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Studies on Taxonomy, Biology and Ecology of Nematodes Associated with Jute Crop

by

Y. CHATURVEDI

and

S. KHERA

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INTRODUCTION

Thorne (1961) and other workers describe Needham's (1943) record of plant nematode as the earliest record of these tiny worms. However, Tiwari and Mitra (1974) have reported that these worms were known to Indians as early as thirteenth century and they were also aware of the methods for their control. In recent years Siddiqi, M. R. (1959–), Das (1960–), Seshadri (1962–), Jairajpuri (1963–), Khan, A. M. (1965–), Khera (1965–), and others have made significant contributions in the field of plant and soil nematology in India. Nematodes of many crops and plants of economic importance have been investigated but except for a few stray papers nothing much is known about the nematodes associated with jute. In the neighbouring country of Bangladesh some research work was carried out on nematodes of jute by a team of workers led by Timm (1959–1961).

Jute, originally a native of Malaya or Ceylon, is now an important Indian crop. Besides India, jute is also cultivated in Bangladesh, Brazil, Mexico, Argentina, U.A.R., Iran, China, Japan, Indonesia, etc. In India jute is grown in the States of West Bengal, Bihar, Uttar Pradesh, Orissa, Assam, Tripura and Manipur. The crop is cultivated on about 0.90 million hectares annually, the annual average production of dry fibre is about 6.3 million bales of 181 kg each. India is the largest manufacturer and exporter of jute products.

Jute, *Corchorus* L. (Tiliacae), is a genus of about 40 species of annual herbs. About eight species occur in India of which two are important, viz. *C. capsularis* L. and *C. olitorius* L.; these two species yield the jute of commerce. Both species have got many varieties.

Jute can be grown on almost all types of soil, which are neither very heavy clay nor very sandy. Loamy alluvial soil with deposits of fertile silt from flood water is considered to be the best for jute cultivation. Generally warm and humid climate with temperature ranging from 24°–35°C and 90% relative humidity favour the growth of jute. In low lands sowing is done in February while medium and high lands are sown in March–April and May–June respectively. The plants grow to the height of 3–6 meters. The crop is harvested within 3–4 months after sowing, while the flowers are still in bloom. Depending upon the time of sowing and the variety grown, the harvesting period varies from June to October. Fibre of jute is obtained from the secondary phloem. Best fibre shows pale—yellow colour and silky lusture, the length varies from 1.8–3.0 meters and is very stiff due to lignification.

Jute is one of the main cash crops of India. It occupies a place second only to cotton amongst fibres. Jute trade holds a leading position in the total foreign trade of India accounting for about a quarter of the total value of all exports. Therefore, it becomes imperative to know the nematodes infesting the jute in our fields, losses caused by them and their control. West Bengal is the principal seat of jute production and industry (production 80%, loomage 96%). For this reason fields of this state were selected for present study.

This work includes the taxonomic studies of the nematodes recovered during the course of survey work, survey of jute fields of West Bengal, population dynamics of three species of tylenchids, namely *Tylenchorhynchus mashhoodi*, *Helicotylenchus indentatus* n. sp. and *Hirschmanniella oryzae* in relation to temperature and rainfall. Effects of crop rotation and fallow have also been observed. Besides, the population fluctuations of rhabiditids and dorylaims have also been dealt with, studies on embryology, life cycle, abundance of males and intersexes of *M. javanica* by potcultures developed on *C. olitorius*, host-parasite relationships and histopathological studies. For this, a predominant species of root-knot nematode, *Meloidogyne javanica* was selected for studies in relation to *C. olitorius*. The experiments were made on potted plants for making observations on 11 characters selected to show the effects of nematode infestation. Ovoviviparity in *Meloidogyne incognita* is also included.

Thanks are due to the Director, Zoological Survey of India, Calcutta for providing facilities for the present work.. We are grateful to Dr. M. Oostenbrink, Prof. of Nematology, Netherlands for critically going through the manuscript and many valuable suggestions. Help of the State Agriculture Department, Government of West Bengal, for providing plots at Burdwan for population studies is acknowledged. Shri G.D. Mukherji, Senior Statistical Assistant, Zoological Survey of India did the statistical analysis of the data pertaining to pathogenicity experiment.

Materials and Methods (general)

Sampling,—Samples of soil and roots were collected from the jute crop at a depth of 10–15 cm with the help of scooping hand-shovel. These were kept in polythene bags. All the samples were properly labelled on the spot giving details of locality, date, host and any other relevant interesting data. All the collections were made by the first author (Y Chaturvedi) except from Bankura, Purulia and Midnapur which were collected by the second author (S. Khera) hence collector's name is not given in the text.

Storage.—When samples were so abundant or due to other unavoidable reasons they could not be processed immediately, these were then stored in the refrigerator at a temperature of 7°C. However, for population studies the soil was processed immediately after having been brought to the laboratory.

Processing.—Roots were separated from the soil carefully for separate examination. The remaining soil was thoroughly mixed. Goodey's (1963) sieving and decantation method was followed for processing and isolation of nematodes. Approximately 500 cc of soil was placed in a plastic bucket and mixed with water so as to make uniform suspension. The suspension was passed through a coarse sieve to remove stones and other big foreign materials. It was, then passed through a set of sieves of 60, 100, 175, 250 and 325 mesh numbers. The residues from last two sieves (*i.e.* 250 and 325 mesh numbers) were taken in a beaker.

Isolation of Nematodes.—The aliquot collected in the manner described above was mixed with water. It was allowed to settle down and most of the supernatant liquid was decanted in a petri dish. The content of petri dish was examined under a stereomicroscope and all the nematodes were picked with the help of a fine needle and collected in water in watchglass. Again some more water was added to the beaker, mixed well, allowed to settle and decanted liquid re-examined for nematodes. The process was repeated till no more nematodes were found in the decanted liquid. Lastly the entire content of the beaker was transferred to petri dish and examined to ensure that no more nematodes were left behind.

Killing, Fixing and Dehydration.—The watch glass containing nematodes was placed on the flame of a spirit lamp for a few seconds just enough to kill the nematodes in well stretched condition. Care was taken to avoid overheating. The water was drawn out with the help of a fine dropper and nematodes were fixed in F.A.A. (formalin 30 ml, glacial acetic acid 5 ml, absolute alcohol 100 ml and distilled water 200 ml) and left in the fixative for at least 24 hours. The fixed nematodes were processed by slow glycerine method (Thorne, 1961). These were transferred to 1% glycerine (96% ethanol 20 parts, glycerine 1 part, distilled water 79 parts) for dehydration. Again, these were passed through 5% glycerine (96% ethanol 95 parts, glycerine 5 parts). The nematodes were kept in the glycerine solution till other components evaporated and only glycerine was left. The nematodes were finally transferred to pure and dehydrated glycerine.

Mounting and Sealing.—Five to ten nematodes were mounted in pure dehydrated glycerine drop on glass slides. Glass-wool supports of the same size as that of nematodes were always used to prevent any pressure on the specimens. The cover slips were sealed with "Gold—size" adhesive.

Temporary slides were prepared for immediate examination by fixing and mounting the specimens in 4% formalin. These slides showed with greater clarity than some of the permanent ones. Buhrer's (1949) technique was followed for beheading and *en face* examination of nematodes.

Examination of Roots.—The roots were examined for endoparasitic nematodes. For this purpose roots were washed thoroughly and cut into small pieces of 2–3 cm length. These were immersed in 0.1% acid-fuchsin lactophenol and heated for 3–4 minutes. The stained roots were cleared in pure lactophenol and examined under a stereomicroscope. The stained nematodes could be seen easily and were dissected out and mounted in pure lactophenol.

Preparation of Perineal Patterns.—The females of *Meloidogyne* spp. were dissected out from the root galls stained in 0.03% cotton blue lactophenol, with the help of dissecting needles. These were placed in a small drop of lactophenol on a celluloid film under a stereomicroscope. The female was punctured in anterior region and pressed to remove as much of body contents as possible. Then the posterior end was cut with the help of a surgeon's eye knife and trimmed so that only a small piece having perineal pattern was left. The tissues on its inner side were removed carefully and the sections were mounted in 0.01% cotton-blue lactophenol.

Measurements and Drawings.—De Man's formula has been used for denoting the dimensions of the nematodes. At certain places modified formula has been used to include some additional indices, *viz.* b', O, c', RB, etc. These, however, have been adopted from standard works on different group of nematodes. In many cases although a large number of specimens were collected only some of these were measured. In the case of new species described here measurements given outside the parentheses are of the holotype and those in the parentheses pertain to the paratypes. All the measurements were taken with the help of an ocular micrometer. The illustrations were made with the help of a camera lucida. Photographs and photomicrographs were also taken wherever necessary and/or feasible.

TAXONOMIC STUDIES ON NEMATODES OF JUTE

Introduction

Bessey (1911) was the first person to report on the nematode parasites of jute. Subsequently Buhrer (1938) and Goodey (1958) recorded some nematodes associated with jute crop. In India a few fragmentary reports on the nematodes of jute by Kundu (1946), Chattopadhyay and Sengupta (1955), Dutt (1960), Banerji and Banerji (1966), and Srivastava *et al.* (1972) have been published. The present study was taken up keeping in view the little knowledge about nematodes associated with jute and the importance of this crop in our national economy.

The present work deals with the taxonomic studies of nematodes associated with jute crop and also gives their distribution in West Bengal. Detailed descriptions are provided for all the new species, supported by illustrations. Some known species have also been recorded and, wherever necessary, these are described in greater details. Such redescriptions will obviously lead to a better understanding of the species.

The classification followed here is after Golden (1971) for Tylenchida and Ferris (1971) for Dorylaimida. For other groups Goodey's work (1963) has been followed except for Isolaimida which is after Timm (1969) and for Monochidal which is after Jairajpuri (1969).

The specimens of four new species of *Hoplolaimus*, *Aphelenchoides*, *Seinura* and *Metaphelenchus* were also subsequently collected and described by Shri R. V. Singh, Senior Research Fellow, Zoological Survey of India, Calcutta. Therefore, credit is being given to him as one of the authors of these four new species.

All the types specimens have been deposited in the National Zoological Collections preserved in the Zoological Survey of India, Calcutta.

In addition to the genera and species described here the specimens of the following were also found: *Paratylenchus* sp., *Acrbeloides* sp., *Alaimus* spp., *Aporcelaimellus* sp., *Belondira* sp., *Carcharolaimus* sp., *Dorylaimus* spp., *Dorylaimoides* sp., *Eucephalobus* sp., *Eudorylaimus* spp., *Leptonchus* sp., *Mesodorylaimus* sp., *Microlaimus* sp., *Monhystera* sp., *Monhystrella* sp., *Mononchus* sp., *Nygolaimus* sp., *Panagrolaimus* sp., *Panagrellus* sp., *Paractinolaimus* sp., *Placodira* sp., *Rhabditis* spp., *Thornenema* spp., and *Tobrilus* sp.

Systematic Account

Order TYLENCHIDA Thorne, 1949

Suborder *TYLENCHINA* (Örley, 1880) Geraert, 1966

Superfamily Tylenchoidea (Örley, 1880) Chitwood and Chitwood, 1937

Family Tylenchidae Örley, 1880

Subfamily Tylenchinae (Örley, 1880) Macinowski, 1909

Genus **Tylenchus** Bastian, 1865

Tylenchus filiformis Bütschli, 1873

Tylenchus filiformis Bütschli, 1873, *Nova Acta Acad. Caesar. Leop. Carol.*, **36**(5): 1–144; Thorne, 1961 *Principles of Nematology*, 553 pp.

Dimensions.—Female (10): L=0.47–0.65 mm, a=27–35, b=4,5–5.2, c=5.8-6,9, V=$^{35-38}$64–71, stylet=8–11 μm.

Male (3): L = 0.42–0.53 mm, a = 34–38, b = 5.2–6.0, c = 5–6, stylet = 8–12 μm, spicula = 14–16 μm, gubernaculum = 4–6 μm.

Description.—Female: Body slender, tapering towards the ends. Cuticle finely striated, lateral field marked with four incisures. Head continuous with body contour, stylet fine, knobs weakly developed and sloping. Ovary single, anterior, outstretched; oöcytes in a single row; postvulvar sac one body width long or slightly longer.

Male: Similar to female in general characters. Spicula tylenchoid. Gubernaculum small. Bursa adanal, about 3 anal body width long.

Remarks.—Although the species is known to be associated with a large number of plants it is also thought to subsist on fungi.

Habitat.—Rhizosphere of *C. capsularis* and *C. olitorius*.

Locality.—Found in most of the places from where samples were collected (see under *Survey*)

Genus **Chitinotylenchus** (Micoletzky, 1922) Filipjev, 1936

Chitinotylenchus paragracilis (Micoletzky, 1922) Filipjev, 1936
(Fig. 1, A–C)

Tylenchus (*Chitinotylenchus*) *paragracilis* Micoletzky, 1922, *Arch, Naturgesch.*, **87**(8): 1–320.
Chitinotylenchus paragracilis (Micoletzky, 1922) Filipjev, 1936, *Trudy Zool. Inst. Nauk SSSR*, **3:** 537–550.
Anguillulina paragracilis (Micoletzky, 1922) T. Goodey, 1932, *J. Helminth.*, **10** (2–3): 75–180; *A.* (*C.*) *paragracilis*, Schneider, 1939, *Tierwelt Dtl.*, **36:** 1–260.

Dimensions.—Male (1): L = 0.48 mm, a = 38, b = 5.7, c = 13, T = 58, stylet = 11 μm, spicula = 15 μm, gubernaculum = 7 μm.

Description.—Male: Body curved ventrally, specially in posterior half. Cuticle finely striated; lateral field 1/3 of body width, marked with four incisures. Head not set off, 3 μm high and 5 μm wide. Cephalic framework very weak, anterior part of lip region narrower than the base. Tail cylindrical, about 4 anal body diameter long, tip rounded. Stylet slender, knobs minute and separate from each other, fork beginning a little anterior to the base. Procorpus cylindrical 31 μm long, median bulb oval 10 × 6 μm, valve inconspicuous, posterior bulb pyriform, joining the median bulb through a narrow isthmus. Posterior bulb and isthmus 32 μm long, one nucleus seen in posterior bulb. Nerve ring 70 μm from anterior end, surrounding isthmus.

Testis single, outstretched; spermatocytes, arranged in a single row, Spicula typlenchoid. Gubernaculum slightly thick in the middle. Bursa adanal, 28 μm long.

Remarks.—Micoletzky (1922) erected a subgenus *Chitinotylenchus* under the genus *Tylenchus* Bastian, 1865 to accommodate his species *Tylenchus* (*Chitinotylenchus*) *paragracilis*. Filipjev (1935) while reclassifying subfamily Tylenchinae gave generic status to *Chitinotylenchus* characterizing it by furcate stylet base. He included *Tylopharynx annulatus* Cassidy, 1930 along with *C. paragracilis* under this genus. Loof (1956) transferred another species *Anguillulina incognata* v.d. Linde, 1930 to this genus. Thus, including *C. sedatus* Kirjanova, 1951 and *C. boevii* Istullaeva, 1967, five species are known in this genus. Sher (1970) invalidated the genus and relegated it to the synonymy of *Ditylenchus* Filipjev, 1936. He could not examine the specimens of other species except of *C. paragracilis*, and considers them *species inquirenda*. Golden (1971) retained the genus, although doubtfully, and transferred

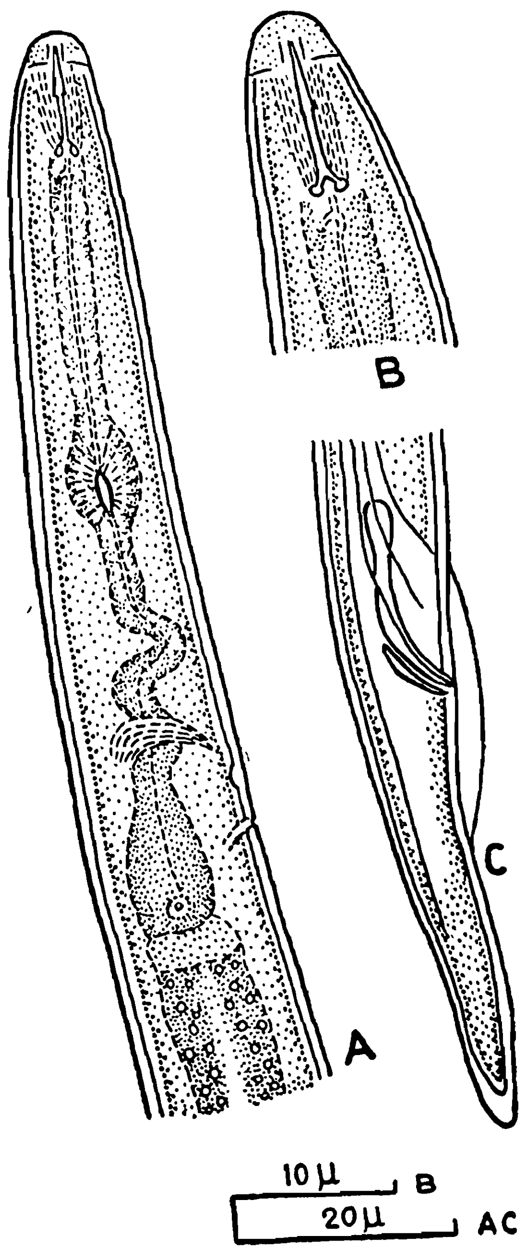

Fig. 1. *Chitinotylenchus paragracilis* (male)—A. Anterior end; B. Head; C. Posterior end.

C. annulatus to the genus *Tylenchorhynchus*. We support Golden's (*loc. cit.*) view and feel that examination of materials of all the species is essential before arriving at a definite conclusion regarding the status of the genus.

C. paragracilis was described only on the basis of female specimens. The single male specimen tallies in all the characters of the species except in the smaller length and stylet length. In nematodes, males are generally smaller in size hence the specimen is considered as male of *C. paragracilis*.

The genus was first recorded from India by Chaturvedi & Khera (1977).

Habitat.—Rhizosphere of *C. olitorius*.

Locality.—Falta, Dist, 24- Parganas.

Subfamily DITYLENCHINAE Golden, 1971

Genus **Ditylenchus** Filipjev, 1936

Ditylenchus? dipsaci (Kuhn, 1857) Filipjev, 1936

(Fig. 2, A–B)

Anguillula dipsaci Kuhn, 1857, *Z. Wiss. Zool.*, **9**(1): 129–137.
Ditylenchus dipsaci (Kuhn, 1857) Filipjev, 1936, *Trudy Zool Inst. Akad, Nauk SSSR*, **3**: 537–550.

Dimensions.—Male (1): L=0.63 mm, a=50, b=6.4, c=11, stylet=10 μm, picula=20 μm, gubernaculum=6 μm.

Description.—Male: Body slightly curved ventrally Cuticular striations transverse, fine; lateral field 1/6 of body width, marked with four incisures. Head

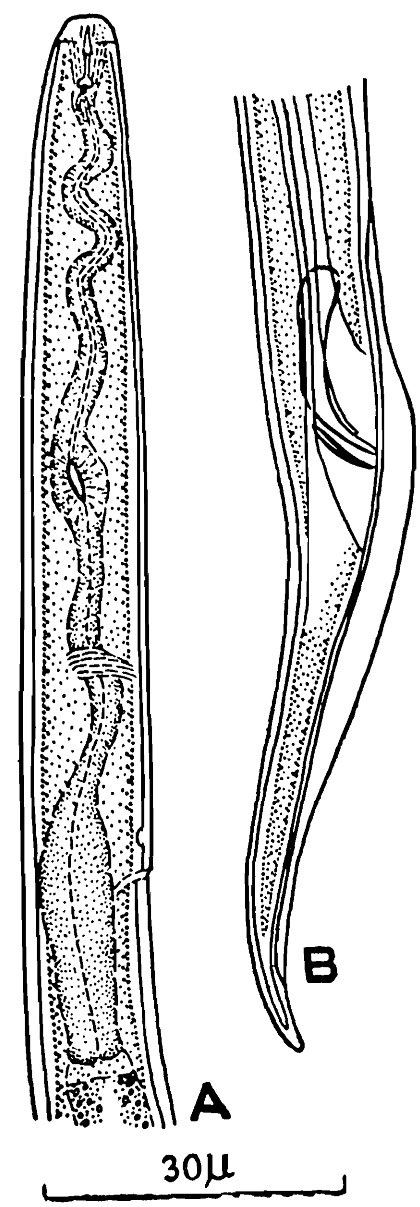

Fig. 2. *Ditylenchus ? dipsaci* (male)—A. Anterior end; B. Posterior end.

continuous with body contour, lip 3×6 μm, low and rounded. Stylet short and fine, knobs minute, round. Oesophagus typical, procorpus 25 μm long; median bulb 14×9 μm, oval, valvular; narrow isthmus joining it to posterior bulb, isthmus and posterior bulb jointly measuring 49 μm in length. Nerve ring surrounding isthmus, 63 μm form anterior end. Excretory pore behind hemizonid, 77 μm from anterior end. Spicula and gubernaculum tylenchoid. Bursa beginning in front of the anterior end of spicula, extended over most of the tail length, stopping short of tail tip.

Remarks.—The specimen fits in well with the description of the species by Thorne (1961). However, in the absence of any symptom in the plants or pathogenicity study the specimen is referred to this species provisionally.

Habitat.—Soil around the roots of *C. capsularis*.

Locality.—Rangsagar, Dist. Murshidabad.

Genus **Pseudhalenchus** Tarjan, 1958

Pseudhalenchus anchilisposomus Tarjan, 1958

Pseudhalenchus anchilisposomus Tarjan, 1958, *Proc. helminth. Soc. Wash.*, **25**(1): 20–25.

Dimensions.—Female (10): L=0.57–0.75 mm, a=35–41, b=4.6–6.5, c=11–16, V=$^{50-52}$75–84, stylet=7–8 μm.

Description.—Female: Body rather straight. Cuticular striations fine, lateral field $\frac{1}{4}$–$\frac{1}{3}$ of body width, marked with six incisures. Tail short, conoid, 4–5 times anal body width long. Postvulvar sac $\frac{1}{3}$ the vulva-anus distance long.

Remarks.—The specimens show slight variation in the length of postvulvar sac which according to Thorne and Malek (1968) is 2/3 of vulva-anus distance.

Geraert and Kheiri (1970) made a comparative study of *P. anchilisposomus* and *Ditylenchus destructor* Thorne, 1945 and they suggested that it could be a case of synonymy.

In India the species has been found associated with pearl-millet in Rajasthan (Nandakumar and Khera, 1970).

Habitat.—Rhizosphere of *C. capsularis* and *C. olitorius*.

Locality.—Jangipara, Dist. Hooghly; Burdwan; Brahmansasan, Dist. Midnapur.

Family TYLENCHORHYNCHIDAE (Eliava, 1964) Golden, 1971

Subfamily TYLENCHORHYNCHINAE Eliava, 1964

Genus **Tylenchorhynchus** Cobb, 1913

Tylenchorhynchus mashhoodi Siddiqi and Basir, 1959

Tylenchorhynchus mashhoodi Siddiqi and Basir, 1959, *Proc. 46th Indian Sci. Congr.*, :35; Siddiqi, 1961, *Z. ParasitKde.*, **21**: 46–64.

T. dactyluris Das, 1960, *Z. ParasitKde.*, **19**: 553–605.

T. digitatus Das, 1960, *Z. ParasitKde.*, **19**: 553–605.

T. crassicaudatus Williams, 1960, *Occ. Pap. Maurit. Sug. Ind. Res. Inst.*, **4**: 1–30.

T. elegans Siddiqi, 1961, *Z. ParasitKde*, **21**: 46–64.

T. zeae Sethi and Swarup, 1968, *Nematologica*, **14**: 77–88.

Dimensions.—Female (10): L=0.43–0.68 mm, a=24–31, b=3.8–5.6, c=12.0–17.8, V=$^{31-33}$52–57$^{29-34}$, stylet=14–21 μm.

Male (3): L=0.50–0.67 mm, a=29–33, b=3.7–5.2, c=12–14, T=46–48, stylet=15–17 μm, spicula=21–22 μm, gubernaculum=11–12 μm.

Description.—Female: Body usually curved ventrally. Cuticular striations distinct. Lateral field 1/3 of body width, marked with four incisures, latter continue up to tail tip, outer incisures crenate. In some specimens outer band of lateral field aerolated. In some specimens outer anterior margin of stylet knobs pointed. Tail cylindrical, 14–24 annules, tip rounded with a large unstriated terminal annule. Phasmid in anterior half of tail.

Male: General characters same as those of female. Incisures expanding on tail, ending at different levels as described in the original description (Siddiqi and Basir, 1959).

Remarks.—*T mashhoodi* was originally described from sugarcane. Baqri and Jairajpuri (1970) reported it from cotton plant, patson and sunhemp in Uttar Pradesh and sugarcane in Andhra Pradesh. They also studied the intraspecific variations and proposed the synonymy as given above.

Habitat.—Rhizosphere of *C. capsularis* and *C. olitorius.*

Locality.—Sujapur, Falta, Bhajna, Barrackpore, Dist. 24–Parganas; Andul, Dist. Howrah; Jangipara, Bishnupur, Uttarpara, Tarkeshwar, Dist. Hooghly; Alaipur, Krishnagar, Dist. Nadia; Burdwan; Rangasagar, Lalgola, Dist. Murshidabad; Susunia, Dist. Bankura; Mangalmuri, Dist. Midnapur.

Family PRATYLENCHIDAE (Thorne, 1949) Siddiqi, 1963

Subfamily PRATYLENCHINAE Thorne, 1949

Genus **Pratylenchus** Filipjev, 1936

Pratylenchus coffeae (Zimmermann, 1898) Goodey, 1951

Tylenchus coffeae Zimmermann, 1898, *Meded. Landb. Voor Dienst. Buitenz.*, **27**: 1–64.
T musicola Cobb, 1919, *W. Indian Bull.*, **17**(3): 179–182.
T. mahogani Cobb, 1920, *J. Parasit.*, **6**(4): 188–191.
Pratylenchus mahogani (Cobb, 1920) Filipjev, 1936, *Trudy Zool. Inst. Akad. Nauk SSSR*, **3**: 537–550.
P. coffeae (Zimmermann, 1898) Goodey, 1951, *Soil and freshwater nematodes*, 399 pp.
P. pratensis (de Man, 1880) in Yokoo, 1956, *Agric. Bull. Saga Univ.*, **4**: 141–162.

Dimensions.—Female (1): L=0.38 mm, a=27, b=5.4, b′=3.3, c=13, V=[14] 72, stylet=17 μm.

Description.—Female: Body curved ventrally, more so in posterior region. Head not set off, narrowing anteriorly, consists of two annules. Cuticular striations light, lateral field about 1/5 the body width, marked with four smooth incisures, Phasmid about the middle of tail. Tail cylindroid, terminus crenate, seems to be bifid, about three anal body width long. Gonads not fully developed.

Remarks.—The specimen fits in well with the description of the species given by Loof (1960) except in the position of vulva which seems to be situated slightly forward. However, this difference is not considered of much significance in the present case since the specimen is immature.

Habitat.—Rhizosphere of *C. olitorius.*

Locality.—Barrackpore, Dist. 24–Parganas.

Pratylenchus minyus Sher and Allen, 1953

Pratylenchus minyus Sher and Allen, 1953, *Univ. Calif. Publs. Zool.*, **57**(6): 441–470; Thorne, 1961, *Principles of Nematology*, 553 pp.

Dimensions.—Female (1): L=0.39 mm, a=20, b=5.7, b′=3.6, c=17, V=^{28} 82, stylet=17 µm.

Description.—Female: Body curved dorsally. Head with two annules, not set off, cuticle transversely striated. Lateral field about $\frac{1}{4}$ of body width, marked with four crenate incisures. Tail short, cylindroid, more than two anal body diameter long, tip unstriated. Phasmid just anterior to middle of tail. Cephalic framework well developed. Stylet massive, basal knobs rounded. Oesophageal gland orifice about 3 µm behind the base of knobs. Procorpus short and tubular, 22 µm long, median bulb subspherical, 14×10 µm, oesophageal gland 56 µm long. Nerve ring 57 µm and excretory pore 66 µm from anterior end.

Vulva posterior, flush with body surface; vagina transverse, about $\frac{1}{2}$ vulvar body width long. Ovary monoprodelphic; oöcytes in a single row; spermatheca absent. Postvulvar sac less than vulvar body width long. Vulva to anus distance thrice the tail length.

Remarks.—The specimen closely fits in with the description of the species given by Sher and Allen (1953) and Thorne (1961). However, the transverse lines in the inner band of lateral field shown by Sher and Allen (*loc. cit.*) were not seen. Loof (1960) considered this species a synonym of *P. neglectus* (Rensch, 1924) Chitwood and Oteifa, 1952. Thorne (*loc. cit.*) and Corbett (1969), however, consider this a valid species. Corbett's work being the most recent one is followed here as regards the status of the species.

Mountain (1955) observed feeding and development of this parasite on corn and tobacco. Benedict and Mountain (1956) found this species constantly associated with root-rot of winter wheat in Ontario.

Habitat.—Rhizosphere of *C. capsularis*.

Locality.—Jangipara, Dist. Hooghly.

Subfamily RADOPHOLINAE Allen and Sher, 1967

Genus **Hirschmanniella** Luc and Goodey, 1963

Hirschmanniella oryzae (Soltwedel, 1889) Luc and Goodey, 1963

Tylenchus oryzae Soltwedel, 1889, *Verlag van de Director vijfde Jversl. Proefstn Midden Java over* 1888/1889, pp. 15–16.

T. papillatus Imamura, 1931, *J. Coll. Agric. imp. Univ. Tokyo*, **11:** 193–240.

Anguillulina apapillata, Goodey, 1932, *J. Helminth.*, **10:** 75–180.

Rotylenchus oryzae, Filipjev and Schuurmans Stekhoven, 1941, *A manual of agricultural helminthology*, 878 pp.

Hirschmannia oryzae, Luc and Goodey, 1962, *Nematologica*, **7:** 197–202.

Hirschmanniella oryzae, Luc and Goodey, 1963, *Nematologica*, **9:** 471; Sher, 1968, *Nematologica*, **14:** 243–275.

H. nana Siddiqi, 1966, *Proc. helminth. Soc. Wash.*, **33:** 173–177.

Dimensions.—Female (10): L=0.94–1.56 mm, a=50–54, b=8.4–11.2, b′=4.2–5.6, c=15–21, c′=3.5–4.0, V=$^{21-24}$51–54$^{17-22}$, stylet=17–21 µm, O=12–18.

Male (5): L=0.85–1.04 mm, a=52–54, b=9.0–9.8, b′=4.0–4.2, c=16–18, c′=3.0–3.7, stylet=16–18 µm, O=14–16, spicula=21–22 µm, gubernaculum=6–8µm.

Description.—Female: Body long, cylindrical, curved in varied fashion, tapering behind anus. Head continuous, lip region slightly flattened, 3–4 indistinct annules. Tail elongate—conoid, annulated up to tip; terminus almost round with a vetral mucro. Cuticle coarsely striated. Lateral field $\frac{1}{4}$ of body width, marked with four incisures, outer ones crenate, in some specimens acrolated in posterior fourth. Phasmid in posterior third of tail. One female (from Susuna, Dist. Bankura) with reflexed ovary.

Male: General morphology same as that of female.

Remarks.—Mathur and Prasad (1971) made a survey of India for *H. oryzae*. They examined six samples from the West Bengal but failed to recover this species. The present studies show that the species is widely distributed in the districts of West Bengal.

Habitiat.—Rhizosphere of *C. capsularis* and *C. olitorius*.

Locality.—Sujapur, Dist. 24-Parganas; Uttarpara, Dist. Hooghly; Susunia, Dist. Burdwan; and Rangasagar, Dist. Murshidabad.

Hoplolaimus dubius Chaturvedi, Singh and Khera, n.sp.

(Fig. 3, A–E, Fig. 4, A–H, Pl. I, A–B)

Dimensions.—Holotype—Female: L=1.14 mm, a=31, b=8.5, b'=5.8, c=54, V=$^{17}58^{17}$, stylet=36 μm, O=11, anterior phasmid 29%, posterior phasmid 81%.

Paratypes—Female (9): L=1.1–1.2 mm, a=29–31, b=8.5–9.2, b'=5.8–7.0, c=52–60, V=$^{15-16}51$–58^{16-17}, stylet=36–38 μm, O=9–11, anterior phasmid 6–30%, posterior phasmid 67–80%.

Male (5): L=0.99–1.12 mm, a=26–28, b=7.0–8.5, b'=4–5, c=32–35, T=51–52, stylet=35–38 μm, spicula=38–39 μm, gubernaculum=18–20 μm, anterior phasmid 32–34%, posterior phasmid 76–80%.

Other material—Female (40): L=1.05–1.27 mm, a=23–38, b=8–13, b'=6.0–8.6, *c*=45–74, V=$^{15-18}53$–60^{16-19}, stylet=31–42 μm, anterior phasmid 27–30%, posterior phasmid 75–80%.

Male (22): L=0.78–1.13 mm, a=20–36, b=6.2–10.6, b'=4.0–7.8, c=31–40, T=50–54, stylet=33–38 μm, spicula=37–44 μm, gubernaculum=15–21 μm, anterior phasmid 31–36%, posterior phasmid 76–85%.

