whitehead (1968) reported that the females of *M. javanica* were pyroid in shape and the posterior end of the body was smoothly rounded. In Indian populations, the shape varied from pyriform to saccate with short to long necks (Sahoo and Ganguly, 2000). Chitwood (1949) reported that the stylet knobs of females of *M. javnica* were prominent and rounded whereas Rammah and Hirschmann (1990) reported that the sylet knobs of *M. javanica* were ovoid.

Whitehead (1968) reported that the females of *M. arenaria* were pyroid in shape and stylet knobs were rounded and slightly sloping towards the anterior

margins. Garcia and Sanchez-Puerta (2012) reported that the females of *M. arenaria* were pyriform and the excretory pore is located close to the stylet base.

Whitehead (1968) reported that the females of *M. hapla* were pear shaped with short neck and the stylet knobs were weakly rounded (Chitwood, 1949). Handoo *et al.* (2005) reported the absence of posterior terminal protuberance in *M. hapla* females.

Golden and Birchfield (1965) described *M. graminicola* and reported that the females were globular to pear shaped and head region was not set off. The stylet knobs were rounded and sloping towards anterior margin. Kaur and Attri (2013b) reported that *M. graminicola* females with longer neck possessed bigger median bulb and valve.

Golden *et al.* (1980) described *M. chitwoodi* and reported that the females were pear shaped with slight posterior terminal protuberance and vesicle like structures were present in median bulb. The stylet was small with rounded stylet knobs.

The body length of females of *M. incognita, M javanica, M. arenaria* and *M. hapla* ranged from 510 to 690 µm, 545 to 800 µm, 500 to 1000 µm and 500 to 790 µm respectively (Chitwood, 1949). The body length of *M. graminicola* was 445 to 573 µm (Golden and Birchfield, 1965) and for *M. chitwoodi* the body length was 430 to 740 µm (Golden *et al.*, 1980).

Kaur and Attri (2013a) reported that the body length of females of Indian populations of *M. incognita* varied from 530 to 812 µm and in *M. javanica*, the body length varied from 333 to 877 µm (Sahoo and Ganguly, 2000).

In Indian populations of *M. incognita*, the characters like body length, width, neck length and ratio a of females were found as stable characters (Kaur and Attri, 2013a). In *M. javanica,* body length and neck length were least variable

characters whereas the characters like width, stylet length and ratio a were moderately variable (Sahoo and Ganguly, 2000).

2.3.2 Perineal pattern

The perineal pattern of *M. incognita* was characterized by high squared dorsal arch with smooth to wavy cuticular striae (Jepson, 1987; Whitehead, 1968) and distinct cuticular whorl which was not interrupted laterally (Chitwood, 1949). Kaur and Attri (2013a) reported that the perineal pattern of Indian populations varied from oval to round with low to high dorsal arch.

The perineal pattern of *M. javanica* was characterized by the presence of lateral field which cut through the striae (Chitwood, 1949; Eisenback *et al.*, 1981; Jepson, 1987). Whitehead (1968) reported that the perineal pattern of *M. javanica* were pyroid in shape with lateral field fairly marked by incisures.

Carneiro *et al.* (1998) reported that the perineal patterns of *M. javanica* in Brazil were rounded with low dorsal arch and characteristic lateral field. Indian populations of *M. javanica* showed variations in the perineal pattern by having continous to discontinuous striae in both the arches of perineal pattern (Sahoo and Ganguly, 2000).

In *M. arenaria*, the perineal pattern was marked by lateral wings or shoulders (Chitwood, 1949) and the lateral lines were poorly marked by broken striae (Whitehead, 1968).

Garcia and Sanchez-puerta (2012) studied the morphological variations of *M. arenaria* population in Argentina and observed that the perineal pattern varied from round to oval (4%) in body shape and low to high (38%) dorsal arch. Skantar *et al.* (2008) reported that the laterally elongated regions were absent in Pennsylvania populations of *M. arenaria*.

Chitwood (1949) reported that the perineal pattern of *M. hapla* was hexagonal in shape, the striae were smooth and sometimes slight shoulders were present. Whitehead (1968) observed that the dorsal arch was rounded and fringing

striae was present at the posterior end of lateral line. The characteristic feature of the perineal pattern was the presence of punctuations between anus and tail terminus (Eisenback *et al*., 1981; Jepson,1987). Handoo *et al*. (2005) reported that twenty populations of *M. hapla* in Maui, Hawaii showed lines perpendicular to annulations in vulval-anal area.

Golden and Birchfield (1965) reported that the perineal pattern of *M. graminicola* was egg shaped with fairly wide striae. Choi-pheng and Birchfield (1978) reported that the perineal patterns have smooth vulvar lips without invaginations.

In West Bengal populations of *M. graminicola*, the shape of perineal pattern varied from round to oval with smooth to wavy striae (Talukder *et al*, 2017). The perineal pattern of *M. chitwoodi* was oval to rounded with striae near anal area being broken or twisted sometimes (Golden *et al*., 1980; Devran *et al*., 2009). Oliveira *et al*. (2005) reported that *M. exigua* populations in Brazil showed intraspecific variations with respect to shape and height of dorsal arch.

The mean length of LVS (length of vulval slit) and IPD (interphasmidial distance) of *M. incognita, M javanica, M. arenaria* and *M. hapla* ranged from 510 to 690µm, 545 to 800 µm, 500 to 1000 µm and 500 to 790 µm respectively (Chitwood, 1949) and for *M. chitwoodi*, the LVS was 19 to 32 µm (Golden *et al*.,1980).

The LVS, AVS and IPD of *M. enterolobii* ranged from 25.3 to 32.4µm, 19.7 to 26.6µm and 22.2 to 42.0µm respectively (Yang and Eisenback,1983). Kaur and Attri (2013a) reported that the mean length of vulval slit of females of Indian populations of *M. incognita* ranged from 16 to 26 µm and the interphasmidial distance was 17 to 26 µm.

In Indian populations of *M. javanica,* LVS and ATT were least variable characters whereas AVS and IPD were moderately variable (Sahoo and Ganguly,

2000). In *M. incognita*, anus to tail terminus (ATT) and interphasmidial distance (IPP) of perineal pattern were found as stable characters (Kaur and Attri, 2013a).

2.3.3 Males

Chitwood (1949) observed that the stylet knobs of males of *M. incognita* and *M. javanica* were rounded and the stylet knobs were not prominent in *M. incognita.* Eisenback and Hirschmann (1981) reported that *M. incognita* and *M. javanica* possessed high head cap and in *M. incognita,* the stylet tip was anteriorly blunt and cone is blade like and in case of *M. javanica* anterior two third of cone gradually increases in size and in *M. hapla* head cap is narrower than head region.

Rammah and Hirschmann (1990) reported that the head morphology of males of three host races of *M. javanica* was consistent with slight variations in head region with respect to annulations. Cliff and Hirschmann (1985) reported that the body length of males of *M. arenaria* varied from slender, tapering to bluntly rounded ends with twisted posterior region.

Chitwood (1949) reported that the head of *M. arenaria* males were low, rounded and truncate in shape. Garcia and Sanchez-Puerta (2012) reported that the males of *M. arenaria* possessed concave head and moderately elevated labial disc.

The males of *M. hapla* possessed weakly rounded stylet knobs and shaft which was tapering (Chitwood, 1949). Whitehead (1968) reported that the head region of *M. hapla* males were not set-off and were truncate cone to hemispherical in shape.

Golden and Birchfield (1965) reported that in *M. graminicola* males, the head region was not set off, the stylet was robust and knobs were rounded. Golden *et al.* (1980) reported that the body of males of *M. chitwoodi* was tapering at both extremities and the head cap was large with slightly set off head. Yang and Eisenback (1983) reported that the head cap of males of *M. enterolobii* was

high and rounded and tail was tapering at both ends with tail end twisted through 90°C in heat killed specimens.

The body length of males of *M. incognita, M. javanica, M. arenaria* and *M. hapla* ranged from 1200 to 2000µm, 940 to 1440 µm, 1270 to 2000 µm and 1000 to 1330 µm respectively (Chitwood, 1949). Whitehead (1968) reported that the length of males of *M. incognita* ranged from 500 to 723 µm and in *M. javanica* the length varied from 757 to 1297 µm. The body length of males of *M. chitwoodi* ranged from 887 to 1268 µm (Golden *et al.*, 1980)

2.3.4 Second stage juveniles

Chitwood (1949) reported that the stylet knobs of second stage juveniles of *M. incognita* were deeply rounded and in *M. javanica* the stylet knobs were not prominent (Whitehead, 1968).

In *M. incognita*, the labial disc was small and rounded. In *M. arenaria* population the labial disc was slightly elevated and lateral lips were in same contour with head region whereas in *M. javanica* the lateral lips were lower. In *M. hapla*, median lips and lateral lips were in same contour (Eisenback and Hirschmann, 1979).

In *M. incognita*, the tail tip was simple and the rectum was dilated (Chitwood, 1949. Sahoo and Ganguly (2000) reported that Indian populations of second stage juveniles of *M. javanica* showed variations in tail characters with respect to tail terminus and rectum dilation.

Whitehead (1968) reported that in second stage juveniles of *M. arenaria*, the head was not set off, stylet knobs were fairly prominent and the rectum was dilated. Esser *et al.* (1976) also reported the rectum dilation in *M. arenaria*.

In second stage juveniles of *M. hapla*, the head cap was small, truncate cone shaped and not set off (Whitehead, 1968). Handoo *et al.* (2005) reported

that the second stage juveniles of *M. hapla* populations in Hawaii were relatively smaller compared to initial species descriptions.

In *M. graminicola*, the stylet knobs of second stage juveniles were rounded with backward sloping anterior margins (Golden and Birchfield, 1965). Golden *et al.* (1980) reported that the second stage juveniles of *M. chitwoodi* possessed head which was not set off, dilated rectum and rounded tail terminus.

The mean length of second stage juveniles of *M. incognita, M javanica, M. arenaria* and *M. hapla* ranged from 360 to 393 µm, 340 to 400 µm, 450 to 490µm and 395 to 466 µm respectively (Chitwood, 1949). In *M. chitwoodi*, the body length ranged from 336 to 417 µm (Golden *et al.*, 1980).

Golden and Birchfield (1965) reported that in *M. graminicola*, the body length ranged from 415 to 484 µm. The populations of *M. graminicola* in Vietam showed significant variations in body length and stylet length for second stage juveniles. The body length ranged from 367 to 501 µm and stylet length ranged from 11.7 to 17.3 µm (Bellafiore *et al.*, 2015).

In Indian populations of *M. incognita*, body length, stylet length ,head to median bulb (H-MB), median bulb to excretory pore distance (MB-EP), tail length, anal body width (ABW),ratio c and c' of second stage juveniles were highly variable characters (Kaur and Attri, 2013a). In *M. javanica,* tail length was least variable character and H-MB, anal body width (ABW) and ratio c, c' were moderately variable characters (Sahoo and Ganguly, 2000).

Material and Methods

3. MATERIAL AND METHODS

The experiment on the "Morphological variations of root knot nematode in vegetables and banana" was carried out at Department of Agricultural Entomology, College of Agriculture, Vellayani during 2015-2017.

The details of material and methods followed during the course of work are mentioned below.

3.1 SAMPLE COLLECTION

Root knot infested root and soil samples were collected from brinjal, okra, tomato and banana in Dhanuvachapuram, Kattakada and Vellayani of Thiruvananthapuram district; Balagram, Pampadumpara and Thovalappady of Idukki district; Chazhoor, Thalikulam and Thaniyam of Thrissur district in Kerala. About 250 g of soil sample from rhizosphere area along with galled roots were collected in polythene covers and labeled carefully. The populations were maintained in the net house by inoculating the collected samples to healthy plants that were planted earlier in sterilized soil.

3.2 EXTRACTION OF NEMATODES

3.2.1 Extraction of Nematodes from Root

3.2.1.1 Extraction of Mature Females from Root

The roots were washed thoroughly, cut into small pieces and stained in lactophenol-acid fucshin (Daykin and Hussey, 1985) and left overnight immersed in clear lactophenol for destaining. The mature females were teased out from galls and kept in lactophenol.

3.2.1.2 Extraction of Males and Second Stage Juveniles from Root

Nematodes were extracted from roots using modified Baermann's funnel technique (Christie and Perry, 1951). The roots were washed in tap water, chopped into small pieces and placed on a double layered tissue paper lined on a wire gauze. The wire gauze was placed on a Petri dish filled with water up to the

level that it just touched the bottom of gauze and roots. Second stage juveniles and males moved through the filter paper and get collected in the water in the Petri dish.

Second stage juveniles were also extracted by picking the egg masses from roots into a Petri dish containing water. The hatched out juveniles were then killed and fixed.

3.2.2 Extraction of Nematodes from Soil

Nematodes were extracted from soil using Cobb's decanting and sieving method followed by Baermann's funnel technique.

3.3 PREPARATION OF FEMALES FOR MORPHOLOGICAL AND MORPHOMETRICAL IDENTIFICATION

The females teased out from the galls were placed on a glass slide and observed under a 40X microscope with calibrated ocular micrometer.

The measurements of length, width, neck length, stylet length, length of median bulb (LMB), width of median bulb (WMB) and ratio a (length/width) were taken. The arithmetic mean, standard error of mean (SEM), standard deviation (SD) and coefficient of variance (CV) for each measurement were computed. Based on CV values, the characters were rated as least variable, moderately variable and highly variable using scale <12%, 12 to 20% and >20% respectively (Sahoo and Ganguly, 2000).

3.4 PREPARATION OF PERINEAL PATTERN FOR MORPHOLOGICAL AND MORPHOMETRICAL IDENTIFICATION

The adult females were teased out from stained roots and each specimen was placed in a drop of lactophenol on a glass slide. The posterior portion of the female was cut with a sharp blade and the inner tissue was carefully removed using a fine bristle (Hartman and Sasser, 1985). The perineal pattern was

transferred to a drop of glycerol on a glass slide and covered with cover slip and sealed using a suitable sealant. Ten specimens from a population were examined.

The measurements of length of vulval slit (LVS), distance from anus to vulval slit (AVS), distance from anus to tail terminus (ATT) and interphasmidial distance (IPD) were made under a 40X microscope with calibrated ocular micrometer. The arithmetic mean, standard error of mean (SEM), standard deviation (SD) and coefficient of variance (CV) for each measurement were computed. Based on CV values, the characters were rated as least variable, moderately variable and highly variable using scale <12%, 12 to 20% and >20% respectively (Sahoo and Ganguly, 2000).

3.3 PREPARATION OF MALES AND SECOND STAGE JUVENILES FOR MORPHOLOGICAL AND MORPHOMETRICAL IDENTIFICATION

3.3.1 Killing and Fixing of Nematodes

The extracted nematodes were killed and fixed in one operation (Seinhorst, 1966). The males and second stage juveniles were killed using the following fixative:

1) FA 4:10

Formalin (40% formaldehyde) - 10ml

Glacial acetic acid - 10ml

Distilled water - 80ml

2) TAF

Formalin (40% formaldehyde) -7ml

Triethanolamine - 2ml

Distilled water - 91ml

The fixative was heated (60° C) and the hot fixative was poured into the nematode suspension to kill the nematodes.

3.3.2 Processing of Nematodes

The fixed J_{2s} and males were picked and transferred to a cavity block containing 0.5 ml Seinhorst solution 1 and kept in a dessicator containing excess of 96% ethanol which was then kept in an oven at 40 °C. After 12 hours, the cavity block was filled with Seinhorst solution 2 and kept partly closed in the dessicator containing calcium chloride for about 3 hours in the oven (40 °C), until the ethanol get evaporated.

3.3.3 Preparation of Permanent Mount

The processed nematodes were picked from the cavity block and placed in a drop of glycerol on a glass slide. Small blocks of paraffin wax were kept on three slides of glycerol and cover slip was applied carefully. The wax blocks were melted by keeping the slide over a hot plate for few seconds, allowed it to cool and sealed using sealant. Ten specimens from a population were examined.

The measurements of length, stylet length, distance from head to median bulb (H-MB), anal body width (ABW), tail length, ratio c (length/tail length) and c' (tail length/ABW) were made under a 40X microscope with calibrated ocular micrometer. The arithmetic mean, standard error of mean (SEM), standard deviation (SD) and coefficient of variance (CV) for each measurement were computed. Based on CV values, the characters were rated as least variable, moderately variable and highly variable using scale <8%, 8 to 12% and >12% respectively (Sahoo and Ganguly, 2000).

Results

4. RESULTS

The diagnostic characters of females, perineal pattern and second stage juveniles were observed and measured to identify the species. Standard error of means and means of morphometric characters were compared with the previous works to delineate the species. The results are presented in this chapter under the following headings.

4.1 IDENTIFICATION

Based on morphological and morphometrical methods of identification, thirty six populations of *Meloidogyne* species infecting brinjal, okra, tomato and banana from Dhanuvachapuram, Kattakada and Vellayani of Thiruvananthapuram district; Balagram, Pampadumpara and Thovalappady of Idukki district; Chazhoor, Thalikulam and Thaniyam of Thrissur district in Kerala were identified. Eighteen populations were identified to be *M. incognita*, nine of *M. javanica*, and eight of *M. arenaria.* Among the sampled populations, *M. hapla* was not identified from vegetables and banana from Kerala. Surprisingly, one of the population showed morphological and morphometrical characters similar to *M. chitwoodi* Golden, O'Bannon, Santo and Finley, 1980 and hence, it needs molecular identification for further confirmation. Out of thirty six populations, only a single population of males were observed in tomato from Pampadumpara.

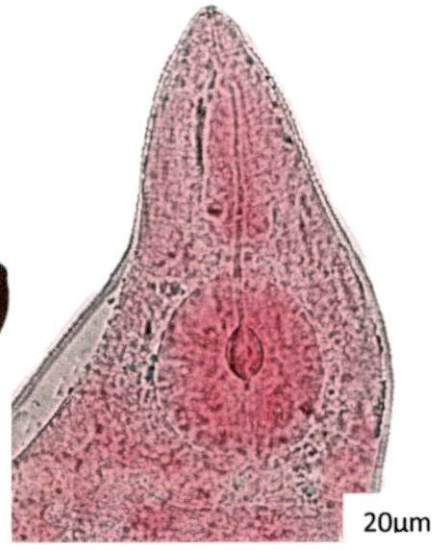
4.1.1 Identification of *Meloidogyne* spp. from Thiruvananthapuram District

4.1.1.1 Identification of Meloidogyne sp in Brinjal from Dhanuvachapuram

The species of root knot nematode infecting brinjal from Dhanuvachapuram was identified as *M. incognita* (Plate 1), based on the morphological and morphometrical data of mature females, perineal pattern and second stage juveniles. The morphometric characters of the population are given in Table 1.

Description: Based on 10 females and 10 juveniles (J_2).

A



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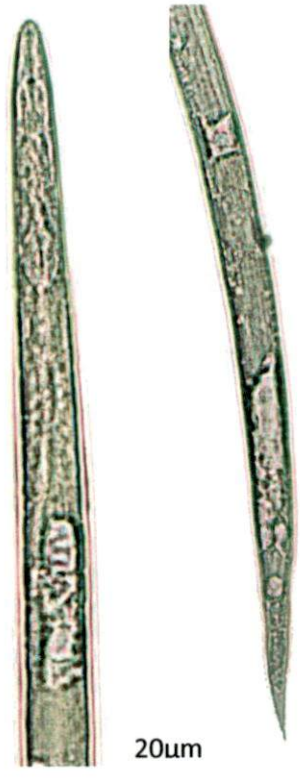

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Plate 1. (A) females, (B) anterior end of female, (C) perineal pattern, (DE) anterior and posterior end of second stage juvenile of *M. incognita* in brinjal from Dhanuvachapuram

Table 1. Morphometric characters of mature females, perineal pattern and second stage juveniles of brinjal population of *M. incognita* from Dhanuvachapuram

Character (µm)	Brinjal population
Females	
Length	684.90±34.59±10.93 (634.51-755.98) 5.05%
Width	447.93±43.89±13.88 (378.02-504.60) 9.79%
Neck length	186.77±32.28±10.20 (145.49-259.98) 17.28%
Stylet length	15.44±0.58±0.18 (14.25-16.32) 3.81%
LMB	36.21±4.33±1.36 (30.24-41.25) 11.95%
WMB	36.01±4.25±1.34 (30.45-41.65) 11.81%
a	1.54±0.16±0.05 (1.298-1.83) 10.68%
Perineal pattern	
LVS	25.25±2.87±0.90 (19.306-28.180) 11.37%
AVS	20.364±2.993±0.949 (15.78-24.17) 14.69%
ATT	17.05±2.35±0.74 (14.38-20.78) 13.79%
IPD	30.79±3.73±1.18 (27.10-37.88) 12.14%
Second stage juveniles	
Length	418.37±13.41±5.07 (360.15-436.18) 4.11%
Stylet length	14.01±0.54±0.21 (13.98-15.01) 3.11%
H-MB	50.26±2.84±0.81 (47.53-52.11) 4.38%
ABW	11.32±1.28±0.41 (8.70-12.11) 10.43%
Tail length	48.38±6.98±2.80 (32.01-58.11) 15.21%
c	8.64±1.81±0.63 (6.90-11.11) 7.21%
c'	5.71±0.51±0.13 (3.47-6.20) 9.48%

LMB-Length of median bulb, WMB- width of median bulb, a-length/width ratio, H-MB-head to median bulb, ABW-anal body width, c- length/tail length ratio, c'- tail length/anal body width ratio

Measurements: Female: Length= 634.51-755.98µm; width=378.02-504.60µm; a=1.29-1.83µm; stylet length= 14.25-16.32µm; neck length=145.49-259.98µm; LMB= 30.24-41.25µm; WMB= 30.45-41.65µm.

Perineal pattern: LVS= 19.30-28.18µm; AVS=15.78-24.17µm; ATT=14.38-20.78µm; IPD=27.10-37.88µm.

Second stage juveniles (J_2): Length=360.15-436.18µm; stylet length=13.98-15.01µm; H-MB=47.53-52.11µm; ABW=8.70-12.11µm; tail length=32.01-58.11µm; c=6.90-11.11µm; c'= 3.47-6.20µm.

4.1.1.2 Identification of Meloidogyne sp in okra from Dhanuvachapuram

The species of root knot nematode infecting okra from Dhanuvachapuram was identified as *M. incognita* (Plate 2), based on the morphological and morphometrical data of mature females, perineal pattern and second stage juveniles. The morphometric characters of the population are given in Table 2.

Description: Based on 10 females and 10 juveniles (J_2).

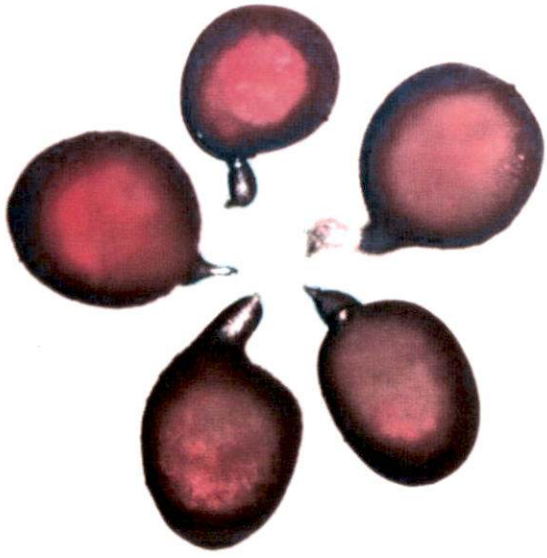
Measurements: Female: Length= 605.37-732.10µm; width=356.14-498.37µm; a=1.24-1.87µm; stylet length= 14.37-17.21µm; neck length=163.78-264.83µm; LMB= 30.11-43.61µm; WMB= 30.43-43.10µm.

Perineal pattern: LVS= 19.80-27.32µm; AVS=15.78-25.11µm; ATT=14.39-22.83µm; IPD=25.30-35.07µm.

Second stage juveniles (J_2): Length=354.23-428.11µm; stylet length=12.01-14.37µm; H-MB=46.11-52.10µm; ABW=8.06-12.15µm; tail length=31.81-56.70µm; c=6.04-7.98µm; c'= 2.17-8.02µm.

4.1.1.3 Identification of Meloidogyne sp in Tomato from Dhanuvachapuram

The species of root knot nematode infecting tomato from Dhanuvachapuram was identified as *M. incognita* (Plate 3), based on the morphological and morphometrical data of mature females, perineal pattern and



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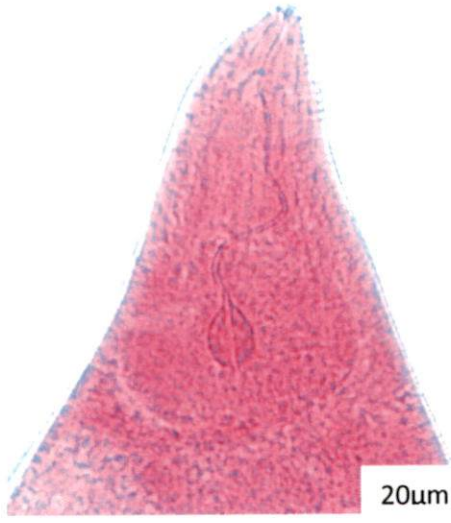

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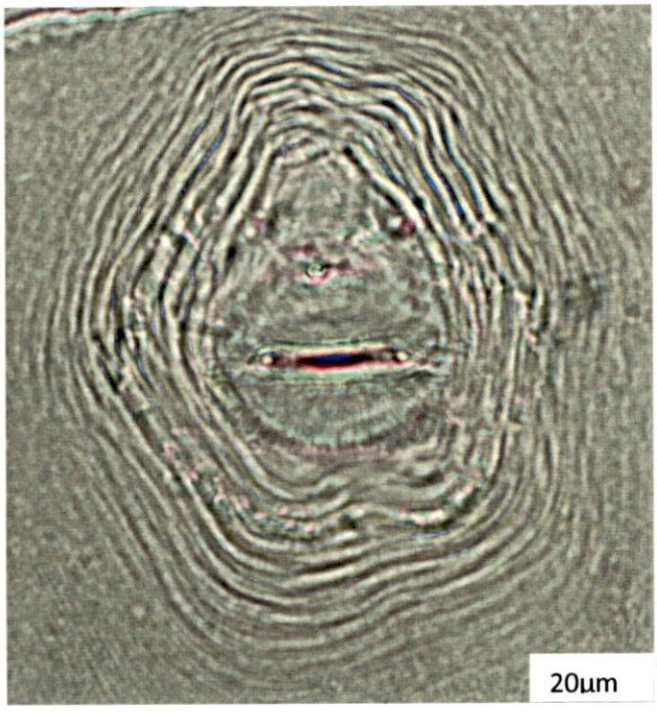

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Plate 2. (A) females, (B) anterior end of female, (C) perineal pattern, (DE) anterior and posterior end of second stage juvenile of *M. incognita* in okra from Dhanuvachapuram

Table 2. Morphometric characters of mature females, perineal pattern and second stage juveniles of okra population of *M. incognita* from Dhanuvachapuram

Character (µm)	Okra population
Females	
Length	646.70±42.11±10.01 (605.37-732.10) 6.00%
Width	430.21±42.80±13.81 (356.14-498.37) 10.07%
Neck length	201.24±35.78±10.30 (163.78-264.83) 17.37%
Stylet length	15.70±0.68±0.18 (14.37-17.21) 4.21%
LMB	38.30±5.21±1.73 (30.11-43.61) 11.27%
WMB	38.00±4.38±1.27 (30.43-43.10) 12.80%
a	1.50±0.21±0.01 (1.24-1.87) 10.78%
Perineal pattern	
LVS	24.32±2.78±0.91 (19.80-27.32) 11.98%
AVS	20.37±2.93±0.81 (15.78-25.11) 15.01%
ATT	18.01±2.41±0.74 (14.39-22.83) 14.81%
IPD	26.37±3.43±1.28 (25.30-35.07) 12.43%
Second stage juveniles	
Length	404.32±12.87±5.11 (354.23-428.11) 4.18%
Stylet length	13.80±0.51±0.11 (12.01-14.37) 2.04%
H-MB	48.01±2.71±0.81 (46.11-52.10) 4.38%
ABW	11.21±1.37±0.45 (8.06-12.15) 4.26%
Tail length	47.60±6.87±2.37 (31.81-56.70) 15.38%
c	8.49±1.80±0.51 (6.04-7.98) 18.32%
c'	5.60±0.41±0.12 (2.17-8.02) 8.13%

LMB-Length of median bulb, WMB- width of median bulb, a-length/width ratio, H-MB-head to median bulb, ABW-anal body width, c- length/tail length ratio, c'- tail length/anal body width ratio

second stage juveniles. The morphometric characters of the population are given in Table 3.

Description: Based on 10 females and 10 juveniles (J_2).

Measurements: Female: Length= 645.88-806.53 µm; width= 409.93-491.92 µm; a= 1.46-1.66 µm; stylet length= 15.21-16.78 µm; neck length= 155.03-284.10 µm; LMB= 30.25-45.21 µm; WMB= 30.86-44.21 µm.

Perineal pattern: LVS= 23.44-29.52µm; AVS=14.88-22.68µm; ATT=13.24-19.94µm; IPD=20.02-30.62µm.

Second stage juveniles (J_2): Length= 399.61-439.17µm; stylet length= 14.02-15.35µm; H-MB= 47.49-53.80µm; ABW= 8.63-12.24µm; tail length= 31.02-57.40µm; c= 7.34-13.83µm; c'= 3.59-4.98µm.

4.1.1.4 Identification of Meloidogyne sp in Banana from Dhanuvachapuram

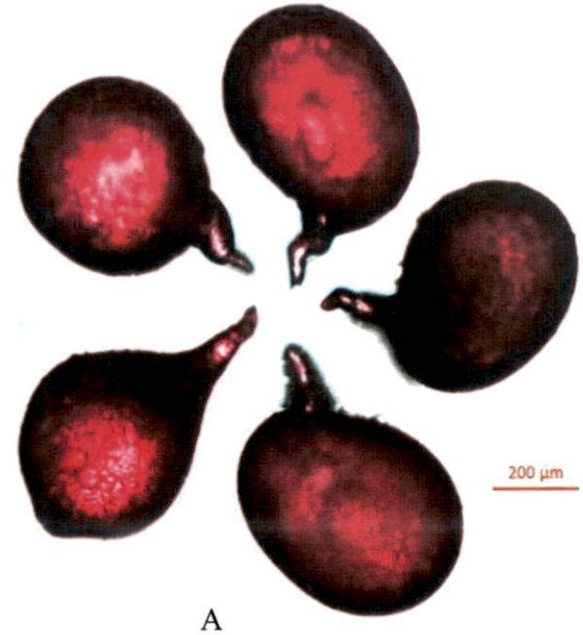
The species of root knot nematode infecting banana from Dhanuvachapuram was identified as *M. incognita* (Plate 4), based on the morphological and morphometrical data of mature females, perineal pattern and second stage juveniles. The morphometric characters of the population are given in Table 4.

Description: Based on 10 females and 10 juveniles (J_2).

Measurements: Female: Length= 653.17-846.17µm; width= 400.34-482.34 µm; a= 1.47-1.61µm; stylet length= 15.20-16.34µm; neck length= 156.62-271.24µm; LMB= 29.17-43.14µm; WMB= 30.81-43.18µm.

Perineal pattern: LVS= 22.17-29.10µm; AVS=15.21-23.40µm; ATT=13.2-19.34µm; IPD=22.15-30.07µm.

Second stage juveniles (J_2): Length= 382.72-430.17µm; stylet length= 14.02-16.73µm; H-MB= 46.38-50.14µm; ABW= 8.92-13.14µm; tail length= 30.17-58.18µm; c= 7.14-14.11µm; c'= 3.47-6.72µm



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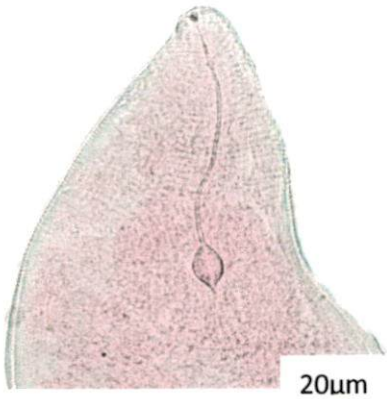

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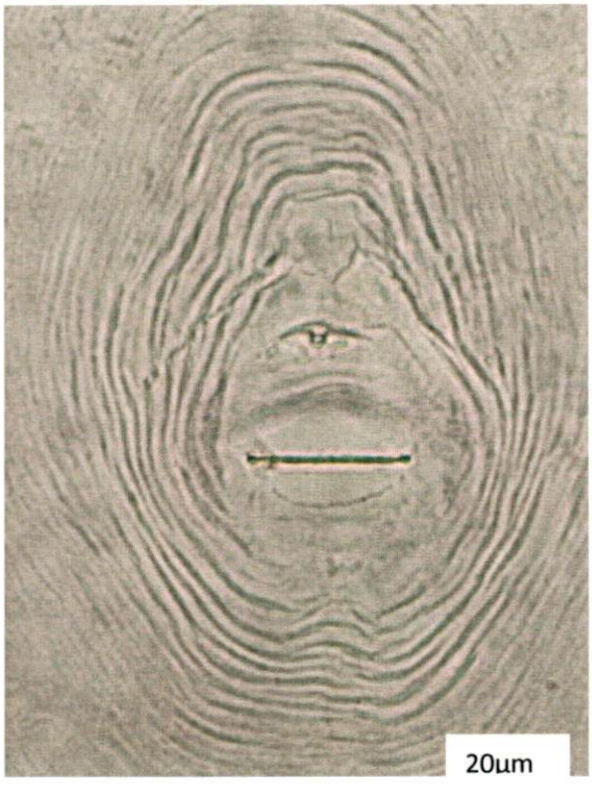

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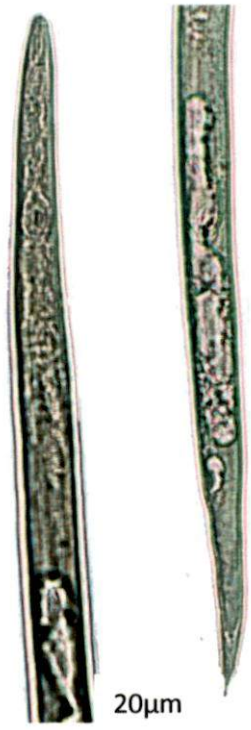

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Plate 3. (A) females, (B) anterior end of female, (C) perineal pattern, (DE) anterior and posterior end of second stage juvenile of *M. incognita* in tomato from Dhanuvachapuram

Table 3. Morphometric characters of mature females, perineal pattern and second stage juveniles of tomato population of *M. incognita* from Dhanuvachapuram

Character (µm)	Tomato population
Females	
Length	702.19±55.23±17.46 (645.88-806.53) 7.86%
Width	453.24±29.58±9.35 (409.93-491.92) 6.52%
Neck length	195.43±36.46±11.53 (155.03-284.10) 18.66%
Stylet length	15.86±0.62±0.19 (15.21-16.78) 3.96%
LMB	38.53±4.78±1.51 (30.25-45.21) 12.41%
WMB	38.09±4.39±1.38 (30.86-44.21) 11.53%
a	1.54±0.06±0.02 (1.46-1.66) 4.30%
Perineal pattern	
LVS	26.50±2.10±0.66 (23.44-29.52) 7.93%
AVS	19.28±2.61±0.82 (14.88-22.68) 13.58%
ATT	16.49±2.32±0.73 (13.24-19.94) 14.09%
IPD	26.24±3.10±0.98 (20.02-30.62) 11.84%
Second stage juveniles	
Length	421.72±12.87±4.07 (399.61-439.1) 3.0%
Stylet length	14.77±0.45±0.14 (14.02-15.35) 3.05%
H-MB	50.98±2.24±0.70 (47.49-53.80) 4.39%
ABW	11.25±1.16±0.36 (8.63-12.24) 10.30%
Tail length	47.59±6.87±2.17 (31.02-57.40) 14.45%
c	9.08±1.80±0.57 (7.34-13.83) 19.85%
c'	4.21±0.41±0.13 (3.59-4.98) 9.94%

LMB-Length of median bulb, WMB- width of median bulb, a-length/width ratio, H-MB-head to median bulb, ABW-anal body width, c- length/tail length ratio, c'- tail length/anal body width ratio

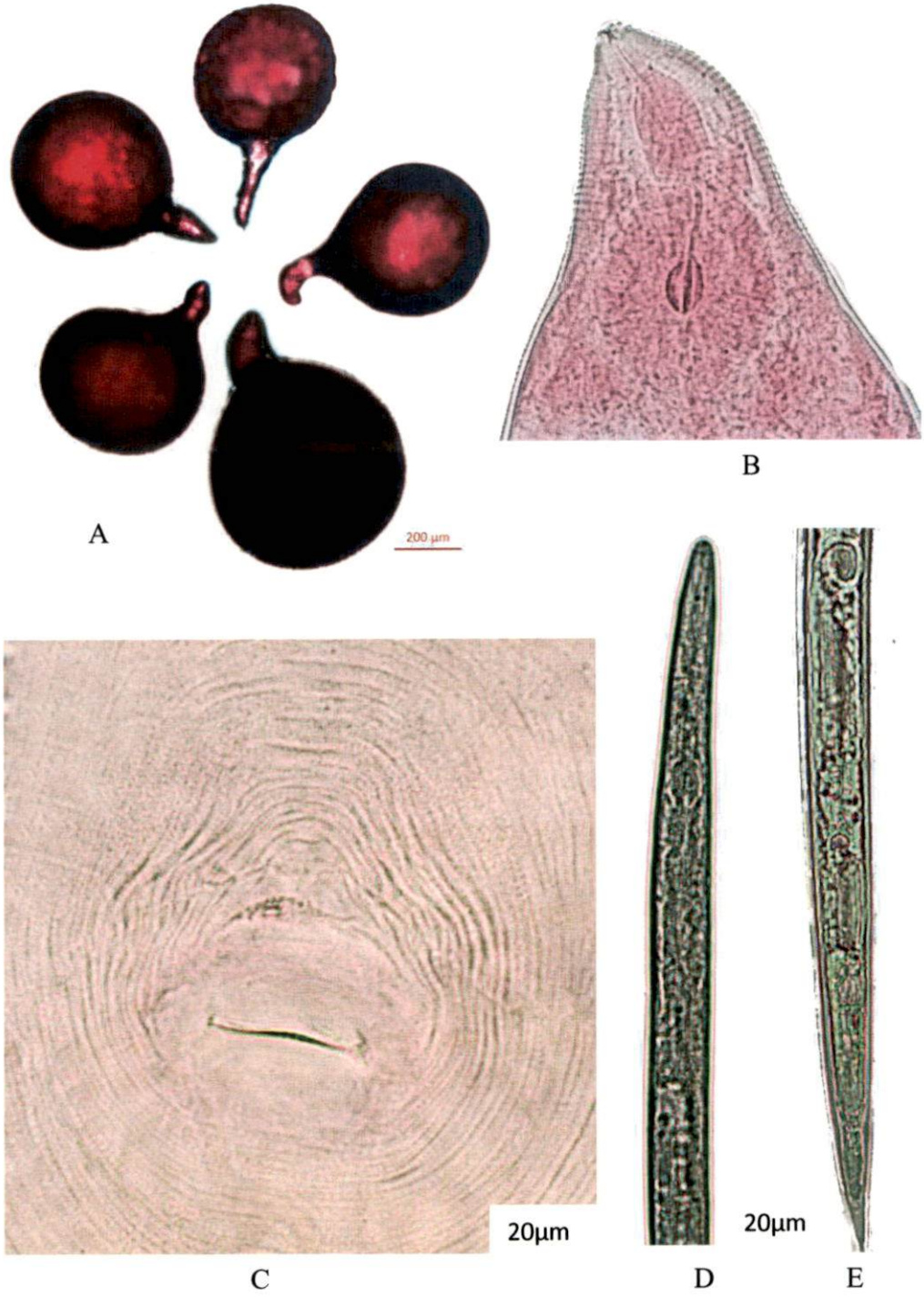

Plate 4. (A) females, (B) anterior end of female, (C) perineal pattern, (DE) anterior and posterior end of second stage juvenile of *M .incognita* in banana from Dhanuvachapuram

Table 4. Morphometric characters of mature females, perineal pattern and second stage juveniles of banana population of *M. incognita* from Dhanuvachapuram

Character (µm)	Banana population
Females	
Length	714.18±50.18±19.34 (653.17-846.17) 10.11%
Width	446.54±30.17±9.83 (400.34-482.34) 7.64%
Neck length	190.43±37.14±12.17 (156.62-271.24) 20.71%
Stylet length	15.98±0.77±0.18 (15.20-16.34) 3.81%
LMB	38.90±4.81±1.67 (29.17-43.14) 11.71%
WMB	38.017±4.132±1.271 (30.81-43.18) 10.67%
a	1.56±0.01±0.02 (1.47-1.61) 3.21%
Perineal pattern	
LVS	26.70±3.17±0.19 (22.17-29.10) 7.91%
AVS	19.29±2.11±0.81 (15.21-23.40) 14.29%
ATT	17.01±2.18±0.51 (13.21-19.34) 15.00%
IPD	28.17±3.17±1.17 (22.15-30.07) 11.21%
Second stage juveniles	
Length	414.31±12.17±5.07 (382.72-430.17) 3.05%
Stylet length	14.38±0.56±0.13 (14.02-16.73) 3.01%
H-MB	48.17±2.54±0.81 (46.38-50.14) 4.38%
ABW	11.74±1.70±0.42 (8.92-13.14) 10.17%
Tail length	48.18±6.78±2.16 (30.17-58.18) 14.51%
c	10.00±1.74±0.68 (7.14-14.11) 18.00%
c'	4.38±0.52±0.28 (3.47-6.72) 8.91%

LMB-Length of median bulb, WMB- width of median bulb, a-length/width ratio, H-MB-head to median bulb, ABW-anal body width, c- length/tail length ratio, c'- tail length/anal body width ratio

4.1.1.5 Identification of Meloidogyne sp in Brinjal from Kattakada

The species of root knot nematode infecting brinjal from Kattakada was identified as *M. incognita* (Plate 5), based on the morphological and morphometrical data of mature females, perineal pattern and second stage juveniles. The morphometric characters of the population are given in Table 5.

