

**Morphological and morphometric variations of
Hoplolaimus and *Helicotylenchus***

A Thesis

Submitted to the
Assam Agricultural University

In partial fulfilment of the requirements for the degree of

MASTER OF SCIENCE (Agriculture)

IN

NEMATOLOGY

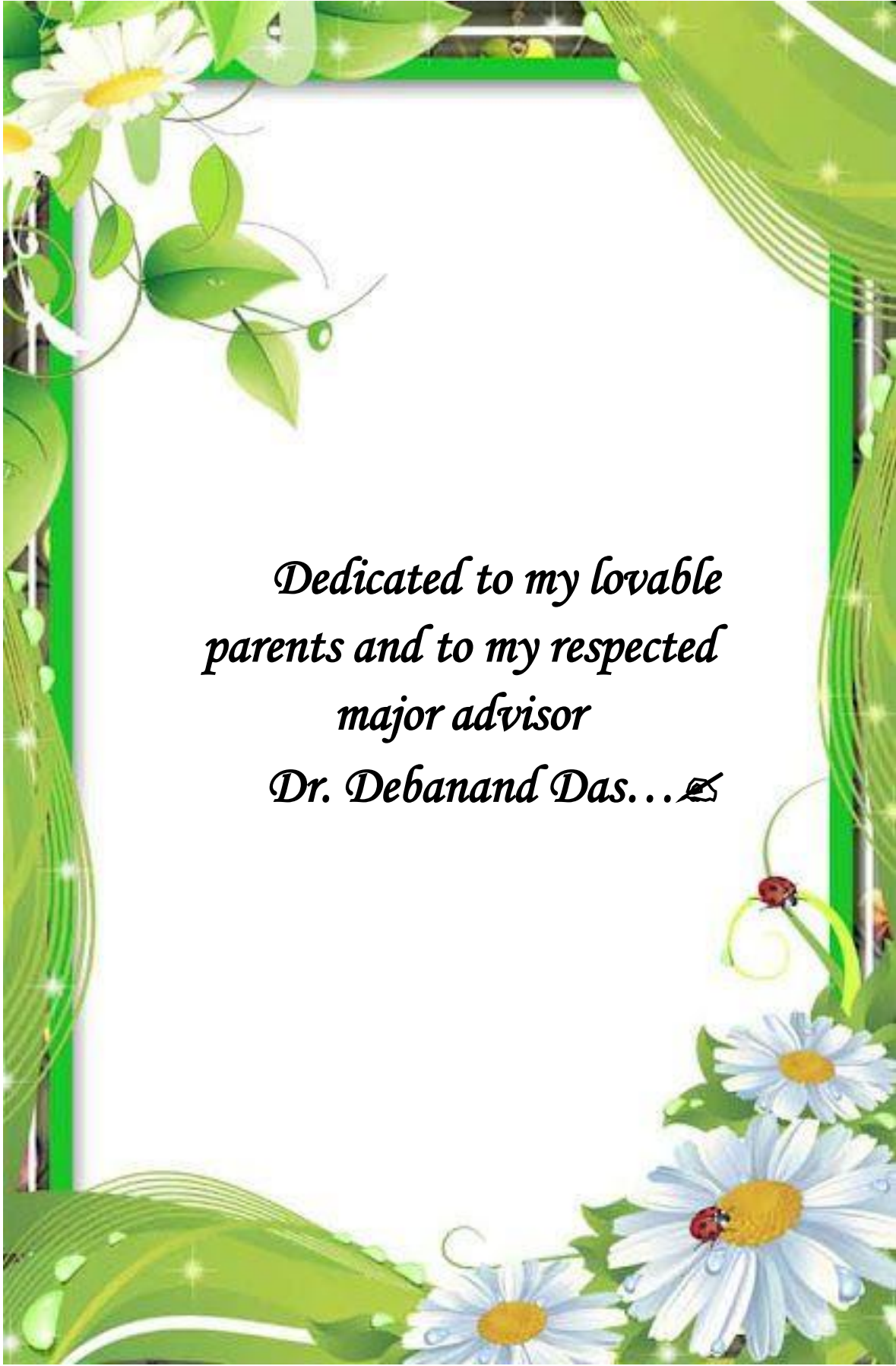


By

VENKADESH G

Regn. No. 193 of 2018
[Roll No. 2018-AMJ-167]

**DEPARTMENT OF NEMATOLOGY
FACULTY OF AGRICULTURE
ASSAM AGRICULTURAL UNIVERSITY
JORHAT-785 013 (ASSAM)
August, 2020**



*Dedicated to my lovable
parents and to my respected
major advisor
Dr. Debanand Das...✍*

ASSAM AGRICULTURAL UNIVERSITY
Faculty of Agriculture

CERTIFICATE – I

This is to certify that the thesis entitled “**Morphological and morphometric variations of *Hoplolaimus* and *Helicotylenchus***” submitted to the Faculty of Agriculture, Assam Agricultural University in partial fulfilment for the degree of **Master of Science (Agriculture) in Nematology** is a record of research work carried out by **Venkadesh G** under my personal supervision and guidance.

All helps received by him have been duly acknowledged.

No part of this thesis has been reproduced elsewhere for any degree.

Dated: Jorhat
The August, 2020

(Debanand Das)
Principal scientist
Department of Nematology
Faculty of Agriculture
Assam Agricultural University
Jorhat-785013 (Assam)

CERTIFICATE – II

This is to certify that the thesis entitled “**Morphological and morphometric variations of *Hoplolaimus* and *Helicotylenchus***” submitted by **Venkadesh G, Roll No. 2018-AMJ-167** to the Assam Agricultural University, in partial fulfilment of the requirements for the degree of **Master of Science (Agriculture)** in the discipline of **Nematology** has been examined and approved by the Student’s Advisory Committee after viva-voce.

(Debanand Das)
Major Advisor

Chairman
Board of Examiners

Members of the Advisory Committee:

1.
(Debanand Das)
2.
(B.N. Choudhury)
3.
(Pradip Kumar Borah)
4.
(Hemanta Saikia)

(B.N. Choudhury)
Professor & Head
Department of Nematology
Assam Agricultural University
Jorhat – 785013 (Assam)

(Ajit Baishya)
Director
Post Graduate studies
Assam Agricultural University
Jorhat – 785013 (Assam)

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Dated, Jorhat

The, 2020

The Author

ABSTRACT

Investigations were carried out to study the morphological and morphometric variations of genera *Hoplolaimus* and *Helicotylenchus* in relation to host plants and geographical locations of Assam. Total of 163 soil samples were collected from Rice, Maize, Banana, Mango, Jackfruit, Citrus, Pea and Tea, and from different geographical locations viz., Jorhat, Kokrajhar, Sivasagar, Kamrup, Lakhimpur, Dhemaji, Nagaon and KarbiAnglong district of Assam. The populations of both genera under survey were identified as *Hoplolaimus columbus*, *Hoplolaimus indicus*, *Helicotylenchus crenacauda* and *Helicotylenchus dihystra*. In the study no morphological variations have been observed in genera *Hoplolaimus* and *Helicotylenchus* in relation to both host plants and geographical locations.

Results of morphometric characters showed that body length, a ratio, oesophagus length, b ratio, oesophageal gland overlapping length, b' ratio, ABW, MB, V, V', stylet length, SE and Pp (only in *Hoplolaimus*) were regarded as least variable characters and considered highly stable in relation to host plants for genera *Hoplolaimus* and *Helicotylenchus*. The c ratio, number of tail annules and Pa of females were least variable characters; while, tail length and c' ratio were moderately variable characters in *Hoplolaimus columbus*. The c ratio, c' ratio, number of tail annules and Pa of females were regarded as moderately variable characters; while, tail length of females was regarded as highly variable character in *Hoplolaimus indicus*. In males of *H. indicus*, tail length, c ratio, c' ratio and Pa were regarded as least variable characters; while, bursa of males was regarded as moderately variable character. The tail length, c ratio, c' ratio and O of females were regarded as moderately variable characters in relation to host plants of *Helicotylenchus dihystra*.

Influence of geographical locations on morphometric characters revealed that the body length, a ratio, oesophagus length, b ratio, oesophageal gland overlapping length, ABW, MB, V, V', stylet length and Pp (only in *Hoplolaimus*) were least variable characters and considered highly stable characters in relation to geographical locations for genera *Hoplolaimus* and *Helicotylenchus*. The b' ratio, c ratio, c' ratio, SE and number of tail annules were least variable characters; while, tail length and Pa of females were moderately variable characters in *Hoplolaimus columbus*. The b' ratio, c ratio, c' ratio, SE, number of tail annules and Pa of females were moderately variable characters; while, tail length of was highly variable character in females of *Hoplolaimus*

indicus. In males of *H. indicus*, b' ratio, tail length, SE, Pp, spicule length and gubernaculum length were least variable characters; while, c ratio, c' ratio, Pa and bursa of males were moderately variable characters. In case of *Helicotylenchus crenacauda* the b' ratio and SE of females were regarded as least variable characters; while, tail length, c ratio, c' ratio and O of females were moderately variable characters. The b' ratio, tail length, c ratio and SE of females were regarded as least variable characters; while, c' ratio and O of females were regarded as moderately variable characters in relation to geographical locations of *Helicotylenchus dihystrera*.

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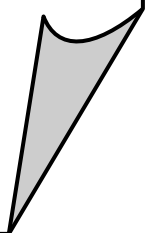
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LIST OF ABBREVIATION

%	:	Per cent
cv.	:	Cultivar
<i>et al.</i> ,	:	<i>Et alli</i> (and co workers)
Fig.	:	Figure
i.e.	:	That is
J ₂	:	Second stage juvenile
max.	:	Maximum
mm	:	Millimeter
µm	:	Micrometer
<i>viz.</i>	:	Videlist (namely)
cm	:	Centimeter
sp.	:	Species
/	:	At par
var.	:	Variety
°C	:	Degree Celsius
CV	:	Coefficient of Variance
=	:	Equal to
hrs	:	Hours
÷	:	Divided by
SD	:	Standard Deviation
±	:	Plus or Minus
<	:	Lesser than
>	:	Greater than
♂	:	Male
♀	:	Female

Introduction... ✍️



CHAPTER I

INTRODUCTION

Nematodes are a highly diversified and abundant group of organisms on earth next to insects. They can survive in almost all environmental conditions. “If all the matters in this universe except the nematodes were swept away our world would still be dimly recognizable, we would find its mountains, hills, valleys, rivers, lakes and oceans represented by a film of nematodes” (Cobb,1914).

The nematodes belonging to suborder Hoplolaimina are obligate parasites of plant roots, not mycetophagus or insect parasite. Hoplolaimina differs from Tylenchina, Criconematina and Hexatylinea in being didelphic and having phasmids on or near the tail. It also differs from Tylenchina and Hexatylinea in being advanced parasites of plant roots. A high-arched, often sclerotized cephalic region, dorsoventrally oval amphidial apertures, cuticle appearing two-layered, usually strong stylet, usual occurrence of axial spermatheca and a tricollellate glandular part of the uterus are also characteristics of Hoplolaimina. It can be differentiated from Criconematina by the structure of the oesophagus in females and juveniles, generally well developed male oesophagus, different face-view structures, absence of lateral oral liplets and sub median lobes, basic didelphy with spermatheca well-formed and not ventrally or sub ventrally located to gonadial axis, a continuous spermatogenesis in the male, differently shaped spicules, paired hypopygia on the posterior cloacal lip, and the absence of retrorse annules, cuticular scales, spines or other configurations and of a body sheath and anchor shaped stylet knobs (Siddiqi, 2000).

Hoplolaimidae comprises some of the economically important nematodes under Hoplolaimina with three subfamilies *viz.*, Hoplolaiminae, Aphasmatylenchinae and Rotylenchoidinae. Females are slender which are migratory ectoparasites of roots, but some have a tendency to bury themselves in roots. Unlike Pratylenchidae, they are seldom able to move freely within the root tissues and have failed to colonize them, their juveniles and adults occurring in soil. In their ecology and ethology, they are similar to the members of the Dolichodoridae, but the sexual dimorphism in their anterior region and enlarged subventral oesophageal glands, which often extend past the dorsal gland, differentiate them. The 3enlarged subventral oesophageal glands enable

them to penetrate deeper into root tissues and establish a physiological relationship with them (Siddiqi, 2000).

Von Daday (1905) erected the genus *Hoplolaimus* with nominal species *Hoplolaimus tylenchiformis*. According to Siddiqi (2000) the genus *Hoplolaimus* contains 32 species in three subgenera, *Basirolaimus*, *Hoplolaimus* and *Ethiolaimus* while Bae *et al.*, (2008) recorded 29 described species. From India four species *viz.*, *Hoplolaimus indicus*, *H. columbus*, *H. galeatus* and *H. seinhorsti* are recorded. Of these, from Assam only *Hoplolaimus indicus*, *H. columbus* and *H. seinhorsti* have been reported so far.

The genus *Hoplolaimus* von Daday, 1905 includes ectoparasites, endoparasites, and semi-endoparasites (Bae *et al.*, 2008). They feed on plant roots, some feeding externally, some burying only their heads in the roots, and some entering the roots to feed. They cause sloughing of the root cortex which are commonly called lance nematodes because of sharp pointed stylet. In India *Hoplolaimus indicus* causes yield loss upto 18% in rice (Prasad *et al.*, 2008).

The genus *Helicotylenchus* Steiner, 1945 contains more than 230 nominal species in the world (Uzma *et al.*, 2015) which are commonly called spiral nematodes because of their coiled habitus. From India following species of *Helicotylenchus* such as *Helicotylenchus dihystera*, *H. multicinctus*, *H. retusus*, *H. crenacauda*, *H. pseudorobustus*, *H. exallus*, *H. morasii*, *H. eletropicus*, *H. astriatus*, *H. magnicephalus*, *H. erythrinae*, *H. digonicus*, *H. rotundicauda* and *H. digonicus* have been recorded. From Assam, *H. dihystera*, *H. crenacauda*, *H. astriatus*, *H. magnicephalus*, *H. erythrinae*, *H. digonicus*, *H. rotundicauda* and *H. digonicus* have been reported so far.

Members of this genus are often considered as second-class parasites. However, some *Helicotylenchus* spp. have been shown to cause heavy damage to crop plants, *viz.*, *Helicotylenchus dihystera* in turf bowling greens (Wallace, 1971), *Helicotylenchus multicinctus* in banana (Baujard and Martiny, 1995; Siddiqi, 2000) and *Helicotylenchus vulgaris* in sugar beet (Spaull, 1982). Burrowing and spiral nematodes from banana are reportedly responsible for yield losses of 30–50 per cent in Costa Rica and Panama, 40 per cent in Africa, 30–60 per cent in India (Davide, 1996) and more than 50 per cent in East Africa (Speijer and Kajumba, 2000; Kashaija *et al.*, 2004).

Due to the cosmopolitan nature and more number of species in both genera *Hoplolaimus* von Daday, 1905 and *Helicotylenchus* Steiner, 1945 intraspecific variability (due to biotic and abiotic factors) is quite frequent and the characters used for identification of the species are considered difficult, leading to confusion in differentiating one species from others.

Nematode taxonomy is still mainly based on morphological characters and therefore, it is essential to know the extent of variability of a particular character due to the influence of different hosts and localities (Neelam *et al.*, 2014). Topotype populations are the best choice to study the variability within the population collected from type host and locality. Use of populations from additional hosts from the type locality may yield more information as variations due to host, if any. Studying several populations from the same hosts at different localities affords opportunity to incorporate the variations due to geographic (or environmental) factors also.

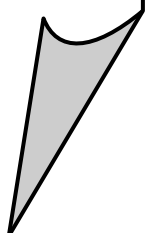
Hosts and localities have been found to influence the morphology and morphometrics of nematodes (Taylor and Pillai, 1967; Ganguly and Ramesh, 1996, 1997; Das and Bajaj, 2005; Cho and Robbins, 1991; Soares *et al.*, 2003). Therefore, the study of living populations is essential to obtain a good phenetic concept of a nematode taxon. Living populations should be collected from as many geographical locations as possible and maintained under different ecological conditions. Each morphometric and allometric character should be evaluated before use in the characterization of a nematode taxon. Previous use of a character for the description of one taxon, does not necessarily mean it is suitable for another (Mai and Bird, 1967).

By knowing the above, the present topic is selected to assign the stable characters which have high taxonomic value and variable characters which have low taxonomic value for describing species of these genera.

Considering the above, the current study was carried out with the following objectives:

1. Morphological and morphometric variations of genera *Hoplolaimus* and *Helicotylenchus* in relation to host plants
2. Morphological and morphometric variations of genera *Hoplolaimus* and *Helicotylenchus* in relation to geographical locations

Review of literature... ✍



CHAPTER II

REVIEW OF LITERATURE

The information pertaining to morphological and morphometrical variations of the genus *Hoplolaimus* and *Helicotylenchus* in relation to hosts and geographical locations is very limited. Therefore, morphological and morphometrical variations of different plant parasitic nematodes with special reference to the effect of hosts and geographical locations other than *Hoplolaimus* and *Helicotylenchus* are reviewed here under:

2.1 Morphological variations of plant parasitic nematodes:

Coomans (1963) recorded small morphological differences in *Hoplolaimus pararobustus* due to environmental conditions from different geographical locations such as Congo, Nigeria and Tanganyika. According to him the position of excretory pore in relation to median bulb, annules in lip region, lateral field, number of anterior projections of stylet knobs and length of oesophageal gland were very variable characters between two populations.

Fortuner (1984 a) observed some morphological differences among the populations of *Helicotylenchus pseudorobustus*, mostly between samples from North America and from Western Europe. The differences were most apparent in the pattern of junction of the inner lines of lateral field on the tail, the position of the phasmids and the dorsal oesophageal gland opening. However, these characters vary within the same populations studied. He stated that the position of the vulva was a stable character.

Ray *et al.* (1985) collected *Hemicriconemoides cocophillus* from the rhizospheres of twelve different species of plants *viz.*, *Cynodon dactylon*, *Curcuma longa*, *Phoenix humilis*, *Musa paradisiaca*, *Rosa sp.*, *Ixora coccinea*, *Opuntia ovata*, *Casuarina equisetifolia*, *Aloe indica*, *Euphorbia tirucalli*, *Oryza sativa* and *Cajanas cajan* and observed morphological variations in tail shape, annule surface, lip sizes and degree of sclerotization among the populations of *Hemicriconemoides cocophillus*. He noticed characters like b, Rex, V, and RV were seem to be highly stable while those like stylet length, knob-width, R, number of annules from anterior end to vulva and anus and width of Ist lip annule were fairly stable; a, c, c', G, head height, length of vulval sheath, post

vulval body length and L/length of post vulval body length looked to be fairly variable and those like L, VL/VB, DOG opening and Rvan were highly variable characters.

Cliff and Hirschmann (1985) studied the morphological variations of *Meloidogyne arenaria* from seven isolates such as Virginia, North Carolina, Colombia, Nigeria, North Carolina, Guadeloupe, Colombia. They found that stylet morphology of female's head, stylet morphologies of males and second-stage juveniles were the most reliable characters for identification. The remaining two populations (E5-Guadeloupe, 392-Colombia) differed consistently from the typical *M. arenaria* in several characters including perineal patterns and head morphology of female and tail shape of second stage juvenile.

Faghihi *et al.*, (1986) studied morphology of five geographical isolates of *Heterodera glycines* in Indiana. They observed that significant differences in means of different morphometric values existed among the isolates of second stage juveniles beside much morphometric overlapping. The Vanderburgh County isolate (Southern Indiana) had the longest oesophagus, tail and tail terminus while the Vigo County isolate had the shortest oesophagus. The White County isolate (Northern Indiana) had the shortest tail, tail terminus and highest total length while the Benton County isolate had the shortest total length. However, their results showed that morphological similarities and differences did not appear to be coordinated with reproductive patterns.

Watson (1986) observed morphological variations on head annules, position of excretory pore, stylet length and caudal morphology in *Subanguina picridis* when it was inoculated in different hosts such as *Acroptilon repens*, *Centaurea diffusa*, *Cynara scolymus*, and *Onopordum acanthium*.

Khan and Khan (1997) studied the intraspecific variations of *Tylenchorhynchus mashhoodi* on shape of spear knobs, position of excretory pore, shape of basal bulb and cardia, number of tail annules, length and shape of spicule and gubernaculum. They collected population from different hosts and observed limited variations in number of lip annules, position of dorsal oesophageal gland opening and hemizonid position between the populations obtained from *Oryza sativa*, *Triticum aestivum*, *Brassica oleracea* var. *capitatum*.

Das and Bajaj (2005) studied intraspecific variations of *Ditylenchus myceliophagus* in relation to hosts viz., *Alternaria alternata*, *Agaricus bisporus*, *Fusarium solani*, *Mucor sp.*, *Pleurotus sajor-caju*, *Rhizoctonia solani*, *R. bataticola*, *Sclerotium sclerotiarum*, *Trichoderma harzianum* and found that occurrence of males, shape of stylet knobs, number of lateral lines, junction between corpus and median bulb, arrangement of oocytes in ovary, crustaformeria, limit of anterior genital tract, shape of spicules, and covering of bursa were not affected by type of host. However, marked variations observed in the basal bulb of oesophagus and tail shape of *Ditylenchus myceliophagus* in different hosts.

Sumita *et al.*, (2018) studied the morphological variations among the populations of *Meloidogyne incognita* from nine districts of Assam. The population exhibited variations only in the tail shape, while other morphological characters showed similarities among the populations. No variation was observed in size and shape of perineal pattern, lip region, stylet, cephalic framework, oesophagus and excretory pore of *M. incognita* collected from nine districts of Assam viz., Golaghat, Kokrajhar, Nagaon, Sibsagar, Dibrugarh, Jorhat, Lakhimpur, Dhubri and Kamrup.

2.2 Morphometric variations of plant parasitic nematodes:

Wu (1960) studied general characters of *Ditylenchus destructor* from the potato, bulbous iris, and dahlia. He did not record any significant difference in the basic structure of the *Ditylenchus destructor* to suggest the presence of more than one species. However, he observed that due to host influence, there may be some variation in total length, width, number and arrangement of sex cells, length of oesophagus, length of spear and tail shape. Nematodes from potatoes were successfully transferred to dahlia and carrot and from iris and dahlia to potato. The result shows only the c value for males and 'V%' from females had some statistical support.

Taylor and Pillai (1967) found that nematode morphometrics of *Ditylenchus sp.*, *Neotylechus linfordi*, *Aphelenchus avenae* and *Paraphelenchus acontoides* varied considerably between populations reared on different fungal hosts viz., *Alternaria solani*, *Pythium irregulare*, *Phytophthora cactorum*, *Mortierella pusilla*, *Pyrenochaeta terrestris*, *Chaetomium globosum*, *Polysporus sulfureus*, *Fusarium solani*, *Fusarium*

moniliforme and *Rhizoctonia solani*. Position of the vulva varied the least (1.3%) of the five characters studied (L, a, b, c and V) from the mean in *Neotylelenchus linfordi*. He concluded that there was no consistent correlation between host preference, host suitability and morphometrics.

Mai and Bird (1967) studied ten morphometric and allometric characters such as body length, body width, V, anterior ovary length, posterior ovary length, stylet length, oesophagus length, excretory pore length and neck length of *Trichodorus christie* from 22 populations. They evaluated the characters with numerical analyses and stated that variations existed within geographical isolates, populations, and strains of *Trichodorus christie*. Stylet length was the least variable morphometric character. Ratios formed from the body length, stylet length and position of the vulva were the least variable allometric characters. They suggested that the variance of morphometric characters and the allometry of pairs of characters used to form ratios should be studied before they are used for taxonomic purposes.

Evans and Fisher (1970) investigated the variation in morphometric characters of *Ditylenchus myceliophagus* and *Ditylenchus destructor* under changing environmental conditions of various temperatures *viz.*, 10⁰, 15⁰, 20⁰, 25⁰ and 30⁰ and observed that the most stable characters were found to be length of post-vulval sac, length of post-vulval sac as a percentage of total length, and length to vulva as a percentage of total length. They found the nematode total length, width, ratio 'c', length to vulva or cloaca, length of gonad and length of gonad as a percentage of total length decreased with increase in culture time and decreased host nutrition.

Koliopanos and Triantaphyllou (1971) observed morphometric variations of *Heterodera glycines* from four populations from four different states *viz.*, North Carolina, Virginia, Lonoke and Arkansas. The morphometrical characters of *Heterodera glycines* differed considerably in numbers of adult females developed on five resistant soybean cultivars, mungbean and lespedeza. Differences were observed in body length, tail length and tail terminus lengths of second stage larvae.

Tarjan and Frederick (1978) studied morphological variations of three populations of *Pratylenchus coffeae* and two populations of *P. brachyurus*, each originating from a single female, maintained on *Citrus* spp. or *Solanum nigrum* for several

years under greenhouse conditions. Measurements of the stylet, posterior uterine sac, and tail were taken. The mean data and coefficients of variability suggested that stylet length had the least variability (CV= 2.48 %), and length of posterior uterine sac had the most (CV= 15.70 %).

Fortuner (1979) studied the morphometrical variations in *Helicotylenchus*. The single female progeny, probably of *Helicotylenchus dihystera* was used in this study. Several criteria used in specific diagnosis and particularly those describing the tail were proved to be highly variable character. Stylet length was the most consistent measurement (CV= 1.7%); total length, length of oesophagus, anal and vulval body diameters were also reliable (CV= 3.2 to 4.5%). On the other hand, criteria related to tail viz., tail length, number of tail annules, position of fusion of inner lateral field incisures and position of phasmids had rather high coefficients of variability (CV= 9.6 to 70 %).

Fortuner (1980) studied the effect of the host on some morphometric characters from the progeny of *Helicotylenchus dihystera* females. The strain was cultivated on ten different host-plants viz., Rice (cv. Moroberekan), Sugar-cane (cv. B-54142), Maize (cv. C.J.B), Sorghum (cv. CE 90), Tomato (cv. Heinz 1370), Pepper (cv. Early California Wonder), Cotton (cv. 1422, C 71-72), Groundnut (cv. Florryrunner), Tropical kudzu (*Pueraria phaseoloides*) and Pencil flower (*Stylosanthes gracilis*). He found that there was a significant difference in all characters studied but only three characters had no significant difference among the ten populations in position of phasmids, fusion of inner incisures and ratio c at 1% level of significance with F- test.

Davide (1980) studied the body length, body width, stylet length, oesophagus length, and tail length using 20 random samples of *Meloidogyne arenaria* inoculated on different host crops from *Ficus carica*. The result showed the wide variation in body length and body width of adult females as influenced by the host crops. It was also shown that the age of pre-parasitic larvae had some effect on the body length but not on the body width, stylet length, oesophagus length, and tail length. He observed that those nematodes in less susceptible crops like barley, corn, and radish were relatively smaller than those in more susceptible crops such as potato, tomato, cucumber and tobacco.

Fortuner (1981) inferred that no difference could be found in morphometrical characteristics such as body length, stylet length, distance between dorsal gland opening and stylet base, length of oesophagus, length of oesophageal gland overlapping, tail length, anal body width, vulval length, length of median bulb and tail annules among the ten African populations of the *Helicotylenchus dihystra*.

Chawla and Yadav (1981) studied the correlation coefficient between any two character of *Hoplolaimus indicus* between hosts (sugarcane, sorghum, citrus and banana), locality (Karnal, Hissar, Narnaul, Udaipur), character under consideration and sex. He found that there was no constant correlation between any two characters other than body length upto vulva and length upto anus and also found that there was no constant correlation between any of the measurements used to calculate the ratios a, a', b, b', c and c'.

Fortuner (1984 b) studied the morphometrical variability in *Helicotylenchus* spp. particularly on the validity of ratios. He did not find any variations in 'a' and 'V' ratios and he considered it as taxonomically valid. Ratios a, c, and c' were often valid but rarely useful because they showed least variations; b, b' and m were valid in only half the samples and most often were not useful because they showed moderate variations. According to him Ratio 'O' must not be used because it showed wide variations.

Olowe and Corbett (1984 a) studied the effect of unfavourable hosts, overcrowding and high temperature on morphometric characters of *Pratylenchus brachyurus*, *P. zae* and recorded decrease in body size. Other characters like excretory pore distance, total oesophageal length, gonad and tail length also tend to vary in the same way as the body size in both species, though oesophageal and tail lengths varied less than the body size. The stylet length varied little. deMan ratios like a, b, b', c, and Geraelt's ratio such as MB varied widely, while the deMan's V ratio and a new ratio designated 'PO' (the percentage of length of posterior oesophagus to the total oesophageal length) varied little.

Olowe and Corbett (1984 b) observed that the linear and relative dimensions in population of *Pratylenchus brachyurus* and *P. zae* from six different geographical areas varied widely, but stylet length and "V" ratio were found to be good diagnostic characters as they were not considerably changed with geographical locations. Populations of the

two species from Australia had larger body sizes than populations from North Carolina, Rhodesia, Singapore, Malawi and Nigeria. The percentage of length of posterior oesophagus to the total oesophageal length (PO) was considered as the useful taxonomic character for *Pratylenchus brachyurus* and *P. zaeae*.

Singh *et al.*, (1985) took seventeen plants, belonging to seven genera, and inoculated with single egg mass populations of *Meloidogyne incognita* in order to determine the extent of variation in the female characters. In his study high CV% values have been found in neck length and width and least for stylet length.

Subramanian and Sivakumar (1988) observed that *Pratylenchus delattrei* showed the morphometric and allometric variations in relation to different host crops (*Crossandra undulaefolia*, *Zea mays*, and *Lycopersicon esculentum*). They found that the stylet length, V% and 'm' value were the least variable (CV= 2.11-2.39%) and most reliable taxonomic characters while, total body length, a, b, b', c, tail length, number of tail annules, excretory pore position and length of the post uterine branch were the most variable characters (CV= 5.75-9.91%). Length of oesophagus and c' were found to be the most variable amongst all the characters studied (CV= 11.56-16.99%).