Description.—Female: Body thick, stout and uniformly cylindrical; on thermal death assumes open 'C' shape, remains almost straight or irregularly curved; some of the females curved dorsally. Cuticle thick, transversely striated, striae 2–3 μm apart in the midbody region. Head distinctly set off from body; head shape showing sexual dimorphism, truncate cone-shaped, marked with three annules. Basal annule marked with 14 longitudinal lines. Cephalic framework typical and well developed. Basal plates strongly cuticularised, curved back for two annules. Stylet massive, basal knobs strong, rounded, 5–6 μm across, their anterior margins with single anterior projection. Dorsal oesophageal gland orifice 4(4–5) μm from the base of the stylet-knobs. Procorpus a cylindrical tube, 42(32–56) μm long, constricted slightly near the junction with median bulb. Median bulb 20(15–28) μm in diameter, subspherical in shape, with well developed crescentic valve plates. Oesophageal gland with six nuclei, dorsally overlapping the intestine. Oesophago-intestinal valve distinct, consisting of two cells. In some specimens one or the other part of oesophagus contracted resulting in either short procorpus or short oesophageal

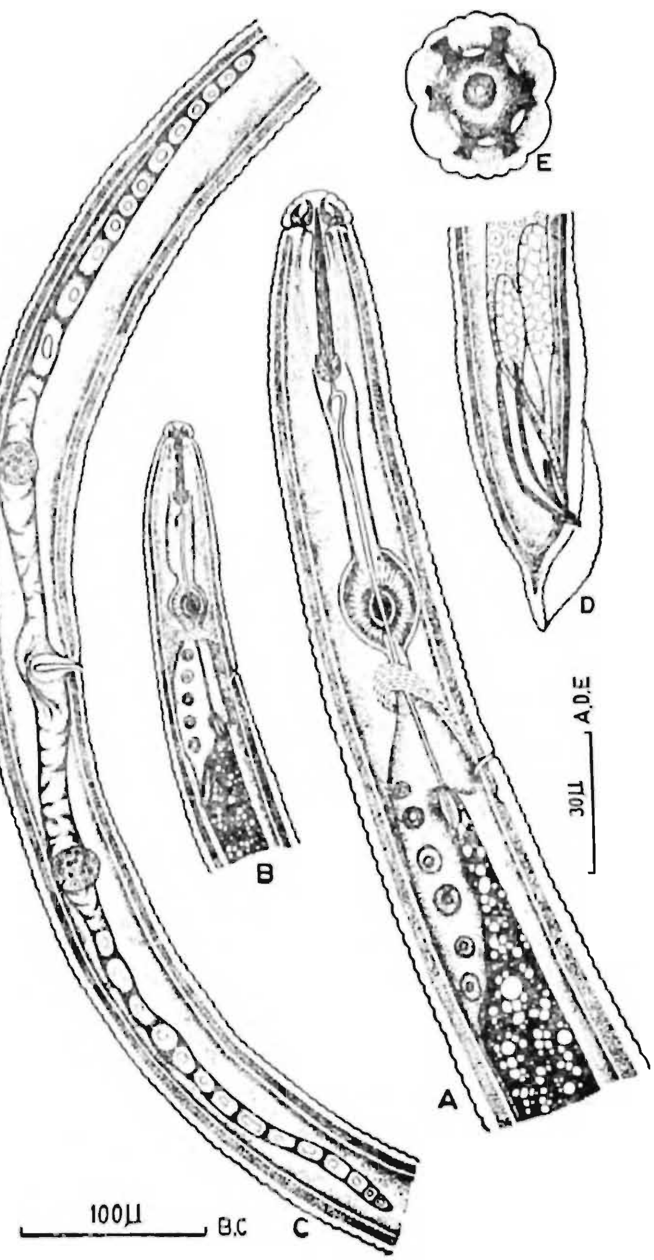

Fig. 3. *Hoplolaimus dubius* n.sp.—A. Female anterior end; B. Male anterior end; C. Female gonads; D. Male tail; E. section of head showing longitudinal markings on basal annule.

gland or showing a clear space around the median bulb. When oesophageal gland is contracted its nuclei become inconspicuous. Nerve ring 105 (82–108) μm from anterior end, nerve strands running from it converging near hemizonid. Excretory pore between median bulb and oesophago-intestinal valve, 91 (85–123) μm from anterior end, anterior to hemizonid, Hemizonid 2–3 annules wide and 2–9 annules behind excretory pore. Hemizonion, cephalids or caudalids not seen. Intestine filled with granules, not overlapping rectum. Tail short, rounded, marked with 10–15 annules ventrally. Tail of one female grooved on dorsal side. Lateral field marked with one incisure represented by breaks in striae for most of the length of the nematodes, prominent only in the caudal region. In a number of specimens 2, 3 or 4 broken incisures were seen (2 in holotype). Out of several, only one specimen showed 4 distinct incisures originating in oesophageal region and running short of tail tip. In case of more than one incisure, lateral field aerolated. Phasmids on either side of vulva, placed erratically.

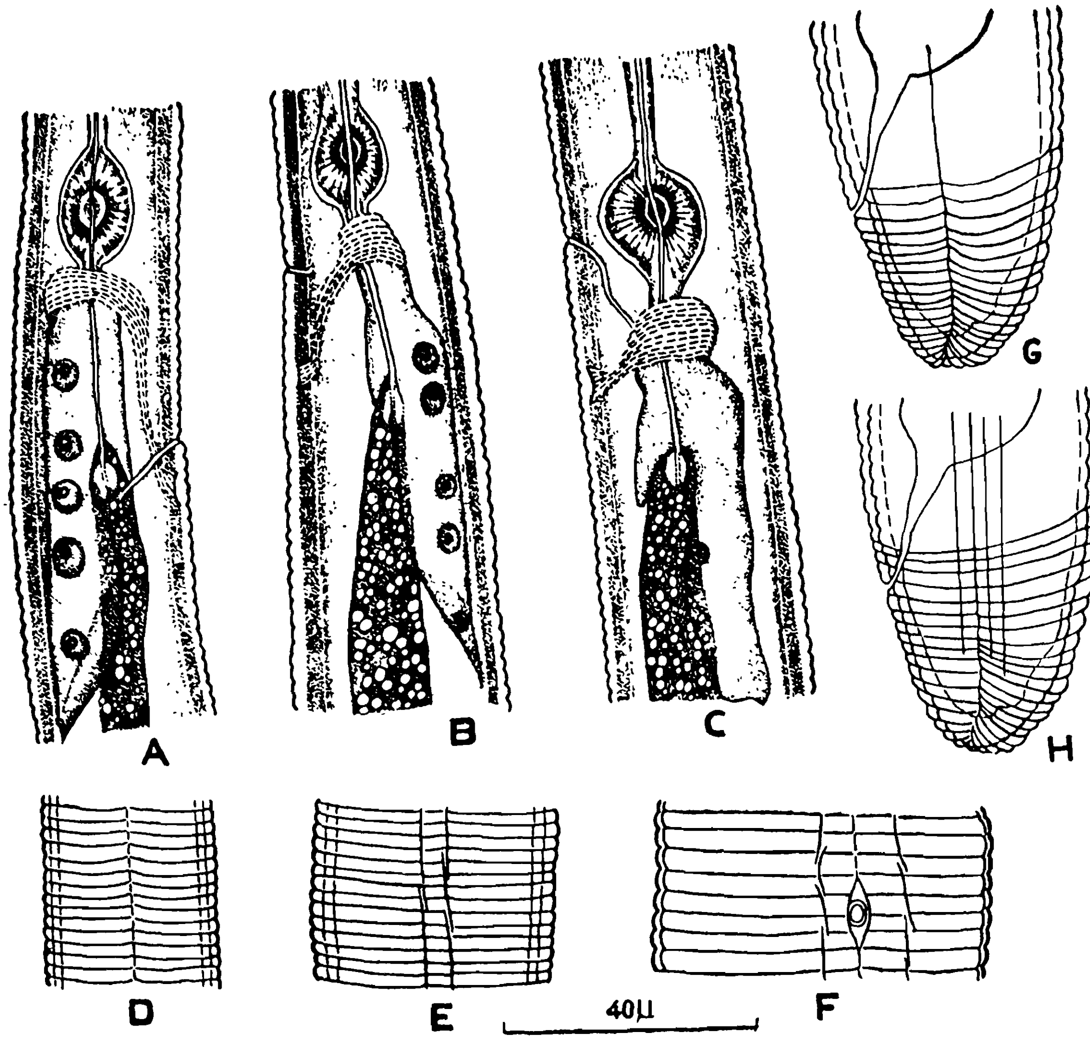

Fig. 4. *Hoplolaimus dubius* n.sp.—A–C. Oesophageal regions showing position of excretory pore; D–H. Lateral field showing variable number of incisures.

Vulva posterior to middle. Epiptygma single, attached anteriorly. Didelphic, amphidelphic gonads. Anterior ovary 182 (180–326) μm and posterior 196 (196–309) μm long. Oöcytes in a single row. Spermatheca round, sperm present in some specimens.

Male: Body rather straight. General morphology similar to that of female. Head unlike that of female, hemispherical, marked with three annules, basal annule marked with 14 longitudinal lines. Tail conical, and spike like portion of tail with very fine striae, appearing at a cursory glance as though devoid of striations. Spicules paired, strong, alate; telamon present; gubernaculum small, distal end thicker, with titillae. Bursa well developed, enveloping tail, its margin crenate.

Differential diagnosis and relationships.—The new species comes close to *H. indicus* Sher, 1963 in having males, functional spermatheca and six nuclei in oesophageal gland but differs from it in having lesser number of head annules (four in *H. indicus* as figured by Sher, 1963, although in description he mentions only three), variable number of incisures, intestine not overlapping rectum, variable position of excretory pore and 14 longitudinal markings on basal annule (11 in *H. indicus*).

Hoplolaimus dubius n.sp. resembles *H. capensis* Berg and Heyns, 1970, in the intestine not overlapping rectum, presence of spermatheca and males and the variable position of excretory pore. It, however, differs from *H. capensis* by possessing lesser number of head annules, six nuclei in oesophageal gland, round spermatheca and smaller body size (in *H. capensis* head annules 5–6, gland nuclei 3, oblong spermatheca, and L=1.6–2.1 mm).

The new species also comes close to *H. dimorphicus* Mulk and Jairajpuri, 1976 in having six nuclei in oesophageal gland, intestine not overlapping rectum, excretory pore above the hemizonid. However, *H. dubius* differs from *H. dimorphicus* by the presence of lateral field, variable number of incisures, number of longitudinal markings on basal annule, longer stylet, position of excretory pore and epiptygma being anterior (lateral field and incisure absent, 18–21 longitudinal markings on basal annule, stylet 34–36 μm, excretory pore below the level of oesophago-intestinal valve, and epiptygma posterior in *H. dimorphicus*).

Banerji and Banerji (1966) reported *H. indicus* from different places in West Bengal. However, their illustrations show that they were dealing with some other species because in their figures the lip region has been shown with at least six annules and intestine does not overlap rectum.

Type habitat.—Found around the roots of *C. olitorius* and *C. capsularis*.

Holotype.—One female; collected on 23.viii.1970.

Paratypes.—Nine females and five males, other particulars as for the holotype.

Type-locality.—Rangsagar, Dist. Murshidabad, West Bengal.

Other material.—Several females and males were collected from various places in districts 24-Parganas, Howrah, Hooghly, Burdwan, Nadia, Midnapur, Murshidabad and Bankura.

Other hosts.—The species was also found associated with the following vegetable crops:

Egg-plant, tomato, potato, okra, cauliflower, cabbage, fenugreek, radish, chilli, pumpkin, pea, spinach, bottle gourd and sponge gourd.

Subfamily ROTYLENCHINAE Golden, 1971

Genus **Helicotylenchus** Steiner, 1945

Helicotylenchus indicus Siddiqi, 1963

Helicotylenchus indicus Siddiqi, 1963, *Z. Parasitkde.*, **23:** 239–244; Nandakumar and Khera, 1970 *Indian J. Helminth.*, **22**(1): 46–52.

H. insignis Khan and Basir, 1964, *Proc. helminth. Soc. Wash.*, **31:** 199–202.

H. plumariae Khan and Basir, 1964, *Proc. helminth. Soc. Wash.*, **31:** 199–202.

Dimensions.—Female (10): L=0.40–0.62 mm, a=20–29, b=4.5–5.9, b′=3.5–5.2, c=22–49, c′=1.0–1.6, V=$^{24-28}$61–67$^{14-22}$, stylet=20–24 μm, O=36–49.

Description.—Female: Body curved spirally. Lip region conoid-rounded, with 4–5 indistinct annules. Lateral field 1/7 of body width, marked with four incisures, continuing on tail tip. Phasmid six annules anterior to six annules posterior of anus. Tail 10–12 annules, tip hemispherical with suggestion of ventral, projection.

Remarks.—The specimens fit in well with the description of the species given by Siddiqi (1963), Sher (1966) and Nandakumar and Khera (1970). The variation in the shape of basal knobs, as recorded by Nandakumar and Khera (*loc. cit.*) was also observed in the present population.

Habitat.—Rhizosphere of *C. olitorius* and *C. capsularis.*

Locality.—Mourigram, Sankrail, Andul and Makad, Dist. Howrah; Sujapur, Falta, Barasat and Barrackpore, Dist. 24-Parganas.

Helicotylenchus retusus Siddiqi and Brown, 1964

Helicotylenchus retusus Siddiqi and Brown, 1964, *Proc. helminth. Soc. Wash.*, **31**: 209-211.

Dimensions.—Female (3): L=0.59-0.63 mm, a=28-30, b=6.2-7.0, b'=4.5-5.0, c=53-64, c'=0.6-0.8, V=$^{19-22}$61-64$^{20-24}$, O=61-64, stylet=23-24 μm.

Description.—Female: Body curved ventrally on thermal death. Cuticle striated, striae interrupted by lateral field. Lateral field occupies about $\frac{1}{4}$ of body width, marked with four incisures, latter continuing up to tail tip. Phasmid 8-10 annules anterior to anus. Tail 9-11 annules, terminus hemispherical.

Remarks.—The species was originally recorded from sugarcane (Philippines). In India it has been recorded from rice (Hyderabad), citrus and sorghum (Mysore) (Sher, 1966).

Habitat.—Rhizosphere of *C. capsularis.*

Locality.—Brahmansasan, Dist. Midnapur.

Helicotylenchus indentatus n.sp.

(Fig. 5, A-E)

Dimensions.—Holotype—Female: L=0.58 mm, a=23, b=5.08, b'=4.08, c=42, c'=1.1, V=^{26}63^{23}, stylet=28 μm, O=25.

Paratypes—Female (8): L=0.52-0.64 mm, a=22-24, b=4.8-6.1, b'=4.0-4.8, c=33-41, c'=1.0-1.2, V=$^{24-30}$62-65$^{22-29}$, stylet=23-29 μm, O=25-36.

Male: Not found.

Description.—Female: Body assuming spiral shape on thermal death. Tail 6-10 annules, with a long ventral projection comprising 6-8 annules and having a deep indentation on the dorsal side of the base of the ventral projection, usually filled with debris. Cuticle transversely striated, striae 1.0-1.5 μm apart on mid-body, closer on tail. Lateral field $\frac{1}{5}$-$\frac{1}{4}$ body width, marked with four incisures. In a few specimens inner incisures fused on tail tip but in majority all the four appear passing round the tail tip. Phasmid 4-8 annules anterior to anus. Lip region continuous with body, 4-5 distinct annules. Cephalic framework well developed. Stylet knobs with flat anterior margins, slightly sloping backward. In some specimens outer anterior margin looks angular. Oesophageal gland orifice 6 (4-7) μm behind the base of stylet knobs. Procorpus tubular 31 (28-36) μm, median bulb oval or subspherical 14×8 (13-15×8-10) μm, crescentic valve well developed. Oesophageal gland 56 (50-57) μm, overlapping intestine ventrally and laterally. Nerve ring 91 (70-95) μm from anterior end. Excretory pore behind nerve ring, 100 (78-102) μm from anterior end. Hemizonid anterior to excretory pore, seen only in a few specimens.

Vulva postequatorial, flush with body surface; vagina at right angle to the body axis, about $\frac{1}{2}$ vulvar body width long. Ovaries paried, opposite and outstretched; anterior ovary 154 (112-155) μm and posterior 140 (105-150) μm long; oocytes arranged in a single row. Spermatheca round, conspicuous, offset and filled with sperm.

Differential diagnosis and relationships.—The genus was revised by Sher (1966) and reviewed by Siddiqi (1972). There are three species of *Helicotylenchus* with

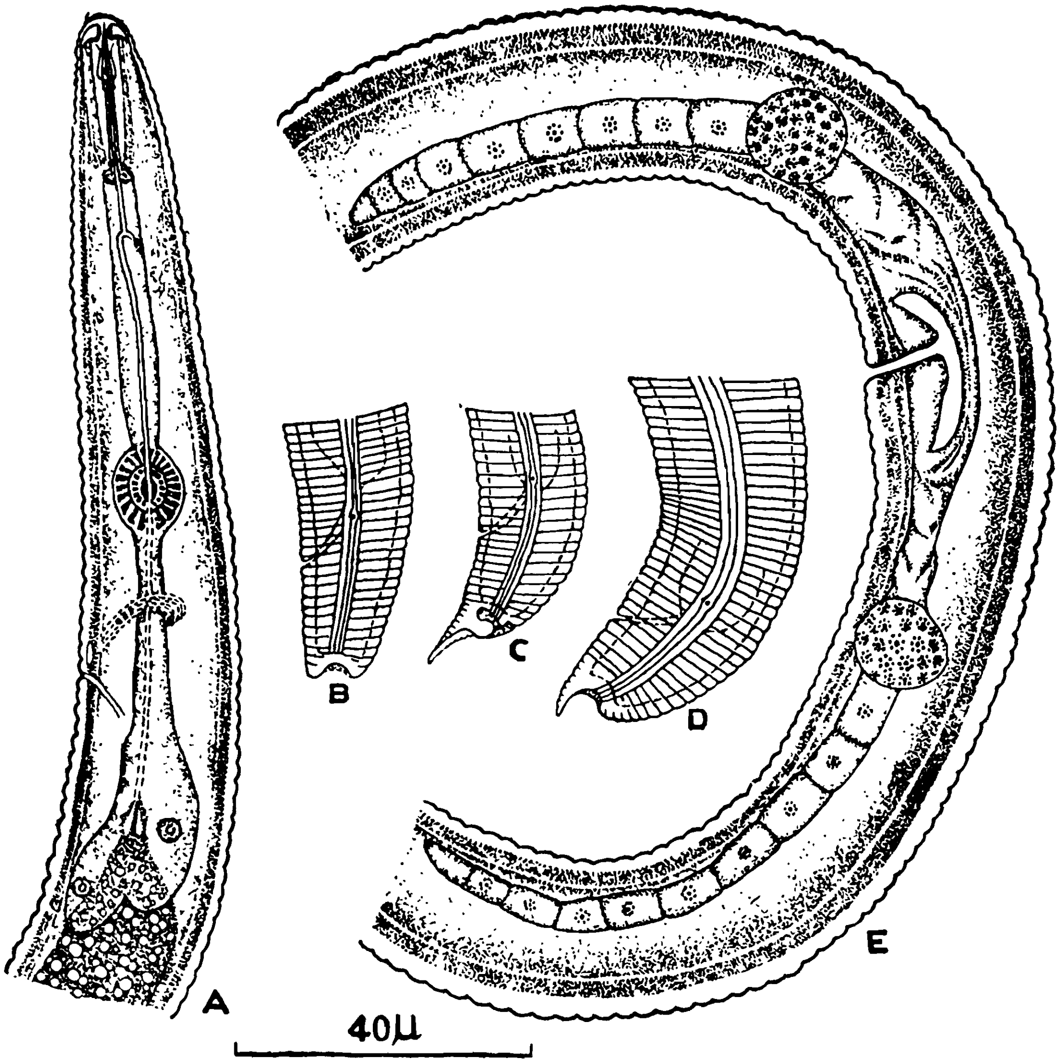

Fig. 5. *Helicotylenchus indentatus* n.sp. (female)—A. Anterior end; B–D. Stages of tail development; F. Female gonads.

indented tail terminus; these are *H. crenacauda* Sher, 1966, *H. pteracercus* Singh, 1971 and *H. indenticaudatus* Mulk & Jairajpuri, 1975. In *H. pteracercus* ventral projection of the tail is enveloped by a cuticular fold, in this respect it differs from the new species as well as from *H. crenacauda*. *H. indentatus* n.sp. closely resembles *H. crenacauda* from which, however, it differs in having robust body, in the presence of an offset spermatheca, presence of sperm in spermatheca, shape of stylet knobs and comparatively longer tail (in *H. crenacauda* a = 24–29, spermatheca not offset, without sperm, stylet knobs not sloping, c = 31–52). As regards fusion of inner incisures on distal end, it is a variable character (Nandakumar and Khera, 1970), however, fusion of incisures was observed only in a few specimens. The present species also comes close to *H. indenticaudatus* Mulk & Jairajpuri, 1975 but differs from the latter mainly by longer stylet, shape of stylet knobs, smooth outer incisures, more anteriorly placed oesophageal gland orifice and phasmids, spermatheca filled with sperm and longer ventral projection of the tail (stylet = 22–24 μm, with anteriorly pointed knobs, outer incisures crenate, O = 44, phasmid below the anal level, spermatheca without sperm—in *H. indenticaudatus*).

Remarks.—A few hundred specimens were collected but no males were found. At the same time females were found with sperm in spermatheca. These facts suggest that *H. indentatus* is a hermaphrodite species.

Type habitat.—Soil around the roots of *C. olitorius*.

Holotype.—Female; collected on 28.v.1972.

Paratypes.—Eight females; other particulars as for the holotype.

Type-locality.—Burdwan, West Bengal.

Other material.—Many females were collected on different dates from Burdwan.

Superfamily HETERODEROIDEA (Filipjev, 1934) Golden, 1971

Family HETERODERIDAE (Filipjev, 1934) Skarbilovich, 1947

Genus **Meloidogyne** Goeldi, 1887

Meloidogyne incognita (Kofoid and White, 1919) Chitwood, 1949

(Pl. II, A–B)

Oxyuris incognita Kofoid and White, 1919, *J. Am. med. Ass.*, **72**(8): 567–569.
Hetrodera incognita (Kofoid and White, 1919), Sandground, 1923, *Parasitology*, **10**(2): 92–94.
Meloidogyne incognita (Kofoid and White, 1919) Chitwood, 1949, *Proc. helminth. Soc. Wash.*, **16**: 90–104.

Dimensions.—Female (15): L=0.41–0.68 mm, width=0.35–0.50 mm, stylet=14–16 μm, knobs=3–5 μm across, orifice=2–3 μm from stylet base, median bulb=42–56×28–42 μm.

Male (10): L=0.91–1.20 mm, a=29–42, b′=11–15, c=72–102, stylet=23–27 μm, knobs=4–6 μm across, orifice=1–2 μm from stylet base, median bulb=12–22×7–15 μm, spicula=25–33 μm, gubernaculum=7–11 μm.

Larva (10): L=0.24–0.37 mm, a=18–28, b=2.5–3.5, c=5–8, stylet=7–10 μm, median bulb=7–8×5–6 μm.

Perineal pattern.—Striae closely spaced, dorsal arch high, round. Lateral line absent. Inter-phasmidal distance 19–21 μm, vulvar width 20–22 μm, anus to tail terminus 11–14 μm, anus to centre of vulva 14–16 μm.

Male: Body long, cylindroid, tapering slightly in anterior region. Cuticular striations prominent. Lateral field about 1/3 of body width, marked with four incisures. Outer band of lateral field aerolated in some specimens.

Remarks.—Some variations occur in the perineal pattern and on that basis two varities *M. incognita* var. *incognita* Chitwood, 1949 and *M. incognita* var. *acrita* Chitwood, 1949 were recognised by earlier workers. Recently Whitehead (1968) reviewed the genus and showed that both types of perineal patterns occur in the same population, therefore, he is not in favour of recognising these varieties. Our opinion is in conformity with that of Whitehead (*loc. cit.*) as both types of patterns were found together.

Habitat.—Collected from the roots of *C. olitorius* and *C. capsularis*.

Locality.—The species has got very wide distribution throughout West Bengal and was found in most of the places surveyed.

Meloidogyne javanica (Treub, 1885) Chitwood, 1949

(Pl. II, C)

Heterodera javanica Treub, 1885, *Meded. Land. Voor Dienst. Buitenz.*, **2**: 1–39.
Tylenchus (*Heterodera*) *javanica* (Treub, 1885) Cobb, 1890, *Agric. Gaz. N.S.W.*, **1**(2): 155–184.
Anguillula javanica (Treub, 1885) Lavergne, 1901, *Rev. Chilena Hist. Nat.*, **5**(4): 85–91.

Meloidogyne javanica (Treub, 1885) Chitwood, 1949, *Proc. helminth. Soc. Wash.*, **16**: 90–104.
M. javanica bauruensis Lordello, 1956, *Bragentia*, **15**(6): 55–64.
M. javanica Gillard and v.d. Brande, 1955, *Parasitica*, **11**(3): 74–80.

Dimensions.—Female (15): L=0.53–0.74 mm, width=0.37–0.53 mm, stylet= 14–18 μm, knobs=3–4 μm across, orifice 3–4 μm from stylet base, median bulb= 35–42×30–39 μm.

Male (10): L=0.72–0.94 mm, a=15–40, b′=9–13, c=45–98, stylet=18–22 μm, knobs=3–5 μm across, orifice=2–3 μm from stylet base, median bulb= 17–23×11–20 μm, spicula=28–31 μm, gubernaculum=6–8 μm.

Larva (10): L=0.35–0.48 mm, a=24–32, b=2.6–3.5, c=6–9, stylet=9–11 μm, median bulb=10–13×5–7 μm.

Perineal pattern.—Striae fine, closely spaced and round. Lateral field fairly wide, marked by two incisures. Anal fold present. Short striae extending towards angle of vulva. Interphasmidal distance 25–27 μm, vulvar width 24–26 μm, anus to tail terminus 10–11 μm, anus to centre of vulva 15–18 μm.

Male: Body cylindroid, tapering slightly in anterior region. Head continuous, 2–3 annules behind head cap. Stylet knobs round to sloping backwards. Lateral field marked by four incisures, aerolation not observed. Phasmid adanal. Tail bluntly rounded. Spicula slightly curved, with ventral and lateral flanges. Gubernaculum small, crescentic.

Remarks.—The intensity of infestation in North 24–Parganas particularly in Barasat and nearby areas was very high, where individual plants showed large number of nematodes.

Mite association.—The species was found associated with the Bulb mite, *Rhizoglyphus echinopus* (Fumouze and Robin). The roots developed galls of enormous size. When dissected, it was found full of mites which, to a naked eye, closely resembled the females of root-knot in size and shape. The cortical tissue was not there and the area between the epiderm and stele was filled with mucilaginous substance. In these the females were already dead and no egg mass found. Doncaster (1962) has reported *Pergamasus crassipes* Berlese, the predacious mite, feeding on *Heterodera* cysts. However, the exact nature of association in present case could not be established.

Habitat.—Roots of *C. capsularis* and *C. oliyorius*.

Locality.—Found in most of the places surveyed (see under *Survey*).

Family NACOBBIDAE (Chitwood and Chitwood, 1950) Golden, 1971

Subfamily ROTYLENCHULINAE Husain and Khan, 1967

Genus **Rotylenchulus** Linford and Oliveira 1940

Rotylenchulus reniformis Linford and Oliveira, 1940

Rotylenchulus reniformis Linford and Oliveira, 1940, *Proc. helminth. Soc. Wash.*, **7**(1): 35–42; Dasgupta, Raski and Sher, 1969, *J. Nematol.*, **1**(2): 126–145.
R. nicotiana (Yokoo and Tanaka, 1954) Baker, 1962, *Checklist of the nematode Superfamilies, Dorylaimoidea. Rhabditoidea, Tylenchoidea and Aphelenchoidea*, 261 pp.
R. queirozi (Lordello and Cesnik, 1958) Sher, 1961, *Nematologica*, **6**(2): 155–169.
R. leiperi (Das, 1960) Loof and Oostenbrink, 1962, *Nematologica*, **7**(1): 83–90.
R. stakmani Husain and Khan, 1965, *Proc. helminth. Soc. Wash.*, **32**(1): 21–23.
Rotylenchus elisensis Carvalho, 1957, *Revta Inst. Adolfo Lutz.*, **17**: 43–46.
Helicotylenchus elisensis (Carvalho, 1957) Carvalho, 1959, *Arq. Inst. Biol. Sao Paulo*, **26**: 45–48.

Spirotylenchus querozi Lordello and Cesnik, 1958, *Revta bras. Biol.*, **18**(2): 159–165.
Leiperotylenchus leiperi Das, 1960, *Z. Parasitkde,*. **19**: 553–605.
Tetylenchus nicotiana Yokoo and Tanaka, 1954, *Bull. Kagoshima Tob. Exp. Stn.*, **9**: 59–63.

Dimension.—Female (immature) (1): L=0.35 mm, a=24, b=3.8, b′=2.6, c=14, c′=2.8, h=4.2, V=$^{10}69^{9}$, stylet=18 μm, O=76.

Male (immature) (1): L=0.38 mm, a=27, b′=3.9, c=21, c′=1.4, h=4.5, stylet=11 μm, O=62, spicula=17 μm, gubernaculum=7 μm.

Description.—Female (immature): Body curved ventrally, more so posteriorly. Head continuous; lip region conoid, rounded, five indistinct annules. Cuticle finely striated. Lateral field marked with four incisures, occupying more than 1/5 body width. Tail conoid, 24 μm in length, more than two anal body diameter long, terminus rounded, striae coarse towards tip. Phasmid anterior to middle of tail. Ovaries two, opposed, with two flexures; rows of oocytes not distinct.

Male (immature): General structure same as of female. More slender. Cephalic framework, stylet and knobs poorly developed than in female. Oesophagus reduced, valve and oesophageal lumen indistinct. Bursa adanal, vestigial. Testis single, outstretched.

Remarks.—Sher (1961) transferred *Helicotylenchus parvus* Wiliams, 1960 to the genus *Rotylenchulus.* Goodey (1963) included this species in the synonymy of *R. reniformis.* Dasgupta *et al.* (1968), however, in their revisionary work, treated it as a valid species. After going through the descriptions of both the species, we agree with the latter workers in treating it as a valid species.

R. reniformis is a widely distributed species having a vast host range. It is being reported from the jute for the first time.

Habitat.—The specimens were collected from the soil around the roots of *C. olitorius.*

Locality.—Tarkeshwar and Duttapur, Dist. Hooghly.

Superfamily CRICONEMATOIDEA (Taylor, 1936) Geraert, 1966

Family CRICONEMATIDAE (Taylor, 1936) Thorne, 1949

Subfamily CRICONEMATINAE Taylor, 1936

Genus **Criconemoides** Taylor, 1936

Criconemoides ornatus Raski, 1958

Criconemoides ornatus Raski, 1958, *Proc. helminth. Soc. Wash.*, **25**(2): 139–142.
C. cylindricum Raski, 1952, *Proc. helminth. Soc. Wash.*, **19**(2): 85–99 (*nec* Kirjanova, 1948).

Dimensions.—Female (5): L=0.45–0.52 mm, a=10–12, b=4.0–4.9, c=15–17, V=$^{61-64}91$–94, stylet=51–53 μm, RB=89–95, stylet=12–16 annules, R—Exp=24–27, R an=7–11, RV—T=8–12, VL/VB=1.0–1.2, stylet % L=11.0–12.5.

Description.—Female: Body arcuate or straight, tapers only slightly on each end so that head and tail terminus appear hemispherical to truncated shape. Head not set off, consisting of two annules, first annule rather straight and smaller than the subsequent one, sublateral lobes present. Tail conoid, tip rounded, button-shaped.

Remarks.—The specimens fit in well with the original description (Raski, 1952) of the species. However, range of various measurements and the de Manian indices have been extended. The species has got a very wide host range.

Habitat.—The specimens were collected from the soil around the roots of *C. capsularis* and *C. olitorius*.

Locality.—Tarkeshwar, Dist. Hooghly; and Burdwan.

Suborder *APHELENCHINA* (Fuchs, 1937) Geraert, 1966

Superfamily APHELENCHOIDEA Fuchs, 1937

Family APHELENCHIDAE (Fuchs, 1937) Steiner, 1949

Subfamily APHELENCHINAE (Fuchs, 1937) Schuurmans Stekhoven & Teunissen, 1938

Genus **Aphelenchus** Bastian, 1865

Aphelenchus avenae Bastian, 1865

Aphelenchus avenae Bastian, 1865, *Trans. Linn. Soc. Lond.*, **25**(2): 73–184.
A. agricola de Man, 1881, *Tijdschr. ned. dierk. vereen.*, **5**(1–2): 138–143.

Dimensions.—Female (15): L=0.58–0.74 mm, a=21–33, b=3.0–5.7, b′=7.8–9.9, c=20–37, V=$^{40-46}$71–78, stylet 14–18 μm.

Male (5): L=0.62–0.73 mm, a=25–32, b=3.9–5.0, b′=7.8, c=26–32, T=46–48, stylet=15–17 μm, spicula=16–28 μm, gubernaculum=6–10 μm.