Description: Based on 10 females and 10 juveniles (J_2).

Measurements: Female: Length= 498.37-776.46µm; width= 305.73-590.06µm; a= 1.05-1.71µm; stylet length= 16.10-19.25µm; neck length= 140.45-299.04µm; LMB= 28.43-42.18µm; WMB= 30.00-40.30µm.

Perineal pattern: LVS= 25.98-31.62µm; AVS= 17.38-23.51µm; ATT= 15.02-22.36µm; IPD= 20.15-28.24µm.

Second stage juveniles (J_2): Length= 380.07-422.15µm; stylet length= 13.80-14.91µm; H-MB= 47.66-52.91µm; ABW= 10.32-11.58µm; tail length= 46.63-55.76µm; c= 7.36-8.91µm; c'= 4.11-5.19µm.

4.1.1.6 Identification of Meloidogyne sp in okra from Kattakada

The species of root knot nematode infecting okra from Kattakada was identified as *M. chitwoodi* (Plate 6), based on the morphological and morphometrical data of mature females, perineal pattern and second stage juveniles. The morphometric characters of the population are given in Table 6.

Description: Based on 10 females and 10 juveniles (J_2).

Measurements: Female: Length= 432.75-756.75µm; width= 356.99-524.54µm; a= 1.28-1.74µm; stylet length= 13.32-14.84µm; neck length= 180.77-259.27µm; LMB= 30.14-50.13µm; WMB= 30.10-42.51µm.

Perineal pattern: LVS= 19.34-30.17µm; AVS= 14.30-24.02µm; ATT= 14.59-22.22µm; IPD= 25.02-44.34µm.

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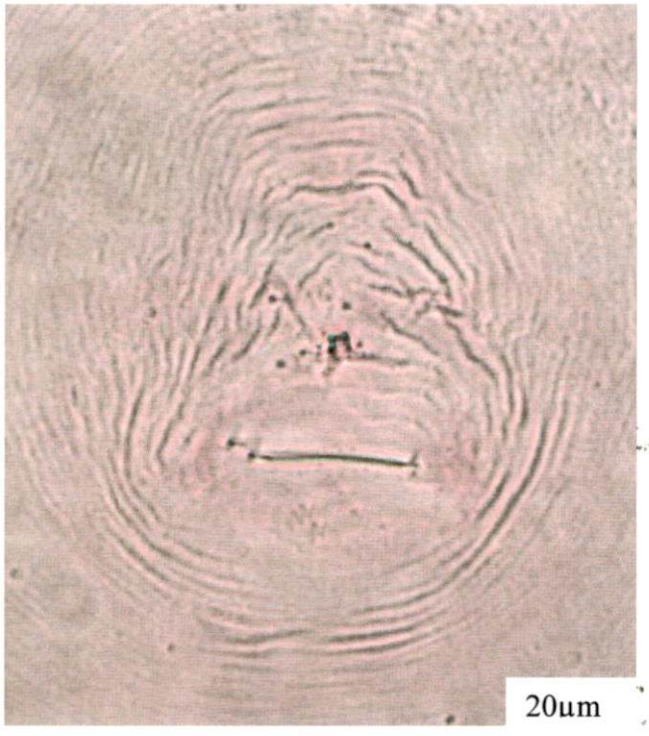

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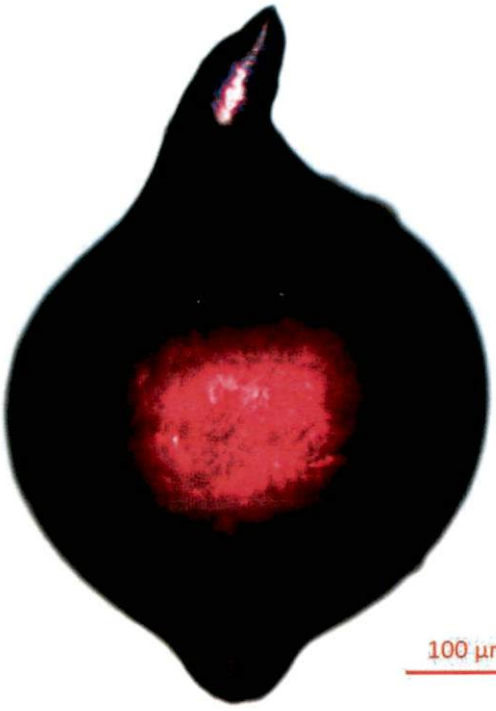
Plate 5. (A) females, (B) anterior end of female, (C) perineal pattern, (DE) anterior and posterior end of second stage juvenile of *M. incognita* in brinjal from Kattakada

Table5. Morphometric characters of mature females, perineal pattern and second stage juveniles of brinjal population of *M. incognita* from Kattakada

Character (µm)	Brinjal population
Females	
Length	626.65±82.89±26.21 (498.37-776.46) 13.22%
Width	453.73±87.58±27.69 (305.73-590.06) 19.30%
Neck length	182.07±51.00±16.12 (140.45-299.04) 28.01%
Stylet length	17.90±1.06±0.33 (16.10-19.25) 5.96%
LMB	35.45±5.12±1.62 (28.43-42.18) 14.46%
WMB	34.07±4.09±1.29 (30.00-40.30) 12.02%
a	1.46±0.21±0.06 (1.05-1.71) 14.41%
Perineal pattern	
LVS	27.90±1.95±0.61 (25.98-31.62) 6.99%
AVS	20.12±2.15±0.68 (17.38-23.51) 10.70%
ATT	17.71±2.38±0.75 (15.02-22.36) 13.45%
IPD	23.72±2.46±0.77 (20.15-28.24) 10.39%
Second stage juveniles	
Length	401.74±12.38±3.91 (380.07-422.15) 3.08%
Stylet length	14.489±0.381±0.120 (13.804-14.911) 2.626%
H-MB	50.241±1.925±0.60 (47.66-52.91) 3.83%
ABW	11.03±0.36±0.11 (10.32-11.58) 3.34%
Tail length	51.23±3.04±0.96 (46.63-55.76) 5.94%
c	7.86±0.51±0.61 (7.36-8.91) 6.52%
c'	4.644±0.280±0.089 (4.119-5.194) 6.036%

LMB-Length of median bulb, WMB- width of median bulb, a-length/width ratio, H-MB-head to median bulb, ABW-anal body width, c- length/tail length ratio, c'- tail length/anal body width ratio



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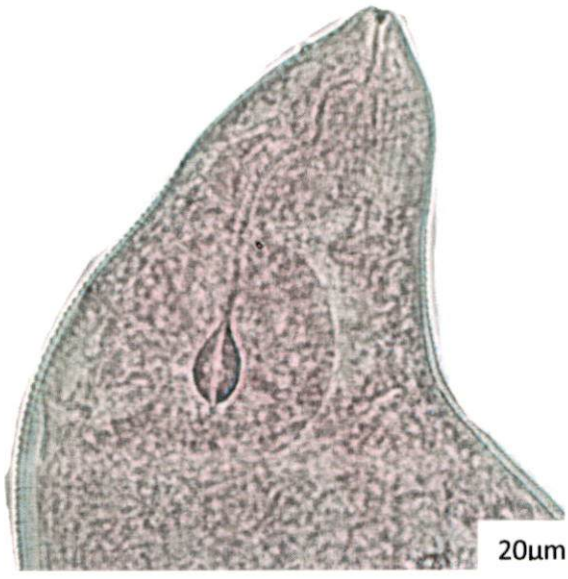

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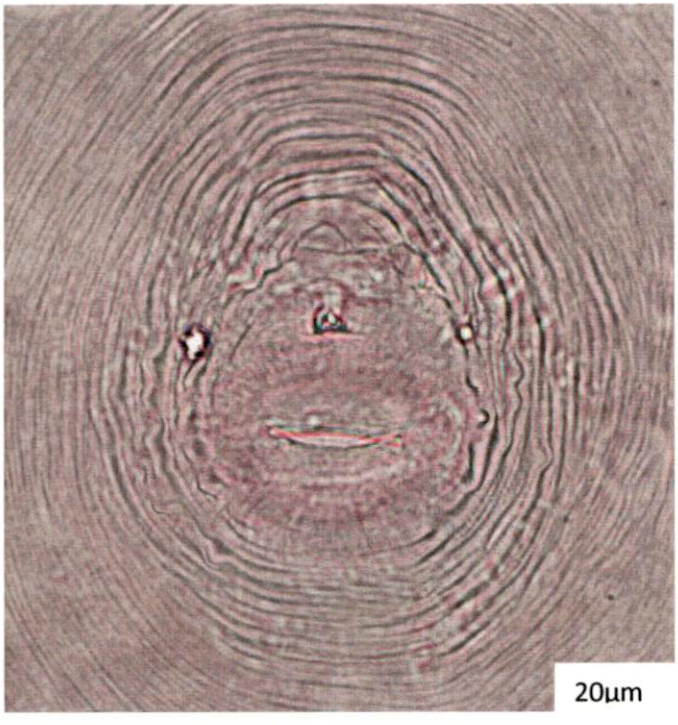

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Plate 6. (A) female, (B) anterior end of female, (C) perineal pattern, (DE) anterior and posterior end of second stage juvenile of *M.chitwoodi* in okra from Kattakada

Table 6. Morphometric characters of mature females, perineal pattern and second stage juveniles of okra population of *M. chitwoodi* from Kattakada

Character (µm)	Okra population
Females	
Length	664.87±47.99±15.17 (432.75-756.75) 6.19%
Width	414.67±53.09±16.78 (356.99-524.54) 10.70%
Neck length	223.68±29.10±9.20 (180.77-259.27) 13.01%
Stylet length	13.98±0.45±0.14 (13.32-14.84) 2.68%
LMB	42.26±6.11±1.93 (30.14-50.13) 14.47%
WMB	35.86±5.06±1.60 (30.10-42.51) 14.11%
a	1.36±0.16±0.05 (1.28-1.74) 10.53%
Perineal pattern	
LVS	25.59±3.52±1.11 (19.34-30.17) 13.76%
AVS	19.11±2.99±0.94 (14.30-24.02) 15.66%
ATT	17.96±2.53±0.80 (14.59-22.22) 14.11%
IPD	29.52±5.45±1.72 (25.02-44.34) 18.48%
Second stage juveniles	
Length	381.64±24.18±7.64 (330.23-410.23) 6.33%
Stylet length	13.75±0.372±0.119 (10.24-12.19) 2.73%
H-MB	46.14±2.29±0.72 (40.93-49.11) 4.96%
ABW	11.11±0.57±0.18 (10.23-12.26) 5.21%
Tail length	45.20±5.87±1.85 (40.30-49.01) 12.18%
c	8.87±0.90±0.28 (7.96-9.81) 11.28%
c'	4.89±0.50±0.16 (4.25-5.90) 11.71%

LMB-Length of median bulb, WMB- width of median bulb, a-length/width ratio, H-MB-head to median bulb, ABW-anal body width, c- length/tail length ratio, c'- tail length/anal body width ratio

Second stage juveniles (J_2): Length= 330.23-410.23µm; stylet length= 10.24-12.19µm; H-MB= 40.81-50.28µm; ABW= 10.81-12.10µm; tail length= 40.30-49.01µm; c= 7.96-9.81µm; c'= 4.25-5.90µm

4.1.1.7 Identification of Meloidogyne sp in Tomato from Kattakada

The species of root knot nematode infecting tomato from Kattakada was identified as *M. incognita* (Plate 7), based on the morphological and morphometrical data of mature females, perineal pattern and second stage juveniles. The morphometric characters of the population are given in Table 7.

Description: Based on 10 females and 10 juveniles (J_2).

Measurements: Female: Length= 558.98-686.01µm; width= 363.90-479.17µm; a= 1.28-1.66µm; stylet length= 14.20-17.79µm; neck length= 149.89-225.44µm; LMB= 35.11-50.52µm; WMB= 35.03-50.08µm.

Perineal pattern: LVS= 20.58-25.33µm; AVS= 16.35-20.25µm; ATT= 11.94-19.12µm; IPD= 18.25-30.45µm.

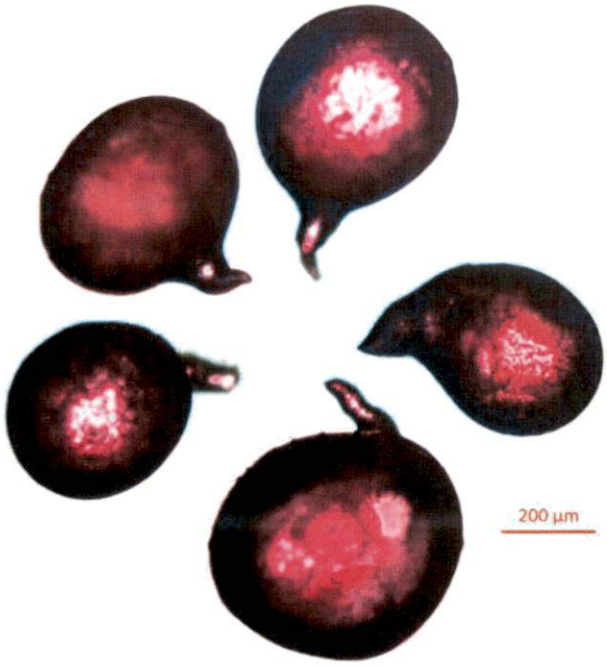
Second stage juveniles (J_2): Length= 345.63-389.17µm; stylet length= 12.73-14.58µm; H-MB= 47.66-53.56µm; ABW= 10.02-11.99µm; tail length= 47.42-66.92µm; c= 5.20-7.89µm; c'= 4.03-5.71µm.

4.1.1.8 Identification of Meloidogyne sp in Banana from Kattakada

The species of root knot nematode infecting banana from Kattakada was identified as *M. incognita* (Plate 8), based on the morphological and morphometrical data of mature females, perineal pattern and second stage juveniles. The morphometric characters of the population are given in Table 8.

Description: Based on 10 females and 10 juveniles (J_2).

Measurements: Female: Length= 435.75- 786.75µm; width= 408.99-589.54µm; a= 1.28-1.74µm; stylet length= 16.32-17.84µm; neck length= 156.27-298.15µm; LMB= 30.14-45.15µm; WMB= 29.18-43.61µm.



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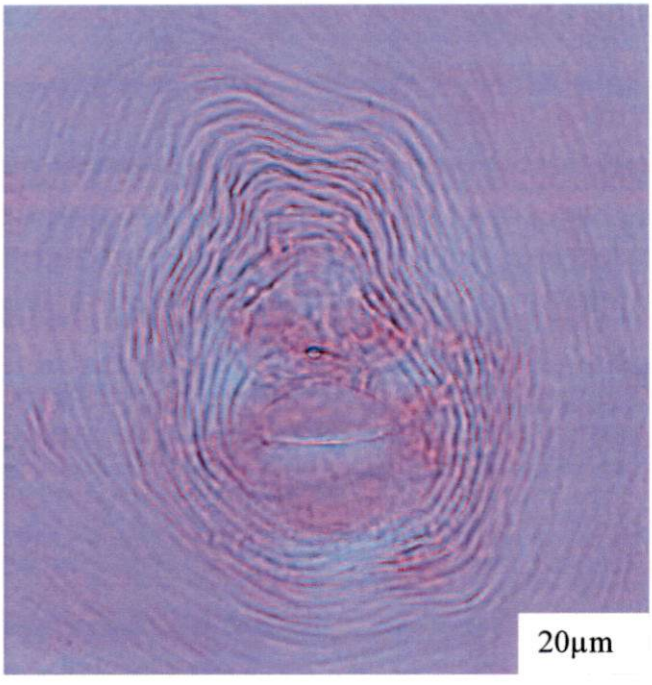

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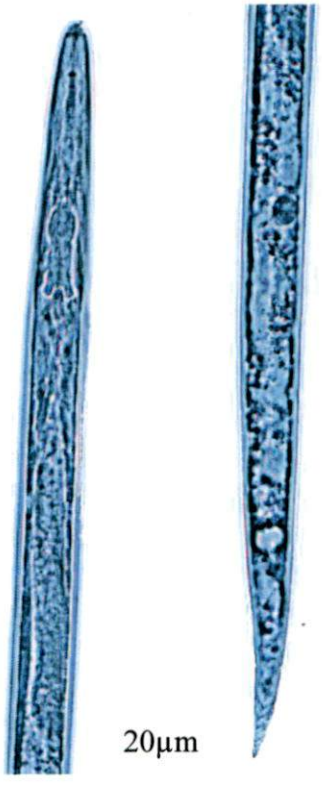

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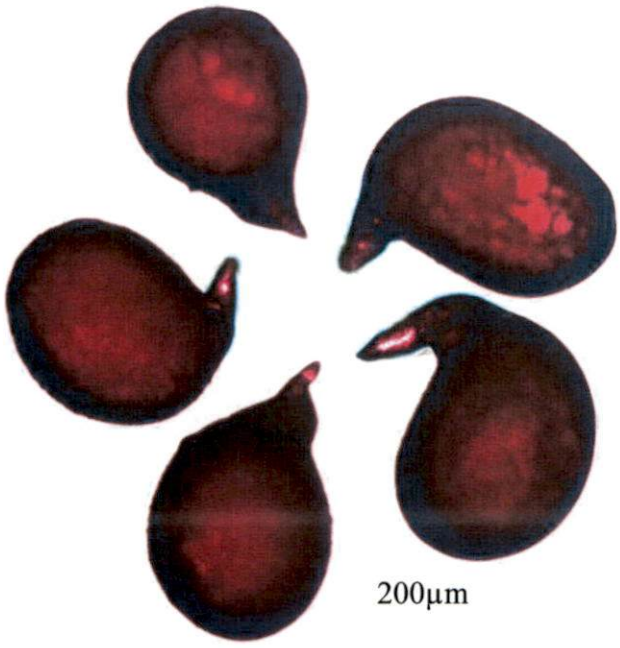
Plate 7. (A) female, (B) anterior end of female, (C) perineal pattern, (DE) anterior and posterior end of second stage juvenile of *M. incognita* in tomato from Kattakada

Table7. Morphometric characters of mature females, perineal pattern and second stage juveniles of tomato population of *M. incognita* from Kattakada

Character (µm)	Tomato population
Females	
Length	618.28±39.96± 12.63 (558.98-686.01) 6.46%
Width	422.36±37.90±11.98 (363.90-479.17) 8.97%
Neck length	173.47±26.09±8.25 (149.89-225.4) 15.04%
Stylet length	16.560±1.02±0.32 (14.20-17.79) 6.19%
LMB	42.28±5.59±1.77 (35.11-50.52) 13.23%
WMB	42.02±4.54±1.43 (35.03-50.08) 9.88%
a	1.46±0.13±0.04 (1.28-1.66) 8.95%
Perineal pattern	
LVS	23.01±1.54±0.48 (20.58-25.33) 6.71%
AVS	17.98±1.23±0.39 (16.35-20.25) 6.87%
ATT	14.98±1.95±0.61 (11.94-19.12) 13.05%
IPD	25.32±3.82±1.20 (18.257-30.455) 15.10%
Second stage juveniles	
Length	368.53±17.79±5.62 (345.63-389.17) 4.82%
Stylet length	13.63±0.67±0.21 (12.73-14.58) 4.98%
H-MB	50.20±2.13±0.67 (47.66-53.56) 4.26%
ABW	10.97±0.74±0.23 (10.02-11.99) 6.78%
Tail length	52.14±5.67±1.79 (47.423-66.923) 10.87%
c	7.13±0.74±0.23 (5.20-7.89) 10.39%
c'	4.75±0.46±0.14 (4.03-5.71) 9.84%

LMB-Length of median bulb, WMB- width of median bulb, a-length/width ratio, H-MB-head to median bulb, ABW-anal body width, c- length/tail length ratio, c'- tail length/anal body width ratio



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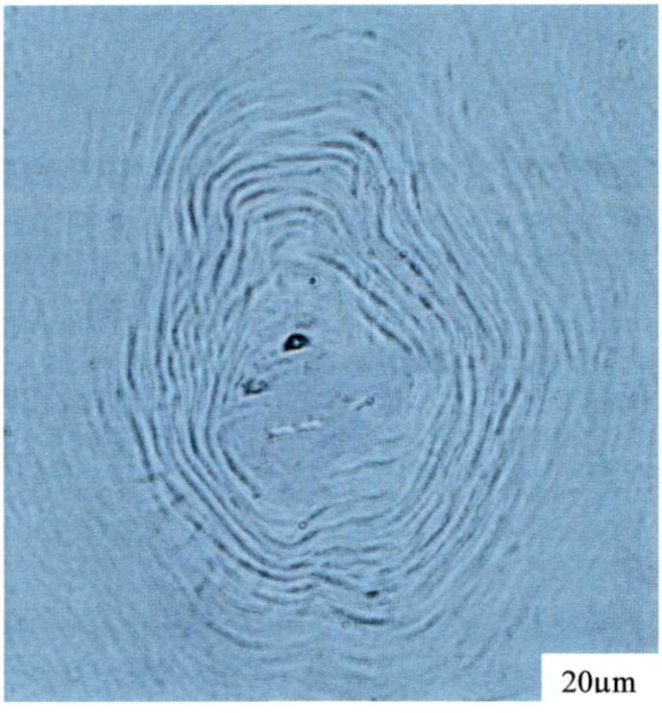

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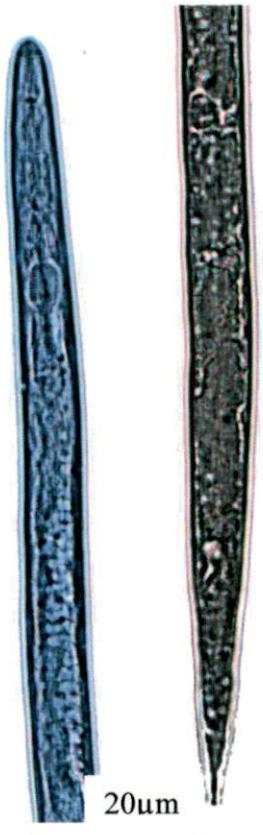

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Plate 8. (A) female, (B) anterior end of female, (C) perineal pattern, (DE) anterior and posterior end of second stage juvenile of *M.incognita* in banana from Kattakada

Table8. Morphometric characters of mature females, perineal pattern and second stage juveniles of banana population of *M. incognita* from Kattakada

Character (µm)	Banana population
Females	
Length	683.29±53.15±16.80 (435.75-786.75) 6.47%
Width	515.82±53.65±16.96 (408.99-589.54) 10.40%
Neck length	201.34±28.14±10.00 (156.27-298.15) 14.13%
Stylet length	17.23±0.16±0.82 (16.32-17.84) 2.67%
LMB	42.37±6.73±1.81 (30.14-45.15) 15.00%
WMB	40.81±5.07±1.70 (30.14-45.15) 15.00%
a	1.35±0.32±0.12 (1.28-1.74) 9.37%
Perineal pattern	
LVS	26.98±5.77±1.24 (24.34-30.17) 15.13%
AVS	20.50±3.82±0.86 (18.30-25.02) 16.40%
ATT	17.40±2.01±0.53 (13.09-20.17) 13.20%
IPD	26.38±2.34±0.58 (22.60-38.09) 17.64%
Second stage juveniles	
Length	378.76±20.15±7.34 (301.23-401.23) 6.32%
Stylet length	13.54±2.57±0.70 (11.24-15.19) 2.81%
H-MB	46.38±2.80±0.81 (40.81-50.28) 5.82%
ABW	11.81±0.38±0.91 (10.81-12.10) 4.06%
Tail length	50.08±6.72±0.08 (45.30-58.01) 6.21%
c	7.80±0.52±0.73 (7.06-9.21) 7.82%
c'	4.98±0.38±1.12 (4.25-5.90) 7.32%

LMB-Length of median bulb, WMB- width of median bulb, a-length/width ratio, H-MB-head to median bulb, ABW-anal body width, c- length/tail length ratio, c'- tail length/anal body width ratio

Perineal pattern: LVS= 24.34-30.17µm; AVS= 18.30-25.02µm; ATT= 13.09-20.17µm; IPD= 22.60-38.09µm.

Second stage juveniles (J_2): Length= 301.23-401.23µm; stylet length= 11.24-15.19µm; H-MB= 40.81-50.28µm; ABW= 10.81-12.10µm; tail length= 45.30-58.01µm; c= 7.06-9.21µm; c'= 4.25-5.90µm.

4.1.1.9 Identification of Meloidogyne sp in Brinjal from Vellayani

The species of root knot nematode infecting brinjal from Vellayani was identified as *M. incognita* (Plate 9), based on the morphological and morphometrical data of mature females, perineal pattern and second stage juveniles. The morphometric characters of the population are given in Table 9.

Description: Based on 10 females and 10 juveniles (J_2).

Measurements: Female: Length= 505.33-671.80µm; width= 386.60-565.99µm; a= 0.93-1.72µm; stylet length= 16.20-18.93µm; neck length= 127.34-264.99µm; LMB= 32.04-35.46µm; WMB= 30.10-32.90µm.

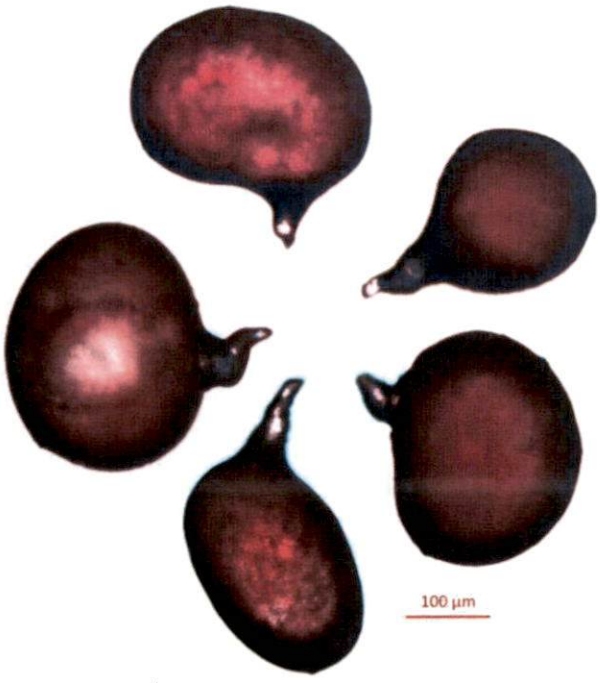
Perineal pattern: LVS= 18.56-27.83µm; AVS= 16.33-25.07µm; ATT= 15.44-24.86µm; IPD= 20.59-38.18µm.

Second stage juveniles (J_2): Length= 350.96-400.31µm; stylet length= 13.16-14.43µm; H-MB= 46.32-53.63µm; ABW= 8.06-11.79µm; tail length= 37.19-56.15µm; c= 6.75-10.58µm; c'= 3.93-6.25µm.

4.1.1.10 Identification of Meloidogyne sp in okra from Vellayani

The species of root knot nematode infecting okra from Vellayani was identified as *M. incognita* (Plate 10), based on the morphological and morphometrical data of mature females, perineal pattern and second stage juveniles. The morphometric characters of the population are given in Table 10.

Description: Based on 10 females and 10 juveniles (J_2).



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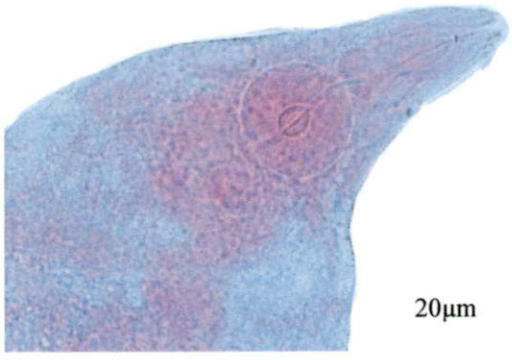

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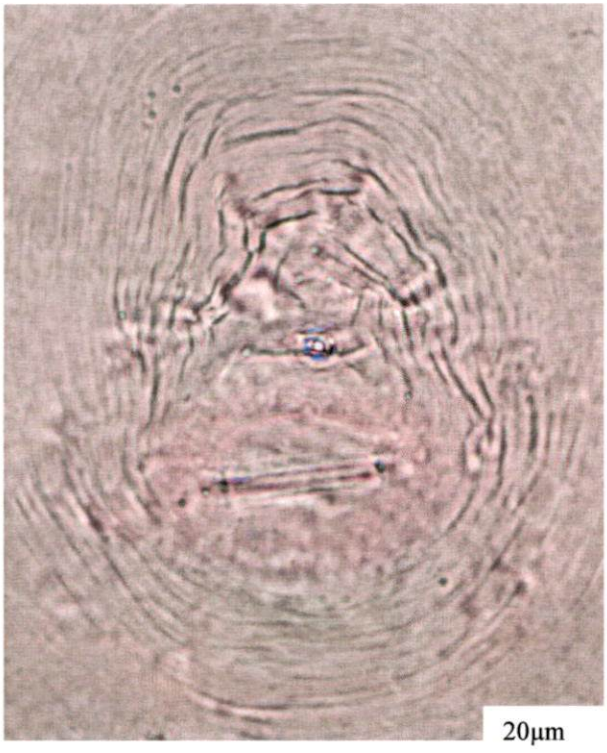

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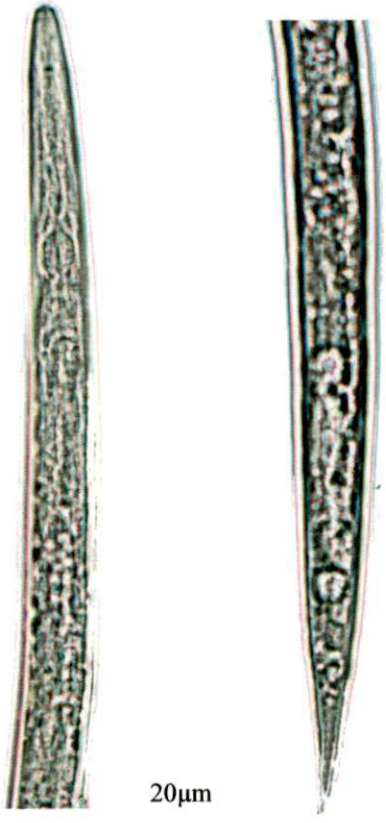

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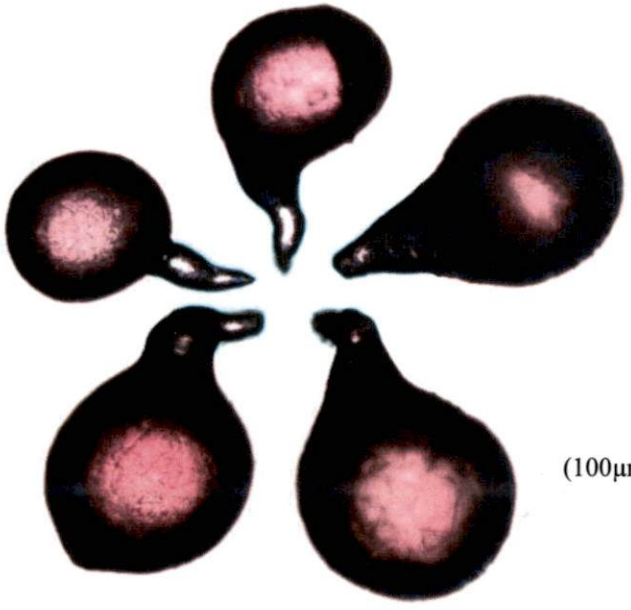
Plate 9. (A) female, (B) anterior end of female, (C) perineal pattern, (DE) anterior and posterior end of second stage juvenile of *M.incognita* in brinjal from Vellayani

Table 9. Morphometric characters of mature females, perineal pattern and second stage juveniles of tomato population of *M. incognita* from Vellayani

Character (µm)	Brinjal population
Females	
Length	606.71±55.16±17.44 (505.33-671.80) 9.09%
Width	481.27±76.36±24.14 (386.60-565.99) 15.86%
Neck length	167.89±43.60±13.78 (127.34-264.99) 25.96%
Stylet length	17.33±0.88±0.27 (16.20-18.93) 5.09%
LMB	34.02±1.29±0.40 (32.04-35.46) 3.80%
WMB	31.44±1.16±0.36 (30.10-32.90) 3.70%
A	1.28±0.22±0.07 (0.93-1.72) 17.41%
Perineal pattern	
LVS	25.40±2.79±0.88 (18.56-27.83) 10.19%
AVS	20.48±2.79±0.88 (16.33-25.07) 13.62%
ATT	21.85±3.42±1.08 (15.44-24.86) 15.66%
IPD	28.13±5.04±1.59 (20.59-38.18) 17.93%
Second stage juveniles	
Length	370.03±16.05±5.07 (350.96-400.31) 4.340%
Stylet length	13.72±0.45±0.14 (13.16-14.43) 3.34%
H-MB	50.03±2.61±0.82 (46.321-53.63) 5.22%
ABW	10.38±1.24±0.39 (8.06-11.79) 11.96%
Tail length	48.96±5.60±1.77 (37.19-56.15) 11.44%
c	7.66±1.11±0.35 (6.75-10.58) 14.54%
c'	4.74±0.59±0.18 (3.93-6.25) 12.45%

LMB-Length of median bulb, WMB- width of median bulb, a-length/width ratio, H-MB-head to median bulb, ABW-anal body width, c- length/tail length ratio, c'- tail length/anal body width ratio



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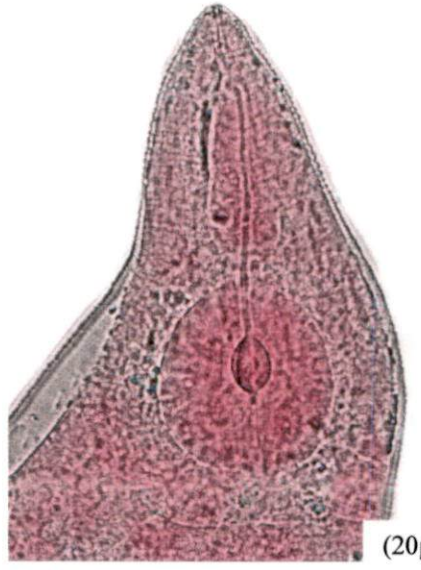

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Plate 10. (A) female, (B) anterior end of female, (C) perineal pattern, (DE) anterior and posterior end of second stage juvenile of *M. incognita* in okra from Vellayani

Table 10. Morphometric characters of mature females, perineal pattern and second stage juveniles of okra population of *M. incognita* from Vellayani

Character (µm)	Okra population
Females	
Length	546.42±33.23±10.50 (489.39-585.61) 6.08%
Width	396.54±54.74±17.31% (288.03-502.14) 13.80%
Neck length	164.34±32.35±10.23 (107.03-198.48) 19.68%
Stylet length	13.64±1.58±0.50 (11.21-15.90) 11.64%
LMB	30.55±2.58±0.81 (28.04-35.23) 8.45%
WMB	26.46±3.69±1.16 (20.08-32.84) 13.94%
a	1.39±0.16±0.053 (1.13-1.69) 12.07%
Perineal pattern	
LVS	26.34±2.48±0.78 (20.50-29.49) 9.42%
AVS	19.70±2.39±0.75 (16.18-24.30) 12.17%
ATT	18.55±2.21±0.70 (15.74-23.29) 11.94%
IPD	30.21±4.65±1.47 (24.27-39.61) 15.40%
Second stage juveniles	
Length	417.60±43.08±13.62 (361.82-468.34) 10.31%
Stylet length	14.10±0.65±0.20 (13.11-15.16) 4.62%
H-MB	50.22±1.96±0.62 (47.60-54.22) 3.91%
ABW	10.34±0.75±0.24 (9.19-11.64) 7.33%
Tail length	54.55±7.41±2.34 (47.78-70.19) 13.58%
c	7.72±0.93±0.29 (6.67-9.38) 12.12%
c'	5.26±0.42±0.13 (4.72-6.02) 8.11%

LMB-Length of median bulb, WMB- width of median bulb, a-length/width ratio, H-MB-head to median bulb, ABW-anal body width, c- length/tail length ratio, c'- tail length/anal body width ratio

Measurements: Female: Length= 489.39-585.61µm; width= 288.03-502.14µm; a= 1.13-1.69µm; stylet length= 11.21-15.90µm; neck length= 107.03-198.48µm; LMB= 28.04-35.23µm; WMB= 20.08-32.84µm.

Perineal pattern: LVS= 20.50-29.49µm; AVS= 16.18-24.30µm; ATT= 15.74-23.29µm; IPD= 24.27-39.61µm.

Second stage juveniles (J_2): Length= 361.82-468.34µm; stylet length= 13.11-15.16µm; H-MB= 47.60-54.22µm; ABW= 9.19-11.64µm; tail length= 47.78-70.19µm; c= 6.67-9.38µm; c'= 4.72-6.02µm.

4.1.1.11 Identification of Meloidogyne sp in Tomato from Vellayani

The species of root knot nematode infecting tomato from Vellayani was identified as *M. incognita* (Plate 11), based on the morphological and morphometrical data of mature females, perineal pattern and second stage juveniles. The morphometric characters of the population are given in Table 11.

Description: Based on 10 females and 10 juveniles (J_2).

Measurements: Female: Length= 462.89-612.95µm; width= 288.61-474.55µm; a= 1.15-1.60µm; stylet length= 16.04-17.80µm; neck length= 128.90-233.66µm; LMB= 30.18-35.26µm; WMB= 20.16-36.20µm.

Perineal pattern: LVS= 23.43-30.06µm; AVS= 15.52-27.09µm; ATT= 16.39-25.92µm; IPD= 21.33-36.70µm.

Second stage juveniles (J_2): Length= 369.03-439.27µm; stylet length= 14.10-16.79µm; H-MB= 51.94-60.94µm; ABW= 10.61-14.98µm; tail length= 49.58-58.68µm; c= 6.82-8.25µm; c'= 3.79-5.09µm.

4.1.1.12 Identification of Meloidogyne sp in Banana from Vellayani

The species of root knot nematode infecting banana in Vellayani was identified as *M. incognita* (Plate 12), based on the morphological and

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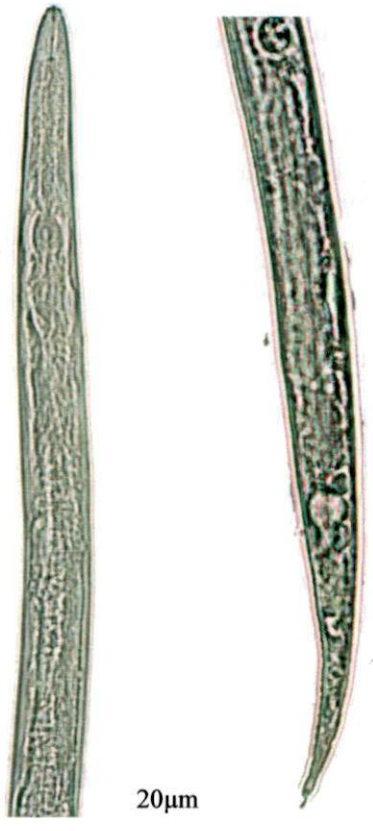

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Plate 11. (A) female, (B) anterior end of female, (C) perineal pattern, (DE) anterior and posterior end of second stage juvenile of *M. incognita* in tomato from Vellayani

Table 11. Morphometric characters of mature females, perineal pattern and second stage juveniles of tomato population of *M. incognita* from Vellayani

Character (µm)	Tomato population
Females	
Length	550.29±45.36±14.34 (462.89-612.95) 8.24%
Width	401.49±55.36±17.50 (288.61-474.55) 13.78%
Neck length	171.21±34.12±10.79 (128.90-233.66) 19.93%
Stylet length	16.53±0.54±0.17 (16.04-17.80) 3.32%
LMB	31.62±2.07±0.65 (30.18-35.26) 6.55%
WMB	30.04±5.56±1.75 (20.16-36.20) 18.51%
a	1.38±0.15±0.04 (1.15-1.60) 11.07%
Perineal pattern	
LVS	27.49±2.23±0.07 (23.43-30.06) 8.14%
AVS	20.61±3.42±1.08 (15.52-27.09) 16.60%
ATT	21.19±2.66±0.84 (16.39-25.92) 12.56%
IPD	25.85±4.61±1.46 (21.33-36.70) 17.85%
Second stage juveniles	
Length	408.45±20.68±6.53 (369.03-439.27) 5.06%
Stylet length	15.05±0.79±0.25 (14.10-16.79) 5.25%
H-MB	56.70±3.23±1.02 (51.94-60.94) 5.70%
ABW	12.67±1.39±0.44 (10.61-14.98) 11.04%
Tail length	53.94±2.43±0.77 (49.58-58.68) 4.51
c	7.58±0.47±0.15 (6.82-8.25) 6.25%
c'	4.29±0.46±0.14 (3.79-5.09) 10.86%

LMB-Length of median bulb, WMB- width of median bulb, a-length/width ratio, H-MB-head to median bulb, ABW-anal body width, c- length/tail length ratio, c'- tail length/anal body width ratio

morphometrical data of mature females, perineal pattern and second stage juveniles. The morphometric characters of the population are given in Table 12.