Koshy *et al.*, (1991) studied the morphometric variations of 12 populations of *Radopholus similis* from different host plants *viz.*, coconut, arecanut, banana and black pepper from different geographical locations of South India. They observed that stylet length (CV= 3.91%) and V% (CV= 3.10%) were the most stable characters, and suggested that body length was found to be a good descriptive ratio of *R. similis* where the correlation was highly significant between the constituting characters.

Das and Bajaj (2005) observed the effects of nine fungal hosts (*Alternaria alternata*, *Agaricus bisporus*, *Fusarium solani*, *Mucor* sp., *Pleurotus sajor-caju*, *Rhizoctonia solani*, *R. bataticola*, *Sclerotium sclerotiarum* and *Trichoderma harzianum*) on taxonomic characters of *Ditylenchus myceliophagus*. They found that morphometric and allometric characters were influenced to varying degrees by these hosts, where body length was found to be highly variable and characters such as V, stylet length and MB were found to be stable characters.

Ghosh and Khan (2007) studied morphological and morphometrical variations of different life stages of *Rotylenchulus reniformis* populations from Orissa, West Bengal and Nagaland. They observed that stylet length was found to be a stable character for the species as low CV value was recorded for all the life stages of *R. reniformis*. Besides V%, stylet length, position of median bulb and excretory pore, body width and lip width exhibited least variations (CV<6), while ratio a, b, m% (length of conus to total stylet length x 100) and body length were found to be the moderately variable characters (CV 6-8) in immature females. In male, stylet length, m%, median bulb position and head width showed a low degree of variability, whereas excretory pore position, DOGO, spicule length, anal body width, 'a' and T% were rated as moderately variable characters. The second stage juveniles of *R. reniformis* exhibited least variations in m%, stylet length and median bulb position. The mature female also showed wide variations in their body shape and size in all the populations. However, the Orissa populations showed lowest mean value in body length, body width, 'a', anal body width and V%. Tail length, tail shape and hyaline portion in tail in immature female, male, female and juveniles exhibited wide variations.

Kaur and Attri (2013) studied morphometric variations of *Meloidogyne incognita* from five different host plants viz., okra, bottle gourd, banana, brinjal, and sunflower collected from four districts of Punjab such as Ludhiana, Gurdaspur, Patiala, and Hoshiarpur. Analysis of interpopulation morphometric characters from mature female of *M. incognita*, namely, body length, width, and ratio 'a' were moderately variable characters (CV 0.26% to 20%) and neck length, stylet length, length of median bulb, and width of median bulb were highly variable characters (CV 1.0% to 36.1%).

Moon *et al.*, (2013) studied intraspecific variation of morphometric characters of pine wood nematodes *Bursaphelenchus xylophilus* and *B. mucronatus* in relation to geographical locations in South Korea. They found that the body length of male and female of *B. xylophilus* had the highest coefficient of variability and showed significant differences among geographical locations. The V% value for female *B. xylophilus* showed the lowest coefficient of variability, with geographical area and host plant. All morphometric characters in *B. mucronatus* except for female body length and stylet length showed no significant differences between locations or hosts, suggesting that they might not be affected by geographical area or host plant.

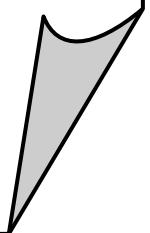
Thakur *et al.*, (2014) stated that females of *Hoplolaimus indicus* collected from different host plants such as mustard (*Brassica campestris*), sunflower (*Helianthus annuus*), cotton (*Gossypium hirsutum*) and groundnut (*Arachis hypogaea*) had body length as a stable character however, in males it was a variable character. They found that ratio 'c', spear length and V% in females were stable characters (CV= <12%), however, a, b and b' were variable characters (CV= 12-20%) and c' ratio, spicules and gubernaculum length were highly variable characters (CV= >20%).

Chandrawat *et al.*, (2014) observed few morphometric variations in *Hoplolaimus* spp. associated with various perennial ornamentals from Udaipur, Rajasthan. They found that *Hoplolaimus tylenchiformis* had slightly more variations in body length, 'b' ratio and spicules length, however lower variations were observed in stylet length, vulval position and 'c' ratio. *Hoplolaimus indicus* populations showed slightly more variations in 'a' ratio, b' ratio, 'c' ratio and stylet length, but lower variations in 'b' ratio and vulval position, while *Hoplolaimus columbus* showed slightly more variations in 'a', b' and 'c' ratio, but lower variations in stylet length and 'b' ratio when compared with original description of the species.

Sumita *et al.*, (2018) studied the morphometric variations (body length, stylet length, lip height, lip width, MB, a, b, b', c and c') among the populations of *Meloidogyne incognita* from nine districts of Assam *viz.*, Golaghat, Kokrajhar, Nagaon, Sibsagar, Dibrugarh, Jorhat, Lakhimpur, Dhubri and Kamrup. They showed no distinct variations in the major characters such as body length, stylet length, lip height, lip width, a, b, b', c and c' except in MB value. The MB value of the Kamrup population was higher (61.79) than other populations.

Roy *et al.*, (2018) studied the morphometric variations of *Radopholus similis* from Banana crop of Thiruvananthapuram, Kerala. The result showed that the morphometric characters like m%, O% and V% of females of *R. similis* shows least variability. These can be considered as the stable morphometric characters (CV= >12%) for discrimination of females of *R. similis*. Ratios like 'a' and 'c' of females of *R. similis* were found moderately variable (CV=12-20%). In case of male, distance from head to basal bulb (μm) was found least variable; while number of lip annuli and spicules length (μm) were moderately variable characters (CV=12-20%).

Materials and methods... ✎



CHAPTER III

MATERIALS AND METHODS

The methods and materials used for perusing the research programme are described below:

1. Collection of samples:

To study the morphology and morphometric variations in relation to hosts soil samples were collected from Rice, Maize, Peas, Banana, Jackfruit, Citrus, Mango and Tea of Jorhat district. While to study the morphology and morphometric variations in relation to geographical locations, soil samples were collected from Jorhat, Sibsagar, Kamrup, Lakhimpur, Dhemaji, Nagaon and KarbiAnlong districts of Assam from around the rhizosphere of banana (Table 3.1, 3.2 and Fig. 3.1).

Soil samples were collected randomly from around the rhizosphere of different crops from a depth of 15- 60 cm and within a radius of 5-30 cm depending upon the crop. A number of subsamples, one each weighing about 50 g of soil, were collected from each location. Later, these all sub samples were mixed together to draw a representative sample of around 500 g of soil. All the samples were collected in polythene bags and sealed tightly with a rubber band. A label containing relevant information like name of host plant, crop history, locality and date of collection along with GPS data was kept with each bag. Same information was recorded separately in a notebook. Care was taken not to expose the samples to the sun. Soil samples were processed for extracting nematodes on the same day or day after or kept in the refrigerator at 4°C for a couple of days if it was not possible to process immediately.

2. Extraction of nematodes from soil:

Extraction of nematodes from the soil sample was carried by following Cobb's modified sieving and decanting technique (Christie and Perry, 1951) by using the series of sieves (20, 60, 150, 250, 350 mesh sieve). Each soil sample was mixed thoroughly and 200 cc of soil was drawn from the homogeneous mixtures for processing. The soil sample was placed in a plastic bucket and soaked in a liter of water. Soil lumps were broken to enable them to mix along with suspension. Then, soil suspension was stirred well and allowed to stand for about 15 seconds for the heavy soil particles to settle at

the bottom of the bucket. This soil suspension was then poured through 20 mesh sieve to discard stones and other coarse materials. The suspension from this bucket was collected in a second bucket and was allowed to settle for about 15-30 seconds, and then passed through a 60mesh sieve to another bucket leaving the heavy particles in the bucket. The residue on the 60 mesh sieve was collected in a 250 ml beaker. The whole aliquot obtained from 60 mesh sieve was then serially passed through 150, 250 and 350 mesh sieve, collecting the residues left over on each sieve in the beaker. The residues collected from different sieves were finally rinsed in 350 mesh sieve with a gentle jet of water and then collected in a beaker. The suspension containing nematodes was then poured gently over a double layered tissue paper placed over an aluminum mesh sieve support and placed as such on a Petri dish containing filter water. After 12 hrs, the nematode suspension was collected and examined under a stereo zoom binocular microscope.

3. Identification of nematodes up to generic level:

Nematodes belonging to genera *Hoplolaimus* and *Helicotylenchus* were identified up to genus under stereo zoom binocular microscope and picked separately with the help of a bamboo splinter.

4. Killing and fixing:

Nematode suspension was concentrated by keeping the suspension undisturbed in a beaker for 30 minutes to settle down the nematodes at the bottom of the beaker and then carefully decanting the supernatant. Concentrated nematode suspension was poured into a McCartney bottle before the nematodes were killed as well as fixed simultaneously by adding equal volume of 8 per cent (double strength) boil formaldehyde. The fixed nematodes were stored with proper labels.

5. Clearing and Dehydration:

For clearing and dehydration, picked nematodes were transferred to a cavity block containing Seinhorst's solution I (96% ethanol-20 ml, glycerol-1 ml, distilled water - 79 ml). The cavity block was kept in a hot air oven at 60°C for 12 hours. Care was taken to keep the lid of the cavity block slightly open inside the oven. After 12 hours, 2 ml of Seinhorst's solution II (Glycerol-5 ml, 96% ethanol-95 ml) was added to each cavity block and kept it again in a hot air oven at 60°C till the cleared nematode

specimens were obtained. Cavity blocks with cleared nematodes were kept in a desiccator containing calcium carbonate at room temperature till the permanent mounts were prepared.

A small bottle with pure glycerine was also kept in the desiccator for mounting the cleared nematodes in dehydrated glycerol.

6. Mounting and sealing:

Dehydrated nematodes were mounted over a small drop of anhydrous glycerine on a clean glass slide. Dehydrated and cleared nematodes were transferred from cavity block to the dehydrated glycerine drop with the help of bamboo splinter under stereo zoom binocular microscope. The nematodes were arranged at the center of the mounted drop by pushing the nematodes with bamboo splinter to settle at the bottom. Small pieces of paraffin wax were placed surrounding the glycerine drop containing nematodes. A round and clean coverslip (size 18 X 18 mm) was placed over the paraffin wax. Then, the glass slide was heated on a slide warming table at 80-85°C till the paraffin melts and sealed the cover slip with a glass slide.

7. Measurements:

Measurements of the mounted nematode were taken with the help of Zeiss Axiostar plus research microscope fitted with an ocular micrometer, calibrated with a stage micrometer. For designating the dimensions of nematodes, De Man (1876 and 1880) formulae or De Man Indices were used which have been added to, modified and amended by Cobb (1914), Thorne (1949) and Geraert (1968). These formulae were referred from Southey (1986).

A) Characters considered for morphological studies:

The structural details of the following morphological characters were studied for all the specimens of *Hoplolaimus* and *Helicotylenchus*

- 1) Body shape
- 2) Lateral fields
- 3) Lip region
- 4) Lip annules

- 5) Stylet
- 6) Oesophagus
- 7) Hemizonid
- 8) Vulva
- 9) Anus
- 10) Tail shape
- 11) Phasmids
- 12) Spicule shape
- 13) Bursa

B) Dimensions considered for morphometrical studies:

The following morphometrical dimensions were studied for all the specimens of *Hoplolaimus* and *Helicotylenchus*

- 1) **L** = Total body length in mm
- 2) **a** = Body length \div maximum body width
- 3) **b** = Body length \div distance from anterior end to the junction of oesophagus and intestine
- 4) **b'** = Body length \div distance from anterior end to posterior end of oesophagus glands
- 5) **c** = Body length \div tail length
- 6) **c'** = Tail length \div anal body width
- 7) **V** = Distance of vulva from anterior end X 100 \div body length
- 8) **V'** = Distance of vulva from anterior end X 100 \div L'
- 9) **L'** = Distance from anterior end to anus
- 10) **MB** = Distance of median bulb from anterior X 100 \div total oesophageal length
- 11) **DOGO** = Distance from base of the stylet to dorsal oesophageal gland opening in μm

- 12) **O** = Distance from base of the stylet to dorsal oesophageal gland outlet
 $X 100 \div \text{total stylet length}$
- 13) **Pa** = Distance of anterior phasmid from anterior end $X 100 \div \text{body length}$
- 14) **Pp** = Distance of posterior phasmid from anterior end $X 100 \div \text{body length}$
- 15) **Stylet length** = length of stylet from anterior end in μm
- 16) **SE** = Distance of excretory pore from anterior end in μm
- 17) **Nerve ring** = Distance of nerve ring from anterior end in μm
- 18) **Spicule length** = Total length of the spicule in μm
- 19) **Gubernaculum length** = Total length of the gubernaculum in μm

8. Photograph:

Photographs were made with the help of Mosaic V 2.0 camera software from Labovision microscope of various magnifications.

9) Statistical analysis:

Mean = sum total measurements of individual nematode ÷ total number of nematodes taken for measurement.

Standard deviation:

$$SD = \sqrt{\frac{\sum(x - \bar{x})^2}{n - 1}}$$

Where, SD= Standard deviation of the nematode population

Σ = Sum of

x = Each value of measured nematode

\bar{x} = Mean value of measured population

n = Number of nematodes taken for measurement

Range = Minimum measurement - Maximum measurement

Coefficient of variation = (Standard deviation ÷ Mean) X 100

Table 3.1. Locations and number of soil sample collected to study the host variations of *Hoplolaimus* and *Helicotylenchus*

Sl. no	Crops	Location	No. of Sample Collected
1	Rice (<i>Oryza sativa</i>)	Jorhat, AAU	13
2	Maize (<i>Zea mays</i>)		10
3	Banana (<i>Musa spp.</i>)		13
4	Mango (<i>Mangifera indica</i>)		10
5	Jackfruit (<i>Artocarpus heterocephalus</i>)		7
6	Citrus (<i>Citrus limon</i>)		9
7	Pea (<i>Pisum sativum</i>)		7
8	Tea (<i>Camellia sinensis</i>)		18
Total samples collected			87

Table 3.2. Locations and number of soil sample collected to study the geographical variations of *Hoplolaimus* and *Helicotylenchus*

Sl. no	District	Location	Crop	No. of Sample Collected
1	Jorhat	Horticulture orchard AAU, Jorhat	Banana	13
2	Kokrajhar	Gossangion	Banana	10
3	Sivasagar	Milanpur	Banana	7
4	Kamrup	Kamrup local	Banana	9
5	Lakhimpur	Regional Agricultural Research Station campus, Garumuria	Banana	11
6	Dhemaji	Joyrampur	Banana	7
7	Nagaon	Kathiatoli	Banana	10
8	KarbiAnglong	Diphu	Banana	9
Total samples collected				76

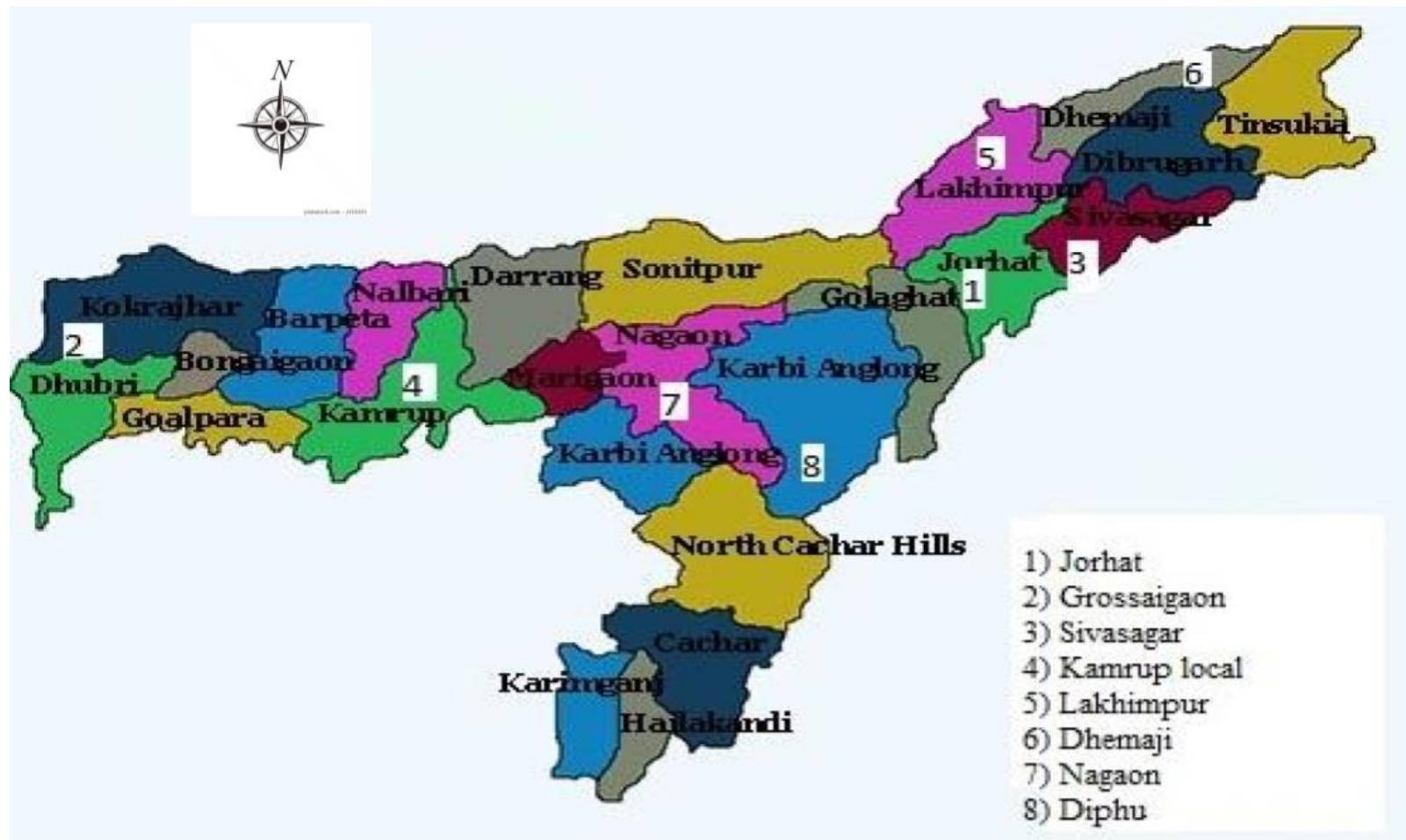
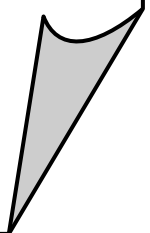


Fig. 3.1. Map of Assam showing the places of sample collected to study the geographical variations of *Hoplolaimus* and *Helicotylenchus*

Experimental findings... ✍



CHAPTER IV

EXPERIMENTAL FINDINGS

4.1 Morphological and morphometric variations of genus *Hoplolaimus* Daday, 1905 in relation to host plants and geographical locations:

A total of 163 soil samples were collected from around the rhizosphere of Rice, Banana, Mango, Jackfruit and Tea from five districts of Assam viz., Jorhat, Kamrup, Lakhimpur, Nagaon, KarbiAnglong. The number of soil samples collected from different host plants and geographical locations are presented in (Table 3.1 and 3.2).

Two species of *Hoplolaimus* viz., *H. columbus* and *H. indicus* were identified during the present investigation.

Identification of species of *Hoplolaimus*:

Genus *Hoplolaimus* Daday, 1905

Diagnosis: Hoplolaiminae. Large-sized nematodes (1-2 mm). Lateral field usually with one or two or four incisures, sometimes obliterated. Cephalic region offset, rounded, marked with prominent transverse and longitudinal striae; labial disc distinct; basal annule marked by more than six longitudinal striae; framework very heavily sclerotized. Stylet massive, with compact tulip-shaped basal knobs having one to three anterior tooth-like projections. Excretory pore present near hemizonid or more anterior. Oesophageal glands large, overlapping intestine dorsally and laterally; dorsal gland uni- or quadrinucleate; subventral glands enlarged equal to or usually larger than dorsal gland. Median bulb always well developed, muscular with refractive thickenings. A cellular cardia absent, but oesophago-intestinal junction is provided with a small cuticular valvula. Female reproductive system didelphic-amphidelphic, both the branch well developed. Epiptygma present in vulval region, often indistinct. Glandular part of uterus tricolomellate. Spermatheca thick walled, round, usually axial or may be absent. Phasmids large, scutellum-like, not opposite each other, one prevulval, one postvulval (except *H. californicus* in which both phasmids are postvulval). Female tail hemispherical, annulated. Spicules massive, somewhat cylindroid, may be dimorphic

with distal flanges variable in size. Gubernaculum is large, protrusible, with titillae and telamon.

Type subgenus: *Hoplolaimus* Daday, 1905

Type species: *Hoplolaimus tylenchiformis* Daday, 1905

***Hoplolaimus columbus* Sher, 1963**

Dimensions:

Female (n=104): L= 1.09-1.60mm (1.34mm); a= 23-33.75 (28.61); b= 7.74-11.07 (9.32); b'= 5.53-9.07 (7.11); c= 41.38-74.94 (55.74); c'= 0.57-0.96 (0.75); V= 51.28-60.67 (56.08); Stylet length= 38.16-45.58 μ m (41.73 μ m); SE= 109.18-156.88 μ m (132.45 μ m); Pa= 26.10-51.96 (31.43); Pp= 70.06-84.00 (77.53); MB= 61.97-75.41 μ m (69.58 μ m)

Description:

Body ventrally curved to C shape upon fixation, 1.09-1.60 mm long. Cuticle coarsely annulated, 2-3 μ m apart at mid body. Cephalic region offset with 3-4 annules, basal annule marked with longitudinal lines, hemispherical, 13.78-18.02 μ m wide and 7.42-9.54 μ m high. Cephalic framework strongly sclerotized. Lateral fields marked with single incisure, faintly visible in some parts of the body. Stylet massive, about thrice the lip width long with lotus shaped basal knobs, with two anteriorly projecting processes. Dorsal oesophageal gland with six nuclei, overlapping the intestine dorsally. Excretory pore located 109.18-156.88 μ m from anterior end, almost at the level of oesophago-intestinal valve. Hemizonid distinct, 2-5 annulus behind the excretory pore. Vulva with a transverse slit. Vagina almost right angle to the body axis Epiptygma paired. Ovaries outstretched, a true spermatheca absent. Anterior phasmid at 31.43% from the anterior end on the right side, posterior phasmid at 77.53% from the anterior end on the left side of the body. Tail 16.96-33.92 μ m long, broadly rounded with 13-20 annules ventrally (Plate 1 A-F).

Male: Not found.

Remark: The present population agrees with the dimensions and description given by Sher (1963); Das (1993) and Chandrawat *et al.*, (2014). However, the present population

differs from the original descriptions given by Sher (1963) in having wider body diameter, slightly shorter stylet and anteriorly located anterior phasmid (a= 30-38, stylet= 40-48 μ m and anterior phasmid: 34-47% in original description). It also differs from the population described by Das (1993) from Assam Agricultural University, Jorhat campus in being slightly longer in the body length, slender body (L= 1.12-1.38mm and a= 26.6-32.0 in Das, 1993); and differs from population described by Chandrawat *et al.*, (2014) from Udaipur, India being slender, having longer oesophagus, longer oesophageal gland overlapping over intestine, longer tail (a= 30.02-49.56, b= 5.91-9.72, c= 31.42-64.91).

4.1.1 Morphological and morphometric variations of *Hoplolaimus columbus* Sher, 1963 in relation to host plants and geographical locations:

4.1.1.1 Morphological and morphometric variations of *Hoplolaimus columbus* Sher, 1963 in relation to host plants:

To study the effect of host plants in morphological and morphometric variations of *Hoplolaimus columbus* we collected samples from different host plants such as Jackfruit, Mango and Tea having the same geographical locations as of Jorhat. The morphological and morphometric measurements of variations are presented hereunder.

a) Habitus:

Body open 'C' shape upon fixation and takes curvature on the ventral side of the nematode body and there is no significant difference in habitus of *Hoplolaimus columbus* in relation to host plants (Plate 6A).

b) Body length:

The body length of females of *Hoplolaimus columbus* collected from all host plants ranged from 1.102-1.608 mm with mean value of 1.356 mm. The body length of populations collected from Jackfruit, Mango and Tea were recorded within the range of 1.261-1.575 mm, 1.169-1.608 mm and 1.102-1.447 mm, respectively. Maximum mean body length (1.399 mm) was recorded in the Jackfruit population and the minimum (1.288 mm) was recorded in the Tea population.

Table 4.1. Morphometric variations of *Hoplolaimus columbus* in relation to host plants.

Characters ♀	Jackfruit (n=16)	Mango (n=20)	Tea (n=18)	Mean (n=54)
Body length (mm)	1.399±0.094 (1.261-1.575) 6.78	1.382±0.127 (1.169-1.608) 9.24	1.288±0.090 (1.102-1.447) 7.04	1.356±0.115 (1.102-1.608) 8.54
Body width (µm)	50.22±5.36 (40.28-58.30) 10.68	45.26±3.44 (37.10-50.88) 7.60	47.41±3.31 (42.40-53.00) 6.98	47.44±4.47 (37.10-58.30) 9.43
Length of oesophagus (µm)	153.90±9.82 (134.62-169.60) 6.38	148.56±6.98 (132.50-159.00) 4.70	143.39±4.75 (128.26-148.40) 3.31	148.42±8.35 (128.26-169.60) 5.62
Oesophageal gland overlapping (µm)	204.65±13.49 (174.90-233.20) 6.59	189.58±12.48 (168.54-212.00) 6.58	197.51±10.17 (179.14-218.36) 5.15	196.69±13.38 (168.54-233.20) 6.80
Tail length (µm)	24.80±3.27 (21.20-31.80) 13.20	25.76±3.39 (16.96-30.74) 13.16	23.71±1.52 (21.20-26.50) 6.41	24.96±3.06 (16.96-31.80) 12.27
Anal body width (µm)	34.49±2.83 (29.68-39.22) 8.20	30.85±2.38 (26.50-34.98) 7.72	32.62±1.65 (29.68-36.04) 5.05	32.48±2.70 (26.50-39.22) 8.32
Position of vulva (µm)	789.37±46.06 (730.34-891.46) 5.84	770.99±73.40 (640.24-906.30) 9.52	730.34±45.28 (652.96-820.44) 6.20	762.89±61.53 (640.24-906.30) 8.07
Lip height (µm)	8.94±0.54 (8.48-9.54) 6.07	8.53±0.42 (7.42-9.54) 4.89	8.24±0.45 (7.42-8.48) 5.50	8.56±0.54 (7.42-9.54) 6.30
Lip width (µm)	16.63±0.64 (15.90-18.02) 3.84	15.69±0.81 (13.78-16.96) 5.19	15.84±0.68 (14.84-16.96) 4.28	16.02±0.82 (13.78-18.02) 5.09
Stylet length (µm)	43.39±1.37 (41.34-45.58) 3.15	40.81±1.17 (39.22-42.40) 2.86	41.16±1.04 (39.22-42.40) 2.54	41.69±1.62 (39.22-45.58) 3.89
SE (µm)	130.98±8.68 (116.60-145.22) 6.63	134.73±9.94 (109.18-150.52) 7.38	132.26±9.71 (117.66-148.40) 7.34	132.79±9.46 (109.18-150.52) 7.12
Nerve ring (µm)	121.44±6.37 (107.06-132.50) 5.25	117.77±6.94 (100.70-128.26) 5.89	116.84±4.42 (106.00-122.96) 3.78	118.54±6.22 (100.70-132.50) 5.25

Median bulb (μm)	105.54 \pm 5.25 (97.52-117.66) 4.97	101.50 \pm 5.90 (87.98-111.30) 5.81	100.35 \pm 3.90 (87.98-103.88) 3.89	102.31 \pm 5.46 (87.98-117.66) 5.34
Tail annules	15.33 \pm 1.60 (13.78-18.02) 10.41	15.28 \pm 1.64 (12.72-19.08) 10.71	15.40 \pm 1.60 (13.78-18.02) 10.36	15.34 \pm 1.58 (12.72-19.08) 10.28
Anus (μm)	1376.48 \pm 95.13 (1239.14-1547.60) 6.91	1356.38 \pm 125.74 (1147.98-1579.40) 9.27	1242.03 \pm 88.11 (1081.20-1350.44) 7.09	1336.46 \pm 118.45 (1081.20-1579.40) 8.86
a	28.13 \pm 3.08 (23.00-32.66) 10.96	30.55 \pm 1.88 (26.76-33.75) 6.16	27.21 \pm 1.36 (24.10-29.43) 5.00	28.72 \pm 2.59 (23.00-33.75) 9.02
b	9.11 \pm 0.56 (7.82-9.88) 6.16	9.30 \pm 0.64 (8.42-10.39) 6.92	8.98 \pm 0.50 (7.76-9.90) 5.53	9.14 \pm 0.58 (7.76-10.39) 6.33
b'	6.85 \pm 0.48 (6.10-7.61) 6.94	7.32 \pm 0.80 (6.39-8.62) 10.88	6.53 \pm 0.51 (5.53-7.35) 7.81	6.92 \pm 0.70 (5.53-8.62) 10.07
c	56.91 \pm 6.70 (46.00-68.10) 11.77	54.29 \pm 6.78 (46.14-74.94) 12.49	53.59 \pm 5.08 (46.48-61.67) 9.47	54.98 \pm 6.41 (46.00-74.94) 11.65
c'	0.72 \pm 0.07 (0.60-0.84) 10.30	0.84 \pm 0.09 (0.57-0.96) 11.03	0.74 \pm 0.06 (0.68-0.89) 8.22	0.77 \pm 0.10 (0.57-0.96) 12.31
V	56.44 \pm 1.30 (54.76-58.90) 2.31	55.78 \pm 1.28 (53.24-57.77) 2.30	56.76 \pm 2.29 (51.58-60.67) 4.03	56.30 \pm 1.71 (51.58-60.67) 3.04
V'	57.40 \pm 1.45 (55.38-59.97) 2.53	56.84 \pm 1.28 (54.32-59.05) 2.24	58.50 \pm 1.79 (55.39-60.88) 3.06	57.42 \pm 1.57 (54.32-60.88) 2.74
MB	68.66 \pm 2.04 (64.71-72.52) 2.97	68.29 \pm 1.25 (65.71-70.83) 1.82	69.97 \pm 1.00 (68.35-71.85) 1.43	68.96 \pm 1.61 (64.71-72.52) 2.34
Pa	30.76 \pm 3.40 (26.91-38.91) 11.07	30.13 \pm 3.23 (26.10-36.77) 10.74	30.50 \pm 2.82 (27.03-36.93) 9.23	30.46 \pm 3.09 (26.10-38.91) 10.14
Pp	77.53 \pm 2.14 (73.82-82.02) 2.76	77.80 \pm 2.40 (73.39-81.81) 3.09	77.31 \pm 3.06 (71.34-83.98) 3.96	77.56 \pm 2.55 (71.34-83.98) 3.29

[Mean \pm SD; (Range); CV%], Least variable (<12%), Moderately variable (12-20%), Highly variable (>20%)

The mean CV value of the body length of female *Hoplolaimus columbus* in relation to host plants was 8.54% indicating as least variable character. The highest CV value of the body length was found in the Mango population (9.24%) and the lowest CV value was found in the Jackfruit population (6.78%) (Table4.1).

c) 'a' ratio:

The 'a' ratio of females of *Hoplolaimus columbus* collected from all host plants ranged from 23.00-33.75 with mean value of 28.71. The 'a' ratio of populations collected from Jackfruit, Mango and Tea were recorded within the range of 23.00-32.66, 26.76-33.75 and 24.10-29.43, respectively. The maximum mean 'a' ratio (30.55) was recorded in the Mango population and the minimum (27.21) was recorded in the Tea population.