Description.—Female: Body tapering towards extremities. Cuticle finely striated. Lateral field occupying $\frac{1}{4}$–$\frac{1}{3}$ of body diameter, marked with 10–12 incisures. Head slightly set off, without striations. Tail cylindrical, short with a rounded terminus. Phasmid not observed. Ovary single, outstretched, reflexed in some; oocytes in a single row. Postvulvar sac 2–3 times of body width.

Male: General morphology similar to that of female. Tail conical, provided with a bursa supported by 4 pairs of ribs, one of these preanal or adanal and three postanal.

Remarks.—The species have a very wide distribution and is found associated with many plants.

Habitat.—Rhizosphere of *C. capsularis* and *C. olitorius*.

Locality.—Found in most of the places surveyed (see under *Survey*).

Family APHELENCHOIDIDAE (Skarbilovich, 1947) Paramonov, 1953

Subfamily APHELENCHOIDINAE Skarbilovich, 1947

Genus **Aphelenchoides** Fischer, 1894

Aphelenchoides saprophilus Franklin, 1957

(Fig. 6, A–C)

Aphelenchoides saprophilus Franklin, 1957, *Nematologica*, **2**(4): 306–313.

Dimensions.—Female (8): L=0.56–0.74 mm, a=25–27, b=8.5–9.9, b′=5.0–5.7, c=14–24, V=$^{34-50}$68–72, stylet=14–15 μm.

Male (5): L=0.59–0.73 mm, a=30–35, b=7.9–9.1, b′=4.7–5.7, c=16–21, T=63–77, stylet=11–15 μm, spicula=14–21 μm, basal width of spicula=8–10 μm dorsal limb=14–21 μm, ventral limb=8–11 μm.

Description.—Female: Body slightly curved ventrally, attenuated behind. Head slightly set off. Tail conical, 2–3 anal body diameter long, tip with single ventral blunt mucro. Cuticle finely striated, lateral field marked with four incisures, occupying $\frac{1}{6}$–$\frac{1}{4}$ of body width.

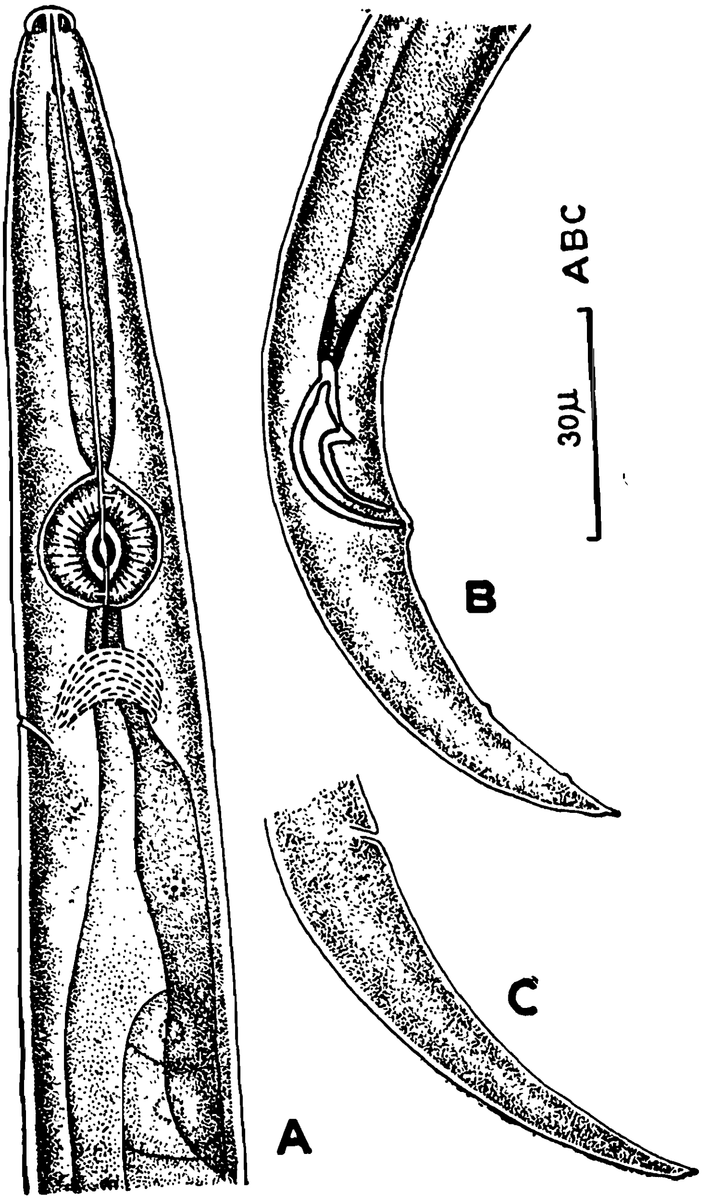

Fig. 6. *Aphelenchoides saprophilus*—A. Anterior end; B. Male tail; C. Female tail.

Male: General characters as in female. Testis extended up to the posterior end of oesophageal gland. Spicula rose-thorn-shaped, ventral prong not reaching the tip of the dorsal one, forms a strong curve near the base. Only two caudal papillae distinct. Tail curved ventrally, conical, tip with long ventral mucro.

Remarks.—The specimens fit in well with the original description of the species. However, they show some difference in de Manian indices, in having smaller spicules and tail and also in the absence of knob-like structure on the tip of the dorsal limb of the spicula (spicula = 23 µm, c = 13–18, after Franklin, 1957).

Habitat.—The specimens were recovered from the rhizosphere of *C. olitorius*.

Locality.—Bhajna, Sujapur, Falta, Rautara, Dist. 24–Parganas; Krishnanagar, Dist. Nadia; Burdwan.

Aphelenchoides asterocaudatus Das, 1960
(Fig. 7, A–C)

Aphelenchoides asterocaudatus Das, 1960, *Z. ParasitKde.*, **19:** 553–605.

Dimensions.—Female (4): L=0.34–0.74 mm, a=24–30, b=8–9, b′=4.0–5.5, c=13–16, V=$^{45-48}$69–72, stylet=11–15 μm.

Male (1): L=0.41 mm, a=28, b=8, b′=4.2, c=18, T=67, stylet=11 μm, spicula=18 μm, dorsal limb=17 μm, ventral limb=9 μm.

Description.—Female: Body curved ventrally in posterior part and constricted posterior to vulva. Cuticle finely striated, lateral field marked with four incisures,

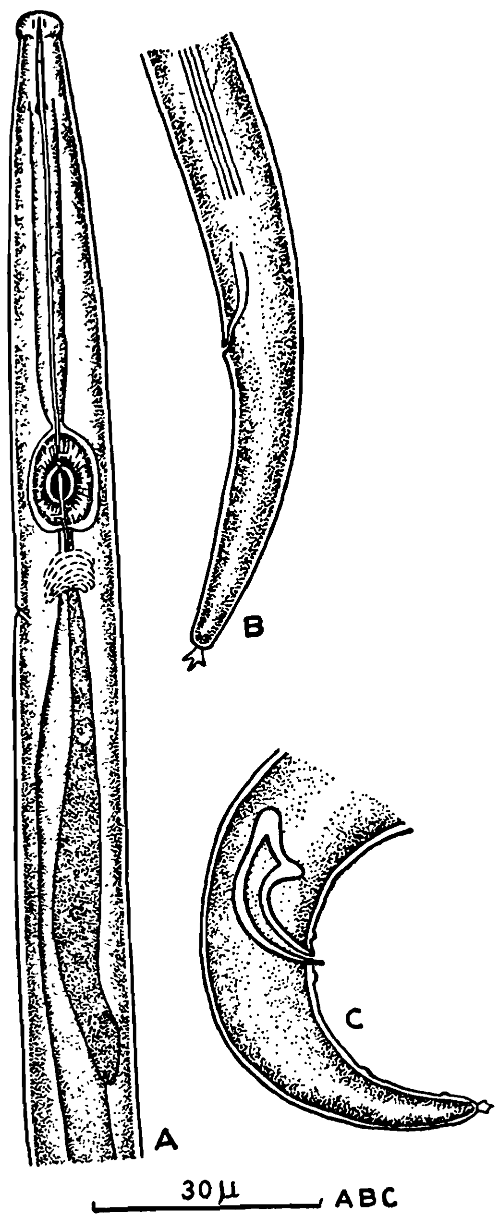

Fig. 7. *Aphelenchoides asterocaudatus*—A. Anterior end; B. Female tail; C. Male tail.

inner ones very faint, outer ones smooth but slight crenation was noticed in one specimen. Head slightly set off. Tail more than three anal body diameter long, cylindrical, mucro star-shaped.

Male: General morphology same as that of female. Tail more than two anal body diameter long. Caudal papillae four, three postanal and one preanal.

Remarks.—Das (1960) described two incisures. Siddiqi and Franklin (1967) after re-examining the holotype stated that the number of incisures was probably four. Four incisures were observed in the present population also. Male is described for the first time.

Habitat.—The specimens were collected from the rhizosphere of *C. capsularis* and *C. olitorius*.

Locality.—Susunia, Dist. Bankura; and Barasat, Dist. 24-Parganas.

Aphelenchoides sanwali Chaturvedi, Singh and Khera, n.sp.

(Fig. 8, A–C)

Dimensions.—Holotype—Female: L=0.54 mm, a=31, b=9, b′=5, c=14, V=^{50}69, stylet=10 μm.

Paratypes—Female (4): L=0.42–0.55 mm, a=28–31, b=7–9, b′=3.4–5.0, c=13–15, V=$^{46-52}$60–71, stylet=11–13 μm.

Male: Not found.

Description.—Female: Body curved in posterior portion, sharply attenuated posteriorly. Head set off from body, 3 μm high and 2–3 μm in diameter. Tail cylindrical, 3–4 anal body diameter long, bluntly round terminus with a ventral mucro. Lateral field marked with two incisures, occupying $\frac{1}{6}$–$\frac{1}{5}$ of body width. Cephalic framework slightly sclerotized, Stylet with weakly developed knobs. Procorpus a cylindrical tube, 32 (28–35) μm long, median bulb round, occupying more than 2/3 of body diameter at the same level. In oesophageal gland one to two nuclei visible. Nerve ring just behind median bulb, 60 (58–67) μm from anterior end. Excretory pore opposite nerve ring.

Vulva post-equatorial, vulvar lips slightly protruded, vagina directed anteriad, occupying about $\frac{1}{2}$ of vulvar body width. Ovary single, anterior, outstretched, 269 (224–269) μm long, reaching close to oesophageal gland; oöcytes arranged in a single row, spermatheca oval, filled with rounded sperm. Postvulvar sac 1–1.5 times the body width, with sperm in one specimen.

Differential diagnosis and relationships.—In the genus *Aphelenchoides* tail shape and number of mucro have been considered of much taxonomic value (Sanwal, 1961). Sanwal (*loc. cit.*) also laid stress on the structure of stylet, presence or absence of postvulvar sac, position of excretory pore and nerve ring, and number of incisures in lateral field. Taking these characters into consideration the new species comes close to *A. subtenuis* (Cobb, 1926) Steiner and Buhrer, 1932; *A. chinensis* Husain and Khan, 1967 and *A. shamimi* Khera, 1970, particularly in possessing cylindrical tail with rounded tip and a ventral mucro. It, however, differs from *A. subtenuis* by its much smaller size and other body dimensions (L=0.87–1.15 mm, a=44–57, b=12–17, c=24–28 in *A. subtenuis* as given by Thorne, 1961), number of incisures, position of nerve ring, presence of spermatheca filled with sperm and smaller postvulvar sac (four incisures, nerve ring more than one body width behind median bulb, spermatheca not mentioned, postvulvar sac reaching halfway to tail in *A. subtenuis*).

A. sanwali n.sp. differs from *A. chinensis* in the number of incisures, longer tail, smaller and knobbed stylet, position of excretory pore and absence of males (6 incisures, c=14–19, stylet without knobs, 12–15 μm, excretory pore much behind and males present in *A. chinensis*).

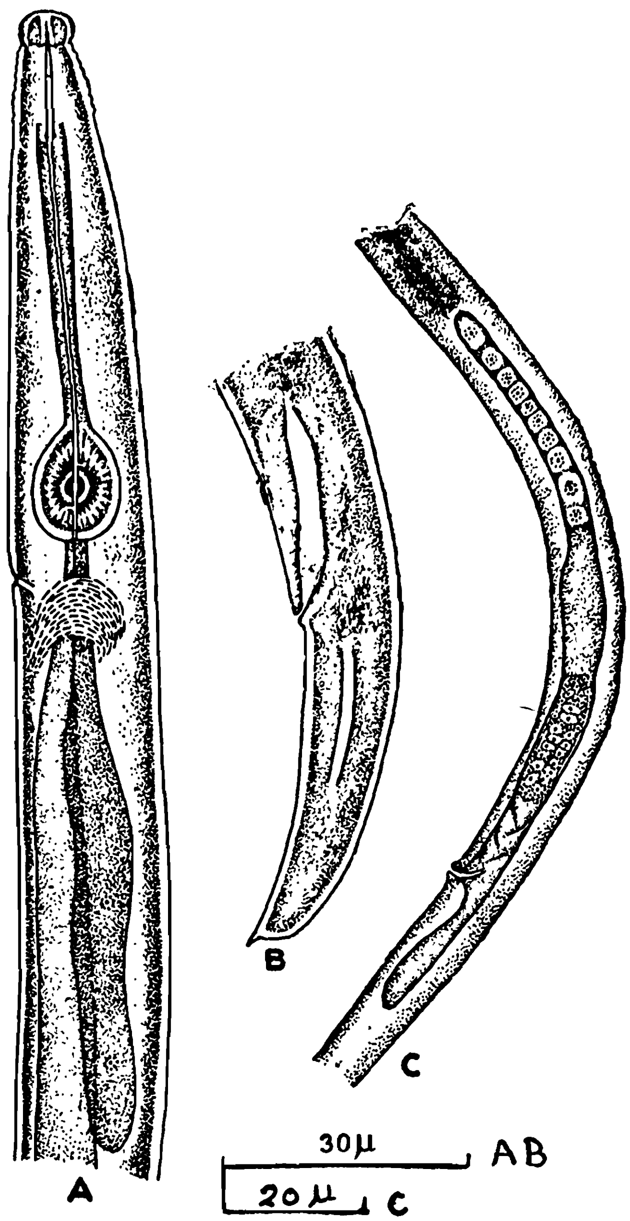

Fig. 8. *Aphelenchoides sanwali* n.sp.—A. Anterior end; B. Female tail; C. Female gonad.

The new species also differs from *A. shamimi* by smaller values of b, b′, smaller tail, longer stylet and number of incisures (b=9.5–10.5, b′=7.0–7.7, stylet=8–9 μm and 5 incisures in *A. shamimi*)·

Remarks.—*A. subtenuis* has been recorded from India by Das (1960) and Khera (1970). While the body dimensions given by the latter fit in well with those of *A. subtenuis* given by Thorne (1916), Das' specimens (a single male) appears to be much smaller and its identity seems doubtful (L=0.54 mm, a=24, b=11, c=13). These measurements come very close to present species although males were not found in this population. However, presence of four incisures in his specimen need confirmation.

Type habitat.—Around the roots of *C. olitorius*.

Holotype.—One female; collected on 4-viii-1970.

Paratype.—Four females, other particulars as for the holotype.

Type-locality.—Chanditalla, Dist. Hooghly, West Bengal.

Other material.—One female, from the rhizosphere of *C. capsularis*, Tarkeshwar, Hooghly; one female from cauliflower, from Narendrapur, 24-Parganas and one female from Okra from Belur, Howrah.

The new species is named after Dr. K. C. Sanwal who has made extensive taxonomic and other studies on the genus *Aphelenchoides*.

Seinura hechlerae Chaturvedi, Singh and Khera, n.sp.

(Fig. 9, A–D)

Dimensions.—Holotype—Female: $L=0.47$ mm, $a=28$, $b=6.5$, $b'=4.4$, $c=7$, $V={}^{38}62$, stylet$=14$ μm.

Paratypes—Female (4): $L=0.32$–0.47 mm, $a=20$–28, $b=6.0$–7.8, $b'=3.4$–4.6, $c=6.0$–7.3, $V={}^{35-40}60$–66, stylet$=14$–15 μm.

Male: Not found.

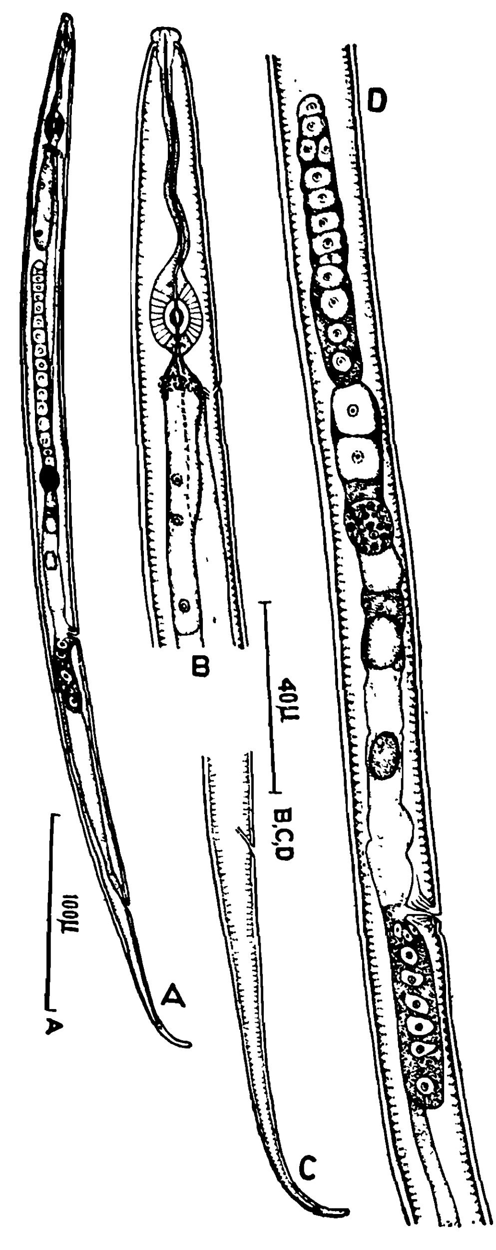

Fig. 9. *Seinura hechlerae* n.sp.—A. Entire female; B. Anterior end; C. Posterior end; D. Female gonad.

Description.—Female: Body arcuate, tapering towards both ends, more so posteriorly. Cuticle finely striated, lateral field absent. Head set off, outer margin of lip region round, low. Cephalic framework poorly developed. Stylet long, slender, without knobs. Procorpus tubular 28 (21–28) μm long, median bulb 14×8 ($13–14 \times 7–8$) μm, oval, crescentic valve plates present; in some specimens a clear space around the bulb was noticed. Dorsal oesophageal gland long, narrow. Intestinal lumen broad and clear behind its junction with oesophageal gland. Nerve ring less than one body width behind median bulb, 63 (52–63) μm from anterior end. Excretory pore opposite or little behind nerve ring, 64 (57–70) μm from anterior end.

Vulva post-equatorial, flush with body surface; vagina oblique; overy monoprodelphic, outstretched, 91–109 μm long, oöcytes in a single row except in multiplication zone where these are in two rows. Spermatheca present, round, filled with sperm; postvulvar sac 2.5–3 vulvar body diameter long, pouch like, filled with round or disc-shaped sperm. Tail conical, long drawn, 5–8 anal body diameter long, tip curved ventrally.

Differential diagnosis and relationships.—Hechler and Taylor (1965) have reviewed the genus. The new species comes close to *S. nagini* Husain and Khan, 1965 in general characters and de Manian indices (♀: L=0.32–0.40 mm, a=28–31, b=3–4, c=6–8, V=60–64, stylet=12–15 μm in *S. nagini*). However, it differs from *S. nagini* in the absence of lateral field, stylet-guiding ring and knobs and in having longer postvulvar sac (slightly more than vulvar body width in *S. nagini*).

Type habitat.—Collected from the rhizosphere of *C. capsularis.*

Holotype.—One female; collected on 9-ix-1970.

Paratype.—Four females, other particulars as for the holotype.

Type-locality.—Nimtalla, near Andul, Dist. Howrah, West Bengal.

Other material.—Six females from the rhizosphere of pea, potato, tomato and egg-plant from Kamalgazi and Mahamayatolla, 24-Parganas; Unsanigualbati, Howrah.

The new species is named after Dr. Helen C. Hechler who has carried out extensive taxonomic and other studies on aphelenchoids in general and the genus *Seinura* in particular.

Family PARAPHELENCHIDAE (T Goodey, 1951) J. B. Goodey, 1960

Subfamily PARAPHELENCHINAE Goodey, 1951

Genus **Paraphelenchus** (Micoletzky, 1922) Micoletzky, 1925

Paraphelenchus myceliophthorus J. B. Goodey, 1958

Paraphelenchus myceliophthorus J. B. Goodey, 1958, *Nematologica*, **3**(1): 1–5; Thorne, 1961, *Principles of Nematology*, 553 pp; T. Goodey, 1963, *Soil and freshwater nematodes.*, 544 pp.

Dimensions.—Female (2): L=0.65–0.68 mm, a=30–38, b=4.9–6.1, c=24–29, V=$^{52-53}$76–77, stylet=17 μm.

Description.—Female: Body cylindrical, slightly curved ventrally in posterior part. Head continuous with body contour. Cuticle finely striated. Lateral field about 1/3 body width, marked with six incisures. Tail cylindrical, more than one anal body diameter long, tip rounded without mucro. Stylet without basal knobs. Procorpus a cylindrical tube, 38–41 μm long. Median bulb oval $17–20 \times 10–12$ μm, valve present. Oesophageal gland contained in a terminal bulb, 40–43 μm long, terminal bulb joining intestine by an obsecure muscular valve. Nerve ring just-behind median bulb, 78–80 μm from anterior end, connected through a duct to the uninucleate gland cell which extends slightly posterior to basal bulb.

Vulva posterior, lips slightly protruded; vagina runs transversely for about 2/3 vulvar body width. Ovary single, prodelphic, outstretched. Oöcytes arranged in a single row. Postvulvar sac 84–91 μm long, 3–4 times the vulvar body width, devoid of sperm.

Remarks.—The specimens closely fit in Goodey's (1963) description of the species. However, there are some variations in the values of 'a' and 'c' (a=22–34, c=13–24 from Goodey, 1963).

Habitat.—Rhizosphere of *C. olitorius* and *C. capsularis*.

Locality.—Mourigram and Nimtalla, Dist. Howrah, Duttapur, Dist. Hooghly and Rangsagar, Dist. Murshidabad.

Metaphelenchus goldeni Chaturvedi, Singh and Khera, n.sp.
(Fig. 10, A–C)

Dimensions.—Holotype—Female: L=0.68 mm, a=32, b=6.2, c=26, V=$^{53}78$, stylet=14 μm.

Paratypes—Female (3): L=0.58–0.71 mm, a=29–34, b=5.7–6.5, c=24–30, V=$^{53-54}79$–80, stylet=14–16 μm.

Description.—Female: Body cylindrical, straight, tapering towards extremities, specially towards anterior side. Cuticle finely striated. Lateral field about 1/3 body width, marked with 8–10 incisures. Tail cylindrical with rounded tip. In some specimens cuticle of the tail tip is much swollen (without the corresponding widening out of the lateral field).

Head not offset, flat. Cephalic framework not cuticularized. Stylet without basal knobs. Procorpus cylindrical, 42 (32–45) μm long, median bulb round, 18 (18–21) μm in diameter, crescentic valve prominent. Basal bulb 35 (35–38) μm long, only slightly overlapping the intestine. Lumen of the intestine clear behind basal bulb in most of the specimens. Nerve ring 80 (77–81) μm from anterior end, less than one body width behind median bulb. Excretory pore behind nerve ring, 89–92 μm from anterior end, not seen in holotype.

Vulva posterior, flush with body surface. Vagina runs transversely for ½ vulvar body width. Ovary single, anterior, outstretched; oöcytes in a single row. Spermatheca absent. Postvulvar sac 2–3 vulvar body width long, without any sperm.

Differential diagnosis and relationships.—Goodey and Hooper (1965) synonymised genus *Metaphelenchus* Steiner, 1943 with *Aphelenchus* Bastian, 1865. Nickle (1970), while reviewing the genera of Aphelenchoidea, followed the synonymy proposed by Goodey and Hooper (*loc. cit.*). Golden (1971), in disagreement with this synonymy, opines, "the writer prefers to retain *Metaphelenchus* since additional collecting, culturing and very careful study might eventually show that a complex of closely related species, rather than a single one is involved". We agree with Golden's view.

So far, three species, viz. *M. rhopalocercus* Steiner, 1943; *M. micoletzkyi* (Steiner, 1941) Steiner, 1943 and *M. sacchari* Akhtar, 1962 have been described under the genus. The new species can easily be distinguished from *M. microletzkyi* by the presence of a postvulvar sac (absent in *M. micoletzkyi*). It differs from *M. sacchari* in body dimensions, unsclerotized lips, transverse vagina and well developed postvulvar sac (♀: L=1.38, V=77.5, stylet=17.5 μm, lips heavily sclerotized, vagina oblique and postvulvar sac rudimentary in *M. sacchari*). *M. goldeni* n. sp. comes

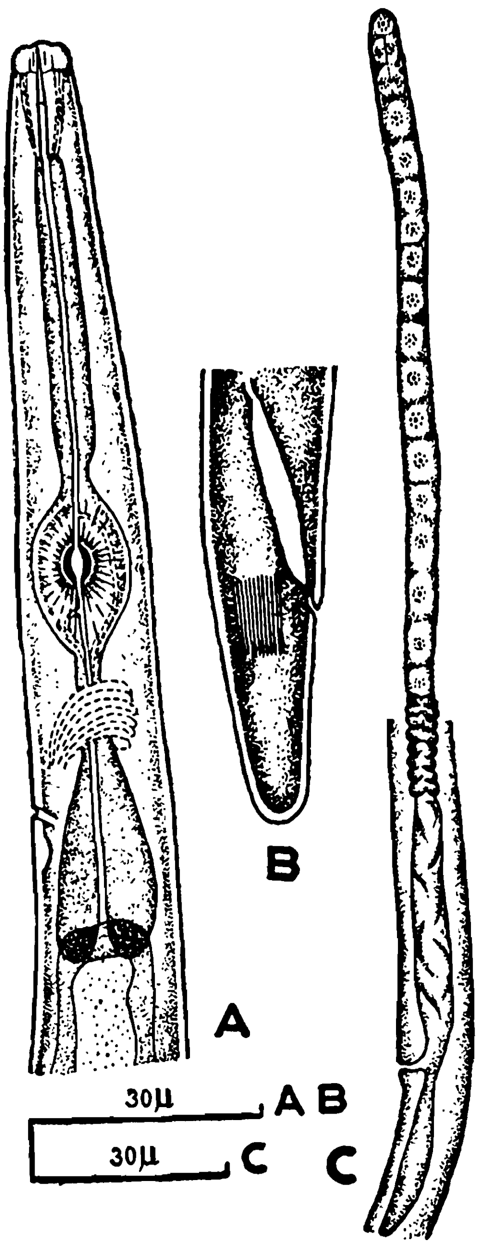

Fig. 10. *Metaphelenchus goldeni* n.sp.-A. Anterior end; B. Posterior end; C. Female goand

closest to *M. rhopalocercus* but differs from it in possessing a longer tail, slightly posterior vulva, long postvulvar sac and lesser number of incisures (c=28–37, V=73–77, short postvulvar sac and 10–12 incisures in *M. rhopalocercus.*)

Type habitat.—Soil around the roots of *C. olitorius.*

Holotype.—Female; collected on 3-xii-1972.

Paratypes.—Three females, other data as for the holotype.

Type-locality.—Burdwan, West Bengal.

Other material.—Two females from the rhizosphere of *C. capsularis* from Chanditalla, Dist. Hooghly. Six females from fenugreek from Narendrapur, 24–Parganas.

The species is named after Dr. A. Morgan Golden.

Order RHABDITIDA (Örley, 1880) Chitwood, 1933

Suborder *RHABDITINA* (Örley, 1880) Chitwood, 1933

Superfamily RHABDITOIDEA (Örley, 1880) Travassos, 1920

Family RHABDITIDAE Örley, 1880

Subfamily RHABDITINAE (Örley, 1880) Micoletzky, 1922

Genus **Rhabditis** Dujardin, 1845

Rhabditis (**Indorhabditis**) **olitorius** n.subgen., n. sp.

(Fig. 11, A–E)

Dimensions.—Holotype—Female: $L=1.20$ mm, $a=17$, $b=6.4$, $c=13$, $V={}^{33}53^{28}$.

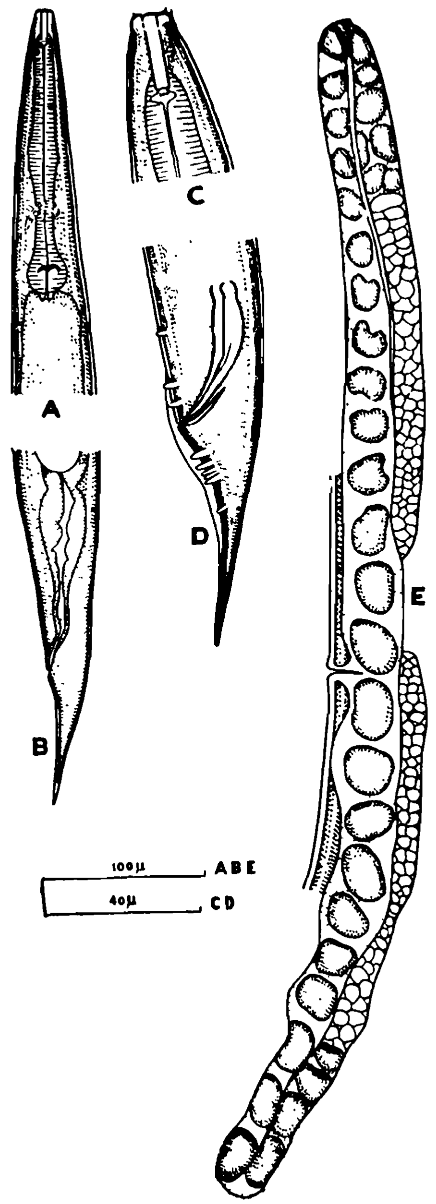

Fig. 11. *Rhabditis* ((*Indorhabditis*) *olitorius* n.subgen; n.sp.—A. Anterior end; B. Female tail; C, Stoma; D, Male tail; E, Female gonad.

Paratypes—Female (4): $L=0.98-1.21$ mm, $a=17-18$, $b=5.0-6.5$, $c=13-15$, $V={}^{31-33}51-53^{28-30}$.

Male (2): $L=0.80-0.89$ mm, $a=17-18$, $b=5.4-6.0$, $c=15-16$, $T=67-71$, spicula $=35-42$ μm, gubernaculum $=15-18$ μm.

Description.—Female: Body straight, tapering towards the extremities from the middle. Cuticular striations transverse, very fine. Lips closed, 8 (8–9) μm in diameter, stoma tubular, isoglottid, isomorphic, 21 (19–23) μm long and 4 (3–4) μm wide. Metarhabdion with three minute tubercles. Oesophageal collar present. Procorpus 109 (105–110) μm, subcylindrical, slightly widening posteriorly; median bulb absent, isthmus 46 (43–47) μm long, terminal bulb 30×28 ($30-31\times28-29$) μm; cardia small, conical. Nerve ring 137 (135–138) μm from anterior end, surrounding isthmus. Excretory pore not seen.

Vulva flush with body surface. Vagine transverse, about ½ the vulvar body width. Ovaries two, opposed and reflexed, the reflexed end reaching close to vulva, anterior ovary 399 (350–400) μm, posterior 338 (335–342) μm long. Oöcytes in multiple rows, 5–7 eggs in each uterus, egg $50-56\times20-25$ μm. Tail elongate conical 2.5–3 times anal body diameter long.

Male: General characters as in females. Testis single, spicula separate, almost straight, gubernaculum thickened at distal end. Bursa open tail leptoderan; papillae 3 preanal and 6 postanal, latter in two groups of five and one.

Differential diagnosis and relationships.—The new subgenus resembles the nominate subgenus *Rhabditis* Dujardin, 1845 in the presence of oesophageal collar, 3 tubercles on each metarhabdion, didelphic gonad and the absence of median bulb. However, it differs in having isoglottid, isomorphic stoma, long conical tail in female and leptoderan tail in male.

The subgenus *Indorhabditis* comes close to subgenus *Choriorhabditis* Osche, 1952 in having isoglottid, isomorphic stoma, long conical tail in female and leptoderan tail in male but differs from this subgenus mainly in the absence of median bulb and anal tubercles.

Indorhabditis n. subgen.

Diagnois—Rhabditis: Lips closed, stoma isoglottid, isomorphic, three tubercles on each metarhabdion. Oesophageal collar present, median bulb absent. Vulva median, didelphic gonads, opposed and reflexed. Female tail elongate–conical. Male bursa open, leptoderan, tail filament extended beyond bursa; anal tubercles absent.

Type-species.—*Rhabditis* (*Indorhabditis*) *olitorius*, n. sp.

Type habitat.—Rhizosphere of *C. olitorius.*

Holotype.—Female: collected on 31-xii-1972.