Description: Based on 10 females and 10 juveniles (J_2).

Measurements: Female: Length= 528.27-693.14µm; width= 373.40-570.14µm; a= 0.98-1.81µm; stylet length= 15.34-18.14µm; neck length= 137.14-282.76µm; LMB= 32.17-42.14µm; WMB= 30.00-42.28µm.

Perineal pattern: LVS= 22.17-32.60µm; AVS= 14.37-27.18µm; ATT= 17.18-26.24µm; IPD= 22.14-41.24µm.

Second stage juveniles (J_2): Length= 362.17-451.20µm; stylet length= 14.10-16.27µm; H-MB= 45.37-56.02µm; ABW= 10.17-15.01µm; tail length= 48.01-58.64µm; c= 6.81-9.27µm; c'= 3.98-5.98µm.

4.1.2 Identification of *Meloidogyne* spp. from Idukki District

4.1.2.1 Identification of Meloidogyne sp in Brinjal from Balagram

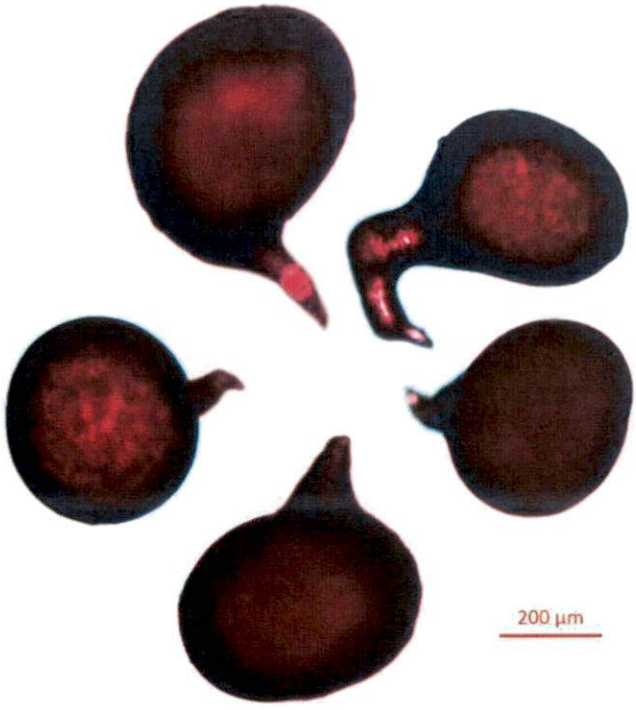
The species of root knot nematode infecting brinjal from Balagram was identified as *M. javanica* (Plate 13), based on the morphological and morphometrical data of mature females, perineal pattern and second stage juveniles. The morphometric characters of the population are given in Table 13.

Description: Based on 10 females and 10 juveniles (J_2).

Measurements: Female: Length= 494.88-807.52µm; width= 363.85-603.10µm; a= 1.27-2.17µm; stylet length= 13.45-15.68µm; neck length= 152.30-302.46µm; LMB= 38.14-46.37µm; WMB= 38.98-46.37µm.

Perineal pattern: LVS= 18.13-24.66µm; AVS= 10.77-19.63µm; ATT= 17.60-25.94µm; IPD= 14.62-29.29µm.

Second stage juveniles (J_2): Length= 360.75-436.71µm; stylet length= 13.26-14.98µm; H-MB= 47.37-58.11µm; ABW= 9.11-11.87µm; tail length= 48.54-55.39µm; c= 6.28-10.31µm; c'= 3.38-7.20µm.



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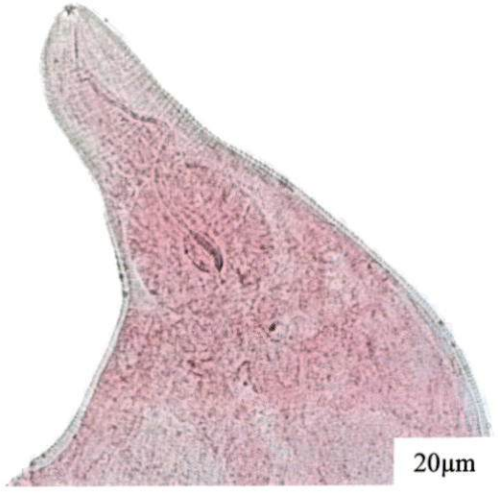

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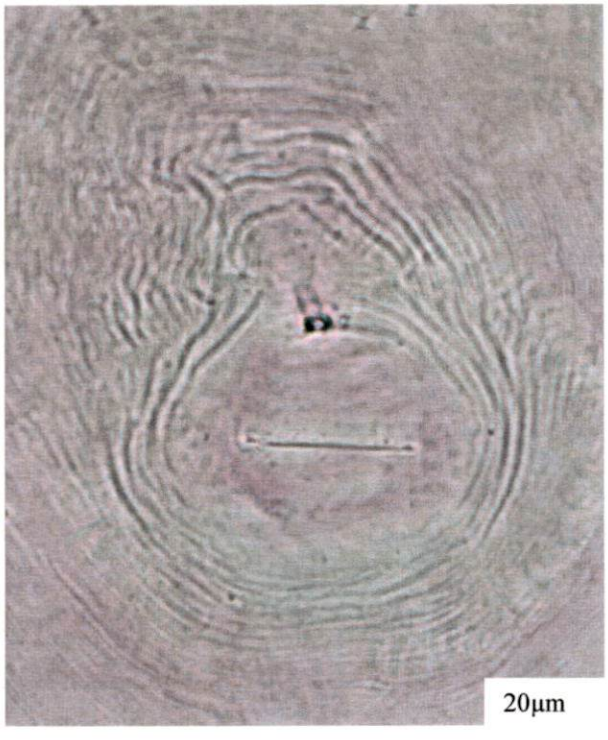

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Plate 12. (A) female, (B) anterior end of female, (C) perineal pattern, (DE) anterior and posterior end of second stage juvenile of *M .incognita* in banana from Vellayani

Table 12. Morphometric characters of mature females, perineal pattern and second stage juveniles of banana population of *M. incognita* from Vellayani

Character (µm)	Banana population
Females	
Length	620.14±64.72±17.14 (528.27-693.14) 11.10%
Width	479.24±82.30±23.17 (373.40-570.14) 15.07%
Neck length	183.24±50.00±16.78 (137.14-282.76) 29.18%
Stylet length	17.18±0.17±0.38 (15.34-18.14) 6.07%
LMB	40.16±1.89±0.17 (32.17-42.14) 4.61%
WMB	40.00±1.67±0.43 (30.00-42.28) 3.81%
a	1.29±0.18±0.03 (0.98-1.81) 16.54%
Perineal pattern	
LVS	27.34±3.48±1.10 (22.17-32.60) 8.21%
AVS	20.81±3.82±1.81 (14.37-27.18) 16.17%
ATT	21.32±2.17±0.91 (17.18-26.24) 13.60%
IPD	27.81±4.10±1.61 (22.14-41.24) 19.21%
Second stage juveniles	
Length	423.19±28.17±7.81 (362.173-451.207) 7.173%
Stylet length	15.67±0.83±0.36 (14.10-16.27) 5.67%
H-MB	54.372±4.317±2.108 (45.37-56.02) 5.37%
ABW	12.17±1.47±0.51 (10.173-15.017) 12.173%
Tail length	52.98±2.45±0.81 (48.01-58.64) 4.52%
c	7.83±0.81±0.25 (6.81-9.27) 6.30%
c'	5.37±0.53±0.13 (3.98-5.98) 11.31%

LMB-Length of median bulb, WMB- width of median bulb, a-length/width ratio, H-MB-head to median bulb, ABW-anal body width, c- length/tail length ratio, c'- tail length/anal body width ratio

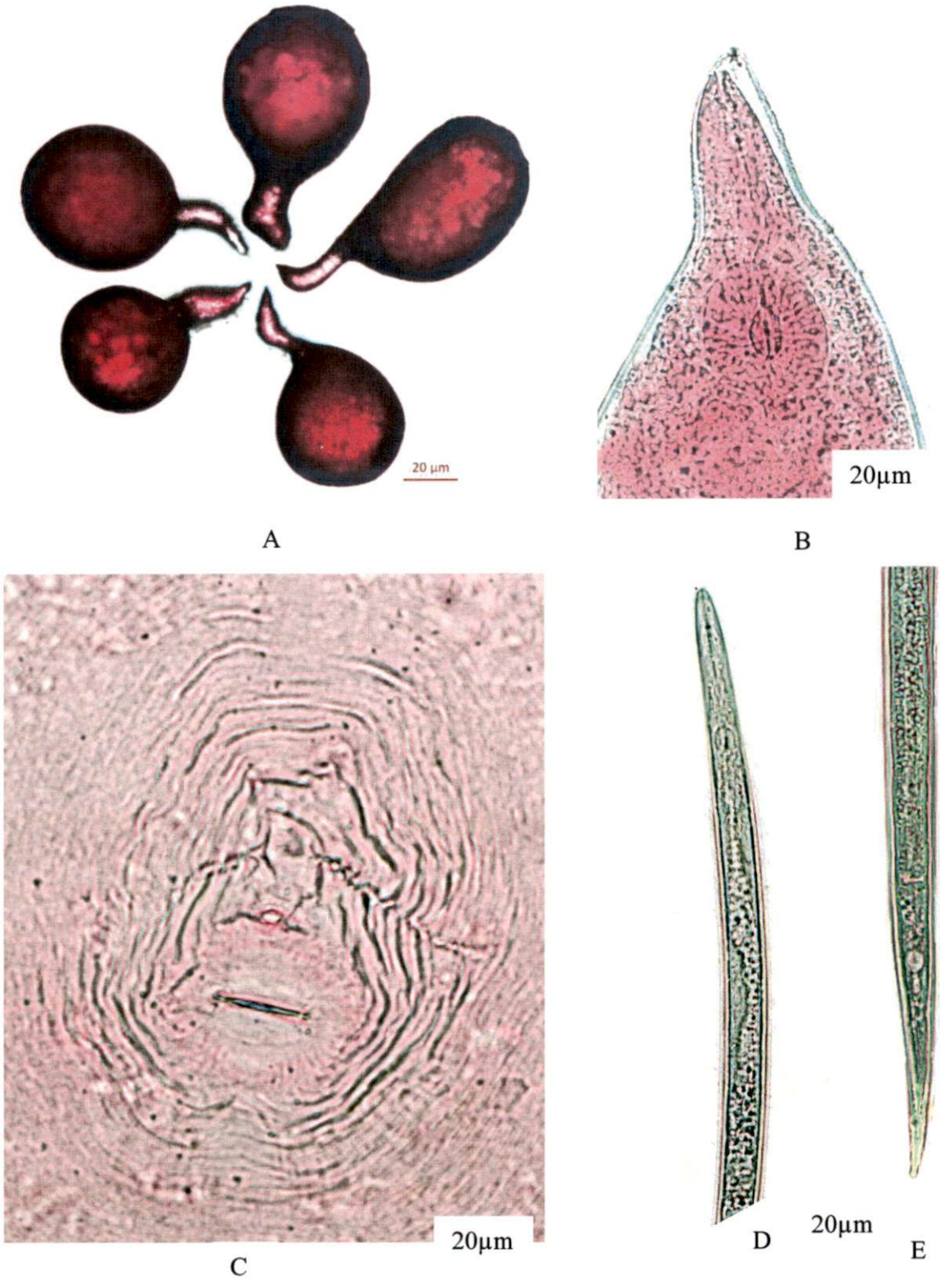


Plate 13. (A) female, (B) anterior end of female, (C) perineal pattern, (DE) anterior and posterior end of second stage juvenile (20µm) of *M. javanica* in brinjal from Balagram

Table 13. Morphometric characters of mature females, perineal pattern and second stage juveniles of brinjal population of *M. javanica* from Balagram

Character (µm)	Brinjal population
Females	
Length	701.50±107.66±34.04 (494.88-807.52) 15.34%
Width	416.66±71.14±22.49 (363.85-603.10) 17.07%
Neck length	223.77±48.33±15.28 (152.30-302.46) 21.59%
Stylet length	14.49±0.84±0.26 (13.45-15.68) 5.88%
LMB	42.11±3.14±0.99 (38.14-46.37) 7.46%
WMB	41.89±2.89±0.91 (38.98-46.37) 6.91%
a	1.72±0.31±0.09 (1.27-2.17) 18.10%
Perineal pattern	
LVS	22.25±2.26±0.71 (18.13-24.66) 10.15
AVS	16.82±2.52±0.79 (10.77-19.63) 14.99%
ATT	21.21±2.99±1.05 (17.60-25.94) 14.12%
IPD	20.94±5.03±1.71 (14.62-29.29) 24.02%
Second stage juveniles	
Length	410.71±21.76±8.41 (360.75-436.71) 6.01%
Stylet length	13.91±0.51±0.24 (13.26-14.98) 3.11%
H-MB	53.04±3.41±1.08 (47.37-58.11) 6.51%
ABW	10.56±0.51±0.16 (9.11-11.87) 4.73%
Tail length	52.11±2.41±0.87 (48.54-55.39) 4.21%
c	7.88±1.70±0.51 (6.28-10.31) 18.21%
c'	4.93±1.11±0.54 (3.38-7.20) 18.01%

LMB-Length of median bulb, WMB- width of median bulb, a-length/width ratio, H-MB-head to median bulb, ABW-anal body width, c- length/tail length ratio, c'- tail length/anal body width ratio

4.1.2.2 Identification of Meloidogyne sp in okra from Balagram

The species of root knot nematode infecting okra from Balagram was identified as *M. incognita* (Plate 14), based on the morphological and morphometrical data of mature females, perineal pattern and second stage juveniles. The morphometric characters of the population are given in Table 14.

Description: Based on 10 females and 10 juveniles (J_2).

Measurements: Female: Length= 554.03-715.42µm; width= 390.40-524.42µm; a= 1.12-1.76µm; stylet length= 13.10-15.32µm; neck length= 102.95-175.60µm; LMB= 38.13-42.04µm; WMB= 37.17-41.37µm.

Perineal pattern: LVS= 18.14-27.88µm; AVS= 15.58-24.51µm; ATT= 16.15-25.38µm; IPD= 23.10-30.36µm.

Second stage juveniles (J_2): Length= 349.07-408.90µm; stylet length= 13.05-14.56µm; H-MB= 46.23-51.41µm; ABW= 9.00-11.10µm; tail length= 42.79-54.59µm; c= 7.26-8.15µm; c'= 4.27-5.52µm.

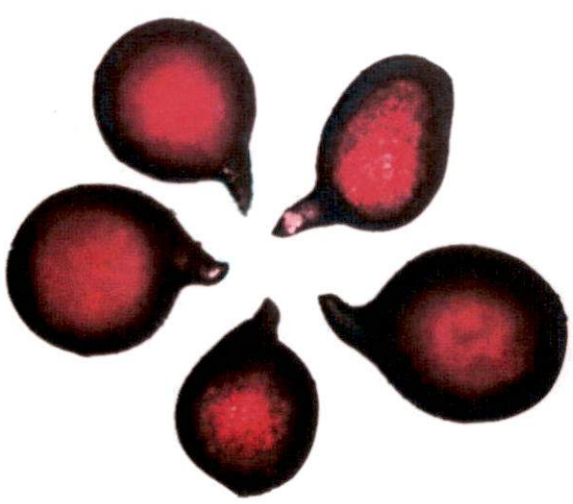
4.1.2.3 Identification of Meloidogyne sp in Tomato from Balagram

The species of root knot nematode infecting tomato from Balagram was identified as *M. incognita* (Plate 15), based on the morphological and morphometrical data of mature females, perineal pattern and second stage juveniles. The morphometric characters of the population are given in Table 15.

Description: Based on 10 females and 10 juveniles (J_2).

Measurements: Female: Length= 495.41-779.60µm; width= 304.16-526.16µm; a= 1.30-1.95µm; stylet length= 12.89-15.28µm; neck length= 111.49-192.18µm; LMB= 40.11-45.56µm; WMB= 39.18-45.10µm.

Perineal pattern: LVS= 16.30-23.75µm; AVS= 16.43-22.47µm; ATT= 17.11-25.79µm; IPD= 16.29-37.80µm.



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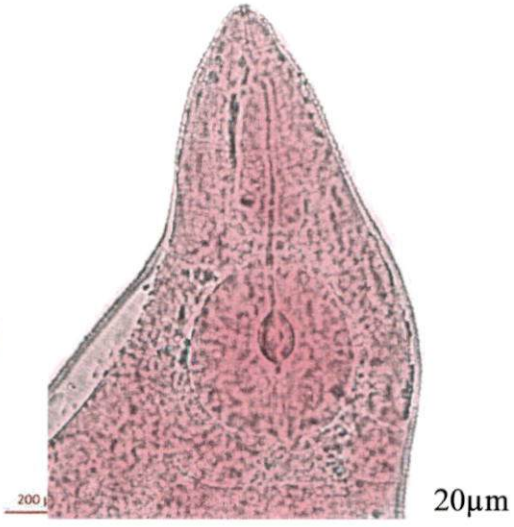

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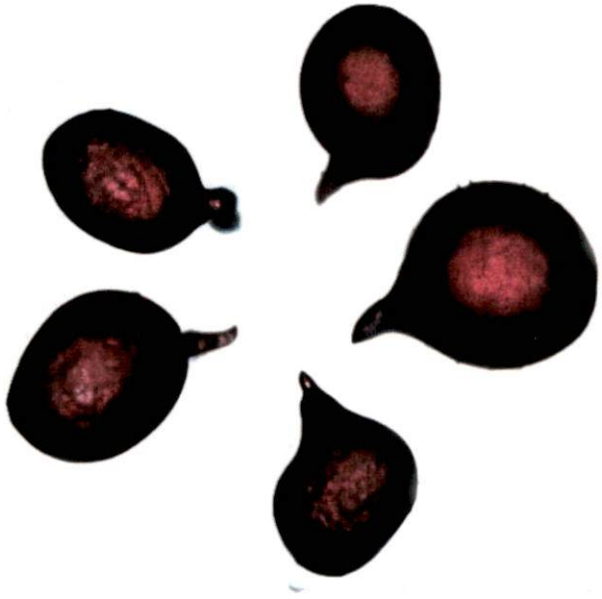
Plate 14. (A) female, (B) anterior end of female, (C) perineal pattern, (DE) anterior and posterior end of second stage juvenile of *M. incognita* in okra from Balagram

Table 14. Morphometric characters of mature females, perineal pattern and second stage juveniles of okra population of *M. incognita* from Balagram

Character (µm)	Okra population
Females	
Length	648.00±58.38±18.46 (554.03-715.42) 9.01%
Width	462.47±40.44±12.78 (390.40-524.42) 8.74%
Neck length	151.47±23.42±7.40 (102.95-175.60) 15.46%
Stylet length	14.37±0.67±0.21 (13.10-15.32) 4.71%
LMB	39.97±1.03±0.32 (38.13-42.04) 2.59%
WMB	39.52±1.17±0.37 (37.17-41.37) 2.96%
a	1.42±0.17±0.05 (1.12-1.76) 12.27%
Perineal pattern	
LVS	22.93±3.33±1.05 (18.14-27.88) 14.52%
AVS	19.67±26.56±0.84 (15.58-24.51) 13.50%
ATT	19.03±2.80±0.88 (16.15-25.38) 14.74%
IPD	27.05±2.78±0.88 (23.10-30.36) 10.29%
Second stage juveniles	
Length	390.86±17.30±5.47 (349.07-408.90) 4.42%
Stylet length	13.66±0.47±0.15 (13.05-14.56) 3.47%
H-MB	48.40±1.77±0.56 (46.23-51.41) 3.67%
ABW	10.05±0.69±0.21 (9.00-11.10) 6.86%
Tail length	50.41±3.36±1.06 (42.79-54.59) 6.66%
c	7.76±0.30±0.09 (7.26-8.15) 3.91%
c'	5.02±0.39±0.12 (4.278-5.527) 7.890%

LMB-Length of median bulb, WMB- width of median bulb, a-length/width ratio, H-MB-head to median bulb, ABW-anal body width, c- length/tail length ratio, c'- tail length/anal body width ratio



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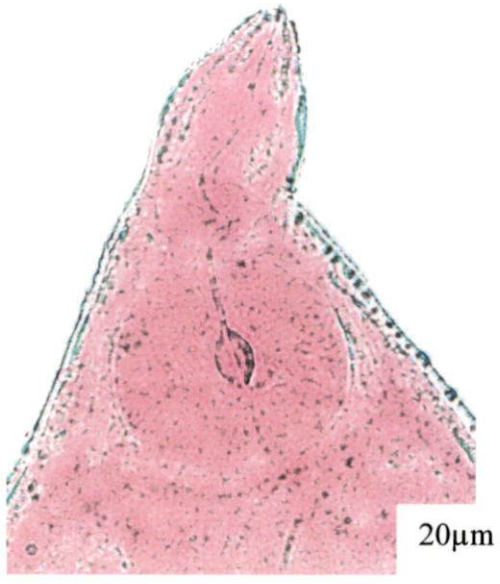

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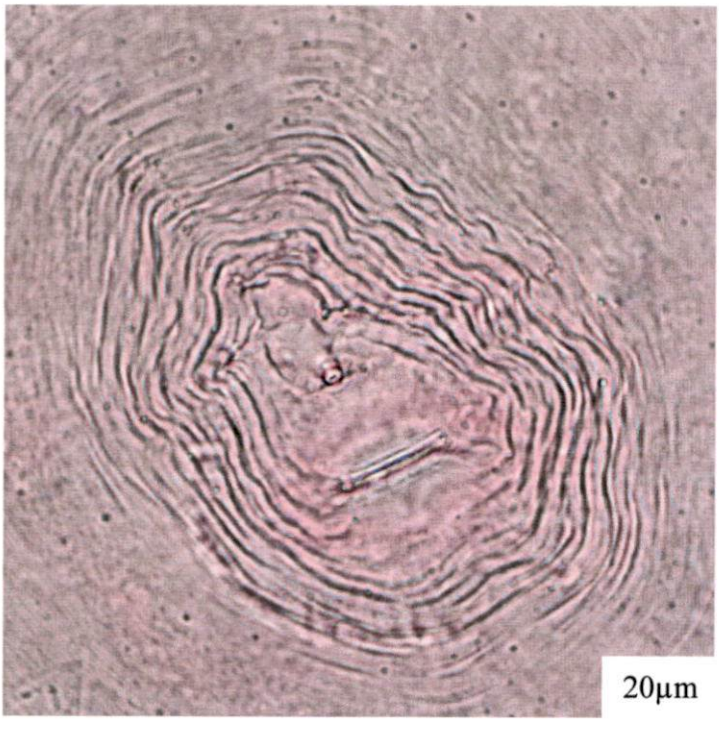

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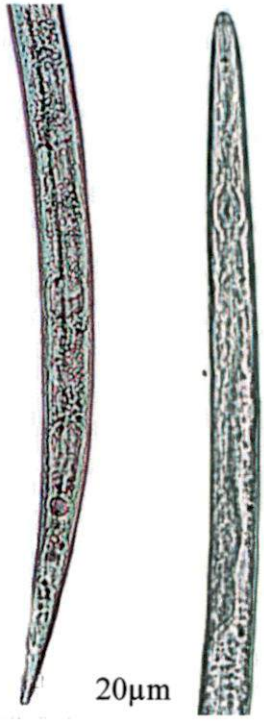

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Plate 15. (A) female, (B) anterior end of female, (C) perineal pattern, (DE) anterior and posterior end of second stage juvenile of *M. incognita* in tomato from Balagram

Table 15. Morphometric characters of mature females, perineal pattern and second stage juveniles of tomato population of *M. incognita* from Balagram

Character (µm)	Tomato population
Females	
Length	589.84±98.69±31.20 (495.41-779.60) 16.73%
Width	388.96±61.12±19.32 (304.16-526.16) 15.71%
Neck length	161.50±25.07±7.92 (111.49-192.18) 15.52%
Stylet length	14.01±0.91±0.28 (12.89-15.28) 6.50%
LMB	41.66±1.70±0.53 (40.11-45.56) 4.09%
WMB	41.00±1.69±0.53 (39.18-45.10) 4.13%
a	1.52±0.21±0.06 (1.30-1.95) 14.31%
Perineal pattern	
LVS	20.68±2.26±0.71 (16.30-23.75) 10.92%
AVS	19.89±1.91±0.60 (16.43-22.47) 9.63%
ATT	20.52±2.91±0.92 (17.11-25.79) 14.21%
IPD	26.58±5.99±1.89 (16.29-37.80) 22.53%
Second stage juveniles	
Length	392.67±18.76±5.93 (344.51-409.67) 4.77%
Stylet length	13.73±0.81±0.25 (12.06-14.97) 5.91%
H-MB	50.36±4.41±1.39 (42.31-59.70) 8.77%
ABW	9.88±1.07±0.33 (8.28-11.84) 10.94%
Tail length	53.57±7.92±2.50 (40.17-68.87) 14.79%
c	7.43±0.87±0.27 (5.65-8.575) 11.77%
c'	5.04±0.51±0.16 (4.65-6.08) 9.48%

LMB-Length of median bulb, WMB- width of median bulb, a-length/width ratio, H-MB-head to median bulb, ABW-anal body width, c- length/tail length ratio, c'- tail length/anal body width ratio

Second stage juveniles (J_2): Length= 344.51-409.67µm; stylet length= 12.06-14.97µm; H-MB= 42.31-59.70µm; ABW= 8.28-11.84µm; tail length= 40.17-68.87µm; c= 5.65-8.57µm; c'= 4.65-6.08µm.

4.1.2.4 Identification of Meloidogyne sp in Banana from Balagram

The species of root knot nematode infecting banana from Balagram was identified as *M. javanica* (Plate 16), based on the morphological and morphometrical data of mature females, perineal pattern and second stage juveniles. The morphometric characters of the population are given in Table 16.

Description: Based on 10 females and 10 juveniles (J_2).

Measurements: Female: Length= 560.26-790.25µm; width= 394.25-560.24µm; a= 1.12-1.87µm; stylet length= 13.20-16.17µm; neck length= 125.60-182.15µm; LMB= 38.01-45.52µm; WMB= 37.14-42.01µm.

Perineal pattern: LVS= 19.48-26.15µm; AVS= 18.24-25.11µm; ATT= 16.29-25.15µm; IPD= 26.21-30.25µm.

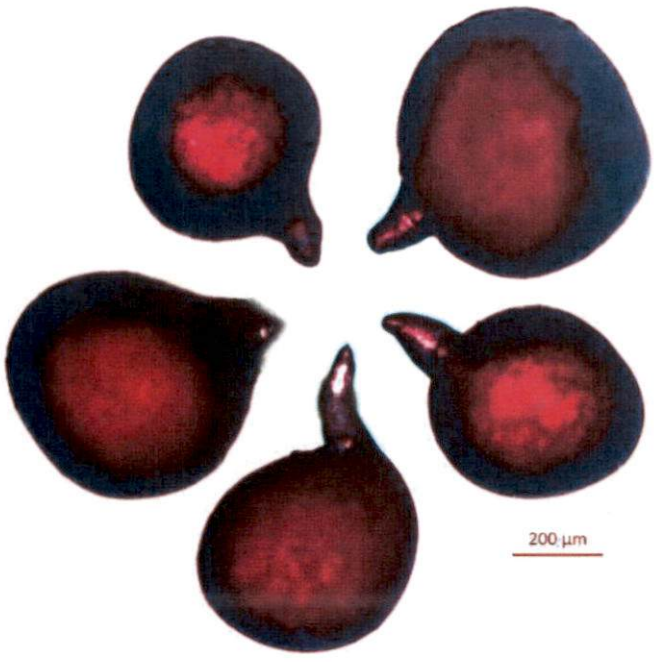
Second stage juveniles (J_2): Length= 350.12-412.14µm; stylet length= 13.21-14.25µm; H-MB= 46.21-53.17µm; ABW= 9.817-11.21µm; tail length= 42.17-54.92µm; c= 7.01-8.25µm; c'= 4.27-7.20µm.

4.1.2.5 Identification of Meloidogyne sp in Brinjal from Pampadumpara

The species of root knot nematode infecting brinjal from Pampadumpara was identified as *M. javanica* (Plate 17), based on the morphological and morphometrical data of mature females, perineal pattern and second stage juveniles. The morphometric characters of the population are given in Table 17.

Description: Based on 10 females and 10 juveniles (J_2).

Measurements: Female: Length= 536.85-817.64µm; width= 375.86-493.68µm; a= 1.30-1.72µm; stylet length= 16.10-17.21µm; neck length= 126.38-249.68µm; LMB= 38.19-50.21µm; WMB= 37.15-50.11µm.



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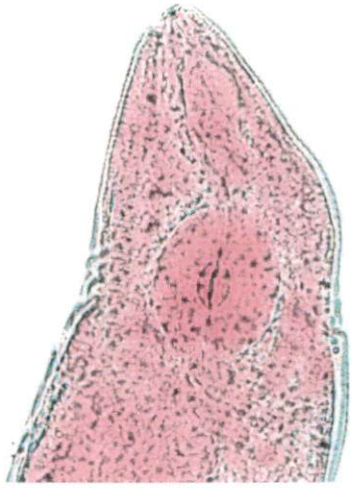

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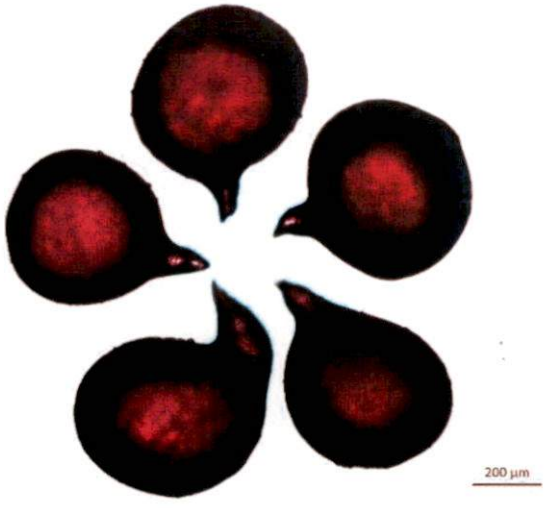
Plate 16. (A) female, (B) anterior end of female, (C) perineal pattern, (DE) anterior and posterior end of second stage juvenile of *M. javanica* in banana from Balagram

Table 16. Morphometric characters of mature females, perineal pattern and second stage juveniles of banana population of *M. incognita* from Balagram

Character (µm)	Banana population
Females	
Length	653.23±69.95±22.12 (560.26-790.25) 10.70%
Width	466.23±51.02±16.13 (394.25-560.24) 10.94%
Neck length	165.23±20.16±6.21 (125.60-182.15) 16.20%
Stylet length	15.23±0.71±0.20 (13.20-16.17) 5.72%
LMB	40.20±1.28±0.32 (38.01-45.52) 3.98%
WMB	39.02±1.78±0.41 (37.14-42.01) 2.8%
a	1.42±0.18±0.61 (1.12-1.87) 13.26%
Perineal pattern	
LVS	23.29±2.62±0.83 (19.48-26.15) 11.27%
AVS	20.21±2.01±0.63 (18.24-25.11) 9.97%
ATT	19.63±2.37±0.75 (16.29-25.15) 12.10%
IPD	28.70±1.43±0.45 (26.21-30.25) 4.99%
Second stage juveniles	
Length	397.60±17.62±5.57 (350.12-412.14) 4.43%
Stylet length	13.63±0.51±0.16 (13.21-14.25) 3.75%
H-MB	50.2±2.07±0.67 (46.21-53.17) 4.92%
ABW	10.98±0.72±0.34 (9.81-11.21) 7.81%
Tail length	50.98±3.45±1.78 (42.17-54.92) 6.76%
c	7.79±0.41±0.12 (7.01-8.25) 3.98%
c'	6.54±0.47±0.12 (4.27-7.20) 8.19%

LMB-Length of median bulb, WMB- width of median bulb, a-length/width ratio, H-MB-head to median bulb, ABW-anal body width, c- length/tail length ratio, c'- tail length/anal body width ratio



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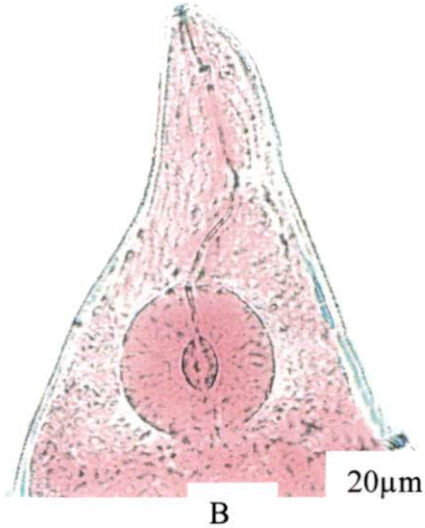

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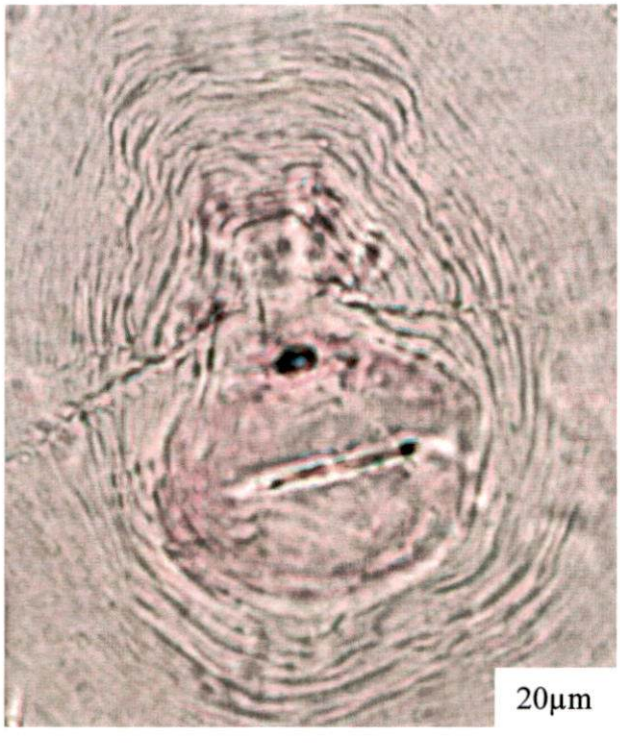

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Plate 17. (A) female, (B) anterior end of female, (C) perineal pattern, (DE) anterior and posterior end of second stage juvenile of *M. javanica* in brinjal from Pampadumpara

Table 17. Morphometric characters of mature females, perineal pattern and second stage juveniles of brinjal population of *M. javanica* from Pampadumpara

Character (µm)	Brinjal population
Females	
Length	646.28±92.17±29.14 (536.85-817.64) 14.26%
Width	431.84±44.68±14.12 (375.86-493.68) 10.34%
Neck length	169.89±38.66±12.22 (126.38-249.68) 22.76%
Stylet length	16.74±0.42±0.13 (16.10-17.21) 2.53%
LMB	42.77±4.45±1.40 (38.19-50.21) 10.42%
WMB	41.93±4.00±1.26 (37.15-50.11) 9.60%
a	1.49±0.15±0.04 (1.30-1.72) 10.09%
Perineal pattern	
LVS	25.56±2.32±0.73 (21.61-28.55) 9.07%
AVS	19.41±5.15±1.63 (14.24-28.99) 26.56%
ATT	16.38±1.42±0.44 (14.24-18.91) 8.67%
IPD	24.17±4.28±1.35 (19.55-32.28) 17.71%
Second stage juveniles	
Length	406.55±16.77±5.30 (384.04-442.18) 4.12%
Stylet length	14.57±0.36±0.11 (13.94-15.03) 2.51%
H-MB	46.22±2.01±0.63 (43.69-49.28) 4.35%
ABW	10.37±0.60±0.19 (9.28-11.46) 5.81%
Tail length	51.45±2.33±0.73 (48.82-55.41) 4.54%
c	7.90±0.32±0.10 (7.35-8.36) 4.05%
c'	4.91±0.38±0.12 (4.17-5.52) 7.76%

LMB-Length of median bulb, WMB- width of median bulb, a-length/width ratio, H-MB-head to median bulb, ABW-anal body width, c- length/tail length ratio, c'- tail length/anal body width ratio

Perineal pattern: LVS= 21.61-28.55µm; AVS= 14.24-28.99µm; ATT= 14.24-18.91µm; IPD= 19.55-32.28µm.

Second stage juveniles (J_2): Length= 384.04-442.18µm; stylet length= 13.94-15.03µm; H-MB= 43.69-49.28µm; ABW= 9.28-11.46µm; tail length= 48.82-55.41µm; c= 7.35-8.36µm; c'= 4.17-5.52µm.

4.1.2.6 Identification of Meloidogyne sp in okra from Pampadumpara

The species of root knot nematode infecting okra from Pampadumpara was identified as *M. javanica* (Plate 18), based on the morphological and morphometrical data of mature females, perineal pattern and second stage juveniles. The morphometric characters of the population are given in Table 18.

Description: Based on 10 females and 10 juveniles (J_2).

Measurements: Female: Length= 562.81-901.22µm; width= 361.57-482.98µm; a= 1.40-2.73µm; stylet length= 15.16-17.28µm; neck length= 148.24-369.07µm; LMB= 30.19-45.10µm; WMB= 28.48-39.26µm.

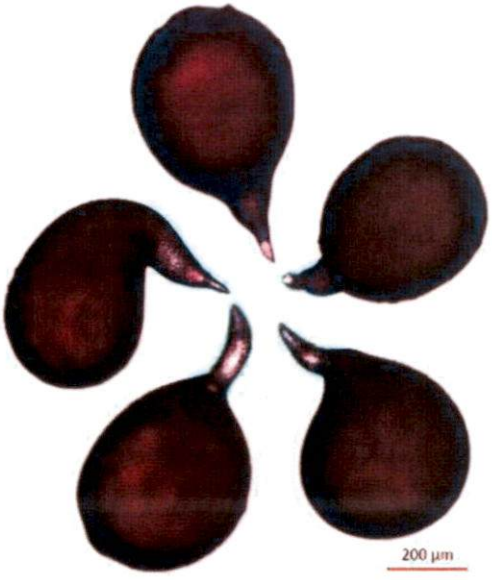
Perineal pattern: LVS= 19.467-26.564µm; AVS= 14.17-18.19µm; ATT= 9.19-19.90µm; IPD= 18.19-27.09µm.

Second stage juveniles (J_2): Length= 384.04-442.18µm; stylet length= 13.94-15.03µm; H-MB= 43.69-49.28µm; ABW= 9.28-11.46µm; tail length= 48.82-55.41µm; c= 7.35-8.36µm; c'= 4.17-5.52µm.

4.1.2.7 Identification of Meloidogyne sp in Tomato from Pampadumpara

The species of root knot nematode infecting tomato from Pampadumpara was identified as *M. javanica* (Plate 19, 20), based on the morphological and morphometrical data of mature females, perineal pattern and second stage juveniles. The morphometric characters of the population are given in Tables 19 and 20.

Description: Based on 10 females and 10 juveniles (J_2).