The mean CV value of 'a' ratio of female *Hoplolaimus columbus* in relation to host plants was 9.02 % indicating as least variable character. The highest CV value of the 'a' ratio was found in the Jackfruit population (10.96%) and the lowest CV value was found in the Tea population (5.00%) (Table4.1).

d) Length of oesophagus and 'b' ratio:

The length of oesophagus in the population of *Hoplolaimus columbus* collected from different hosts was within the range of 128.26-169.60 μm ; while the 'b' ratio was within the range of 7.76-10.39 with a mean value of 9.14. The 'b' ratio of Jackfruit, Mango and Tea populations were recorded within the range of 7.82-9.88, 8.42-10.39 and 7.76-9.90, respectively. The maximum mean 'b' ratio (9.11) was recorded in the Jackfruit population and the minimum (8.98) was recorded in the Tea population.

The mean CV values of both length of oesophagus and 'b' ratio of female *Hoplolaimus columbus* in relation to host plants was 5.62% and 6.33%, respectively indicating them as least variable characters. The highest CV value (6.92 %) of the 'b' ratio was found in the Mango population and the lowest CV value (5.53 %) was found in the Tea population (Table4.1).

e) Length of oesophageal gland overlapping and b' ratio:

The length of oesophageal gland overlapping in the population of *Hoplolaimus columbus* collected from different hosts was within the range of 168.54-233.20 μm ; while the b' ratio was within the range of 5.53-8.62 with a mean value of 6.92. The b' ratio of

Jackfruit, Mango and Tea populations were recorded in the range of 6.10-7.61, 6.39-8.62 and 5.53-7.35, respectively. The maximum mean b' ratio (7.32) was recorded in the Mango population and the minimum (6.53) was recorded in the Tea population.

The mean CV values of both length of oesophageal gland overlapping and b' ratio of female *Hoplolaimus columbus* in relation to host plants was 6.80% and 10.07%, respectively indicating them as least variable characters. The highest CV value (10.88 %) of the b' ratio was found in the Mango population and the lowest CV value (6.94 %) was found in the Jackfruit population (Table4.1).

f) Tail length and 'c' ratio:

The tail length in the population of *Hoplolaimus columbus* collected from different hosts plants was within the range of 16.96-31.80 μm ; while the 'c' ratio was within the range of 46.00-74.94 with a mean value of 54.98. The 'c' ratio of Jackfruit, Mango and Tea populations were recorded in the range of 46.00-68.10, 46.14-74.94 and 46.48-61.67, respectively. The maximum mean 'c' ratio (56.91) was recorded in the Jackfruit population and the minimum (53.59) was recorded in the Tea population.

The mean CV value of tail length of female *Hoplolaimus columbus* in relation to host plants was 12.27% indicating as moderately variable character, while 'c' ratio with a mean CV value of 11.65% was indicating as least variable character. The highest CV value (11.77 %) of the 'c' ratio was found in the Jackfruit population and the lowest CV value (9.47%) was found in the Tea population (Table4.1).

g) Anal body width (ABW) and c' ratio:

The anal body width (ABW) in the population of *Hoplolaimus columbus* collected from different hosts plants was within the range of 26.50-39.22 μm ; while the c' ratio was within the range of 0.57-0.96 μm with a mean value of 0.77. The c' ratio of Jackfruit, Mango and Tea populations were recorded in the range of 0.60-0.84, 0.57-0.96 and 0.68-0.89, respectively. The maximum mean c' ratio (0.84) was recorded in Mango population and the minimum (0.72) was recorded in the Jackfruit population.

The mean CV value of ABW of female *Hoplolaimus columbus* in relation to host plants was 8.32% indicating as least variable character while, c' ratio with a mean CV value of 12.31% was indicating as moderately variable character. The highest CV value

(11.03%) of the c' ratio was found in the Mango population and the lowest CV value (8.22%) was found in the Tea population (Table4.1).

h) MB:

The MB of females of *Hoplolaimus columbus* collected from all host plants ranged from 64.71-72.52% with mean value of 68.96%. The MB of populations collected from Jackfruit, Mango and Tea populations were recorded within the range of 64.71-72.52%, 65.71-70.83% and 68.35-71.85%, respectively. The maximum mean MB (69.97%) was recorded in the Tea population and the minimum (68.29%) was recorded in the Mango population.

The mean CV value of the MB of female *Hoplolaimus columbus* in relation to host plants was 2.34% indicating as least variable character. The highest CV value of the MB was found in the Jackfruit population (2.97%) and the lowest CV value (1.43 %) was found in Tea (Table4.1).

i) V and V':

The V and V' of females of *Hoplolaimus columbus* collected from all host plants ranged from 51.58-60.67% and 54.32-60.88% with mean value of 56.30% and 57.42%, respectively. The V of populations collected from Jackfruit, Mango and Tea population were recorded within the range of 54.76-58.90%, 53.24-57.77% and 51.58-60.67%, respectively while, V' ranged from 55.38-59.97%, 54.32-59.05% and 55.39-60.88%, respectively. The maximum mean V and V' (56.76% and 58.50%) were recorded in Tea population and the minimum (55.78% and 56.84%) were recorded in the Mango population.

The mean CV values of the V and V' of female *Hoplolaimus columbus* in relation to host plants were 3.04% and 2.74%, respectively indicating that they are least variable characters. The highest CV values of the V and V' were found in the Tea population (4.03% and 3.06%) and the lowest CV values (2.30% and 2.24%) were found in Mango population (Table4.1).

j) Stylet length:

The stylet length of females of *Hoplolaimus columbus* collected from all host plants ranged from 39.22-45.58 μ m with mean value of 41.69 μ m. The stylet length of

populations collected from Jackfruit, Mango and Tea were recorded within the range of 41.34-45.58 μm , 39.22-42.40 μm and 39.22-42.40 μm , respectively. The maximum mean stylet length (43.39 μm) was recorded in the Jackfruit population and the minimum (40.81 μm) was recorded in the Mango population.

The mean CV value of the stylet length of female *Hoplolaimus columbus* in relation to host plants was 3.89% indicating as least variable character. The highest CV value of the stylet length was found in the Jackfruit population (3.15%) and the lowest CV value (2.54%) was found in the Tea population (Table4.1).

k) SE:

The SE of females of *Hoplolaimus columbus* collected from all host plants ranged from 109.18-150.52 μm with mean value of 132.79 μm . The SE of populations collected from Jackfruit, Mango and Tea were recorded within the range of 116.60-145.22 μm , 109.18-150.52 μm and 117.66-148.40 μm , respectively. The maximum mean SE (134.73 μm) was recorded in the Mango population and the minimum (130.98 μm) was recorded in the Jackfruit population.

The mean CV value of the SE of female *Hoplolaimus columbus* in relation to host plants was 7.12% indicating as least variable character. The highest CV value of the SE was found in the Mango population (7.38%) and the lowest CV value (6.63%) was found in the Jackfruit population (Table4.1).

l) Tail annules:

The number of tail annules of females of *Hoplolaimus columbus* collected from all host plants ranged from 12.72-19.08 with mean value of 15.34. The number of tail annules of populations collected from Jackfruit, Mango and Tea were recorded within the range of 13.78-18.02, 12.72-19.08 and 13.78-18.02, respectively. The maximum mean number of tail annules (15.40) was recorded in the Tea population and the minimum (15.28) was recorded in the Mango population.

The mean CV value of the number of tail annules of female *Hoplolaimus columbus* in relation to host plants was 10.28 % indicating as least variable character. The highest CV value of the number of tail annules was found in the Mango population (10.71%) and the lowest CV value (10.36%) was found in the Tea population (Table4.1).

m) Pa:

The Pa of females of *Hoplolaimus columbus* collected from all host plants ranged from 26.10-38.91% with mean value of 30.46%. The Pa of populations collected from Jackfruit, Mango and Tea were recorded within the range of 26.91-38.91%, 26.10-36.77% and 27.03-36.93%, respectively. The maximum mean Pa (30.76%) was recorded in the Jackfruit population and the minimum (30.13%) was recorded in the Mango population.

The mean CV value of the Pa of female *Hoplolaimus columbus* in relation to host plants was 10.14 % indicating as least variable character. The highest CV value of the Pa was found in the Jackfruit population (11.07%) and the lowest CV value (9.23%) was found in the Tea population (Table4.1).

n) Pp:

The Pp of females of *Hoplolaimus columbus* collected from all host plants ranged from 71.34-83.98% with mean value of 77.56%. The Pp of populations collected from Jackfruit, Mango and Tea were recorded within the range of 73.82-82.02%, 73.39-81.81% and 71.34-83.98%, respectively. The maximum mean Pp (77.80%) was recorded in the Mango population and the minimum (77.31%) was recorded in the Tea population.

The mean CV value of the Pp of female *Hoplolaimus columbus* in relation to host plants was 3.29 % indicating as least variable character. The highest CV value of the Pp was found in the Tea population (3.96%) and the lowest CV value (2.76%) was found in the Jackfruit population (Table4.1).

4.1.1.2 Morphometric variations of *Hoplolaimus columbus* Sher, 1963 in relation to geographical locations:

To study the effect of geographical locations in morphological and morphometric variations of *Hoplolaimus columbus* we collected samples from different geographical locations such as Lakhimpur, Nagaon and KarbiAnglong having the same host plant as Banana. The morphological and morphometric measurements of variations are presented hereunder.

a) Habitus:

Body open 'C' shape upon fixation and takes curvature on the ventral side of the nematode body and there is no significant difference in habitus of *Hoplolaimus columbus* in relation to geographical locations (Plate 6A).

b) Body length:

The body length of females of *Hoplolaimus columbus* collected from all geographical locations ranged from 1.090-1.535mm with mean value of 1.340 mm. The body length of populations collected from Lakhimpur, Nagaon and KarbiAnglong were recorded within the range of 1.090-1.534mm, 1.171-1.535mm and 1.259-1.453mm, respectively. Maximum mean body length (1.353mm) was recorded in the KarbiAnglong population and the minimum (1.327mm) was recorded in the Lakhimpur population.

The mean CV value of the body length of female *Hoplolaimus columbus* in relation to geographical locations was 7.79% indicating as least variable character. The highest CV value of the body length was found in the Lakhimpur population (9.80%) and the lowest CV value (4.74%) was found in the KarbiAnglong population (Table4.2).

c) 'a' ratio:

The 'a' ratio of females of *Hoplolaimus columbus* collected from all geographical locations ranged from 23.75-33.74 with mean value of 28.50. The 'a' ratio of populations collected from Lakhimpur, Nagaon and KarbiAnglong were recorded within the range of 27.36-33.74, 23.75-30.63 and 23.98-30.70, respectively. The maximum mean 'a' ratio (29.79) was recorded in the Lakhimpur population and the minimum (27.62) was recorded in the Nagaon population.

The mean CV value of the 'a' ratio of female *Hoplolaimus columbus* in relation to geographical locations was 7.04% indicating as least variable character. The highest CV value of the 'a' ratio was found in the KarbiAnglong population (6.98%) and the lowest CV value (4.77%) was found in the Lakhimpur population (Table4.2).

d) Length of oesophagus and 'b' ratio:

The length of oesophagus in the population of *Hoplolaimus columbus* collected from different geographical locations was within the range of 128.26-174.90µm while, 'b' ratio was within the range of 7.74-11.07 with a mean value of 9.55. The 'b' ratio of

Table 4.2 Morphometric variations of *Hoplolaimus columbus* in relation to geographical locations (Host: Banana)

Characters ♀	Lakhimpur (n=20)	Nagaon (n=16)	KarbiAnglong (n=17)	Mean (n= 53)
Body length (mm)	1.327±0.130 (1.090-1.534) 9.80	1.343±0.105 (1.171-1.535) 7.85	1.353±0.064 (1.259-1.453) 4.74	1.340±0.104 (1.090-1.535) 7.79
Body width (µm)	44.57±4.13 (38.16-50.88) 9.27	48.91±5.68 (40.28-58.30) 11.62	49.16±4.15 (43.46-55.12) 8.44	47.25±5.04 (38.16-58.30) 10.66
Length of oesophagus (µm)	142.78±7.14 (129.32-155.82) 5.00	147.25±11.27 (137.80-174.90) 7.65	134.20±3.62 (128.26-139.92) 2.70	141.18±9.06 (128.26-174.90) 6.42
Oesophageal gland overlapping (µm)	190.86±11.87 (170.66-214.12) 6.22	183.48±10.46 (168.54-197.16) 5.70	171.72±9.15 (152.64-184.44) 5.33	182.92±13.36 (152.64-214.12) 7.30
Tail length (µm)	24.43±4.03 (16.96-30.74) 16.50	24.83±3.92 (21.20-33.92) 15.77	22.99±2.25 (19.08-27.56) 9.78	24.08±3.54 (16.96-33.92) 14.69
Anal body width (µm)	32.65±2.68 (26.50-37.10) 8.20	32.33±4.05 (27.56-41.34) 12.52	32.07±1.19 (29.68-33.92) 3.72	32.37±2.76 (26.50-41.34) 8.53
Position of vulva (µm)	748.57±68.16 (630.70-871.32) 9.11	742.98±59.25 (645.54-850.12) 7.97	751.81±46.26 (658.26-833.16) 6.15	748.04±58.31 (630.70-871.32) 7.79
Lip height (µm)	8.43±0.42 (7.42-9.54) 4.96	8.18±0.65 (7.42-9.54) 7.92	8.02±0.67 (7.42-9.54) 8.32	8.23±0.59 (7.42-9.54) 7.16
Lip width (µm)	16.01±0.76 (14.84-16.96) 4.76	15.37±0.91 (13.78-16.96) 5.90	15.57±0.75 (14.84-16.96) 4.79	15.69±0.83 (13.78-16.96) 5.29
Stylet length (µm)	42.82±1.35 (40.28-45.58) 3.15	41.42±1.53 (39.22-44.52) 3.68	40.81±1.40 (38.16-42.40) 3.42	41.79±1.65 (38.16-45.58) 3.94
SE (µm)	136.74±10.51 (113.42-156.88) 7.68	130.73±5.54 (120.84-138.86) 4.24	124.55±7.37 (113.42-134.62) 5.91	132.01±9.76 (113.42-156.88) 7.40
Nerve ring (µm)	117.10±6.20 (104.94-126.14) 5.30	125.79±11.11 (116.60-145.22) 8.83	112.36±2.68 (107.06-116.60) 2.39	116.52±7.44 (104.94-145.22) 6.39

Median bulb (μm)	100.91 \pm 4.83 (92.22-108.12) 4.79	98.35 \pm 7.81 (91.16-118.72) 7.94	96.79 \pm 2.18 (93.28-100.70) 2.25	98.88 \pm 5.47 (91.16-118.72) 5.53
Tail annules	15.16 \pm 1.65 (12.72-18.02) 10.90	17.72 \pm 1.34 (15.90-20.14) 7.58	16.50 \pm 1.77 (13.78-19.08) 10.74	16.30 \pm 1.90 (12.72-20.14) 11.67
Anus (μm)	1302.74 \pm 127.80 (1073.78-1504.14) 9.81	1318.49 \pm 102.62 (1146.92-1502.02) 7.78	1330.70 \pm 63.61 (1237.02-1429.94) 4.78	1316.10 \pm 102.52 (1073.78-1504.14) 7.79
a	29.79 \pm 1.42 (27.36-33.74) 4.77	27.62 \pm 1.91 (23.75-30.63) 6.93	27.66 \pm 1.93 (23.98-30.70) 6.98	28.50 \pm 2.01 (23.75-33.74) 7.04
b	9.29 \pm 0.76 (7.74-10.72) 8.13	9.23 \pm 0.69 (8.31-10.30) 7.45	10.14 \pm 0.51 (9.38-11.07) 5.01	9.55 \pm 0.77 (7.74-11.07) 8.09
b'	6.95 \pm 0.57 (5.69-7.91) 8.16	7.27 \pm 0.57 (6.48-8.15) 7.90	7.96 \pm 0.45 (7.31-9.07) 5.62	7.35 \pm 0.68 (5.69-9.07) 9.26
c	55.27 \pm 7.24 (41.38-67.29) 13.10	54.79 \pm 5.74 (45.28-63.05) 10.48	59.37 \pm 6.07 (52.08-72.39) 10.23	56.45 \pm 6.67 (41.38-72.39) 11.82
c'	0.75 \pm 0.08 (0.61-0.88) 11.23	0.77 \pm 0.08 (0.62-0.91) 11.04	0.72 \pm 0.07 (0.60-0.84) 9.13	0.74 \pm 0.08 (0.60-0.91) 10.74
V	56.45 \pm 1.30 (54.28-58.86) 2.30	55.33 \pm 1.81 (51.44-60.29) 3.27	55.52 \pm 1.66 (51.28-58.06) 3.00	55.84 \pm 1.62 (51.28-60.29) 2.90
V'	57.51 \pm 1.31 (55.39-59.97) 2.29	56.37 \pm 1.84 (52.36-61.34) 3.26	56.48 \pm 1.69 (52.18-58.91) 2.99	56.86 \pm 1.65 (52.18-61.34) 2.91
MB	70.70 \pm 1.41 (67.97-73.08) 1.99	67.32 \pm 2.33 (61.97-70.68) 3.45	72.17 \pm 1.66 (68.99-75.41) 2.30	70.30 \pm 2.55 (61.97-75.41) 3.62
Pa	32.40 \pm 5.29 (28.68-51.96) 16.34	33.48 \pm 5.14 (26.57-47.46) 15.36	31.14 \pm 1.78 (28.41-33.61) 5.70	32.50 \pm 4.71 (26.57-51.96) 14.49
Pp	78.40 \pm 2.81 (73.16-84.00) 3.58	76.11 \pm 2.62 (70.06-79.78) 3.44	77.96 \pm 4.72 (70.90-80.60) 6.05	77.50 \pm 3.09 (70.06-84.00) 3.98

[Mean \pm SD; (Range); CV%], Least variable (<12%), Moderately variable (12-20%), Highly variable (>20%)

Lakhimpur, Nagaon and KarbiAnglong populations were recorded within the range of 7.74-10.72, 8.31-10.30 and 9.38-11.07, respectively. The maximum mean 'b' ratio (10.14) was recorded in the KarbiAnglong population and the minimum (9.23) was recorded in the Nagaon population.

The mean CV values of both length of oesophagus and 'b' ratio of female *Hoplolaimus columbus* in relation to host plants was 6.42% and 8.09%, respectively indicating them as least variable characters. The highest CV value (8.13 %) of the 'b' ratio was found in the Lakhimpur population and the lowest CV value (5.01 %) was found in the KarbiAnglong population (Table4.2).

e) Length of oesophageal gland overlapping and b' ratio:

The length of oesophageal gland overlapping in the population of *Hoplolaimus columbus* collected from different geographical locations was within the range of 152.64-214.12 μm while, the b' ratio was within the range of 5.69-9.07 with a mean value of 7.35. The b' ratio of Lakhimpur, Nagaon and KarbiAnglong populations were recorded in the range of 5.69-7.91, 6.48-8.15 and 7.31-9.07, respectively. The maximum mean b' ratio (7.96) was recorded in the KarbiAnglong population and the minimum (6.95) was recorded in the Lakhimpur population.

The mean CV values of both length of oesophageal gland overlapping and b' ratio of female *Hoplolaimus columbus* in relation to geographical locations was 7.30% and 9.26%, respectively indicating them as least variable characters. The highest CV value (8.16 %) of the b' ratio was found in the Lakhimpur population and the lowest CV value (5.62 %) was found in the KarbiAnglong population (Table4.2).

f) Tail length and 'c' ratio:

The tail length in the population of *Hoplolaimus columbus* collected from different geographical locations was within the range of 16.96-33.92 μm while, the 'c' ratio was within the range of 41.38-72.39 with a mean value of 56.45. The 'c' ratio of Lakhimpur, Nagaon and KarbiAnglong populations were recorded in the range of 41.38-67.29, 45.28-63.05 and 52.08-72.39, respectively. The maximum mean 'c' ratio (59.37) was recorded in the KarbiAnglong population and the minimum (54.79) was recorded in the Nagaon population.

The mean CV value of tail length of female *Hoplolaimus columbus* in relation to geographical locations was 14.69% indicating as moderately variable character while, 'c' ratio with a mean CV value of 11.82% was indicating as least variable character. The highest CV value (13.10 %) of the 'c' ratio was found in the Lakhimpur population and the lowest CV value (10.23%) was found in the KarbiAnglong population (Table4.2).

g) Anal body width (ABW) and c' ratio:

The anal body width (ABW) in the population of *Hoplolaimus columbus* collected from different geographical locations was within the range of 26.50-41.34 μm while, the c' ratio was within the range of 0.60-0.91 with a mean value of 0.74. The c' ratio of Lakhimpur, Nagaon and KarbiAnglong populations were recorded in the range of 0.61-0.88, 0.62-0.91 and 0.60-0.84, respectively. The maximum mean c' ratio (0.77) was recorded in Nagaon population and the minimum (0.72) was recorded in the KarbiAnglong population.

The mean CV values of ABW and c' ratio of female *Hoplolaimus columbus* in relation to geographical locations were 8.32% and 10.74%, respectively indicating them as least variable characters. The highest CV value (11.23%) of the c' ratio was found in the Lakhimpur population and the lowest CV value (9.13%) was found in the KarbiAnglong population (Table4.2).

h) MB:

The MB of females of *Hoplolaimus columbus* collected from all geographical locations ranged from 61.97-75.41% with mean value of 70.30%. The MB of populations collected from Lakhimpur, Nagaon and KarbiAnglong populations were recorded within the range of 67.97-73.08%, 61.97-70.68% and 68.99-75.41% respectively. The maximum mean MB (72.17%) was recorded in the KarbiAnglong population and the minimum (67.32%) was recorded in the Nagaon population.

The mean CV value of the MB of female *Hoplolaimus columbus* in relation to geographical locations was 3.62% indicating as least variable character. The highest CV value of the MB was found in the Nagaon population (3.45 %) and the lowest CV value (1.99 %) was found in the Lakhimpur population (Table4.2).

i) V and V':

The V and V' of females of *Hoplolaimus columbus* collected from all geographical locations ranged from 51.28-60.29% and 52.18-61.34% with mean value of 55.84% and 56.86%, respectively. The V of populations collected from Lakhimpur, Nagaon and KarbiAnglong population were recorded within the range of 54.28-58.86%, 51.44-60.29% and 51.28-58.06%, respectively while, V' ranged from 55.39-59.97%, 52.36-61.34% and 52.18-58.91%, respectively. The maximum mean V and V' (56.45% and 57.51%) were recorded in Lakhimpur population and the minimum (55.33% and 56.37%) were recorded in the Nagaon population.

The mean CV values of the V and V' of female *Hoplolaimus columbus* in relation to geographical locations were 2.90% and 2.91%, respectively indicating as least variable characters. The highest CV values of the V and V' were found in the Nagaon population (3.27% and 3.26%) and the lowest CV values were found in the Lakhimpur population (2.30 % and 2.29 %) (Table4.2).

j) Stylet length:

The stylet length of females of *Hoplolaimus columbus* collected from all geographical locations ranged from 38.16-45.58 μ m with mean value of 41.79 μ m. The stylet length of populations collected from Lakhimpur, Nagaon and KarbiAnglong were recorded within the range of 40.28-45.58 μ m, 39.22-44.52 μ m and 38.16-42.40 μ m, respectively. The maximum mean stylet length (42.82 μ m) was recorded in the Lakhimpur population and the minimum (40.81 μ m) was recorded in the KarbiAnglong population.

The mean CV value of the stylet length of female *Hoplolaimus columbus* in relation to geographical locations was 3.94% indicating as least variable character. The highest CV value of the stylet length was found in the Nagaon population (3.68 %) and the lowest CV value (3.15 %) was found in the Lakhimpur population (Table4.2).

k) SE:

The SE of females of *Hoplolaimus columbus* collected from all geographical locations ranged from 113.42-156.88 μ m with mean value of 132.01 μ m. The SE of populations collected from Lakhimpur, Nagaon and KarbiAnglong were recorded within the range of 113.42-156.88 μ m, 120.84-138.86 μ m and 113.42-134.62 μ m, respectively. The maximum mean SE (136.74 μ m) was recorded in the Lakhimpur population and the minimum (124.55 μ m) was recorded in the KarbiAnglong population.

The mean CV value of the SE of female *Hoplolaimus columbus* in relation to geographical locations was 7.40% indicating as least variable character. The highest CV value of the SE was found in the Lakhimpur population (7.68%) and the lowest CV value (4.24%) was found in the Nagaon population (Table4.2).

l) Tail annules:

The number of tail annules of females of *Hoplolaimus columbus* collected from all geographical locations ranged from 12.72-20.14 with mean value of 16.30. The number of tail annules of populations collected from Lakhimpur, Nagaon and KarbiAnglong were recorded within the range of 12.72-18.02, 15.90-20.14 and 13.78-19.08, respectively. The maximum mean number of tail annules (17.72) was recorded in the Nagaon population and the minimum (15.16) was recorded in the Lakhimpur population.

The mean CV value of the number of tail annules of female *Hoplolaimus columbus* in relation to geographical locations was 11.67% indicating as least variable character. The highest CV value of the number of tail annules was found in the Lakhimpur population (10.90%) and the lowest CV value (7.58%) was found in the Nagaon population (Table4.2).

m) Pa:

The Pa of females of *Hoplolaimus columbus* collected from all geographical locations ranged from 26.57-51.96% with mean value of 32.50%. The Pa of populations collected from Lakhimpur, Nagaon and KarbiAnglong were recorded within the range of 28.68-51.96%, 26.57-47.46% and 28.41-33.61%, respectively. The maximum mean Pa (33.48%) was recorded in the Nagaon population and the minimum (31.14%) was recorded in the KarbiAnglong population.

The mean CV value of the Pa of female *Hoplolaimus columbus* in relation to geographical locations was 14.49% indicating as moderately variable character. The highest CV value of the Pa was found in the Lakhimpur population (16.34%) and the lowest CV value (5.70%) was found in the KarbiAnglong population (Table4.2).

n) Pp:

The Pp of females of *Hoplolaimus columbus* collected from all geographical locations ranged from 70.06-84.00% with mean value of 77.50%. The Pp of populations

collected from Lakhimpur, Nagaon and KarbiAnglong were recorded within the range of 73.16-84.00%, 70.06-79.78% and 70.90-80.60%, respectively. The maximum mean Pp (78.40%) was recorded in the Lakhimpur population and the minimum (76.11%) was recorded in the Nagaon population.

The mean CV value of the Pp of female *Hoplolaimus columbus* in relation to geographical locations was 3.98% indicating as least variable character. The highest CV value of the Pp was found in the KarbiAnglong population (6.05%) and the lowest CV value (3.44%) was found in the Nagaon population (Table4.2).

Hololaimus indicus Sher, 1963

Dimensions:

Female (n=52): L = 0.947-1.409mm (1.178 mm); a= 22.42-35.70 (28.23); b= 7.98-12.75 (9.57); b'= 5.77-9.51 (7.23); c= 43.72-91.64 (60.90); c'= 0.46-1.04 (0.72); V= 51.24-58.86 (55.89); Stylet length= 32.86-38.16 μ m (35.20 μ m); Excretory pore= 93.28-156.88 μ m(114.37 μ m); Pa= 22.34-47.02 % (33.72 %); Pp= 74.91-88.18 % (81.86 %); MB= 61.02-72.07(67.60)

Male (n=52): L = 0.859-1.173mm (1.024 mm); a= 20.77-34.50 (28.65); b= 7.05-10.06 (8.62); b'= 5.45-7.99(6.53); c= 28.79-52.26 (36.18); c'= 1.10-2.00 (1.57); Stylet length= 30.74-34.98 μ m(32.18 μ m); Excretory pore= 90.10-130.38 μ m(103.78 μ m); Pa= 29.07-51.08 % (34.64 %); Pp= 72.48-85.25 % (80.50 %); MB= 60.87-72.73(67.47); Spicule length= 32.86-40.28 μ m(37.01 μ m); Gubernaculum length= 13.78-21.20 μ m(18.04 μ m)

Description:

Female: Body ventrally curved upon fixation. Cuticle strongly striated, annules around 3 μ m apart at mid body. Lateral fields marked by single incisure, distinct in the tail region only. Lip region distinctly set-off, hemispherical measuring 6.36-8.48 μ m height and 11.66-15.90 μ m width, marked with 3-4 annules. Cephalic framework strongly sclerotized. Stylet massive, 32.86-38.16 μ m; stylet knob furnished with anteriorly projecting tooth like processes. Dorsal oesophageal gland with six nuclei, overlapping the intestine dorsally. Nerve ring surrounds the isthmus below the median oesophageal bulb, 82.68-114.48 μ m from anterior end. Excretory pore located at 93.28-156.88 μ m from

anterior end, mostly at the level of cardia. Hemizonids distinct, 3 to 4 annulus behind the excretory pore. Vulva with a transverse slit, almost median (55.89% of body), vagina almost right angle to the body axis. Epiptygma indistinct. Ovaries didelphic-amphidelphic, outstretched. Spermatheca present, axial, filled with sperms. Tail short, 11.66-30.74 μ m, with rounded annulated end. Cuticle markedly thickened in the tail terminus (Plate 2A-F and Plate 3G).