Paratypes.—Four females and two males, other data as for the holotype.

Type-locality.—Burdwan, West Bengal.

Genus **Pelodera** Schneider, 1866

Pelodera (**Cruznema**) **dunensis** Khera, 1971

Pelodera (*Cruznema*) *dunensis* Khera, 1971, *Indian J. Nematol.*, **1:** 237–243.

Dimension.—Female (4): $L=0.36-0.51$ mm, $a=15-18$, $b=3.2-3.9$, $c=13-15$, $V={}^{30-35}61-69$, Male (3): L=0.46–0.47 mm, a=19–20, b=3.5–3.8, c=40.8–47.0, T=47–48, spicula=15–21 μm, gubernaculum=8–10 μm.

Description.—Female: Body stout, straight, narrowing towards extremities, specially in posterior region. Cuticle transversely striated; striations fine. Lateral field absent. Head broad, slightly offset. Tail 3–4.5 times the anal body diameter long, conical, tapering. Vulva to anus distance 1.5 times of the tail length. Ovary single, anterior, reflexed, short of vulva. Egg 42×21 μm.

Male: General morphology similar to that of female. Tail small, peloderan, conical, about one anal body diameter in length; bursa open. Preanal papillae four, postanal three, all pedunculate. Spicula long, slightly arcuate. Gubernaculum straight. Testis single, anterior and reflexed in some specimens.

Remarks.—Khera (1971) described the species based on females only. In the present population males were also found (collected in August, 1972) and these are described here. The females tally with original description in all respect except in the vulva to anus distance (less than tail length in original description). However, in long tailed species tails could break off and regenerate very slowly—hence the ratio vulva-anus distance/tail cannot be considered a dependable character.

Habitat.—Rhizosphere of *C. olitorius*.

Locality.—Burdwan.

Family PANAGROLAIMIDAE (Thorne, 1937) Paramonov, 1956

Subfamily PANAGROLAIMINAE Thorne, 1937

Genus **Panagrolaimus** Fuchs, 1930

Panagrolaimus burdwanensis n.sp.

(Fig. 12, A–C)

Dimensions.—Holotype—Female: L=0.77 mm, a=25, b=4.8, c=13, V=^{19}51.

Paratypes—Female (3): 0.74–0.78 mm, a=23–26, b=4.7–5.0, c=13–52, V=${}^{19-21}$55–58.

Male (2): L=0.56–0.62 mm, a=31–33, b=4.3–4.6, c=14.6–21.0, T=59–61, spicula=18–20 μm, gubernaculum=8–10 μm.

Description.—Female: Body straight, tapering towards both ends. Cuticle rather smooth. Lips three amalgamated. Stoma 7 (7–10) μm, cheiltstom, prostom and mesostom forming a wide chamber about 3 μm in diameter. Metastom and telostom small and narrow, metastom bearing minute dorsal tooth. Oesophagus panagrolaimoid, procorpus subcylindrical 91 μm long, isthmus 42 (35–45) μm, terminal bulb valvular 21×18 (20–22×16–18) μm. Cardia conoid comprising two cells. Nerve ring 105 (80–105) μm from anterior end, surrounding isthmus. Excretory pore 121 (100–122) μm from anterior end, behind nerve ring.

Vulva postequatorial, lips slightly protruding. Vagina about 1/3 the vulvar body diameter long. Ovary single, anterior, reflexed, the reflexed end reaching close to rectum. Oocytes in multiple rows for most of the part, in a single row in the region of maturity. Postvulvar sac less than one body diameter long. Egg 49×22 μm. Tail convex-conoid, spicate, 2–3 anal body diameter long.

Male: General monophology as of female. Testis single, tip reflexed, Spicula and gubernaculum panagrolaimoid. Tail conoid, tapering. Preanal papillae two pairs situated subventrally, anterior to the level of spicular head. Postanal papillae four pairs, three subventral and one subdorsal.

Differential diagnosis and relationships.—Of the various species of the genus *Panagrolaimus* Fuchs, 1930 there are three species in which the value of 'c' exceeds 10,

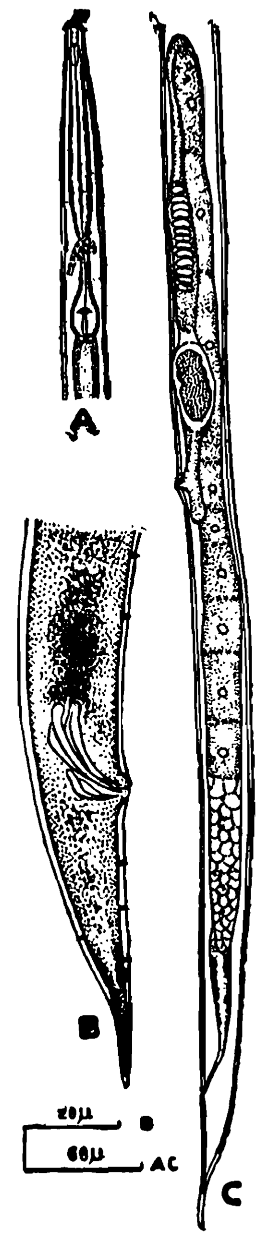

Fig. 12. *Panagrolaimus burdwanensis* n.sp.—A. Anterior end; B. Male tail; C. Female gonad.

namely *P. goodeyi* Rühm, 1956; *P. subelongatus* (Cobb, 1941) Thorne, 1937 and *P. detritophagus* Fuchs, 1930.

The new species comes closest to *P. goodeyi*. However, it differs from *P. goodeyi* in size, shape of the female tail, number and arrangement of caudal papillae, size of spicula and gubernaculum in male (in *P. goodeyi*—L=0.90–1.08 mm in female, 0.75–0.98 mm in male, tail conoid, not spicate in female; one pair preanal and six pairs postanal papillae, spicula 24–29 μm, gubernaculum 9–14 μm in male).

P. burdwanensis n.sp. differs from *P. subelongatus* in body size, tail shape and in the values of 'a', 'b', 'V' and size of spicula and gubernaculum (♀: L=0.95–1.215 mm, a=27.86–30.36, b=5.16–6.51, V=52.57–53.90 and ♂: L=0.960–1.185 mm, a=24.57–30.78, b=4.90–5.37, spicula=29–32 μm, gubernaculum= 9–15 μm in *P. subelongatus*; tail conoid but not spicate in both sexes of the latter species).

From *P. detritophagus* the new species differs in the size of male, position of vulva, size of spicula and gubernaculum, and smaller number of postanal papillae

(♂: L=0.69–0.75 mm; spicula=25–32 μm, gubernaculum=10–12 μm and postanal papillae eight pairs, V=58.90–61.83, in *P. detritophagus*).

Type habitat.—Rhizosphere of *C. olitorius*.

Holotype.—Female; collected on 5-xi-1972.

Paratypes.—Three females and two males; other data as for the holotype.

Type-locality.—Burdwan, West Bengal.

Family CEPHALOBIDAE (Filipjev, 1934) Chitwood and Chitwood, 1934

Subfamily CEPHALOBINAE Filipjev, 1934

Genus **Cephalobus** Bastian, 1865

Cephalobus persegnis Bastian, 1865

(Fig. 13, A–D)

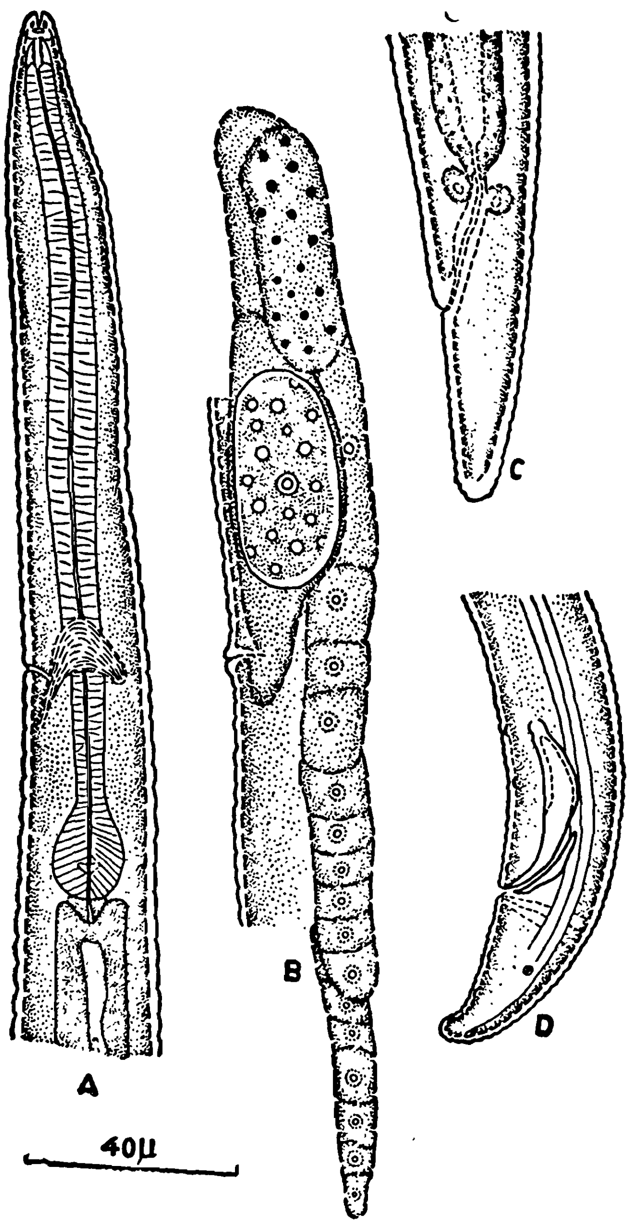

Fig. 13. *Cephalobus persegnis*—A. Anterior end; B. Female gonad; C. Female tail; D. Male tail.

Cephalobus persegnis Bastian, 1865, *Trans. Linn. Soc. Lond.*, **25**(2): 73–184; *C.* (*C.*) *persegnis*, Schneider 1939, *Tierwelt Dtl.*, **36:** 1–260; *C.* (*Eucephalobus*) *persegnis*, Allgen, 1953, *Ann. Mag. nat. Hist.* **6**(12): 665–688.

Dimensions.—Female (4): L=0.36–0.51 mm, a=15–18, b=3.2–3.9, c=13–15, V=$^{11-13}$61–69.

Male (2): L=0.51–0·52 mm, a=19–23, b=3.4–4.2, c=16–17, T=47–50, spicula=28–30 μm, gubernaculum=15–17 μm.

Description.—Female: Body straight, spindle shaped, more attenuated anteriorly. Cuticle transversely striated; lateral field about $\frac{1}{4}$ the body width, marked with three incisures, latter extended to tail tip. Lips obscure, low, rounded; stoma 10–14 μm deep. Oesophagus cylindrical with a terminal valvular bulb. Cardia small. Tail conoid, terminus bluntly rounded.

Male: General morphology similar to that of female. Tail curved ventrally, phasmid about middle of tail. Papillae six pairs, three preanal and three postanal. Spicula cephalated, arcuate, gubernaculum straight.

Remarks.—Goodey (1963) described six pairs of papillae in male and four incisures in the lateral field in *C. persegnis* whereas Andrassy (1967) described eight pairs of papillae, three preanal and five postanal and only three incisures in the species. However, in the present specimens six pairs of papillae and three incisures were found.

Kannan (1960) described *C. minor* but his description is inadequate and not well illustrated. Therefore, identity of *C. minor* Kannan, 1960 is doubtful. It may be treated as *species inquirenda*.

Recently Kunz and Klingler (1971) have reported air swallowing by individuals of this species, probably for respiration.

Habitat.—Soil around the roots of *C. olitorius* and *C. capsularis*.

Locality.—Burdwan; Sujapur and Falta, Dist. 24–Parganas; Chanditalla, Hooghly and Susunia, Dist. Bankura.

Subfamily ACROBELINAE Thorne, 1937

Genus **Acrobeles** Linstow, 1877

Acrobeles timmi n.sp.

(Fig. 14, A–F)

Dimensions.—Holotype—Female: L=0.49 mm, a=18, b=3.5, c=9.2, V=^{25}57.

Paratypes—Female (4): L=0.49–0.62 mm, a=17–18, b=3.5–4.1, c=9.2–11.0, V=$^{23-25}$57–59.

Male (4): L=0.51–0.63 mm, a=16–20, b=4.1–4.2, c=12.0–14.9, T=47–60, spicula=28–39 μm, gubernaculum=17–21 μm.

Description.—Female: Body robust, tapering towards both ends, straight or curved ventrally. Cuticle thick, coarsely straited. In many specimens cuticle expanded after thermal killing, remaining attached only to the anterior end, vulva and anus, showing thereby that cuticle is loosely attached to the body. Lateral field about $\frac{1}{4}$ body width, marked with four incisures of which inner two crenate, extended up to phasmid; latter at about $\frac{1}{3}$ of tail length from cloaca.

Labial probolae deeply furcate, 8–10 μm long, their margins very lightly fringed so that only some serrations could be marked. Cephalic probolae reaching half way to labials, acute, forwardly pointing, lightly fringed. Head offset, wider than body immediately behind. Stoma 10 (10–11) μm, as deep as head width, rhabdions typical of the genus. Amphid round, prominent, near the base of the cephalic probolae. Oesophagus with subcylindrical corpus 84 (84–91) μm long, isthmus 28 (28–30) μm and terminal bulb 25×18 ($24–32 \times 16–22$) μm, valvular. Cardia small. Nerve ring around isthmus, 91 (90–100) μm from anterior end. Excretory pore not discernible.

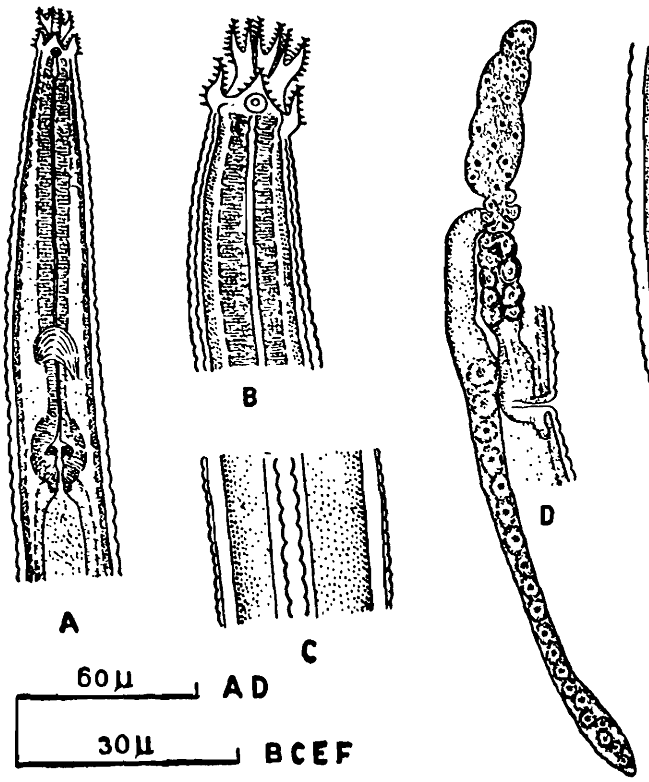

Fig. 14. *Acrobeles timmi* n.sp.—A. Anterior end; B. Cephalic region; C. Lateral field; D. Female gonad; E. Female tail; F. Male tail.

Vulva postequatorial, flush with body surface, vagina extending to ½ the vulval body width. Ovary single, anterior and reflexed. Spermatheca anterori to flexure, the reflexed end running posterior to vulva; second flexure absent. Post-vulvar sac very small. Tail conoid, 3–4 times the anal body diameter long.

Male: Similar to female in general characters. Tail conoid, weakly arcuate, terminus acute. Lips of cloaca protruding. Three pairs preanal papillae and five pairs postanal. Spicula cephalated, arcuate. Gubernaculum arched. Anterior end of testis reflexed.

Differential diagnosis and relationships.—The new species comes closest to *A. cephalatus* (Cobb. 1901) Thorne, 1925 in the values of de Manian indices and certain other characters, particularly in the very minute nature of the tines of probolae (♀: L=0.40 mm, a=17, b=3.8, c=10, V=58; ♂: L=0.40 mm, a=18, b=3.8, c=25 in *A. cephalatus*, calculated from Cobb's formula). It, however, differs from *A. cephalatus* in bifurcated terminus of labial probolae, number and arrangement of caudal papillae (papillae four pairs, two preanal and two postanal in *A. cephalatus*) and gubernaculum being longer than half the length of spicula, latter more than one anal body diameter long (gubernaculum half of spicula and latter equal to anal body diameter in length in *A. cephalatus*).

A. timmi n.sp. comes also near to *A. ciliatus* Linstow, 1877 (redescribed by Thomas and Allen, 1965) but differs from it by the very minute tines of probolae, crenate inner incisures, more anteriorly placed phasmid and much smaller postvulvar sac (phasmid less than $\frac{1}{4}$ tail from cloaca, incisures smooth, postvulvar sac 1.5 times of body width long in *A. ciliatus*).

Type habitat.—Rhizosphere of *C. olitorius*.

Holotype.—Female; collected on 18-vi-1972.

Paratypes.—Four females and four males, other particulars as for the holotype.

Type-locality.—Burdwan, West Bengal.

Other material.—Several females and males, locality—Burdwan, collected on several occasions from the rhizosphere of *C. olitorius*. Two females from Duttapur, Dist. Hooghly from the rhizosphere of *C. capsularis*.

The new species is named after Father Dr. R.W. Timm, who has contributed to the study of nematodes of jute.

Order ARAEOLAIMIDA de Coninck and Schuurmanns Stekhoven, 1933

Superfamily PLECTOIDEA (Örley, 1880) Chitwood, 1937

Family PLECTIDAE Örley, 1880

Subfamily PLECTINAE (Örley, 1880) Micoletzky, 1922

Genus **Chronogaster** Cobb, 1913

Chronogaster loofi n.sp.

(Fig. 15, A–E)

Dimensions.—Holotype—Female: L=1.14 mm, a=46, b=4.6, c=7.7, V=$^{30}49$.

Paratypes—Female (5): L=1.14–1.29 mm, a=41–46, b=4.6–5.3, c=4.6–5.6, V=$^{30-32}47\text{–}51^{0.96-0.98}$.

Male: Not found.

Description.—Female: Body very slender, attenuated only slightly anteriorly but more so posteriorly. Tail long, filiform, ending in a single mucro. Cuticular striations coarse, 3 µm apart in oesophageal to midbody region, about 2 µm in anal region and narrowing behind gradually. Anastomoses absent. Lateral field absent. Epidermal glands inconspicuous. Crystalloids absent in the body cavity.

Head 7–9 µm in diameter, not offset, flatly rounded, without distinct lips. Cephalic setae 4–5 µm long, originating 2–3 µm behind anterior extremity of the nematode. Amphid small, funnel-shaped with oval opening, 8 (8–9) µm from anterior end, at third annule behind the head. Stoma 28 (28–35) µm long, in two parts, anterior 10×2 (10–11×2–3) µm, a long cylindrical funnel about 1/3 head width long, narrowing posteriorly; posterior part narrow 19 (18–25) µm long with lumen transversely expanding at the base. Oesophagus cylindrical 245 (245–275) µm, long, terminal bulb oval, 18×14 (17–21×14) µm, its lumen divided into two parts, anterior part serrate with 5–7 denticles on either side, posterior part of lumen smooth. Postbulbr neck 17 (14–18) µm long. Rectum 21 (15–22) µm, about 1.5 times the anal body diameter long. Caudal glands present. Nerve ring 107 (105–110) µm from anterior end. Excretory pore not seen. Vulva equatorial, flush with body surface. Ovary single, anterior and reflexed. Oöcytes in a single file. Postvulvar sac very small.

Differential diagnosis and relationships.—The new species resembles *C. daoi* Loof, 1964, *C. andrassyi* Loof and Jairajpuri, 1965 and *C. tenuis* Loof and Jairajpuri, 1965,

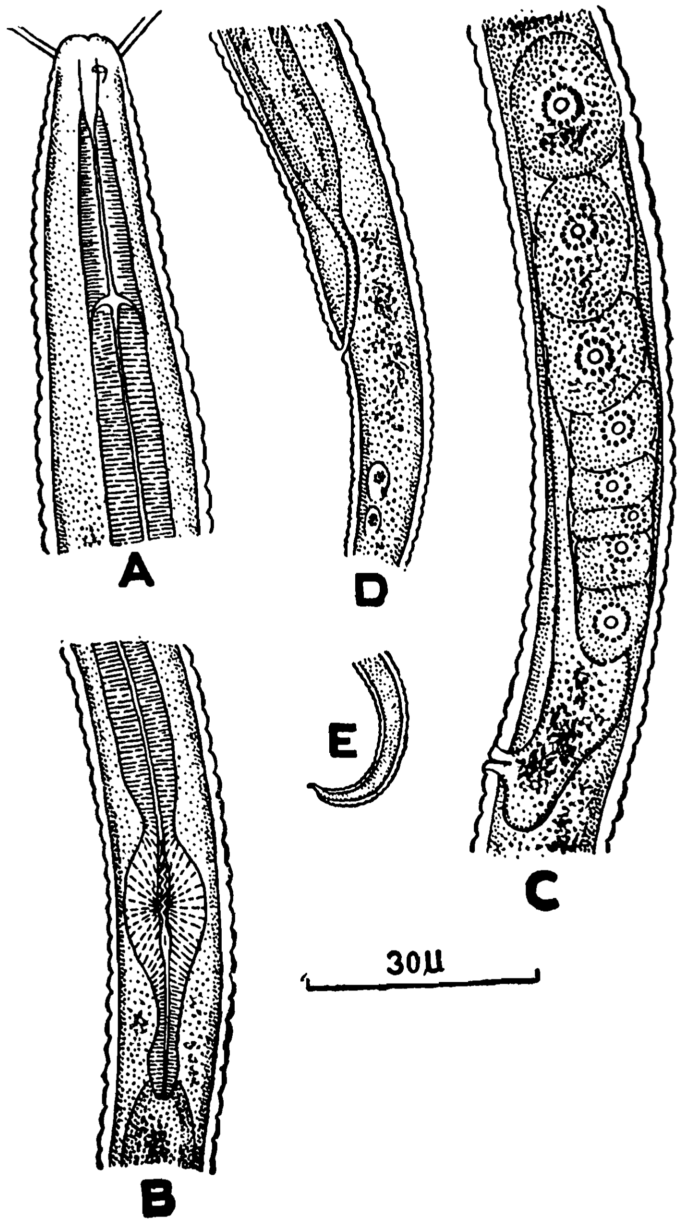

Fig. 15. *Chronogaster loofi* n.sp.—A. Anterior end; B. Oesophageal bulb; C. Female gonad; D–E. Female tail.

However, it differs from *C. daoi* mainly in having uniformly cylindrical oesophagus and single mucro at the tail tip (oesophagus broad anteriorly, two mucro at the tail tip in *C. daoi*). Besides, the two species also show difference in body size (L= 0.72–0.78 mm, in *C. daoi*).

C. loofi n.sp. differs from *C. andrassyi* mainly in having a single mucro without spines and the position and shape of the amphidial opening (mucro with 4 spines, amphid stirrup-shaped, opening curved transverse slit on I & II annules in *C. andrassyi*). It also differs in the values of 'b' and 'c' (b=4.4–4.7, c=5.5–6.4 in *C. andrassyi*) and in the absence of anastomoses.

The new species differs from *C. tenuis* in having coarse annulations, robust body, in the values of 'a', 'b' and 'V' and short postbulbar neck (annulation 1.3–1.7 μm apart, a=67–75, b=4.2–4.4, V=45–47 and postbulbar neck 27–29 μm in *C. tenuis*). *C. tenuis* is the most slender species and has longer cephalic setae (9 μm in *C. tenuis*.)

Type habitat.—Soil around the roots of *C. olitorius.*

Holotype.—Female; Collected on 31-vii-1922.

Paratypes.—Five females; other data as for the holotype.

Type-locality.—Burdwan, West Bengal.

Other material.—One female from Sujapur, Dist. 24–Parganas and one from Mourigram, Dist. Howrah from *C. olitorius.*

The new species is named after Dr. P. A. A. Loof.

Order MONHYSTERIDA (Örley, 1880) Schuurmanns Stekhoven & de Coninck, 1933

Family MONHYSTERIDAE Örley, 1880

Subfamily MONHYSTERINAE (Örley, 1880) Micoletzky, 1922

Genus **Prismatolaimus** de Man, 1880

Prismatolaimus andrassyi Khera and Chaturvedi, 1977

Prismatolaimus andrassyi Khera and Chaturvedi, 1977, *Rec. zool. Surv., India,* **72:** 125–152.

Dimensions.—Female (2): L=0.61–0.70 mm, a=41–43, b=4.0–4.6, c=3.6–4.0, $V = {}^{11-13}54\text{–}56$.

Description.—Female: Body arcuate, tapering more towards posterior than anterior end. Cuticle transversely striated, striae fine. Head not set off, low and rounded anteriorly. Posterior part of stoma narrow with denticulate basal cushion and dorsal tooth. Oesophago-intestinal valve oval with two rows of cells, four cells in each row.

Vulva flush with body surface, vagina directed anteriad. Ovary single, anterior, reflexed. Vulva to anus distance 105–108 μm. Tail 168–172 μm, 17–18 anal body diameter long, filiform.

Remarks.—The species was first described by Khera and Chaturvedi (1977) from tea gardens of Dehra Dun, Uttar Pradesh. Now it is being recorded from West Bengal thus it seems to be a fairly wide-spread species.

Habitat.—Rhizosphere of *C. capsularis* and *C. olitorius.*

Locality.—Sujapur, Falta, Bhajna, Dist. 24-Parganas; Rangsagar, Dist. Murshidabad; Brahmansasan, Dist. Midnapur and Duttapur, Tarkeshwar, Dist. Hooghly.

Genus **Abunema** Khera, 1971

Abunema indicum Khera, 1971

(Fig. 16, A–E)

Abunema indicum Khera, 1971, *Nematologica,* **16:** 490–502.

Dimensions.—Female (1): L=1.01 mm, a=22, b=5.5, c=13, $V = {}^{17}67$.

Description.—Body stout, narrowing posteriorly, ventrally curved, particularly in posterior region. Tail conical 74 μm long, curved ventrally, terminus narrow, rounded. Amphid oval with a central point, at about one head width from anterior end. Head broad, rounded, continuous with body contour. Cephalic setae six. Stoma in two parts, anterior part funnel shaped, posterior part bears three teeth, dorsal one bigger than subventrals. Basal part of stoma expanded transversely

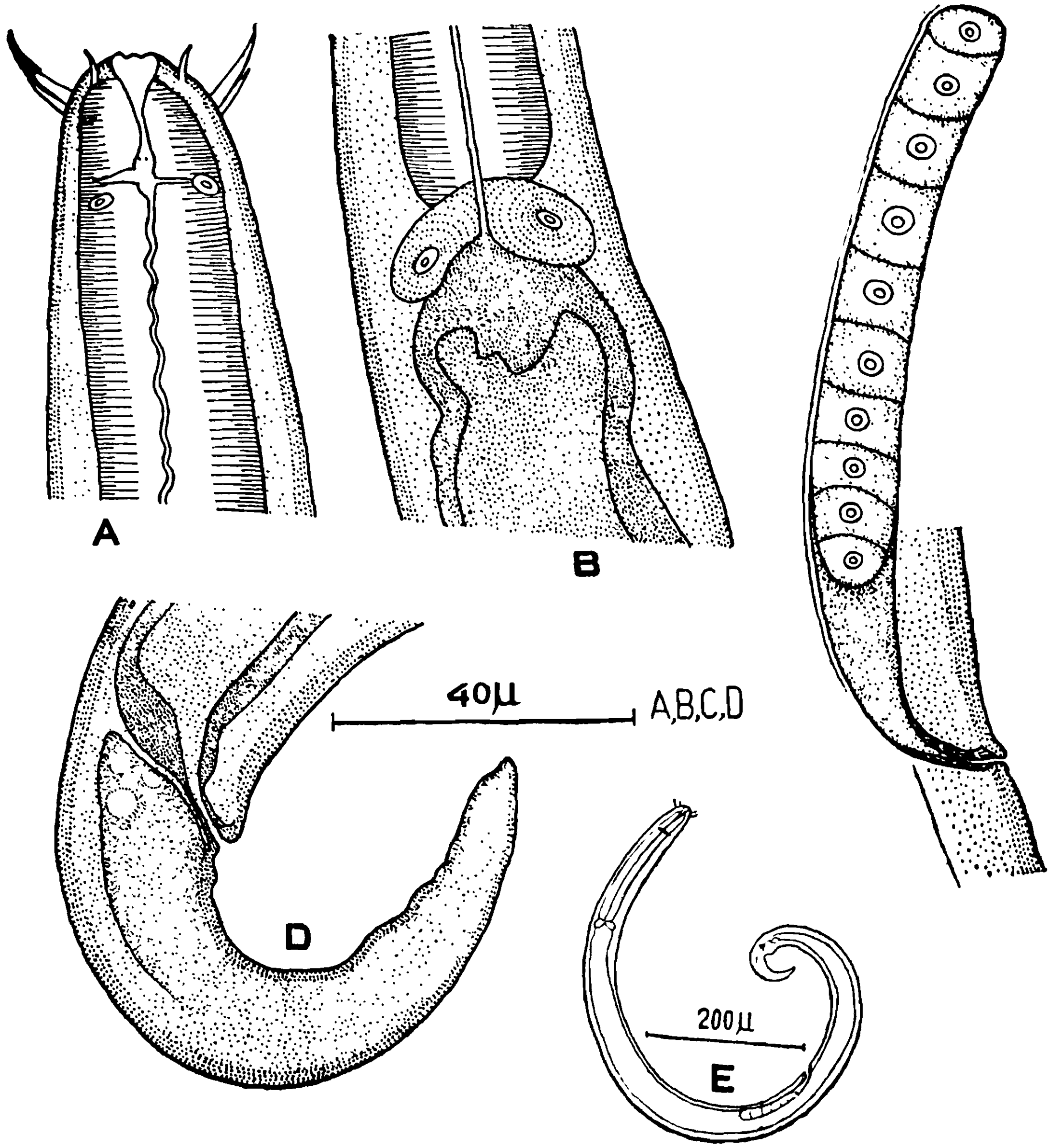

Fig. 16. *Abunema indicum*—A. Anterior end; B. Oesophago-intestinal junction; C. Female gonad; D. Female tail; E. Entire female.

near its junction with the oesophagus. Oesophago-intestinal valve cells large, oval with prominent nuclei. Rectum less than one anal body width long. Caudal glands present, gland duct indistinct. Nerve ring 84 μm from anterior end. Excretory pore not seen.

Vulva posterior, flush with body surface. Ovary single, anterior and reflexed, the reflexed end reaching closed to vulva. Vagina oblique, about $\frac{1}{4}$ the vulvar body width long.

Remarks.—The specimen closely fits in the description of the species by Khera (1971) except for the position of amphids which are stated to be placed far behind (about 1.5 times the head width).

Habitat.—Rhizosphere of *C. olitorius.*

Locality.—Barrackpore, Dist. 24-Parganas; Belur, Dist. Howrah and Mangalmuri, Dist. Midnapur.

Order CHROMADORIDA (Filipjev, 1917) Chitwood, 1933

Family CYATHOLAIMIDAE (Micoletzky, 1922) de Coninck and Schuurmanns Stekhoven, 1933

Subfamily CYTHOLAIMINAE Micoletzky, 1922

Genus **Achromadora** Cobb, 1913

Achromadora ruricola (de Man, 1880) Micoletzkiy 1925

(Fig. 17, A–C)

Cyatholaimus ruricola de Man, 1880, *Tijdschr. ned. dierk. Vereen.*, **3**: 88–118.
Chromadora minima Cobb, 1893, *Macleay Mem. Vol. Linn. Soc. N.S.W.*, pp. 1–59.
Achromadora ruricola (de Man, 1880) Micoletzky, 1925, *K. Danske. Vidensk. Selsk. Skr.*, **10**(2): 57–310.

Dimensions.—Female (1): L=0.75 mm, a=25, b=6.8, c=9.7, V=$^{11}50^{6}$.