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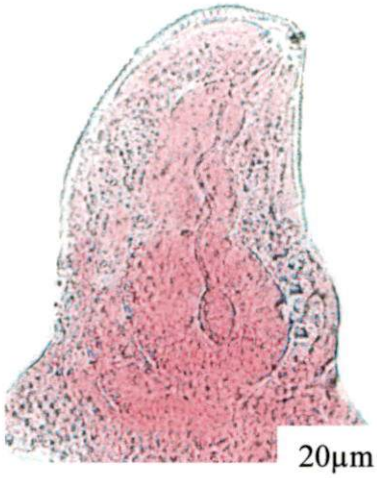

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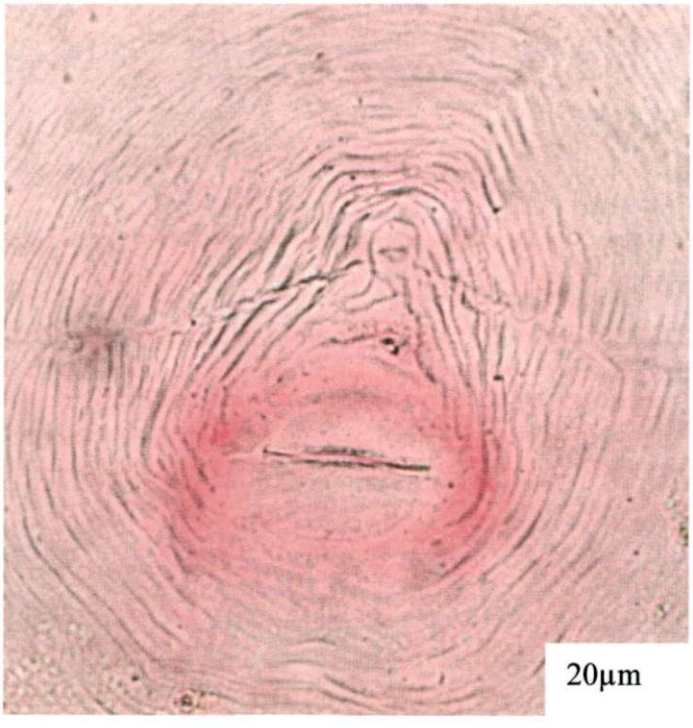

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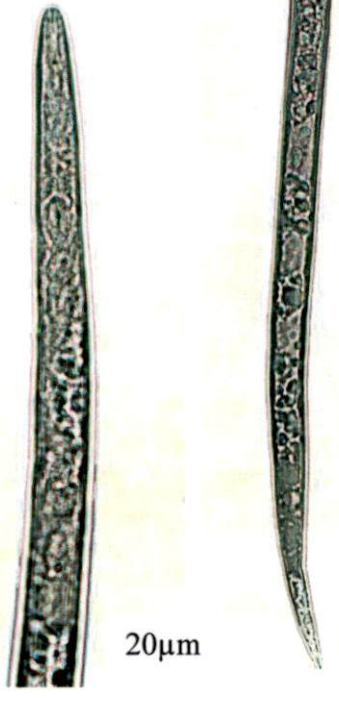

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Plate 18. (A) female, (B) anterior end of female, (C) perineal pattern, (DE) anterior and posterior end of second stage juvenile of *M. javanica* in okra from Pampadumpara

Table 18. Morphometric characters of mature females, perineal pattern and second stage juveniles of okra population of *M. javanica* from Pampadumpara

Character (µm)	Okra population
Females	
Length	735.32±105.63±32.16 (562.81-901.22) 14.38%
Width	410.71±33.50±10.38 (361.57-482.98) 8.12%
Neck length	221.76±71.53±21.50 (148.24-369.07) 31.70%
Stylet length	16.55±0.77±0.24 (15.16-17.28) 4.12%
LMB	35.58±4.30±1.72 (30.19-45.10) 13.79%
WMB	34.93±4.47±1.41 (28.48-39.26) 13.97%
a	1.49±0.15±0.08 (1.40-2.73) 15.55%
Perineal pattern	
LVS	24.24±2.44±0.76 (19.46-26.56) 9.83%
AVS	16.05±1.75±0.55 (14.17-18.19) 10.33%
ATT	14.38±3.06±0.97 (9.19-19.90) 21.28%
IPD	22.45±2.29±0.35 (18.19-27.09) 11.84%
Second stage juveniles	
Length	396.60±26.54±8.23 (359.43-420.34) 6.07%
Stylet length	13.56±0.63±0.20 (12.60-14.58) 4.65%
H-MB	52.32±3.49±1.61 (47.64-57.24) 6.71%
ABW	9.84±1.01±0.32 (8.00-10.86) 10.31%
Tail length	45.46±15.08±4.77 (34.47-60.14) 33.06%
c	8.54±1.81±0.57 (6.05-11.19) 21.27%
c'	4.95±1.10±0.34 (3.38-7.02) 21.27%

LMB-Length of median bulb, WMB- width of median bulb, a-length/width ratio, H-MB-head to median bulb, ABW-anal body width, c- length/tail length ratio, c'- tail length/anal body width ratio

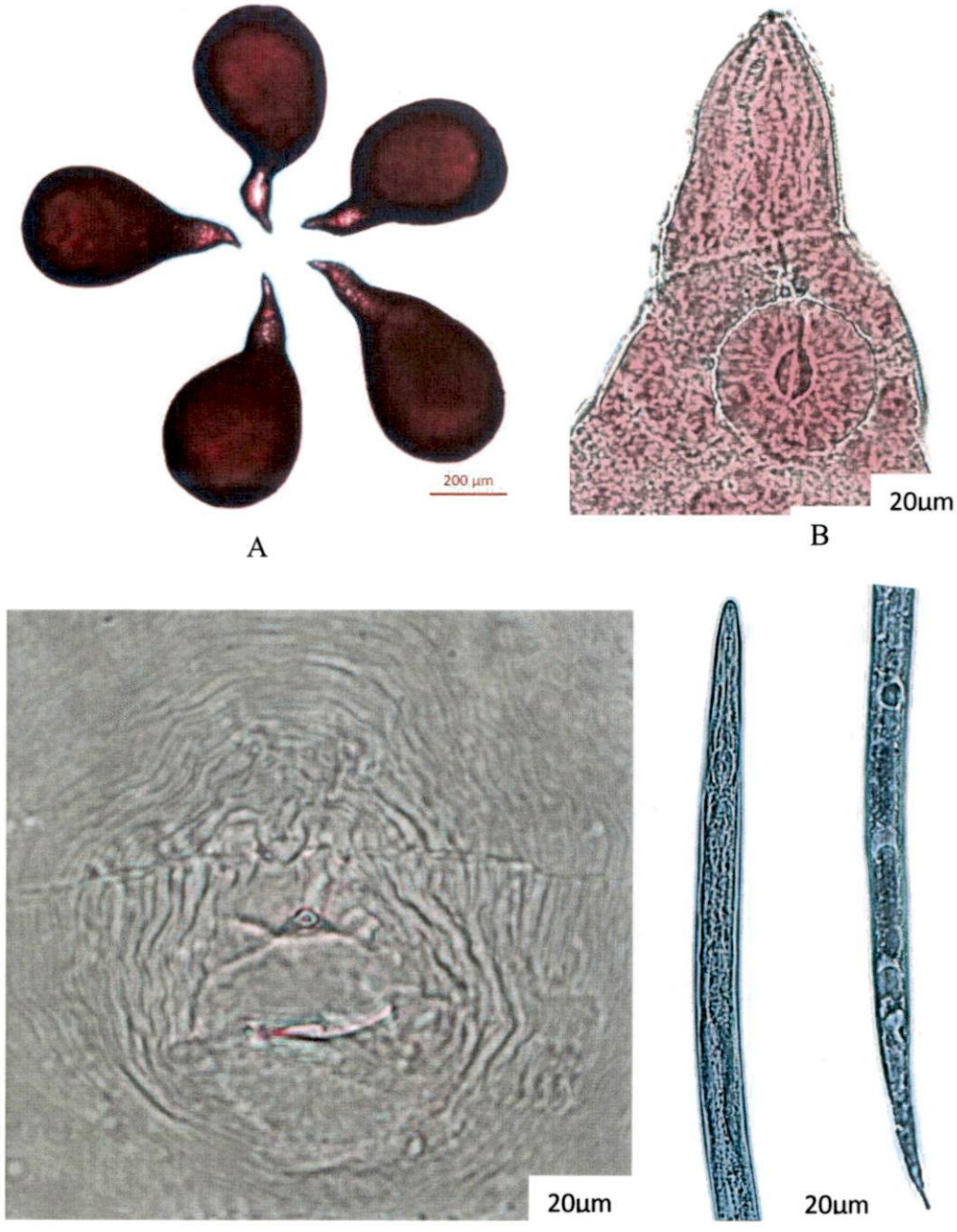


Plate 19. (A) female, (B) anterior end of female, (C) perineal pattern, (DE) anterior and posterior end of second stage juvenile of *M. javanica* in tomato from Pampadumpara

Table 19. Morphometric characters of mature females, perineal pattern and second stage juveniles of tomato population of *M. javanica* from Pampadumpara

Character (µm)	Pampadumpara population (Tomato)
Females	
Length	740.18±107.31±33.93 (565.18-906.18) 14.49%
Width	415.38±32.85±10.39 (362.32-482.85) 7.91%
Neck length	233.20±74.33±23.50 (147.29-379.72) 31.87%
Stylet length	16.55±0.59±0.81 (15.79-17.60) 3.58%
LMB	41.32±4.15±1.31 (34.63-49.80) 10.04%
WMB	40.29±3.08±0.97 (34.87-47.00) 8.74%
a	1.79±0.29±0.09 (1.38-2.30) 16.62%
Perineal pattern	
LVS	25.06±3.20±1.01 (19.06-29.81) 12.77%
AVS	16.83±1.68±0.53 (14.28-18.60) 9.98%
ATT	14.82±2.78±0.87 (10.64-19.18) 18.76%
IPD	23.58±2.11±0.67 (20.34-27.34) 8.98%
Second stage juveniles	
Length	395.94±26.47±8.37 (358.23-422.57) 6.68%
Stylet length	13.64±0.65±0.20 (12.57-14.84) 4.77%
H-MB	52.06±3.49±1.10 (47.27-57.67) 6.70%
ABW	10.00±0.81±0.25 (8.54-10.91) 8.18%
Tail length	48.86±9.21±2.91 (32.19-60.70) 18.85%
c	8.39±1.75±0.55 (6.05-11.12) 20.91%
c'	4.91±1.06±0.33 (3.37-6.58) 21.69%

LMB-Length of median bulb, WMB- width of median bulb, a-length/width ratio, H-MB-head to median bulb, ABW-anal body width, c- length/tail length ratio, c'- tail length/anal body width ratio

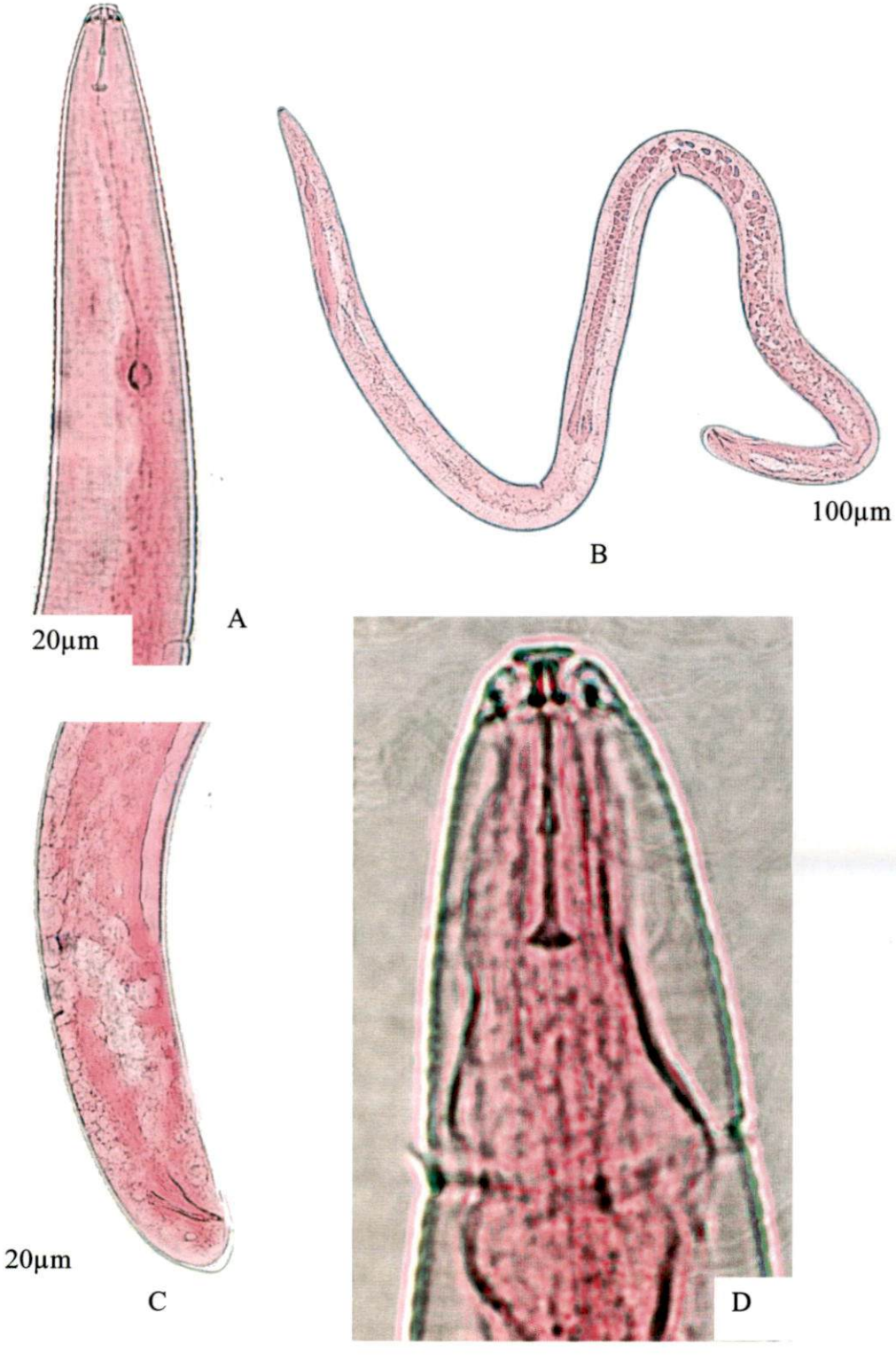


Plate 20. (A) anterior end of male, (B) male, (C) posterior end of male, (D) head region with stylet of *M. javanica* in tomato from Pampadumpara

Table 20. Morphometric characters of males of tomato population of *M. javanica* from Pampadumpara

Character (µm)	Tomato population
Females	
Length	1558.98±118.47±52.98 (1396.76-1687.94) 7.59%
Width	40.14±2.95±1.32 (35.11-42.81) 7.35%
Stylet length	21.25±0.41±0.18 (20.69-21.63) 1.93%
Stylet cone length	10.82±0.33±0.14 (10.27-11.10) 3.06%
DGO from stylet base	3.44±0.38±0.17 (2.90-3.98) 11.12%
Tail length	13.08±1.00±0.44 (11.80-14.20) 7.68%
Tail width at anus	18.41±1.08±0.48 (16.71-19.28) 5.86%
Spicule length	27.98±0.78±0.34 (27.15-29.17) 2.79%

DGO- distance from dorsal oesophagal gland orifice to stylet base

Measurements: Female: Length= 565.18-906.18µm; width= 362.32-482.85µm; a= 1.38-2.30µm; stylet length= 15.79-17.60µm; neck length= 147.29-379.72µm; LMB= 34.63-49.80µm; WMB= 34.87-47.00µm.

Perineal pattern: LVS= 19.06-29.81µm; AVS= 14.28-18.60µm; ATT= 10.64-19.18µm; IPD= 20.34-27.34µm.

Second stage juveniles (J_2): Length= 358.23-422.57µm; stylet length= 12.57-14.84µm; H-MB= 47.27-57.67µm; ABW= 8.54-10.91µm; tail length= 32.19-60.70µm; c= 6.05-11.12µm; c'= 3.37-6.58µm.

Males: Length= 1396.76-1687.94 µm; width= 35.11-42.81 µm; stylet length= 20.69-21.63 µm; stylet cone length= 10.27-11.10 µm; DGO from stylet base= 2.90-3.98 µm; tail length= 11.80-14.20 µm; tail width at anus= 16.71-19.28 µm; spicule length= 27.15-29.17 µm.

4.1.2.8 Identification of Meloidogyne sp in Banana from Pampadumpara

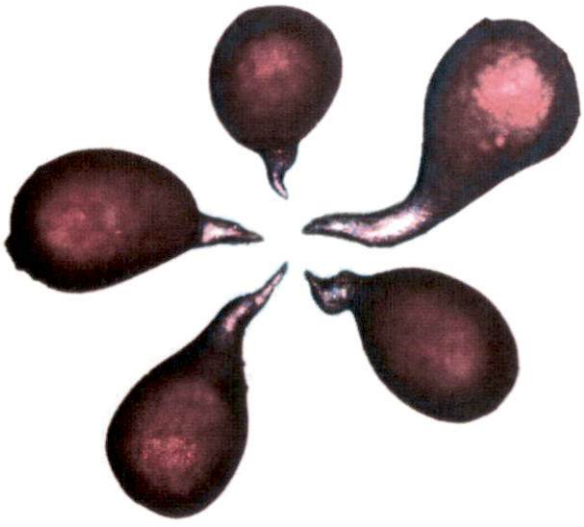
The species of root knot nematode infecting banana from Pampadumpara was identified as *M. javanica* (Plate 21), based on the morphological and morphometrical data of mature females, perineal pattern and second stage juveniles. The morphometric characters of the population are given in Table 21.

Description: Based on 10 females and 10 juveniles (J_2).

Measurements: Female: Length= 573.31-918.42µm; width= 373.24-501.39µm; a= 1.32-1.97µm; stylet length= 15.88-17.93µm; neck length= 156.20-364.93µm; LMB= 35.79-49.02µm; WMB= 30.02-45.00µm.

Perineal pattern: LVS= 20.25-29.25µm; AVS= 14.25-18.25µm; ATT= 11.25-19.24µm; IPD= 20.25-28.25µm.

Second stage juveniles (J_2): Length= 365.23-435.26µm; stylet length= 13.25-14.25µm; H-MB= 47.24-58.24µm; ABW= 9.25-11.25µm; tail length= 48.39-55.51µm; c= 6.42-12.17µm; c'= 3.38-7.10µm.



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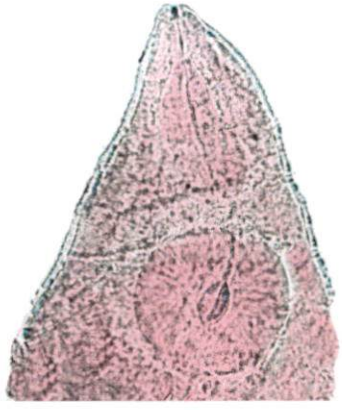

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Plate 21. (A) female, (B) anterior end of female, (C) perineal pattern, (DE) anterior and posterior end of second stage juvenile of *M. javanica* in banana from Pampadumpara

Table 21. Morphometric characters of mature females, perineal pattern and second stage juveniles of banana population of *M. javanica* from Pampadumpara

Character (µm)	Banana population
Females	
Length	746.17±84.24±28.93 (573.31-918.42) 13.98%
Width	436.37±30.18±10.29 (373.24-501.39) 8.81%
Neck length	232.93±7.68±24.01 (156.20-364.93) 32.10%
Stylet length	16.89±0.67±0.19 (15.88-17.93) 2.98%
LMB	42.77±4.61±1.31 (35.79-49.02) 10.11%
WMB	41.81±3.04±0.98 (30.02-45.00) 8.42%
a	1.71±0.31±0.08 (1.32-1.97) 15.00%
Perineal pattern	
LVS	25.38±2.62±0.82 (20.25-29.25) 10.35%
AVS	17.11±1.43±0.45 (14.25-18.25) 8.35%
ATT	15.78±2.64±0.83 (11.25-19.24) 16.73%
IPD	24.12±2.70±0.85 (20.25-28.25) 11.19%
Second stage juveniles	
Length	409.58±23.64±7.47 (365.23-435.26) 5.84%
Stylet length	13.84±0.44±0.14 (13.25-14.25) 3.20%
H-MB	53.04±3.42±1.08 (47.24-58.24) 6.45%
ABW	10.38±0.48±0.15 (9.25-11.25) 4.72%
Tail length	51.67±2.41±0.81 (48.39-55.51) 4.21%
c	8.47±1.60±0.61 (6.42-12.17) 18.21%
c'	4.91±1.11±0.45 (3.38-7.10) 19.00%

LMB-Length of median bulb, WMB- width of median bulb, a-length/width ratio, H-MB-head to median bulb, ABW-anal body width, c- length/tail length ratio, c'- tail length/anal body width ratio

4.1.2.9 Identification of Meloidogyne sp in Brinjal from Thovalappady

The species of root knot nematode infecting brinjal from Thoavlappady was identified as *M. incognita* (Plate 22), based on the morphological and morphometrical data of mature females, perineal pattern and second stage juveniles. The morphometric characters of the population are given in Table 22.

Description: Based on 10 females and 10 juveniles (J_2).

Measurements: Female: Length= 618.05-888.89µm; width= 364.09-594.68µm; a= 1.22-1.91µm; stylet length= 15.27-16.70µm; neck length= 164.82-267.02µm; LMB= 25.03-40.45µm; WMB= 25.12-39.27µm.

Perineal pattern: LVS= 20.32-29.76µm; AVS= 12.62-21.19µm; ATT= 14.28-19.97µm; IPD= 20.18-31.46µm.

Second stage juveniles (J_2): Length= 400.55-448.54µm; stylet length= 13.87-15.26µm; H-MB= 50.00-57.55µm; ABW= 9.60-12.79µm; tail length= 48.16-67.52µm; c= 6.21-8.74µm; c'= 4.06-5.54µm.

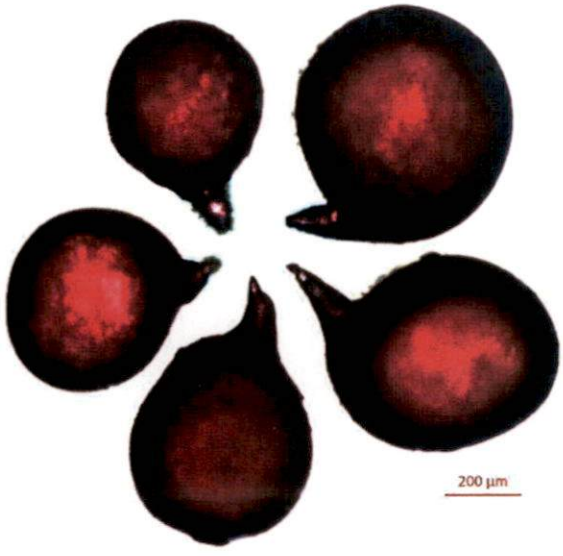
4.1.2.10 Identification of Meloidogyne sp in okra from Thovalappady

The species of root knot nematode infecting okra from Thoavlappady was identified as *M. incognita* (Plate 23), based on the morphological and morphometrical data of mature females, perineal pattern and second stage juveniles. The morphometric characters of the population are given in Table 23.

Description: Based on 10 females and 10 juveniles (J_2).

Measurements: Female: Length= 672.81-899.88µm; width= 522.33-637.62µm; a= 1.05-1.59µm; stylet length= 16.08-18.29µm; neck length= 111.08-232.67µm; LMB= 25.84-36.85µm; WMB= 25.17-36.34µm.

Perineal pattern: LVS= 18.22-27.60µm; AVS= 13.71-20.11µm; ATT= 12.13-20.28µm; IPD= 20.98-41.16µm.



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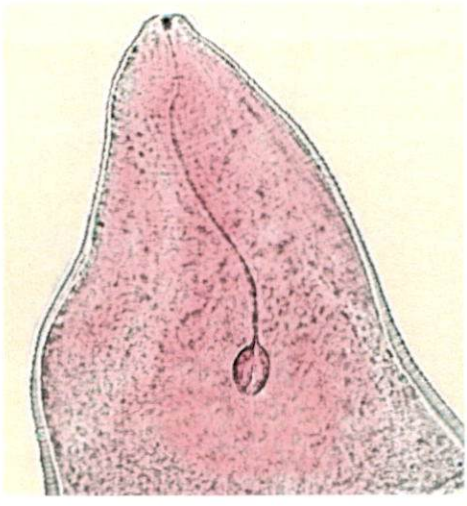

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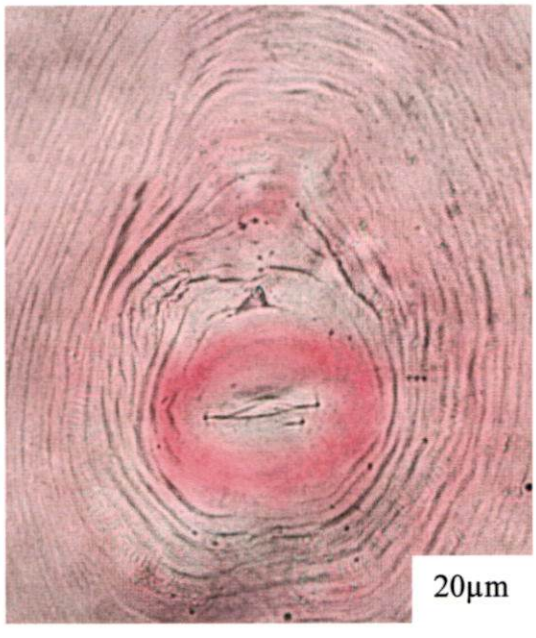

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Plate 22. (A) female, (B) anterior end of female, (C) perineal pattern, (DE) anterior and posterior end of second stage juvenile of *M. incognita* in brinjal from Thovalappady

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Table 22. Morphometric characters of mature females, perineal pattern and second stage juveniles of brinjal population of *M. incognita* from Thovalappady

Character (µm)	Brinjal population
Females	
Length	740.06±97.55±30..85 (618.05-888.89) 13.18%
Width	482.36±63.068±19.944 (364.093-594.687) 13.075%
Neck length	206.72±40.21±12.71 (164.82-267.02) 19.45%
Stylet length	16.05±0.51±0.16 (15.27-16.70) 3.22%
LMB	33.11±5.17±1.63 (25.03-40.45) 15.62%
WMB	32.75±3.80±1.20 (25.12-39.27) 12.79%
a	1.54±0.21±0.06 (1.22-1.91) 13.55%
Perineal pattern	
LVS	23.88±2.53±0.80 (20.32-29.76) 10.62%
AVS	18.49±2.45±0.77 (12.62-21.19) 13.25%
ATT	16.86±2.21±0.70 (14.28-19.97) 13.11%
IPD	24.98±4.03±1.27 (20.18-31.46) 16.13%
Second stage juveniles	
Length	415.70±13.86±4.38 (400.55-448.54)3.33%
Stylet length	14.53±0.40±0.12 (13..87-15.26) 2.76%
H-MB	53.69±2.28±0.72 (50.00-57.55) 4.25%
ABW	10.91±1.22±0.38 (9.60-12.79) 11.23%
Tail length	53.51±5.79±1.83 (48.16-67.52) 10.82%
c	7.84±0.79±0.252 (6.210-8.742) 10.14%
c'	4.93±0.54±0.17 (4.06-5.54) 11.07%

LMB-Length of median bulb, WMB- width of median bulb, a-length/width ratio, H-MB-head to median bulb, ABW-anal body width, c- length/tail length ratio, c'- tail length/anal body width ratio

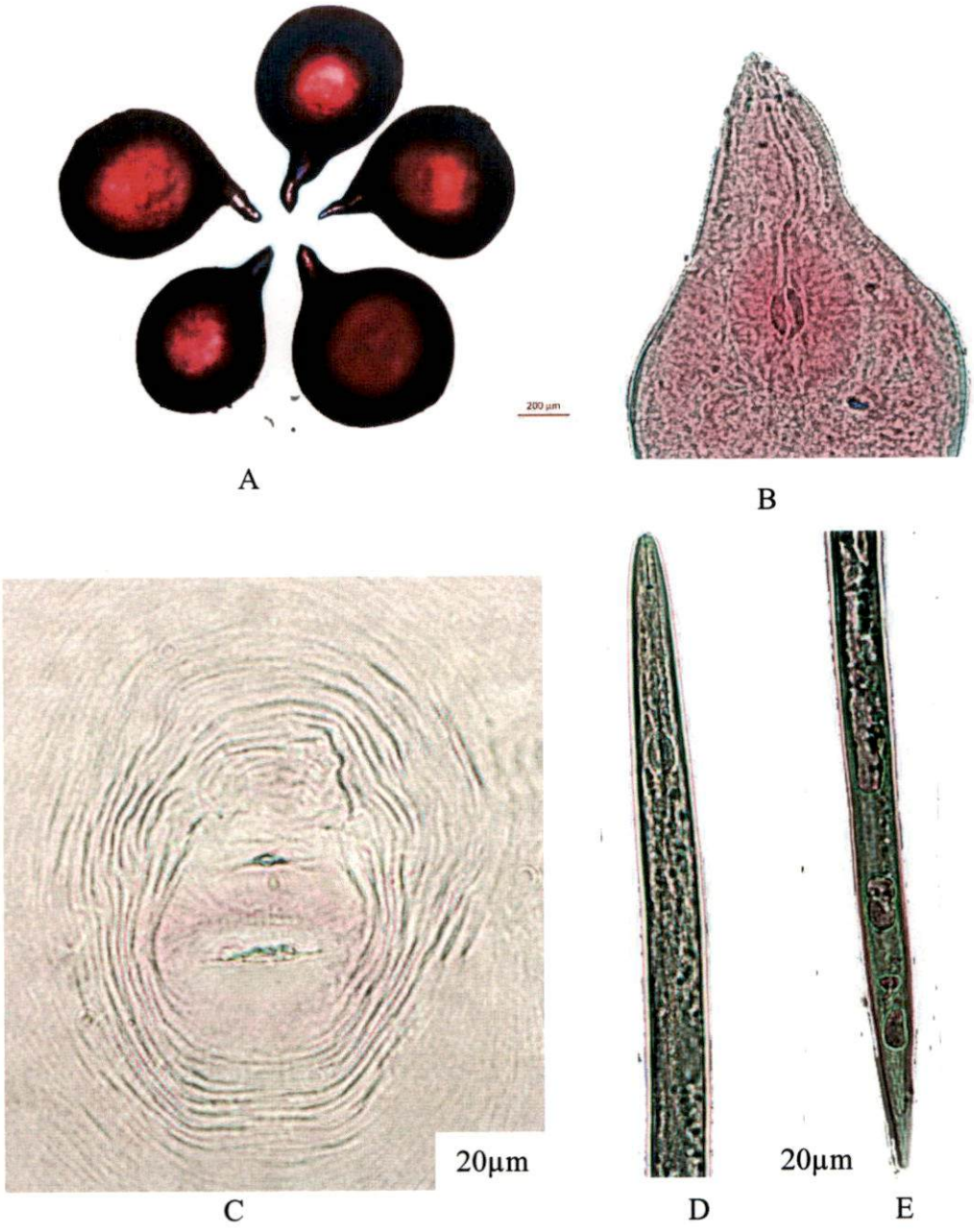

Plate 23. (A) female, (B) anterior end of female, (C) perineal pattern, (DE) anterior and posterior end of second stage juvenile of *M. incognita* in okra from Thovalappady

Table 23. Morphometric characters of mature females, perineal pattern and second stage juveniles of okra population of *M. javanica* from Thovalappady

Character (µm)	Okra population
Females	
Length	789.27±69.77±22.06 (672.81-899.88) 8.84%
Width	570.41±41.98±13.27 (522.33-637.62) 7.36%
Neck length	182.52±37.48±11.85% (111.08-232.67) 20.53%
Stylet length	16.88±0.83±0.26 (16.08-18.29) 4.92%
LMB	31.47±3.05±0.96 (25.84-36.85)9.69%
WMB	30.48±3.59±1.13 (25.17-36.34) 11.78%
a	1.39±0.18±0.05 (1.05-1.59) 13.14%
Perineal pattern	
LVS	24.56±3.01±0.95 (18.22-27.60) 12.25%
AVS	17.82±1.99±0.63 (13.71-20.11) 11.19%
ATT	15.55±3.08±0.97 (12.13-20.28) 19.83%
IPD	27.34±6.32±2.00 (20.98-41.16) 23.14%
Second stage juveniles	
Length	408.32±13.95±4.41 (379.94-424.74) 3.41%
Stylet length	13.93±0.30±0.09 (13.23-14.36) 2.20%
H-MB	49.93±2.38±0.75 (45.80-53.39) 4.78%
ABW	10.75±1.02±0.32 (9.17-12.50) 9.50%
Tail length	51.85±8.21±2.59 (40.96-72.39) 15.83%
c	8.03±1.188±0.37 (5.46-10.08) 14.69%
c'	4.82±0.49±0.15 (4.24-5.79) 10.15%

LMB-Length of median bulb, WMB- width of median bulb, a-length/width ratio, H-MB-head to median bulb, ABW-anal body width, c- length/tail length ratio, c'- tail length/anal body width ratio

Second stage juveniles (J_2): Length= 379.94-424.74µm; stylet length= 13.23-14.36µm; H-MB= 45.80-53.39µm; ABW= 9.17-12.50µm; tail length= 40.96-72.39µm; c= 5.46-10.08µm; c'= 4.24-5.79µm.

4.1.2.11 Identification of Meloidogyne sp in Tomato from Thovalappady

The species of root knot nematode infecting tomato in Thoavlappady was identified as *M. javanica* (Plate 24), based on the morphological and morphometrical data of mature females, perineal pattern and second stage juveniles. The morphometric characters of the population are given in Table 24.

Description: Based on 10 females and 10 juveniles (J_2).

Measurements: Female: Length= 631.10-758.58µm; width= 441.91-555.83µm; a= 1.17-1.50µm; stylet length= 10.43-16.58µm; neck length= 137.40-223.99µm; LMB= 32.11-41.81µm; WMB= 25.84-40.35µm.

Perineal pattern: LVS= 25.06-32.06µm; AVS= 16.15-24.43µm; ATT= 10.73-19.18µm; IPD= 17.09-34.91µm.

Second stage juveniles (J_2): Length= 360.96-418.60µm; stylet length= 13.47-14.97µm; H-MB= 50.41-57.57µm; ABW= 9.06-12.23µm; tail length= 33.98-77.92µm; c= 5.11-10.62µm; c'= 3.19-6.36µm.

4.1.2.12 Identification of Meloidogyne sp in Banana from Thovalappady

The species of root knot nematode infecting banana from Thoavlappady was identified as *M. javanica* (Plate 25), based on the morphological and morphometrical data of mature females, perineal pattern and second stage juveniles. The morphometric characters of the population are given in Table 25.

Description: Based on 10 females and 10 juveniles (J_2).

Measurements: Female: Length= 680.35-901.54µm; width= 530.29-629.45µm; a= 1.17-1.68µm; stylet length= 15.25-18.01µm; neck length= 120.09-241.32µm; LMB= 25.08-38.11µm; WMB= 25.01-38.00µm.

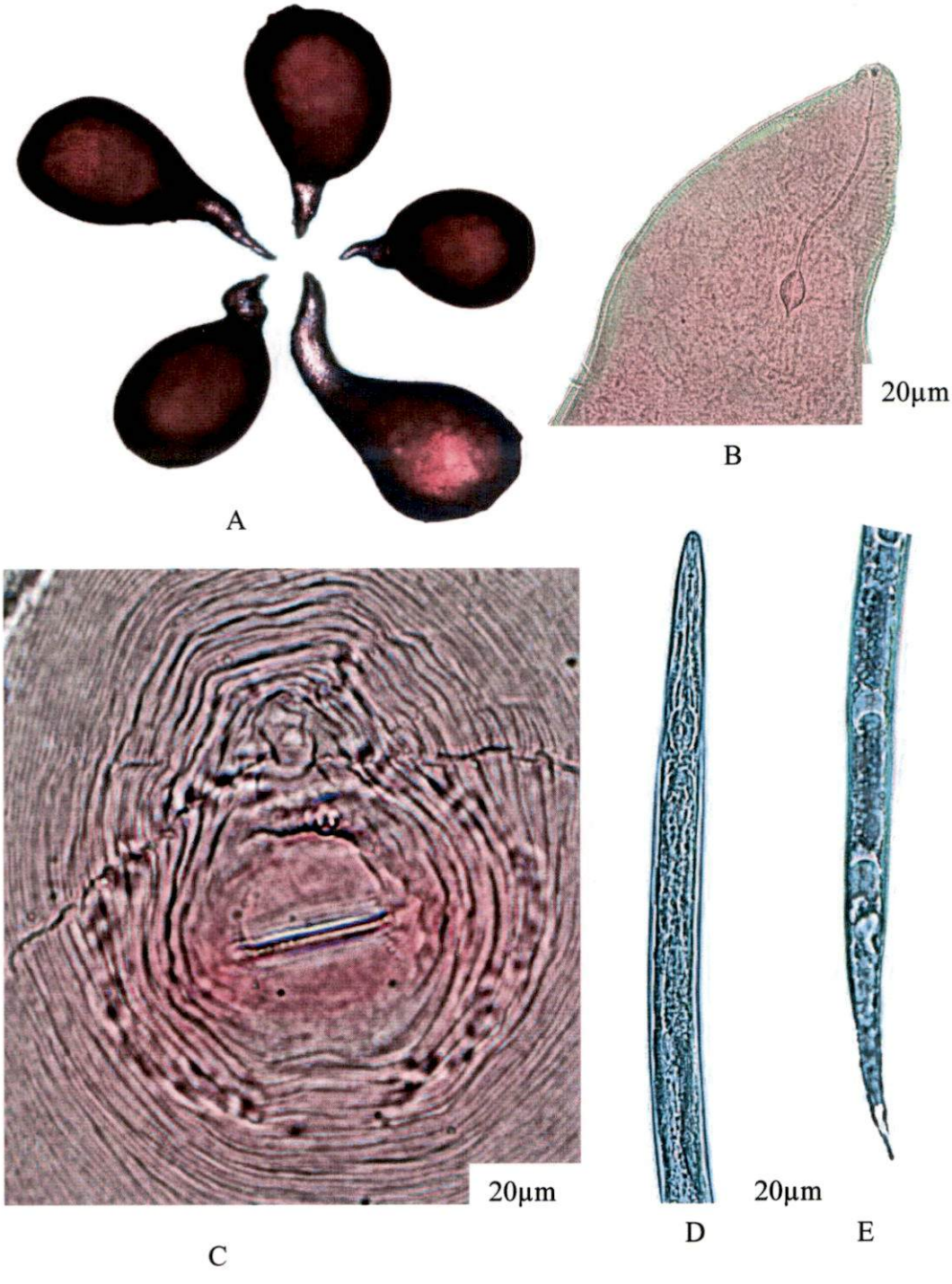

Plate 24. (A) female, (B) anterior end of female, (C) perineal pattern, (DE) anterior and posterior end of second stage juvenile of *M. javanica* in tomato from Thovalappady

Table 24. Morphometric characters of mature females, perineal pattern and second stage juveniles of tomato population of *M. javanica* from Thovalappady

Character (µm)	Tomato population
Females	
Length	683.99450.92±16.10 (631.10-758.58) 7.44%
Width	491.61±37.35±11.81 (441.91-555.83) 7.59%
Neck length	179.33±26.14±8.26 (137.40-223.99) 14.58%
Stylet length	12.89±1.86±0.59 (10.43-16.58) 14.49%
LMB	37.42±3.18±1.00 (32.11-41.81) 8..50%
WMB	33.98±4.75±1.50 (25.84-40.35) 1.50%
a	1.38±0.08±0.02 (1.17-1.50) 6.35%
Perineal pattern	
LVS	27.80±2.45±0.77 (25.06-32.06) 8.82%
AVS	19.32±2.31±0.67 (16.15-24.43) 11.06%
ATT	13.19±2.66±0.84 (10.73-19.18) 20.20%
IPD	25.21±5.39±1.70 (17.09-34.91) 21.38%
Second stage juveniles	
Length	400.30±17.28±5.466 (360.96-418.60) 4.31%
Stylet length	14.33±0.50±0.15 (13.47-14.97) 3.51%
H-MB	54.72±2.43±0.77 (50.41-57.57) 4.45%
ABW	10.24±1.03±0.32 (9.06-12.23) 10.09%
Tail length	54.43±12.63±3.99 (33.98-77.92) 23.20%
c	7.71±1.75±0.55 (5.11-10.62) 22.75%
c'	5.29±0.96±0.30 (3.19-6.36) 18.13%

LMB-Length of median bulb, WMB- width of median bulb, a-length/width ratio, H-MB-head to median bulb, ABW-anal body width, c- length/tail length ratio, c'- tail length/anal body width ratio

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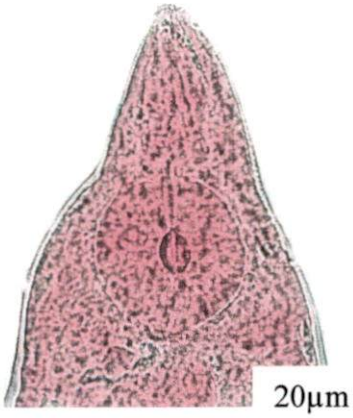

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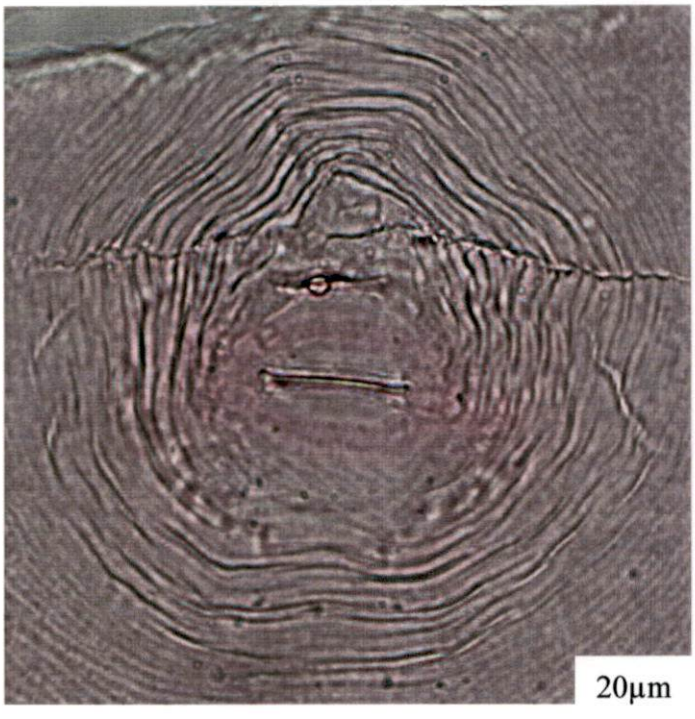

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Plate 25. (A) female, (B) anterior end of female, (C) perineal pattern, (DE) anterior and posterior end of second stage juvenile of *M.javanica* in banana from Thovalappady

Table 25. Morphometric characters of mature females, perineal pattern and second stage juveniles of banana population of *M. javanica* from Thovalappady

Character (µm)	Banana population
Females	
Length	792.85±72.00±23.78 (680.35-901.54) 9.46%
Width	564.39±53.98±16.20 (530.29-629.45) 7.29%
Neck length	198.20±41.38±12.00 (120.09-241.32) 20.39%
Stylet length	16.97±0.79±0.25 (15.25-18.01) 4.82%
LMB	35.04±2.89±0.90 (25.08-38.11) 10.01%
WMB	34.99±2.97±1.12 (25.01-38.00) 12.72%
a	1.48±0.21±0.06 (1.17-1.68) 12.81%
Perineal pattern	
LVS	27.18±2.81±0.71 (25.17-31.21) 8.24%
AVS	19.86±2.41±0.54 (16.13-26.17) 12.01%
ATT	14.01±2.61±0.79 (11.29-18.10) 19.15%
IPD	26.15±5.21±2.81 (22.17-38.10) 17.20%
Second stage juveniles	
Length	410.17±14.01±5.73 (351.42-431.71) 3.40%
Stylet length	14.91±0.40±0.91 (13.20-15.10) 2.30%
H-MB	52.00±2.41±0.61 (46.37-56.43) 5.21%
ABW	10.81±1.37±0.41 (9.17-13.01) 11.83%
Tail length	54.01±12.17±4.01 (36.17-72.15) 24.01%
c	7.18±1.72±0.56 (5.17-11.08) 21.32%
c'	5.72±0.81±0.41 (3.25-6.37) 19.17%

LMB-Length of median bulb, WMB- width of median bulb, a-length/width ratio, H-MB-head to median bulb, ABW-anal body width, c- length/tail length ratio, c'- tail length/anal body width ratio

Perineal pattern: LVS= 25.17-31.21µm; AVS= 16.13-26.17µm; ATT= 11.29-18.10µm; IPD= 22.17-38.10µm.