Male: Male is similar to female in general body shape and morphology but proportionately smaller in dimensions. Testis single. Spicules paired, 32.86-40.28 μ m in length, slightly arcuate, gubernaculum about half of spicule length with titillae. Bursa enveloping tail tip (Plate 3H-J).

Remarks: The present populations of *Hoplolaimus indicus* Sher, 1963 matched well with the dimensions and description given by Sher (1963); Khan & Chawla (1975); Anderson (1983) and Das (1993) except the body length, a ratio, MB, Pa, Pp, spicule length and gubernaculum length. [**Female:**L= 1.25-1.38mm, a= 18.25-25.55 and MB= 43.73-66.00 by Sher, (1963); L= 1.090-1.629 mm, Pa=33-45%, Pp=76-88% by Anderson (1983); L= 1.216-1.526mm, a= 29.0-37.0, MB= 55-65 by Das, (1993); **Male:** L= 1.15-1.45, a= 21.45-31.35, MB= 47.23-64.35, spicule length = 30.0-34.0 μ m, gubernaculum length= 18-20 μ m by Sher, (1963); L= 0.965-1.133, a= 31-34, Pa= 32-39%, Pp= 79-83%, spicule length = 34.0-41.0 μ m, gubernaculum length= 19-21 μ m by Anderson (1983); L=0.92-1.08, a= 29-33, spicule length = 37.0-40.0 μ m, gubernaculum length= 17-20 μ m by Das (1993)]

4.1.2 Morphological and morphometric variations of *Hoplolaimus indicus* Sher, 1963 in relation to host plants and geographical locations:

4.1.2.1 Morphological and morphometric variations of *Hoplolaimus indicus* Sher, 1963 in relation to host plants:

To study the effect of host plants in morphological and morphometric variations of *Hoplolaimus indicus* we collected samples from different host plants such as Banana and Rice having the same geographical locations as of Jorhat. The morphological and morphometric measurements of variations are presented hereunder.

a) Habitus:

Body open 'C' shape upon fixation and takes curvature on the ventral side of the nematode body and there is no significant difference in habitus of *Hoplolaimus indicus* in relation to host plants (Plate 6B).

b) Body length:

Female: The body length of females of *Hoplolaimus indicus* collected from all host plants ranged from 0.947-1.409 mm with mean value of 1.189 mm. The body length of populations collected from Banana and Rice were recorded within the range of 1.009-1.409 mm and 0.947-1.325mm, respectively. Maximum mean body length (1.255 mm) was recorded in the Banana population and the minimum (1.123 mm) was recorded in the Rice population.

The mean CV value of the body length of female *Hoplolaimus indicus* in relation to host plants was 10.22% indicating as least variable character. The highest CV value of the body length was found in the Rice population (9.12%) and the lowest CV value (8.25%) was found in the Banana population (Table4.3).

Male: The body length of males of *Hoplolaimus indicus* collected from all host plants ranged from 0.928-1.173 mm with mean value of 1.038 mm. The body length of populations collected from Banana and Rice were recorded within the range of 0.928-1.173 mm and 0.929-1.156 mm, respectively. Maximum mean body length (1.075 mm) was recorded in the Banana population and the minimum (1.007 mm) was recorded in the Rice population.

The mean CV value of the body length of male *Hoplolaimus indicus* in relation to host plants was 7.60% indicating as least variable character. The highest CV value of the body length was found in the Banana population (7.39%) and the lowest CV value (6.50%) was found in the Rice population (Table4.3).

c) 'a' ratio:

Female: The 'a' ratio of females of *Hoplolaimus indicus* collected from all host plants ranged from 22.42-35.70 with mean value of 28.39. The 'a' ratio of populations collected from Banana and Rice were recorded within the range of 22.42-31.93 and

Table 4.3. Morphometric variations of *Hoplolaimus indicus* in relation to host plants.

Characters ♀	Banana (n=18) ♀	Rice (n=20) ♀	Mean (n=38) ♀	Characters ♂	Banana (n=18) ♂	Rice (n=19) ♂	Mean (n=37) ♂
Body length (mm)	1.255±0.103 (1.009-1.409) 8.25	1.123±0.102 (0.947-1.325) 9.12	1.189±0.121 (0.947-1.409) 10.22	Body length (mm)	1.075±0.079 (0.928-1.173) 7.39	1.007±0.065 (0.929-1.156) 6.50	1.038±0.078 (0.928-1.173) 7.60
Body width (µm)	45.11±3.11 (42.40-55.12) 6.90	39.10±3.76 (31.80-45.58) 9.61	42.11±4.57 (31.80-55.12) 10.84	Body width (µm)	35.71±2.89 (28.62-41.34) 8.09	35.59±4.06 (29.68-42.40) 11.42	35.65±3.53 (28.62-42.40) 9.89
Length of oesophagus (µm)	127.97±10.42 (103.88-144.16) 8.14	120.96±6.67 (111.30-136.74) 5.52	124.46±9.33 (103.88-144.16) 7.49	Length of oesophagus (µm)	121.77±5.42 (114.48-133.56) 4.45	115.42±5.69 (107.06-125.08) 4.93	118.50±6.35 (107.06-133.56) 5.36
Oesophageal gland overlapping (µm)	168.19±13.17 (142.04-187.62) 7.83	157.94±9.13 (145.22-178.08) 5.78	163.21±12.37 (142.04-187.62) 7.58	Oesophageal gland overlapping (µm)	156.62±8.61 (143.10-171.72) 5.50	155.20±11.62 (133.56-170.66) 7.49	155.88±10.14 (133.56-171.72) 6.50
Tail length (µm)	22.88±4.37 (18.02-30.74) 19.10	18.64±2.761 (13.78-22.26) 14.78	20.76±4.19 (13.78-30.74) 20.19	Tail length (µm)	28.29±2.56 (23.32-31.80) 9.05	29.12±1.43 (27.56-31.80) 4.91	28.74±2.04 (23.32-31.80) 7.09
Anal body width (µm)	29.74±1.93 (25.44-32.86) 6.48	25.38±2.04 (21.20-28.62) 8.04	27.50±2.95 (21.20-32.86) 10.74	Anal body width (µm)	18.95±1.68 (15.90-21.20) 8.87	17.52±1.47 (14.84-20.14) 8.41	18.17±1.71 (14.84-21.20) 9.40

Position of vulva (μm)	702.13±53.55 (589.36-785.46) 7.63	624.10±62.16 (522.58-735.64) 9.96	663.12±69.53 (522.58-785.46) 10.49	Lip height (μm)	6.56±0.43 (6.36-7.42) 6.51	6.30±0.24 (5.30-6.36) 3.86	6.42±0.36 (5.30-7.42) 5.58
Lip height (μm)	7.30±0.50 (6.36-8.48) 6.84	6.77±0.64 (6.36-8.48) 9.51	7.04±0.63 (6.36-8.48) 8.93	Lip width (μm)	12.19±0.77 (10.60-12.72) 6.35	11.49±0.64 (10.60-12.72) 5.55	11.81±0.78 (10.60-12.72) 6.58
Lip width (μm)	13.90±0.80 (12.72-15.90) 5.78	13.07±0.73 (11.66-13.78) 5.56	13.49±0.86 (11.66-15.90) 6.40	Stylet length (μm)	33.59±1.08 (31.80-34.98) 3.20	32.13±0.87 (30.74-33.92) 2.71	32.80±1.20 (30.74-34.98) 3.67
Stylet length (μm)	35.63±1.21 (33.92-38.16) 3.41	34.69±0.95 (32.86-36.04) 2.73	35.16±1.17 (32.86-38.16) 3.34	SE (μm)	109.18±9.13 (96.46-130.38) 8.36	100.17±7.01 (91.16-116.60) 6.99	104.11±9.08 (91.16-130.38) 8.72
SE (μm)	123.12±15.90 (103.88-156.88) 12.91	110.24±7.23 (97.52-118.72) 6.56	116.68±13.77 (97.52-156.88) 11.80	Nerve ring (μm)	99.51±5.16 (91.16-113.42) 5.19	93.17±4.07 (86.92-101.76) 4.37	96.07±5.55 (86.92-113.42) 5.78
Nerve ring (μm)	101.39±8.18 (82.68-114.48) 8.07	96.58±5.57 (86.92-109.18) 5.77	98.91±7.28 (82.68-114.48) 7.36	Median bulb (μm)	83.48±4.23 (77.38-95.40) 5.07	77.27±2.91 (73.14-82.68) 3.77	80.11±4.71 (73.14-95.40) 5.89
Median bulb (μm)	85.62±7.66 (68.90-97.52) 8.94	81.97±4.24 (76.32-90.10) 5.17	83.80±6.37 (68.90-97.52) 7.61	Spicule length (μm)	36.97±1.64 (33.92-39.22) 4.43	36.49±1.91 (32.86-39.22) 5.24	36.71±1.78 (32.86-39.22) 4.86

Tail annules	13.28±1.95 (10.60-15.90) 14.69	10.41±1.51 (8.48-12.72) 14.50	11.85±2.25 (8.48-15.90) 19.01	Gubernaculum length (µm)	18.59±0.79 (16.96-19.08) 4.24	18.55±1.42 (15.90-21.20) 7.65	18.57±1.16 (15.90-21.20) 6.24
Anus (µm)	1233.90±104.44 (990.04-1385.42) 8.46	1106.17±101.52 (930.68-1308.04) 9.18	1168.21±120.34 (930.68-1385.42) 10.30	Bursa (µm)	60.57±6.92 (51.94-73.14) 11.42	58.69±7.56 (47.70-75.26) 12.89	59.49±7.25 (47.70-75.26) 12.18
a	27.92±2.64 (22.42-31.93) 9.44	28.86±2.64 (24.90-35.70) 9.13	28.39±2.64 (22.42-35.70) 9.30	Anus (µm)	1047.02±79.71 (898.88-1147.98) 7.61	978.55±65.13 (902.06-1124.66) 6.66	1009.85±79.03 (898.88-1147.98) 7.83
b	9.89±1.32 (8.07-12.75) 13.33	9.30±0.75 (7.98-10.45) 8.10	9.59±1.10 (7.98-12.75) 11.47	a	30.22±2.47 (26.86-34.50) 8.19	28.53±2.42 (24.03-32.93) 8.47	29.30±2.56 (24.03-34.50) 8.72
b'	7.52±0.97 (5.77-9.51) 12.95	7.11±0.56 (6.08-8.10) 7.85	7.32±0.82 (5.77-9.51) 11.15	b	8.84±0.69 (7.75-10.06) 7.78	8.69±0.63 (7.56-9.90) 7.25	8.76±0.65 (7.56-10.06) 7.45
c	56.28±8.52 (43.72-67.16) 15.14	61.68±10.57 (44.90-82.79) 17.14	58.98±9.84 (43.72-82.79) 16.69	b'	6.89±0.65 (5.76-7.94) 9.48	6.47±0.66 (5.45-7.99) 10.20	6.67±0.68 (5.45-7.99) 10.20
c'	0.77±0.13 (0.62-1.04) 17.48	0.74±0.10 (0.58-0.91) 14.11	0.75±0.12 (0.58-1.04) 15.85	c	38.34±4.95 (31.29-50.18) 12.91	34.65±2.42 (30.76-41.50) 6.98	36.34±4.17 (30.76-50.18) 11.48
V	55.96±1.38 (53.50-58.40) 2.46	55.53±1.90 (51.95-58.81) 3.42	55.75±1.65 (51.95-58.81) 2.96	c'	1.50±0.16 (1.16-1.75) 10.90	1.67±0.16 (1.42-2.00) 9.56	1.59±0.18 (1.16-2.00) 11.37

V'	56.87±1.34 (54.69-59.53) 2.35	56.42±2.04 (52.65-59.83) 3.61	56.64±1.72 (52.65-59.83) 3.04	MB	68.58±2.47 (63.48-72.73) 3.60	66.67±1.68 (62.83-70.30) 2.52	67.59±2.28 (62.83-72.73) 3.38
MB	66.89±1.99 (61.02-69.53) 2.97	67.80±1.82 (64.29-72.07) 2.68	67.35±1.93 (61.02-72.07) 2.87	Pa	34.10±2.86 (29.40-38.11) 8.38	32.84±2.02 (29.07-36.54) 6.16	33.40±2.46 (29.07-38.11) 7.38
Pa	32.84±4.43 (22.34-42.20) 13.49	33.78±3.61 (28.10-41.16) 10.69	33.24±4.05 (22.34-42.20) 12.19	Pp	80.78±2.19 (77.85-85.25) 2.71	79.67±3.63 (72.48-84.72) 4.55	80.17±3.07 (72.48-85.25) 3.83
Pp	82.73±2.66 (76.85-86.06) 3.22	79.96±3.10 (74.91-83.90) 3.88	81.35±3.16 (74.91-86.06) 3.89				

[Mean±SD; (Range); CV%], Least variable (<12%), Moderately variable (12-20%), Highly variable (>20%)

24.90-35.70, respectively. The maximum mean 'a' ratio (28.86) was recorded in the Rice population and the minimum (27.92) was recorded in the Banana population.

The mean CV value of the 'a' ratio of female *Hoplolaimus indicus* in relation to host plants was 9.30 % indicating as least variable character. The highest CV value of the 'a' ratio was found in the Banana population (9.44%) and the lowest CV value (9.13%) was found in the Rice population (Table4.3).

Male: The 'a' ratio of males of *Hoplolaimus indicus* collected from all host plants ranged from 24.03-34.50 with mean value of 29.30. The 'a' ratio of populations collected from Banana and Rice were recorded within the range of 26.86-34.50 and 24.03-32.93, respectively. The maximum mean 'a' ratio (30.22) was recorded in the Banana population and the minimum (28.53) was recorded in the Rice population.

The mean CV value of the 'a' ratio of male *Hoplolaimus indicus* in relation to host plants was 8.72% indicating as least variable character. The highest CV value of the 'a' ratio was found in the Rice population (8.47%) and the lowest CV value (8.19%) was found in the Banana population (Table4.3).

d) Length of oesophagus and 'b' ratio:

Female: The length of oesophagus in the population of *Hoplolaimus indicus* collected from different hosts was within the range of 103.88-144.16 μm while, the 'b' ratio was within the range of 7.98-12.75 with a mean value of 9.59. The 'b' ratio of Banana and Rice populations were recorded within the range of 8.07-12.75 and 7.98-10.45, respectively. The maximum mean 'b' ratio (9.89) was recorded in the Banana population and the minimum (9.30) was recorded in the Rice population.

The mean CV values of both length of oesophagus and 'b' ratio of female *Hoplolaimus indicus* in relation to host plants was 7.49% and 11.47%, respectively indicating them as least variable characters. The highest CV value (13.33%) of the 'b' ratio was found in the Banana population and the lowest CV value (8.10 %) was found in the Rice population (Table4.3).

Male: The length of oesophagus in the population of *Hoplolaimus indicus* collected from different hosts was within the range of 107.06-133.56 μm while, the 'b' ratio was within the range of 7.56-10.06 with a mean value of 8.76. The 'b' ratio of Banana and Rice populations were recorded within the range of 7.75-10.06 and 7.56-

9.90, respectively. The maximum mean 'b' ratio (8.84) was recorded in the Banana population and the minimum (8.69) was recorded in the Rice population.

The mean CV values of both length of oesophagus and 'b' ratio of male *Hoplolaimus indicus* in relation to host plants was 5.36% and 7.45%, respectively indicating them as least variable characters. The highest CV value (7.78%) of the 'b' ratio was found in the Banana population and the lowest CV value (7.25 %) was found in the Rice population (Table4.3).

e) Length of oesophageal gland overlapping and b' ratio:

Female: The length of oesophageal gland overlapping in the population of *Hoplolaimus indicus* collected from different hosts was within the range of 142.04-187.62 μm while, the b' ratio was within the range of 5.77-9.51 with a mean value of 7.32. The b' ratio of Banana and Rice populations were recorded in the range of 5.77-9.51 and 6.08-8.10, respectively. The maximum mean b' ratio (7.52) was recorded in the Banana population and the minimum (7.11) was recorded in the Rice population.

The mean CV values of both length of oesophageal gland overlapping and b' ratio of female *Hoplolaimus indicus* in relation to host plants was 7.58% and 7.85%, respectively indicating them as least variable characters. The highest CV value (12.95 %) of the b' ratio was found in the Banana population and the lowest CV value (7.85 %) was found in the Rice population (Table4.3).

Male: The length of oesophageal gland overlapping in the population of *Hoplolaimus indicus* collected from different hosts was within the range of 133.56-171.72 μm ; while the b' ratio was within the range of 5.45-7.99 with a mean value of 6.67. The b' ratio of Banana and Rice populations were recorded in the range of 5.76-7.94 and 5.45-7.99, respectively. The maximum mean b' ratio (6.89) was recorded in the Banana population and the minimum (6.47) was recorded in the Rice population.

The mean CV values of both length of oesophageal gland overlapping and b' ratio of male *Hoplolaimus indicus* in relation to host plants was 6.50% and 10.20%, respectively indicating them as least variable characters. The highest CV value (10.20%) of the b' ratio was found in the Rice population and the lowest CV value (9.48%) was found in the Banana population (Table4.3).

f) Tail length and 'c' ratio:

Female: The tail length in the population of *Hoplolaimus indicus* collected from different hosts plants was within the range of 13.78-30.74 μm while, the 'c' ratio was within the range of 43.72-82.79 with a mean value of 58.98. The 'c' ratio of Banana and Rice populations were recorded in the range of 43.72-67.16 and 44.90-82.79, respectively. The maximum mean 'c' ratio (61.68) was recorded in the Rice population and the minimum (56.28) was recorded in the Banana population.

The mean CV value of tail length of female *Hoplolaimus indicus* in relation to host plants was 20.19% indicating as highly variable character while, 'c' ratio with a mean CV value of 16.69% was indicating as moderately variable character. The highest CV value (17.14%) of the 'c' ratio was found in the Rice population and the lowest CV value (15.14%) was found in the Banana population (Table4.3).

Male: The tail length in the male population of *Hoplolaimus indicus* collected from different hosts plants was within the range of 23.32-31.80 μm while, the 'c' ratio was within the range of 30.76-50.18 with a mean value of 36.34. The 'c' ratio of Banana and Rice populations were recorded in the range of 31.29-50.18 and 30.76-41.50, respectively. The maximum mean 'c' ratio (38.34) was recorded in the Banana population and the minimum (34.65) was recorded in the Rice population.

The mean CV values of both tail length and 'c' ratio of male *Hoplolaimus indicus* in relation to host plants were 7.09% and 11.48%, respectively indicating them as least variable characters. The highest CV value (17.14%) of the 'c' ratio was found in the Rice population and the lowest CV value (15.14%) was found in the Banana population (Table4.3).

g) Anal body width (ABW) and c' ratio:

Female: The anal body width (ABW) in the population of *Hoplolaimus indicus* collected from different hosts plants was within the range of 21.20-32.86 μm while, the c' ratio was within the range of 0.58-1.04 μm with a mean value of 0.75. The c' ratio of Banana and Rice populations were recorded in the range of 0.62-1.04 and 0.58-0.91, respectively. The maximum mean c' ratio (0.77) was recorded in Banana population and the minimum (0.74) was recorded in the Rice population.

The mean CV value of ABW of female *Hoplolaimus indicus* in relation to host plants was 10.74% indicating as least variable character while, c' ratio with a mean CV

value of 15.85% was indicating as moderately variable character. The highest CV value (17.48%) of the c' ratio was found in the Banana population and the lowest CV value (14.11%) was found in the Rice population (Table4.3).

Male: The anal body width (ABW) in the male population of *Hoplolaimus indicus* collected from different hosts plants was within the range of 14.84-21.20 μ m while, the c' ratio was within the range of 1.16-2.00 μ m with a mean value of 1.59. The c' ratio of Banana and Rice populations were recorded in the range of 1.16-1.75 and 1.42-2.00, respectively. The maximum mean c' ratio (1.67) was recorded in Rice population and the minimum (1.50) was recorded in the Banana population.

The mean CV values of both ABW and c' ratio of male *Hoplolaimus indicus* in relation to host plants were 9.40% and 11.37%, respectively indicating them as least variable characters. The highest CV value (10.90%) of the c' ratio was found in the Banana population and the lowest CV value (9.56%) was found in the Rice population (Table4.3).

h) MB:

Female: The MB of females of *Hoplolaimus indicus* collected from all host plants ranged from 61.02-72.07% with mean value of 67.35%. The MB of populations collected from Banana and Rice populations were recorded within the range of 61.02-69.53% and 64.29-72.07%, respectively. The maximum mean MB (67.80%) was recorded in the Rice population and the minimum (66.89%) was recorded in the Banana population.

The mean CV value of the MB of female *Hoplolaimus indicus* in relation to host plants was 2.87% indicating as least variable character. The highest CV value of the MB was found in the Banana population (2.97 %) and the lowest CV value (2.68 %) was found in the Rice population (Table4.3).

Male: The MB of males of *Hoplolaimus indicus* collected from all host plants ranged from 62.83-72.73% with mean value of 67.59%. The MB of populations collected from Banana and Rice populations were recorded within the range of 63.48-72.73% and 62.83-70.30%, respectively. The maximum mean MB (68.58%) was recorded in the Banana population and the minimum (66.67%) was recorded in the Rice population.

The mean CV value of the MB of male *Hoplolaimus indicus* in relation to host plants was 3.38% indicating as least variable character. The highest CV value of the MB

was found in the Banana population (3.60 %) and the lowest CV value was found in the Rice population (2.52 %) (Table4.3).

i) V and V':

The V and V' of females of *Hoplolaimus indicus* collected from all host plants ranged from 51.95-58.81% and 52.65-59.83% with mean value of 56.42% and 56.64%, respectively. The V of populations collected from Banana and Rice population were recorded within the range of 53.50-58.40% and 51.95-58.81%, respectively while, V' ranged from 54.69-59.53% and 52.65-59.83%, respectively. The maximum mean V and V' (55.96% and 56.87%) were recorded in Banana population and the minimum (55.53% and 56.42%) were recorded in the Rice population.

The mean CV values of the V and V' of female *Hoplolaimus indicus* in relation to host plants were 2.96 % and 3.04%, respectively indicating as least variable characters. The highest CV values of the V and V' were found in the Rice population (3.42% and 3.61%) and the lowest CV values (2.46 % and 2.35 %) were found in Banana population (Table4.3).

j) Stylet length:

Female: The stylet length of females of *Hoplolaimus indicus* collected from all host plants ranged from 32.86-38.16 μ m with mean value of 35.16 μ m. The stylet length of populations collected from Banana and Rice were recorded within the range of 33.92-38.16 μ m and 32.86-36.04 μ m, respectively. The maximum mean stylet length (35.63 μ m) was recorded in the Banana population and the minimum (34.69 μ m) was recorded in the Rice population.

The mean CV value of the stylet length of female *Hoplolaimus indicus* in relation to host plants was 3.34 % indicating as least variable character. The highest CV value of the stylet length was found in the Banana population (3.41 %) and the lowest CV value (2.73 %) was found in the Rice population (Table4.3).

Male: The stylet length of males of *Hoplolaimus indicus* collected from all host plants ranged from 30.74-34.98 μ m with mean value of 32.80 μ m. The stylet length of populations collected from Banana and Rice were recorded within the range of 31.80-34.98 μ m and 30.74-33.92 μ m, respectively. The maximum mean stylet length (33.59 μ m)

was recorded in the Banana population and the minimum (32.13 μm) was recorded in the Rice population.

The mean CV value of the stylet length of male *Hoplolaimus indicus* in relation to host plants was 3.67% indicating as least variable character. The highest CV value of the stylet length was found in the Banana population (3.20%) and the lowest CV value (2.71%) was found in the Rice population (Table4.3).

k) SE:

Female: The SE of females of *Hoplolaimus indicus* collected from all host plants ranged from 97.52-156.88 μm with mean value of 116.68 μm . The SE of populations collected from Banana and Rice were recorded within the range of 103.88-156.88 μm and 97.52-118.72 μm , respectively. The maximum mean SE (123.12 μm) was recorded in the Banana population and the minimum (110.24 μm) was recorded in the Rice population.

The mean CV value of the SE of female *Hoplolaimus indicus* in relation to host plants was 11.80% indicating as least variable character. The highest CV value of the SE was found in the Banana population (12.91%) and the lowest CV value (6.56%) was found in the Rice population (Table4.3).

Male: The SE of males of *Hoplolaimus indicus* collected from all host plants ranged from 91.16-130.38 μm with mean value of 104.11 μm . The SE of populations collected from Banana and Rice were recorded within the range of 96.46-130.38 μm and 91.16-116.60 μm , respectively. The maximum mean SE (109.18 μm) was recorded in the Banana population and the minimum (100.17 μm) was recorded in the Rice population.

The mean CV value of the SE of male *Hoplolaimus indicus* in relation to host plants was 8.72% indicating as least variable character. The highest CV value of the SE was found in the Banana population (8.36%) and the lowest CV value (6.99%) was found in the Rice population (Table4.3).

l) Tail annules:

The number of tail annules of females of *Hoplolaimus indicus* collected from all host plants ranged from 8.48-15.90 with mean value of 11.85. The number of tail annules of populations collected from Banana and Rice were recorded within the range of 10.60-15.90 and 8.48-12.72, respectively. The maximum mean number of tail annules (13.28)

was recorded in the Banana population and the minimum (10.41) was recorded in the Rice population.

The mean CV value of the number of tail annules of female *Hoplolaimus indicus* in relation to host plants was 19.01% indicating as moderately variable character. The highest CV value of the number of tail annules was found in the Banana population (14.69%) and the lowest CV value (14.50%) was found in the Rice population (Table4.3).

m) Pa:

Female: The Pa of females of *Hoplolaimus indicus* collected from all host plants ranged from 22.34-42.20% with mean value of 33.24%. The Pa of populations collected from Banana and Rice were recorded within the range of 22.34-42.20% and 28.10-41.16%, respectively. The maximum mean Pa (33.78%) was recorded in the Rice population and the minimum (32.84%) was recorded in the Banana population.

The mean CV value of the Pa of female *Hoplolaimus indicus* in relation to host plants was 12.19% indicating as moderately variable character. The highest CV value of the Pa was found in the Banana population (13.49%) and the lowest CV value (10.69%) was found in the Rice population (Table4.3).

Male: The Pa of males of *Hoplolaimus indicus* collected from all host plants ranged from 29.07-38.11% with mean value of 33.40%. The Pa of populations collected from Banana and Rice were recorded within the range of 29.40-38.11% and 29.07-36.54%, respectively. The maximum mean Pa (34.10%) was recorded in the Banana population and the minimum (32.84%) was recorded in the Rice population.

The mean CV value of the Pa of male *Hoplolaimus indicus* in relation to host plants was 7.38% indicating as least variable character. The highest CV value of the Pa was found in the Banana population (8.38%) and the lowest CV value (6.16%) was found in the Rice population (Table4.3).

n) Pp:

Female: The Pp of females of *Hoplolaimus indicus* collected from all host plants ranged from 74.91-86.06% with mean value of 81.35%. The Pp of populations collected from Banana and Rice were recorded within the range of 76.85-86.06% and 74.91-

83.90%, respectively. The maximum mean Pp (82.73%) was recorded in the Banana population and the minimum (79.96%) was recorded in the Rice population.

The mean CV value of the Pp of female *Hoplolaimus indicus* in relation to host plants was 3.89% indicating as least variable character. The highest CV value of the Pp was found in the Rice population (3.88%) and the lowest CV value (3.22%) was found in the Banana population (Table4.3).

Male: The Pp of males of *Hoplolaimus indicus* collected from all host plants ranged from 72.48-85.25% with mean value of 80.17%. The Pp of populations collected from Banana and Rice were recorded within the range of 77.85-85.25% and 72.48-84.72%, respectively. The maximum mean Pp (80.78%) was recorded in the Banana population and the minimum (79.67%) was recorded in the Rice population.

The mean CV value of the Pp of male *Hoplolaimus indicus* in relation to host plants was 3.83% indicating as least variable character. The highest CV value of the Pp was found in the Rice population (4.55%) and the lowest CV value (2.71%) was found in the Banana population (Table4.3).

o) Spicule length:

The spicule length of males of *Hoplolaimus indicus* collected from all host plants ranged from 32.86-39.22 μ m with mean value of 36.71 μ m. The spicule length of populations collected from Banana and Rice were recorded within the range of 33.92-39.22 μ m and 32.86-39.22 μ m, respectively. The maximum mean spicule length (36.97 μ m) was recorded in the Banana population and the minimum (36.49 μ m) was recorded in the Rice population.

The mean CV value of the spicule length of male *Hoplolaimus indicus* in relation to host plants was 4.86% indicating as least variable character. The highest CV value of the spicule length was found in the Rice population (5.24%) and the lowest CV value (4.43%) was found in the Banana population (Table4.3).

p) Gubernaculum length:

The gubernaculum length of males of *Hoplolaimus indicus* collected from all host plants ranged from 15.90-21.20 μ m with mean value of 18.57 μ m. The gubernaculum length of populations collected from Banana and Rice were recorded within the range of

16.96-19.08 μm and 15.90-21.20 μm , respectively. The maximum mean gubernaculum length (18.59 μm) was recorded in the Banana population and the minimum (18.55 μm) was recorded in the Rice population.