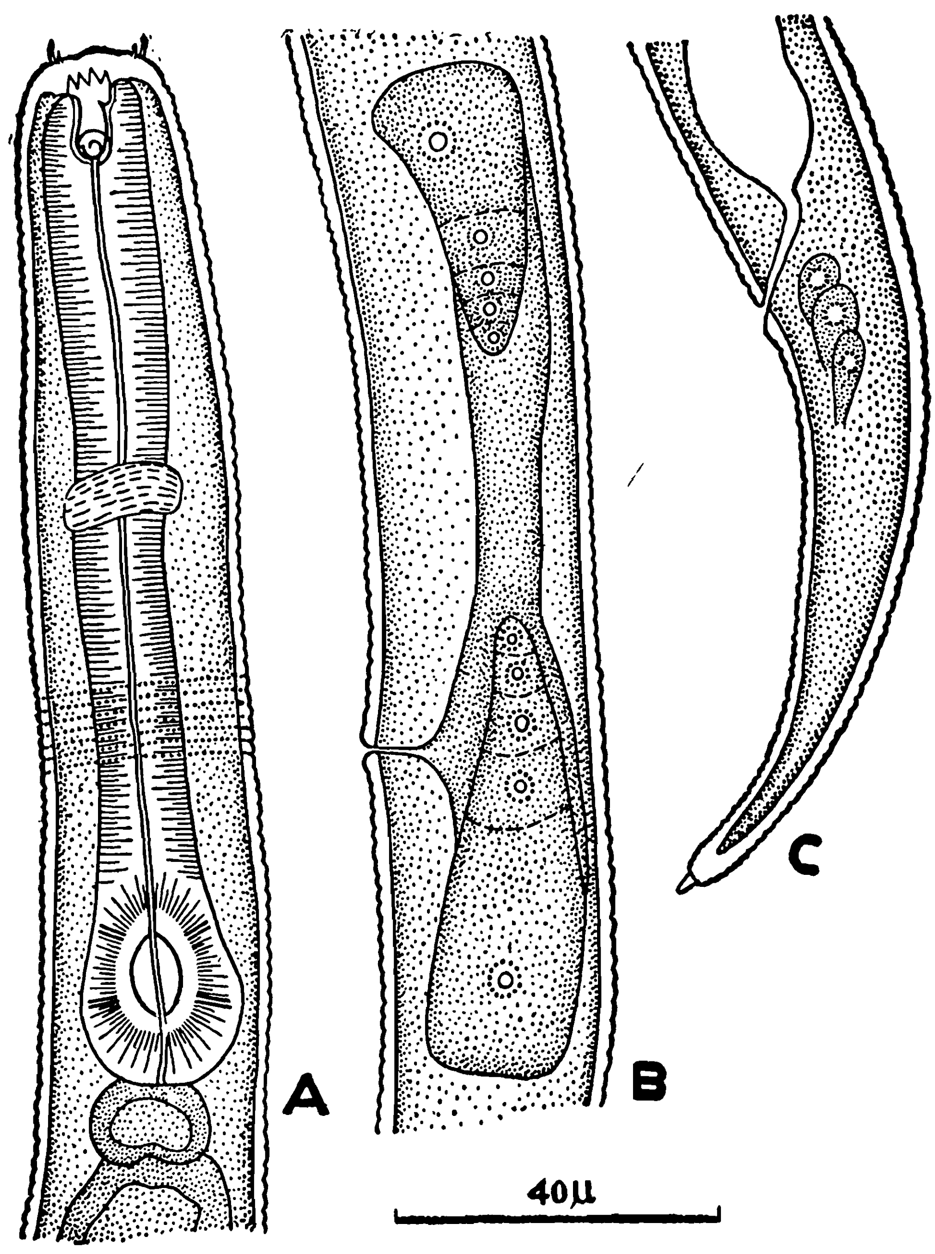

Fig. 17. *Achromadora ruricola*—A. Anterior end; B. Female gonad; C. Female tail.

Description.—Female: Body curved ventrally, cylindircal, narrowing in posterior third. Cuticle transversely striated, striae ornamented with rows of cuticular punctations. Head truncated, lips with minute apical papillae. Cephalic setae ten. Stoma funnel-shaped, dorsal tooth situated at anterior third of stoma. Subventral teeth small, two in number, situated near the base of the stoma. Amphid spiral, situated at the ventral level of stoma. Oesophago-intestinal valve spherical 15×11 μm. Rectum 6/7 the anal body diameter long.

Vulva equatorial, vulvar lips slightly protruding from body contour. Ovaries two, opposite and reflexed. Tail tapering more than three times the anal body diameter long, with a small process at the tip.

Remarks.—The specimen fits well in the description of the species given by Goodey (1963) except for some variations in de Manian indices. A comparison of the descriptions of the species given by Altherr (1952), Goodey (1963) and Loof (1964) shows wide range of variations in body dimensions. The divisions of the musculature of oesophageal bulb is the same as described by Loof (*loc. cit.*). None of the previous workers have ever reported a well developed oesophago-intestinal valve as in the present specimen. According to Loof (*loc. cit.*) rectum is 1–2.5 times the anal body width long, which, however, is less than one anal body diameter in this specimen.

Habitat.—Rhizosphere of *C. olitorius.*

Locality.—Burdwan; Rautara, Dist. 24–Parganas.

Order ENOPLIDA (Baird, 1853) Chitwood, 1933

Superfamily TRIPYLOIDEA (Örley, 1880) Chitwood, 1937

Family TRIPYLIDAE Örley, 1880

Genus **Tripyla** Bastian, 1865

Tripyla (Trischistoma) arenicola de Man, 1880

Tripyla arenicola de Man, 1880, *Tijdschr. ned. dierk. Vereen.*, **5**(1–2): 1–104.

T. minor Cobb, 1893, *Agric. Gaz., N.S.W.*, **4**(10): 808–833.

Trischistoma arenicola (de Man, 1880) Altherr, 1952, *Ergebn. Wiss. Unters. Schweiz, NatnParks.*, n.F. **3**(26): 315–356.

Tripylina arenicola (de Man, 1880) Brzeski, 1963, *Acta Zool. Cracov.*, **8**: 295–308.

Dimensions.—Female (3): L=0.82–0.95 mm, a=21–25, b=4.5–4.8, c=12–13, $V = {}^{11-12}66\text{–}67$.

Description.—Female: Body cylindrical, tapering behind vulva, ventrally curved, specially in posterior region. Cuticle thick, striations fine. Head continuous with body contour. Amphid inconspicuous. Stoma narrow, long, dorsal tooth 15–21 μm from anterior end. Rectum less than one body width long. Vulva flush with body surface. Ovary single, anterior, reflexed. Vagina half as long as the vulvar body width. Tail conical-elongate, about three anal body diameters long, terminus rounded.

Remarks.—Khera, (1970) in his review of the genus has recognised three subgenera; *Trischistoma* Cobb. 1913 is one in which gonad is monodelphic. Under this subgenus four species *T* (*Tr.*) *pellucida* (Cobb, 1913) Micoletzky, 1925; *T* (*Tr.*) *arenicola* de Man, 1880; *T* (*Tr.*) *monohystera* de Man, 1880 and *T* (*Tr.*) *sheri* (Brzeski, 1963) Khera, 1970 were included by Khera (*loc. cit.*). The present specimens come close to *T* (*Tr.*) *arenicola*. However, these show slight variation in the de Manian indices (♀: L = 1.4 mm, a = 30, b = 6, c = 20 in *T* (*Tr.*) *arenicola* de Man, 1880).

Habitat.—Rhizosphere of *C. capsularis*.

Locality.—Belur, Dist. Howrah; Rautara, Dist. 24–Parganas and Burdwan.

Family IRONIDAE de Man, 1876

Subfamily IRONINAE (de Man, 1876) Micoletzky, 1922

Genus **Ironus** Bastian, 1865

Ironus longicaudatus De Man, 1884

Ironus longicaudatus De Man, 1884. *Eine systematische-faunistische. Monographic* Leiden, 206 pp.
Cephalonema longicauda Cobb, 1893 ,*Agric. Gaz. N.S.W.*, **4**(10): 808–833.
Nanonema longicauda (Cobb, 1893) Cobb in Stiles & Hassall, 1905, *Bull. Bur. Anim. Ind. U.S. Dept. Agric.*, **79**: 1–150.
Ironus filicauda Daday, 1899, *Ert. Magy. Tudo. Akad. Budapest,* **17**(5): 557–572.
Aphanolaimus papillatus Daday, 1899, *ibid.*

Dimensions.—Female (2): L = 1.48–1.67 mm, a = 41–54, b = 5.0–5.6, c = 3.5–5.0, V = $^{7-8}$38–45$^{8-10}$

Description.—Female: Body long, slender, tapering towards either end, more so posteriorly. Cuticle smooth. Head slightly set off, 7–8 μm long and 11–14 μm wide. Lips three, each with one apical papilla and four submedian setae. Amphid cup like, near the head base. Stoma tubular, 70–84 μm long. Three hook-like teeth present in anterior most part of stoma. Excretory pore not seen. Oesophagus almost cylindrical, slightly expanded posteriorly, 290–294 μm long. Nerve ring 126 μm from anterior end. Cardia small rounded. Rectum more than one anal body diameter long. Vulva anterior, flush with body surface. Ovaries paired, opposed and reflexed. Tail filiform, 406–469 μm long.

Remarks.—The specimens closely fit in the description of the species given by Andrassy (1968).

Habitat.—Rhizosphore of *C. capsularis* and *C. olitorius*.

Locality.—Sujapur, Barrackpore, Dist. 24–Parganas; Alaipur, Dist. Nadia; Lalgola, Dist. Murshidabad; Mangalmuri, Dist. Midnapur.

Subfamily CRYPTONCHINAE Chitwood, 1937

Genus **Cryptonchus** Cobb, 1913

Cryptonchus abnormis (Allgen, 1933) Schuurmans Stekhoven, 1951

Cylindrolaimus abnormis Allgen, 1933, *Zool. Anz.*, **103**(11–12): 312–320.
Cryptonchus abnormis (Allgen, 1933) Schuurmans Stekhoven, 1951, *Mem. Inst. Roy. Sc. Nat. Belg.*, 2 Ser., **39**: 3–79.

Dimensions.—Female (1): L = 0.96 mm, a = 37, b = 4.1, c = 4, V = ^{12}47.

Description.—Female: Body long and slender, rather straight. Cuticle smooth. Head continuous with the body, flatly rounded, without distinct lips, 8 μm in diameter. Stoma long and tubular, 39 × 4 μm with two dorsal teeth at its base. Amphid 4 μm from anterior end. Oesophago-intestinal valve spherical. Rectum more than one anal body width long.

Vulva about the middle of body, flush with body surface. Ovary single, anterior and reflexed. Tail long, filiform; caudal glands and terminal duct present.

Remarks.—Sukul (1968) described *C. papillatus* from Andamans. It shows very close resemblance to *C. abnormis*. Sukul (*loc. cit.*) distinguished *C. papillatus* from *C. abnormis* mainly in the "form of stoma and cephalic papillae". As regards form of stoma, from his illustration the stoma seems to be tubular in *C. papillatus*. Stoma walls have been shown ending abruptly and dorsal teeth situated in oesophageal lumen, which is rather unusual for the genus. The ovary has been described as "reflexed halfway back to vulva" but in illustration the reflexed and has been depicted reaching almost up to vulva. The stoma in *C. papillatus* is 8 times longer than wide; in the present specimen about 10 times and Goodey (1963) records it 13 times longer than wide. These lengths indicate towards a cline. In view of this as well as other facts discussed above, the types of *C. papillatus* need re-examination.

Habitat.—Rhizosphere of *C. olitorius*.

Locality.—Burdwan.

Order DORYLAIMIDA Pearse, 1942

Suborder *DORYLAIMINA* (Chitwood, 1933) Pearse, 1936

Superfamily DORYLAIMOIDEA (de Man, 1876) Thorne, 1934

Family DORYLAIMIDAE de Man, 1876

Subfamily DISCOLAIMINAE (Siddiqi, 1969) Ferris, 1971

Genus **Discolaimoides** Heyns, 1963

Discolaimoides bulbiferus (Cobb, 1906) Heyns, 1963

Dorylaimus bulbiferus Cobb, 1906, *Bull. Div. Path. Physiol. Hawaiin Sugè Plrs' Ass. Exp. Stn*, **5**: 163–195.
Discolaimoides bulbiferus (Cobb, 1906) Thorne and Swanger, 1936, *Capita zool.*, **6**(4): 1–223.
Discolaimumbulbiferum (Cobb, 1906) Timm and Bhulyan, 1963, *Biologia*, **9**: 53–56.
Discolaimoides bulbiferus (Cobb, 1906) Heyns, 1963, *Proc. helminth. Soc. Wash.*, **30**: 1–6.

Dimensions.—Female (3): L = 1.28–1.31 mm, a = 42–45, b = 4.2–4.3, c = 43–46, $V = {}^{7-8}50\text{–}51^{8-10}$, odontostyle = 10–12 μm, odontophore = 14–17 μm.

Description.—Female: Body straight, arcuate in posterior part. Cuticle finely striated, striations distinct in oesophageal region, lateral chord about $\frac{1}{4}$ the body width, with about 60 pores, pores oval, not very distinct. Head set off, lips six, fused at the base. Amphid 4–6 μm from anterior end, stirrup-shaped, about 1/3 the head width. Stylet aperture 50% of odontostyle length, odontophore surrounded by slightly swollen part of oesophagus at its base. Guiding ring 6–7 μm from anterior end, behind the head constriction. Pre-rectum about four rectum lengths long, rectum about one anal body diameter long.

Vulva equatorial, flush with body surface. Vagina unsclerotized, transverse, extended to about 1/3 vulvar body diameter. Ovary didelphic, amphidelphic and reflexed. Tail short, 1.5 anal body diameter long, terminus rounded.

Remarks.—The specimens fit in well with the description of the species given by Thorne (1939) as well as by Das *et al.* (1969). The latter have also discussed the systematic status of the genus and we fully agree with their opinion.

Habitat.—Rhizosphere of *C. olitorius*.

Locality.—Burdwan; Duttapur, Dist. Hooghly and Sujapur, Rautara, Dist. 24–Parganas.

Subfamily NORDINAE Jairajpuri and Siddiqi, 1964

Genus **Longidorella** Thorne, 1939

Longidorella macramphis (Altherr, 1950) Altherr, 1950

Dorylaimus (*Longidorus*) *macramphis* Altherr, 1950, *Ergebn. Wiss. Unters. Schweiz. Natn.Parks.*, n.f. **3**(22): 3–46.

Longidorella macramphis (Altherr, 1950) Altherr, 1950, *Bull. Murithienne.*, **67**: 90–103.

Dimensions.—Juvenile (1): L=0.63 mm, a=30, b=3.3, c=22, odontostyle= 49 μm, odontophore =48 μm.

Description.—Juvenile: Body tapering towards both ends. Cuticle and sub-cuticle thick. Head not set off, lips amalgamated, Amphid cuplike near the base of the lip region, aperture slit-like, 2/3 as wide as head. Odontostyle long and slender, odontophore almost equal to stylet, about 20% of oesophageal length; odontostyle and odontophore jointly about half the neck length and 11.5 times the head width. Guiding ring distinct, at anterior third of odontostyle.

Pre-rectum 21 μm long, about 1.5 times the length of rectum. Rectum 14 μm, about one anal body diameter long. Tail short, conoid, 2.5 anal body diameter long.

Remarks.—The specimen fits in well with the description of the species given by Jairajpuri and Siddiqi (1964) and also the dimensions given by Jairajpuri and Hooper (1969).

Habitat.—Recovered from the soil around the roots of *C. olitorius.*

Locality.—Mourigram, Dist. Howrah.

Family LONGIDORIDAE (Thorne, 1935) Meyl, 1961

Genus **Xiphinema** Cobb, 1913

Xiphinema (**Xiphinema**) **americanum** Cobb, 1913

Xiphinema americanum Cobb, 1913, *J. Wash. Acad. Sci.*, **3**(16): 432–444; Thorne, 1939, *Capita zool.*, **8**(5): 1–261.

X. (*X.*) *americanum*, Cohn & Sher, 1972, *J. Nematol.*, **4**(1): 36–65.

Dimensions.—Female (1): L=1.59 mm, a=42, b=6, c=49, c′=1.5, V= $^{10}52^{10}$, odontostyle=73 μm, odontophore=43 μm.

Description.—Female: Body arcuate, tapering towards extremities. Cuticle smooth. Lateral field about $\frac{1}{4}$ body width. Lip region slightly narrower than neck. Amphid aperture slit-like, about $\frac{3}{4}$ as wide as lip region. Stylet long, straight; guiding rings two, 19 μm apart; flanges 8 μm wide. Oesophagus typical of the genus. Pre-rectum not clearly discernible, rectum half the anal body diameter long. Tail short, conoid; only two caudal pores seen. Vulva postequatorial, vagina about 2/5 vulvar body width long. Ovaries two, opposite and reflexed. Both ovaries equally developed. Oöcytes in a single row.

Remarks.—The present specimen fits in well with the descriptions of the species given by Siddiqi (1959) and Thorne (1961). The odontostyle, however, is slightly smaller.

X. (*X.*) *americanum* is a consmopolitan species with a wide host range. In India it has been reported from citrus and mango.

Habitat.—Rhizosphere of *C. olitorius.*

Locality.—Nimtalla, Dist. Howrah.

Xiphinema (Elongiphinema) insigne Loos, 1949

Xiphinema insigne Loos, 1949, *J. zool. Soc. India*, **1**(1): 23–29.
X. indicum Siddiqi, 1959, *Proc. helminth. Soc. Wash.*, **26**: 151–163.
X. (*Elongiphinema*) *insigne*, Cohn & Sher, 1972, *J. Nematol.*, **4**(1): 36–65.

Dimensions.—Female (2): L=2.19–2.22 mm, a=60–62, b=6.0–6.5, c=28.0–28.4, c′=3.6, V=$^{7-9}29\text{–}30^{10-12}$, odontostyle=98–99 μm, odontophore=56–58 μm.

Juv. (5): L=0.83–1.26 mm, a=35–51, b=3.3–4.6, c=14–20, odontostyle=52–53 μm, odontophore=37–39 μm.

Description.—Female: Body slightly arcuate, tapering towards both ends. Lip region hemispherical, slightly offset, narrower than neck, 10–11 μm wide, lips amalgamated. Amphid aperture indistinct. Cuticle smooth. Lateral field about 1/3 body width at mid body region.

Odontostyle robust, straight, followed by odontophore. Flanges 8–10 μm wide. Stylet guide composed of two guiding rings 26–27 μm apart, in posterior part of stylet. All the juvenile specimens have a larval stylet embedded in the wall of the oesophagus. However, one of the mature females also retains this structure. Pre-rectum obscure, rectum 28 μm long.

Vulva anterior, flush with body surface. Vagina 2/5 vulvar body width long, opening into ovejector. Gonads didelphic, amphidelphic, reflexed and asymmetrical, 'Z' organ absent. Tail elongate conical; caudal pores three.

Remarks.—Cohn and Sher (1972) divided the genus *Xiphinema* Cobb, 1913 into three groups based on the branching of the gonads. They further divided the genus into eight subgenera mainly on the basis of body size, tail size and shape, structure of the gonads and position of the vulva. The present specimens fall under the subgenus *Elongiphinema* and fit well in the description of the species given by Tarjan and Luc (1963).

Cohn and Sher (*loc. cit.*) after examining several geographical populations of *X. insigne* and *X. elongatus* Schuurmans Stekhoven and Teunissen, 1938 found that two species come very close to each other except in the values of V, c and c′ which, however, remain consistent in different environment; according to them the two species are sibling species.

The species has been recorded from citrus and coffee roots in India.

Habitat.—Found around the roots of *C. olitorius* and *C. capsularis.*

Locality.—Sujapur, Dist. 24–Parganas; Duttapur, Dist. Hooghly.

Superfamily ACTINOLAIMOIDEA Thorne, 1967

FamilyNEOACTIONLAIMIDAE Thorne, 1967

Genus **Neoactinolaimus** Thorne, 1967

Neoactinolaimus thornei n.sp.

(Fig. 18, A–E)

Dimensions.—Holotype—Female: L=2.28 mm, a=46, b=4.3, c=13, V=$^{11}43^{14}$, odontostyle=21 μm, odontophore=42 μm.

Paratype—Male (1): L=2.66 mm, a=47, b=4.2, c=126, T=71, odontostyle=22 μm, odontophore=42 μm, spicula=49 μm.

Description.—Female: Body straight, cylindroid except at extremities. Cuticle thick, striae very fine. Lateral field occupying ¼ body width; lateral pores indistinct. Lips low, round. Amphid goblet shaped, half as wide as head. Vestibule a sclerotized ring with corrugations. Pharynx armed with four onchia and four small submedian teeth. Odontostyle less than two head widths long, aperture about half of its length. Guiding ring double, 17 μm from anterior end. Odontophore twice as long as odontostyle, surrounded by muscular tissue set off from oesophagus by a constriction. Oesophagus cylindrical, expanding in posterior half. Basal shield present. Cardia hemispherical with an elongate conoid part going deep into intestine. Cardia enveloped by intestine. Pre-rectum four times as long as rectum. Rectum more than 1.5 times the anal body diameter. Nerve ring 196 μm from anterior end.

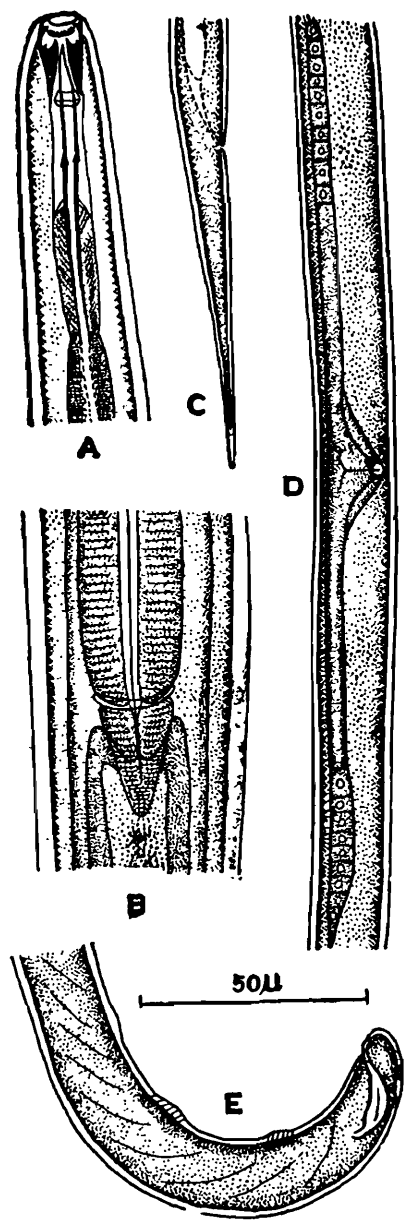

Fig. 18. *Neoactinolaimus thornei* n.sp.—A. Anterior end; B. Oesophago-intestinal junction; C. Female tail; D. Female gonads.

Vulva pore like, in a rounded depression, vagina about $\frac{1}{3}$ of vulvar body width. Ovaries paired, opposed and reflexed, the reflexed end reaching close to vulva. Anterior ovary, 245 μm posterior 308 μm long. Oöcytes in a single row. Tail elongate-conoid, tapering to filiform.

Male: General morphology as of female. Body comparatively robust. Tail curved ventrally, less than one anal body diameter long, tip bluntly rounded. Spicula and lateral guiding pieces dorylaimoid. Supplements in two fascicles, anterior with 7 and posterior with 6 supplements. There is a third fascicle anterior to these two, devoid of any supplement.

Differential diagnosis and relationships.—The new species comes close to *N. agilis* Thorne, 1967 in general characters particularly in the odontostyle being less than twice the head width, the value of 'V' (V=43 in *N. agilis*) and the presence of a third fascicle without supplements. However, *N. thornei* n.sp. differs from *N. agilis* in body size, corrugations in vestibule, size of odontophore and the presence of basal shield (♀: L=3 mm, : L=3.5 mm♂, no corrugations in vestibule, odontophore equal to odontostyle and basal shield absent in *N. agilis*).

The new species resembles *N. michaelsoni* (Steiner, 1916) Thorne, 1967 in the rectum being twice the anal body width and the arrangement of supplements in two fascicles, but differs in the lips being not set off and the absence of any supplement in between two fascicles (lips set off, two isolated supplements between two fascicles in *N. Michalsoni*.)

Type habitat.—Rhizosphere of *C. olitorius*.

Holotype.—Female; Collected on 29-vii-1970.

Paratype.—Male; Other data as for the holotype.

Type-locality.—Sujapur, Dist. 24–Parganas, West Bengal.

Species is named in the memory of Dr. G. Thorne, a pioneer in nematology.

Superfamily BELONDIROIDEA Thorne, 1964

Family DORYLAIMELLIDAE (Jairajpuri, 1964) Thorne, 1964

Genus **Dorylaimellus** Cobb, 1913

Dorylaimellus parvulus Thorne, 1939

(Fig. 19, A–E)

Dorylaimellus parvulus Thorne, 1939, *Capita zool.*, **8:** 1–261.

Dimensions.—Female (5): L=0.46–0.53 mm, a=23–28, b=2.9–3.9, c=27–34, V=$^{9-12}$54–59$^{11-15}$, odontostyle=7–8 μm, odontophore=8–10 μm.

Male (1): L=0.55 mm, a=31, b=4, c=26, T=53, odontostyle=7 μm, odontophore=11 μm, spicula=18 μm.

Description.—Female: Body rather straight, slightly tapering towards both ends from the middle, more so anteriorly. Lip region amalgamated, forming a small disc. Head slightly set ff, cuticular pieces about vestibule minute. Odontostyle-aperture about 1/3 odontostyle length; odontophore flanged. Guiding ring not observed. Amphids cup-shaped, nearly encircling head. Oesophagus typical, with spindleshaped swelling a little behind odontophore; posterior expanded part of oesophagus ensheathed by spiral muscles. Pre-rectum 50–60 μm, rectum 10–11 μm long. Tail more than one anal body diameter long, terminus hemispherical, with thick cuticle. Vulva postequatorial, vagina about 1/3 body width; ovaries paired, opposed and reflexed. One egg present at a time, either in anterior or posterior uterus. Egg 92–105 μm long and 19–23 μm wide, slightly distending the body.

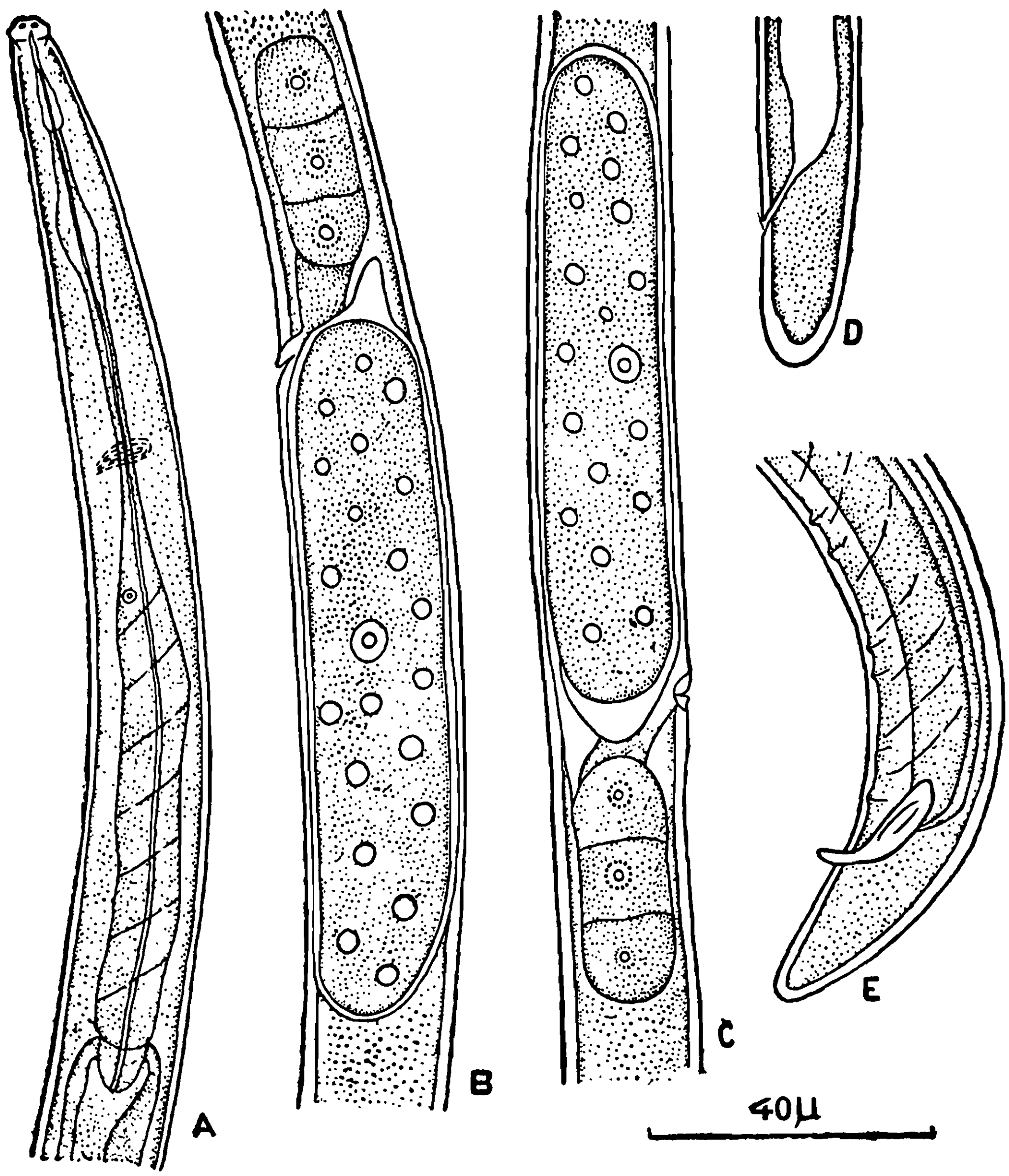

Fig. 19. *Dorylaimellus parvulus*—A. Anterior end; B–C. Female gonad; D. Female tail; E. Male tail.

Male: General structure as in female. Anterior oesophagus 77 μm, posterior 59 μm long. Pre-rectum 40 μm, rectum 10 μm long. Testes two, opposed. Spicula curved, lateral guiding pieces obscure. Supplements five, arranged in three groups of one, two and two. Tail differs from that of female in being conoid, dorsally convex, terminus round, cuticle not as thick as in female.

Remarks.—So far only females have been described in this species. The single male recovered resembles closely with females in all the details except for tail shape; hence, it is considered a male of *D. parvulus*.

Habitat.—Rhizosphere of *C. olitorius* and *C. capsularis*.

Locality.—Burdwan; Sujapur, Dist. 24–Parganas; Jangipara, Uttarpara, Dist. Hooghly; Alaipur, Dist. Nadia; Susunia, Dist. Bankura and Brahmansasan, Dist, Midnapur.

Dorylaimellus andrassyi Heyns, 1963

(Fig. 20, A–D)

Dorylaimellus andrassyi Heyns, 1963, *Nematologica*, **9**: 391–404.

Dimensions.—Female (1): L=1.05 mm, a=47, b=6.7, c=31, V=$^{16}50^{13}$, odontostyle=6 μm, odontophore=9 μm.

Male (1): L=0.89 mm, a=43, b=5.5, c=27, T=50, spicula=20 μm, odontostyle=6 μm, odontophore=9 μm.

Description.—Female: Body long, tapering towards both ends. Head set off, 6–7 μm wide, odontostyle-aperture 1/3 of its length, odontophore 1.5 times the odontostyle, broadly flanged. Amphid cup-like near the base of the head. Oesophagus behind odontophore spindle-shaped, then narrowing and finally expanded in posterior half, expanded part ensheathed by spiral muscles. Cardia small, cylindroid. Vulva longitudinal, vagina about 1/3 vulvar body diameter. Ovaries

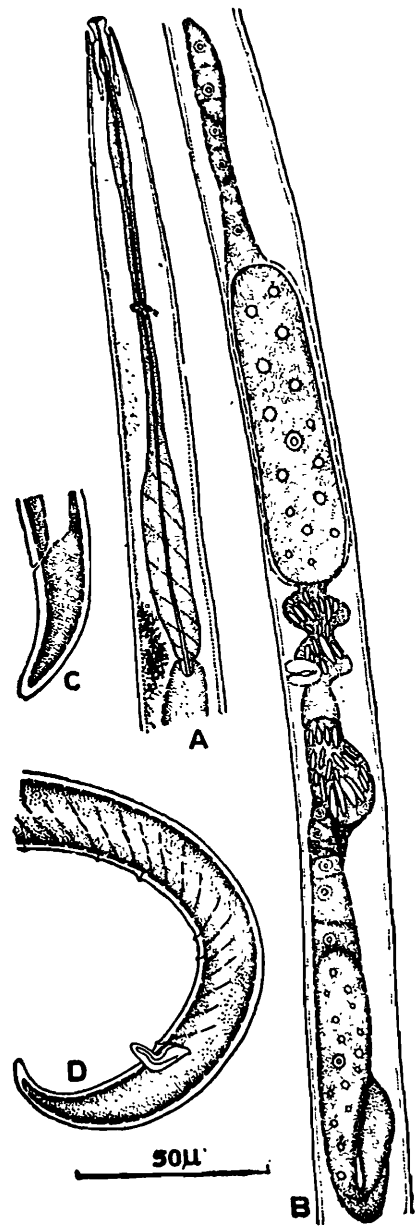

Fig. 20. *Dorylaimellus andrassyi*—A. Anterior end; B. Female gonad; C. Female tail; D. Male tail.

two, opposed and reflexed; each uterus with one egg 82×21 μm. Pre-rectum not clearly discernible, rectum less than one anal body width. Tail conoid, arcuate, more than two anal body diameters long, terminus rounded.

Male: General morphology as of female. Testes two, opposed. Spicula strongly curved in the middle, broader near the head, lateral guiding pieces obscure. Supplements six, preanal one near cloaca and two placed much anterior to cloaca close to each other; anterior to these two are three supplements placed at a distance from each other. Tail conoid, strongly curved, about two anal body diameter long, tip rounded.

Remarks.—The description of specimens closely tallies with the description given by Heyns (1963). However, there is some variation in the disposition of ventromedian supplements. This difference, by itself, is considered an intraspecific variation.