Second stage juveniles (J_2): Length= 351.42-431.71µm; stylet length= 13.20-15.10µm; H-MB= 46.37-56.43µm; ABW= 9.17-13.01µm; tail length= 36.17-72.15µm; c= 5.17-11.08µm; c'= 3.25-6.37µm.

4.1.3 Identification of *Meloidogyne* spp. from Thrissur District

4.1.3.1 Identification of Meloidogyne sp in Brinjal from Chazhoor

The species of root knot nematode infecting brinjal from Chazhoor was identified as *M. arenaria* (Plate 26), based on the morphological and morphometrical data of mature females, perineal pattern and second stage juveniles. The morphometric characters of the population are given in Table 26.

Description: Based on 10 females and 10 juveniles (J_2).

Measurements: Female: Length= 639.15-1019.46µm; width= 359.66-600.06µm; a= 1.13-2.13µm; stylet length= 16.28-18.57µm; neck length= 104.70-302.42µm; LMB= 35.73-45.97µm; WMB= 30.19-40.69µm.

Perineal pattern: LVS= 23.34-30.27µm; AVS= 16.06-22.42µm; ATT= 17.61-22.70µm; IPD= 30.20-39.09µm.

Second stage juveniles (J_2): Length= 400.41-440.29µm; stylet length= 12.76-14.78µm; H-MB= 45.25-53.11µm; ABW= 8.37-11.31µm; tail length= 40.11-57.00µm; c= 7.66-9.98µm; c'= 3.81-5.20µm.

4.1.3.2 Identification of Meloidogyne sp in okra from Chazhoor

The species of root knot nematode infecting okra from Chazhoor was identified as *M. arenaria* (Plate 27), based on the morphological and morphometrical data of mature females, perineal pattern and second stage juveniles. The morphometric characters of the population are given in Table 27.

Description: Based on 10 females and 10 juveniles (J_2).

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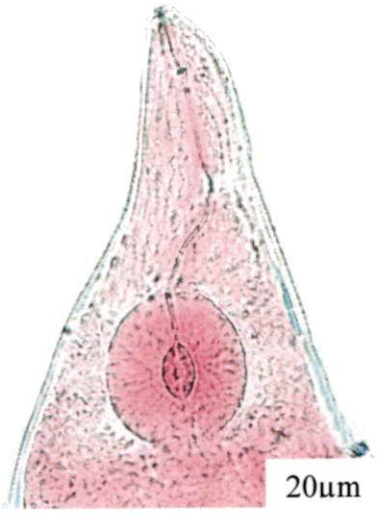

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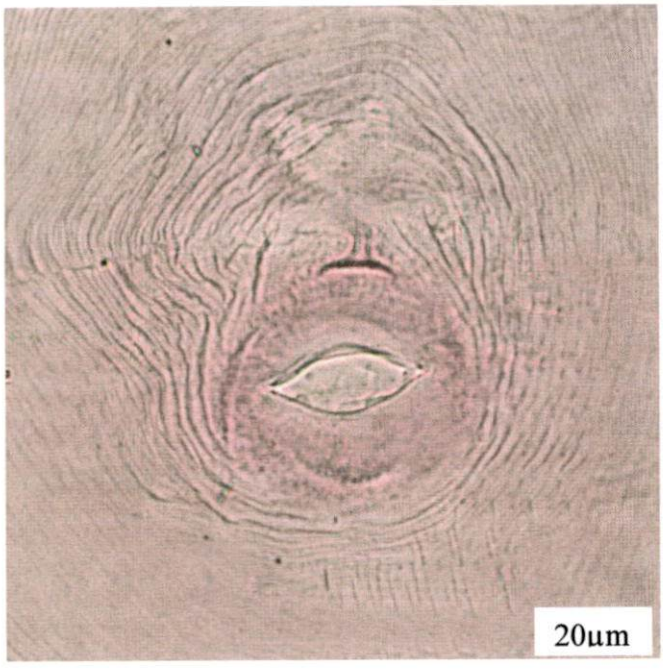

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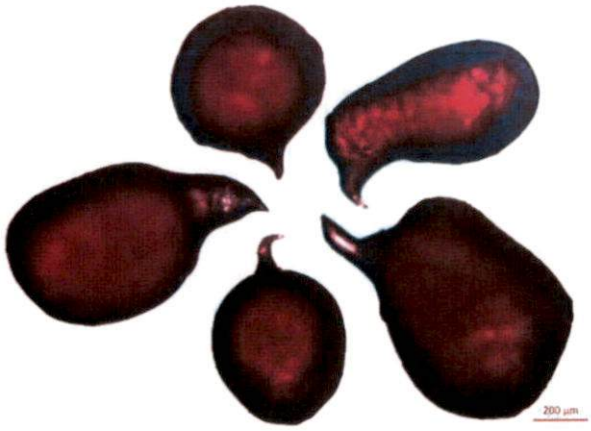
Plate 26. (A) female, (B) anterior end of female, (C) perineal pattern,(DE)anterior and posterior end of second stage juvenile of *M. arenaria* in brinjal from Chazhoor

Table 26. Morphometric characters of mature females, perineal pattern and second stage juveniles of brinjal population of *M. arenaria* from Chazhoor

Character (µm)	Brinjal population
Females	
Length	785.41±141.68±44.80 (639.15-1019.46) 18.04%
Width	483.88±76.06±24.05 (359.66-600.06) 15.05%
Neck length	203.63±61.30±19.38 (104.70-302.42) 30.10%
Stylet length	17.18±0.83±0.26 (16.28-18.57) 4.86%
LMB	41.57±2.86±0.90 (35.73-45.97) 6.89%
WMB	34.66±4.07±1.28 (30.19-40.69) 11.74%
a	1.67±0.34±0.10 (1.13-2.13) 20.49%
Perineal pattern	
LVS	27.75±2.37±0.68 (23.34-30.27) 8.55%
AVS	19.06±2.02±0.58 (16.06-22.42) 10.63%
ATT	19.48±1.38±0.39 (17.61-22.70) 7.10%
IPD	33.55±2.75±0.79 (30.20-39.09) 8.21%
Second stage juveniles	
Length	420.37±12.81±4.30 (400.41-440.29) 3.28%
Stylet length	13.81±0.61±0.27 (12.76-14.78) 3.28%
H-MB	48.93±2.78±1.32 (45.25-53.11) 7.21%
ABW	10.21±2.11±0.53 (8.37-11.31) 10.11%
Tail length	49.08±6.72±1.21 (40.11-57.00) 10.98%
c	8.56±0.60±0.31 (7.66-9.98) 12.35%
c'	4.80±0.50±0.27 (3.81-5.20) 10.98%

LMB-Length of median bulb, WMB- width of median bulb, a-length/width ratio, H-MB-head to median bulb, ABW-anal body width, c- length/tail length ratio, c'- tail length/anal body width ratio



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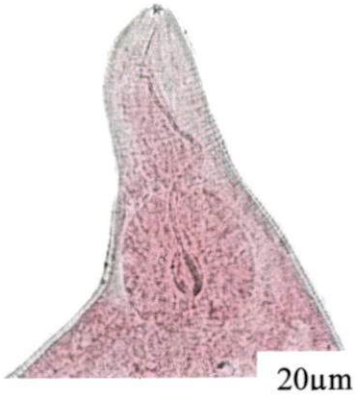

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Plate 27. (A) female, (B) anterior end of female, (C) perineal pattern, (DE)anterior and posterior end of second stage juvenile of *M. arenaria* in okra from Chazhoor

Table 27. Morphometric characters of mature females, perineal pattern and second stage juveniles of okra population of *M. arenaria* from Chazhoor

Character (µm)	Okra population
Females	
Length	898.37±120.67±36.18 (798.32-1139.98) 12.78%
Width	485.91±58.07±19.21 (418.37-605.34) 10.17%
Neck length	280.01±80.19±26.08 (259.19-398.17) 27.18%
Stylet length	16.98±0.81±0.23 (16.23-18.45) 4.80%
LMB	41.54±2.07±0.65 (38.15-45.26) 4.99%
WMB	40.80±3.33±1.05 (34.02-44.02) 8.59%
a	1.68±0.38±0.19 (1.30-2.24) 18.13%
Perineal pattern	
LVS	26.38±1.99±0.62 (23.69-30.00) 7.54%
AVS	18.01±1.26±0.40 (16.25-20.36) 7.02%
ATT	19.16±1.42±0.45 (17.12-22.26) 7.44%
IPD	30.60±1.98±0.78 (26.24-32.18) 7.91%
Second stage juveniles	
Length	421.36±14.40±4.55 (401.28-440.86) 3.41%
Stylet length	13.76±0.80±0.43 (12.27-14.98) 7.04%
H-MB	49.97±6.11±1.53 (40.20-55.76) 10.00%
ABW	10.80±3.81±0.48 (9.06-11.98) 10.11%
Tail length	48.01±4.23±0.80 (40.01-56.00) 10.38%
c	8.77±1.38±0.53 (7.60-10.87) 11.31%
c'	4.44±0.63±0.31 (2.98-5.76) 10.25%

LMB-Length of median bulb, WMB- width of median bulb, a-length/width ratio, H-MB-head to median bulb, ABW-anal body width, c- length/tail length ratio, c'- tail length/anal body width ratio

Measurements: Female: Length= 798.32-1139.98µm; width= 418.37-605.34µm; a= 1.30-2.24µm; stylet length= 16.23-18.45µm; neck length= 259.19-398.17µm; LMB= 38.15-45.26µm; WMB= 34.02-44.02µm.

Perineal pattern: LVS= 23.69-30.00µm; AVS= 16.25-20.36µm; ATT= 17.12-22.26µm; IPD= 26.24-32.18µm.

Second stage juveniles (J_2): Length= 401.28-440.86µm; stylet length= 12.27-14.98µm; H-MB= 40.20-55.76µm; ABW= 9.06-11.98µm; tail length= 40.01-56.00µm; c= 7.60-10.87µm; c'= 2.98-5.76µm.

4.1.3.3 Identification of Meloidogyne sp in Tomato from Chazhoor

The species of root knot nematode infecting tomato from Chazhoor was identified as *M. arenaria* (Plate 28), based on the morphological and morphometrical data of mature females, perineal pattern and second stage juveniles. The morphometric characters of the population are given in Table 28.

Description: Based on 10 females and 10 juveniles (J_2).

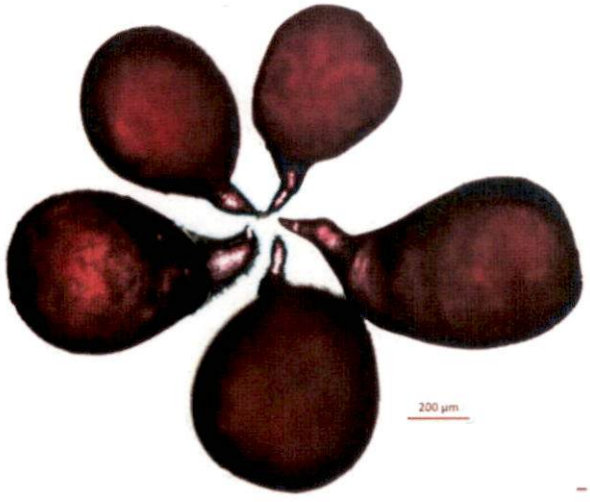
Measurements: Female: Length= 810.97-1030.25µm; width= 496.66-707.73µm; a= 1.02-2.24µm; stylet length= 16.16-18.24µm; neck length= 211.07-354.27µm; LMB= 37.25-44.38µm; WMB= 34.08-45.02µm.

Perineal pattern: LVS= 30.24-34.45µm; AVS= 19.16-24.01µm; ATT= 13.26-17.54µm; IPD= 25.28-39.50µm.

Second stage juveniles (J_2): Length= 404.14-445.82µm; stylet length= 12.13-15.01µm; H-MB= 42.74-59.81µm; ABW= 9.31-12.97µm; tail length= 40.41-56.01µm; c= 7.67-10.01µm; c'= 3.98-6.10µm.

4.1.3.4 Identification of Meloidogyne sp in Banana from Chazhoor

The species of root knot nematode infecting banana from Chazhoor was identified as *M. arenaria* (Plate 29), based on the morphological and



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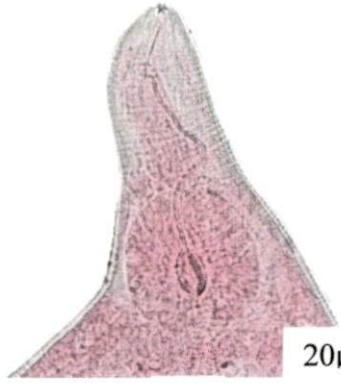

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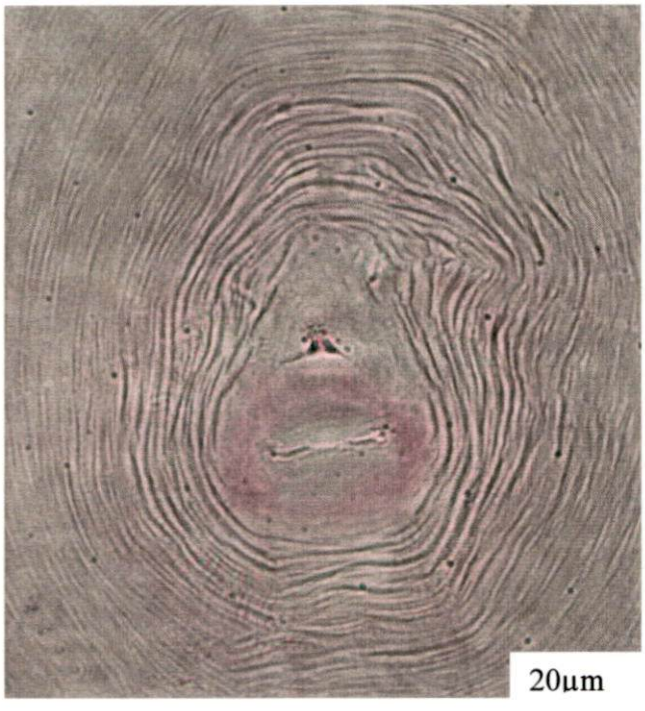

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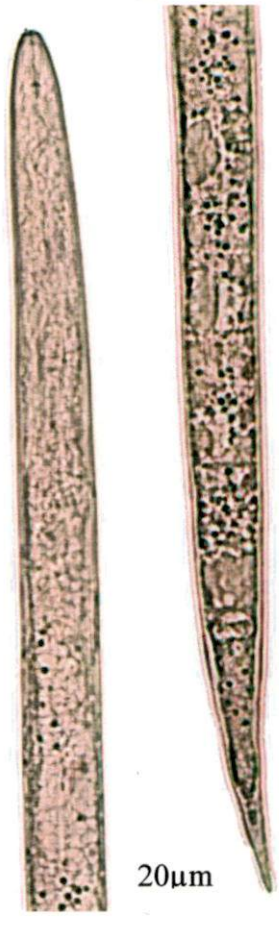

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Plate 28. (A) female, (B) anterior end of female, (C) perineal pattern, (DE)anterior and posterior end of second stage juvenile of *M. arenaria* in tomato from Chazhoor

Table 28. Morphometric characters of mature females, perineal pattern and second stage juveniles of tomato population of *M. arenaria* from Chazhoor

Character (µm)	Tomato population
Females	
Length	916.88±68.26±21.58 (810.97-1030.25) 7.44%
Width	588.32±72.89±23.04 (496.66-707.73) 12.38%
Neck length	265.44±45.86±14.50 (211.07-354.27) 17.17%
Stylet length	16.84±0.71±0.23 (16.16-18.24) 4.12%
LMB	40.25±2.00±0.58 (37.25-44.38) 4.81%
WMB	40.08±2.00±0.58 (34.08-45.02) 7.81%
a	1.59±0.21±0.12 (1.02-2.24) 17.39%
Perineal pattern	
LVS	32.15±1.53±0.48 (30.24-34.45) 4.76%
AVS	21.16±1.61±0.50 (19.16-24.01) 7.45%
ATT	15.83±1.65±0.52 (13.26-17.54) 10.46%
IPD	33.16±4.57±1.44 (25.28-39.50) 13.80%
Second stage juveniles	
Length	423.54±15.09±4.77 (404.14-445.82) 3.56%
Stylet length	13.83±0.71±0.31 (12.13-15.01) 6.81%
H-MB	50.31±5.61±1.44 (42.74-59.81) 9.21%
ABW	10.99±2.00±0.43 (9.31-12.97) 10.98%
Tail length	48.91±5.62±1.91 (40.41-56.01) 11.21%
c	8.65±1.42±0.47 (7.67-10.01)10.25%
c'	5.98±0.51±0.25 (3.98-6.10) 10.00%

LMB-Length of median bulb, WMB- width of median bulb, a-length/width ratio, H-MB-head to median bulb, ABW-anal body width, c- length/tail length ratio, c'- tail length/anal body width ratio

morphometrical data of mature females, perineal pattern and second stage juveniles. The morphometric characters of the population are given in Table 29.

Description: Based on 10 females and 10 juveniles (J_2).

Measurements: Female: Length= 749.95-1162.16µm; width= 438.69-617.01µm; a= 1.32-2.43µm; stylet length= 16.52-18.47µm; neck length= 155.30-442.81µm; LMB= 35.68-45.08µm; WMB= 34.88-42.83µm.

Perineal pattern: LVS= 20.91-30.39µm; AVS= 15.20-28.88µm; ATT= 10.47-31.03µm; IPD= 20.07-33.22µm.

Second stage juveniles (J_2): Length= 405.30-446.82µm; stylet length= 12.90-14.80µm; H-MB= 46.35-55.96µm; ABW= 10.02-13.86µm; tail length= 40.40-56.24µm; c= 7.67-10.73µm; c'= 3.71-5.18µm.

4.1.3.5 Identification of Meloidogyne sp in Brinjal from Thalikulam

The species of root knot nematode infecting brinjal from Thalikulam was identified as *M. javanica* (Plate 30), based on the morphological and morphometrical data of mature females, perineal pattern and second stage juveniles. The morphometric characters of the population are given in Table 30.

Description: Based on 10 females and 10 juveniles (J_2).

Measurements: Female: Length= 552.83-826.28µm; width= 389.17-547.26µm; a= 1.37-1.65µm; stylet length= 15.07-17.26µm; neck length= 104.38-206.65µm; LMB= 30.12-45.69µm; WMB= 30.02-44.89µm.

Perineal pattern: LVS= 22.35-28.88µm; AVS= 16.39-23.26µm; ATT= 11.32-18.10µm; IPD= 17.68-31.55µm.

Second stage juveniles (J_2): Length= 338.64-419.88µm; stylet length= 13.14-14.22µm; H-MB= 48.19-52.09µm; ABW= 9.11-11.00µm; tail length= 48.19-58.31µm; c= 6.52-7.85µm; c'= 4.75-5.89µm.

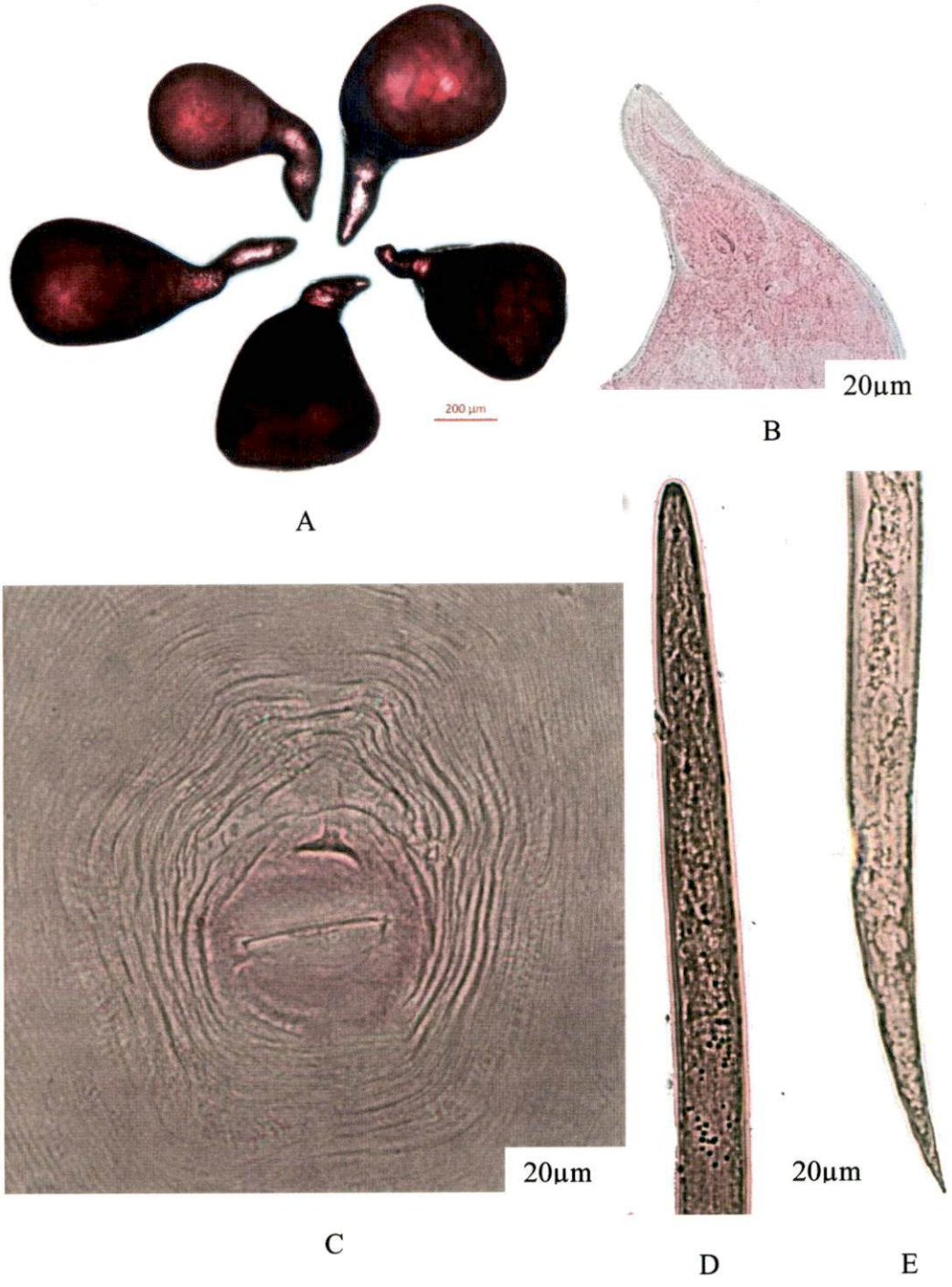
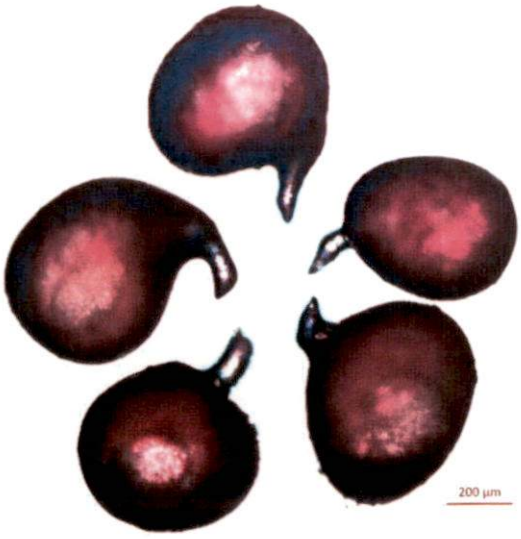


Plate 29. (A) female, (B) anterior end of female, (C) perineal pattern, (DE)anterior and posterior end of second stage juvenile of *M. arenaria* in banana from Chazhoor

Table 29. Morphometric characters of mature females, perineal pattern and second stage juveniles of banana population of *M. arenaria* from Chazhoor

Character (µm)	Banana population
Females	
Length	927.46±133.36±42.17 (749.95-1162.16) 14.37%
Width	516.99±61.01±19.29 (438.69-617.01) 11.80%
Neck length	296.91±88.69±28.04 (155.30-442.81) 29.87%
Stylet length	17.88±0.92±0.26 (16.52-18.47) 4.71%
LMB	42.67±2.98±0.92 (35.68-45.08) 6.87%
WMB	41.78±4.21±1.31 (34.88-42.83) 12.43%
a	1.79±0.42±0.20 (1.32-2.43) 19.38%
Perineal pattern	
LVS	24.96±2.70±0.81 (20.91-30.39) 10.85%
AVS	19.56±3.69±1.11 (15.20-28.88) 18.88%
ATT	18.90±5.64±1.70 (10.47-31.03) 29.87%
IPD	26.44±4.56±1.37 (20.07-33.22) 17.26%
Second stage juveniles	
Length	428.39±13.95±4.41 (405.30-446.82) 3.25%
Stylet length	13.92±0.53±0.16 (12.90-14.80) 3.85%
H-MB	50.95±3.36±1.06 (46.35-55.96) 6.61%
ABW	11.81±1.32±0.41 (10.02-13.86) 11.21%
Tail length	49.88±5.87±1.85 (40.40-56.24) 11.78%
c	8.69±1.04±0.32 (7.67-10.73) 11.96%
c'	4.23±0.45±0.14 (3.71-5.18) 10.83%

LMB-Length of median bulb, WMB- width of median bulb, a-length/width ratio, H-MB-head to median bulb, ABW-anal body width, c- length/tail length ratio, c'- tail length/anal body width ratio



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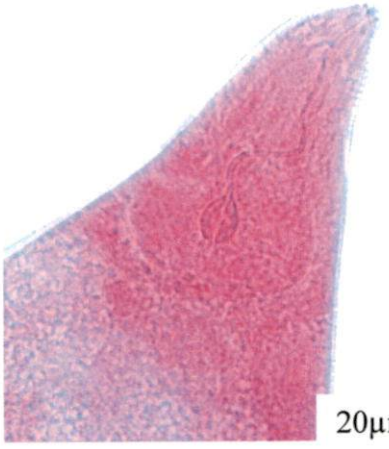

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Plate 30. (A) female, (B) anterior end of female, (C) perineal pattern, (DE)anterior and posterior end of second stage juvenile of *M. javanica* in brinjal from Thalikulam

Table 30. Morphometric characters of mature females, perineal pattern and second stage juveniles of brinjal population of *M. arenaria* from Thalikulam

Character (µm)	Brinjal population
Females	
Length	708.57±68.47±21.65 (552.83-826.28) 9.66%
Width	470.40±51.57±16.31 (389.17-547.26) 10.96%
Neck length	168.28±30.40±9.61 (104.38-206.65) 18.06%
Stylet length	16.08±0.79±0.25 (15.07-17.26) 4.93%
LMB	39.85±4.53±1.43 (30.12-45.69) 11.37%
WMB	39.32±4.29±1.35 (30.02-44.89) 10.92%
a	1.50±0.09±0.02 (1.37-1.65) 5.97%
Perineal pattern	
LVS	25.17±1.75±0.558 (22.35-28.88) 6.82%
AVS	19.85±2.02±0.64 (16.39-23.26) 10.22%
ATT	14.19±1.94±0.61 (11.32-18.10) 13.69%
IPD	26.25±4.66±1.47 (17.68-31.55) 17.78%
Second stage juveniles	
Length	380.43±28.98±9.16 (338.64-419.88) 7.61%
Stylet length	13.54±0.33±0.10 (13.14-14.22) 2.45%
H-MB	49.87±1.51±0.47 (48.19-52.09) 3.03%
ABW	10.07±0.62±0.91 (9.11-11.00) 6.20%
Tail length	53.11±3.33±1.05 (48.19-58.31) 6.28%
c	7.16±0.38±0.12 (6.52-7.85) 5.39%
c'	5.30±0.39±0.12 (4.75-5.89) 7.45%

LMB-Length of median bulb, WMB- width of median bulb, a-length/width ratio, H-MB-head to median bulb, ABW-anal body width, c- length/tail length ratio, c'- tail length/anal body width ratio

4.1.3.6 Identification of Meloidogyne sp in okra from Thalikulam

The species of root knot nematode infecting okra from Thalikulam was identified as *M. arenaria* (Plate 31), based on the morphological and morphometrical data of mature females, perineal pattern and second stage juveniles. The morphometric characters of the population are given in Table 31.

Description: Based on 10 females and 10 juveniles (J_2).

Measurements: Female: Length= 541.21-999.01µm; width= 376.09-547.58µm; a= 1.168-1.931µm; stylet length= 15.47-16.59µm; neck length= 138.10-297.65µm; LMB= 40.15-45.48µm; WMB= 39.16-45.00µm.

Perineal pattern: LVS= 26.10-31.13µm; AVS= 17.46-22.82µm; ATT= 16.94-29.47µm; IPD= 24.58-35.70µm.

Second stage juveniles (J_2): Length= 360.12-461.28µm; stylet length= 12.80-14.79µm; H-MB= 45.73-53.92µm; ABW= 9.18-12.04µm; tail length= 39.30-55.95µm; c= 6.66-10.06µm; c'= 4.16-5.67µm.

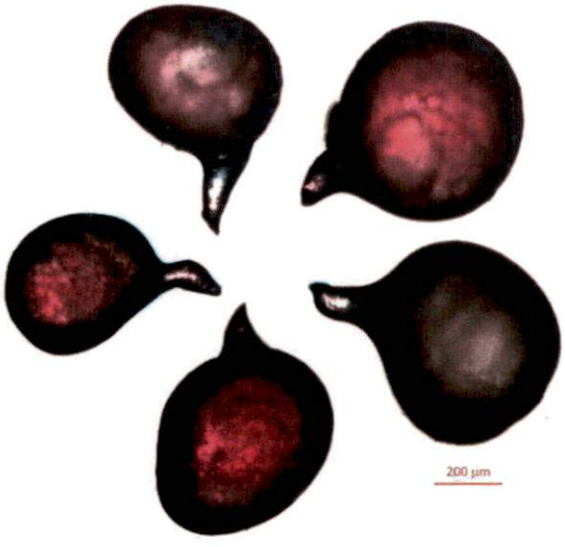
4.1.3.7 Identification of Meloidogyne sp in Tomato from Thalikulam

The species of root knot nematode infecting tomato from Thalikulam was identified as *M. arenaria* (Plate 32), based on the morphological and morphometrical data of mature females, perineal pattern and second stage juveniles. The morphometric characters of the population are given in Table 32.

Description: Based on 10 females and 10 juveniles (J_2).

Measurements: Female: Length= 645.56-933.81µm; width= 356.18-608.91µm; a= 1.24-1.98µm; stylet length= 15.23-16.98µm; neck length= 112.69-303.58µm; LMB= 35.12-41.54µm; WMB= 30.21-40.12µm.

Perineal pattern: LVS= 21.51-29.19µm; AVS= 14.36-19.79µm; ATT= 12.32-23.09µm; IPD= 26.14-36.40µm.



A

20um

B

C

20um

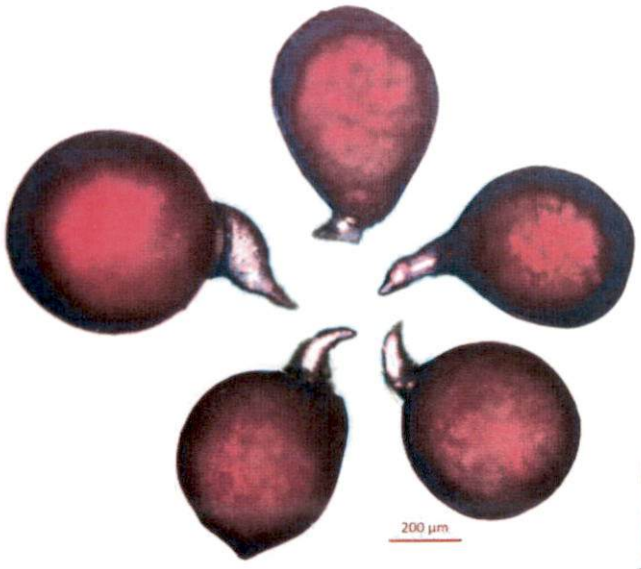
D E

Plate 31. (A) female, (B) anterior end of female, (C) perineal pattern, (DE)anterior and posterior end of second stage juvenile of *M. arenaria* in okra from Thalikulam

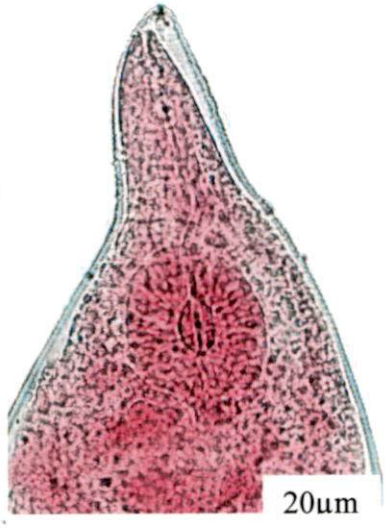
Table 31. Morphometric characters of mature females, perineal pattern and second stage juveniles of okra population of *M. arenaria* from Thalikulam

Character (µm)	Okra population
Females	
Length	665.93±83.91±26.53 (541.21-799.01) 12.60%
Width	459.93±53.63±16.96 (376.093-547.583) 11.662%
Neck length	191.49±51.49±16.28 (138.10-297.65) 26.88%
Stylet length	15.95±0.46±0.14 (15.47-16.59) 2.93%
LMB	42.40±2.36±0.74 (40.15-45.48) 5.57%
WMB	41.86±2.16±0.68 (39.16-45.00) 5.18%
a	1.45±0.20±0.06 (1.16-1.93) 14.22%
Perineal pattern	
LVS	28.07±1.49±0.47 (26.10-31.13) 5.33%
AVS	19.90±1.85±0.58 (17.46-22.82) 9.31%
ATT	20.19±3.48±1.10 (16.94-29.47) 17.25%
IPD	30.10±4.12±1.30 (24.58-35.70) 13.69%
Second stage juveniles	
Length	395.49±27.08±8.56 (360.12-461.28) 6.84%
Stylet length	14.10±0.55±3.94 (12.80-14.79) 3.94%
H-MB	51.30±3.01±0.95 (45.73-53.92) 5.88%
ABW	10.85±0.97±0.30 (9.18-12.04) 8.96%
Tail length	51.59±4.67±1.47 (39.30-55.95) 9.06%
c	7.73±1.01±0.32 (6.66-10.06) 13.12%
c'	4.76±0.45±0.14 (4.16-5.67) 9.46%

LMB-Length of median bulb, WMB- width of median bulb, a-length/width ratio, H-MB-head to median bulb, ABW-anal body width, c- length/tail length ratio, c'- tail length/anal body width ratio



A



B

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E

Plate 32. (A) female, (B) anterior end of female, (C) perineal pattern, (DE)anterior and posterior end of second stage juvenile of *M. arenaria* in tomato from Thalikulam

Table 32. Morphometric characters of mature females, perineal pattern and second stage juveniles of tomato population of *M. arenaria* from Thalikulam

Character (µm)	Tomato population
Females	
Length	774.27±87.60±27.70 (645.56-933.81) 11.27%
Width	481.24±73.76±23.32 (356.18-608.91) 15.32%
Neck length	208.35±57.70±18.24 (112.69-303.58) 27.69%
Stylet length	15.92±0.64±0.20 (15.23-16.98) 4.04%
LMB	38.06±2.48±0.78 (35.12-41.54) 6.52%
WMB	37.43±4.03±1.27 (30.21-40.12) 11.08%
a	1.64±0.25±0.08 (1.24-1.98) 15.81%
Perineal pattern	
LVS	25.47±2.21±0.70 (21.51-29.19) 8.69%
AVS	17.95±1.65±0.52 (14.36-19.79) 9.23%
ATT	16.18±3.53±1.11 (12.32-23.09) 21.86%
IPD	30.47±3.10±0.98 (26.14-36.40) 10.17%
Second stage juveniles	
Length	380.14±36.13±11.42 (339.46-452.43) 9.50%
Stylet length	13.74±0.56±0.17 (13.102-14.52) 4.07%
H-MB	46.96±3.11±0.98 (41.50-52.03) 6.62%
ABW	10.43±1.44±0.45 (8.25-12.76) 13.82%
Tail length	46.36±6.32±1.99 (36.92-58.64) 13.63%
c	8.37±1.64±0.51 (6.33-11.23) 19.62%
c'	4.45±0.41±0.31 (3.81-5.12) 9.26%

LMB-Length of median bulb, WMB- width of median bulb, a-length/width ratio, H-MB-head to median bulb, ABW-anal body width, c- length/tail length ratio, c'- tail length/anal body width ratio

Second stage juveniles (J_2): Length= 339.46-452.43µm; stylet length= 13.10-14.52µm; H-MB= 41.50-52.03µm; ABW= 8.25-12.76µm; tail length= 36.92-58.64µm; c= 6.33-11.23µm; c'= 3.81-5.12µm.

4.1.3.8 Identification of Meloidogyne sp in Banana from Thalikulam

The species of root knot nematode infecting banana in Thalikulam was identified as *M. arenaria* (Plate 33), based on the morphological and morphometrical data of mature females, perineal pattern and second stage juveniles. The morphometric characters of the population are given in Table 33.

Description: Based on 10 females and 10 juveniles (J_2).

Measurements: Female: Length= 671.60-936.11µm; width= 361.27-619.01µm; a= 1.24-1.98µm; stylet length= 15.20-17.38µm; neck length= 208.21-321.27µm; LMB= 35.62-43.98µm; WMB= 30.18-42.21µm.

Perineal pattern: LVS= 25.14-29.25µm; AVS= 17.15-20.25µm; ATT= 13.25-22.25µm; IPD= 26.21-36.25µm.