The mean CV value of the gubernaculum length of male *Hoplolaimus indicus* in relation to host plants was 6.24% indicating as least variable character. The highest CV value of the gubernaculum length was found in the Rice population (7.65%) and the lowest CV value (4.24%) was found in the Banana population (Table4.3).

4.1.2.2 Morphological and morphometric variations of *Hoplolaimus indicus* Sher, 1963 in relation to geographical locations:

To study the effect of geographical locations in morphological and morphometric variations of *Hoplolaimus indicus* we collected samples from different geographical locations such as Jorhat and Kamrup having the same host plant as Banana. The morphological and morphometric measurements of variations are presented hereunder

a) Habitus:

Body open 'C' shape upon fixation and takes curvature on the ventral side of the nematode body and there is no significant difference in habitus of *Hoplolaimus indicus* in relation to geographical locations (Plate 6B).

b) Body length:

Female: The body length of females of *Hoplolaimus indicus* collected from all geographical locations ranged from 1.009-1.409 mm with mean value of 1.207 mm. The body length of populations collected from Jorhat and Kamrup were recorded within the range of 1.009-1.409 mm and 1.045-1.280mm, respectively. Maximum mean body length (1.255 mm) was recorded in the Jorhat population and the minimum (1.154 mm) was recorded in the Kamrup population.

The mean CV value of the body length of female *Hoplolaimus indicus* in relation to geographical locations was 8.70% indicating as least variable character. The highest CV value of the body length was found in the Jorhat population (8.25%) and the lowest CV value (6.88%) was found in the Kamrup population (Table4.4).

Table.4.4 Morphometric variations of *Hoplolaimus indicus* in relation to geographical locations (Host: Banana)

Characters ♀	Jorhat (n=18) ♀	Kamrup (n=17) ♀	Mean (n=35) ♀	Characters ♂	Jorhat (n=18) ♂	Kamrup (n=18) ♂	Mean (n=36) ♂
Body length (µm)	1.255±0.103 (1.009-1.409) 8.25	1.154±0.079 (1.045-1.280) 6.88	1.207±0.105 (1.009-1.409) 8.70	Body length (µm)	1.075±0.079 (0.928-1.173) 7.39	0.994±0.067 (0.859-1.102) 6.75	1.033±0.082 (0.859-1.173) 8.03
Body width (µm)	45.11±3.11 (42.40-55.12) 6.90	41.61±4.01 (34.98-49.82) 9.65	43.46±3.93 (34.98-55.12) 9.05	Body width (µm)	35.71±2.89 (28.62-41.34) 8.09	36.85±4.33 (30.74-45.58) 11.75	36.30±3.69 (28.62-45.58) 10.17
Length of oesophagus (µm)	127.97±10.42 (103.88-144.16) 8.14	121.30±7.18 (106.00-134.62) 5.92	124.83±9.52 (103.88-144.16) 7.63	Length of oesophagus (µm)	121.77±5.42 (114.48-133.56) 4.45	119.28±3.40 (114.48-124.02) 2.85	120.49±4.60 (114.48-133.56) 3.81
Oesophageal gland overlapping (µm)	168.19±13.17 (142.04-187.62) 7.83	164.50±12.52 (132.50-181.26) 7.61	166.45±12.81 (132.50-187.62) 7.70	Oesophageal gland overlapping (µm)	156.62±8.61 (143.10-171.72) 5.50	158.88±7.98 (144.16-169.60) 5.03	157.78±8.24 (143.10-171.72) 5.22
Tail length (µm)	22.88±4.37 (18.02-30.74) 19.10	18.35±3.54 (11.66-23.32) 19.30	20.69±4.55 (11.66-30.74) 22.01	Tail length (µm)	28.29±2.56 (23.32-31.80) 9.05	28.22±3.26 (20.14-32.86) 11.55	28.26±2.88 (20.14-32.86) 10.20
Anal body width (µm)	29.74±1.93 (25.44-32.86) 6.48	27.03±2.12 (23.32-29.68) 7.84	28.43±2.42 (23.32-32.86) 8.52	Anal body width (µm)	18.95±1.68 (15.90-21.20) 8.87	18.58±1.55 (15.90-22.26) 8.34	18.76±1.60 (15.90-22.26) 8.53

Position of vulva (µm)	702.13±53.55 (589.36-785.46) 7.63	648.59±44.95 (579.82-726.10) 6.93	676.93±55.96 (579.82-785.46) 8.27	Lip height (µm)	6.56±0.43 (6.36-7.42) 6.51	6.61±0.46 (6.36-7.42) 7.01	6.58±0.44 (6.36-7.42) 6.68
Lip height (µm)	7.30±0.50 (6.36-8.48) 6.84	6.49±0.36 (6.36-7.42) 5.58	6.92±0.60 (6.36-8.48) 8.63	Lip width (µm)	12.19±0.77 (10.60-12.72) 6.35	11.97±0.73 (10.60-12.72) 6.07	12.08±0.75 (10.60-12.72) 6.18
Lip width (µm)	13.90±0.80 (12.72-15.90) 5.78	13.18±0.67 (12.72-14.84) 5.06	13.56±0.82 (12.72-15.90) 6.02	Stylet length (µm)	33.59±1.08 (31.80-34.98) 3.20	32.86±0.75 (31.80-33.92) 2.28	33.21±0.98 (31.80-34.98) 2.95
Stylet length (µm)	35.63±1.21 (33.92-38.16) 3.41	35.31±1.21 (33.92-37.10) 3.42	35.48±1.20 (33.92-38.16) 3.39	SE (µm)	109.18±9.13 (96.46-130.38) 8.36	103.05±8.60 (90.10-124.02) 8.35	106.11±9.25 (90.10-130.38) 8.71
SE (µm)	123.12±15.90 (103.88-156.88) 12.91	110.38±10.34 (93.28-127.20) 9.37	116.30±14.48 (93.28-156.88) 12.45	Nerve ring (µm)	99.51±5.16 (91.16-113.42) 5.19	95.52±3.20 (86.92-99.64) 3.35	97.46±4.66 (86.92-113.42) 4.78
Nerve ring (µm)	101.39±8.18 (82.68-114.48) 8.07	97.32±5.72 (84.80-109.18) 5.88	99.42±7.29 (82.68-114.48) 7.33	Median bulb (µm)	83.48±4.23 (77.38-95.40) 5.07	80.19±3.04 (74.20-85.86) 3.80	81.78±3.98 (74.20-95.40) 4.86
Median bulb (µm)	85.62±7.66 (68.90-97.52) 8.94	82.68±4.96 (74.20-93.28) 6.00	84.24±6.60 (68.90-97.52) 7.84	Spicule length (µm)	36.97±1.64 (33.92-39.22) 4.43	37.66±1.60 (34.98-40.28) 4.24	37.32±1.63 (33.92-40.28) 4.36

Tail annules	13.28±1.95 (10.60-15.90) 14.69	12.57±2.15 (9.54-16.96) 17.14	12.96±2.04 (9.54-16.96) 15.76	Gubernaculum length (µm)	18.59±0.79 (16.96-19.08) 4.24	16.96±1.94 (13.78-20.14) 11.41	17.75±1.69 (13.78-20.14) 9.50
Anus (µm)	1233.90±104.44 (990.04-1385.42) 8.46	1135.86±77.92 (1026.08-1262.46) 6.86	1186.36±103.81 (990.04-1385.42) 8.75	Bursa (µm)	60.57±6.92 (51.94-73.14) 11.42	59.80±4.56 (53.00-72.08) 7.63	60.15±5.66 (51.94-73.14) 9.40
a	27.92±2.64 (22.42-31.93) 9.44	27.87±1.99 (24.82-31.55) 7.14	27.90±2.32 (22.42-31.93) 8.31	Anus (µm)	1047.02±79.71 (898.88-1147.98) 7.61	968.22±67.17 (833.16-1075.90) 6.94	1006.42±82.66 (833.16-1147.98) 8.21
b	9.89±1.32 (8.07-12.75) 13.33	9.55±0.91 (8.30-11.74) 9.55	9.73±1.14 (8.07-12.75) 11.74	a	30.22±2.47 (26.86-34.50) 8.19	27.30±3.35 (20.77-32.94) 12.25	28.72±3.27 (20.77-34.50) 11.37
b'	7.52±0.97 (5.77-9.51) 12.95	7.06±0.77 (6.00-9.39) 10.87	7.30±0.90 (5.77-9.51) 12.34	b	8.84±0.69 (7.75-10.06) 7.78	8.35±0.60 (7.05-9.37) 7.19	8.59±0.68 (7.05-10.06) 7.94
c	56.28±8.52 (43.72-67.16) 15.14	65.01±12.49 (47.43-91.64) 19.21	60.51±11.36 (43.72-91.64) 18.77	b'	6.89±0.65 (5.76-7.94) 9.48	6.28±0.54 (5.48-7.30) 8.60	6.57±0.66 (5.48-7.94) 10.11
c'	0.77±0.13 (0.62-1.04) 17.48	0.68±0.10 (0.46-0.79) 15.26	0.72±0.13 (0.46-1.04) 17.59	c	38.34±4.95 (31.29-50.18) 12.91	35.84±5.66 (28.79-52.26) 15.80	37.09±5.38 (28.79-52.26) 14.52
V	55.96±1.38 (53.50-58.40) 2.46	56.23±2.01 (51.24-58.86) 3.57	56.09±1.68 (51.24-58.86) 3.00	c'	1.50±0.16 (1.16-1.75) 10.90	1.53±0.24 (1.10-1.93) 15.48	1.52±0.20 (1.10-1.93) 13.26

V'	56.87±1.34 (54.69-59.53) 2.35	57.13±1.99 (52.08-59.74) 3.57	57.00±1.66 (52.08-59.74) 2.92	MB	68.58±2.47 (63.48-72.73) 3.60	67.24±2.24 (60.87-69.83) 3.33	67.89±2.41 (60.87-72.73) 3.55
MB	66.89±1.99 (61.02-69.53) 2.97	68.17±1.29 (66.07-70.00) 1.90	67.50±1.79 (61.02-70.00) 2.66	Pa	34.10±2.86 (29.40-38.11) 8.38	36.61±5.15 (29.58-51.08) 14.07	35.57±4.47 (29.40-51.08) 12.56
Pa	32.84±4.43 (22.34-42.20) 13.49	34.64±4.64 (28.21-47.02) 13.38	33.71±4.55 (22.34-47.02) 13.49	Pp	80.78±2.19 (77.85-85.25) 2.71	81.13±2.53 (73.99-84.67) 3.12	80.97±2.35 (73.99-85.25) 2.90
Pp	82.73±2.66 (76.85-86.06) 3.22	82.76±2.70 (79.42-88.18) 3.26	82.75±2.63 (76.85-88.18) 3.18				

[Mean±SD; (Range); CV%], Least variable (<12%), Moderately variable (12-20%), Highly variable (>20%)

Male: The body length of males of *Hoplolaimus indicus* collected from all geographical locations ranged from 0.859-1.173 mm with mean value of 1.033 mm. The body length of populations collected from Jorhat and Kamrup were recorded within the range of 0.928-1.173 mm and 0.859-1.102 mm, respectively. Maximum mean body length (1.075 mm) was recorded in the Jorhat population and the minimum (0.994 mm) was recorded in the Kamrup population.

The mean CV value of the body length of male *Hoplolaimus indicus* in relation to geographical locations was 8.03% indicating as least variable character. The highest CV value of the body length was found in the Jorhat population (7.39%) and the lowest CV value (6.75%) was found in the Kamrup population (Table4.4).

c) 'a' ratio:

Female: The 'a' ratio of females of *Hoplolaimus indicus* collected from all geographical locations ranged from 22.42-31.93 with mean value of 27.90. The 'a' ratio of populations collected from Jorhat and Kamrup were recorded within the range of 22.42-31.93 and 24.82-31.55, respectively. The maximum mean 'a' ratio (27.92) was recorded in the Jorhat population and the minimum (27.87) was recorded in the Kamrup population.

The mean CV value of the 'a' ratio of female *Hoplolaimus indicus* in relation to geographical locations was 8.31% indicating as least variable character. The highest CV value of the 'a' ratio was found in the Jorhat population (9.44%) and the lowest CV value (7.14%) was found in the Kamrup population (Table4.4).

Male: The 'a' ratio of males of *Hoplolaimus indicus* collected from all geographical locations ranged from 20.77-34.50 with mean value of 28.72. The 'a' ratio of populations collected from Jorhat and Kamrup were recorded within the range of 26.86-34.50 and 20.77-32.94, respectively. The maximum mean 'a' ratio (30.22) was recorded in the Jorhat population and the minimum (27.30) was recorded in the Kamrup population.

The mean CV value of the 'a' ratio of male *Hoplolaimus indicus* in relation to geographical locations was 11.37% indicating as least variable character. The highest CV value of the 'a' ratio was found in the Kamrup population (12.25%) and the lowest CV value (8.19%) was found in the Jorhat population (Table4.4).

d) Length of oesophagus and 'b' ratio:

Female: The length of oesophagus in the population of *Hoplolaimus indicus* collected from different geographical locations was within the range of 103.88-144.16 μ m while, the 'b' ratio was within the range of 8.07-12.75 with a mean value of 9.73. The 'b' ratio of Jorhat and Kamrup populations were recorded within the range of 8.07-12.75 and 8.30-11.74, respectively. The maximum mean 'b' ratio (9.89) was recorded in the Jorhat population and the minimum (9.55) was recorded in the Kamrup population.

The mean CV values of both length of oesophagus and 'b' ratio of female *Hoplolaimus indicus* in relation to geographical locations was 7.63% and 11.74%, respectively indicating them as least variable characters. The highest CV value (13.33%) of the 'b' ratio was found in the Jorhat population and the lowest CV value (9.55%) was found in the Kamrup population (Table4.4).

Male: The length of oesophagus in the male population of *Hoplolaimus indicus* collected from different geographical locations was within the range of 114.48-133.56 μ m while, the 'b' ratio was within the range of 7.05-10.06 with a mean value of 8.59. The 'b' ratio of Jorhat and Kamrup populations were recorded within the range of 7.75-10.06 and 7.05-9.37, respectively. The maximum mean 'b' ratio (8.84) was recorded in the Jorhat population and the minimum (8.35) was recorded in the Kamrup population.

The mean CV values of both length of oesophagus and 'b' ratio of male *Hoplolaimus indicus* in relation to geographical locations was 3.81% and 7.94%, respectively indicating them as least variable characters. The highest CV value (7.78%) of the 'b' ratio was found in the Jorhat population and the lowest CV value (7.19%) was found in the Kamrup population (Table4.4).

e) Length of oesophageal gland overlapping and b' ratio:

Female: The length of oesophageal gland overlapping in the population of *Hoplolaimus indicus* collected from different geographical locations was within the range of 132.50-187.62 μ m; while the b' ratio was within the range of 5.77-9.51 with a mean value of 7.30. The b' ratio of Jorhat and Kamrup populations were recorded in the range of 5.77-9.51 and 6.00-9.39, respectively. The maximum mean b' ratio (7.52) was recorded in the Jorhat population and the minimum (7.06) was recorded in the Kamrup population.

The mean CV value of length of oesophageal gland overlapping of the female *Hoplolaimus indicus* in relation to geographical locations was 7.70% indicating as least variable character while b' ratio with a mean CV value of 12.34% was indicating as moderately variable character. The highest CV value (12.95 %) of the b' ratio was found in the Jorhat population and the lowest CV value (10.87 %) was found in the Kamrup population (Table4.4).

Male: The length of oesophageal gland overlapping in the male population of *Hoplolaimus indicus* collected from different geographical locations was within the range of 143.10-171.72 μ m while, the b' ratio was within the range of 5.48-7.94 with a mean value of 6.57. The b' ratio of Jorhat and Kamrup populations were recorded in the range of 5.76-7.94 and 5.48-7.30, respectively. The maximum mean b' ratio (6.89) was recorded in the Jorhat population and the minimum (6.28) was recorded in the Kamrup population.

The mean CV values of both length of oesophageal gland overlapping and b' ratio of male *Hoplolaimus indicus* in relation to geographical locations was 5.22% and 10.11%, respectively indicating them as least variable characters. The highest CV value (9.48%) of the b' ratio was found in the Jorhat population and the lowest CV value (8.60%) was found in the Kamrup population (Table4.4).

f) Tail length and 'c' ratio:

Female: The tail length in the population of *Hoplolaimus indicus* collected from different geographical locations was within the range of 11.66-30.74 μ m while, the 'c' ratio was within the range of 43.72-91.64 with a mean value of 60.51. The 'c' ratio of Jorhat and Kamrup populations were recorded in the range of 43.72-67.16 and 47.43-91.64, respectively. The maximum mean 'c' ratio (65.01) was recorded in the Kamrup population and the minimum (56.28) was recorded in the Jorhat population.

The mean CV value of tail length of female *Hoplolaimus indicus* in relation to geographical locations was 22.01% indicating as highly variable character while, 'c' ratio with a mean CV value of 18.77% was indicating as moderately variable character. The highest CV value (19.21%) of the 'c' ratio was found in the Kamrup population and the lowest CV value (15.14%) was found in the Jorhat population (Table4.4).

Male: The tail length in the population of *Hoplolaimus indicus* collected from different geographical locations was within the range of 20.14-32.86 μ m while, the 'c'

ratio was within the range of 28.79-52.26 with a mean value of 37.09. The 'c' ratio of Jorhat and Kamrup populations were recorded in the range of 31.29-50.18 and 28.79-52.26, respectively. The maximum mean 'c' ratio (38.34) was recorded in the Jorhat population and the minimum (35.84) was recorded in the Kamrup population.

The mean CV value of tail length of male *Hoplolaimus indicus* in relation to geographical locations was 10.20% indicating as least variable character while, 'c' ratio with a mean CV value of 14.52% was indicating as moderately variable character. The highest CV value (15.80%) of the 'c' ratio was found in the Kamrup population and the lowest CV value (12.91%) was found in the Jorhat population (Table4.4).

g) Anal body width (ABW) and c' ratio:

Female: The anal body width (ABW) in the population of *Hoplolaimus indicus* collected from different geographical locations was within the range of 23.32-32.86 μ m while, the c' ratio was within the range of 0.46-1.04 μ m with a mean value of 0.72. The c' ratio of Jorhat and Kamrup populations were recorded in the range of 0.62-1.04 and 0.46-0.79, respectively. The maximum mean c' ratio (0.77) was recorded in Jorhat population and the minimum (0.68) was recorded in the Kamrup population.

The mean CV value of ABW of female *Hoplolaimus indicus* in relation to geographical locations was 8.52% indicating as least variable character while, c' ratio with a mean CV value of 17.59% indicating as moderately variable character. The highest CV value (17.48%) of the c' ratio was found in the Jorhat population and the lowest CV value (15.26%) was found in the Kamrup population (Table4.4).

Male: The anal body width (ABW) in the population of *Hoplolaimus indicus* collected from different geographical locations was within the range of 15.90-22.26 μ m while, the c' ratio was within the range of 1.10-1.93 μ m with a mean value of 1.52. The c' ratio of Jorhat and Kamrup populations were recorded in the range of 1.16-1.75 and 1.10-1.93, respectively. The maximum mean c' ratio (1.53) was recorded in Kamrup population and the minimum (1.50) was recorded in the Jorhat population.

The mean CV value of ABW of male *Hoplolaimus indicus* in relation to geographical locations was 8.53% indicating as least variable character while, c' ratio with a mean CV value of 13.26% was indicating as moderately variable character. The

highest CV value (15.48%) of the c' ratio was found in the Kamrup population and the lowest CV value (10.90%) was found in the Jorhat population (Table4.4).

h) MB:

Female: The MB of females of *Hoplolaimus indicus* collected from all geographical locations ranged from 61.02-70.00% with mean value of 67.50%. The MB of populations collected from Jorhat and Kamrup populations were recorded within the range of 61.02-69.53% and 66.07-70.00%, respectively. The maximum mean MB (68.17%) was recorded in the Kamrup population and the minimum (66.89%) was recorded in the Jorhat population.

The mean CV value of the MB of female *Hoplolaimus indicus* in relation to geographical locations was 2.66% indicating as least variable character. The highest CV value of the MB was found in the Jorhat population (2.97 %) and the lowest CV value (1.90%) was found in the Kamrup population (Table4.4).

Male: The MB of males of *Hoplolaimus indicus* collected from all geographical locations ranged from 60.87-72.73% with mean value of 67.89%. The MB of populations collected from Jorhat and Kamrup populations were recorded within the range of 63.48-72.73% and 60.87-69.83%, respectively. The maximum mean MB (68.58%) was recorded in the Jorhat population and the minimum (67.24%) was recorded in the Kamrup population.

The mean CV value of the MB of male *Hoplolaimus indicus* in relation to geographical locations was 3.55% indicating as least variable character. The highest CV value of the MB was found in the Jorhat population (3.60 %) and the lowest CV value (3.33 %) was found in the Kamrup population (Table4.4).

i) V and V':

The V and V' of females of *Hoplolaimus indicus* collected from all geographical locations ranged from 51.24-58.86% and 52.08-59.74% with mean value of 56.09% and 57.00%, respectively. The V of populations collected from Jorhat and Kamrup population were recorded within the range of 51.24-58.86% and 52.08-59.74%, respectively while V' ranged from 54.69-59.53% and 52.08-59.74%, respectively. The maximum mean V and V' (56.23% and 57.13%) were recorded in Kamrup population and the minimum (55.96% and 56.87%) were recorded in the Jorhat population.

The mean CV values of the V and V' of female *Hoplolaimus indicus* in relation to geographical locations were 3.00% and 2.92%, respectively indicating as least variable characters. The highest CV values of the V and V' were found in the Kamrup population (3.57% and 3.57%) and the lowest CV values (2.46 % and 2.35 %) were found in Jorhat population (Table4.4).

j) Stylet length:

Female: The stylet length of females of *Hoplolaimus indicus* collected from all geographical locations ranged from 33.92-38.16 μ m with mean value of 35.48 μ m. The stylet length of populations collected from Jorhat and Kamrup were recorded within the range of 33.92-38.16 μ m and 33.92-37.10 μ m, respectively. The maximum mean stylet length (35.63 μ m) was recorded in the Jorhat population and the minimum (35.31 μ m) was recorded in the Kamrup population.

The mean CV value of the stylet length of female *Hoplolaimus indicus* in relation to geographical locations was 3.39% indicating as least variable character. The highest CV value of the stylet length was found in the Kamrup population (3.42%) and the lowest CV value (3.41%) was found in the Jorhat population (Table4.4).

Male: The stylet length of males of *Hoplolaimus indicus* collected from all geographical locations ranged from 31.80-34.98 μ m with mean value of 33.21 μ m. The stylet length of populations collected from Jorhat and Kamrup were recorded within the range of 31.80-34.98 μ m and 31.80-33.92 μ m, respectively. The maximum mean stylet length (33.59 μ m) was recorded in the Jorhat population and the minimum (32.86 μ m) was recorded in the Kamrup population.

The mean CV value of the stylet length of male *Hoplolaimus indicus* in relation to geographical locations was 2.95% indicating as least variable character. The highest CV value of the stylet length was found in the Jorhat population (3.20%) and the lowest CV value (2.28%) was found in the Kamrup population (Table4.4).

k) SE:

Female: The SE of females of *Hoplolaimus indicus* collected from all geographical locations ranged from 93.28-156.88 μ m with mean value of 116.30 μ m. The SE of populations collected from Jorhat and Kamrup were recorded within the range of 103.88-156.88 μ m and 93.28-127.20 μ m, respectively. The maximum mean SE

(123.12 μm) was recorded in the Jorhat population and the minimum (110.38 μm) was recorded in the Kamrup population.

The mean CV value of the SE of female *Hoplolaimus indicus* in relation to geographical locations was 12.45% indicating as moderately variable character. The highest CV value of the SE was found in the Jorhat population (12.91%) and the lowest CV value (9.37%) was found in the Kamrup population (Table4.4).

Male: The SE of males of *Hoplolaimus indicus* collected from all geographical locations ranged from 90.10-130.38 μm with mean value of 106.11 μm . The SE of populations collected from Jorhat and Kamrup were recorded within the range of 96.46-130.38 μm and 90.10-124.02 μm , respectively. The maximum mean SE (109.18 μm) was recorded in the Jorhat population and the minimum (103.05 μm) was recorded in the Kamrup population.

The mean CV value of the SE of male *Hoplolaimus indicus* in relation to geographical locations was 8.71% indicating as least variable character. The highest CV value of the SE was found in the Jorhat population (8.36%) and the lowest CV value (8.35%) was found in the Kamrup population (Table4.4).

l) Tail annules:

The number of tail annules of females of *Hoplolaimus indicus* collected from all geographical locations ranged from 9.54-16.96 with mean value of 12.96. The number of tail annules of populations collected from Jorhat and Kamrup were recorded within the range of 10.60-15.90 and 9.54-16.96, respectively. The maximum mean number of tail annules (13.28) was recorded in the Jorhat population and the minimum (12.57) was recorded in the Kamrup population.

The mean CV value of the number of tail annules of female *Hoplolaimus indicus* in relation to geographical locations was 15.76% indicating as moderately variable character. The highest CV value of the number of tail annules was found in the Kamrup population (17.14%) and the lowest CV value (14.69%) was found in the Jorhat population (Table4.4).

m) Pa:

Female: The Pa of females of *Hoplolaimus indicus* collected from all geographical locations ranged from 22.34-47.02% with mean value of 33.71%. The Pa of populations collected from Jorhat and Kamrup were recorded within the range of 22.34-42.20% and 28.21-47.02%, respectively. The maximum mean Pa (34.64%) was recorded in the Kamrup population and the minimum (32.84%) was recorded in the Jorhat population.

The mean CV value of the Pa of female *Hoplolaimus indicus* in relation to geographical locations was 13.49% indicating as moderately variable character. The highest CV value of the Pa was found in the Jorhat population (13.49%) and the lowest CV value (13.38%) was found in the Kamrup population (Table4.4).

Male: The Pa of males of *Hoplolaimus indicus* collected from all geographical locations ranged from 29.40-51.08% with mean value of 35.57%. The Pa of populations collected from Jorhat and Kamrup were recorded within the range of 29.40-38.11% and 29.58-51.08%, respectively. The maximum mean Pa (36.61%) was recorded in the Kamrup population and the minimum (34.10%) was recorded in the Jorhat population.

The mean CV value of the Pa of male *Hoplolaimus indicus* in relation to geographical locations was 12.56% indicating as moderately variable character. The highest CV value of the Pa was found in the Kamrup population (14.07%) and the lowest CV value (8.38%) was found in the Jorhat population (Table4.4).

n) Pp:

Female: The Pp of females of *Hoplolaimus indicus* collected from all geographical locations ranged from 76.85-88.18% with mean value of 82.75%. The Pp of populations collected from Jorhat and Kamrup were recorded within the range of 76.85-86.06% and 79.42-88.18%, respectively. The maximum mean Pp (82.76%) was recorded in the Kamrup population and the minimum (82.73%) was recorded in the Jorhat population.

The mean CV value of the Pp of female *Hoplolaimus indicus* in relation to geographical locations was 3.18% indicating as least variable character. The highest CV value of the Pp was found in the Kamrup population (3.26%) and the lowest CV value (3.22%) was found in the Jorhat population (Table4.4).

Male: The Pp of males of *Hoplolaimus indicus* collected from all geographical locations ranged from 73.99-85.25% with mean value of 80.97%. The Pp of populations collected from Jorhat and Kamrup were recorded within the range of 77.85-85.25% and 73.99-84.67%, respectively. The maximum mean Pp (81.13%) was recorded in the Kamrup population and the minimum (80.78%) was recorded in the Jorhat population.

The mean CV value of the Pp of male *Hoplolaimus indicus* in relation to geographical locations was 2.90% indicating as least variable character. The highest CV value of the Pp was found in the Kamrup population (3.12%) and the lowest CV value (2.71%) was found in the Jorhat population (Table4.4).

o) Spicule length:

The spicule length of males of *Hoplolaimus indicus* collected from all geographical locations ranged from 33.92-40.28 μ m with mean value of 37.32 μ m. The spicule length of populations collected from Jorhat and Kamrup were recorded within the range of 33.92-39.22 μ m and 34.98-40.28 μ m, respectively. The maximum mean spicule length (37.66 μ m) was recorded in the Kamrup population and the minimum (36.97 μ m) was recorded in the Jorhat population.

The mean CV value of the spicule length of male *Hoplolaimus indicus* in relation to geographical locations was 4.36% indicating as least variable character. The highest CV value of the spicule length was found in the Jorhat population (4.43%) and the lowest CV value (4.24%) was found in the Kamrup population (Table4.4).

p) Gubernaculum length:

The gubernaculum length of males of *Hoplolaimus indicus* collected from all geographical locations ranged from 13.78-20.14 μ m with mean value of 17.75 μ m. The gubernaculum length of populations collected from Jorhat and Kamrup were recorded within the range of 16.96-19.08 μ m and 13.78-20.14 μ m, respectively. The maximum mean gubernaculum length (18.59 μ m) was recorded in the Jorhat population and the minimum (16.96 μ m) was recorded in the Kamrup population.

The mean CV value of the gubernaculum length of male *Hoplolaimus indicus* in relation to geographical locations was 9.50% indicating as least variable character. The highest CV value of the gubernaculum length was found in the Kamrup population (11.41%) and the lowest CV value (4.24%) was found in the Jorhat population (Table4.4).

4.2 Morphological and morphometric variations of genus *Helicotylenchus* Steiner, 1945 in relation to host plants and geographical locations:

A total of 163 soil samples were collected from around the rhizosphere of Rice, Banana, Mango, Jackfruit and Tea from five districts of Assam viz., Jorhat, Kamrup, Lakhimpur, Nagaon, KarbiAnglong. The number of soil samples collected from different host plants and geographical locations are presented in (Table 3.1 and 3.2).