Habitat.—Rhizosphere of *C. capsularis*.

Locality.—Alaipur, Dist. Nadia.

Suborder *ALAIMINA* (Micoletzky, 1922) Clark, 1961

Superfamily ALAIMOIDEA (Micoletzky, 1922) Goodey, 1963

FamilyALAIMIDAE Micoletzky, 1922

Genus **Alaimus** de Man, 1880

Alaimus siddiqii n.sp.

(Fig. 21, A–D)

Dimensions.—Holotype—Female: L=0.91 mm, a=41, b=4.4, c=10, V=39^{22}.

Paratype—Male (1): L=0.83 mm, a=49, b=4.3, c=11.8, T=50, spicula= 13 μm.

Description.—Female: Body ventrally arcuate, more so in posterior region, tapering towards extremities. Cuticle smooth. Lip region rounded, continuous, with body contour, 4 μm wide. Amphid indistinct. Oesophagus cylindrical, expanding in posterior fourth. Anterior oesophagus 154 μm, posterior 49 μm long. Oesophago-intestinal valve small, disc shaped. Excretory pore not discernible. Nerve ring at 105 μm from anterior end.

Vulva anterior, flush with body surface. Vagina transverse, extending about 1/3 the vulvar body width. Ovary single, posterior, reflexed. Single egg in uterus, 76×18 μm, less than 4 body width long. Rectum more than one anal body diameter long. Tail 91 μm, more than 7 anal body diameter long, ventrally hooked, tapering gradually, terminus acute.

Male: Body ventrally arcuate, more curved in posterior region than anterior. General characters as of female. Anterior oesophagus 148 μm, posterior 43 μm long. Nerve ring 91 μm from anterior end. Excretory pore not seen. Testis single. Spicula slender, almost straight. Ventromedian supplementary papillae sixteen, anterior to cloaca. Tail 70 μm, five times the anal body diameter long, terminus abruptly narrowed, pointed.

Differential diagnosis and relationships.—The female of the new species comes close to *A. parvus* Thorne, 1939 in body size and tail shape. However, it differs from *A. parvus* in the shape of the oesophagus, longer rectum and presence of male (anteriormost portion of oesophagus broader, rectum less than one anal body diameter long and male absent in *A. parvus*). It also comes close to females of *A. primitivus* de Man,

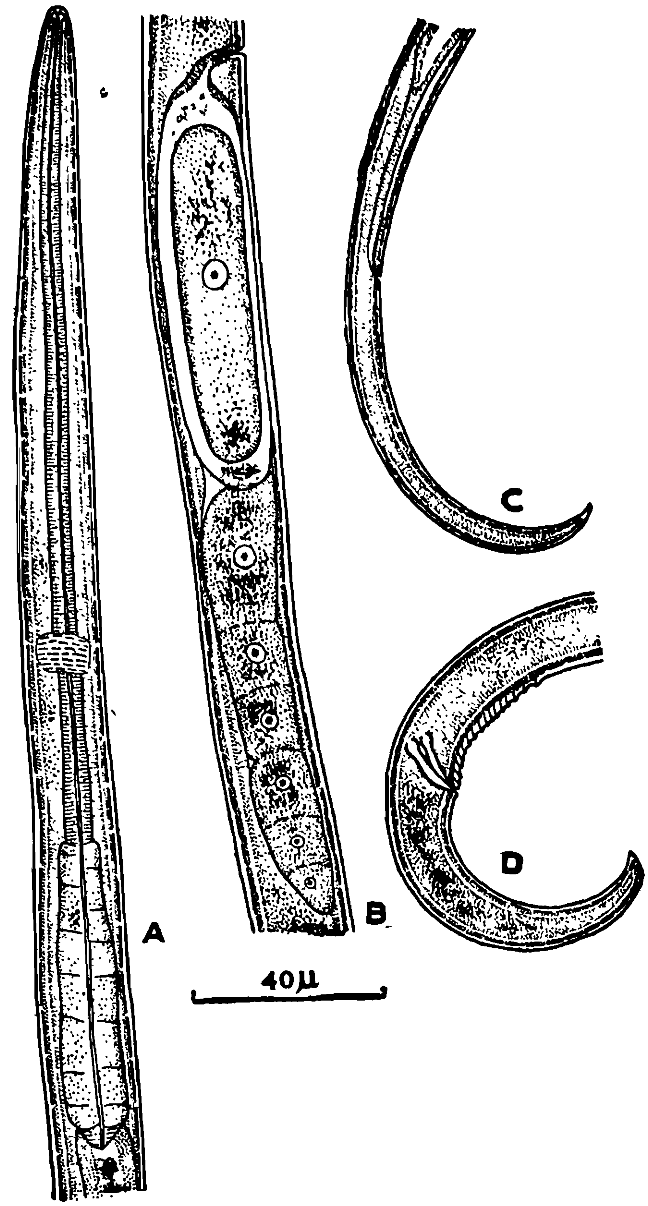

Fig. 21. *Alaimus siddiqii* n.sp.—A. Anterior end; B. Female gonad; C. Female tail; D. Male tail.

1880 in the values of some de Manian indices, but differs in body size, in the size of eggs (L = 1.2 mm, egg five to six times body width long in *A. primitivus*) and also in male characters (four supplements in *A. primitivus*).

The male specimen comes close to *A. multipapillatus* Wu and Hoeppli, 1929 and *A. himatangiensis* Yeates, 1967 particularly in the large number of ventromedian supplements. It differs from *A. multipapillatus* in size and other de Manian indices (L = 1.5–2.1 mm, a = 52–53, b = 6.3–8.4, c = 23.2–26.0 in *A. multipapillatus*). It also differs from *A. himatangiensis* in body dimensions and number of supplements (L = 2.14 mm, a = 63, b = 6.5, c = 26, spicula = 19 μm, supplements 11–14 in *A. himatangiensis*).

Type habitat.—Rhizosphere of *C. olitorius.*

Holotype.—Female, Collected on 13-viii-1972.

Paratype.—One male, other data as for the holotype.

Type-locality.—Burdwan, West Bengal.

The species is named after Dr. M. R. Siddiqi.

Order MONONCHIDA Jairajpuri, 1969
Superfamily MONONCHOIDEA (Chitwood, 1937) Clark, 1961
Family MYLONCHULIDAE Jairajpuri, 1969
Subfamily MYLONCHULINAE Jairajpuri, 1969
Genus **Mylonchulus** (Cobb, 1916) Altherr, 1953

Mylonchulus lacustris (N. A. Cobb, in M. V. Cobb, 1915) Andrassy, 1958

Mononchus (*Mylonchulus*) *lacustris* N.A. Cobb, in M.V. Cobb, 1915, *Trans. Am. microsc. Soc.*, **34**(1): 21–47.
Mylonchulus lacustris (N.A. Cobb, in M.V. Cobb, 1915) Andrassy, 1958, *Annls hist.—nat. Mus. natn. hung.*, n.s., **9**(50): 151–171.

Dimensions.—Female (5): L = 0.78–1.47 mm, a = 27–33, b = 3.0–4.6, c = 33–37, V = $^{5-7}$56–61$^{6-8}$.

Description.—Female: Body strongly curved in posterior half after fixation, cylindroid, tapering only slightly towards extremities. Cuticle thick and smooth. Lip region 16–24 μm wide and 4–5 μm high. Amphid 7–8 μm from anterior end, aperture a narrow slit 6–7 μm wide. Buccal cavity 20–28 × 9–13 μm. Dorsal tooth in the middle, 12–13 μm from anterior end. Seven transverse rows of denticles. Oesophagus cylindrical. Oesophago-intestinal junction non-tuberculate. Nerve ring 87–92 μm from anterior end. Rectum 16–18 μm, less than one anal body width long. Gonads didelphic, amphidelphic, reflexed. Vagina guarded by two cuticularised pieces. Tail 22–43 μm long, sharply bent about midway to terminus. Caudal glands three, spinneret terminal.

Remarks.—The specimens fit well in the description of the species given by Mulvey (1961), Mulvey & Jensen (1967) and Jairajpuri (1970). The latter recorded the species from guava, mango, banana, citrus and paddy from Uttar Pradesh, India.

Habitat.—Rhizosphere of *C. capsularis* and *C. olitorius.*

Locality.—Alaipur, Dist. Nadia; Belur, Dist. Howrah; Sujapur, Barrackpore, Dist. 24-Parganas; Mangalmuri, Dist. Midnapur; Burdwan.

Family IOTONCHIDAE Jairajpuri, 1969
Genus **Iotonchus** (Cobb, 1916) Altherr, 1950

Iotonchus trichurus (Cobb, 1917) Andrassy, 1958

Mononchus (*Iotonchus*) *trichurus* Cobb, 1917, *Soil Sci.*, **3**(5): 431–486.
Iotonchus trichrus (Cobb, 1917) Andrassy, 1958, *Annls hist. nat. mus. natn. hung.*, n.s. **9**(50): 151–171.

Dimensions.—Female (1): L = 1.72 mm, a = 41, b = 4.6, c = 4, V = ^{13}62.

Description.—Female: Body curved ventrally upon fixation, tapering slightly anterior to base of oesophagus but sharply behind the vulva. Cuticle thick and smooth, lateral chords about 1/3 as wide as the body width. Lip region 25 μm wide and 7 μm high. Amphid 12 μm from anterior end, aperture 7 μm wide. Buccal cavity 32 × 8 μm. Dorsal tooth posterior, 7 μm from the base of the buccal cavity. Subventral foramina not observed. Oesophagus cylindrical, oesophago-intestinal junction tuberculate. Nerve ring 105 μm from anterior end. Rectum 21 μm less than one anal body diameter. Gonad monoprodlephic, reflexed. Cuticularised pieces near vulva. Tail long, filiform, whip-like, 24% of total body length.

Remarks.—Jairajpuri (1969) recorded the species from Nainital, Uttar Pradesh; Andamans; Jorhat, Assam; and Waltair, Andhra Pradesh from wild plants, rose, paddy and cashewnut respectively. A widely distributed species.

Habitat.—Rhizosphere of *C. capsularis* and *C. olitorius*.

Locality.—Lalgola, Dist. Murshidabad; and Mangalmuri, Dist. Midnapur.

Genus **Hadronchus** Mulvey and Jensen, 1967

Hadronchus sp.

Dimensions.—Juvenile (2): L=0.99–1.22 mm, a=32–36, b=3.5–3.7, c=7.

Description.—Juvenile: Body arcuate, tapering more towards the posterior end than anteriorly. Cuticle thick and smooth. Lateral chord 1/5 of body width. Lip region 21–28 μm wide and 7–8 μm high, wider than adjoining body region. Amphid 9–10 μm from anterior end, cup-shaped, aperture 3–4 μm wide with anterior marginal line slightly depressed in the middle. Buccal cavity 30–39 × 11–14 μm, dorsal tooth 10–11 μm from the base of the cavity, 2–4 teeth on the ventral wall of the buccal cavity. Foramina on the oblique walls not clear. Oesophagus simple, cylindrical. Oesophago-intestinal junction tuberculate. Nerve ring 100–105 μm from anterior end. Rectum less than one anal body width long. Tail 140–172 μm, 6–7 times the anal body width long, elongate-conoid, tapering, caudal glands opening terminally.

Remarks.—The genus *Hadronchus* Mulvey and Jensen, 1967 was first reported from Indian Mainland and the Andamans by Jairajpuri (1969) from the rhizosphere of papaya, coconut, sweet-orange, plum and citrus. The specimens, being juvenile cannot be identified up to specific level.

Habitat.—Rhizosphere of *C. capsularis*.

Locality.—Barasat, Dist. 24–Parganas.

Order ISOLAIMIDA Cobb, 1920

Superfamily ISOLAIMOIDEA Timm, 1969

Family ISOLAIMINAE Timm, 1969

Genus **Isolaimium** Cobb, 1920

Isolaimium sp.

Dimensions.—Juvenile (1): L=1.60 mm, a=46, b=9.7, c=26, V=?

Description.—Juvenile: Body straight on thermal death, cylindrical for most of its length, slightly narrow towards extremities. Cuticle transversely striated, striations very fine, distinct mainly behind head region. Longitudinal striations absent. Head not set off, lips amalgamated, lip region 18 μm wide, only two tubular structures seen on either side of head, papillae not distinct. Stoma 52 μm long and 3 μm wide, walls strongly cuticularized. Oesophagus cylindroid, 165 μm long. Cardia round. Nerve ring 105 μm from anterior end. Tail conoid, spicate, 60 μm long, about twice the anal body diameter. Germinal primordium at 61% from anterior end. Amphid not seen.

Remarks.—The specimen being juvenile, could not be identified up to specific level. However, the specimen resembles the description of *I. andrassyi* Hogewind and Heyns, 1967 (=*I. papillatum* of Andrassy, 1962) in having fine transverse striae distinct behind the lip region but the longitudinal striae observed by Andrassy (1962) on posterior end of the body are absent.

Remarks.—The systematic position of the genus *Isolaimium* Cobb, 1920 is controversial and attempts have been made by Timm (1961) and Andrassy (1962) to clarify the same. Timm (1969) revived the order Isolaimida Cobb, 1920 and erected a separate superfamily to accommodate this genus. We accept the systematic status proposed by Timm (1969).

Habitat.—Rhizosphere of *C. capsularis.*

Locality.—Rangsagar, Dist. Murshidabad.

General Remarks

Fortyeight species of nematodes belonging to 42* genera, 26 families and nine orders have been described; this includes the description of one new subgenus and eleven new species. Five genera and nine species have been recorded for the first time from India. Except *Meloidogyne incognita*, *M. javanica* and *Hirschmanniella oryzae* all the species are new records from jute fields. Out of 42 genera recorded only nine were reported from jute crop by earlier workers while the rest 33* genera are being recorded for the first time from this host crop (Table 1).

New subgenus

Indorhabditis Chaturvedi & Khera

New species

1. *Hoplolaimus dubius* Chaturvedi, Singh & Khera
2. *Helicotylenchus indentatus* Chaturvedi & Khera
3. *Aphelenchoides sanwali* Chaturvedi, Singh & Khera
4. *Seinura hechlerae* Chaturvedi, Singh & Khera
5. *Metaphelenchus goldeni* Chaturvedi, Singh & Khera
6. *Rhabditis* (*Indorhabditis*) *olitorius* Chaturvedi & Khera
7. *Panagrolaimus burdwanensis* Chaturvedi & Khera
8. *Acrobeles timmi* Chaturvedi & Khera
9. *Chronogaster loofi* Chaturvedi & Khera
10. *Neoactinolaimus thornei* Chaturvedi & Khera
11. *Alaimus siddiqii* Chaturvedi & Khera

Genera constituting first record from India (Chaturvedi & Khera, 1977)

1. *Chitinotylenchus* (Micoletzky, 1922) Filipjev, 1936
2. *Metaphelenchus* Steiner, 1943
3. *Neoactinolaimus* Thorne, 1967
4. *Isolaimium* Cobb, 1920
5. *Discolaimoides* Heyns, 1963

Species constituting first record from India (Chaturvedi & Khera, 1977)

1. *Chitinotylenchus paragracilis* (Micoletzky, 1922) Filipjev, 1936
2. *Pratylenchus minyus* Sher & Allen, 1953
3. *Paraphelenchus myceliophthorus* Goodey, 1958
4. *Cephalobus persegnis* Bastian, 1865
5. *Tripyla* (*Trischistoma*) *arenicola* de Man, 1880
6. *Dorylaimellus parvulus* Thorne, 1939
7. *Dorylaimellus andrassyi* Heyns, 1963
8. *Discolaimoides bulbiferus* (Cobb, 1906) Heyns, 1963
9. *Ironus longicaudatus* de Man, 1884

* One new genus and new species published elsewhere *Caballeroides Olitorius* Chaturvedi & Khera, 1977.

TABLE 1. Nematodes associated with jute

Nematodes	Earlier record	Present record
1. *Tylenchus filiformis*	–	+
2. *Chitinotylenchus paragracilis*	–	+
3. *Ditylenchus? dipsaci*	–	+
4. *Pseudhalenchus anchilisposomus*	–	+
5. *Tylenchorhynchus* sp.	+	–
6. *T. martini*	+	–
7. *T. mashhoodi*	–	+
8. *Pratylenchus coffeae*	–	+
9. *P. minyus*	–	+
10. *P. pratensis*	+	–
11. *Hirschmanniella oryzae*	+	+
12. *Hoplolaimus* sp.	+	–
13. *H. indicus*	+	–
14. *H. dubius* n.sp.	–	+
15. *Helicotylenchus multicinctus*	+	–
16. *H. indicus*	–	+
17. *H. retusus*	–	+
18. *H. indentatus* n.sp.	–	+
19. *Meloidogyne* spp.	+	–
20. *M. incognita*	+	+
21. *M. javanica*	+	+
22. *Rotylenchulus reniformis*	–	+
23. *Paratylenchus* sp.	–	+
24. *Criconemoides rusticum*	+	–
25. *C. ornatus*	–	+
26. *Aphelenchus avenae*	–	+
27. *Aphelenchoides* spp.	+	+
28. *A. saprophilus*	–	+
29. *A. asterocaudatus*	–	+
30. *A. sanwali* n.sp.	–	+
31. *Caballeroides olitorius*	–	+
32. *Seinura hechlerae* n.sp.	–	+
33. *Paraphelenchus myceliophthorus*	–	+
34. *Metaphelenchus goldeni* n.sp.	–	+
35. *Rhabditis (Indorhabditis) olitorius* n.subgen., n.sp. ...	–	+
36. *Pelodera (Cruznema) dunensis*	–	+
37. *Panagrolaimus burdwanensis* n.sp.	–	+
38. *Cephalobus persegnis*	–	+
39. *Acrobeles timmi* n.sp.	–	+
40. *Chronogaster loofi* n.sp.	–	+
41. *Priamatolaimus andrassyi*	–	+
42. *Abunema indicum*	–	+
43. *Achromadora ruricola*	–	+
44. *Tripyla (Trischistoma) arenicola*	–	+
45. *Ironus longicaudatus*	–	+
46. *Cryptonchus abnormis*	–	+
47. *Discolaimoides bulbiferus*	–	+
48. *Longidorella macramphis*	–	+
49. *Xiphinema (X.) americanum*	–	+
50. *X. (Elongiphinema) insigne*	–	+
51. *X. indicum*	+	–
52. *Neoactinotaimus thornei* n.sp.	–	+
53. *Dorylaimellus parvulus*	–	+
54. *D. andrassyi*	–	+
55. *Alaimus siddiqii* n.sp.	–	+
56. *Mylonchulus lacustris*	–	+
57. *Iotonchus trichurus*	–	+
58. *Hadronchus* sp.	–	+
59. *Isolaimium* sp.	–	+

SURVEY

Nematodes cause considerable damage to various crops and jute is not an exception to this. There have been frequent reports of wilting, stunting, crinkled leaf and other symptoms of nematode infestation in jute crop but hardly anything is known about these pests of jute beyond these reports. Organised attempts have not been made in any country to survey the jute growing areas regarding the qualitative and quantitative data pertaining to nematodes associated with the crop—hence the present study.

Materials and Methods

In India, West Bengal being the main jute growing state, jute fields of this state were selected for the present study. A statewide survey was conducted in three jute seasons during the years 1970 to 1972. An attempt was made to represent almost all the major jute growing tracts of West Bengal. The various localities in

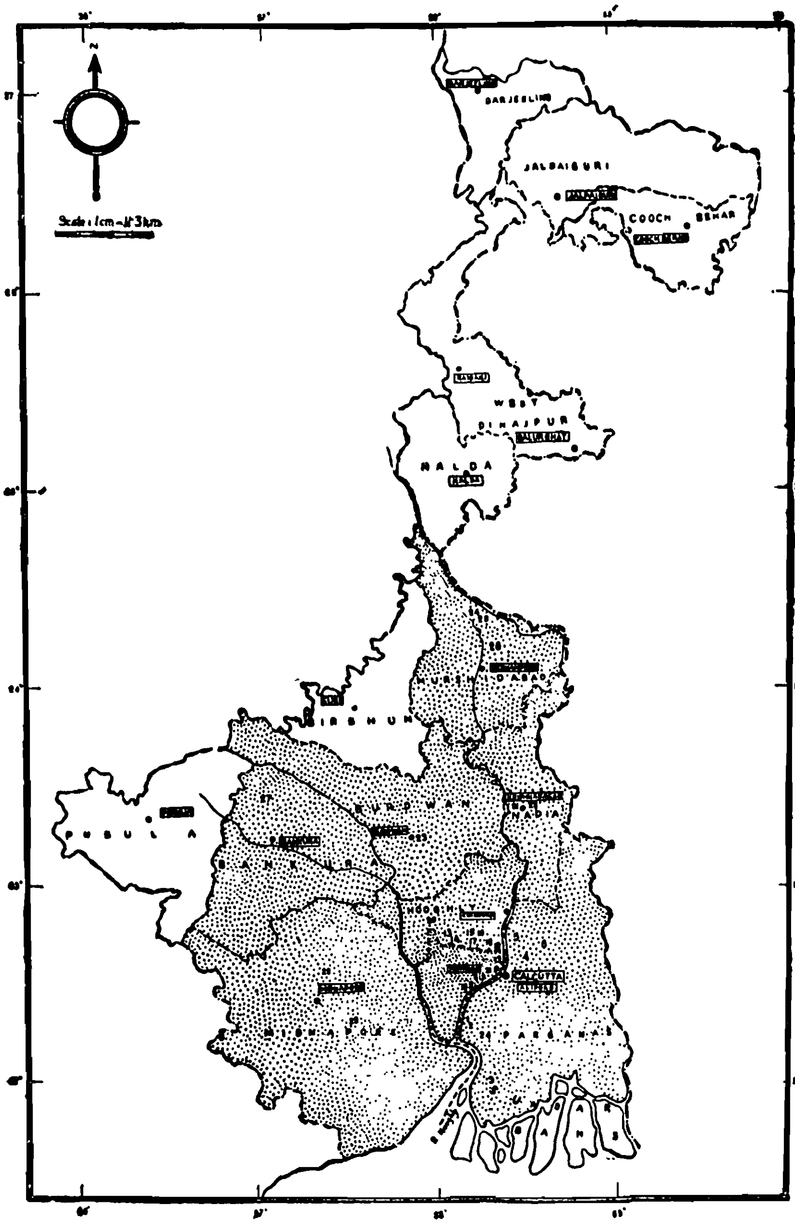

Fig. 22. Map of West Bengal depicting collection sites.

the eight districts, 24-Parganas, Howrah, Hooghly, Burdwan, Nadia, Midnapur, Murshidabad and Bankura (Fig. 22) were visited in all the three seasons on several occasions and the soil as well as root samples were collected. District Purulia was visited once but no sample could be collected because jute is rarely grown in this district, the latter being a dry area. The samples collected were processed by the method described in the chapter on general materials and methods.

RESULTS

Two hundred thirty samples from 173 fields, belonging to 29 localities, covering eight districts of West Bengal were examined. Qualitative data are presented in the Table 2. Altogether 48 species of nematodes were encountered. Of these, 27 species are plant parasitic and 21 species are free-living. The plant parasites included tylenchids, aphelenchoids and some dorylaims like *Xiphinema* and *Longidorella*. Most of the free-living species found are also said to cause damage to the plants (Paramonov, 1968). Further, these nematodes also included some predators such as *Seinura* and mononchs. Two species of *Xiphinema* a proven virus vector, were also found. Three endoparasites, two species of root-knot nematodes and one species of reniform nematodes, were also recorded.

The external examination of plants in the fields hardly showed any pathogenic symptoms except in those which were infested with root-knot nematodes. The plant infested with root-knot nematodes showed wilting, stunted growth, crinkled and variegated leaves, shrivelled stem and galled roots. Heavily infested fields showed patchy growth in the field. The examination of roots in the laboratory showed scars of mechanical injuries by ectoparasitic nematodes.

DISCUSSION

The data obtained (table 2) show that *Hoplolaimus dubius* n.sp., *Tylenchus filiformis* Butschli, 1873, *Meloidogyne javanica* (Treub, 1885), *M. incognita* (Kofoid and White, 1919), *Tylenchorhynchus mashhoodi* Siddiqi and Basir, 1959, *Aphelenchus avenae* Bastian, 1865 are widely distributed species in that order and were recovered from more than 50% of the localities. *H. dubius* n.sp., *T. filiformis*, *M. javanica* and *M. incognita* were present in more than 25% of the samples examined from various places. The number of *M. javanica*, *M. incognita*, *H. dubius*, *T filiformis* and *A. avenae* were abundant in individual samples. Numerically other plant parasitic species could be rated as low and their distribution very much restricted. The number of rhabditid and dorylaim was much higher than those of tylenchids. They showed wide distribution; higher incidence of occurrence and intensity.

The predators and vectors were less in number and limited in distribution. A single reniform nematode was found from each of the two localities. Similarly, a single specimen (a female) of *Paratylenchus* Micoletzky, 1922 was collected from the soil around the roots of *C. olitorius* from Sujapur, Dist. 24-Pargana which, however, was damaged and is not included in the chapter on taxonomy.

POPULATION DYNAMICS

The fluctuations in nematode population in fields with relation to environmental conditions and crop management have been studied by Hollis and Fielding (1955) on soybeans and rice; Stemerding (1961) on pea; Zuckerman, Khera and Pierce (1964) on cranberry; Rodriguez, Jordan and Hollis (1965) on rice; Mukhopadhyay and Prasad (1968) on wheat, maize, cotton and sugarcane; and Khan, Adhami and Saxena (1971) on mango. A study of populations, in the absence of host, has been made amongst other by Overmann (1965), Tikyani and Khera (1969) and Seinhorst (1970).

Timm and Ahmed (1961) and Timm, Ahmed and Waseque (1961a, b) have studied the influence of root-knot and lance nematode on growth and wilting of jute, effect of lime fertilizer and other chemical treatment of soil. However, no study seems to have been made on the population dynamics of nematodes in jute fields. The present study is an attempt in this direction.

Materials and Methods

It is known that the method employed does not ensure recovery of absolute number of nematodes hence the population data in present study show only the trend of fluctuations in population and not the absolute changes.

For population studies two plots of 2×2 meters size were selected at the State Agricultural Farm, Burdwan, West Bengal. The study was taken up in May, 1972 and was continued up to and including May, 1973 (observations could be made only for 13 months for the reasons beyond authors' control). Prior to the present study the plots were left fallow for about two months. The soil of the plots was sandy-loam. There were paddy fields on the three sides of the plots. In the beginning of May, 1972, jute (*Corchorus olitorius* var. JRO620) was sown in the plots.

The collection of soil samples was started from the time just before sowing of jute, then weekly samples were collected for six weeks, after which fortnightly samples were taken till the 10th day of sowing of the jute in the next season. The samples were taken at random leaving the edges of the plots, from 10–15 cm depth with the help of a soil-auger and scooping hand-shovel. The time of watering, monthly rainfall and temperature were noted.

Processing of soil samples and assessment of nematode population.—The soil of each ample was mixed well, 500 c.c. of the composite sample was taken and mixed with water in a plastic bucket. The mixture was passed through sieves of 60, 100, 175, 250 and 325 mesh numbers. The residues from the sieves of 250 and 325 mesh numbers were taken in a beaker. It was made up to 100 ml by adding more water. The mixture was made homogenous by bubbling air through it. A volume of 10 ml was pipetted out in a petri dish from this mixture. All the nematodes present in it were hand-picked, killed by heating up to 60°C for a few seconds avoiding overheating. The nematodes were fixed in F.A.A. (formalin 30 ml, glacial acetic acid 5 ml, absolute alcohol 100 ml and distilled water 200 ml). The specimens were processed by slow-glycerine method (Thorne, 1961) and mounted on glass slides. The nematodes thus mounted were identified and counted. As this number indicated the nematodes present in 10 ml suspension, it was multiplied by ten, which gave the total number of nematodes present in 500 c.c. of the soil. From this computation an average monthly data was obtained for each plot. Again, average population of two plots jointly was calculated for analysing the results. The samples could not be collected in September.

Crop management.—Jute was sown in the plots in the first week of May, 1972 (the sowing was rather late due to late rainfall). This crop was harvetsed in the middle of September. From the middle of September up to a few days in November the plots were left fallow (About 1½ months). During this period tillage was done twice. On the fourth day of November, 1972, pea (*Pisum sativum* Linn.) was sown. It was harvested in the middle of February, 1973. After pea, sesame (*Sesamum indicum* Linn.) was sown but the latter failed to grow, hence, the plots were left fallow from mid February to the second week of April. In the beginning of the third week of April jute was sown again. The crop management was done by the farm authorities and was beyond the control of the authors. However, the crop management thus provided an opportunity to observe the effects of fallow as well as alternate cropping on the nematode population.

Climate.—West Bengal is rarely subjected to extreme climatic conditions. The rainfall is common throughout the year although in winters it may be very meagre or even nil. Sometimes nor' westers which occur in April and May, and the summer monsoons cause heavy downpours. Temperature rarely goes above 40°C (max.) and below 10°C (min.).

During the period of observation May, 1972 was the hottest month (max. 40.6°C) and January, 1973 the coldest (min. 14.7°C). Near drought conditions prevailed during March and April, 1972. Maximum rainfall was in August, 1972 (598.9 mm) while December, 1972 and April, 1973 were dry months (Table 3, Fig. 23, A).

Results

A break up of nematode population is shown in the table 3. Dorylaims and rhabditids constituted the major portion of the total population. Tylenchids, other than root-knot nematodes, came third in numbers. The root-knot nematode was left out of consideration because it requires an altogether different technique for population studies. The three tylenchids, viz. *Hirschmanniella oryzae* (Soltwedel, 1889) Luc and Goodey, 1963; *Tylenchorhynchus mashhoodi* Siddiqi and Basir 1959 and *Helicotylenchus indentatus* n.sp. were chosen for detailed studies because of their larger number.

(i) *Hirschmanniella oryzae* (Fig. 23, B).—In May, 1972 population of *H. oryzae* was the highest (52/500 ml of soil) encountered throughout this study. In June and July a fall in nematode population (37 and 12 respectively) was noticed. In August the population came down to a very low level (5). This was the time of maximum precipitation. Population of this nematode remained low (3) till October. Again in November there was a rise in population (20) and there was another population build up from November, 1972 to February, 1973 (20, 24, 12 and 15 respectively). However, this rise of population was not as high as that of May, 1972. Population remained much low (5) in March, 1973. It started rising in April (15) and showed a high build up (30) again in May, 1973. Although smaller than that of May, 1972, the tendency of this build up was unmistakable.

(ii) *Helicotylenchus indentatus* (Fig. 23, B).—The population fluctuations of *H. indentatus* were more or less consistent with those of *H. oryzae*. The population was high (52/500)ml of soil) in May, 1972. A slight reduction in population was noticed in June and July (46 and 38 respectively). In August the nematode population went down drastically so that no nematode could be detected in the sample. Some rise in population was registered in October (6). Further build up of population took place from November, 1972 to February, 1973 (15, 25, 10 and 10 respectively) showing a small peak in December. In March population came so low that *H. indentatus* could not be detected again. The population started building up in April (4) and rose high (28) in May, 1973. However, population in May, 1973 could not reach the level of May, 1972.