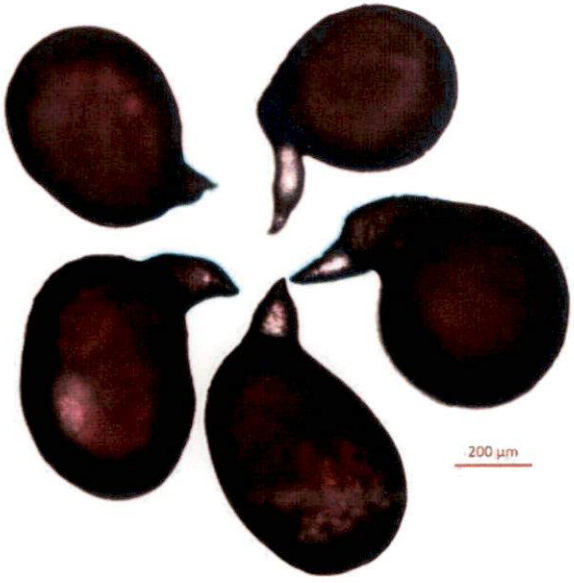
Second stage juveniles (J_2): Length= 340.57-458.29µm; stylet length= 13.25-14.65µm; H-MB= 42.01-53.41µm; ABW= 8.31-12.81µm; tail length= 38.21-59.24µm; c= 6.31-11.24µm; c'= 3.18-6.34µm.

4.1.3.9 Identification of Meloidogyne sp in Brinjal from Thanniyam

The species of root knot nematode infecting brinjal from Thanniyam was identified as *M. incognita* (Plate 34), based on the morphological and morphometrical data of mature females, perineal pattern and second stage juveniles. The morphometric characters of the population are given in Table 34.

Description: Based on 10 females and 10 juveniles (J_2).

Measurements: Female: Length= 668.22-863.19µm; width= 472.07-616.89µm; a= 1.16-1.54µm; stylet length= 14.25-16.45µm; neck length= 160.99-234.13µm; LMB= 32.48-42.15µm; WMB= 32.05-42.15µm.



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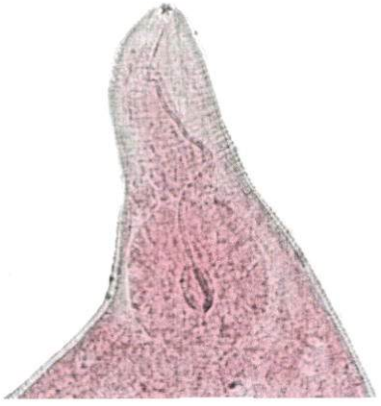


B

C

D

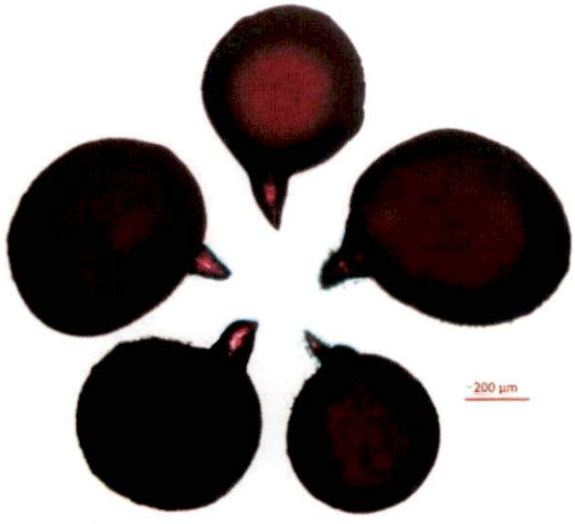
E

Plate 33. (A) female, (B) anterior end of female, (C) perineal pattern, (DE)anterior and posterior end of second stage juvenile of *M. arenaria* in banana from Thalikulam

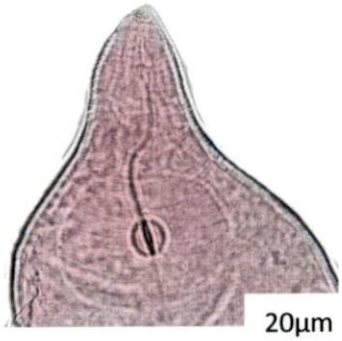
Table 33. Morphometric characters of mature females, perineal pattern and second stage juveniles of banana population of *M. arenaria* from Thalikulam

Character (µm)	Banana population
Females	
Length	781.36±81.20±28.10 (671.60-936.11) 12.38%
Width	490.02±64.21±26.01 (361.27-619.01) 16.31%
Neck length	217.11±57.02±19.21 (208.21-321.27) 28.57%
Stylet length	16.98±0.23±0.17 (15.20-17.38) 5.02%
LMB	39.23±3.42±0.98 (35.62-43.98) 6.25%
WMB	39.02±4.21±1.21 (30.18-42.21) 12.71%
a	1.60±0.25±0.10 (1.24-1.98) 16.21%
Perineal pattern	
LVS	26.10±1.30±0.41 (25.14-29.25) 5.00%
AVS	18.77±1.10±0.35 (17.15-20.25) 5.90%
ATT	17.56±2.74±0.86 (13.25-22.25) 15.64%
IPD	29.93±3.06±0.96 (26.21-36.25) 10.23%
Second stage juveniles	
Length	401.14±51.28±12.26 (340.57-458.29) 10.01%
Stylet length	13.94±0.51±0.16 (13.25-14.65) 3.65%
H-MB	48.73±3.21±1.11 (42.01-53.41) 0.71%
ABW	10.74±1.56±0.81 (8.31-12.81) 12.11%
Tail length	47.21±7.11±1.81 (38.21-59.24) 14.21%
c	8.49±1.74±0.61 (6.31-11.24) 18.21%
c'	5.55±0.51±0.21 (3.18-6.34) 10.22%

LMB-Length of median bulb, WMB- width of median bulb, a-length/width ratio, H-MB-head to median bulb, ABW-anal body width, c- length/tail length ratio, c'- tail length/anal body width ratio



A



B

C

D E

Plate 34. (A) female, (B) anterior end of female, (C) perineal pattern, (DE)anterior and posterior end of second stage juvenile of *M. incognita* in brinjal from Thanniyam

Table 34. Morphometric characters of mature females, perineal pattern and second stage juveniles of brinjal population of *M. incognita* from Thanniyam

Character (µm)	Brinjal population
Females	
Length	724.04±56.11±17.74 (668.22-863.19) 7.74%
Width	525.77±47.55±15.03 (472.07-616.89) 9.04%
Neck length	190.35±26.99±8.53 (160.99-234.13) 14.81%
Stylet length	15.47±0.71±0.22 (14.25-16.45) 4.62%
LMB	38.62±3.53±1.11 (32.48-42.15) 9.15%
WMB	38.13±3.57±1.13 (32.05-42.15) 9.38%
a	1.38±0.10±0.03 (1.16-1.54) 7.88%
Perineal pattern	
LVS	23.30±1.97±0.62 (19.63-25.80) 8.47%
AVS	18.82±2.20±0.63 (14.18-21.34) 11.69%
ATT	20.74±2.17±0.62 (17.46-24.75) 10.46%
IPD	25.76±6.90±1.99 (18.09-38.62) 26.79%
Second stage juveniles	
Length	401.59±16.86±5.33 (368.69-428.67) 4.20%
Stylet length	13.87±0.31±0.10 (13.48-14.43) 2.28%
H-MB	47.93±1.54±0.48 (46.32-51.27) 3.21%
ABW	11.08±0.57±0.81 (10.12-11.83) 5.14%
Tail length	50.51±4.44±1.40 (41.83-55.60) 8.78%
c	7.99±0.61±0.19 (7.32-9.06) 7.66%
c'	4.57±0.45±0.14 (3.84-5.45) 10.01%

LMB-Length of median bulb, WMB- width of median bulb, a-length/width ratio, H-MB-head to median bulb, ABW-anal body width, c- length/tail length ratio, c'- tail length/anal body width ratio

Perineal pattern: LVS= 19.63-25.80µm; AVS= 14.18-21.34µm; ATT= 17.46-24.75µm; IPD= 18.09-38.62µm.

Second stage juveniles (J_2): Length= 368.69-428.67µm; stylet length= 13.48-14.43µm; H-MB= 46.32-51.27µm; ABW= 10.12-11.83µm; tail length= 41.83-55.60µm; c= 7.32-9.06µm; c'= 3.84-5.45µm.

4.1.3.10 Identification of Meloidogyne sp in okra from Thanniyam

The species of root knot nematode infecting okra from Thanniyam was identified as *M. arenaria* (Plate 35), based on the morphological and morphometrical data of mature females, perineal pattern and second stage juveniles. The morphometric characters of the population are given in Table 35.

Description: Based on 10 females and 10 juveniles (J_2).

Measurements: Female: Length= 750.02-1139.82µm; width= 439.52-630.75µm; a= 1.27-1.99µm; stylet length= 14.25-16.48µm; neck length= 185.58-317.98µm; LMB= 35.14-49.83µm; WMB= 31.79-47.46µm.

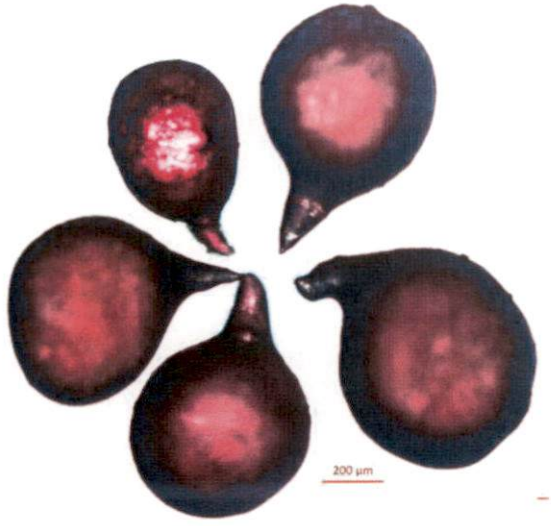
Perineal pattern: LVS= 22.43-35.52µm; AVS= 16.95-32.50µm; ATT= 13.61-25.70µm; IPD= 23.20-40.78µm.

Second stage juveniles (J_2): Length= 366.90-436.35µm; stylet length= 13.18-14.80µm; H-MB= 39.69-51.52µm; ABW= 10.90-12.50µm; tail length= 41.84-57.41µm; c= 7.60-9.20µm; c'= 4.62-7.55µm.

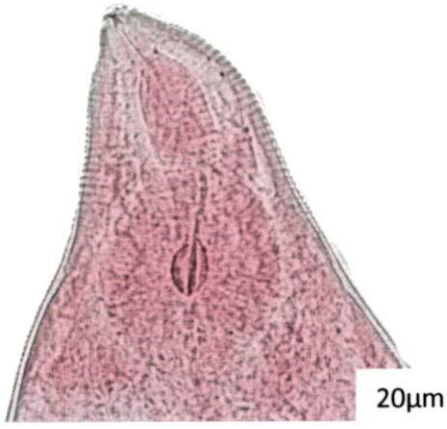
4.1.3.11 Identification of Meloidogyne sp in Tomato from Thanniyam

The species of root knot nematode infecting tomato from Thanniyam was identified as *M. incognita* (Plate 36), based on the morphological and morphometrical data of mature females, perineal pattern and second stage juveniles. The morphometric characters of the population are given in Table 36.

Description: Based on 10 females and 10 juveniles (J_2).



A



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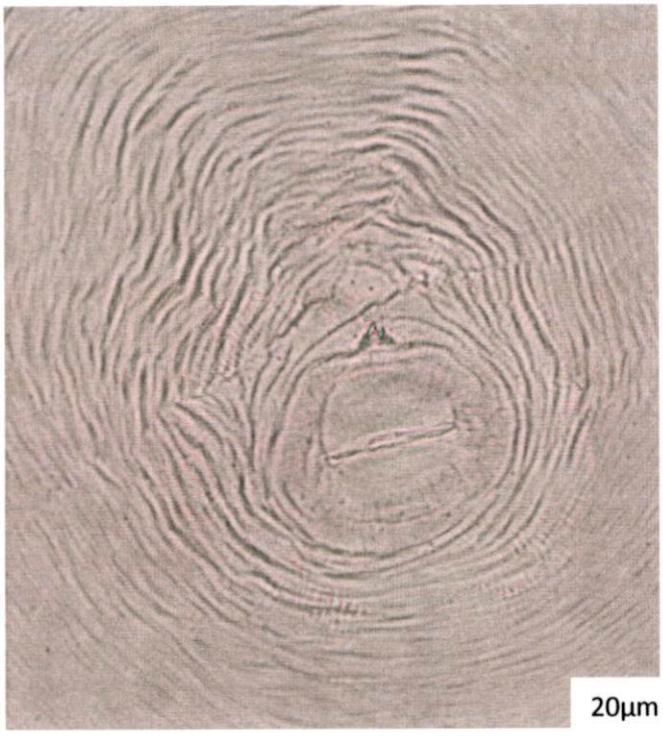


C

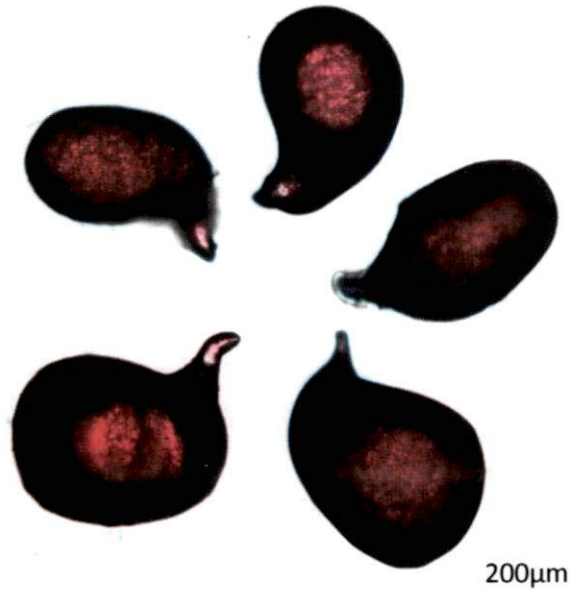
D E

Plate 35. (A) female, (B) anterior end of female, (C) perineal pattern, (DE)anterior and posterior end of second stage juvenile of *M. arenaria* in okra from Thanniyam

Table 35. Morphometric characters of mature females, perineal pattern and second stage juveniles of okra population of *M. arenaria* from Thanniyam

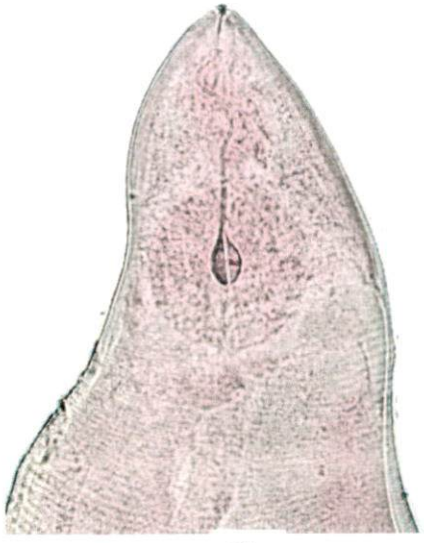
Character (µm)	Okra population
Females	
Length	877.79±121.44±38.40 (750.02-1139.82) 13.83%
Width	552.73±61.87±19.56 (439.52-630.75) 11.19%
Neck length	236.61±46.49±14.70 (185.58-317.98) 19.64%
Stylet length	15.53±0.81±0.25 (14.25-16.48) 5.26%
LMB	41.85±5.31±1.67 (35.14-49.83) 12.69%
WMB	40.42±4.44±1.40 (31.79-47.46) 10.99%
a	1.60±0.26±0.08 (1.27-1.99) 16.31%
Perineal pattern	
LVS	26.29±3.51±1.11 (22.43-35.52) 13.36%
AVS	21.56±4.26±1.34 (16.95-32.50) 19.79%
ATT	19.93±3.86±1.22 (13.61-25.70) 19.38%
IPD	31.37±6.47±2.04 (23.20-40.78) 20.62%
Second stage juveniles	
Length	409.39±22.90±7.24 (366.90-436.35) 5.59%
Stylet length	14.23±0.47±0.14 (13.18-14.80) 3.31%
H-MB	45.32±3.64±1.15 (39.69-51.52) 8.04%
ABW	11.48±0.51±0.61 (10.90-12.50) 4.49%
Tail length	48.95±4.96±1.57 (41.84-57.41) 10.14%
c	8.40±0.61±0.91 (7.60-9.20) 7.35%
c'	5.81±0.98±0.31 (4.62-7.55) 16.81%

LMB-Length of median bulb, WMB- width of median bulb, a-length/width ratio, H-MB-head to median bulb, ABW-anal body width, c- length/tail length ratio, c'- tail length/anal body width ratio

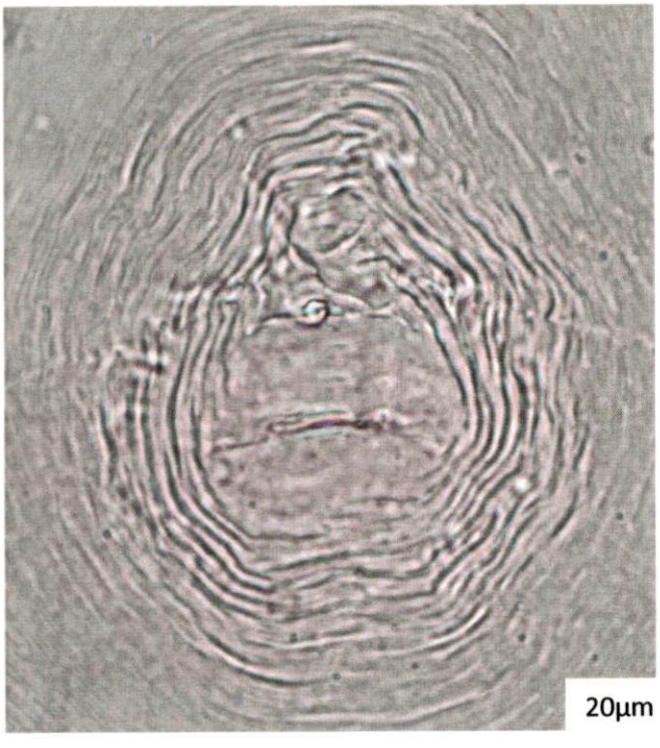


200µm

A



B



20µm

C

D

20µm

E

Plate 36. (A) female, (B) anterior end of female, (C) perineal pattern, (DE)anterior and posterior end of second stage juvenile of *M. incognita* in tomato from Thanniyam

Table 36. Morphometric characters of mature females, perineal pattern and second stage juveniles of tomato population of *M. incognita* from Thanniyam

Character (µm)	Tomato population
Females	
Length	631.87±56.97±18.01 (549.53-757.59) 9.01%
Width	435.10±25.31±8.00 (403.59-481.37) 5.81%
Neck length	167.90±31.18±9.86 (130.67-225.80) 18.57%
Stylet length	15.46±1.33±0.42 (13.11-16.81) 8.60%
LMB	39.07±1.97±0.62 (35.12-41.14) 5.05%
WMB	38.69±2.13±0.67 (35.26-41.25) 15.52%
a	1.45±0.10±0.03 (1.30-1.67) 7.45%
Perineal pattern	
LVS	20.84±2.66±0.76 (14.61-24.11) 12.78%
AVS	19.12±2.18±4.78 (16.52-24.03) 11.43%
ATT	19.27±3.33±0.96 (12.94-24.26) 17.30%
IPD	26.64±3.68±1.06 (22.06-35.76) 13.84%
Second stage juveniles	
Length	371.25±9.99±3.16 (357.88-385.70) 2.69%
Stylet length	13.25±0.45±0.14 (12.40-13.89) 3.47%
H-MB	45.84±1.91±0.60 (42.75-49.09) 4.17%
ABW	10.43±0.49±0.15 (9.84-11.18) 4.78%
Tail length	55.30±8.81±2.78 (43.92-72.16) 15.93%
c	6.85±1.01±0.32 (5.09-8.14) 14.84%
c'	5.29±0.77±0.24 (4.43-6.44) 14.62%

LMB-Length of median bulb, WMB- width of median bulb, a-length/width ratio, H-MB-head to median bulb, ABW-anal body width, c- length/tail length ratio, c'- tail length/anal body width ratio

Measurements: Female: Length= 549.53-757.59µm; width= 403.59-481.37µm; a= 1.30-1.67µm; stylet length= 13.11-16.81µm; neck length= 130.67-225.80µm; LMB= 35.12-41.14µm; WMB= 35.26-41.25µm.

Perineal pattern: LVS= 14.61-24.11µm; AVS= 16.52-24.03µm; ATT= 12.94-24.26µm; IPD= 22.06-35.76µm.

Second stage juveniles (J_2): Length= 357.88-385.70µm; stylet length= 12.40-13.89µm; H-MB= 42.75-49.09µm; ABW= 9.84-11.18µm; tail length= 43.92-72.16µm; c= 5.09-8.14µm; c'= 4.43-6.44µm.

4.1.3.12 Identification of Meloidogyne sp in Banana from Thanniyam

The species of root knot nematode infecting banana from Thanniyam was identified as *M. incognita* (Plate 37), based on the morphological and morphometrical data of mature females, perineal pattern and second stage juveniles. The morphometric characters of the population are given in Table 37.

Description: Based on 10 females and 10 juveniles (J_2).

Measurements: Female: Length= 550.96-768.98µm; width= 414.35-505.11µm; a= 1.38-1.64µm; stylet length= 14.31-16.81µm; neck length= 172.17-327.11µm; LMB= 35.45-49.38µm; WMB= 36.38-47.51µm.

Perineal pattern: LVS= 18.31-25.72µm; AVS= 17.09-27.11µm; ATT= 13.91-26.30µm; IPD= 25.21-38.98µm.

Second stage juveniles (J_2): Length= 372.01-420.31µm; stylet length= 13.28-14.98µm; H-MB= 39.72-52.77µm; ABW= 10.98-12.61µm; tail length= 41.27-58.23µm; c= 7.52-9.01µm; c'= 3.72-561µm.

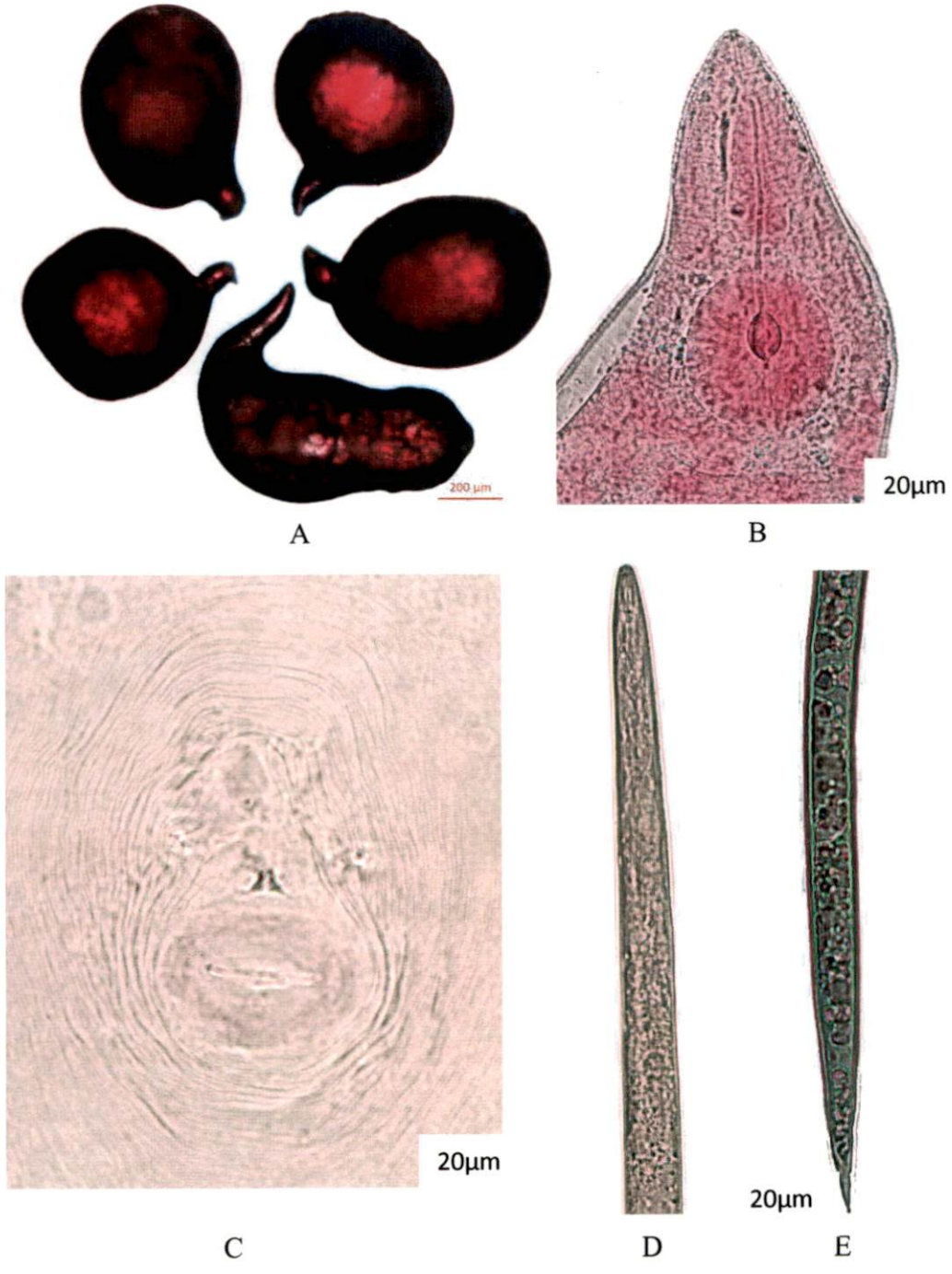


Plate 37. (A) female, (B) anterior end of female, (C) perineal pattern, (DE)anterior and posterior end of second stage juvenile of *M. incognita* in banana from Thanniyam

Table 37. Morphometric characters of mature females, perineal pattern and second stage juveniles of banana population of *M. incognita* from Thanniyam

Character (µm)	Banana population
Females	
Length	640.76±60.17±18.04 (550.96-768.98) 10.91%
Width	439.38±56.04±20.18 (414.35-505.11) 12.96%
Neck length	201.01±38.31±15.74 (172.17-327.11) 18.21%
Stylet length	15.97±0.71±0.31 (14.31-16.81) 4.32%
LMB	42.96±6.21±1.72 (35.45-49.38) 7.67%
WMB	41.71±4.56±1.51 (36.38-47.51) 11.81%
a	1.45±0.26±0.08 (1.38-1.64) 7.41%
Perineal pattern	
LVS	22.01±4.26±1.21 (18.31-25.72) 14.41%
AVS	19.62±4.36±1.41 (17.09-27.11) 12.18%
ATT	19.98±3.91±1.28 (13.91-26.30) 18.22%
IPD	27.01±7.18±2.41 (25.21-38.98) 21.01%
Second stage juveniles	
Length	409.39±23.07±7.61 (372.01-420.31) 6.91%
Stylet length	13.91±0.51±0.24 (13.28-14.98) 4.27%
H-MB	47.96±3.78±1.25 (39.72-52.77) 9.41%
ABW	11.53±0.61±0.21 (10.98-12.61) 4.59%
Tail length	50.62±5.21±1.81 (41.27-58.23) 11.41%
c	8.08±0.71±0.18 (7.52-9.01) 7.35%
c'	4.38±0.11±0.43 (3.72-561) 15.80%

LMB-Length of median bulb, WMB- width of median bulb, a-length/width ratio, H-MB-head to median bulb, ABW-anal body width, c- length/tail length ratio, c'- tail length/anal body width ratio

4.2 MORPHOLOGY AND MORPHOMETRICS OF MATURE FEMALES, PERINEAL PATTERN, SECOND STAGE JUVENILES AND MALES

4.2.1 Morphology and Morphometrics of Mature Females, Perineal Pattern and Second Stage Juveniles of *M. incognita* from Thiruvananthapuram District

The following were the morphological characters of populations of *M. incognita* from Thiruvananthapuram district.

A. Mature females:

The females were pear shaped to saccate shaped with no posterior terminal protuberance. The neck was straight to curved to sickle shaped, directed ventrally or at an angle (brinjal from Kattakda and Vellayani) to the body of nematode. The shape and size of females were variable within and between the populations. The stylet cone was curved to straight at dorsal region and the knobs were set off from the shaft.

B. Perineal pattern:

The perineal pattern was characterized by high, squared dorsal arch. There was distinct whorl of striae near the tail terminal area and was prominent in tomato from Vellayani. The striae was wavy in majority of population, whereas it was smooth in populations from brinjal and tomato in Dhanuvachapuram and tomato in Vellayani. Weak lateral lines were present in populations in tomato and banana from Kattakada, banana from Dhanuvachapuram and tomato from Vellayani.

C. Second stage juveniles (J_2):

In J_2, the character length was least variable. The labial region was not set off. The basal knobs of stylet were rounded and set off. The shape and size of rectal sac was variable between the populations and the rectal sac was prominent

in populations in banana from Dhanuvachapuram, brinjal and tomato from Kattakada and brinjal, tomato and banana from Vellayani.

The morphemetric characters of mature females, perineal pattern and second stage juveniles of populations of *M. incognita* from Thiruvananthapuram district are given in tables 38, 39 and 40.

A. Mature females:

The range of mean values for body length and width in the populations were 550.29 to 714.18 µm and 396.54 to 515.82 µm respectively. The maximum mean value for body length was observed for the species identified in banana from Dhanuvachapuram (714.18 µm). These characters were observed as moderately variable with maximum variation in population in brinjal from Dhanuvachapuram which was up to 13.22 per cent for length and 19.30 per cent for width.

The character neck length was highly variable between the populations (CV 5.04% to 29.18%). Population in banana from Kattakada had the maximum mean value for neck length (201.34 µm) and the minimum for population in okra from Vellayani. The character stylet length was the least variable character (CV 3.33% to 11.64%) between the populations with the mean values ranging from 13.64 to 17.90 µm. The range of mean values for LMB and WMB were 30.55 to 42.37 µm and 26.46 to 42.02 µm respectively. These characters were seen to be moderately variable between the populations. The character ratio a was also moderately variable (CV 3.21% to 17.41%) with mean values ranging from 1.28 to 1.56 µm.

B. Perineal pattern:

The character LVS was observed to be the least variable (CV 6.71% to 11.98%) with maximum mean value in the population identified in brinjal from Dhanuvachapuram and the minimum in population in tomato from Kattakada. The characters AVS, ATT and IPD were moderately variable (CV 6.87% to

16.60%; 11.94% to 15.66%; 10.39% to 19.21% respectively). The range of mean values for IPD was 27.81 to 30.79 µm with maximum mean value in the population in brinjal from Dhanuvachapuram and minimum in the population in brinjal from Kattakada.

C. Second stage juveniles (J_2):

The coefficient of variability for the seven characters of second stage juveniles varied from population to population. The characters body length, stylet length and H-MB were least variable (CV 3.05% to 10.31%; 2.04% to 5.67% and 3.83% to 5.70% respectively) and the characters ABW, tail length, ratio c and c' were highly variable (CV 3.34% to 12.17%; 4.51% to 15.38%; 6.25% to 19.852% and 6.03% to 12.45% respectively). The mean values for body length, stylet length and H-MB ranges from 370.03 to 423.19 µm, 13.54 to 15.67 µm and 46.38 to 56.70 µm respectively. The maximum body length and stylet length was observed in population in banana from Vellayani with mean values 423.19 µm and 15.671 µm respectively. In general, tail length was smaller in population in tomato from Dhanuvachapuram than the other populations. The longest tail length was observed in population in okra from Vellayani. The ratio c and c' were highest in population in banana from Dhanuvachapuram and population in brinjal from Dhanuvachapuram respectively.

4.2.2 Morphology of Mature Females, Perineal Pattern and Second Stage Juveniles of *M. chitwoodi* from Thiruvananthapuram District

The following were the morphological characters of *M. chitwoodi* from Kattakada:

A. Mature females:

The females were pear shaped with a slight posterior terminal protuberance. The neck was directed ventrally and the neck length was variable within the population.

Table 38. Morphometric characters of mature females of *M. incognita* in Thiruvananthapuram district, [Mean,(CV%)], n=10

Character (µm)	Populations											CR*
	Dhanuvachapuram				Kattakada			Vellayani				
	Okra	Brinjal	Tomato	Banana	Brinjal	Tomato	Banana	Okra	Brinjal	Tomato	Banana	
Length	646.70 (6.00%)	684.90 (5.05%)	702.19 (7.86%)	714.18 (10.11%)	626.65 (13.22%)	618.28 (6.46%)	683.29 (6.47%)	546.42 (6.08%)	606.71 (9.09%)	550.29 (8.24%)	620.14 (11.10%)	MV
Width	430.21 (10.07%)	447.93 (9.79%)	453.24 (6.522%)	446.54 (7.64%)	453.73 (19.30%)	422.36 (8.97%)	515.82 (10.40%)	396.54 (13.80%)	481.27 (15.86%)	401.49 (13.78%)	479.24 (15.07%)	MV
Neck length	201.24 (17.37%)	186.77 (17.28%)	195.43 (18.66%)	190.43 (20.71%)	182.07 (28.01%)	173.47 (5.04%)	201.34 (14.13%)	164.34 (19.68%)	167.89 (25.96%)	171.21 (19.93%)	183.24 (29.18%)	HV
Stylet length	15.70 (4.21%)	15.44 (3.81%)	15.86 (3.96%)	15.98 (3.81%)	17.90 (5.96%)	16.56 (6.19%)	17.23 (2.67%)	13.64 (11.64%)	17.33 (5.09%)	16.53 (3.32%)	17.18 (6.07%)	LV
LMB	38.30 (11.27%)	36.21 (11.95%)	38.53 (12.41%)	38.90 (11.71%)	35.45 (14.46%)	42.28 (13.23%)	42.37 (15.00%)	30.55 (8.45%)	34.02 (3.80%)	31.62 (6.55%)	40.16 (4.61%)	MV
WMB	38.00 (12.80%)	36.01 (11.81%)	38.0 (11.5%)	38.01 (10.67%)	34.07 (12.02%)	42.02 (9.88%)	40.81 (15.00%)	26.46 (13.94%)	31.44 (3.70%)	30.04 (18.51%)	40.00 (3.81%)	MV
a	1.50 (10.78%)	1.54 (10.68%)	1.54 (4.30%)	1.56 (3.21%)	1.46 (14.41%)	1.46 (8.95%)	1.35 (9.37%)	1.39 (12.07%)	1.28 (17.41%)	1.38 (11.07%)	1.29 (16.54%)	MV

*LV- least variable (<12%):MV-moderately variable (12%-20%); HV-highly variable (>20%), CR= Character ranking.
LMB-Length of median bulb, WMB-Width of median bulb, a-Length/width ratio

Table 39. Morphometric characters of perineal pattern of *M. incognita* in Thiruvananthapuram district, [Mean,(CV%)], n=10

Character (µm)	Populations											CR*
	Dhanuvachapuram				Kattakada			Vellayani				
	Okra	Brinjal	Tomato	Banana	Brinjal	Tomato	Banana	Okra	Brinjal	Tomato	Banana	
LVS	24.32 (11.98%)	25.25 (11.37%)	26.50 (7.93%)	26.70 (7.91%)	27.90 (6.99%)	23.01 (6.71%)	26.98 (15.13%)	26.34 (9.42%)	25.40 (10.19%)	27.49 (8.14%)	27.34 (8.21%)	LV
AVS	20.37 (15.01%)	20.36 (14.69%)	19.28 (13.58%)	19.29 (14.29%)	20.12 (10.70%)	17.98 (6.87%)	20.50 (16.40%)	19.70 (12.17%)	20.48 (13.62%)	20.61 (16.60%)	20.81 (16.17%)	MV
ATT	18.01 (14.81%)	17.05 (13.79%)	16.49 (14.09%)	17.01 (15.00%)	17.71 (13.45%)	14.98 (13.05%)	17.40 (13.20%)	18.55 (11.94%)	21.85 (15.66%)	21.19 (12.56%)	21.32 (13.60%)	MV
IPD	26.37 (12.43%)	30.79 (12.14%)	26.24 (11.84%)	28.17 (11.21%)	23.70 (10.398 %)	25.32 (15.10%)	26.38 (17.64%)	30.21 (15.40%)	28.13 (17.93%)	25.85 (17.85%)	27.81 (19.21%)	MV

*LV- least variable (<12%):MV-moderately variable (12%-20%); HV-highly variable (>20%), CR= Character ranking.
LVS-length of vulval slit, AVS- Anus to vulval slit, ATT- Anus to tail terminus, IPD-Interphasmidial distance

Table 40. Morphometric characters of second stage juveniles of *M. incognita* in Thiruvananthapuram district, [Mean,(CV%)], n=10

Character (µm)	Populations											CR*
	Dhanuvachapuram				Kattakada			Vellayani				
	Okra	Brinjal	Tomato	Banana	Brinjal	Tomato	Banana	Okra	Brinjal	Tomato	Banana	
Length	404.32 (4.18%)	418.37 (4.11%)	421.72 (3.05%)	414.31 (3.05%)	401.74 (3.08%)	368.53 (4.82%)	378.76 (6.321%)	417.60 (10.31%)	370.03 (4.34%)	408.45 (5.06%)	423.19 (7.17%)	LV
Stylet length	13.80 (2.04%)	14.01 (3.11%)	14.77 (3.05%)	14.38 (3.015%)	14.48 (2.626%)	13.63 (4.98%)	13.54 (2.81%)	14.10 (4.62%)	13.72 (3.34%)	15.05 (5.25%)	15.67 (5.67%)	LV
H-MB	48.01 (4.38%)	50.26 (4.38%)	50.98 (4.39%)	48.17 (4.38%)	50.24 (3.83%)	50.20 (4.26%)	46.38 (5.82%)	50.22 (3.91%)	50.03 (5.22%)	56.70 (5.70%)	54.37 (5.37%)	LV
ABW	11.21 (4.26%)	11.32 (10.43%)	11.25 (10.30%)	11.74 (10.17%)	11.03 (3.34%)	10.97 (6.78%)	11.81 (4.06%)	10.34 (7.333%)	10.38 (11.96%)	12.67 (11.04%)	12.17 (12.17%)	HV
Tail length	47.60 (15.38%)	48.38 (15.21%)	47.59 (14.45%)	48.18 (14.51%)	51.23 (5.94%)	52.14 (10.87%)	50.08 (6.21%)	54.55 (13.587%)	48.96 (11.44%)	53.94 (4.511%)	52.98 (4.52%)	HV
c	8.49 (18.32%)	8.64 (7.21%)	9.08 (19.85%)	10.00 (18.00%)	7.86 (6.52%)	7.13 (10.39%)	7.80 (7.82%)	7.72 (12.12%)	7.66 (14.54%)	7.58 (6.25%)	7.83 (6.30%)	HV
c'	5.60 (8.13%)	5.71 (9.48%)	4.21 (9.94%)	4.38 (8.91%)	4.64 (6.03%)	4.75 (9.84%)	4.98 (7.32%)	5.26 (8.11%)	4.74 (12.45%)	4.29 (10.86%)	5.37 (11.31%)	HV

*LV- least variable (<8%); MV-moderately variable (8%-12%); HV-highly variable (>12%), CR= Character ranking.
H-MB-head to median bulb; ABW-anal body width ;c- length/tail length; c'- tail length/anal body width

B. Perineal pattern:

The perineal pattern was rounded to oval. The dorsal arch was low and rounded. Near the perineal area, the striae were broken and twisted. Weak lateral lines were visible which cut through the striae.

C. Second stage juveniles(J_2):

The Second stage juveniles were 330.71 to 414.66 µm in length. The stylet knobs were small and set off. The labial region was not set off. The head possessed an elevated labial disc. The rectal sac was prominent in the population.

4.2.3 Morphology and Morphometrics of Mature Females, Perineal Pattern, Second Stage Juveniles and Male of *M. javanica* from Idukki District

The following were the morphological characters of populations of *M. javanica* from Idukki district.

A. Mature females:

The shape of females varied from pear shaped to rounded to kidney shaped with short (brinjal from Pampadumpara) to long (banana from Pampadumpara) neck directed ventrally or at right angles (tomato and banana from Thovalappady and banana from Balagram) to the body of nematode. The body shape and size were variable within and between the populations. The head region was slightly set off. The stylet knobs were small and sloping posteriorly and the cone was slightly curved at the dorsal region.

B. Perineal pattern:

The perineal pattern was oval to rounded with low dorsal arch. The striae was smooth to wavy. The pattern possessed distinct lateral field which was marked by two well defined incisures which cut through the striae. The lateral line was sloping laterally or at right angles to the striae (banana from Pampadumpara and Thovalappady).