Two species of *Helicotylenchus* viz., *H. crenacauda* and *H. dihystra* were identified during the present investigation.

Identification of species of *Helicotylenchus*:

Genus *Helicotylenchus* Steiner, 1945

Diagnosis: Rotylenchoidinae. Small to medium-sized nematodes (0.4-1.2 mm). Females spirally coiled or rarely arcuate. Cephalic region low or elevated, continuous and rarely offset, with or without annulation; no longitudinal indentations on annules. Stylet robust, about three to four times the maximum width of the cephalic region. Orifice of dorsal oesophageal gland $\frac{1}{4}$ to a little more than $\frac{1}{2}$ of stylet length behind base of stylet. Postcorporal bulb well developed, usually slightly offset from precorpus (stylet and bulb slightly reduced in males of some species). Excretory pore behind hemizonid, near base of isthmus. Oesophageal glands form a wraparound over the anterior end of the intestine, longest overlap being ventral. Intestine rarely with fasciculi; not overlapping rectum. Both branches of female reproductive organs are well developed and functional. Female tail short, hemispherical, dorsally convex-conoid, with or without a ventral or terminal projection. Male tail short (less than two anal body width), conical, with a distinct terminal hyaline portion. Bursa enveloping the entire tail tip, rarely subterminal. Gubernaculum trough- or rod-shaped, fixed; telamon not seen.

Type species: *Helicotylenchus nannus* Steiner, 1945

***Helicotylenchus crenacauda* Sher, 1966**

Dimensions:

Female (n=39): L = 0.533-0.727mm (0.630mm); a= 20.50-37.67 (24.93); b= 5.12-7.36 (6.00); b'= 4.15-6.03 (4.98); c= 25.04-53.08 (39.97); c'= 0.88-1.53 (1.16); V= 59.31-66.95 (63.67); Stylet length= 22.26-26.50 μ m (24.35 μ m); Excretory pore= 86.92-110.74 μ m (101.73 μ m); O= 28.00-45.45 (33.19); MB= 58.70-81.82 (64.56)

Descriptions:

Female: Spiral shaped when relaxed. Cuticle with coarse annules. Lateral field with 4 incisures. Lip region continuous with body contour, usually hemispherical, sometimes slightly obtuse, marked with 4–5 distinct annules. Cephalic framework moderately developed. Stylet well developed with anteriorly flat basal knobs. Orifice of dorsal pharyngeal gland located more than $\frac{1}{4}$ of stylet length from stylet base. Hemizonid is usually indistinct. Excretory pore anterior to level of oesophageal intestinal valve. Female reproductive system didelphic amphidelphic, both ovaries are functional, spermatheca rounded, slightly set off and without sperm. Tail indented terminally, with short to long, variously-shaped ventral projection. Phasmids are very small, pore-like, located six annules anterior to anus, in some specimens difficult to observe or indistinct (Plate 4A-F).

Male: Not found.

Remark: The present populations of *Helicotylenchus crenacauda* matched well with the dimensions and description given by Sher (1966); Das (1993) except the body length, a ratio and c ratio. [L= 0.57-0.77 mm, a= 24.0-29.0 by Sher (1966); L= 0.513-0.663 mm, a= 22.0-29.0 and c ratio=32-41 by Das (1993)].

Hoplolaimus crenacauda is a monophagous pest of Rice, so that's why there is no morphological and morphometric variations of *Helicotylenchus crenacauda* in relation to host plants.

4.2.1 Morphological and morphometric variations of *Helicotylenchus crenacauda* Sher, 1966 in relation to geographical locations:

To study the effect of geographical locations in morphological and morphometric variations of *Hoplolaimus crenacauda* we collected samples from different geographical

locations such as Jorhat and Kokrajhar having the same host plant as Rice. The morphological and morphometric measurements of variations are presented hereunder.

a) Habitus:

Body spirally coiled upon fixation, coiling takes place on the ventral side of the nematode body and there is no significant difference in habitus of *Helicotylenchus crenacauda* in relation to geographical locations (Plate 6C).

b) Body length:

The body length of females of *Helicotylenchus crenacauda* collected from all geographical locations ranged from 0.533-0.727mm with mean value of 0.630mm. The body length of populations collected from Jorhat and Kokrajhar were recorded within the range of 0.535-0.727mm and 0.533-0.693mm, respectively. Maximum mean body length (0.637mm) was recorded in the Jorhat population and the minimum (0.623mm) was recorded in the Kokrajhar population.

The mean CV value of the body length of female *Helicotylenchus crenacauda* in relation to geographical locations was 7.77% indicating as least variable character. The highest CV value of the body length was found in the Jorhat population (8.44%) and the lowest CV value (7.02%) was found in the Kokrajhar population (Table4.5).

c) 'a' ratio:

The 'a' ratio of females of *Helicotylenchus crenacauda* collected from all geographical locations ranged from 20.50-37.67 with mean value of 24.93. The 'a' ratio of populations collected from Jorhat and Kokrajhar were recorded within the range of 20.50-37.67 and 23.21-28.14, respectively. The maximum mean 'a' ratio (25.39) was recorded in the Kokrajhar population and the minimum (24.50) was recorded in the Jorhat population.

The mean CV value of the 'a' ratio of female *Helicotylenchus crenacauda* in relation to geographical locations was 11.48% indicating as least variable character. The highest CV value of the 'a' ratio was found in the Jorhat population (15.45%) and the lowest CV value (5.20%) was found in the Kokrajhar population (Table4.5).

Table 4.5. Morphometric variations of *Helicotylenchus crenacauda* in relation to geographical location (Host: Rice)

Characters ♀	Jorhat (n=20)	Kokrajhar (n=19)	Mean (n=39)
Body length (mm)	0.637±0.053 (0.535-0.727) 8.44	0.623±0.043 (0.533-0.693) 7.02	0.630±0.048 (0.533-0.727) 7.77
Body width (µm)	26.42±3.60 (17.64-35.28) 13.63	24.60±1.75 (21.20-27.56) 7.12	25.53±2.96 (17.64-35.28) 11.61
Length of oesophagus (µm)	106.34±9.67 (86.24-119.56) 9.09	105.00±6.45 (96.46-117.66) 6.15	105.67±8.14 (86.24-119.56) 7.70
Oesophageal gland overlapping (µm)	128.93±9.07 (109.18-145.04) 7.03	124.69±6.45 (108.12-136.74) 5.17	126.86±8.09 (108.12-145.04) 6.38
Tail length (µm)	16.45±2.70 (11.66-22.54) 16.40	15.62±1.99 (11.66-20.14) 12.76	16.05±2.39 (11.66-22.54) 14.88
Anal body width (µm)	14.37±1.55 (11.66-17.64) 10.81	13.17±1.24 (11.66-15.90) 9.42	13.78±1.52 (11.66-17.64) 11.01
Position of vulva (µm)	408.67±30.94 (358.28-460.60) 7.57	394.04±30.63 (341.32-445.20) 7.77	401.54±31.27 (341.32-460.60) 7.79
Lip height (µm)	4.72±0.50 (3.92-5.30) 10.53	4.24±0.00 (4.24-4.24) 0.00	4.49±0.43 (3.92-5.30) 9.51
Lip width (µm)	6.92±0.49 (5.88-7.84) 7.04	6.53±0.64 (5.30-7.42) 9.78	6.73±0.59 (5.30-7.84) 8.80

Stylet length (μm)	23.85 \pm 0.73 (22.26-24.50) 3.07	24.88 \pm 1.19 (23.32-26.50) 4.79	24.35 \pm 1.10 (22.26-26.50) 4.52
DOGO (μm)	7.38 \pm 0.57 (6.86-8.48) 7.67	8.54 \pm 0.90 (7.42-10.60) 10.53	8.11 \pm 0.97 (6.86-10.60) 11.92
SE (μm)	103.53 \pm 4.65 (95.40-110.74) 4.50	100.42 \pm 7.37 (86.92-110.24) 7.34	101.73 \pm 6.45 (86.92-110.74) 6.34
Nerve ring (μm)	84.96 \pm 5.39 (75.26-94.08) 6.34	83.46 \pm 4.88 (77.38-96.46) 5.85	84.19 \pm 5.12 (75.26-96.46) 6.08
Medianbulb (μm)	67.39 \pm 5.35 (57.24-76.44) 7.93	68.45 \pm 3.78 (62.54-77.38) 5.52	67.91 \pm 4.62 (57.24-77.38) 6.80
Phasmid (μm)	28.41 \pm 3.04 (24.50-33.92) 10.70	31.74 \pm 3.99 (24.38-39.22) 12.58	30.43 \pm 3.95 (24.38-39.22) 12.98
Anus (μm)	620.86 \pm 53.31 (520.46-708.54) 8.59	608.22 \pm 42.96 (521.52-677.34) 7.06	614.70 \pm 48.34 (520.46-708.54) 7.86
a	24.50 \pm 3.78 (20.50-37.67) 15.45	25.39 \pm 1.32 (23.21-28.14) 5.20	24.93 \pm 2.86 (20.50-37.67) 11.48
b	6.06 \pm 0.73 (5.12-7.36) 12.04	5.95 \pm 0.43 (5.16-6.68) 7.30	6.01 \pm 0.60 (5.12-7.36) 9.90
b'	4.96 \pm 0.51 (4.15-6.03) 10.32	5.01 \pm 0.40 (4.30-5.57) 7.96	4.99 \pm 0.46 (4.15-6.03) 9.13
c	39.56 \pm 6.03 (25.04-51.75) 15.25	40.41 \pm 4.73 (31.47-53.08) 11.69	39.98 \pm 5.38 (25.04-53.08) 13.46
c'	1.15 \pm 0.17 (0.88-1.53) 14.96	1.19 \pm 0.14 (0.92-1.42) 12.17	1.17 \pm 0.16 (0.88-1.53) 13.57

V	64.18±1.34 (61.73-66.95) 2.09	63.15±1.64 (59.31-65.93) 2.59	63.68±1.56 (59.31-66.95) 2.46
V'	65.88±1.40 (63.51-68.84) 2.13	64.77±1.67 (60.74-67.53) 2.58	65.35±1.62 (60.74-68.84) 2.48
O	31.07±3.21 (28.00-38.10) 10.34	34.43±4.52 (28.00-45.45) 13.12	33.20±4.35 (28.00-45.45) 13.11
MB	63.87±4.91 (58.70-81.82) 7.69	65.25±2.00 (60.95-69.15) 3.07	64.56±3.77 (58.70-81.82) 5.83

[Mean±SD; (Range); CV%], Least variable (<12%), Moderately variable (12-20%), Highly variable (>20%)

d) Length of oesophagus and 'b' ratio:

The length of oesophagus in the population of *Helicotylenchus crenacauda* collected from different geographical locations was within the range of 86.24-119.56 μ m while, the 'b' ratio was within the range of 5.12-7.36 with a mean value of 6.01. The 'b' ratio of Jorhat and Kokrajhar populations were recorded within the range of 5.12-7.36 and 5.16-6.68. The maximum mean 'b' ratio (6.06) was recorded in the Jorhat population and the minimum (5.95) was recorded in the Kokrajhar population.

The mean CV values of both length of oesophagus and 'b' ratio of female *Helicotylenchus crenacauda* in relation to geographical locations was 7.70% and 9.90% respectively indicating them as least variable characters. The highest CV value (12.04%) of the 'b' ratio was found in the Jorhat population and the lowest CV value (7.30%) was found in the Kokrajhar population (Table4.5).

e) Length of esophageal gland overlapping and b' ratio:

The length of oesophageal gland overlapping in the population of *Helicotylenchus crenacauda* collected from different geographical locations was within the range of 108.12-145.04 μ m while, the b' ratio was within the range of 4.15-6.03 with a mean value of 4.99. The b' ratio of Jorhat and Kokrajhar populations were recorded in the range of 4.15-6.03 and 4.30-5.57, respectively. The maximum mean b' ratio (5.01) was recorded in the Kokrajhar population and the minimum (4.96) was recorded in the Jorhat population.

The mean CV values of both length of oesophageal gland overlapping and b' ratio of female *Helicotylenchus crenacauda* in relation to geographical locations was 6.38% and 9.13%, respectively indicating them as least variable characters. The highest CV value (10.32%) of the b' ratio was found in the Jorhat population and the lowest CV value (7.96%) was found in the Kokrajhar population (Table4.5).

f) Tail length and 'c' ratio:

The tail length in the population of *Helicotylenchus crenacauda* collected from different geographical locations was within the range of 11.66-22.54 μ m while, the 'c' ratio was within the range of 25.04-53.08 with a mean value of 39.98. The 'c' ratio of Jorhat and Kokrajhar populations were recorded in the range of 25.04-51.75 and 31.47-

53.08, respectively. The maximum mean 'c' ratio (40.41) was recorded in the Kokrajhar population and the minimum (39.56) was recorded in the Jorhat population.

The mean CV values of both tail length and 'c' ratio of female *Helicotylenchus crenacauda* in relation to geographical locations was 14.88% and 13.46% respectively indicating them as moderately variable characters. The highest CV value (15.25%) of the 'c' ratio was found in the Jorhat population and the lowest CV value (11.69%) was found in the Kokrajhar population (Table4.5).

g) Anal body width (ABW) and c' ratio:

The anal body width (ABW) in the population of *Helicotylenchus crenacauda* collected from different geographical locations was within the range of 11.66-17.64 μ m while, the c' ratio was within the range of 0.88-1.53 μ m with a mean value of 1.17. The c' ratio of Jorhat and Kokrajhar populations were recorded in the range of 0.88-1.53 and 0.92-1.42, respectively. The maximum mean c' ratio (1.19) was recorded in Kokrajhar population and the minimum (1.15) was recorded in the Jorhat population.

The mean CV value of ABW of female *Helicotylenchus crenacauda* in relation to geographical locations was 11.01% indicating as least variable character while c' ratio with a mean CV value of 13.57% was indicating as moderately variable character. The highest CV value (14.96%) of the c' ratio was found in the Jorhat population and the lowest CV value (12.17%) was found in the Kokrajhar population (Table4.5).

h) MB:

The MB of females of *Helicotylenchus crenacauda* collected from all geographical locations ranged from 58.70-81.82% with mean value of 64.56%. The MB of populations collected from Jorhat and Kokrajhar populations were recorded within the range of 58.70-81.8% and 60.95-69.15%, respectively. The maximum mean MB (65.25%) was recorded in the Kokrajhar population and the minimum (63.87%) was recorded in the Jorhat population.

The mean CV value of the MB of female *Helicotylenchus crenacauda* in relation to geographical locations was 5.83% indicating as least variable character. The highest CV value of the MB was found in the Jorhat population (7.69%) and the lowest CV value (3.07%) was found in the Kokrajhar population (Table4.5).

i) V and V':

The V and V' of females of *Helicotylenchus crenacauda* collected from all geographical locations ranged from 59.31-66.95% and 60.74-68.84% with mean value of 63.68% and 65.35%, respectively. The V of populations collected from Jorhat and Kokrajhar population were recorded within the range of 61.73-66.95% and 59.31-65.93%, respectively while, V' ranged from 63.51-68.84% and 60.74-67.53%, respectively. The maximum mean V and V' (64.18% and 65.88%) were recorded in Jorhat population and the minimum (63.15% and 64.77%) were recorded in the Kokrajhar population.

The mean CV values of the V and V' of female *Helicotylenchus crenacauda* in relation to geographical locations were 2.46% and 2.48%, respectively indicating as least variable characters. The highest CV values of the V and V' were found in the Kokrajhar population (2.59% and 2.58%) and the lowest CV values (2.09% and 2.13%) were found in Jorhat population (Table4.5).

j) Stylet length:

The stylet length of females of *Helicotylenchus crenacauda* collected from all geographical locations ranged from 22.26-26.50 μ m with mean value of 24.35 μ m. The stylet length of populations collected from Jorhat and Kokrajhar were recorded within the range of 22.26-24.50 μ m and 23.32-26.50 μ m, respectively. The maximum mean stylet length (24.88 μ m) was recorded in the Kokrajhar population and the minimum (23.85 μ m) was recorded in the Jorhat population.

The mean CV value of the stylet length of female *Helicotylenchus crenacauda* in relation to geographical locations was 4.52% indicating as least variable character. The highest CV value of the stylet length was found in the Kokrajhar population (4.79%) and the lowest CV value (3.07%) was found in the Jorhat population (Table4.5).

k) SE:

The SE of females of *Helicotylenchus crenacauda* collected from all geographical locations ranged from 86.92-110.74 μ m with mean value of 101.73 μ m. The SE of populations collected from Jorhat and Kokrajhar were recorded within the range of 95.40-110.74 μ m and 86.92-110.24 μ m, respectively. The maximum mean SE (103.53 μ m) was

recorded in the Jorhat population and the minimum (100.42 μ m) was recorded in the Kokrajhar population.

The mean CV value of the SE of female *Helicotylenchus crenacauda* in relation to geographical locations was 6.34% indicating as least variable character. The highest CV value of the SE was found in the Kokrajhar population (7.34%) and the lowest CV value (4.50%) was found in the Jorhat population (Table4.5).

1) O:

The 'O' of females of *Helicotylenchus crenacauda* collected from all geographical locations ranged from 28.00-45.45% with mean value of 33.20%. The 'O' of populations collected from Jorhat and Kokrajhar were recorded within the range of 28.00-38.10% and 28.00-45.45% respectively. The maximum mean 'O' (34.43%) was recorded in the Kokrajhar population and the minimum (31.07%) was recorded in the Jorhat population.

The mean CV value of the 'O' of female *Helicotylenchus crenacauda* in relation to geographical locations was 13.11% indicating as moderately variable character. The highest CV value of the SE was found in the Kokrajhar population (13.12%) and the lowest CV value (10.34%) was found in the Jorhat population (Table4.5).

Helicotylenchus dihystrera (Cobb, 1892) Sher, 1961

Dimensions:

Female (n=237):L = 0.443-0.881mm (0.627 mm); a= 17.73-33.50 (25.35); b= 4.48-8.03 (5.77); b'= 3.68-5.91 (4.74); c= 26.45-59.18 (41.64); c'= 0.67-1.69 (1.16); V= 59.58-74.64 (64.49); Stylet length= 20.14-24.38 μ m (22.76 μ m); Excretory pore= 91.16-136.74 μ m (110.96 μ m); O= 31.82-63.64% (49.19%); MB= 56.47-73.96% (64.96%)

Descriptions:

Female: Body in spiral shape. Lip region hemispherical, 4-5 annules often indistinct. Cephalic framework moderately developed. Spear knobs with indented anterior surfaces. Orifice of dorsal pharyngeal gland located more than $\frac{1}{4}$ of stylet length from stylet base. Excretory pore at anterior end of esophageal glands. Oesophageal gland

overlapping the intestine in the latero-ventral side. Hemizonid just anterior to excretory pore. Vulva with a transverse slit, vagina extended halfway across the body. Spermatheca is conspicuous, offset without sperm. Phasmids 5-11 annules anterior to level of anus. Tail more curved dorsally, with slight ventral projection (Plate 5A-F).

Male: Not found.

Remark: The present populations of *Helicotylenchus dihyстера* (Cobb, 1892) Sher, 1961 matched well with the dimensions and description given by Sher, (1961); Das, (1993) except the body length, a ratio, b ratio and stylet length. [L= 0.65-0.84mm, a= 24-31, b= 5.6-6.5 and stylet length= 25-29 μ m by Sher, (1961); L= 0.59-0.71mm, a= 24-33, b ratio=5-7 and stylet length=24-27 μ m by Das, (1993)]

4.2.2 Morphological and morphometric variations of *Helicotylenchus dihyстера* (Cobb, 1892) Sher, 1961 in relation to host plants and geographical locations:

4.2.2.1 Morphological and morphometric variations of *Helicotylenchus dihyстера* (Cobb, 1892) Sher, 1961 in relation to host plants:

To study the effect of host plants in morphological and morphometric variations of *Helicotylenchus dihyстера* we collected samples from different host plants such as Rice, Maize, Banana, Jackfruit, Mango, citrus and pea having the same geographical locations as of Jorhat. The morphological and morphometric measurements of variations are presented hereunder.

a) Habitus:

Body spirally coiled upon fixation, coiling takes place on the ventral side of the nematode body and there is no significant difference in habitus of *Helicotylenchus dihyстера* in relation to host plants (Plate 6D).

b) Body length:

The body length of females of *Helicotylenchus dihyстера* collected from all host plants ranged from 0.468-0.881mm with mean value of 0.657mm. Maximum mean body length (0.712mm) was recorded in the Citrus population and the minimum (0.581mm) was recorded in the Banana population.

The mean CV value of the body length of female *Helicotylenchus dihystrera* in relation to host plants was 10.86% indicating as least variable character. The highest CV value of the body length was found in the Rice population (11.92%) and the lowest CV value (5.93%) was found in the Citrus population (Table4.6).

c) 'a' ratio:

The 'a' ratio of females of *Helicotylenchus dihystrera* collected from all host plants ranged from 17.73-33.50 with mean value of 25.71. The maximum mean 'a' ratio (27.50) was recorded in the Mango population and the minimum (23.04) was recorded in the Banana population.

The mean CV value of the 'a' ratio of female *Helicotylenchus dihystrera* in relation to host plants was 11.40% indicating as least variable character. The highest CV value of the 'a' ratio was found in the Pea population (13.58%) and the lowest CV value (6.00%) was found in the Citrus population (Table4.6).

d) Length of oesophagus and 'b' ratio:

The length of oesophagus in the population of *Helicotylenchus dihystrera* collected from different host plants was within the range of 90.10-131.44 μ m while, the 'b' ratio was within the range of 4.63-8.03 with a mean value of 6.00. The maximum mean 'b' ratio (6.50) was recorded in the Maize population and the minimum (5.53) was recorded in the Banana population.

The mean CV values of both length of oesophagus and 'b' ratio of female *Helicotylenchus dihystrera* in relation to host plants was 7.79% and 10.84%, respectively indicating them as least variable characters. The highest CV value (13.17%) of the 'b' ratio was found in the Rice population and the lowest CV value (6.06%) was found in the Pea population (Table4.6).

e) Length of oesophageal gland overlapping and b' ratio:

The length of oesophageal gland overlapping in the population of *Helicotylenchus dihystrera* collected from different host plants was within the range of 113.42-157.94 μ m while, the b' ratio was within the range of 3.98-5.91 with a mean value of 4.91. The maximum mean b' ratio (5.27) was recorded in the Maize population and the minimum (4.57) was recorded in the Banana population.

Table 4.6. Morphometric variations of *Helicotylenchus dihytera* in relation to host plants

Characters ♀	Rice (n=20)	Maize (n=20)	Banana (n=20)	Jackfruit (n=20)	Mango (n=20)	Citrus (n=20)	Pea (n=20)	Mean (n=140)
Body length (mm)	0.609±0.072 (0.468-0.776) 11.92	0.688± 0.052 (0.620-0.784) 7.69	0.581±0.047 (0.515-0.678) 8.21	0.691±0.070 (0.585-0.881) 10.25	0.647±0.054 (0.568-0.783) 8.49	0.712±0.042 (0.640-0.784) 5.93	0.676±0.048 (0.614-0.770) 7.10	0.657±0.071 (0.468-0.881) 10.86
Body width (µm)	23.373±2.90 (19.08-29.68) 12.43	27.91±3.88 (22.26-33.92) 13.91	25.54±3.33 (21.20-31.80) 13.05	26.89±3.36 (23.32-36.04) 12.48	23.74±2.65 (19.08-28.62) 11.16	27.40±2.07 (24.38-33.92) 7.56	26.11±5.49 (21.20-39.22) 21.02	25.81±3.79 (19.08-39.22) 14.70
Length of oesophagus (µm)	108.91±10.91 (91.16-128.26) 10.01	106.35± 7.43 (93.28-117.66) 6.99	107.06 ±5.57 (97.52-118.72) 5.20	117.78 ±7.74 (100.70-126.14) 6.57	106.05±6.73 (90.10-114.48) 6.35	114.80±8.81 (94.34-131.44) 7.67	111.75±4.14 (101.76-116.60) 3.71	110.43±8.60 (90.10-131.44) 7.79
Oesophageal gland overlapping (µm)	127.49 ±10.56 (113.42-148.40) 8.28	131.36 ±6.89 (119.78-144.16) 5.24	128.61±6.85 (119.78-146.28) 5.33	142.46 ±7.65 (129.32-156.88) 5.37	131.83±10.77 (116.60-148.40) 8.17	141.69±6.90 (129.32-157.94) 4.87	135.51±7.99 (119.78-149.46) 5.90	134.35±9.99 (113.42-157.94) 7.43
Tail length (µm)	16.16± 2.85 (11.66- 23.32) 17.65	15.72±2.06 (11.66-19.08) 13.13	14.94±1.29 (12.72-16.96) 8.66	15.79±2.12 (12.72-21.20) 13.41	14.95±2.62 (10.60-21.20) 17.51	16.85±1.61 (14.84-21.20) 9.55	15.11±1.68 (11.66-19.08) 11.12	15.64±2.15 (10.60-23.32) 13.77
Anal body width (µm)	13.67± 1.37 (11.66-16.96) 10.02	13.84±1.48 (11.66-15.90) 10.66	13.83±1.08 (11.66-15.90) 7.84	13.04±1.65 (10.60-15.90) 12.68	12.56±1.43 (10.60-15.90) 11.38	13.36±0.94 (11.66-14.84) 7.00	13.36±2.07 (11.66-19.08) 15.54	13.38±1.50 (10.60-19.08) 11.22

Position of vulva (µm)	389.17±49.53 (308.46-483.36) 12.72	443.49±32.12 (398.56-501.38) 7.24	369.74±29.75 (330.72-428.24) 8.05	451.45±40.80 (387.96-549.08) 9.04	418.54±34.36 (374.18-514.10) 8.21	453.79±22.98 (417.64-495.02) 5.06	440.70±26.25 (404.92-492.90) 5.96	423.17±45.91 (308.46-549.08) 10.85
Lip height (µm)	3.55±0.51 (3.18-4.24) 14.60	4.18±0.44 (3.18-5.30) 10.55	4.14±0.57 (3.18-5.30) 13.80	4.29±0.42 (3.18-5.30) 9.73	4.13±0.59 (3.18-5.30) 14.17	4.24±0.34 (3.18-5.30) 8.11	4.13±0.33 (3.18-4.24) 7.89	4.10±0.51 (3.18-5.30) 12.54
Lip width (µm)	6.307±0.72 (5.3-7.42) 11.53	6.92±0.55 (6.36-7.42) 7.88	6.71±0.51 (6.36-7.42) 7.63	6.68±0.50 (6.36-7.42) 7.46	6.68±0.50 (6.36-7.42) 7.46	6.68±0.50 (6.36-7.42) 7.46	6.86±0.54 (6.36-7.42) 7.92	6.68±0.57 (5.30-7.42) 8.50
Stylet length (µm)	21.99±1.49 (20.14-24.38) 6.79	23.44±0.74 (22.26-24.38) 3.15	22.31±0.62 (21.20-23.32) 2.80	23.74±0.53 (23.32-24.38) 2.24	22.58±0.98 (20.14-24.38) 4.34	22.95±0.52 (22.26-23.32) 2.26	23.21±0.90 (21.20-24.38) 3.89	22.87±1.05 (20.14-24.38) 4.58
DOGO (µm)	11.04±2.09 (8.48-13.78) 19.00	12.64±1.69 (9.54-14.84) 13.34	9.54±1.20 (7.42-11.66) 12.54	12.67±1.31 (10.60-14.84) 10.33	11.54±1.25 (9.54-13.78) 10.86	11.47±1.64 (7.42-13.78) 14.33	10.84±1.12 (9.54-12.72) 10.37	11.46±1.75 (7.42-14.84) 15.29
SE (µm)	107.55±11.08 (94.34- 126.14) 10.30	119.03 ±6.86 (106.00-135.68) 5.76	102.26 ±8.88 (91.16-125.08) 8.68	121.45±8.45 (109.18-136.74) 6.96	114.37±9.37 (101.76-133.56) 8.19	118.51±4.72 (104.94-125.08) 3.99	119.14±5.39 (108.12-127.20) 4.52	114.56±10.37 (91.16-136.74) 9.05
Nerve ring (µm)	88.37±7.730 (74.2-99.64) 8.74	94.34±4.74 (86.92-100.70) 5.02	86.81±5.63 (75.26-98.58) 6.48	99.83±4.80 (92.22-109.18) 4.81	88.59±6.89 (74.20-96.46) 7.78	95.58±8.89 (85.86-124.02) 9.30	92.80±5.24 (80.56-108.12) 5.65	92.24±7.72 (74.20-124.02) 8.37