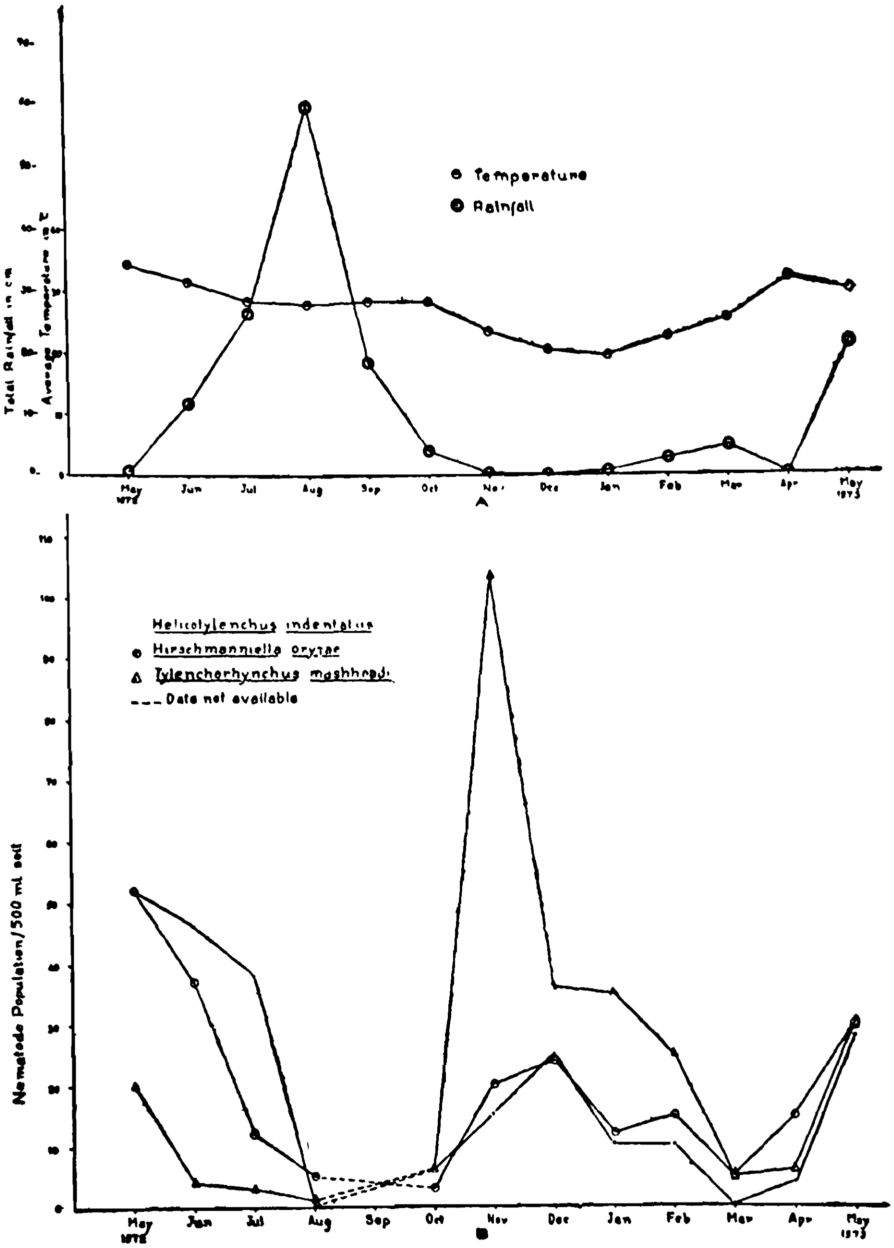

Fig. 23. A. Graph showing rainfall and temperature; B. Graph showing population fluctuations of:

(*i*) *Hirschmamniella oryzae*

(*ii*) *Helicotylenchus indentatus*

(*iii*) *Tylenchorhynchus mashhoodi*

(iii) *Tylenchorhynchus mashhoodi* (Fig. 23, B).—The population of *T mashhoodi* showed a completely different pattern than those of *H. oryzae* and *H. indentatus*. In the month of May, 1972 population showed a small build up (20/500 ml of soil). There was a sharp fall in June (4) and the population went on decreasing gradually from July to August (3 and 1 respectively). A very small population was noticeable in August. In October a slight rise in population was observed (6). In November the population of *T mashhoodi* shot up very high (104). This peak in population was followed by a sudden crash in December (36). From December to January, 1973 there was little change and population remained rather stable. It showed a gradual fall in February and March (25 and 5 respectively). In April some rise in population was observed (6) and in May, 1973 it showed a higher build up (30) than in May, 1972.

(iv) Dorylaims (Fig. 24).—The initial population of dorylaims in May, 1972 was higher (458/500 ml of soil) as compared to the combined total of the three species of tylenchid nematodes dealt with above. There was only a slight increase in June (532) but in July the population reached its peak (888). This sudden increase in population was followed by a decline in the population in August (280) which was even lower than the initial population. The population remained low till October (95). In November there was a build up in the population (223). The population more or less maintained itself in December (198). Again it came down in January (100). From February onwards population of dorylaims went on rising (with slight depression in April) and in May, 1973 it reached its second peak (735). However, this peak was slightly smaller than that of July, 1972.

(v) Rhabditids (Fig. 24).—The rhabditid population was second to that of dorylaims. This population showed three peak periods in July (330), December (485) and February (425). The initial population in May, 1972 was low (67) and three peaks were followed by three periods of fall in population in August to October (105–25), January (222) and March to April (137-115). In May, 1973 again it showed a tendency towards increase (148).

Discussion

The population of nematode parasites of plants is governed by the same general rules which affect the population of other animals, but it is complicated by the requirements of suitable hosts. The animal population is influenced by two sets of factors, one which favours increase in population—"Welfare factors" and other set which brings a fall—"Decimating factors" These factors may be density-dependent like sex ratio, competition for food, etc. or density-independent like environmental factors, host specificity, resistance, etc. The sum total of all decimating factors, which operate to cause mortality added to those effects of welfare factors is known as the "Environmental resistance" It represents resistance of any environment to the unlimited increase of a species population.

Each population has a theoretical maximum growth rate, which is known as "biotic potential" The growth, decline or stability of population can be regarded as the resultant of the action of two forces: biotic potential and environmental reistance. According to the nature of fluctuations, populations may be stable, irruptive or cyclic type. Lack (1954) and Odum (1959) have shown that a marked increase brings proportionately higher loss; a decrease brings reduced rate of loss. In other words it can be said that every population—peak is followed by a crash period.

In the present studies mainly density-independent factors: temperature, moisture or rainfall and host or crop management are considered. A glance at the population curves (Figs. 23, B; 24) shows that all the populations taken into consideration are irruptive in nature, showing peak and falls but not in a fixed cyclci order.

Rainfall (Table 3; Fig. 23, A–B).—Rainfall keeps the soil moist and the soil moisture plays an important role in the life of a nematode. Workers like Collis-George and Blake (1959), Wallace (1963), Tikyani and Khera (1969), and Simons (1973) have studied the role played by moisture as a factor in population dynamics.

In May, 1972 there was little rainfall but the plots were irrigated once a week to maintain the moisture. During this month the population of *H. oryzae* and *H. indentatus* were found to be the highest as compared to the populations in the following months. The rainfall gradually increased in June and July and was maximum in August. As a result the plots were flooded and all the three populations showed a

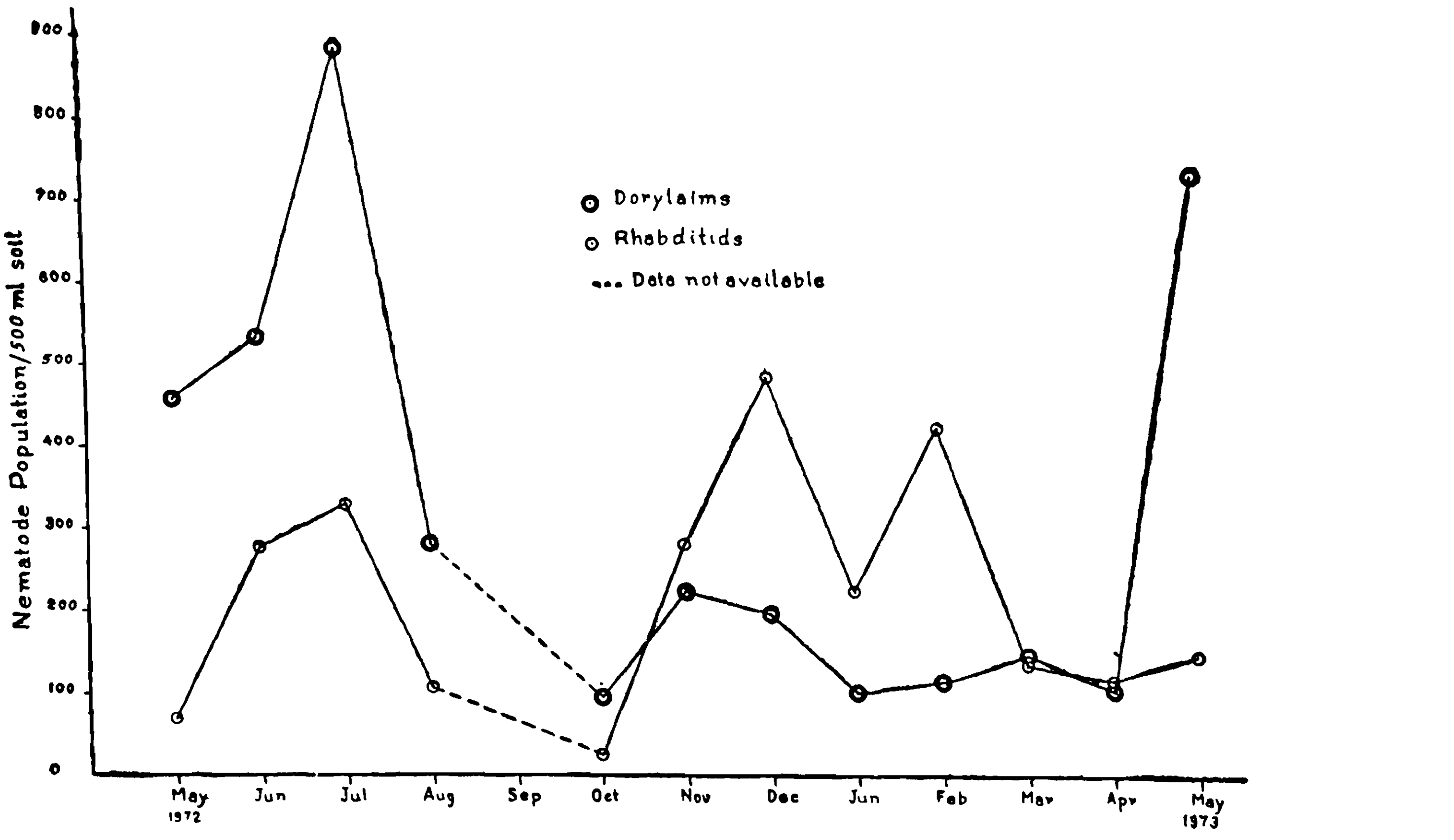

Fig. 24. Graph depicting population fluctuations of dorylaims and rhabditids.

steep decline which was much sharp in the case of *H. oryzae* and *H. indentatus.* Previously it was known that *H. oryzae* was more tolerant to saturated moisture conditions (Wallace, 1963) and was expected to endure the heavy rains. But the present study indicates that the contention of Rodriguez, Jordan and Hollis (1965), who found the fluctuations in *H. oryzae* population in paddy fields similar to those of other nematodes, was more true. Thus it appears that under the influence of heavy rains population level of all the three species remained low till October.

In winters there were little or no rains. The three populations showed a build up from October to February. However, populations of *H. oryzae* and *H. indentatus* remained much low but that of *T mashhoodi* reached its maximum in the month of November. Thus it becomes obvious that soil moisture requirement of *T mashhoodi* was much less than that of *H. oryzae* and *H. indentatus.* It may also be so because pea was sown on the 4th November. In March there were good rains and three populations again showed a downward trend. The rainfall in May, 1973 was higher, yet the three populations showed high build up for which some other factor(s) must have been responsible.

Temperature (Table 3; Fig. 23, A–B).—Average temperature in the more or less rainless month of May 1972 was 34.2°C, this appeared to favour *H. oryzae* and *H. indentatus* but not *T mashhoodi* to the same extent. The first two species showed high peaks (when compared to populations in the following months) in this month while the population of the latter species showed a small peak. Krusberg (1959) has shown that optimum temperature for *Tylenchorynchus claytoni* was 29°–35°C on tobacco and 21°–27°C on wheat. It appears that higher range of temperature was not favourable for *T mashhoodi* in the present case.

In June the temperature came down slightly (31.4°C average) but from July to October there was little change (average 28°–28.9°C) yet all the three populations showed a downward trend. This shows that during this period temperature did not play the role of decimating factor. It was rainfall rather than temperature which played the decisive role.

The temperature decreased to 23.4°-20°C in November, 1972 to February, 1973. This range does not appear much favourable to *H. oryzae* and *H. indentatus* because these two populations showed only a small build up during this period. However, population of *T mashhoodi* had a high biotic potential and reached its maximum in November (perhaps also due to the sowing of pea). Soon in December there was a proportionate crash in population of *T mashhoodi* due to self limiting factor and low temperature. After that, rate of decrease in population slowed down till February, 1973. The peak formation in November by *T mashhoodi* indicates that like *T claytoni* on wheat (Krusberg, 1959), *T mashhoodi* has an optimum temperature in lower range i.e. 23.4°C. In March and April temperature rose (25.6°–32.1°C) and all the three populations decreased to a great extent. In May, 1973 although temperature came down slightly (30°C) yet it was higher than in March. Even then populations of the three species increased. It seems that the population from March to May, 1973 fluctuated irrespective of temperature changes, probably under the influence of some other factor (perhaps because jute was sown in April).

Fallow.—Our knowledge regarding the longevity of nematodes in fallow soil is of much importance in their control. *Tylenchorhynchus* has got maximum longevity in fallow. *T claytoni* is reported to survive for ten months (Krusberg, 1959) and *T icarus* for nine months (Wallace and Great, 1963). *Helicotylenchus* comes next, it can survive for eight months (Golden, 1956). *Radopholus* an allied genus of *Hirschmanniella*—has got low longevity about three months (Simons, 1973).

The present study shows that during two fallow periods, first from the middle of September to early November and second, from the middle of February to the second week of April, populations of all the three species declined greatly. Very hot and dry soil conditions, essential for rapid desiccation during fallow period, were however, not available because of frequent rains and the population of nematodes resurrected itself with the reapproaching of suitable conditions.

Crop management.—The nematodes show host preference not only for feeding but their biotic potential too vary from host to host. In resistant varieties or non-host species there may be less or no reproduction; consequently the population falls (Wallace, 1963).

The two species *H. oryzae* and *H. indentatus* showed maximum population build up in two jute seasons. When pea was grown these two species showed an increase in population which, however, remained much low than on jute. On the other hand, *T mashhoodi* showed a reverse host preference. Its population attained peak during pea-growing period while there was only a small build up in jute-growing months. Stemerding (1961) has shown that pea is a preferred host crop for *T dubius*.

Summing up it can be said that *H. oryzae*, *H. indentatus* and *T mashhoodi* have got irruptive populations which fluctuate under the influence of environmental resistance created by the factors like temperature, rainfall and host on one hand and their biotic potential on the other hand.

For *H. oryzae* and *H. indentatus* 30°–34°C appears to be favourable temperature and for *T mashhoodi* 23°C was more suitable. The observations also revealed that rainfall had a greater effect on nematode populations than the temperature. Whenever there were heavy rains, population of all the three species suffered a severe setback. However, difference in the rate and degree of fall in populations indicated that the three species have different tolerance for soil moisture. Although *H. oryzae*

TABLE 3. Crop management, total rainfall, average temperature and nematode population/500 ml soil.

Sl. No.	Month	Crop Management	Rainfall (in cm)	Average temperature (°C)	NEMATODE POPULATION					Total Population
					Helicotylenchus indentatus	*Hirschmanniella oryzae*	*Tylenchorhynchus mashhoodi*	Dorylaims	Rhabditids	
1.	May, 1972	↑	0.24	34.2	52	52	20	458	67	649
2.	June	|	11.68	31.4	46	37	4	532	278	897
3.	July	Jute	26.20	28.9	38	12	3	888	330	1271
4.	August	↓	59.89	28.0	nil	5	1	280	105	391
5.	September	↑	18.10	28.5	—	—	—	—	—	—
6.	October	Fallow	3.95	28.4	6	3	6	95	25	135
7.	November	↓	0.06	23.4	15	20	104	223	280	642
8.	December	↑	nil	20.3	25	24	36	198	485	768
9.	January, 1973	Pea	0.52	19.7	10	12	35	100	222	379
10.	February	↓	2.45	22.8	10	15	25	115	425	590
11.	March	↑ Fallow	9.57	25.6	nil	5	5	147	137	294
12.	April	↓	nil	32.1	4	15	6	102	115	242
13.	May	↑ Jute	21.17	30.0	28	30	30	735	148	971
			Total		234	230	275	3873	2617	7229
			Percentage		3.2	3.1	3.8	53.5	36.2	X

and *H. indentatus* showed preference for jute and *T mashhoodi* for pea, yet, the three species could subsist upon either jute or pea. Therefore, these two crops cannot be considered a good combination for alternate cropping. Further, leaving fallow land also cannot be much useful under humid climatic conditions of West Bengal

The present observations also show that 28°–32°C temperature range and heavy rainfalls were favourable for dorylaims. Incidentally, these two factors are also responsible for rapid decomposition of organic matter. The rhabditids required comparatively low temperature and less rainfall or soil moisture. The low population of predatory dorylaims also should have helped in the high build up of the rhabditids.

EMBRYOLOGY, LIFE CYCLE, ABUNDANCE OF MALES AND INTERSEXUALITY OF *MELOIDOGYNE JAVANICA* (TREUB, 1885) CHITWOOD, 1949 PARASITIC ON JUTE

The sedentary mode of life and highly pathogenic character of *Meloidogyne* spp. have earned the latter a notoriety amongst the plant parasitic nematodes. For these reasons different species of the genus have been studied extensively and their life cycles investigated. The first comprehensive account of the life cycle of *Meloidogyne* sp. was given by Nagakura (1930). Later on Tyler (1933), and Christie and Cobb (1941) studied the life cycles of different species. As these studies were made before the revision of the genus by Chitwood (1949), the identification of the species cannot be stated with any certainty. Tarjan (1952) worked on five species of *Meloidogyne* but he did not give details of moults, etc. and confined his studies mainly on comparative changes in size. Recently more complete accounts of the life cycles of *Meloidogyne* spp. have been given [Ritter and Ritter (1958) on *M. incognita acrita*, Triantaphyllou and Hirschamann (1960) on *M. incognita* and Bird (1959) on *M. javanica* and *M. hapla*]. The life cycle of *M. javanica* was studied on tomato plants in Australia by Bird (*loc. cit.*). In India although histopathological studies have been made on *M. javanica* (Swarup and Pillai, 1963; Lall *et al.*, 1965) its embryology and life cycle have not been worked out under Indian conditions, as well as on jute plant.

Materials and Methods

The method described by Seshadri (1964) was tried for embryological studies but without success since the fungal contamination interfered with the development of the eggs. The eggs were, therefore, collected at different stages of development from the egg masses of the females developed from a single egg mass. These were stained in 0.1% acid fuchsin lactophenol and cleared in pure lactophenol. The embryonic development was reconstructed by the various stages of developing eggs.

For life cycle studies, fifty 15 cm earthen pots were filled with a mixture of soil and cowdung manure (3 : 1) and sterilized with methyl bromide. The soil was thereafter tested for phytotoxic effect, if any, by growing some jute plants in two pots filled with this soil. Seeds of jute, *Corchorus olitorius* var. JRO 632 were then sown in the rest of the pots. The seedlings sprouted after three days and were allowed to grow for ten days. On the 11th day tillering of plants was done and only three plants were left in each pot. The pots were kept in the open for one month.

A large number of second stage infective larvae of *M. javanica* were obtained from a single egg mass culture maintained on tomato plants. Approximately five hundred larvae were inoculated in each pot. The requisite number of larvae was drawn by a pipette from a suspension in water (the number of larvae in the stock suspension was calculated per millilitre and adjusted suitably by adding more water) and poured in 3–4cm deep holes made around plant roots, in each pot. The holes were closed and soil irrigated lightly. One pot was washed after 24 hours interval regularly. The removed plants along with the soil were kept in a bucket of water for about 30–45 minutes to remove the soil without any mechanical damage to the roots. After taking out the plants, roots were washed gently under water tap to remove all the soil particles adhering to the root hairs. The roots were cut into pieces of 2–3 cm length. The pieces were boiled in 0.1% acid fuchsin lactophenol for three to five minutes, then changed to pure lactophenol for clearing. The washing, processing and study of the roots were undertaken till the females matured and started laying eggs. Some egg masses collected from gravid females were kept in water in a petri plate and the time for emergence of the second stage infective larvae was noted. The period from the second stage larvae at the time of inoculation to the emergence of the new generation of second larvae was counted as one complete life cycle.

The stained roots were dissected with the help of fine needles for different larval growth stages. The larvae were mounted in lactophenol on glass slides according to their age (in number of days). The slides were studied and various growth changes as well as measurements recorded.

During the period of first infestation males were not seen within the roots. Some of the infested plants left for four more weeks to allow secondary infestation were processed as described above; these revealed the presence of males. However, development of males could not be correlated with the ages of larvae because exact time of penetration by second generation larvae was not possible to ascertain. Observation related to abundance of males, sex reversal and intersexuality were also made. The experiments were performed from 4th July to 23rd August, 1974. During the period of experiment maximum temperature ranged from 29°–35.1°C (average 32.5°C) and minimum 23.6°–28.7°C (average 26.3°C). The total precipitation amounted to 318.7 mm.

Experimental Results

Embryogenesis.—The freshly laid eggs were oblong in shape, single-celled, measuring 77–88 × 31–38 μm (Fig. 25, A). The outer cover comprised a smooth

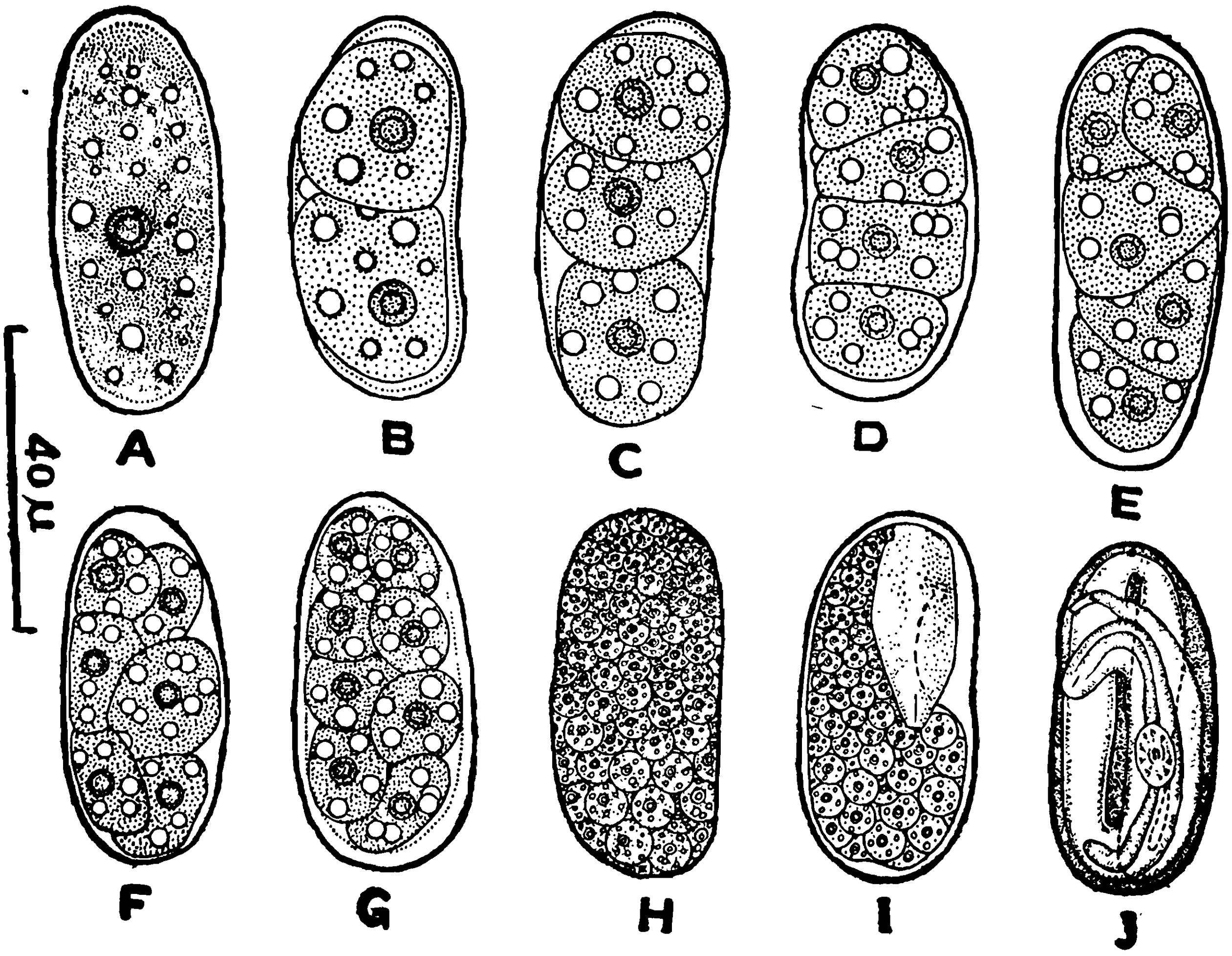

Fig. 25. Embryogenesis of *M. javanica* on *C. olitorius*—A. egg, single celled stage; B. Two celled stage; C. Three celled stage; D. Four celled stage; E. Five celled stage; F. Six celled stage; G. Eight celled stage; H. Multicellular stage; I. Tadpole stage; J. Second stage larva within egg shell.

shell or chorion followed by a thin transparent vitelline membrane which surrounded the protoplasm, the latter being composed of cytoplasmic globules of different sizes with a large nucleus in the middle. In some eggs the protoplasmic mass shrank away from the walls which rendered the vitelline membrane more prominent at the poles.

The single-celled egg divided transversely giving rise to a two-celled stage (Fig. 25, B). A small polar body was also seen at this stage. The anterior cell divided transversely into two, resulting in a three-celled stage (Fig. 25, C). The three cells lay longitudinally in a row. The posterior undivided cell appeared larger. The third division took place in the larger cell and this also was at right angle to the axis of the egg. The eggs now reached the four-celled stage (Fig. 25, D).

In most of the cases the four cells were seen arranged in linear fashion. In a few eggs the orientation of the cells was different giving rise to a somewhat rhomboidal shape. The anterior-most cell of the four-celled stage divided longitudinally and the two divided cells lay side by side (Fig. 25, E). After this one more cell divided giving rise to a six-celled stage; however, it could not be traced as to which cell underwent this division (Fig. 25, F). At this stage the cells became arranged into three tiers, each consisting of two cells. The eight-celled stage, which followed, presented different and varied patterns of cell arrangement (Fig. 25, G). Further divisions resulted in a multicellular stage (Fig. 25, H). Many eggs were found in tadpole stage in which differentiation of the anterior parts had started (Fig. 25, I). Following this stage, fully developed larvae were seen coiled within the egg shell (Fig. 25, J). In a few eggs the loose cuticle of the first moult was also visible at the anterior end of the larvae. The second stage larvae hatched through the shed cuticle of the first moult as well as the egg shell. This was the second stage infective larva.

Postembryonic Development

Second stage female larva (Fig. 26, A–D).—The vermiform second stage infective larvae penetrated the roots of jute within 24 hours after inoculation. The larvae were found in the roots just anterior to the root tip or in meristematic region. After sometime they migrated higher up in the root tissues and settled. Their bodies lay in the cortex while the heads were attached to the stele. The larva showed all the structures like stylet, oesophageal lumen, valve of the median bulb, elongated oesophageal gland, etc. They started feeding on the plant tisue but no change was noticed for the first two days. Third day onward the larva grew thicker without any increase in length. On the 5th day the characteristic spiked tail was noticed although it was not very prominent. The stylet measured 14 μm. The genital primordium, consisting of a few cells, was situated at 58% of body length from the anterior end. Although the larva grew rapidly in thickness, they remained undifferentiated sexually. At this stage the larva differed from the infective stage in its shape, in possessing a stout body, a multicellular genital primordium, broader intestine, shortened gland lobes and a spiked tail (Fig. 26, B). For a few days the growth in body width continued, the posterior end became much broader giving the spiked tail more prominence. On the 6th day genital primordium assumed a triangular shape with base towards the anterior end. The rectal glands also made their appearance for the first time. This was the first sexually differentiated female larva. On the seventh day cell division and enlargement was initiated at two sides of genital primordium and it achieved 'V' shape (Fig. 26, C). The two branches generally directed anteriad, increased in length. Meanwhile genital primordium migrated posteriorly and fixed itself close to the body wall in the vicinity of the rectum. In the second stage excretory pore remained behind the level of median bulb and hypodermis was thicker with prominent nuclei. Thus

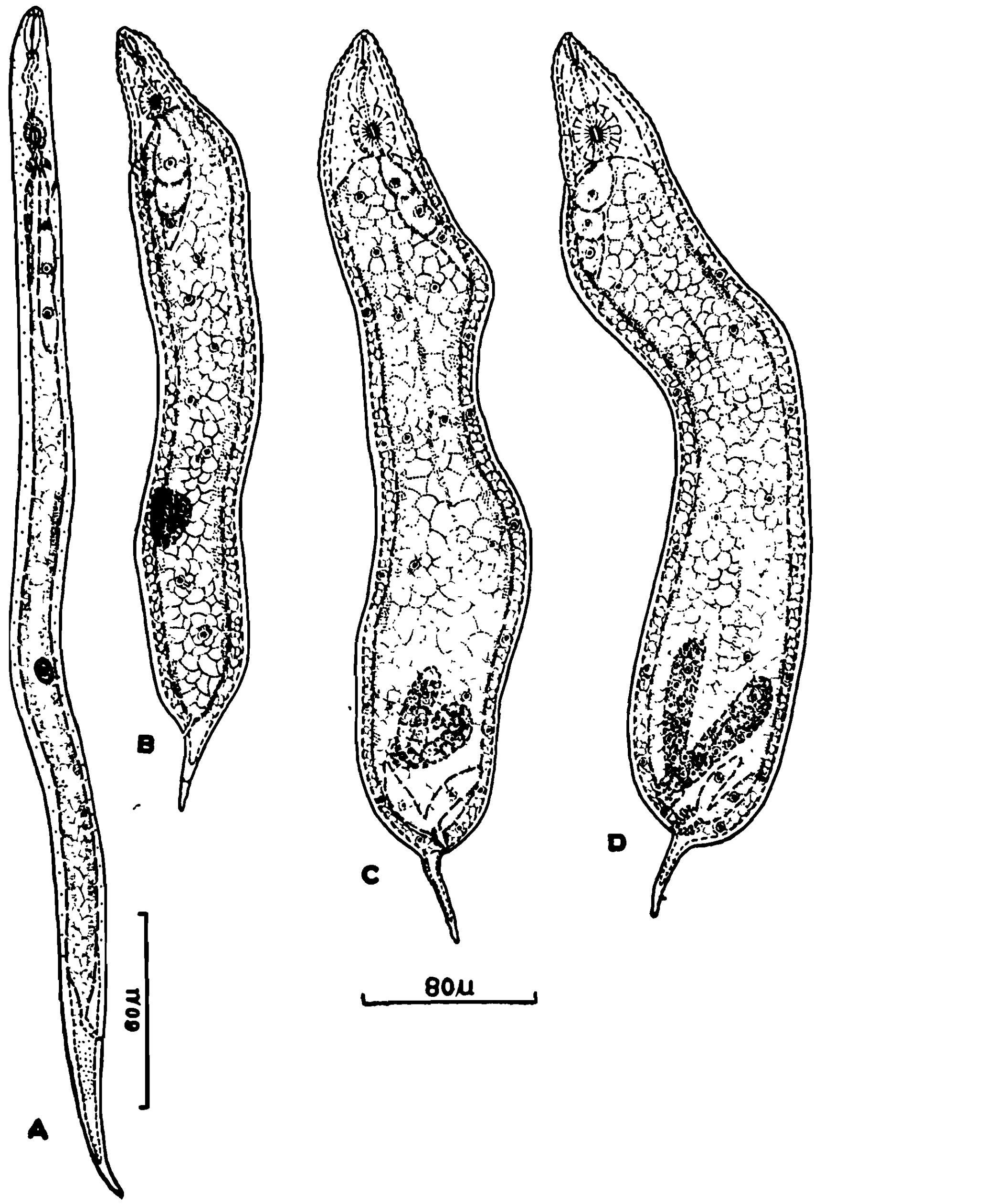

Fig. 26. Different developmental stages of second stage female larva of *M. javanica*.—A. Infective stage; B. Larva with multicellular germinal primordium; C. 'V' shaped germinal primordium, showing sexual differentiation; D. Germinal primordium fixed near rectum.

the second stage larva had four distinct phases; (i) Pre-hatch second stage larva within the egg, (ii) Infective second stage larva, (iii) Second stage larva developed but sexually undifferentiated, (iv) Second stage larva developed and sexually differentiated.

Second moult (Fig. 27, A).—Second moult was observed on the 8th day after inoculation. At the beginning of the second moult, the stylet shaft and knobs disappeared. The cuticle in the lip region separated and the conical part of the stylet (metenchium) was moulted along with it. The area between the old and newly forming cuticle enclosed some coarse granules. The oesophagus shortened, oesophageal lumen and valve plates of the median bulb appeared faintly. Oesophageal gland lobes were compressed. The dorsal gland enlarged and the subventral glands diminished. When moulting proceeded further, the entire old cuticle separated from the newly forming cuticle. The separation of cuticle was best marked in the anterior and posterior regions. The feeding stopped with the onset of moult because the larva remained enclosed in the moulted cuticle and the stylet was moulted.

Third stage female larva (Fig. 27, A).—The third stage larva did not show cuticular striations nor did it possess a stylet. The hypodermis became thicker than that of second stage larva. The oesophagus was further shortened; the lumen of the procorpus vanished and valve plates of the metacorpus were inconspicuous. The head end looked blunt with a rounded mouth opening. The gonads (ovaries) increased in length. At this stage the formation of vagina and uterus was initiated. The rectum narrowed to assume tubular shape. The rectal glands enlarged further. The posterior part of the body became rounded and was without the tail spike. Excretory pore was inconspicuous.