C. Second stage juveniles (J_2):

In J_2, tail length was highly variable in the populations with long hyaline region. The tail terminus was either blunt or pointed. Rectum dilation was very prominent in populations in okra and brinjal from Pamadumpara and banana from Thovalappady.

D. Males:

Males were vermiform. The head region was not set off with non elevated labial disc. The length of cone was higher than that of shaft. The stylet knobs were small and sloping posteriorly. Tail region was rounded with hyaline region.

The morphometric characters of mature females, perineal pattern and second stage juveniles of populations of *M. javanica* from Idukki district are given in tables 41, 42 and 43.

A. Mature females:

The range of mean values for body length and width in the populations were 646.28 to 792.852 µm and 410.71 to 564.39 µm respectively. The maximum mean value for body length and width was observed in the species identified in banana from Thovalappady (792.85 and 564.39 µm respectively). These characters were observed as moderately variable with maximum variation in population in brinjal from Balagram which was up to 15.34 per cent for length and 17.07 per cent for width.

The character neck length was highly variable between the populations (CV 14.58% to 32.10%). Population from tomato in Pampadumpara had the maximum mean value for neck length (233.20 µm) and the minimum value was observed in the population from banana in Balagram. The character stylet length was moderately variable character (CV 2.53% to 14.49%) between the populations with the mean values ranging from 12.89 to 16.97 µm. The range of mean values for LMB and WMB were 35.04 to 42.77µm and 33.98 to 41.93 µm respectively. These characters were seen to be least variable and moderately

variable respectively. The character ratio 'a' was also moderately variable (CV 6.35% to 18.10%) with mean values ranging from 1.38 to 1.79 µm.

B. Perineal pattern:

The character LVS was observed to be moderately variable (CV 8.243% to 12.773%) with maximum mean value in the population identified in tomato from Thoavalappady and the minimum in the population in brinjal from Balagram. The mean value for LVS ranges from 22.25 to 27.80 µm. The characters AVS, ATT and IPD were highly variable (CV 8.35% to 26.56%; 8.67% to 21.28% and 4.99% to 24.02% respectively). The range of mean values for IPD was 23.58 to 28.70 µm with maximum mean value in population in banana from Balagram and minimum in population in tomato from Pampadumpara.

C. Second stage juveniles (J_2):

The coefficient of variability for the seven characters of second stage juveniles varied from population to population. The characters body length, stylet length and H-MB were least variable (CV 3.25% to 6.68%; 2.30% to 4.77% and 4.35% to 6.71% respectively) and the characters ABW was moderately variable (CV 4.72% to 11.83%) and tail length, ratio c and c' were highly variable (CV 4.21% to 24.01%; 3.98% to 22.75% and 7.76% to 21.69% respectively). The mean values for body length, stylet length and H-MB ranges from 395.94 to 428.39 µm, 13.56 to 14.91 µm and 46.22 to 54.72 µm respectively. The highest body length was observed in population in brinjal from Balagram (428.39 µm) and minimum value in population in tomato from Pampadumpara (395.94 µm). In general, tail length was smaller in population infecting okra from Balagram than the other populations. The longest tail length was observed in population in tomato from Thoavlappady (54.43 µm). The range of mean values for c and c' varies from 7.18 to 8.69 µm and 4.23 to 5.72 µm respectively. The ratio c and c' were maximum in population in brinjal from Balagram and banana from Thovalappady respectively.

Table 41. Morphometric characters of mature females of *M. javanica* in Idukki district, [Mean,(CV%)], n=10

Character (µm)	Populations								CR*
	Balagram		Pampadumpara				Thovalappady		
	Brinjal	Banana	Okra	Brinjal	Tomato	Banana	Tomato	Banana	
	Females								
Length	701.50 (15.34%)	653.23 (10.70%)	735.32 (14.38%)	646.28 (14.26%)	740.18 (14.49%)	746.17 (13.98%)	683.99 (7.44%)	792.85 (9.46%)	MV
Width	416.66 (17.07%)	466.23 (10.94%)	410.71 (8.12%)	431.84 (10.34%)	415.38 (7.91%)	425.37 (8.81%)	491.61 (7.59%)	564.39 (7.29%)	MV
Neck length	223.77 (21.59%)	165.23 (16.20%)	221.76 (31.70%)	169.89 (22.76%)	233.20 (31.87%)	232.93 (32.10%)	179.33 (14.58%)	198.20 (20.39%)	HV
Stylet length	14.49 (5.88%)	15.23 (5.72%)	16.55 (4.12%)	16.74 (2.53%)	16.55 (3.58%)	16.89 (2.98%)	12.89 (14.49%)	16.97 (4.82%)	MV
LMB	42.11 (7.46%)	40.20 (3.98%)	35.58 (13.79%)	42.77 (10.42%)	41.32 (10.04%)	42.77 (10.11%)	37.42 (8.50%)	35.04 (10.01%)	LV
WMB	41.89 (6.91%)	39.02 (2.84%)	34.93 (13.97%)	41.93 (9.60%)	35.29 (8.74%)	41.81 (8.42%)	33.98 (1.50%)	34.99 (12.72%)	MV
a	1.72 (18.10%)	1.42 (13.26%)	1.49 (15.55%)	1.49 (10.09%)	1.79 (16.62%)	1.76 (15.00%)	1.38 (6.35%)	1.48 (12.81%)	MV

*LV- least variable (<12%):MV-moderately variable (12%-20%); HV-highly variable (>20%), CR= Character ranking.
LMB-Length of median bulb, WMB-Width of median bulb, a-Length/width ratio

Table 42. Morphometric characters of perineal pattern of *M. javanica* in Idukki district, [Mean,(CV%)], n=10

Character (µm)	Populations								CR*
	Balagram		Pampadumpara				Thovalappady		
	Brinjal	Banana	Okra	Brinjal	Tomato	Banana	Tomato	Banana	
	Females								
LVS	22.25 (10.15%)	23.29 (11.27%)	24.24 (9.83%)	25.56 (9.07%)	25.06 (12.77%)	25.32 (10.35%)	27.80 (8.82%)	27.18 (8.24%)	MV
AVS	16.82 (14.99%)	20.21 (9.97%)	16.05 (10.33%)	19.41 (26.56%)	16.83 (9.98%)	17.11 (8.35%)	19.32 (11.06%)	19.86 (12.01%)	HV
ATT	21.21 (14.12%)	19.63 (12.10%)	14.38 (21.28%)	16.38 (8.67%)	14.82 (18.76%)	15.78 (16.73%)	13.19 (20.20%)	14.01 (19.15%)	HV
IPD	20.94 (24.02%)	28.70 (4.99%)	22.46 (11.84%)	24.17 (17.71%)	23.58 (8.98%)	24.12 (11.19%)	25.21 (21.38%)	26.15 (17.20%)	HV

*LV- least variable (<12%):MV-moderately variable (12%-20%); HV-highly variable (>20%), CR= Character ranking.
LVS-length of vulval slit, AVS- Anus to vulval slit, ATT- Anus to tail terminus, IPD-Interphasmidial distance

Table 43. Morphometric characters of second stage juveniles of *M. javanica* in Idukki district, [Mean,(CV%)], n=10

Character (µm)	Populations								CR*
	Balagram		Pampadumpara				Thovalappady		
	Brinjal	Banana	Okra	Brinjal	Tomato	Banana	Tomato	Banana	
				Females					
Length	428.39 (3.25%)	397.60 (4.43%)	396.60 (6.07%)	406.55 (4.12%)	395.94 (6.68%)	404.58 (5.84%)	400.30 (4.31%)	410.17 (3.40%)	LV
Stylet length	13.92 (3.85%)	13.63 (3.75%)	13.56 (4.65%)	14.57 (2.51%)	13.64 (4.77%)	13.84 (3.20%)	14.33 (3.51%)	14.91 (2.30%)	LV
H-MB	50.95 (6.61%)	50.21 (4.92%)	52.32 (6.71%)	46.22 (4.35%)	52.06 (6.70%)	53.04 (6.45%)	54.72 (4.45%)	52.00 (5.21%)	LV
ABW	11.81 (11.21%)	10.98 (7.81%)	9.84 (10.31%)	10.37 (5.81%)	10.00 (8.18%)	10.38 (4.72%)	10.24 (10.09%)	10.81 (11.83%)	MV
Tail length	49.88 (11.78%)	50.98 (6.76%)	45.46 (33.06%)	51.45 (4.54%)	48.86 (18.85%)	51.67 (4.21%)	54.43 (23.20%)	54.01 (24.01%)	HV
c	8.69 (11.96%)	7.79 (3.98%)	8.54 (21.27%)	7.90 (4.05%)	8.39 (20.91%)	8.47 (18.21%)	7.71 (22.75%)	7.18 (21.32%)	HV
c'	4.23 (10.83%)	6.54 (8.19%)	4.95 (21.27%)	4.91 (7.76%)	4.91 (21.69%)	4.91 (19.00%)	5.29 (18.13%)	5.72 (19.17%)	HV

*LV- least variable (<8%):MV-moderately variable (8%-12%); HV-highly variable (>12%), CR= Character ranking.
H-MB-head to median bulb; ABW-anal body width ;c- length/tail length; c'- tail length/anal body width

4.2.4 Morphology and Morphometrics of Mature females, Perineal Pattern and Second Stage Juveniles of *M. arenaria* from Thrissur District

The following were the morphological characters of populations of *M. arenaria* from Thrissur district.

A. Mature females:

Females were larger in size with elongated to rounded body with no posterior terminal protuberance. The body shape and size were variable within and between populations. The neck was directed ventrally from the body of nematode. Basal knobs of stylet were rounded and set off from the shaft.

B. Perineal pattern:

Perineal pattern was rounded to oval in shape with coarse to smooth striae which was either continuous or broken. The dorsal and ventral striae met at an angle forming shoulders or wings on the lateral portion of the pattern. In populations in tomato from Chazhoor and okra from Thanniyam, the wings were prominent in one side of the perineal pattern.

C. Second stage juveniles (J_2):

The tail tip was blunt to pointed. The size and shape of rectal sac and position of anus were variable within and between the populations. Rectum dilation was prominent in populations in banana from Chazhoor, tomato from Thalikulam and okra from Thanniyam. The hyaline region was prominent in population in brinjal from Chazhoor.

The morphometric characters of populations of mature females, perineal pattern and second stage juveniles of *M. arenaria* from Thrissur district are given in tables 44, 45 and 46.

A. Mature females:

The range of mean values for body length and width in eight populations were 665.93 to 927.46 µm and 459.93 to 588.32 µm respectively. The maximum mean value for body length and width was observed for the species identified in banana and tomato from Chazhoor respectively. These characters were observed as moderately variable with maximum variation in population in brinjal from Chazhoor which was up to 18.04 per cent for body length and 16.31 per cent for width.

The character neck length was highly variable between the populations (CV 19.64% to 30.10%). Population in banana from Chazhoor had the maximum mean value for neck length (296.91 µm) and the minimum for population in okra from Thalikulam (191.49 µm). The character stylet length was least variable character (CV 2.93% to 5.26%) between the populations with the mean values ranging from 15.53 to 17.88 µm. The range of mean values for LMB and WMB were 38.06 to 42.67µm and 34.66 to 41.86 µm respectively. These characters were seen to be moderately variable. The character ratio 'a' was highly variable (CV 14.22% to 20.49%) with mean values ranging from 1.45 to 1.68 µm.

B. Perineal pattern:

The characters LVS and AVS were observed to be moderately variable (CV 4.76% to 13.36% and 5.90% to 19.79% respectively). The maximum mean value for LVS was observed in population in tomato from Chazhoor and the minimum in population in tomato from Thalikulam. The mean value for LVS ranges from 25.47 to 32.15 µm. The characters ATT and IPD were highly variable (CV 7.10% to 29.87% and 7.91% to 20.62% respectively). The range of mean values for IPD was 26.44 to 33.55 µm with maximum mean value in population in banana from Chazhoor and minimum in population in tomato from Chazhoor.

Table 44. Morphometric characters of mature females of *M. arenaria* in Thrissur district, [Mean,(CV%)], n=10

Character (µm)	Populations								CR*
	Chazhoor				Thalikulam			Thanniaym	
	Okra	Brinjal	Tomato	Banana	Okra	Tomato	Banana	Okra	
	Females								
Length	898.37 (12.78%)	785.41 (18.04%)	916.88 (7.44%)	927.46 (14.37%)	665.93 (12.60%)	774.27 (11.27%)	781.36 (12.38%)	877.79 (13.83%)	MV
Width	485.91 (10.17%)	483.88 (15.05%)	588.32 (12.38%)	516.99 (11.80%)	459.93 (11.66%)	481.24 (15.32%)	490.02 (16.31%)	552.73 (11.19%)	MV
Neck length	280.01 (27.18%)	203.63 (30.10%)	265.44 (17.17%)	296.91 (29.87%)	191.49 (26.88%)	208.35 (27.69%)	217.11 (28.57%)	236.61 (19.64%)	HV
Stylet length	16.98 (4.80%)	17.18 (4.86%)	16.84 (4.12%)	17.88 (4.71%)	15.95 (2.93%)	15.92 (4.04%)	16.98 (5.02%)	15.53 (5.26%)	LV
LMB	41.54 (4.99%)	41.57 (6.89%)	40.25 (4.81%)	42.67 (6.87%)	42.40 (5.57%)	38.06 (6.52%)	39.23 (6.25%)	41.85 (12.69%)	MV
WMB	40.80 (8.59%)	34.66 (11.74%)	40.08 (7.81%)	41.78 (12.43%)	41.86 (5.18%)	37.43 (11.08%)	39.02 (12.71%)	40.42 (10.99%)	MV
a	1.68 (18.13%)	1.67 (20.49%)	1.59 (17.39%)	1.79 (19.38%)	1.45 (14.22%)	1.64 (15.81%)	1.60 (16.21%)	1.60 (16.31%)	HV

*LV- least variable (<12%):MV-moderately variable (12%-20%); HV-highly variable (>20%), CR= Character ranking.
LMB-Length of median bulb, WMB-Width of median bulb, a-Length/width ratio

Table 45. Morphometric characters of perineal pattern of *M. arenaria* in Thrissur district , [Mean,(CV%)], n=10

Character (µm)	Populations								CR*
	Chazhoor				Thalikulam			Thanniaym	
	Okra	Brinjal	Tomato	Banana	Okra	Tomato	Banana	Okra	
	Females								
LVS	26.38 (7.54%)	27.75 (8.55%)	32.15 (4.76%)	24.96 (10.85%)	28.07 (5.33%)	25.47 (8.69%)	26.10 (5.00%)	26.29 (13.36%)	MV
AVS	18.01 (7.02%)	19.06 (10.63%)	21.16 (7.45%)	19.56 (18.88%)	19.90 (9.31%)	17.95 (9.23%)	18.77 (5.90%)	21.56 (19.79%)	MV
ATT	19.16 (7.44%)	19.48 (7.10%)	15.83 (10.46%)	18.90 (29.87%)	20.19 (17.25%)	16.18 (21.86%)	17.56 (15.64%)	19.93 (19.38%)	HV
IPD	30.60 (7.91%)	33.55 (8.21%)	33.16 (13.80%)	26.44 (17.26%)	30.10 (13.69%)	30.47 (10.17%)	29.93 (10.23%)	31.37 (20.62%)	HV

*LV- least variable (<12%):MV-moderately variable (12%-20%); HV-highly variable (>20%), CR= Character ranking.
H-MB-head to median bulb; ABW-anal body width ;c- length/tail length; c'- tail length/anal body width

Table 46. Morphometric characters of second stage juveniles of *M. arenaria* in Thrissur district, [Mean,(CV%)], n=10

Character (µm)	Populations								CR*
	Chazhoor				Thalikulam			Thanniaym	
	Okra	Brinjal	Tomato	Banana	Okra	Tomato	Banana	Okra	
	Females								
Length	421.36 (3.41%)	420.37 (3.28%)	423.54 (3.56%)	428.39 (3.25%)	395.49 (6.84%)	380.14 (9.50%)	401.14 (10.01%)	409.39 (5.59%)	MV
Stylet length	13.76 (7.04%)	13.81 (3.28%)	13.83 (6.81%)	13.92 (3.85%)	14.10 (3.94%)	13.74 (4.07%)	13.94 (3.65%)	14.23 (3.31%)	LV
H-MB	49.97 (10.00%)	48.93 (7.21%)	50.31 (9.21%)	50.95 (6.61%)	51.30 (5.88%)	46.96 (6.62%)	48.73 (0.71%)	45.32 (8.04%)	MV
ABW	10.80 (10.11%)	10.21 (10.11%)	10.99 (10.98%)	11.81 (11.21%)	10.85 (8.96%)	10.43 (13.82%)	10.74 (12.11%)	11.48 (4.49%)	HV
Tail length	48.01 (10.38%)	49.08 (10.98%)	48.91 (11.21%)	49.88 (11.78%)	51.59 (9.06%)	46.36 (13.63%)	47.21 (14.21%)	48.95 (10.14%)	HV
c	8.77 (11.31%)	8.56 (12.35%)	8.65 (10.25%)	8.69 (11.96%)	7.73 (13.12%)	8.37 (19.62%)	8.49 (18.21%)	8.40 (7.35%)	HV
c'	4.44 (10.25%)	4.80 (10.98%)	5.98 (10.00%)	4.23 (10.83%)	4.76 (9.46%)	4.45 (9.26%)	5.55 (10.22%)	5.81 (16.81%)	HV

*LV- least variable (<8%):MV-moderately variable (8%-12%); HV-highly variable (>12%), CR= Character ranking.
H-MB-head to median bulb; ABW-anal body width ;c- length/tail length; c'- tail length/anal body width

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C. Second stage juveniles (J_2):

The coefficient of variability for the seven characters of second stage juveniles varied from population to population. The characters body length and H-MB were moderately variable (CV 3.28% to 10.01% and 0.71% to 10.00% respectively) and the character stylet length was least variable (CV 3.28% to 4.07%). The characters ABW, tail length, ratio c and c' were highly variable (CV 4.49% to 13.82%; 9.06% to 13.63%; 7.35% to 19.62% and 9.26% to 16.81% respectively). The mean values for body length, stylet length and H-MB ranges from 380.14 to 423.54 µm, 13.74 to 14.23 µm and 45.32 to 51.30 µm respectively. The maximum length was observed in population in tomato from Chazhoor (423.54 µm) and minimum value for population in tomato from Thalikulam (380.14 µm). In general, tail length was smaller in population in tomato from Thalikulam than the other populations. The longest tail length was observed in population in okra from Thalikulam (51.59 µm). The range of mean values for c and c' varies from 7.73 to 8.77 µm and 4.233 to 5.98 µm respectively. The ratio c and c' were maximum in population in okra and banana from Chazhoor respectively.

4.2.4 Morphometrics of Mature Females, Perineal Pattern and Second Stage Juveniles of *M. incognita* from Three Districts of Kerala

The morphometric characters of mature females, perineal pattern and second stage juveniles of *M. incognita* from three districts of Kerala are given in tables 47 and 48.

A. Mature females:

The range for mean values of body length and width in the three populations were 546.42 to 821.29 µm and 388.96 to 570.41 µm, respectively, with the maximum length and width being in Idukki population. The characters body length and width showed maximum variation within the population in

Idukki which was up to 12.96 per cent for body length and 15.67 percent for width.

The character of neck length was moderately variable with maximum variation in Idukki population (CV 13.94%). The maximum mean value for neck length was observed in Thiruvananthapuram population (187.67 µm) and the least in Idukki population (175.55 µm). Stylet length showed least variation among the populations in their mean values and the maximum mean value was observed in Thiruvananthapuram population (16.30 µm).

The size of the median bulb varied from 36.55 to 40.22 µm and 35.91 to 39.51 µm in length (LMB) and width (WMB) respectively, with maximum length and width in Thrissur population. The ratio a was least variable character with the maximum mean value for Idukki population (1.473 µm) and least for Thrissur population (1.432 µm).

B. Perineal pattern:

The characters LVS, AVS and IPD were highest in Thiruvananthapuram population (26.02 µm, 19.95 µm and 27.18 µm respectively). These characters were rated as least variable with maximum variation in Idukki population for LVS and AVS and for IPD the maximum variation was observed in Thiruvananthapuram population. The coefficient of variability for the four characters of perineal patterns varied from population to population. The character ATT was rated as moderately variable (2.43% to 12.30%). The length of vulval slit (LVS) was almost similar in all the three populations with mean values ranging from 20.68 to 27.90 µm.

C. Second stage juveniles (J_2):

The average body length of second stage juveniles was 394.08 to 402.46 µm, with maximum body length recorded in Thiruvananthapuram population. The body length, stylet length, H-MB, ABW and tail length were the

Table 47. Morphometric characters of mature females, perineal pattern and second stage juveniles of *M. incognita* from three districts in Kerala, [Mean±SD±SE;(range);CV%], n=10

Character (µm)	Populations			CR*
	Thiruvananthapuram	Idukki	Thrissur	
Females				
Length	648.88±78.98±23.81 (546.42-821.29) 12.17%	691.79±89.70±44.85 (589.84-789.27) 12.96%	665.56±50.84±29.35 (631.87-724.04) 7.63%	MV
Width	448.03±35.39±10.67 (396.54-515.82) 7.90%	476.05±74.63±37.31 (388.96-570.41) 15.67%	466.75±51.16±29.53 (435.10-525.77) 10.96%	MV
Neck length	187.67±23.22±7.00 (164.34-248.34) 12.37%	175.55±24.47±12.23 (151.47-206.72) 13.94%	186.42±16.90±9.75 (167.90-201.01) 9.06%	MV
Stylet length	16.30±1.17±0.35 (13.64-17.90) 7.21%	15.33±1.36±0.68 (14.01-16.88) 8.90%	15.63±0.29±0.16 (15.46-15.97) 1.85%	LV
LMB	37.13±3.95±1.19 (30.55-42.37) 10.66%	36.55±5.01±2.50 (31.47-41.66) 13.71%	40.22±2.38±1.37 (38.62-42.96) 5.92%	MV
WMB	35.91±4.88±1.47 (26.46-42.02) 11.47%	35.94±5.11±2.55 (30.48-41.00) 14.22%	39.51±1.92±1.11 (38.13-41.71) 4.86%	MV
a	1.46±0.10±0.03 (1.28-1.59) 7.27%	1.47±0.07±0.03 (1.39-1.54) 5.12%	1.43±0.04±0.02 (1.38-1.45) 3.02%	LV
Perineal pattern				
LVS	26.02±1.45±0.43 (23.01-27.90) 5.58%	23.01±1.69±0.84 (20.68-24.56) 7.35%	22.05±1.23±0.71 (20.84-23.30) 5.58%	LV
AVS	19.95±0.83±0.25 (17.98-20.81) 4.17%	18.97±0.97±0.48 (17.82-19.89) 5.15%	19.19±0.40±0.23 (18.82-19.62) 2.09%	LV
ATT	18.32±2.21±0.66 (14.98-21.85) 12.06%	17.99±2.21±1.10 (15.55-20.52) 12.30%	26.47±0.64±0.37 (25.76-27.01) 2.43%	MV
IPD	27.18±2.09±0.63 (23.70-30.79) 7.71%	26.49±1.05±0.52 (24.98-27.34) 3.97%	20.00±0.73±0.42 (19.27-20.74) 3.68%	LV

*LV- least variable (<12%):MV-moderately variable (12-20%); HV-highly variable (>20%), CR= Character ranking. LMB- length of median bulb, WMB- width of median bulb, a- length/width ratio, LVS-length of vulval slit, AVS-anus to vulval slit, ATT-anus to tail terminus, IPD-interphasmidial distance.

Table 48. Morphometric characters of second stage juveniles of *M. incognita* from three districts in Kerala, [Mean±SD±SE;(range);CV%], n=10

Character (µm)	Populations			CR*
	Thiruvananthapuram	Idukki	Thrissur	
		Females		
Length	402.46±20.56±6.20 (368.53-423.19) 5.10%	401.89±12.09±6.04 (390.86-415.70) 3.00%	394.08±20.15±11.63 (371.25-409.39) 5.11%	LV
Stylet length	14.29±0.66±0.20 (13.54-15.67) 4.65%	13.96±0.39±0.19 (13.66-14.53) 2.84%	13.68±0.36±0.21 (13.25-13.91) 2.68%	LV
H-MB	50.50±2.87±0.86 (46.38-56.70) 5.69%	50.59±2.22±1.11 (48.40-53.69) 4.40%	47.24±1.21±0.70 (45.84-47.96) 2.56%	LV
ABW	11.35±0.70±0.21 (10.34-12.67) 6.23%	10.40±0.51±0.25 (9.88-10.91) 4.91%	11.01±0.55±0.31 (10.43-11.53) 5.01%	LV
Tail length	50.51±2.58±0.78 (47.59-54.55) 5.12%	52.34±1.15±0.75 (50.41-53.57) 2.88%	52.15±2.73±1.57 (50.51-55.30) 5.24%	LV
c	8.16±0.82±0.24 (7.13-10.00) 10.06%	7.76±0.24±0.12 (7.43-8.03) 3.20%	7.64±0.86±0.39 (6.856-8.086) 8.961%	MV
c'	4.90±0.52±0.15 (4.21-5.71) 10.64%	4.95±0.09±0.04 (4.82-5.04) 1.98%	4.75±0.48±0.27 (4.38-5.29) 10.15%	MV

*LV- least variable (<8%):MV-moderately variable (8%-12%); HV-highly variable (>12%), CR= Character ranking.
H-MB-head to median bulb; ABW-anal body width ;c- length/tail length; c'- tail length/anal body width

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least variable characters and the maximum values being 402.46 µm, 14..29 µm , 50.59 µm, 11.35 µm and 52.34 µm respectively. The maximum stylet length was observed in Thiruvanthapuram population whereas minimum value was recorded in Thrissur population (13.68 µm).

Ratio c and c' were moderately variable with maximum mean values being 8.16 µm and 4.95 µm respectively. The tail was longer in Idukki population (52.34 µm) and smaller in Thiruvananthapuram population (47.591 µm).

4.2.5 Morphometrics of Mature Females, Perineal Pattern and Second Stage Juveniles of *M. incognita* in Four Crops in Kerala

The morphometric characters of mature females, perineal pattern and second stage juveniles of *M. incognita* in four crops in Kerala are given in tables 49 and 50.

A. Mature females:

The range for mean values of body length and width in the four populations were 618.49 to 676.47 µm and 420.23 to 478.21 µm, respectively, with the maximum length and width being in banana population. The character body length and width showed maximum variation within the population in okra which was up to 15.18 per cent for body length and 16.19 per cent for width.

The character of neck length was moderately variable with maximum variation in okra population (CV 12.404%). The maximum mean value for neck length was observed in banana population (194.00 µm) and the least in tomato population (173.90 µm). Stylet length showed least variation among the populations in their mean values and the maximum mean value was observed in banana population (16.59 µm).

The size of the median bulb varied from 35.07 to 41.10 µm and 33.62 to 40.13 µm in length (LMB) and width (WMB) respectively, with maximum length and width in banana population. The ratio a was least variable character with the maximum mean value for tomato population (1.47 µm) and least for brinjal population (1.41 µm).

Table 49.Morphometric characters of mature females and perineal pattern of *M. incognita* in four crops in Kerala,[Mean±SD±SE;(range);CV%], n=10

Character (µm)	Populations				CR*
	Brinjal	Okra	Tomato	Banana	
Females					
Length	664.59±42.23±21.11 (620.14-714.18) 6.35%	657.60±99.84±49.92 (546.42-789.27) 15.18%	618.49±56.25±25.15 (550.29-702.19) 9.09%	676.47±58.57±26.19 (606.71-740.06) 8.65%	MV
Width	470.24±34.98±17.49 (439.38-515.82) 7.44%	464.91±75.31±37.65 (396.54-570.41) 16.19%	420.23±25.70±11.49 (388.96-453.24) 6.11%	478.21±30.84±13.79 (447.93-525.77) 6.44%	MV
Neck length	186.76±14.04±6.28 (167.89-206.72) 7.52%	174.89±21.69±10.84 (151.47-201.24) 12.40%	173.90±12.85±5.74 (161.50-195.43) 7.39%	194.00±8.78±4.39 (183.24-201.34) 4.52%	MV
Stylet length	16.44±1.11±0.50 (15.44-17.90) 6.80%	15.15±1.43±0.71 (13.64-16.88) 9.47%	15.68±1.04±0.46 (14.01-16.56)6.66%	16.59±0.71±0.35 (15.97-17.23)4.28%	LV
LMB	35.48±2.13±0.95 (33.116-38.62) 6.00%	35.07±4.75±2.37 (30.55-39.97) 13.55%	38.76±4.26±1.90 (31.62-42.28) 11.00%	41.10±1.89±0.94 (38.90-42.96) 4.61%	MV
WMB	34.48±2.65±1.18 (31.44-38.13) 7.68%	33.62±6.19±3.09 (26.46-39.52) 18.41%	37.97±4.71±2.10 (30.04-42.02) 12.41%	40.13±1.57±0.78 (38.01-41.71)3.92%	MV
a	1.41±0.12±0.06 (1.29-1.56)8.47%	1.43±0.05±0.02 (1.39-1.50)3.67%	1.47±0.06±0.02 (1.38-1.54) 4.31%	1.44±0.11±0.05 (1.28-1.54) 7.69%	LV
Perineal pattern					
LVS	25.15±1.78±0.79 (23.30-27.90) 7.79%	24.54±1.40±0.70 (22.93-26.34) 5.70%	23.70±3.16±1.41 (20.68-27.49) 13.34%	25.76±2.50±1.25 (22.01-27.34) 9.74%	MV
AVS	19.66±0.92±0.41 (18.49-20.48) 4.71%	19.39±1.09±0.54 (17.82-20.37) 5.63%	19.38±0.97±0.43 (17.98-20.61) 5.02%	20.05±0.71±0.35 (19.29-20.81) 3.57%	LV
ATT	18.84±2.29±1.02 (16.86-21.85) 12.18%	17.792±1.546±0.773 (15.557-19.032) 8.691%	18.49±2.66±1.19 (14.98-21.19) 14.39%	18.93±2.06±1.03 (17.01-21.32) 10.91%	MV
IPD	26.67±2.81±1.25 (23.70-30.79) 10.54%	27.74±1.69±0.84 (26.370-30.21)6.11%	26.13±0.54±02 (25.326-26.64) 2.10%	27.34±0.80±0.40 (26.38-28.17) 2.93%	LV

*LV- least variable (<12%):MV-moderately variable (12-20%); HV-highly variable (>20%), CR= Character ranking. LMB- length of median bulb, WMB- width of median bulb, a- length/width ratio, LVS-length of vulval slit, AVS-anus to vulval slit, ATT-anus to tail terminus, IPD-interphasmidial distance.

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Table 50. Morphometric characters of second stage juveniles of *M. incognita* in four crops in Kerala,[Mean±SD±SE;(range);CV%], n=10

Character (µm)	Populations				CR*
	Brinjal	Okra	Tomato	Banana	
Length	401.49±19.21±8.59 (370.03-418.37) 4.78%	405.28±11.10±5.55 (390.86-417.60) 2.74%	392.52±23.10±10.33 (368.53-421.72) 5.88%	406.41±19.30±9.65 (378.76-423.19)4.74%	LV
Stylet length	14.12±0.36±0.16 (13.72-14.53) 2.60%	13.87±0.18±0.09 (13.66-14.10) 1.36%	14.09±0.77±0.34 (13.25-15.05) 5.52%	14.37±0.92±0.46 (13.54-15.67)6.45%	LV
H-MB	50.43±2.06±0.92 (47.93-53.69) 4.09%	49.09±1.03±0.51 (48.01-50.02) 2.10%	50.82±3.87±1.73 (45.84-56.70) 7.62%	49.22±3.52±1.76 (46.38-54.37)7.16%	LV
ABW	10.94±0.34±0.15 (10.38-11.32) 3.16%	10.59±0.50±0.25 (10.05-11.21) 4.77%	11.04±1.05±0.47 (9.88-12.67) 9.53%	11.81±0.26±0.13 (11,53-12.17) 2.25%	MV
Tail length	50.52±2.01±0.90 (48.38-53.51) 4.01%	51.10±2.89±1.44 (47.60-54.55) 5.67%	52.51±2.97±1.32 (47.59-55.30) 5.66%	50.46±1.97±0.98 (48.18-52.98) 3.91%	LV
c	8.00±0.38±1.17 (7.66-8.64) 4.75%	8.00±0.35±0.17 (7.72-8.49) 4.43%	7.61±0.86±0.38 (6.85-9.08) 11.38%	8.43±1.05±0.52 (7.80-10.00)12.51%	HV
c'	4.92±0.46±0.20 (4.57-5.71) 9.40%	5.18±0.33±0.16 (4.82-5.60)6.43%	4.72±0.46±0.20 (4.21-5.29) 9.90%	4.78±0.48±0.24 (4.38-5.37)10.15%	MV

*LV- least variable (<8%):MV-moderately variable (8%-12%); HV-highly variable (>12%), CR= Character ranking.
H-MB-head to median bulb; ABW-anal body width ;c- length/tail length; c'- tail length/anal body width

B. Perineal pattern:

The characters LVS, AVS and ATT were highest in banana population (25.76 µm, 20.05 µm and 18.93 µm respectively). The coefficient of variability for the four characters of perineal patterns varied from population to population. The characters LVS and ATT were rated as moderately variable with maximum variation in tomato population (CV 13.34% and 14.39% respectively). The character AVS and IPD were least variable with maximum variation in okra and brinjal population respectively. Okra population showed maximum mean value for IPD (27.74 µm).

C. Second stage juveniles (J_2):

The average body length of second stage juveniles was 392.52 to 406.41 µm, with maximum body length recorded in banana population. The body length, stylet length, H-MB and tail length were the least variable characters and the maximum mean values being 406.41 µm, 14.37 µm, 50.82 µm and 52.51 µm respectively. The maximum stylet length was observed in banana population whereas minimum value was observed in okra population (13.87 µm). The characters ABW and ratio c' were moderately variable with maximum variation in tomato and banana population respectively.

Ratio c was highly variable with maximum variation in banana population and maximum mean values being 8.43 µm. The tail was longer in tomato population and smaller in banana population (50.46 µm).

4.2.6 Morphometrics of Mature Females, Perineal Pattern and Second Stage Juveniles of *M. javanica* from Two Districts of Kerala

The morphometric characters of mature females, perineal pattern and second stage juveniles of *M. javanica* from two districts of Kerala are given in tables 51 and 52.

A. Mature females:

The range for mean values of body length and width in the four populations were 708.57 to 712.44 µm and 454.15 to 470.40 µm, respectively. The maximum body length was observed in Thrissur population and width in Idukki population. These characters were rated as least variable. The character body length showed maximum variation within the population in Thrissur which was up to 9.66 per cent and the character width showed maximum variation in Idukki population which was up to 11.56 per cent.

The character of neck length was moderately variable with maximum variation in Thrissur population (CV 18.06%). The maximum mean value for neck length was observed in Idukki population (203.04 µm) and the least in Thrissur population (168.28 µm). Stylet length showed least variation among the populations in their mean values and the maximum mean value was observed in Thrissur population (16.08 µm).

The size of the median bulb varied from 39.65 to 39.85 µm and 38.79 to 39.32 µm in length (LMB) and width (WMB) respectively, with the maximum length and width in Thrissur population. The character ratio a was least variable with maximum mean value for Idukki population (1.56µm) and least for Thrissur population (1.50 µm).

B. Perineal pattern:

The characters LVS and ATT were maximum in Idukki population (25.46 µm and 16.17 µm respectively). The coefficient of variability for the four characters of perineal patterns varied from population to population. The characters LVS and AVS were rated as least variable with maximum variation in Thrissur population (CV 6.82% and 10.22% respectively). The character ATT and IPD were moderately variable with maximum variation in Idukki and Thrissur population respectively. Idukki population showed maximum mean value for IPD (24.42 µm).

Table 51. Morphometric characters of mature females, perineal pattern and second stage juveniles of *M. javanica* from three districts in Kerala, [Mean±SD±SE;(range);CV%], n=10

Character (µm)	Populations		CR*
	Idukki	Thrissur	
Females			
Length	712.44±50.29±17.78 (646.28-792.85) 7.06%	708.57±68.47±21.65 (552.83-826.28) 9.66%	LV
Width	454.15±52.52±18.56 (410.71-564.39) 11.56%	470.40±51.57±16.31 (389.17-547.26) 10.96%	LV
Neck length	203.04±28.53±10.08 (165.23-233.20) 14.05%	168.28±30.40±9.61 (104.38-206.65) 18.02%	MV
Stylet length	15.79±1.46±0.51 (12.89-16.97) 9.29%	16.08±0.79±0.25 (15.07-17.26) 4.93%	LV
LMB	39.65±3.19±1.12 (35.04-42.77) 8.05%	39.85±4.53±1.43 (30.12-45.69) 11.37%	LV
WMB	38.79±3.27±1.09 (33.98-41.93) 8.43%	39.32±4.29±1.351 (30.02-44.89) 10.92%	LV
a	1.56±0.15±0.05 (1.38-1.79) 9.81%	1.50±0.09±0.02 (1.37-1.65) 5.97%	LV
Perineal pattern			
LVS	25.46±1.45±0.51 (23.29-27.80) 5.72%	25.17±1.75±0.55 (22.35-28.88) 6.82%	LV
AVS	18.20±1.65±0.58 (16.05-20.21) 9.07%	19.85±2.02±0.64 (16.39-23.26) 10.22%	LV
ATT	16.17±8.01±1.00 (13.19-21.21) 17.50%	14.19±1.94±0.61 (11.32-18.10) 13.69%	MV
IPD	24.42±2.35±0.83 (20.94-28.70) 9.63%	26.25±4.66±1.47 (17.68-31.55) 17.78%	MV

*LV- least variable (<12%):MV-moderately variable (12-20%); HV-highly variable (>20%), CR= Character ranking. LMB- length of median bulb, WMB- width of median bulb, a- length/width ratio, LVS-length of vulval slit, AVS-anus to vulval slit, ATT-anus to tail terminus, IPD-interphasmidial distance.

Table 52. Morphometric characters of second stage juveniles of *M. javanica* from three districts in Kerala, [Mean±SD±SE;(range);CV%], n=10

Character (µm)	Populations		CR*
	Idukki	Thrissur	
Females			
Length	403.43±6.46+2.28 (395.94-410.71) 1.60%	380.43±28.98±9.16 (338.64-419.88) 7.61%	LV
Stylet length	14.05±0.49±0.17 (13.56-14.91) 3.53%	13.54±0.33±0.10 (13.14-14.22) 2.45%	LV
H-MB	51.70±2.55±0.90 (46.22-54.72) 4.93%	49.87±1.51±0.47 (48.19-52.09) 3.03%	LV
ABW	10.40±0.38±0.13 (9.84-10.98) 3.67%	10.07±0.62±0.91 (9.11-11.00) 6.20%	LV
Tail length	51.12±2.87±1.01 (45.46-54.43) 5.62%	53.11±3.33±1.05 (48.19-58.31) 6.28%	LV
c	7.98±0.46±0.16 (7.18-8.54) 5.77%	7.16±0.38±0.12 (6.52-7.85) 5.39%	LV
c'	5.27±0.58±0.20 (4.91-6.54) 11.11%	5.30±0.39±0.12 (4.75-5.89) 7.45%	MV

*LV- least variable (<8%):MV-moderately variable (8%-12%); HV-highly variable (>12%), CR= Character ranking.
H-MB-head to median bulb; ABW-anal body width ;c- length/tail length; c'- tail length/anal body width

C. Second stage juveniles (J_2):

The average body length of second stage juveniles was 308.43 to 403.43 µm, with maximum body length recorded in Idukki population. The body length, stylet length, H-MB, ABW, tail length and ratio c were the least variable characters and the maximum mean values being 403.43 µm, 14.05 µm , 51.70 µm, 10.403 µm, 53.11 µm and 7.98 µm respectively. The maximum stylet length was observed in Idukki population whereas minimum value was observed in Thrissur population (13.54 µm). The characters ratio c' was moderately variable with maximum variation in Idukki population and maximum mean value being 5.307 µm. The tail was longer in Thrissur population and smaller in Idukki population (51.12 µm).

4.2.7 Morphometrics of Mature Females, Perineal Pattern and Second Stage Juveniles of *M. javanica* in Four Crops in Kerala

The morphometric characters of mature females, perineal pattern and second stage juveniles of *M. javanica* in four crops in Kerala are given in tables 53 and 54.

A. Mature females:

The range for mean values of body length and width in the four populations were 685.45 to 735.32 µm and 410.71 to 453.50 µm, respectively, with the maximum length in banana population and maximum width in tomato population. The character length showed maximum variation within the population in banana which was up to 14.38 per cent and the character width showed maximum variation in tomato which was up to 11.85 per cent.

The character of neck length was highly variable with maximum variation in banana population (CV 31.70%). The maximum mean value for neck length was observed in banana population (221.76 µm) and the least in brinjal population (187.31 µm). Stylet length showed moderate variation among the populations in their mean values and the maximum mean value was observed in banana population (16.55 µm).