Medianbulb (μm)	70.43 \pm 5.91 (61.48-82.68) 8.39	70.96 \pm 3.80 (63.60-76.32) 5.36	68.04 \pm 5.11 (60.42-81.62) 7.51	78.49 \pm 5.18 (66.78-87.98) 6.59	67.89 \pm 7.11 (50.88-78.44) 10.47	73.88 \pm 5.04 (63.60-84.80) 6.83	73.14 \pm 4.03 (60.42-81.62) 5.50	71.82 \pm 6.23 (50.88-87.98) 8.68
Phasmid (μm)	24.38 \pm .49 (15.9-31.8) 18.44	27.33 \pm 2.25 (22.26-30.74) 8.22	25.61 \pm 2.27 (22.26-31.80) 8.86	26.30 \pm 2.48 (18.02-28.62) 9.45	26.15 \pm 4.46 (16.96-4.98) 17.04	28.25 \pm 2.34 (23.32-31.80) 8.28	28.23 \pm 2.38 (25.44-33.92) 8.42	26.67 \pm 3.23 (15.90-34.98) 12.10
Anus (μm)	593.38 \pm 73.32 (453.68-760.02) 12.35	672.92 \pm 53.33 (604.20-767.44) 7.93	566.14 \pm 47.18 (500.32-662.50) 8.33	675.49 \pm 69.75 (569.22-864.96) 10.33	632.66 \pm 53.27 (556.50-762.14) 8.42	695.25 \pm 42.49 (625.40-769.56) 6.11	661.86 \pm 47.11 (601.02-751.54) 7.12	641.54 \pm 70.81 (453.68-864.96) 11.04
a	26.19 \pm 2.44 (21.83-31) 9.35	24.98 \pm 2.84 (20.07-30.95) 11.38	23.04 \pm 2.92 (17.73-28.59) 12.65	25.75 \pm 1.84 (21.54-29.14) 7.15	27.50 \pm 2.94 (22.78-33.50) 10.67	26.06 \pm 1.56 (22.44-28.79) 6.00	26.52 \pm 3.60 (18.46-31.67) 13.58	25.71 \pm 2.93 (17.73-33.50) 11.40
b	5.63 \pm 0.74 (4.63-7.15) 13.17	6.50 \pm 0.67 (5.42-8.03) 10.24	5.53 \pm 0.40 (4.81-6.48) 7.14	5.86 \pm 0.69 (4.64-7.56) 11.73	6.12 \pm 0.52 (5.27-7.24) 8.55	6.24 \pm 0.58 (5.19-7.47) 9.30	6.04 \pm 0.37 (5.47-6.67) 6.06	6.00 \pm 0.65 (4.63-8.03) 10.84
b'	4.79 \pm 0.50 (3.98-5.91) 10.47	5.27 \pm 0.47 (4.42-5.87) 8.96	4.57 \pm 0.29 (4.08-5.24) 6.27	4.85 \pm 0.41 (4.10-5.66) 8.50	4.95 \pm 0.39 (4.24-5.56) 7.91	5.05 \pm 0.32 (4.50-5.52) 6.36	4.99 \pm 0.32 (4.47-5.58) 6.49	4.91 \pm 0.43 (3.98-5.91) 8.72
c	38.98 \pm 9.23 (26.45-59.18) 23.70	44.62 \pm 7.41 (32.89-59.17) 16.62	39.07 \pm 3.55 (33.25-45.00) 9.10	44.19 \pm 4.98 (34.78-52.00) 11.26	44.23 \pm 6.29 (36.95-55.83) 14.23	42.64 \pm 5.04 (34.05-52.86) 11.81	45.18 \pm 4.51 (39.33-59.09) 9.99	42.65 \pm 6.45 (26.45-59.18) 15.12
c'	1.18 \pm 0.21 (0.8-1.69) 18.07	1.14 \pm 0.16 (0.92-1.45) 13.73	1.09 \pm 0.12 (0.86-1.25) 10.75	1.22 \pm 0.17 (0.92-1.50) 13.55	1.19 \pm 0.13 (0.92-1.36) 11.22	1.27 \pm 0.14 (1.00-1.54) 11.01	1.14 \pm 0.14 (0.85-1.36) 12.42	1.18 \pm 0.16 (0.80-1.69) 13.73

V	63.81±1.96 (60-66.5) 3.08	64.43±1.32 (62.25-68.03) 2.05	63.64±0.82 (62.01-65.16) 1.28	65.39±1.51 (61.70-67.84) 2.31	64.67±1.89 (59.58-67.84) 2.91	63.76±1.06 (61.98-65.48) 1.66	65.16±1.57 (60.64-67.95) 2.41	64.41±1.60 (59.58-68.03) 2.49
V'	65.57±1.79 (61.99-68.28) 2.74	65.95±1.42 (63.32-69.82) 2.15	65.31±0.91 (63.59-66.95) 1.40	66.92±1.59 (63.17-69.44) 2.38	66.20±1.92 (61.16-69.13) 2.91	65.33±1.13 (63.39-67.33) 1.73	66.65±1.61 (62.02-69.52) 2.42	65.99±1.60 (61.16-69.82) 2.42
O	49.67±6.80 (40-59.09) 13.69	54.10±7.40 (40.91-63.64) 13.67	42.77±5.99 (33.33-55.00) 14.00	53.36±5.46 (43.48-60.87) 10.22	51.38±5.79 (40.91-61.90) 11.28	49.90±7.25 (31.82-59.09) 14.54	46.95±4.66 (39.13-54.55) 9.92	50.00±6.90 (31.82-63.64) 13.81
MB	64.80±2.23 (61.95-70.93) 3.45	66.84±2.85 (59.46-71.00) 4.27	64.21±3.38 (59.62-72.12) 5.27	66.74±2.73 (61.34-71.17) 4.10	63.88±3.25 (56.47-69.81) 5.09	64.46±2.81 (60.00-71.91) 4.35	66.12±3.11 (61.90-73.96) 4.71	65.27±3.07 (56.47-73.96) 4.71

[Mean±SD; (Range); CV%], Least variable (<12%), Moderately variable (12-20%), Highly variable (>20%)

The mean CV values of both length of oesophageal gland overlapping and b' ratio of female *Helicotylenchus dihystera* in relation to host plants was 7.43% and 8.72%, respectively indicating them as least variable characters. The highest CV value (10.47%) of the b' ratio was found in the Rice population and the lowest CV value (6.27%) was found in the Banana population (Table4.6).

f) Tail length and 'c' ratio:

The tail length in the population of *Helicotylenchus dihystera* collected from different host plants was within the range of 10.60-23.32 μ m while, the 'c' ratio was within the range of 26.45-59.18 with a mean value of 42.65. The maximum mean 'c' ratio (45.18) was recorded in the Pea population and the minimum (38.98) was recorded in the Rice population.

The mean CV values of both Tail length and 'c' ratio of female *Helicotylenchus dihystera* in relation to host plants was 13.77% and 15.12%, respectively indicating them as moderately variable characters. The highest CV value (23.70%) of the 'c' ratio was found in the Rice population and the lowest CV value (9.10%) was found in the Banana population (Table4.6).

g) Anal body width (ABW) and c' ratio:

The anal body width (ABW) in the population of *Helicotylenchus dihystera* collected from different host plants was within the range of 10.60-19.08 μ m while, the c' ratio was within the range of 0.80-1.69 μ m with a mean value of 1.18. The maximum mean c' ratio (1.27) was recorded in Citrus population and the minimum (1.09) was recorded in the Banana population.

The mean CV value of ABW of female *Helicotylenchus dihystera* in relation to host plants was 11.22% indicating as least variable character while, c' ratio with a mean CV value of 13.73% was indicating as moderately variable character. The highest CV value (18.07%) of the c' ratio was found in the Rice population and the lowest CV value (10.75%) was found in the Maize population (Table4.6).

h) MB:

The MB of females of *Helicotylenchus dihystera* collected from all host plants ranged from 56.47-73.96% with mean value of 65.27%. The maximum mean MB (66.84%)

was recorded in the Maize population and the minimum (63.88%) was recorded in the Mango population.

The mean CV value of the MB of female *Helicotylenchus dihystra* in relation to host plants was 4.71% indicating as least variable character. The highest CV value of the MB was found in the Banana population (5.27%) and the lowest CV value (3.45%) was found in the Rice population (Table4.6).

i) V and V':

The V and V' of females of *Helicotylenchus dihystra* collected from all host plants ranged from 59.58-68.03% and 61.16-69.82% with mean value of 64.41% and 65.99%, respectively. The maximum mean V and V' (65.39% and 66.92%) were recorded in Jackfruit population and the minimum (63.64% and 65.31%) were recorded in the Banana population.

The mean CV values of the V and V' of female *Helicotylenchus dihystra* in relation to host plants were 2.49% and 2.42%, respectively indicating as least variable characters. The highest CV values of the V and V' were found in the Rice and Mango populations (3.08% and 2.91%) and the lowest CV values (1.28% and 1.40%) were found in Banana population (Table4.6).

j) Stylet length:

The stylet length of females of *Helicotylenchus dihystra* collected from all host plants ranged from 20.14-24.38 μ m with mean value of 22.87 μ m. The maximum mean stylet length (23.74 μ m) was recorded in the Jackfruit population and the minimum (21.99 μ m) was recorded in the Rice population.

The mean CV value of the stylet length of female *Helicotylenchus dihystra* in relation to host plants was 4.58% indicating as least variable character. The highest CV value of the stylet length was found in the Rice population (6.79%) and the lowest CV value (2.24%) was found in the Jackfruit population (Table4.6).

k) SE:

The SE of females of *Helicotylenchus dihystra* collected from all host plants ranged from 91.16-136.74 μ m with mean value of 114.56 μ m. The maximum mean SE

(121.45 μ m) was recorded in the Jackfruit population and the minimum (102.26 μ m) was recorded in the Banana population.

The mean CV value of the SE of female *Helicotylenchus dihystrera* in relation to host plants was 9.05% indicating as least variable character. The highest CV value of the SE was found in the Rice population (10.30%) and the lowest CV value (3.99%) was found in the Citrus population (Table4.6).

1) O:

The 'O' of females of *Helicotylenchus dihystrera* collected from all host plants ranged from 31.82-63.64% with mean value of 50.00%. The maximum mean 'O' (54.10%) was recorded in the Maize population and the minimum (42.77%) was recorded in the Banana population.

The mean CV value of the 'O' of female *Helicotylenchus dihystrera* in relation to host plants was 13.81% indicating as moderately variable character. The highest CV value of the 'O' was found in the Citrus population (14.54%) and the lowest CV value (9.92%) was found in the Pea population (Table4.6).

4.2.2.2 Morphological and morphometric variations of *Helicotylenchus dihystrera* (Cobb, 1892) Sher, 1961 in relation to geographical locations:

To study the effect of geographical locations in morphological and morphometric variations of *Helicotylenchus dihystrera* we collected samples from different geographical locations such as Jorhat, Sivasagar, Kamrup, lakhimpur and Dhemaji having the same host plant as Banana. The morphological and morphometric measurements of variations are presented hereunder.

a) Habitus:

Body spirally coiled upon fixation, coiling takes place on the ventral side of the nematode body and there is no significant difference in habitus of *Helicotylenchus dihystrera* in relation to geographical locations (Plate 6D).

b) Body length:

The body length of females of *Helicotylenchus dihystrera* collected from all geographical locations ranged from 0.443-0.691mm with mean value of 0.586mm.

Maximum mean body length (0.634mm) was recorded in the Dhemaji population and the minimum (0.566mm) was recorded in the Kamrup population.

The mean CV value of the body length of female *Helicotylenchus dihystra* in relation to geographical locations was 8.54% indicating as least variable character. The highest CV value of the body length was found in the Sivasagar population (8.74%) and the lowest CV value (4.67%) was found in the Lakhimpur population (Table4.7).

c) 'a' ratio:

The 'a' ratio of females of *Helicotylenchus dihystra* collected from all geographical locations ranged from 17.73-31.90 with mean value of 24.85. The maximum mean 'a' ratio (27.56) was recorded in the Dhemaji population and the minimum (23.04) was recorded in the Jorhat population.

The mean CV value of the 'a' ratio of female *Helicotylenchus dihystra* in relation to geographical locations was 10.88% indicating as least variable character. The highest CV value of the 'a' ratio was found in the Jorhat population (12.65%) and the lowest CV value (6.82%) was found in the Dhemaji population (Table4.7).

d) Length of oesophagus and 'b' ratio:

The length of oesophagus in the population of *Helicotylenchus dihystra* collected from different geographical locations was within the range of 86.92-130.38 μ m while, the 'b' ratio was within the range of 4.48-6.56 with a mean value of 5.44. The maximum mean 'b' ratio (5.55) was recorded in the Dhemaji population and the minimum (5.20) was recorded in the Sivasagar population.

The mean CV values of both length of oesophagus and 'b' ratio of female *Helicotylenchus dihystra* in relation to geographical locations was 8.00% and 7.61% indicating them as least variable characters. The highest CV value (8.08%) of the 'b' ratio was found in the Lakhimpur population and the lowest CV value (4.47%) was found in the Kamrup population (Table4.7).

e) Length of oesophagus overlapping and b' ratio:

The length of oesophagus overlapping in the population of *Helicotylenchus dihystra* collected from different geographical locations was within the range of 111.30-156.88 μ m while, the b' ratio was within the range of 3.68-5.43 with a mean value of 4.51.

Table 4.7. Morphometric variations of *Helicotylenchus dihystra* in relation to geographical locations (Host: Banana)

Characters ♀	Jorhat (n=20)	Sivasagar (n=20)	Kamrup (n=20)	Lakhimpur (n=20)	Dhemaji (n=20)	Mean (n=100)
Body length (mm)	0.581±0.047 (0.515-0.678) 8.21	0.572±0.050 (0.498-0.654) 8.74	0.566±0.046 (0.443-0.639) 8.21	0.572±0.026 (0.518-0.606) 4.67	0.634±0.046 (0.549-0.691) 7.38	0.586±0.050 (0.443-0.691) 8.54
Body width (µm)	25.54±3.33 (21.20-31.80) 13.05	23.80±1.90 (21.20-26.50) 7.98	22.63±1.59 (20.14-25.44) 7.01	23.43±1.53 (21.20-26.50) 6.55	23.11±2.35 (19.08-26.50) 10.16	23.75±2.44 (19.08-31.80) 10.29
Length of oesophagus (µm)	107.06 ±5.57 (97.52-118.72) 5.20	110.36±11.60 (92.22-130.38) 10.51	108.03±7.74 (86.92-117.66) 7.17	103.88±6.32 (92.22-116.60) 6.09	114.30±7.60 (103.88-126.14) 6.65	108.70±8.70 (86.92-130.38) 8.00
Oesophageal gland overlapping (µm)	128.61±6.85 (119.78-146.28) 5.33	130.43±12.09 (111.30-156.88) 9.27	128.54±7.15 (113.42-140.98) 5.56	127.78±6.69 (114.48-142.04) 5.24	136.03±8.52 (121.90-148.40) 6.26	130.29±8.94 (111.30-156.88) 6.86
Tail length (µm)	14.94±1.29 (12.72-16.96) 8.66	14.31±2.27 (10.60-19.08) 15.85	14.59±1.82 (10.60-16.96) 12.46	14.73±1.19 (12.72-16.96) 8.05	14.89±1.74 (10.60-16.96) 11.66	14.70±1.68 (10.60-19.08) 11.42
Anal body width (µm)	13.83±1.08 (11.66-15.90) 7.84	13.57±1.31 (11.66-15.90) 9.69	11.97±1.17 (10.60-13.78) 9.78	13.41±0.93 (11.66-14.84) 6.92	11.55±1.62 (9.54-13.78) 13.99	12.92±1.52 (9.54-15.90) 11.81

Position of vulva (μm)	369.74 \pm 29.75 (330.72-428.24) 8.05	372.59 \pm 33.78 (319.06-427.18) 9.07	369.25 \pm 26.11 (323.30-414.46) 7.07	369.25 \pm 15.07 (344.50-393.26) 4.08	410.54 \pm 29.67 (359.34-446.26) 7.23	378.46 \pm 31.68 (319.06-446.26) 8.37
Lip height (μm)	4.14 \pm 0.57 (3.18-5.30) 13.80	3.98 \pm 0.47 (3.18-4.24) 11.85	3.99 \pm 0.46 (3.18-4.24) 11.61	3.98 \pm 0.47 (3.18-4.24) 11.85	4.19 \pm 0.24 (3.18-4.24) 5.66	4.06 \pm 0.46 (3.18-5.30) 11.27
Lip width (μm)	6.71 \pm 0.51 (6.36-7.42) 7.63	6.84 \pm 0.54 (6.36-7.42) 7.91	6.42 \pm 0.26 (6.36-7.42) 4.00	6.36 \pm 0.00 (6.36-6.36) 0.00	6.52 \pm 0.52 (5.30-7.42) 7.96	6.58 \pm 0.46 (5.30-7.42) 6.93
Stylet length (μm)	22.31 \pm 0.62 (21.20-23.32) 2.80	22.74 \pm 0.80 (21.20-24.38) 3.54	22.14 \pm 0.51 (21.20-23.32) 2.32	22.58 \pm 0.50 (22.26-23.32) 2.21	23.21 \pm 0.76 (22.26-24.38) 3.28	22.61 \pm 0.74 (21.20-24.38) 3.28
DOGO (μm)	9.54 \pm 1.20 (7.42-11.66) 12.54	9.30 \pm 1.48 (7.42-11.66) 15.89	11.13 \pm 0.96 (9.54-12.72) 8.61	11.37 \pm 0.95 (9.54-13.78) 8.35	11.78 \pm 1.24 (9.54-13.78) 10.49	10.83 \pm 1.47 (7.42-13.78) 13.61
SE (μm)	102.26 \pm 8.88 (91.16-125.08) 8.68	104.78 \pm 7.21 (96.46-118.72) 6.88	104.07 \pm 6.43 (91.16-117.66) 6.18	101.65 \pm 3.70 (95.40-110.24) 3.64	113.92 \pm 6.52 (103.88-127.20) 5.73	105.37 \pm 8.05 (91.16-127.20) 7.64
Nerve ring (μm)	86.81 \pm 5.63 (75.26-98.58) 6.48	87.29 \pm 6.58 (77.38-98.58) 7.54	87.27 \pm 5.22 (72.08-94.34) 5.98	86.10 \pm 3.81 (77.38-93.28) 4.42	94.23 \pm 5.44 (84.80-100.70) 5.77	88.38 \pm 6.13 (72.08-100.70) 6.94
Medianbulb (μm)	68.04 \pm 5.11 (60.42-81.62) 7.51	69.32 \pm 6.17 (60.42-80.56) 8.89	69.65 \pm 4.35 (56.18-74.20) 6.25	67.10 \pm 4.49 (58.30-76.32) 6.68	75.68 \pm 5.37 (65.72-82.68) 7.09	69.95 \pm 5.91 (56.18-82.68) 8.44

Phasmid (μm)	25.61 \pm 2.27 (22.26-31.80) 8.86	24.77 \pm 2.16 (21.20-28.62) 8.70	26.12 \pm 2.34 (22.26-31.80) 8.95	25.76 \pm 2.09 (22.26-29.68) 8.13	26.68 \pm 2.25 (23.32-31.80) 8.43	25.76 \pm 2.26 (21.20-31.80) 8.76
Anus (μm)	566.14 \pm 47.18 (500.32-662.50) 8.33	558.30 \pm 48.35 (485.48-637.06) 8.66	552.38 \pm 45.93 (429.30-624.34) 8.31	557.93 \pm 26.14 (504.56-592.54) 4.69	619.15 \pm 45.49 (535.30-674.16) 7.35	571.30 \pm 49.15 (429.30-674.16) 8.60
a	23.04 \pm 2.92 (17.73-28.59) 12.65	24.14 \pm 2.27 (20.96-30.15) 9.41	25.12 \pm 2.24 (19.00-29.45) 8.90	24.54 \pm 1.85 (21.08-28.45) 7.54	27.56 \pm 1.88 (25.04-31.90) 6.82	24.85 \pm 2.70 (17.73-31.90) 10.88
b	5.53 \pm 0.40 (4.81-6.48) 7.14	5.20 \pm 0.42 (4.63-5.91) 7.99	5.35 \pm 0.24 (5.05-5.85) 4.47	5.53 \pm 0.45 (4.48-6.56) 8.08	5.55 \pm 0.41 (4.64-6.39) 7.37	5.44 \pm 0.41 (4.48-6.56) 7.61
b'	4.57 \pm 0.29 (4.08-5.24) 6.27	4.40 \pm 0.35 (3.88-5.06) 7.86	4.43 \pm 0.33 (3.84-5.11) 7.55	4.49 \pm 0.32 (3.68-5.24) 7.19	4.68 \pm 0.34 (4.02-5.43) 7.28	4.51 \pm 0.33 (3.68-5.43) 7.42
c	39.07 \pm 3.55 (33.25-45.00) 9.10	40.60 \pm 4.65 (33.28-50.90) 11.44	39.37 \pm 5.63 (32.15-56.30) 14.31	39.03 \pm 2.63 (34.44-44.00) 6.74	42.93 \pm 4.07 (38.40-55.90) 9.47	40.22 \pm 4.35 (32.15-56.30) 10.81
c'	1.09 \pm 0.12 (0.86-1.25) 10.75	1.06 \pm 0.19 (0.67-1.50) 17.97	1.23 \pm 0.17 (1.00-1.60) 13.86	1.10 \pm 0.09 (0.93-1.27) 8.27	1.30 \pm 0.17 (1.10-1.67) 13.35	1.15 \pm 0.17 (0.67-1.67) 15.16

V	63.64±0.82 (62.01-65.16) 1.28	65.07±1.62 (62.45-68.13) 2.49	65.24±2.65 (62.08-74.64) 4.06	64.50±1.04 (62.96-67.28) 1.61	64.76±0.85 (63.71-66.51) 1.32	64.62±1.58 (62.01-74.64) 2.44
V'	65.31±0.91 (63.59-66.95) 1.40	66.73±1.59 (64.18-69.59) 2.38	66.97±2.85 (63.51-77.04) 4.25	66.21±1.05 (64.56-69.12) 1.59	66.32±0.84 (65.23-68.23) 1.26	66.28±1.64 (63.51-77.04) 2.47
O	42.77±5.99 (33.33-55.00) 14.00	40.83±5.35 (33.33-50.00) 13.10	50.16±3.64 (45.00-57.14) 7.27	50.42±4.46 (42.86-61.90) 8.85	50.55±5.20 (40.91-59.09) 10.29	47.79±6.23 (33.33-61.90) 13.04
MB	64.21±3.38 (59.62-72.12) 5.27	63.18±2.09 (59.46-66.30) 3.30	64.63±2.23 (61.26-70.00) 3.45	64.59±1.65 (61.62-67.68) 2.55	65.83±1.76 (62.63-70.48) 2.67	64.49±2.38 (59.46-72.12) 3.69

[Mean±SD; (Range); CV%], Least variable (<12%), Moderately variable (12-20%), Highly variable (>20%)

The maximum mean b' ratio (4.68) was recorded in the Dhemaji population and the minimum (4.40) was recorded in the Sivasagar population.

The mean CV values of both length of oesophagus overlapping and b' ratio of female *Helicotylenchus dihystera* in relation to geographical locations was 6.86% and 7.42% indicating them as least variable characters. The highest CV value (7.86%) of the b' ratio was found in the Sivasagar population and the lowest CV value (6.27%) was found in the Jorhat population (Table4.7).

f) Tail length and 'c' ratio:

The tail length in the population of *Helicotylenchus dihystera* collected from different geographical locations was within the range of 10.60-19.08 μ m while the 'c' ratio was within the range of 32.15-56.30 with a mean value of 40.22. The maximum mean 'c' ratio (42.93) was recorded in the Dhemaji population and the minimum (39.03) was recorded in the Lakhimpur population.

The mean CV values of both Tail length and 'c' ratio of female *Helicotylenchus dihystera* in relation to geographical locations was 11.42% and 10.81% indicating them as least variable characters. The highest CV value (14.31%) of the 'c' ratio was found in the Kamrup population and the lowest CV value (6.74%) was found in the Lakhimpur population (Table4.7).

g) Anal body width (ABW) and c' ratio:

The anal body width (ABW) in the population of *Helicotylenchus dihystera* collected from different geographical locations was within the range of 9.54-15.90 μ m while, the c' ratio was within the range of 0.67-1.67 μ m with a mean value of 1.15. The maximum mean c' ratio (1.30) was recorded in Dhemaji population and the minimum (1.06) was recorded in the Sivasagar population.

The mean CV value of ABW of female *Helicotylenchus dihystera* in relation to geographical locations was 11.81% indicating as least variable character while c' ratio with a mean CV value of 15.16% was indicating as moderately variable character. The highest CV value (17.97%) of the c' ratio was found in the Sivasagar population and the lowest CV value (8.27%) was found in the Lakhimpur population (Table4.7).

h) MB:

The MB of females of *Helicotylenchus dihystra* collected from all geographical locations ranged from 59.46-72.12% with mean value of 64.49%. The maximum mean MB (65.83%) was recorded in the Dhemaji population and the minimum (63.18%) was recorded in the Sivasagar population.

The mean CV value of the MB of female *Helicotylenchus dihystra* in relation to geographical locations was 3.69% indicating as least variable character. The highest CV value of the MB was found in the Jorhat population (5.27%) and the lowest CV value (2.55%) was found in the Lakhimpur population (Table4.7).

i) V and V':

The V and V' of females of *Helicotylenchus dihystra* collected from all geographical locations ranged from 62.01-74.64% and 63.51-77.04% with mean value of 64.62% and 66.28%. The maximum mean V and V' (65.24% and 66.97%) were recorded in Kamrup population and the minimum (63.64% and 65.31%) were recorded in the Jorhat population.

The mean CV values of the V and V' of female *Helicotylenchus dihystra* in relation to geographical locations were 2.44% and 2.47%, respectively indicating as least variable characters. The highest CV values of the V and V' were found in the Kamrup population (4.06% and 4.25%) and the lowest CV values (1.28% and 1.26%) were found in Jorhat and Dhemaji populations (Table4.7).

j) Stylet length:

The stylet length of females of *Helicotylenchus dihystra* collected from all geographical locations ranged from 21.20-24.38 μ m with mean value of 22.61 μ m. The maximum mean stylet length (23.21 μ m) was recorded in the Dhemaji population and the minimum (22.14 μ m) was recorded in the Kamrup population.

The mean CV value of the stylet length of female *Helicotylenchus dihystra* in relation to geographical locations was 3.28% indicating as least variable character. The highest CV value of the stylet length was found in the Sivasagar population (3.54%) and the lowest CV value (2.21%) was found in the Lakhimpur population (Table4.7).

k) SE:

The SE of females of *Helicotylenchus dihystera* collected from all geographical locations ranged from 91.16-127.20 μ m with mean value of 105.37 μ m. The maximum mean SE (113.92 μ m) was recorded in the Dhemaji population and the minimum (102.26 μ m) was recorded in the Jorhat population.

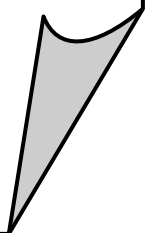
The mean CV value of the SE of female *Helicotylenchus dihystera* in relation to geographical locations was 7.64% indicating as least variable character. The highest CV value of the SE was found in the Jorhat population (8.68%) and the lowest CV value (3.64%) was found in the Lakhimpur population (Table4.7).

l) O:

The 'O' of females of *Helicotylenchus dihystera* collected from all geographical locations ranged from 33.33-61.90% with mean value of 47.79%. The maximum mean 'O' (50.55%) was recorded in the Dhemaji population and the minimum (40.83%) was recorded in the Sivasagar population.

The mean CV value of the 'O' of female *Helicotylenchus dihystera* in relation to geographical locations was 13.04% indicating as moderately variable character. The highest CV value of the 'O' was found in the Jorhat population (14.00%) and the lowest CV value (7.27%) was found in the Kamrup population (Table4.7).

Discussion... 



CHAPTER V

DISCUSSION

The present investigation on morphological and morphometric variations of genera *Hoplolaimus* and *Helicotylenchus* in relation to host plants and geographical locations of Assam were carried out during the year 2018-2020. The results obtained from the present investigations under each objective are discussed below:

1. Morphological and morphometric variations of genera *Hoplolaimus* and *Helicotylenchus* in relation to host plants:

Random survey was conducted from different host plants of Jorhat district. A total of 87 samples were collected from the rhizosphere of different plants. The survey yielded *Hoplolaimus columbus* from Jackfruit, Mango and Tea; *Hoplolaimus indicus* from Banana and Rice; and *Helicotylenchus dihystra* from Rice, Maize, Banana, Jackfruit, Citrus, Mango and Pea. The nematode species recorded during the present investigation was already known and there was no addition of new species to science. In the current study no morphological variation was observed in both the species of *Hoplolaimus* and *Helicotylenchus* due to the effect of host plants.

The dimensions of *Hoplolaimus columbus* recorded in the present investigation were in conformity with the dimensions recorded by the original author (Sher, 1963) and other workers (Das, 1993 and Chandrawat *et al.*, 2014). The present investigation recorded that in case of *Hoplolaimus columbus*; morphometric characters like body length, a ratio, oesophagus length, b ratio, length of oesophageal gland overlapping, b' ratio, c ratio, ABW, MB, V, V', stylet length, SE, number of tail annules, Pa and Pp of females were least variable characters; while tail length and c' ratio of females were moderately variable characters in relation to host plants.

The dimensions of *Hoplolaimus indicus* recorded in the present investigation were in conformity with the dimensions recorded by the original author (Sher, 1963) and other workers (Khan and Chawla, 1975; Anderson, 1983 and Das, 1993). In the present investigation morphometric characters of female of *H. indicus* such as - body length, a ratio, oesophagus length, b ratio, length of oesophageal gland overlapping, b' ratio, ABW, MB, V, V', stylet length, SE and Pp were regarded as least variable characters; c ratio, c' ratio, tail annules and Pa were regarded as moderately variable

characters; while tail length was regarded as highly variable character in relation to host plants.

Body length, a ratio, oesophagus length, b ratio, length of oesophageal gland overlapping, b' ratio, tail length, c ratio, ABW, c' ratio, MB, stylet length, SE, Pa, Pp, spicule length and gubernaculum length of male of *Hoplolaimus indicus* were regarded as least variable characters ;while bursa of males was regarded as moderately variable character in relation to host plants.

The effect of the host plant on morphometric characters has been reported for several nematodes species such as *Ditylenchus destructor* (Goodey, 1952), *Ditylenchus myceliophagus* (Das and Bajaj, 2005), *Meloidogyne incognita* (Singh *et al.*, 1985), *Heterodera glycines* (Golden and Epps, 1965), *Paratylenchus nanus* (Fisher, 1965), *Aphelenchoides fragariae* (B'Chir, 1977), *H. rostochiensis* (Trudgill and Parrot, 1970) and *Trichodorus christiei* (Bird and Mai, 1965). Thakur *et al.* (2014) studied the morphometric variations on *Hoplolaimus indicus* in relation host plants and reported that ratio 'c', spear length and V in females were stable characters (CV= <12%) however; a, b and b' were variable characters (CV= 12-20%) and c' ratio, spicules and gubernaculum length were highly variable characters (CV= >20%). The result of the current study was different from Thakur *et al.* (2014), except spear length and V. They also observed that the two sexes may respond differently to the host-effect.