The size of the median bulb varied from 35.58 to 41.58 µm and 34.93 to 41.05 µm in length (LMB) and width (WMB) respectively, with maximum length and width in banana population. The ratio a was moderately variable with the maximum mean value for tomato population (1.59 µm) and least for banana population (1.49 µm).

B. Perineal pattern:

The characters LVS and AVS were maximum in tomato population (26.43 µm) and brinjal population (18.70 µm) respectively. The coefficient of variability for the four characters of perineal patterns varied from population to population. The characters LVS and AVS were rated as least variable with maximum variation in tomato population (CV 9.83%) and banana population (11.73%) respectively. The character ATT was highly variable with maximum variation in okra (CV 21.28%) and the character IPD was moderately variable with maximum variation in banana population (CV 12.25%). Banana population showed maximum mean value for IPD (27.74 µm).

C. Second stage juveniles (J_2):

The average body length of second stage juveniles was 396.60 to 403.59 µm, with maximum body length recorded in banana population. The body length, stylet length, H-MB were the least variable characters and the maximum mean values being 403.59 µm, 14.01 µm and 53.39 µm respectively. The maximum stylet length was observed in brinjal population whereas minimum value was observed in okra population (13.56 µm). The characters ABW was moderately variable with maximum variation in okra population and the maximum mean value being 9.84 µm.

Tail length, ratio c and c' were highly variable with maximum variation in okra population and maximum mean values being 52.22 µm, 8.54 µm and 5.79 µm respectively.

Table 53.Morphometric characters of mature females and perineal pattern of *M. javanica* in four crops in Kerala, [Mean±SD±SE;(range);CV%], n=10

Character (µm)	Populations				CR*
	Brinjal	Okra	Tomato	Banana	
Females					
Length	685.45±34.10±19.69 (646.28-708.57)4.97%	699.70±65.72±46.47 (653.23-746.17) 9.39%	712.09±39.73±28.09 (683.99-740.18) 5.58%	735.32±105.63±32.16 (562.81-90.22) 14.38%	MV
Width	439.64±27.70±15.99 (416.66-470.40) 6.30%	451.30±21.11±14.93 (436.37-466.23)4.67%	453.50±53.89±38.11 (415.38-491.61)11.85%	410.71±33.50±10.38 (361.57-482.98) 8.12%	LV
Neck length	187.31±31.582±18.234 (168.28-223.774)16.86%	199.08±47.86±33.84 (165.23-232.93)24.04%	206.27±38.09±26.93 (179.33-233.20)18.46%	221.76±71.53±21.50 (148.24-369.0731.70%	HV
Stylet length	15.77±1.15±0.66 (14.49-16.74) 7.31%	16.06±1.17±0.83 (15.23-16.89)7.31%	14.72±2.59±1.83 (12.89-16.55)17.59%	16.55±0.77±0.24 (15.16-17.28) 4.12%	MV
LMB	41.58±1.53±0.88 (39.85-42.77)3.68%	41.48±1.81±1.28 (40.20-42.77)4.38%	39.37±2.76±1.95 (37.42-41.32)7.01%	35.58±4.30±1.72 (30.19-45.10) 13.79%	MV
WMB	41.05±1.49±0.86 (39.32-41.93)3.63%	40.91±2.68±1.89 (39.02-42.81)6.55%	37.14±4.46±3.15 (33.98-40.29)12.01%	34.93±4.47±1.41 (28.48-39.26) 13.97%	MV
a	1.57±0.12±0.07 (1.49-1.72)8.05%	1.56±0.20±0.14 (1.42-1.71)13.05%	1.59±0.28±0.20 (1.38-1.79)17.83%	1.49±0.15±0.08 (1.40-2.73) 15.55%	MV
Perineal pattern					
LVS	24.36±1.83±1.05 (22.25-25.52)7.51%	24.24±2.44±0.76 (19.46-26.56) 9.83%	26.43±1.93±1.36 (25.06-27.80)7.32%	24.31±1.43±1.01 (23.29-25.32)5.91%	LV
AVS	18.70±1.64±0.94 (16.82-19.85)8.70%	16.05±1.75±0.55 (14.17-18.19) 10.33%	18.08±1.76±1.24 (16.83-19.32) 9.75%	18.66±2.19±1.54 (17.11-20.21)11.73%	LV
ATT	17.26±3.58±2.07 (14.19-21.21) 20.79%	14.38±3.06±0.97 (9.19-19.90) 21.282%	14.00±1.15±0.81 (13.19-14.82) 8.20%	17.70±2.72±1.92 (15.78-19.63)15.37%	HV
IPD	23.79±2.67±1.54 (20.94-26.25) 11.23%	22.46±2.29±0.35 (18.19-27.09) 11.84%	24.40±1.15±0.81 (23.58-25.21) 4.72%	26.41±3.23±2.28 (24.12-28.70)12.25%	MV

*LV- least variable (<12%):MV-moderately variable (12-20%); HV-highly variable (>20%), CR= Character ranking. LMB- length of median bulb, WMB-width of median bulb, a- length/width ratio, LVS-length of vulval slit, AVS-anus to vulval slit, ATT-anus to tail terminus, IPD-interphasmidial distance.

Table 54. Morphometric characters of second stage juveniles of *M. javanica* in four crops in Kerala, [Mean±SD±SE;(range);CV%], n=10

Character (µm)	Populations				CR*
	Brinjal	Okra	Tomato	Banana	
Length	399.23±16.40±9.47 (380.43-410.71)4.11%	396.60±26.54±8.23 (359.43-420.34) 6.07%	398.12±3.07±2.17 (395.94-400.30)0.77%	403.59±8.47±5.99 (397.60-409.58)2.10%	LV
Stylet length	14.01±0.52±0.30 (13.54-14.57)3.72%	13.56±0.63±0.20 (12.60-14.58) 4.65%	13.98±0.49±0.34 (13.64-14.33)3.50%	13.74±0.14±0.10 (13.63-13.84)1.08%	LV
H-MB	49.71±3.41±1.97 (46.22-53.04)6.86%	52.32±3.49±1.61 (47.64-57.24) 6.71%	53.39±1.88±1.33 (52.06-54.72)3.52%	51.63±2.00±1.41 (50.21-53.04)3.87%	LV
ABW	10.34±0.24±0.14 (10.07-10.56)2.36%	9.84±1.01±0.32 (8.00-10.86) 10.31%	10.12±0.16±0.11 (10.00-10.24)1.64%	10.68±0.42±0.30 (10.38-10.98)3.98%	MV
Tail length	52.22±0.83±0.48 (51.45-53.11)1.60%	45.46±15.08±4.77 (34.47-60.14) 33.06%	51.64±3.94±2.78 (48.86-54.43) 7.63%	51.33±0.49±0.34 (50.98-51.67)0.96%	HV
c	7.65±0.42±0.24 (7.16-7.09) 5.49%	8.54±1.81±0.57 (6.05-11.19) 21.27%	8.32±0.86±0.61 (7.71-8.93)10.37%	8.13±0.47±0.33 (7.79-8.47)5.89%	HV
c'	5.05±0.22±0.12 (4.91-5.30)4.38%	4.95±1.10±0.34 (3.38-7.02) 21.27%	5.10±0.26±0.19 (4.91-5.29)5.26%	5.79±1.14±0.81 (4.91-6.54)20.05%	HV

*LV- least variable (<8%):MV-moderately variable (8%-12%); HV-highly variable (>12%), CR= Character ranking.
H-MB-head to median bulb; ABW-anal body width ;c- length/tail length; c'- tail length/anal body width

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4.2.8 Morphometrics of Mature Females, Perineal Pattern and Second Stage Juveniles of *M. arenaria* in Four Crops in Kerala

The morphometric characters of mature females, perineal pattern and second stage juveniles of *M. arenaria* in four crops in Kerala are given in tables 55 and 56.

A. Mature females:

The range for mean values of body length and width in the four populations were 785.41 to 854.41 µm and 483.88 to 534.78 µm, respectively, with the maximum body length and width being in banana and tomato population respectively. The character body length and width showed maximum variation within the population in brinjal which was up to 18.04 per cent for length and 15.05 per cent for width.

The character neck length was highly variable with maximum variation in brinjal population (CV 30.10%). The maximum mean value for neck length was observed in banana population (257.01 µm) and the least in brinjal population (203.63 µm). Stylet length showed least variation among the populations in their mean values and the maximum mean value was observed in banana population (17.43 µm).

The size of the median bulb varied from 39.16 to 41.57 µm and 34.66 to 41.03 µm in length (LMB) and width (WMB) respectively, with maximum length and width in okra population. The ratio 'a' was highly variable character with the maximum mean value for banana population (1.69 µm) and least for okra population(1.58 µm).

B. Perineal pattern:

The characters LVS and AVS were maximum in tomato population (28.81 µm) and okra population (19.82 µm) respectively. The coefficient of variability for the four characters of perineal patterns varied from population to population. The characters LVS was rated as moderately variable with maximum variation in

Table 55. Morphometric characters of mature females and perineal pattern of *M. arenaria* in four crops in Kerala, [Mean±SD±SE;(range);CV%], n=10

Character (µm)	Populations				CR*
	Brinjal	Okra	Tomato	Banana	
Females					
Length	785.41±141.68±44.80 (639.15-1019.46) 18.04%	814.03±128.66±74.28 (665.93-898.37)15.80%	845.57±100.84±71.30 (534.27-916.88)11.92%	854.41±103.31±73.05 (781.36-927.46)12.09%	MV
Width	483.88±76.06±24.05 (359.66-600.06) 15.05%	499.52±47.87±27.64 (459.93-552.73) 9.58%	534.78±75.71±53.53 (481.24-588.32)14.15%	503.51±19.07±13.48 (490.02-516.99)3.78%	MV
Neck length	203.63±61.30±19.38 (104.70-302.42) 30.10%	236.03±44.26±25.55 (191.49-280.01)18.75%	236.90±40.36±28.54 (208.35-265.44)17.03%	257.01±56.42±39.90 (217.11-296.91)21.95%	HV
Stylet length	17.18±0.83±0.26 (16.28-18.57) 4.86%	16.15±0.74±0.42 (15.53-16.98)4.59%	16.38±0.64±0.45 (15.92-16.84)3.95%	17.43±0.63±0.44 (16.98-17.88)3.64%	LV
LMB	41.57±2.86±0.90 (35.73-45.97) 6.89%	41.93±0.43±0.25 (41.54-42.40)1.03%	39.16±1.55±1.09 (38.06-40.25)3.96%	40.95±2.43±1.72 (39.23-42.67)5.94%	LV
WMB	34.66±4.07±1.28 (30.197-40.69) 11.74%	41.03±0.74±0.43 (40.42-41.86)1.81%	38.75±1.87±1.32 (37.43-40.08)4.83%	40.40±1.95±1.38 (39.02-41.78)4.83%	LV
a	1.67±0.34±0.10 (1.13-2.13) 20.49%	1.58±0.11±0.06 (1.45-1.68)7.31%	1.62±0.03±0.02 (1.59-1.64) 2.05%	1.69±0.13±0.09 (1.60-1.79)8.00%	HV
Perineal pattern					
LVS	27.75±2.37±0.68 (23.34-30.27) 8.55%	26.91±0.99±0.57 (26.29-28.07)3.71%	28.88±4.72±3.34 (25.47-32.15)16.39%	25.53±0.80±0.57 (24.96-26.10)3.15%	MV
AVS	19.06±2.02±0.58 (16.06-22.42) 10.63%	19.82±1.77±1.02 (18.01-21.56)8.95%	19.55±2.26±1.60 (17.95-21.16)11.58%	19.16±0.55±0.39 (18.77-19.56)2.90%	LV
ATT	19.48±1.38±0.39 (17.61-22.70) 7.10%	19.76±0.53±0.30 (19.16-20.19)2.70%	16.01±0.24±0.17 (15.83-16.18)1.55%	18.23±0.94±0.66 (17.56-18.90)5.17%	LV
IPD	33.55±2.75±0.79 (30.20-39.09) 8.21%	30.69±0.63±0.36 (30.10-31.37)2.08%	31.82±1.90±1.34 (30.47-33.16)5.98%	28.19±2.47±1.74 (26.44-29.93)8.76%	LV

*LV- least variable (<12%):MV-moderately variable (12-20%); HV-highly variable (>20%), CR= Character ranking. LMB- length of median bulb, WMB- width of median bulb, a- length/width ratio, LVS-length of vulval slit, AVS-anus to vulval slit, ATT-anus to tail terminus, IPD-interphasmidial distance.

Table 56.Morphometric characters of second stage juveniles of *M. arenaria* in three districts in Kerala, [Mean±SD±SE;(range);CV%], n=10

Character (µm)	Populations				CR *
	Brinjal	Okra	Tomato	Banana	
Length	420.37±12.81±4.30 (400.41-440.29) 3.28%	408.75±12.95±7.47 (395.49-42.36)3.16%	401.84±30.68±21.70 (380.14-423.54)7.63%	414.77±19.27±13.62 (401.14-428.39)4.64%	LV
Stylet length	13.81±0.61±0.27 (12.76-14.78) 3.28%	14.06±0.26±0.15 (13.76-14.23)1.87%	13.78±0.06±0.04 (13.74-13.83)0.49%	13.93±0.01±0.01 (13.92-13.94)0.10%	LV
H-MB	48.93±2.78±1.32 (45.25-53.11) 7.21%	48.87±3.13±1.81 (45.32-51.30)6.42%	48.63±2.36±1.67 (46.96-50.31)4.86%	49.84±1.57±1.11 (48.73-50.95)3.15%	LV
ABW	10.21±2.11±0.53 (8.37-11.31) 10.11%	11.04±0.37±0.21 (10.80-11.48)3.42%	10.71±0.39±0.27 (10.43-10.99)3.65%	11.28±0.75±0.53 (10.74-11.81)6.72%	MV
Tail length	49.08±6.72±1.21 (40.11-57.00) 10.98%	49.55±1.85±1.07 (48.01-51.59)3.75%	47.63±1.80±1.27 (46.36-48.91)3.78%	48.54±1.88±1.33 (47.21-49.88)3.88%	MV
c	8.56±0.60±0.31 (7.66-9.98) 12.35%	8.03±0.52±0.30 (7.73-8.77)6.31%	8.515±0.203±0.144 (8.371-8.658)2.383%	8.59±0.14±0.10 (8.49-8.69)1.65%	HV
c'	4.80±0.50±0.27 (3.81-5.20) 10.98%	5.01±0.71±0.41 (4.44-5.81)14.32%	5.220±1.077±0.762 (4.458-5.981)20.633%	4.89±0.93±0.65 (4.23-5.55)19.02%	HV

*LV- least variable (<8%):MV-moderately variable (8%-12%); HV-highly variable (>12%), CR= Character ranking.
H-MB-head to median bulb; ABW-anal body width ;c- length/tail length; c'- tail length/anal body width

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tomato population (CV 16.39%). The character AVS, ATT and IPD were least variable and the maximum mean values being 19.82 µm (okra), 19.76 µm (okra) and 33.55 µm (brinjal) respectively.

C. Second stage juveniles (J_2):

The average body length of second stage juveniles was 401.84 to 420.37 µm, with maximum body length recorded in brinjal population. The body length, stylet length, H-MB were the least variable characters and the maximum mean values being 420.37 µm, 14.06 µm and 49.84 µm respectively. The maximum stylet length was observed in okra population whereas minimum value was observed in tomato population (13.78 µm). The characters ABW and tail length were moderately variable with maximum variation in brinjal population (CV 10.11 per cent and 10.98 per cent respectively).

Ratio c and c' were highly variable with maximum variation in okra population and tomato population respectively. The maximum mean values for c and c' were 8.59 µm (banana) and 5.22 µm (tomato) respectively.

Discussion

5. DISCUSSION

Accurate identification of *Meloidogyne* species is essential for efficient and successful management of these nematodes. Morphological and morphometric studies are useful in identification of root-knot nematodes from different crops and locations which in turn help in species specific management. The study focused on the identification of *Meloidogyne* species primarily based on the morphology of perineal pattern and other morphological characters of females, second stage juveniles and males which infest different crops in different localities in three districts of Kerala. The study also focussed on the inter and intra specific morphological and morphometrical variations of different species in different hosts and districts. This gave an insight on the different species of root knot nematode in brinjal, okra, tomato and banana in Thiruvananthapuram, Idukki and Thrissur districts of Kerala.

Results from sampled areas indicated the presence of *M. incognita*, *M. javanica* and *M. arenaria,* which was not a surprise as they were indicated as the major *Meloidigyne* species in tropical regions (Taylor and Sasser, 1978; Perry and Moens, 2009) like Kerala where the annual temperature ranges between 18 to 35°C.

The present study records the report of *M. incognita* from brinjal, okra, tomato and banana in Dhanuvachapuram, Kattakada and Vellayani of Thiruvananthapuram district, brinjal and tomato in Thanniyam of Thrissur district and tomato (Balagram), okra and tomato (Thovalappady) of Idukki district.

M. javanica was recorded from brinjal in Kannara of Thrissur district and brinjal and banana (Balagram),brinjal, okra, tomato and banana (Pampadumpadumpara), tomato and banana (Thovalappady) of Idukki district.

M. arenaria was recorded from brinjal, okra, tomato and banana (Chazhoor) and okra, tomato and banana (Thalikulam) and brinjal (Thanniyam) of Thrissur district. The study presents the first report of *M. arenaria* from

banana in Kerala. These results obtained provide an additional information on the host and locality status of *Meloidogyne* species in Kerala. Among the sampled populations, *M. hapla* was not identified which shows that *M. hapla* is not common in Kerala conditions.

Surprisingly, one of the population showed morphological and morphometrical characters similar to *M. chitwoodi* from okra in Thiruvananthapuram. As this species was not recorded and identified from India earlier, further confirmation through molecular analyses is required which provides additional information to the host status of *M. chitwoodi* which usually infests several monocots and dicots including potato, tomato and carrot (Santo *et al.*, 1980).

Out of the 36 sampled populations, a single population of male was obtained from tomato in Pampadumpara, which suggests that the extent of parthenogenesis of root knot nematode was found to be very high (97.22%) in Kerala population which further points the fact of parthenogentic (mitotic) reproduction in *M. incognita*, *M. javanica* and *M. arenaria* (Taylor and Sasser, 1978).

M. incognita dominated the samples presently studied and collected from different crops with 55.55 per cent in brinjal and tomato and 44.44 per cent in okra and banana followed by *M. javanica* (Figure 1). These results were in agreement with Eisenback *et al.* (1981) and Khan *et al.* (2014) where *M. incognita* was the most prevalent among all the *Meloidogyne* species. The above results also corroborates with the findings of Sahu *et al.*, 2015, who reported *M. incognita* and *M. javanica* as the predominant nematode species associated with vegetables.

In Thrivananthapuram district, *M. incognita* was present while in Idukki, *M. javanica* and *M. incognita* were present. Among the *Meloidogyne* species recorded in crops of agricultural importance in tropical and subtropical regions, *M. incognita* and *M. javanica* were considered as widespread (Sasser, 1979). The present findings further confirm the contention. In Thrissur district, *M. arenaria*

and *M. javanica* were found to be the species infesting the crops. The above results further confirmed that the prevalence of different *Meloidogyne* species varied according to locality (Estahni, 2009), district and crop (Sao *et al.*, 2008: Gautam *et al.*, 2014; Sahu *et al.*, 2015)

The study indicated *M. incognita* as the major species of root knot nematode in Thiruvananthapuram district (91.66%) with highest percentage of occurrence in brinjal and tomato (27.77). In Idukki district, the major species of root knot nematode was *M. javanica* (66.66%) with highest percentage of occurrence in brinjal and banana (33.33). In Thrissur district, *M. arenaria* was found to be the major species (66.66%) with highest percentage of occurrence in okra (37.5) (Figure 2). The three districts, Thiruvananthapuram, Idukki and Thrissur fall in different agroclimatic regions *i.e.*, Southern low land, Southern high land and Central mid land respectively. The obtained results were in accordance with those reported by Khan *et al.* (2014) where in the species varied in different agroclimatic regions of India.

The study examined the morphological and morphometrical variations of *M. incognita*, *M. javanica* and *M. arenaria* from four crops in three districts in Kerala which provides additional information to the works by Sahoo and Ganguly (2000) and Kaur and Attri (2013a) who studied the morphological and morphometrical variations of *M. javanica* and *M. incognita* in India.

Intraspecific morphological variations were observed within the three species with respect to shape of females, length and position of neck, perineal pattern morphology, tail characters including rectum dilation. The variations in morphological characters among the individuals may be geographical, ecophenotypic or host induced as reported by Ahmed and Jairajpuri (1981).

On comparing the size of mature females among the vegetable crops, it was observed that the body size of females of *M. incognita*, *M. javanica* and *M. arenaria* was higher in tomato plants. Similar results were obtained by Davide (1979) where adult females were bigger and broader in tomato plants. These

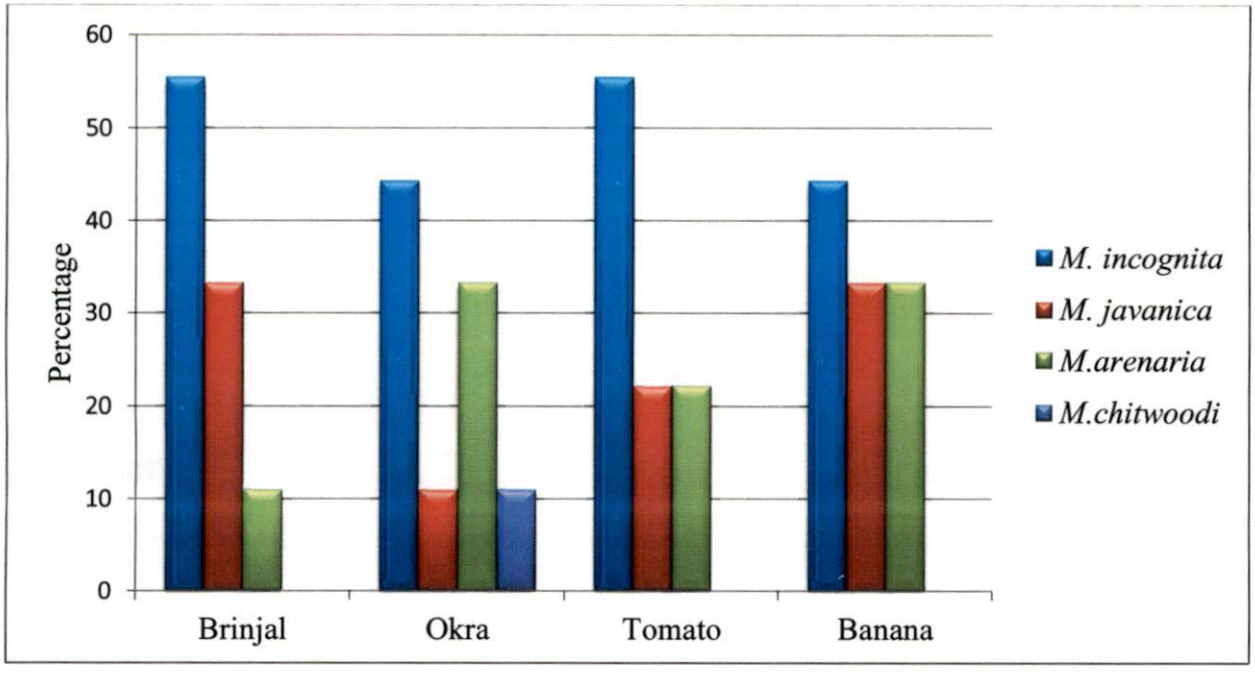

Figure 1. Occurrence of different *Meloidogyne* spp. in four crops in Kerala

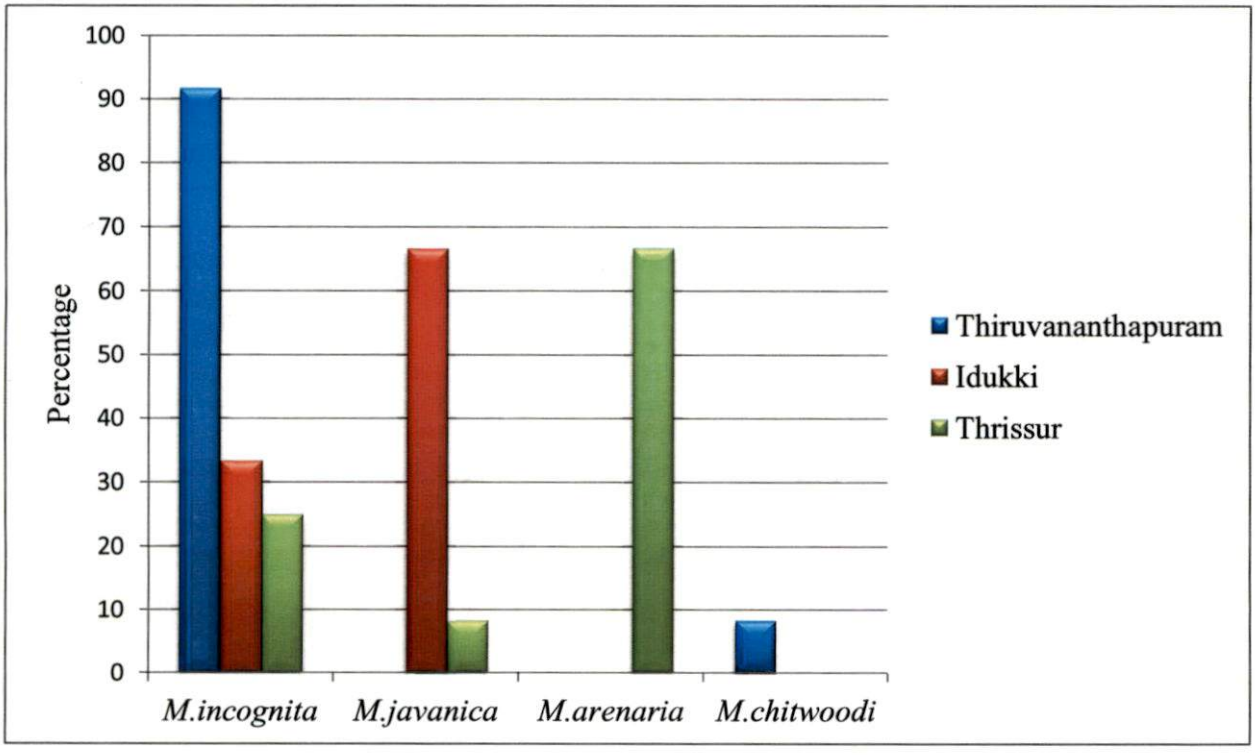

Figure 2. Occurrence of different *Meloidogyne* spp. from three districts of Kerala

results can be explained by the findings of Davide (1980), Pant *et al.* (1983), Powers *et al.* (1991) where the size of mature females varied with the degree of susceptibility of crops to *Meloidogyne* species. Davide (1980) reported that the nematodes in more susceptible crops were relatively bigger in size than the less susceptible crops. Hence, it can be concluded that among the vegetable crops (brinjal, okra and tomato), tomato is highly susceptible to root knot nematodes.

Intraspecific variations in morphometric characters of mature females and perineal pattern of *M. incognita* in three districts of Kerala showed that the characters length, width, neck length, LMB, WMB and ATT were found to be moderately variable and the other characters were least variable. Interpopulation comparison of morphometric characters of second stage juveniles indicated that Thrissur population to be the smallest of all populations. All other populations shared almost similar mean values for body length. The characters length, stylet length, H-MB, ABW and tail length were found to be least variable whereas ratio c and c' were moderately variable. Based on the CV values, the characters length, width, neck length, stylet length, LMB, WMB and ratio a of females, LVS, AVS, ATT and IPD of perineal pattern and length, stylet length, H-MB, ABW, tail length, ratio c and c' were recorded as stable characters and found useful in characterizing species.

Comparing the morphometric characters of three populations with type description of *M. incognita* by Kofoid and White (1919) showed that these populations shared most of the characters except for slightly larger size of females, stylet length and length of juveniles in Kerala populations. The populations studied where in conformity with the morphological characters of the type species. The differences were attributed as the intraspecific variations of *M. incognita*.

Comparing the characters of present populations with Indian populations of *M. incognita* (Kaur and Attri, 2013a) showed that the Kerala populations were similar in morphometrics with Indian populations with slight variations including

lower values for width, neck length and stylet length of females and higher values for length of juveniles which can be attributed to intraspecific variations.

Comapring the morphological characters of mature female and perineal pattern with four different host plants in Kerala, it was found that mean value for body length, width, neck length, stylet length, LMB, WMB, LVS, AVS and ATT were maximum in banana population. In the present study, the gross range of female stylet was between 13.64 to 17.90 µm with mean value of 16.30 µm which was exceptionally longer than earlier reported populations (Jepson, 1983; Chitwood, 1949; Hunt and Handoo, 2009). The variation can be attributed to reports by Jepson (1983) that the stylet structure is adapted to the feeding habit of nematode which usually varies with the host plant.

Interpopulation comparison of second stage juveniles of *M. incognita* with four different host plants showed that the maximum mean values for length, stylet length, ABW, tail length and ratio c were maximum for banana population. On comparing the CV values, it was found that the characters length, stylet length, H-MB, ABW, tail length and ratio c' were stable characters in the population and ratio c was not stable exhibiting high variability.

Interpopulation comparison of morphometric characters of mature females, perineal pattern and second stage juveniles of *M. javanica* in two districts in Kerala showed that all the characters of females, perineal pattern and second stage juveniles were stable characters. In second stage juveniles, Thrissur population was the smallest.

Comparing the morphometric characters of the present populations with the type description of *M. javanica* by Chitwood (1949) and redescription by Whitehead (1968), the morphometrics of the characters were almost similar but with slightly larger values for the characters body length and width of females and smaller values for stylet length of females and body length of juveniles. Comparing the morphometric characters with the morphometrics of Indian populations of *M. javanica* (Sahoo and Ganguly, 2000), these populations shared

most of the characters except for slightly larger body length of females and juveniles. The present populations were also in similarity with the morphological characters of the species outlined by Jepson (1987) and, Sahoo and Ganguly (2000).

After comparing the mature females and perineal pattern of *M. arenaria* from four host plants in Kerala, the characters such as length, width and LVS were found to be moderately variable and the other characters were least variable except neck length which was highly variable. Interpopulation comparison of morphometric characters of second stage juveniles indicated that tomato population to be the smallest of all populations. The characters length, stylet length and H-MB were found to be least variable whereas ABW and tail length were moderately variable and ratio c and c' were highly variable.

Based on the CV values, the characters *viz.,* length, width, neck length, stylet length, LMB and WMB of females, LVS, AVS, ATT and IPD of perineal pattern and length, stylet length, H-MB, ABW and tail length were recorded as stable characters and found useful in characterizing species.

Comparing the morphometric characters of the present populations with the type description of *M. arenaria* by Chitwood (1949) and Cliff and Hirschmann (1985), the morphometrics of the characters studied were almost similar but with slightly larger values for the characters like body length and stylet length of females and smaller values for body length of juveniles. Comparing the morphometric characters with the morphometrics of populations of *M. arenaria* (Garcia and Sanchez-Puerta, 2012), these populations shared most of the characters except for slightly smaller body length of females and juveniles.

Morphological and morphometric variations of *Meloidogyne* species infecting brinjal, okra, tomato and banana from Thiruvananthapuram, Idukki and Thrissur districts has been documented, which in turn helps in use of resistant varieties and species specific management practices to control these nematodes.

Summary

6. SUMMARY

Root knot nematodes are economically important polyphagous group of highly adapted plant parasites which are distributed worldwide and can parasitize nearly every species of cultivated plants. The attacks by these nematodes also pay way to infection by secondary pathogens which further increase the severity of damage. The lack of awareness about the existence of these nematodes due to its microscopic nature and lack of characteristic symptom often make them as neglected one, but are of full potential to cause serious threat to crop production. Morphological and morphometric studies are useful in identification of root-knot nematodes from different crops and locations which in turn help in species specific management. Varietal resistance is reported in some crops and identification of nematode species in an area will help in selection of plant varieties resistant to that species for cultivation and thus, effective management practices can be developed by precise identification of nematode species and variation within single nematode species. In Kerala, vegetables and banana are the most important crops under cultivation and are also more prone to nematode infections. In this ground, the study entitled "Morphological variations of root knot nematode in vegetables and banana" was undertaken at Department of Agricultural Entomology, College of Agriculture, Vellayani during 2015-17.

The main objective of the present work was to study the morphological and morphometric variations of root-knot nematode in brinjal, okra, tomato and banana in Kerala.

The salient findings of the present study are as follows

Four species of root knot nematode, *M. incognita* (Kofoid & White, 1919) Chitwood, 1949, *M. javanica* (Treub, 1885) Chitwood, 1949, *M. arenaria* (Neal, 1889) Chitwood, 1949 and *M. chitwoodi* Golden, O'Bannon, Santo and Finley, 1980 were identified from brinjal, okra, tomato and banana in Thiruvananthapuram, Idukki and Thrissur districts of Kerala.

The study presents the report of *M. incognita* from brinjal, okra, tomato and banana in Dhanuvachapuram, Kattakada and Vellayani of Thiruvananthapuram district, brinjal and tomato in Thanniyam of Thrissur district and tomato (Balagram), okra and tomato (Thovalappady) of Idukki district.

M. javanica was identified from brinjal in Kannara of Thrissur district and brinjal and banana (Balagram), brinjal, okra, tomato and banana (Pampadumpadumpara), tomato and banana (Thovalappady) of Idukki district.

M. arenaria was identified from brinjal, okra, tomato and banana (Chazhoor) and okra, tomato and banana (Thalikulam) and brinjal (Thanniyam) of Thrissur district. The study presents the first report of *M. arenaria* from banana in Kerala. These results obtained provide an additional information on the host and locality status of *Meloidogyne* species in Kerala. Among the sampled populations, *M. hapla* was not identified which shows that *M. hapla* is not common in Kerala conditions.

The study recorded the first report of species having morphological and morphometrical characters similar to *M. chitwoodi* from okra in Thiruvananthapuram which opens way to molecular studies in future.

Among the root knot nematodes, *M. incognita, M. javanica and M. arenaria* were the major species infesting vegetables and banana in Kerala among which *M. incognita* was found to be the major species in brinjal (55.55%), okra (44.44%), tomato (55.55%) and banana (44.44%) in Thiruvananthapuram, Idukki and Thrissur districts.

The study indicated *M. incognita* as the major species of root knot nematode in Thiruvananthapuram district (91.66%) with highest percentage of occurrence in brinjal and tomato (27.77). In Idukki district, the major species of root knot nematode was *M. javanica* (66.66%) with highest percentage of occurrence from brinjal and banana (33.33). In Thrissur district, *M. arenaria* was

found to be the major species (66.66%) with highest percentage of occurrence in okra (37.5).

Intraspecific morphological variations were observed within the three species with respect to shape of females, length and position of neck, perineal pattern morphology, tail characters including rectum dilation. The shape of females varied from pear shaped to saccate shaped to kidney shaped with short to long neck directed ventrally or at an angle to the body of nematode. The perineal pattern varied with respect to presence or absence of weak lateral lines in *M. incognita* populations whereas in *M. arenaria* populations, the perineal pattern varied with respect to presence of lateral line in one side of the pattern. The tail length, position of anus and rectum dilation was highly variable within the populations, with majority of the populations showing dilated rectum.

Interpopulation comparison of mature females of *M. incognita* showed that length, width, neck length, LMB (length of median bulb) and WMB (width of median bulb) were moderately variable (CV 3.928% to 18.419%). In perineal pattern, LVS (length of vulval slit), AVS (anus to vulval slit) and IPD (interphasmidial distance) were least variable (CV 2.092% to 7.359%). In second stage juveniles, the character ratio c was highly variable (CV 4.423% to 12.518%).

Interpopulation comparison of mature females and perineal pattern of *M. javanica* from surveyed districts showed that the characters neck length, ATT and IPD were moderately variable (CV 9.630% to 18.062%). In second stage juveniles, all the characters were least variable (CV 1.602% to 7.612%) except ratio c' which was moderately variable. On comparing the interpopulation variations of *M. javanica* in the four crops, the character neck length of females and ATT of perineal pattern (CV 8.028% to 31.701%) and the characters tail length, ratio c and c' (CV 0.960% to 21.279%) of second stage juveniles were highly variable.

Interpopulation comparison of mature females and perineal pattern of *M. arenaria* in four crops showed that the characters neck length and ratio a (length/width) were highly variable (CV 2.050% to 30.107%). Similarly in second stage juveniles, the characters c and c' were highly variable (CV 1.653% to 20.633%) in the population.

Intraspecific morphological and morphometric variations of *M. incognita, M. javanica, M. arenaria* were recorded from four host plants in three districts in Kerala. *M. arenaria* and *M. javanica* showed high variability between the populations compared to *M. incognita* in Kerala.

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Appendix

APPENDIX-I

COMPOSITION OF STAIN USED

1. Lactophenol-acid fucshin

5 ml of acid fucshin stock solution in 100 ml lactophenol

Preparation of lactophenol solution

Lactic acid	- 1 part
Phenol	- 1 part
Glycerine	- 2 parts
Distilled water	- 1 part

Preparation of acid fucshin stock solution

1 g of acid fucshin is dissolved in 100 ml distilled water

MORPHOLOGICAL VARIATIONS OF ROOT KNOT NEMATODE IN VEGETABLES AND BANANA

by

CHINCHU P. BABU

(2015-11-082)

Abstract of the thesis

Submitted in partial fulfilment of the

requirements for the degree of

MASTER OF SCIENCE IN AGRICULTURE

Faculty of Agriculture

Kerala Agricultural University

DEPARTMENT OF AGRICULTURAL ENTOMOLOGY

COLLEGE OF AGRICULTURE

VELLAYANI, THIRUVANANTHAPURAM-695522

KERALA, INDIA

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2017

ABSTRACT

The study entitled "Morphological variations of root knot nematode in vegetables and banana" was conducted at College of Agriculture, Vellayani during 2015-17 with the objective to study the morphological and morphometric variations of root knot nematode in brinjal, okra, tomato and banana in Kerala. Morphological and morphometrical studies of females, perineal pattern, second stage juveniles and males of root knot nematodes collected from Dhanuvachapuram, Kattakada and Vellayani of Thiruvananthapuram district; Balagram, Pampadumpara and Thovalappady of Idukki district; Chazhoor, Thalikulam and Thaniyam of Thrissur district infecting brinjal, okra, tomato and banana were done and the data was analysed to identify the species.

M.incognita (Kofoid & White, 1919) Chitwood, 1949, *M. javanica* (Treub, 1885) Chitwood, 1949, *M. arenaria* (Neal, 1889) Chitwood, 1949 and *M. chitwoodi* Golden, O'Bannon, Santo & Finley 1980 were identified from brinjal, okra, tomato and banana in Thiruvananthapuram, Idukki and Thrissur districts of Kerala. The study indicated *M. incognita* as the major species of root knot nematode in Thiruvananthapuram district (91.66%) with highest percentage of occurrence in brinjal and tomato (27.77). In Idukki district, the major species of root knot nematode was *M. javanica* (66.66%) with highest percentage of occurrence from brinjal and banana (33.33). In Thrissur district, *M. arenaria* was found to be the major species (66.66%) with highest percentage of occurrence in okra (37.5). *M. incognita* was found to be the major species in brinjal (55.55%), okra (44.44%), tomato (55.55%) and banana (44.44%) in Thiruvananthapuram, Idukki and Thrissur districts. The extent of parthenogenesis of root knot nematode was found to be very high (97.22%) in these populations.

Intraspecific morphological variations were observed within *M. incognita*, *M. javanica* and *M. arenaria* with respect to shape of females, length and position of neck, perineal pattern morphology, tail characters including rectum dilation.

Interpopulation comparison of mature females, perineal pattern and second stage juveniles of *M. incognita* showed that the characters length, width, neck length, stylet length, LMB, WMB and ratio a of females, LVS, AVS, ATT and IPD of perineal pattern and body length, stylet length, H-MB, ABW, tail length, ratio c and c' were recorded as stable characters. Interpopulation comparison of mature females, perineal pattern and second stage juveniles of *M. javanica* showed that all the characters of females, perineal pattern and second stage juveniles were stable characters and in *M. arenaria*, the characters like body length, width, neck length, stylet length, LMB and WMB of females, LVS, AVS, ATT and IPD of perineal pattern and length, stylet length, H-MB, ABW and tail length were recorded as stable characters and found useful in characterizing species.

Intraspecific morphological and morphometric variations of *M. incognita, M. javanica, M. arenaria* were recorded from four host plants in three districts in Kerala. *M. arenaria* and *M. javanica* showed high variability between the populations compared to *M. incognita* in Kerala. The study indicated that *M. incognita, M. javanica and M. arenaria* were the major species infesting vegetables and banana in Kerala. Among the sampled populations, *M. hapla* was not identified which shows that *M. hapla* is not common in Kerala conditions. The study recorded the first report of species having morphological and morphometrical characters similar to *M. chitwoodi* from okra in Thiruvananthapuram which opens way to molecular studies in future.

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