The dimensions of *Helicotylenchus dihystra* recorded in the present investigation were in conformity with the dimensions recorded by the original author (Sher, 1961) and other workers (Das, 1993). In the present investigation body length, a ratio, oesophagus length, b ratio, length of oesophageal gland overlapping, b' ratio, ABW, MB, V, V', stylet length and SE of females were regarded as least variable characters ; while tail length, c ratio, c' ratio and O of females were regarded as moderately variable characters in relation to host plants of *Helicotylenchus dihystra*.

Fortuner (1980) observed that there was no significant difference in position of phasmids, fusion of inner incisures and c ratio of *Helicotylenchus dihystra* in relation to host-plants but, the present study showed significant variation in c ratio.

In the current study lip height and lip width of all the nematodes in relation to host plants were least variable characters, except in *Helicotylenchus dihystra* where, lip height was moderately variable character. Singh *et al.* (1985) reported that lip height was not the valid taxonomic character as it might vary in relation to host plants.

Subramanian and Sivakumar (1988) found that the stylet length and V% were the least variable taxonomic character in relation to host plants of *Pratylenchus delattrei* while, length of oesophagus and c' were most variable amongst all the characters studied. Similar results have been obtained in the present study except, length of oesophagus which was least variable taxonomic character.

Koshy *et al.* (1991) studied the morphometric variations of *Radopholus similis* in relation to host plants and observed that stylet length and V% were the most stable characters which coincided with the present study.

Das and Bajaj (2005) studied morphometric variations of *Ditylenchus myceliophagus* in relation to host plants. They reported that body length was highly variable character, which was in contrary to the present study. However, they recorded that characters like V, stylet length and MB were stable characters for *D. myceliophagus* which was in conformity with the present study.

2. Morphological and morphometric variations of genera *Hoplolaimus* and *Helicotylenchus* in relation to geographical locations:

Random survey was conducted from different geographical locations of Assam *viz.*, Jorhat, Kokrajhar, Sivasagar, Kamrup, Lakhimpur, Dhemaji, Nagaon and KarbiAnglong. A total of 76 soil samples were collected from the rhizosphere of Banana (as fixed host plant). The survey yielded the *Hoplolaimus columbus*, *Hoplolaimus indicus*, *Helicotylenchus crenacauda* and *Helicotylenchus dihystra*. The nematode species recorded in the present investigation were already known and there was no addition of new species to science. In the current study no morphological variation was observed in both the species of *Hoplolaimus* and *Helicotylenchus* due to the effect of geographical locations.

The dimensions of *Hoplolaimus columbus* recorded in the present investigation were in conformity with the dimensions recorded by the original author (Sher, 1963) and other workers (Das, 1993 and Chandrawat *et al.*, 2014). In the present investigation body length, a ratio, oesophagus length, b ratio, length of oesophageal gland overlapping, b' ratio, c ratio, ABW, c' ratio, MB, V, V', stylet length, SE, number of tail annules and Pp of female *Hoplolaimus columbus* were regarded as least variable characters; while tail length and Pa of female *H. columbus* were regarded as moderately variable characters in relation to geographical locations.

The dimensions of *Hoplolaimus indicus* recorded in the present investigation were in conformity with the dimensions recorded by the original author (Sher, 1963) and other workers (Khan and Chawla, 1975; Anderson, 1983 and Das, 1993). The present investigation revealed that the body length, a ratio, oesophagus length, b ratio, length of oesophageal gland overlapping, ABW, MB, V, V', stylet length and Pp of females of *Hoplolaimus indicus* were least variable characters; b' ratio, c ratio, c' ratio, SE, number of tail annules and Pa were regarded as moderately variable characters; while tail length of females was regarded as highly variable character in relation to geographical locations.

In case of males of *Hoplolaimus indicus*; body length, a ratio, oesophagus length, b ratio, oesophagus overlapping length, b' ratio, tail length, ABW, MB, stylet length, SE, Pp, spicule length and gubernaculum length were regarded as least variable characters; while c ratio, c' ratio, Pa, bursa were regarded as moderately variable characters in relation to geographical locations.

The dimensions of *Helicotylenchus crenacauda* recorded in the present investigation found conformity with the original author (Sher, 1966) and other workers (Das, 1993). The present investigation revealed that the body length, a ratio, oesophagus length, b ratio, oesophageal gland overlapping length, b' ratio, ABW, MB, V, V', stylet length and SE of females were regarded as least variable characters; while, tail length, c ratio, c' ratio and O of females were regarded as moderately variable characters in relation to geographical locations.

The dimensions of *Helicotylenchus dihystra* recorded in the present investigation found conformity with the original author (Sher, 1961) and other workers (Das, 1993). The present investigation revealed that body length, a ratio, oesophagus length, b ratio, oesophageal gland overlapping length, b' ratio, tail length, c ratio, ABW, MB, V, V', stylet length and SE of females were regarded as least variable characters; while, c' ratio and O of females were regarded as moderately variable characters in relation to geographical locations.

In the present study of stylet length and V ratio in relation to geographical locations of *Hoplolaimus columbus*, *Hoplolaimus indicus*, *Helicotylenchus crenacauda* and *Helicotylenchus dihystra* were least variable characters, similar results were obtained by Olowe and Corbett (1984 b) in *Pratylenchus brachyurus* and *P. zae* from six different geographical locations.

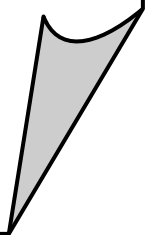
The stylet length, V ratio and 'a' ratio in relation to geographical locations of all nematodes in the present study were least variable character and are in conformity with Koshy *et al.* (1991) for *Radopholus similis* and Ghosh and Khan (2007) for *Rotylenchulus reniformis*. However, 'c' and c' ratio was moderately variable in *Hoplolaimus indicus* and *Helicotylenchus crenacauda*. In *Helicotylenchus dihystra* only c' ratio was moderately variable and in *Hoplolaimus columbus* both 'c' and c' ratios are least variable characters.

Hazarika (2017) studied the morphometric variations in relation to geographical locations and found that the V ratio, stylet length and MB ratio as stable characters, and a ratio, b ratio, lip height and lip width as least variable characters while body length, c ratio, c' ratio, R, Rst and Rvan as moderately variable character in both *Paratylenchus curvatus* and *Macroposthonia onostris* which was found agreement with the present study in all nematodes except body length which was least variable character.

Salalia *et al.* (2017) observed that certain J₂ morphometric values, e.g., the distance from the anterior end up to gland overlap, b'-value, length of hyaline portion of tail and c'-value were highly variable in some populations of *Meloidogyne graminicola*. Least variation of characters of *M. graminicola* was observed for stylet length, distance of excretory pore from the anterior end, maximum body width, a-value, b-value, and anal body width. Among males, stylet length, spicule length, and gubernaculum length were least variable, whereas characters like tail length, c-value, c'-value were highly variable in Hisar, Jorhat, Samastipur, and Vellayani populations. Among female characteristics, stylet length and vulval length were most stable within populations. Sumita *et al.* (2018) reported that morphometric characters such as body length, stylet length, lip height, lip width, MB, a, b, b', c and c' among the populations of *M. incognita* from nine districts of Assam showed no distinct variations, except in MB value. MB value; and is conformity with the present study.

Intraspecific variations in the morphometrics of the plant parasitic nematodes exists in relation to geographical locations may be due to changes in the soil type, temperature, soil pH and also by various environmental factors. Similar results were observed by Sasser (1954), Sleeth and Reynolds (1955), Abed and Taha (1975) in soil type, Loewenberg *et al.*, (1960), Wallace (1966); Morgan and MacLean (1968) in soil pH and Daulton and Nusbaum (1962) in soil moisture.

Summary... 



CHAPTER VI

SUMMARY

The present investigations were carried out during 2018-2020 with two objectives: to study the morphological and morphometric variations of genera *Hoplolaimus* and *Helicotylenchus* in relation to host plants, and to study the morphological and morphometric variations of genera *Hoplolaimus* and *Helicotylenchus* in relation to geographical locations of Assam. The results obtained from the current study are summarized below:

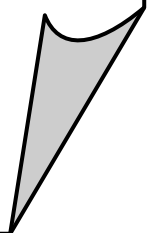
- ❑ No morphological variations were observed in genera *Hoplolaimus* and *Helicotylenchus* in relation to host plants.
- ❑ Morphometric characters like body length, a ratio, oesophagus length, b ratio, oesophagus overlapping length, b' ratio, c ratio, ABW, MB, V, V', stylet length, SE, number of tail annules, Pa and Pp of females were regarded as least variable (stable) characters; while, tail length and c' ratio of females were regarded as moderately variable characters in relation to host plants (Jackfruit, Mango and Tea) of *Hoplolaimus columbus*.
- ❑ The body length, a ratio, oesophagus length, b ratio, oesophagus overlapping length, b' ratio, ABW, MB, V, V', stylet length, SE and Pp of females were regarded as least variable characters; while, c ratio, c' ratio, tail annules and Pa of females were regarded as moderately variable characters; while, tail length of females was regarded as highly variable character in relation to host plants (Banana and Rice) of *Hoplolaimus indicus*.
- ❑ In males of *Hoplolaimus indicus*; body length, a ratio, oesophagus length, b ratio, oesophageal gland overlapping length, b' ratio, tail length, c ratio, ABW, c' ratio, MB, stylet length, SE, Pa, Pp, spicule length and gubernaculum length were regarded as least variable (stable) characters; while, bursa of males was regarded as moderately variable character in relation to host plants (Banana and Rice).

- ❑ The body length, a ratio, oesophagus length, b ratio, oesophagus overlapping length, b' ratio, ABW, MB, V, V', stylet length and SE of females were regarded as least variable (stable) characters; while, tail length, c ratio, c' ratio and O of females were regarded as moderately variable characters in relation to host plants (Rice, Maize, Banana, Jackfruit, Mango, Citrus and Pea) of *Helicotylenchus dihystra*.
- ❑ No morphological variations observed in genera *Hoplolaimus* and *Helicotylenchus* in relation to geographical locations.
- ❑ The body length, a ratio, oesophagus length, b ratio, oesophageal gland overlapping length, b' ratio, c ratio, ABW, c' ratio, MB, V, V', stylet length, SE, tail annules and Pp of females were regarded as least variable (stable) characters; while, tail length and Pa of females were regarded as moderately variable characters in relation to geographical locations (Lakhimpur, Nagaon and KarbiAnglong) of *Hoplolaimus columbus*.
- ❑ In females of *Hoplolaimus indicus*; body length, a ratio, oesophagus length, b ratio, oesophageal gland overlapping length, ABW, MB, V, V', stylet length and Pp of females were regarded as least variable (stable) characters; while, b' ratio, c ratio, c' ratio, SE, number of tail annules and Pa of females were regarded as moderately variable characters; while, tail length of females was regarded as highly variable character in relation to geographical locations (Jorhat and Kamrup).
- ❑ In males of *Hoplolaimus indicus*; body length, a ratio, oesophagus length, b ratio, oesophageal gland overlapping length, b' ratio, tail length, ABW, MB, stylet length, SE, Pp, spicule length and gubernaculum length were regarded as least variable (stable) characters; while, c ratio, c' ratio, Pa and bursa of males were regarded as moderately variable characters in relation to geographical locations (Jorhat and Kamrup).
- ❑ The body length, a ratio, oesophagus length, b ratio, oesophageal gland overlapping length, b' ratio, ABW, MB, V, V', stylet length and SE of females were regarded as least variable (stable) characters; while, tail length, c ratio, c' ratio and O of females were regarded as moderately variable characters in

relation to geographical locations (Jorhat and Kokrajhar) of *Helicotylenchus crenacauda*.

- The body length, a ratio, oesophagus length, b ratio, oesophageal gland overlapping length, b' ratio, tail length, c ratio, ABW, MB, V, V', stylet length and SE of females were regarded as least variable (stable) characters; while, c' ratio and O of females were regarded as moderately variable characters in relation to geographical locations (Jorhat, Sivasagar, Kamrup, Lakhimpur and Dhemaji) of *Helicotylenchus dihystra*.

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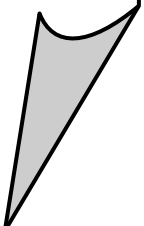
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Plates... 



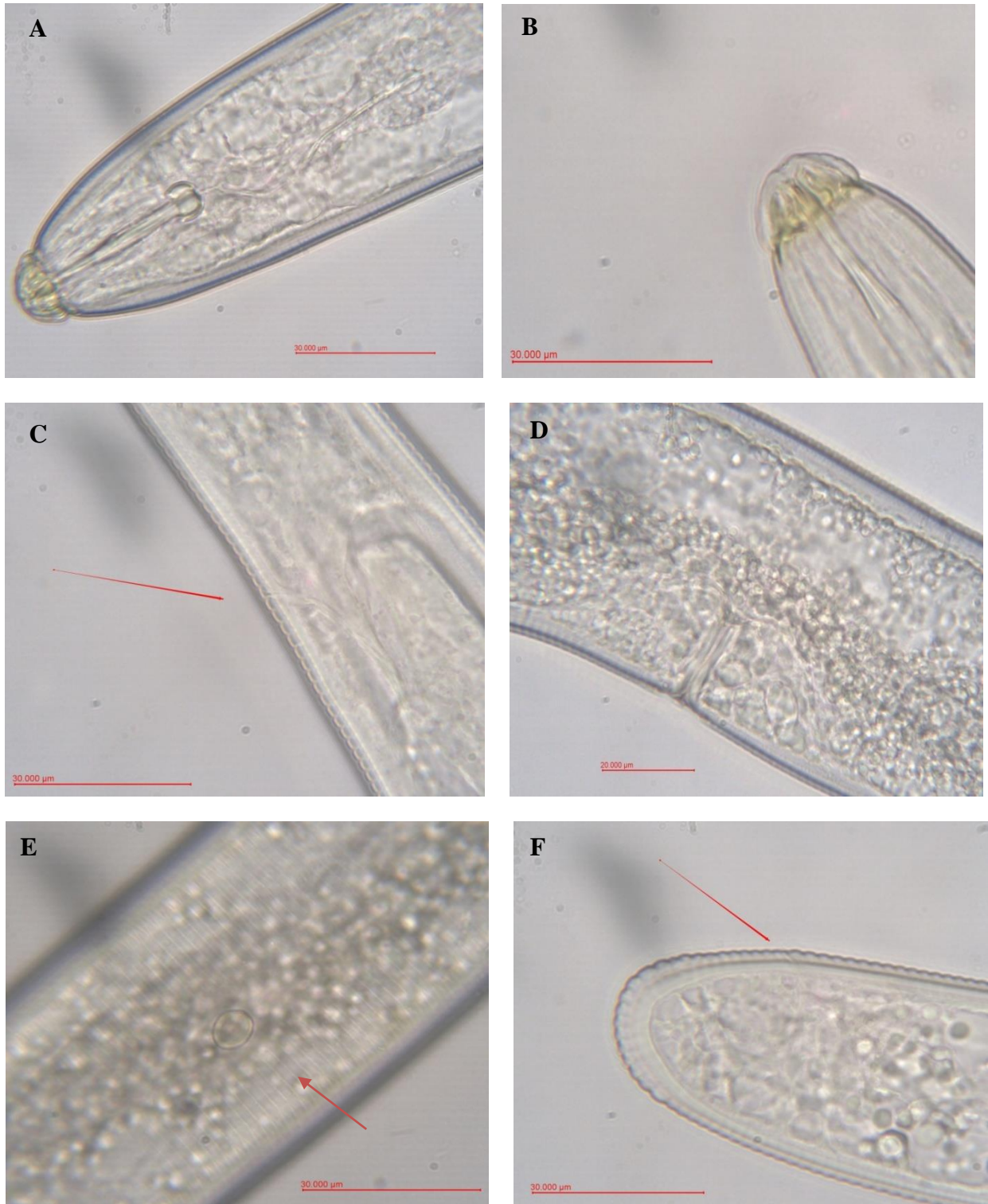


Plate 1 (A-F). *Hoplolaimus columbus* (10 X 100x)

A. Anterior with lip region, stylet and DOGO B. Lip annules C. Excretory pore (Arrow)
 D. Vulval region E. Phasmid F. Tail annules and anus (Arrow)

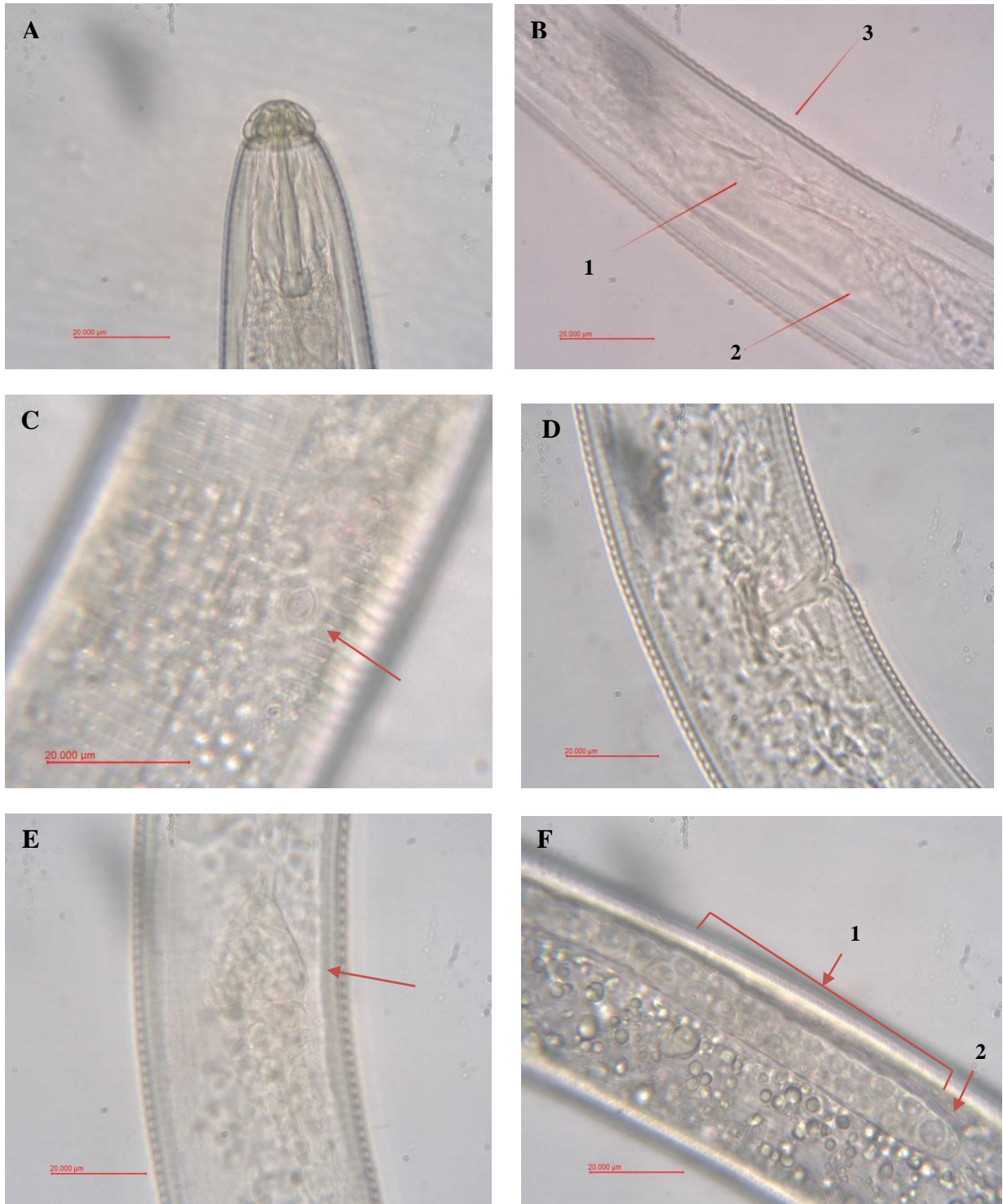


Plate 2(A-F). *Hoplolaimus indicus* (10 X 100x)

A. Anterior with lip region and stylet of female B. Oesophageal region - cardia (arrow 1), oesophageal gland overlapping (arrow 2) and excretory pore of female (arrow 3) C. Phasmid of female (arrow) D. Vulval region E. Spermatheca (arrow) F. Gonad region of female - germinal zone (arrow 1) and cap cell of germinal zone (arrow 2)

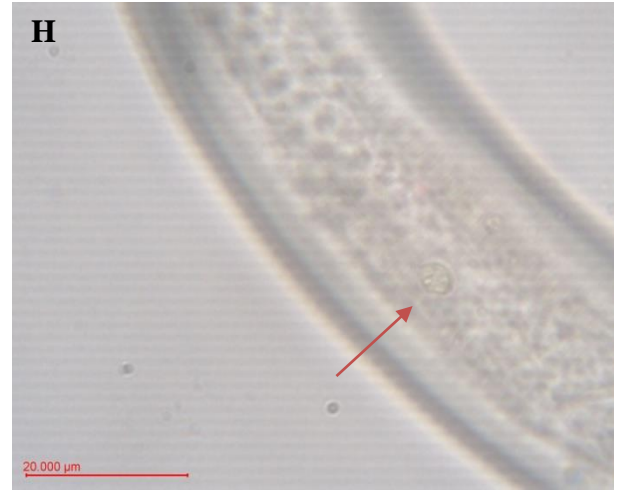


Plate 3 (G-J). *Hoplolaimus indicus* (10 X 100x)

G. Tail annules H. Phasmid of male (arrow) I. Caudal alae J. Spicule and gubernaculum

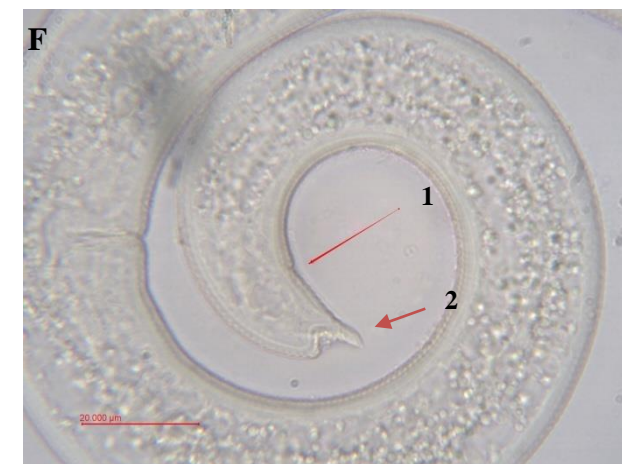
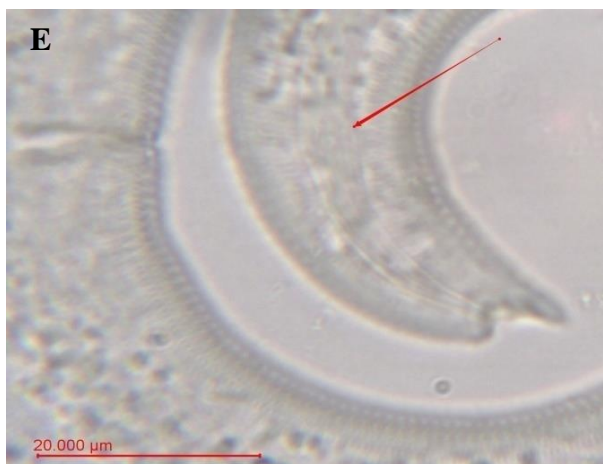
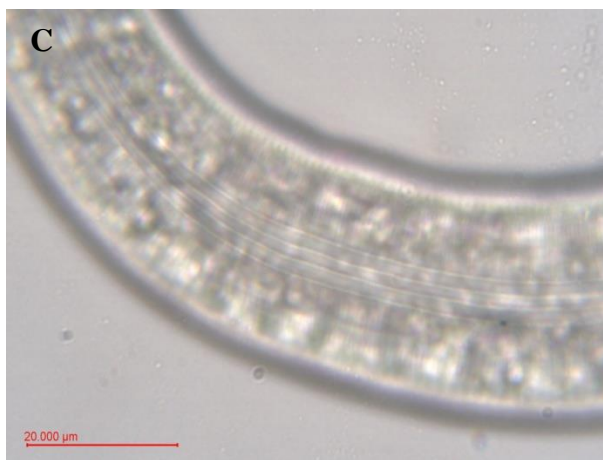


Plate 4 (A-F). *Helicotylenchus crenacauda* (10 X 100x)

A. Anterior with lip region, stylet and stylet knobs B. DOGO (arrow) C. Incisures
 D. DOGO (arrow 1), median bulb (arrow 2), nerve ring (arrow 3) and excretory pore (arrow 4) E. Phasmid F. Anus (arrow 1) and tail (arrow 2) with ventrally curved elongate projection (caudate)

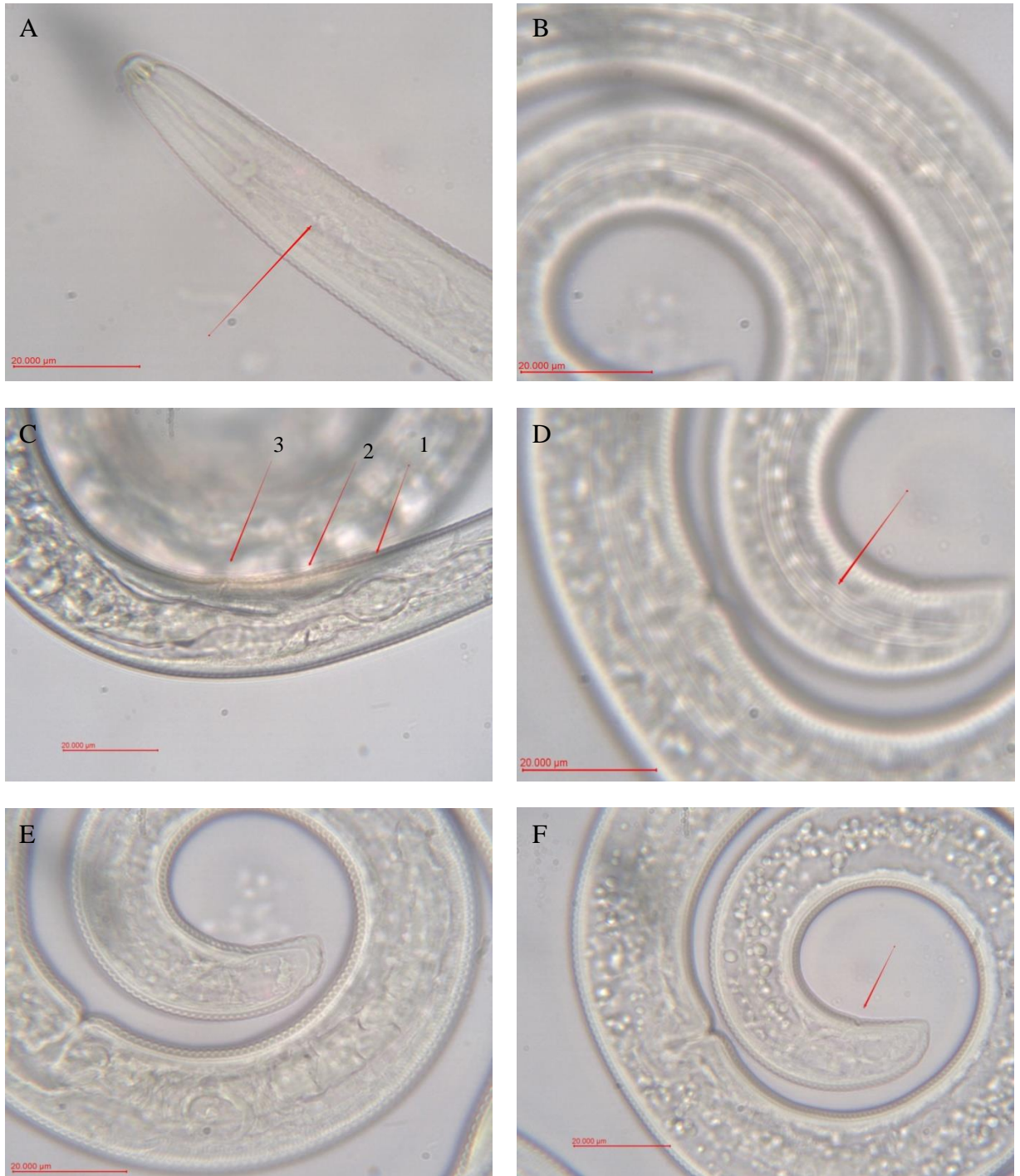


Plate 5 (A-F). *Helicotylenchus dihystrera* (10 X 100x)

A. Anterior head region, stilet, stilet knobs and DOGO (arrow) B. Incisures
 C. Oesophageal region - median bulb (arrow 1), nerve ring (arrow 2) and excretory pore (arrow 3) D. Phasmid (arrow) E. Posterior gonad F. Anus (arrow)

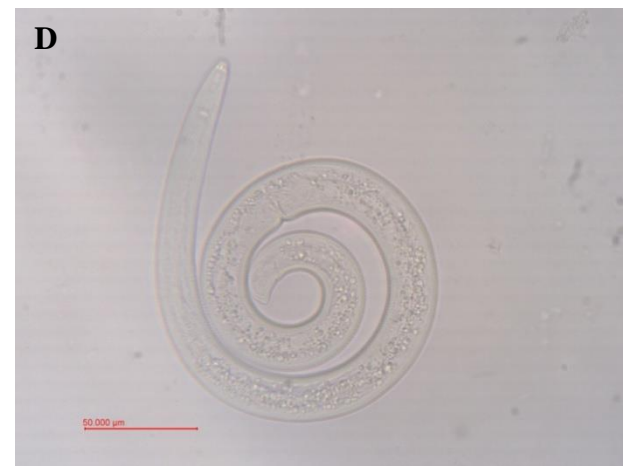


Plate 6 (A-D). Full length nematode (10 X 20x) and habitus

A. *Hoplolaimus columbus*

B. *Hoplolaimus indicus*

C. *Helicotylenchus crenacauda*

D. *Helicotylenchus dihystra*