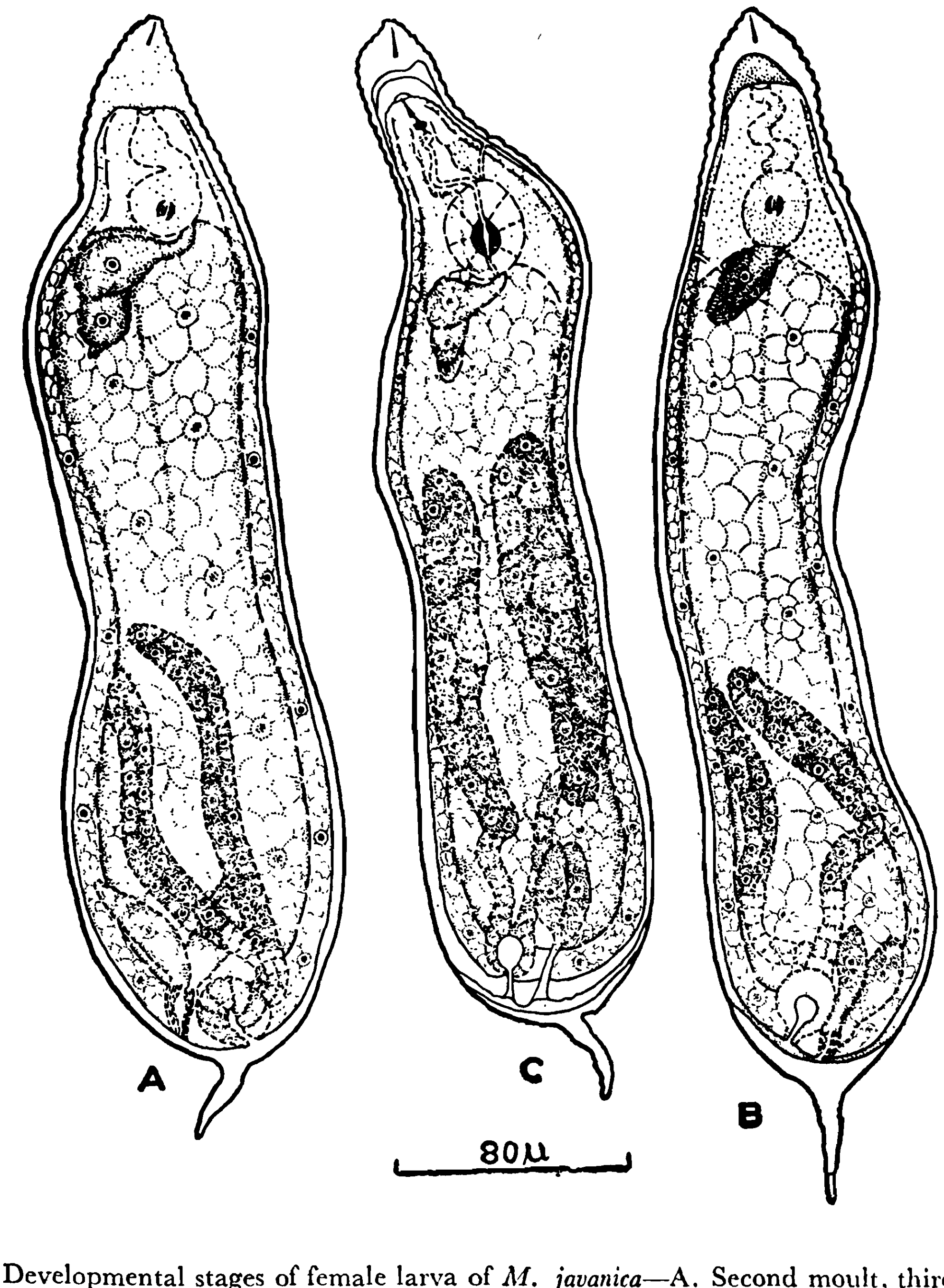

Fig. 27. Developmental stages of female larva of *M. javanica*—A. Second moult, third stage larva B. Third moult, fourth stage larva; C. Fourth moult, adult female within larval cuticle

Third moult (Fig. 27, B).—The third moult was observed on the 9th day. The larva underwent the third moult in a similar fashion as the second. The cuticle first separated off at the anterior end and then in posterior part. The detached cuticle lay between the cuticle of the second moult and the newly formed cuticle. It did not possess any moulted part of stylet by which it could be distinguished from the cuticle of the second moult. In addition, at the posterior end the third moult cuticle was rounded and devoid of any tail spike. At this stage coarse granules were seen on anterior as well as posterior ends, between the newly formed cuticle and the cuticle of the third moult. There was not much change noticed in the larval body. The valve of the median bulb regained some of its definition as also the excretory pore. Ovaries continued to grow further. Likewise, the uterus and vagina also continued their development. The rectal glands enlarged further.

Fourth stage female larva (Fig. 27, B).—Third moult gave rise to fourth stage larva, which remained enclosed within the moulted cuticles of second and the third moult. This larva, too, did not possess any stylet. Oesophagus remained short, its procorpus without distinct lumen. Valve of metacorpus reformed but remained ill-defined. Excretory pore was apparent at about the level of oesophago-intestinal junction. Ovaries were much enlarged. The uterus took a tublar shape and distinct vaginal chamber was formed. The rectal glands increased in size. Hypodermis remained thick, particularly so in the posterior region.

Fourth moult (Fig. 27, C).—The fourth and the last moult was seen on the 10th day after inoculation. The three moulted cuticles of the second, third and fourth moult were clearly visible in the anterior region but less prominently in the posterior region. The main and the most rapid changes occurred during this moult. The lip region assumed the usual cap like shape. The stylet was reformed again after being moulted at the second moult. The procorpus narrowed a little, lengthened, and the lumen became distinct. The valve of the metacorpus became very conspicuous. The excretory pore was clearly distinguishable. The oesophageal glands became rather compact. The ovaries enlarged and started coiling, as also the uteri. Formation of vagina was completed; the vulva became clearly distinguishable. The rectum became tubular and rectal glands attained their maximum size. The folds in cuticle at posterior end were to form the future perineal pattern.

Immature adult female within larval cuticle (Fig. 27, C).—The last and fifth stage of immature adults appeared after the fourth moult. The adult female was enclosed within three moulted cuticles, the outermost of which still carried the conical part of the stylet anteriorly and a spiked tail posteriorly. All the three cuticles could be easily seen on anterior and posterior ends. The immature female shows cuticular striations in the anterior region. Its head end was cap like as in adults. It also possessed well developed stylet. The oesophagus became longer with a distinct lumen. The valve of the median bulb became prominent and larger in size. Oesophageal glands became rather compact. Ovaries and uterine ducts were very much enlarged and were coiled several times. Vulvar opening and vagina were well developed. The rectum became tubular and rectal glands attained maximum growth. The rudiments of perineal pattern appeared on the posterior end.

On the 11th and 12th day many immature females were seen out of their larval cuticles. They started feeding rapidly and increased in diameter extensively, particularly in the posterior region. The secretion of gelatinous matrix which formed the egg sac, started on the 14th day (pl. IV, C). Egg laying started on the 15th day, four to six eggs were seen in each egg sac on that day. On the 16th day some egg masses were collected and kept in distilled water at room temperature (30°C). After three days, hatching of larvae started and on the fourth day the larvae were seen in quite large numbers.

Second stage male larva (Fig. 28, A–B).—The sexually differentiated second stage larva was essentially similar to the female larva and differed only in the shape of the genital primordium. Here, the cell division took place only on one site in the anterior region of the primordium and gonad attained a long rod-like shape. The female larva was distinguishable from male larva by a two-horned genital primordium and the presence of rectal glands. After some time the genital primordium of male larva started moving posteriad and its posterior end became somewhat swollen. In the late second stage posterior end of the gonad reached close to the rectum but remained separate from it. The male larva lacked rectal glands. At this stage the second moult took place.

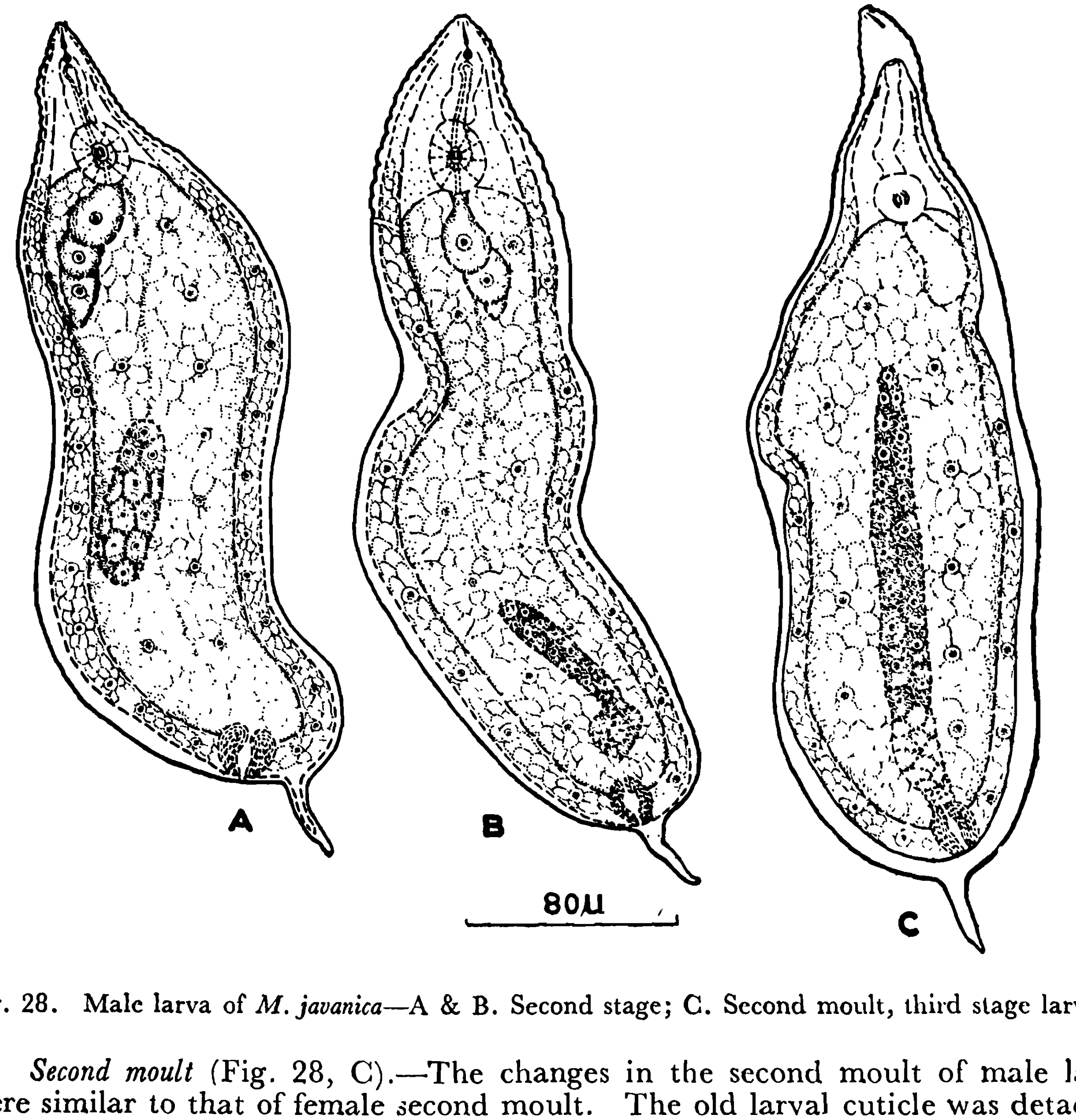

Fig. 28. Male larva of *M. javanica*—A & B. Second stage; C. Second moult, third stage larva.

Second moult (Fig. 28, C).—The changes in the second moult of male larva were similar to that of female second moult. The old larval cuticle was detached and along with it the conical part of the stylet was also separated. However, the granular structures seen in between the two cuticles of the female larva were not visible in this case. The other changes, *viz.* blunt lip region, shortening of the oesophagus, disappearing of the lumen of the procorpus, valves of the median bulb, etc. occurred just as in the female larva. The formation of vasdeferens started at the posterior end of the genital primordium.

Third stage male larva (Fig. 28, C).—The third stage male larva was enclosed in the loosened cuticle of second moult. It was characterized by a blunt rounded head end, absence of stylet, oesophageal duct, valves of the median bulb and the tail spike. It also possessed the rudiments of vasdeferens.

Third moult (Fig. 29, A).—The third moult did not induce much change in the early stage. The larval cuticle separated in anterior region and then in posterior part. Other structures remained more or less as in the third stage larva. The median bulb became discernible. Testis and vasdeferens developed further in size. In the later third moult stage the body started becoming elongate. The narrowing of the body started first from anterior end then in posterior end. The larva started coiling and the formation of stylet, valve plates, spicules and gubernaculum commenced.

Fourth stage male larva (Fig. 29, A).—The fourth stage larva was similar to the third stage larva and differed from the latter only by much enlarged testis and tubular vas diferens connected with the rectum. In the late fourth stage the larval body shape beeame more elongate. The anterior and posterior ends became narrow and coiled, the middle part of the body was still swollen. The rudiments of stylet, valve plates, spicules and gubernaculum were present.

Fourth moult (Fig. 29, B).—The fourth moult brought quite a number of changes. The head assumed its usual wide and flat shape. Cuticular striations became prominent, particularly in anterior region. The body of the adult was coiled two to four times within the cuticle of the third moult. The fourth moult cuticle became visible on the anterior end of the elongate coiled adult male. The stylet was re-formed and the lumen of procorpus reappeared. The median bulb and its valve became very prominent. The oesophageal gland became compact and assumed an elongate shape. Testis and vasdeferens developed fully. The spicules and gubernaculum were also formed and became well sclerotized.

Adult male within larval cuticle (Fig. 29, B).—The fourth moult gave rise to the adult male. It carried a well defined head, well formed stylet, spicules and gubernaculum. Oesophacus was much enlarged and all its components well developed. Testis and vasdeferens became much longer. The body lay coiled within the larval cuticle. The fourth moult cuticle was seen at the anterior end of the adult. After some time adult male came out of the larval cuticle and started feeding.

The complete life cycle took 18 to 19 days. The details of different moults and larval stages with their duration are given in the table 4. While dissecting out and studying the various developmental stages, it was noticed that although inoculated on one and the same day, all the larvae did not show the same stage of development on a particular day. Therefore, a number of larvae (60–175) were examined every day and the number of larvae showing different stages of development was counted. The percentage occurrence of each stage was calculated. The results are summarised in the table 5. From the table, it is obvious that up to the 2nd day the larvae did not show any change in their development. From 3rd to 5th day they increased in size but sexual differentiation started only on the 6th day. On the 7th day maximum number of larvae were sexually differentiated. The moulting started on the 8th day and by 10th day all the three parasitic moults were completed. Adult females, although still within larval cuticle, made appearance on the 10th day. It was noticed that maximum number of larvae of particular stage were found only 2nd or 3rd day after initiation of that stage. The infective larvae were seen even one day before the appearance of adult females, these obviously belonged to the first inoculum. Developed and sexually differentiated second stage female larvae of the first inoculum were found even after the completion of the life cycle.

Abundance of males, Sex reversal and Intersexes.—In the first series of observations not even a single male was found in root tissues. Very few males were recovered

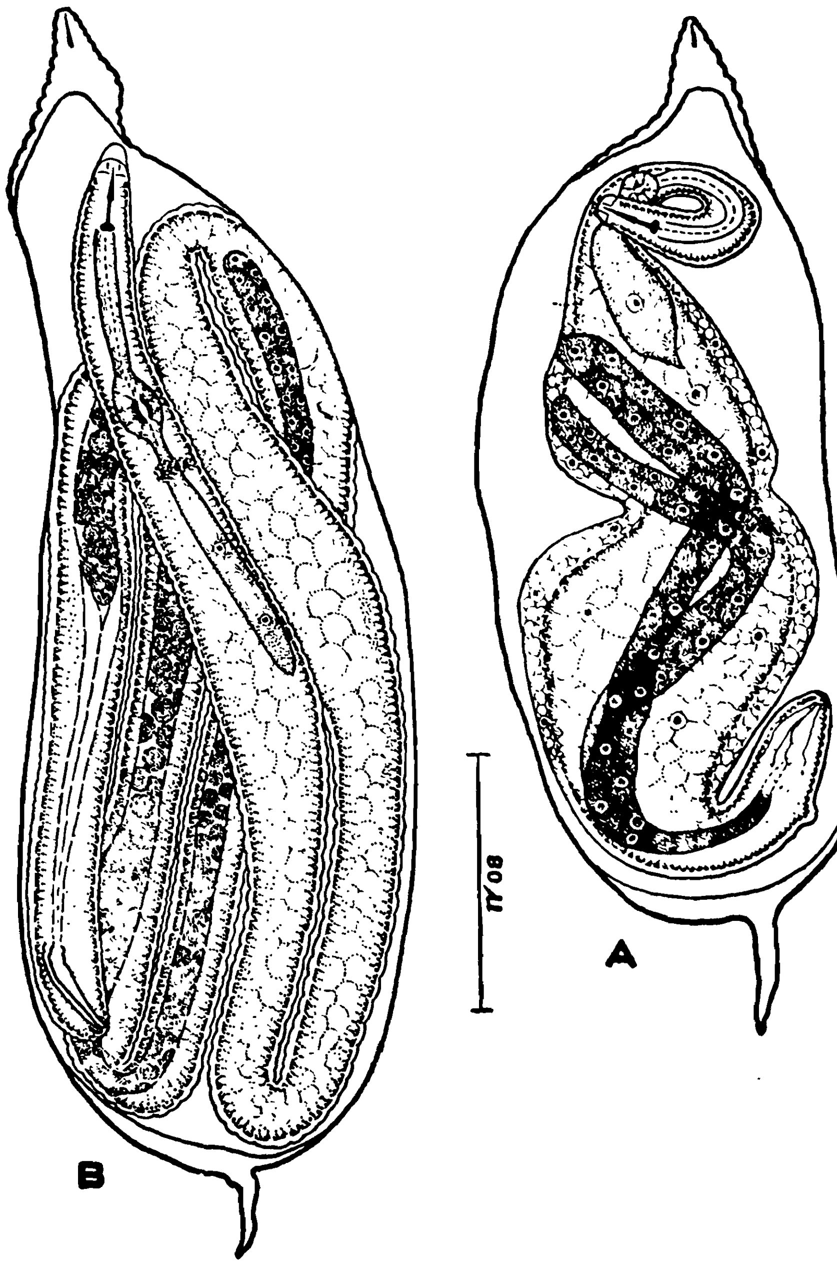

Fig. 29. Male larva of *M. javanica*—A. Third moult, fourth stage larva; B. Fourth moult, adult male within larval cuticle.

from the soil. This was observed till the third week of initial inoculation *i.e.* completion of the first life cycle. Further observations were made in the seventh week after inoculation. It was observed that most of the galls contained males. In thicker roots 13–20 males were found in a simple knot enclosing a single female. In many cases males were also found embedded in the egg masses. In composite knots with many females, "male-nests" were formed enclosing hundreds of males. The apical knots or knots slightly above the apex of the roots were found comprising only males, their number varied from 6–15; the males here were smaller and slower in movement than other males. Such knots were not much swollen and could be distinguished easily by their size, position and wrinkled appearance. Many male larvae were also dissected out showing various developmental stages. Very few female larvae were found with them.

As regards sex, average of ten counts showed that 60% of the adult males possessed single testes showing that they were true males developed from male larvae whereas 40% of males had two testes. These were true males developed from second stage female larvae through sex reversal, without any female character. In these sex reversal was completed at a very early stage.

Only two intersexes were found out of fifty males which showed presence of vulva or some other cuticular structures, reminiscent of an incipient vulva, anterior to the cloaca (Pl. IV, A). The case of larvae was completely different. More than 30% of the males still enclosed inside larval cuticle were found to be male intersexes. Almost all of them had two testes as well as vulva or some other cuticular protuberance, reminiscent of an incipient, vulva, anterior to cloaca (Pl. IV, B).

DISCUSSION

Embryogenesis.—The egg-laying, embryogenesis and hatching in *M. javanica* have been studied by workers like Bird and Wallace (1965), Wallace (1971) and Bird (1972). The present observations show that embryogenesis follows the same pattern as stated by Bird (1972). He has shown that minimum time required for embryogenesis is three to four days at 30°C and maximum seven to ten days at 15°C. In the present studies embryogenesis was completed in three days. Besides temperature, factors like moisture and host plants also play important role as controlling factor in embryonic development (Wallace, 1963).

Life cycle.—The life cycle studies of *M. javanica* show some differences from those made by Bird (1959). In his studies second moult occurred on the 14th day of inoculation, while it was observed on the 8th day in present case. Bird (*loc. cit.*) observed the fourth moult on 15th day of inoculation and the third moult was reported to be of very short duration, quickly followed by fourth moult as also recorded for *M. incognita* by Triantaphyllou and Hirschmann (1960). In the present case the third moult was seen on 9th day and the fourth on 10th day of inoculation. Although a large number of specimens were examined, the fourth moult could not be detected on the 9th day; instead it was observed on 10th day of inoculation. It seems that the duration of third moult was somehow lengthened in the present case. In the experiments conducted by Bird (1959) adult females appeared on the 15th day of inoculation whereas in the present case they were observed on the 10th day of inoculation although within larval cuticle. Other changes during the course of development were found to be the same as reported by Bird (1959). The granular substances seen in between the old cuticle and the newly forming one may be similar to those encountered by Bird and Rogers (1965). These particles are presumed to be associated with the breakdown and re-absorption of the innermost layers of the old cuticle. Regarding the atrophy of subventral oesophageal glands, Bird (1968) suggested that it could be due to its functional disuse as its secretions were perhaps needed for the penetration of roots only. The first parasitic moult involves many structural break downs whereas the final moult induces considerable resynthesis of internal structures.

Bird (1959) has not mentioned the time of egg laying by gravid females, hence, if the time of appearance of adult females alone is taken into consideration the life cycle of *M. javanica* on jute seems to be shorter at least by five days. Various reasons can be assigned for these differences. Triantaphyllou and Hirschmann (1960) suggested that populations of *Meloidogyne* spp. from different geographical areas may differ in their developmental pattern. Temperature was found to be another factor influencing the development of *M. javanica* (Bird and Wallace, 1965; Wallace, 1969). Likewise, soil moisture, host response, age of the plant, nematode population, etc. also have their role to play on the life cycle of a nematode species (Wallace, 1963, 1970; Swarup and Pillai, 1964).

The growth in the size of larvae closely follows the pattern described by Bird (1959). After the final moult females increase in width and attain rounded shape whereas males increase in length and assume elongate shape.

It may be pointed out that the life cycle of *M. javanica* from egg to egg is completed in 18 days on *C. olitorius* JRO 632, which is harvested after three to four months. Hence, during one crop season five to six infestations may take place under favourable conditions for nematodes, causing heavy damage to the crop.

Abundance of Males.—During secondary infestation males were found in large numbers as also noted by Tyler (1933), van der Linde (1956) and Dropkin (1959). Tyler (1933), giving a probable explanation for abundance of males in the populations of root knot nematodes, suggested that under adverse conditions males occur in increased numbers. Her view was further supported by Linford (1941) and Triantaphyllou (1960) and it was established that under unfavourable conditions like food stress males occur in higher number. The occurrence of large number of males in secondary infestation supports Tyler's views. This sex reversal is perhaps a self limiting mechanism.

Intersexes.—Many male intersexes were found during the course of present studies. Occurrence of such intersexes in nematodes has been reported on many occasions. Steiner (1923) and Hirschmann and Sasser (1955) have reviewed the literature on the subject. It is interesting to note that most of the intersexes of tylenchids reported so far are females. The male intersexes are known to occur only in *Meloidogyne* spp. These were first recorded in *M. javanica* by Chitwood (1949). Varma *et al.* (1971) first reported male intersexes of *M. incognita* from a natural population although earlier Ishibashi (1965) succeeded in producing them by Gamma ray irradiation. David and Triantaphyllou (1968) also induced intersexuality by using maleic hydrazides. However, it was only Triantaphyllou (1960) who experimentally showed how sex reversal and intersexuality take place.

The present observations support the views expressed by Triantaphyllou (*loc. cit.*) and others. During the period of primary infestation the environmental conditions along with sufficient food supply helped the normal development of nematodes hence the males were rare (a few found only in soil) as in normal populations. In the case of secondary infestation high population stress and less availability of food as well as the reduced accommodating capacity of roots must have created unfavourable conditions resulting in increased number of males. The males with two testes indicated that these developed through sex reversal of female larvae. The adult intersexes were smaller in number as compared to those within the larval cuticle. Probably the latter represented the third generation infesting the host third time. When the crowding increased conditions became more rigorous, inducing sex reversal in females even under advance stages of their development, resulting in the males without complete obliteration of vulva or its rudiment.

Mayr (1969) described the possible occurrence of intersexes in population of interspecific or inter-subspecific hybrids. This possibility is precluded in this case, because, the inoculum used in the experiment was obtained from a single egg mass culture. According to Krall (1972) an upset in balance between "male tendency" and "female tendency" genes, resulting from irregularities in fertilization or mitosis or from physiological disturbance may cause development of intersexes. However, these factors may be means towards the achievement of the end but not the cause. For *Meloidogyne* sp., Krall (*loc. cit.*), however, supports the view of Triantaphyllou (1960) who postulated that intersexes are apparently derived from second stage female larva, through sex reversal. Laughlin *et. al.* (1969) have shown that temperature is also a factor in sex determination,

TABLE 4. Details of the time period for various stages (♀) of the life cycle of *M. javanica* on *C. olitorius* L.

Days after inoculation	Moult	Developmental stage	Duration in Number of days
—	—	II - larva	7
8th	II	III - larva	1
9th	III	IV - larva	1
10th	IV	adult within larval cuticle	1–2
11th, 12th & 13th	—	adult out of larval cuticle	3
14th	—	secretion of gelatinous matrix	1
15th	—	egg laying	1
16th–18th	—	hatching of larva	3
Total			18–19

TABLE 5. The percentage occurrence of developmental stages during the life cycle of *M. javanica*.

No. of days after inoculation	Larval stage %					Females %	
	Infective	Developed sex un-differentiated	Sexually differentiated	III	IV	Without eggs	With eggs
1	100	—	—	—	—	—	—
2	100	—	—	—	—	—	—
3	70	30	—	—	—	—	—
4	40	60	—	—	—	—	—
5	20	80	—	—	—	—	—
6	15	65	20	—	—	—	—
7	5	20	75	—	—	—	—
8	3	12	60	25	—	—	—
9	1	5	24	55	15	—	—
10	—	3	6	29	42	20	—
11	—	3	5	20	47	25	—
12	—	1	4	15	34	46	—
13	—	1	3	10	40	46	—
14	—	—	2	5	18	75	—
15	—	—	2	3	10	80	5

HOST-PARASITE RELATIONSHIPS OF *MELOIDOGYNE JAVANICA* (TREUB, 1885) CHITWOOD, 1949, AND *CORCHORUS OLITORIUS* L.

INTRODUCTION

Treub (1886), while working on the root-knot nematodes, described the multinucleate cells in the vicinity of the lip region of *Meloidogyne javanica.* Since then many workers like Christie (1936, 1949), Allen (1952), Dropkin (1954, 1955), (asser (1954), Lall and Das (1959), Dropkin and Nelson (1960), Davis and Jenkins S1960), Bird (1961, 1962, 1968), Prasad (1961), Jones and Nirula (1963), Swarup and Pillai (1963), Wardojo *et al.* (1963), Hijink and Kuiper (1964), Lall *et al.* (1965), Siddiqui and Taylor (1970) amongst others have studied the host-parasite relationships of *Meloidogyne* spp. in relation to various plants. Little attention has been paid to jute plants although these are highly susceptible to root-knot infestation. Only some stray reports on the subject are to be found in literature. The root-knot disease of *Corchorus olitorius* L. was first reported by Bessey (1911). Franklin (in Chattopadhyay and Sengupta, 1955) also observed galls on roots of *C. capsularis* L. sent to her from Borneo. Kundu (1946) was the first to report on root-knot infestation in *C. capsularis* and *C. olitorius* in West Bengal. Further observations on infestation of jute by root-knot nematodes were made by Chattopadhyay and Sengupta (1955), Timm (1959), Dutt (1960), Tripathi and Bhattacharya (1969), and Srivastava *et. al.* (1969). However, it was only Timm who made some experimental studies regarding the influence of root-knot and lance nematodes on growth and wilting of jute (Timm and Ahmed, 1961; Timm, Ahmed and Waseque, 1961 a, b). Their work, however, was only of fragmentry nature and dealt with *C. capsularis*—hence these studies on the host parasite relationships between *M. javanica* and *C. olitorius.*

MATERIALS AND METHODS

The present studies were based on three sets of experiments : (i) Penetration (ii) Pathogenicity and (iii) Histopathology.

Penetration.—For observing penetration of the roots by the larvae, method described by Khera and Zuckerman (1963) and Tikyani and Khera (1969) was employed. A number of larvae were collected from hatching egg masses. The nematodes were then surface sterilized in 0.5% Hibitane diacetate for five minutes and washed twice in sterile distilled water before inoculation. The seeds of jute (*C. olitorius* var. JRO 632) were surface sterilized with 0.1% mercuric chloride for five minutes and a few others were scarified by concentrated sulphuric acid for three minutes. The seeds were washed twice with sterile distilled water and placed on 1% agar plates for germination.

Earlier germination resulted in the case of scarified seeds. After three days, when roots grew to a length of about 2.5 cm, inoculations were made by placing 50–60 larvae in a drop of sterile distilled water, close to the roots of the seedling growing in horizontal plane. The agar was cut gently along the roots to facilitate the entry of larvae. After 12–18 hours plates were examined under a stereomicroscope and observations recorded.

Pot experiments.—For pot experiment a number of 15 cm pots were filled with a mixture of soil and cowdung (3 : 1) sterilized with methyl bromide and tested to be free from phytotoxic effect. Seeds of *C. olitorius.* var JRO 632 were sown in all the pots. The seedlings sprouted after 3–4 days. Two weeks after the sowing tillering of plants was done and only three plants were allowed to remain in each pot. The pots were kept in open on a cemented floor and the plants were allowed to grow for a period of one month.

A large number of egg masses were obtained from a culture of *M. javanica* developed from a single egg mass on tomato plants. The egg masses thus collected in distilled water in petri plates were kept in a B.O.D. incubator at 29°C. The egg masses were examined daily and hatched larvae were pipetted out in a beaker containing distilled water. Within three days large number of larvae were collected. The number of larvae per millilitre of stock suspension was counted in a counting dish. The average of three counts gave the number of larvae per millilitre in the suspension. The concentration of larvae was adjusted suitably by adding more water and made ready for inoculation.

Five series of pots were maintained. The first series without inoculation served as control. The pots in the rest four series were inoculated in the log series of 10, 100, 1,000 and 10,000 larvae per pot. The actual inoculation was done by boring three or four holes 3–4 cm deep and 7–8 mm in diameter in the soil around each plant. The exact volume of suspension containing requisite number of larvae was taken out with the help of a calibrated pipette and inoculated in these holes. After inoculation the holes were closed and pots were watered very lightly. All the pott were inoculated on one and the same day. Metallic labels were given to each pos indicating the number of larvae inoculated. The pots were kept in open in a random design. Five replicates of each series were maintained. The experiment was performed in the months of July and August. During the period ambient temperature was: maximum 29°–35.1°C (average 32.5°C) and minimum 23.6°–28.7°C (average 26.3°C). The total rainfall was 318.7 mm.

After seven weeks (when a few plants started dying) all the plants were removed from the pots and kept in plastic containers filled with water. When the roots became free from the soil, plants were taken out with utmost care so that minimum damage was done to the root system. The roots were washed carefully with water to remove all the soil particles adhering to the root hairs. These were dried by pressing gently in between the folds of blotting paper. The following data were collected for each plant.

1. Length of shoot from 1st node to the tip.
2. Diameter of the shoot at 1st node.
3. Number of nodes (instead of leaves, nodes were counted as most of the leaves fall off).
4. Green (fresh) weight of shoot.
5. Dry weight of shoot (for drying shoots were kept at 70°C in an incubator for seven days).
6. Maximum length of roots.
7. Green (fresh) weight of roots.
8. Total number of roots (branches arising from the main root were counted).
9. Total number of roots with knots.
10. Total number of root-knots.
11. Gall size.
12. Root-knot index $= \left(\frac{\text{Number of roots with knot}}{\text{Total number of roots}} \times 100 \right)$

Statistical procedure.—Various statistical parameters, viz. range, mean, standard deviation and their standard errors were estimated. To study the difference between control and inoculated plants with different number of nematodes the significant tests were employed. As the sample sizes were small and standard deviations equal, the student 't' test for the small sample theory was employed. In samples having different variances, the more exact test due to Behrens was used. The difference was deemed to be real when it was significant at 5%, 1% or 0.1% levels of probability.

Histopathology.—For histopathological studies infested roots were cut into small pieces and fixed in hot F.A.A. solution (formalin 30 ml, glacial acetic acid 5 ml, absolute alcohol 100 ml and distilled water 200 ml). After 24 hours roots were washed thoroughly in water and passed through ascending grades of ethyl alcohol for dehydration. Further, following the common procedure of microtomy (Southey, 1970) 6 μm and 10 μm thick transverse and longitudinal serial sections were cut. The sections were stained with Safranin and Fast green. Some fine infested roots were also stained in acid fuchsin lactophenol and mounted. The stained slides were examined and histopathological changes brought by nematode infestations were observed.

EXPERIMENTAL RESULTS

Penetration (Pl. V).—Examination of agar plates showed that larvae were able to penetrate the roots of jute seedlings within 12 hours of inoculation. To begin with, the larvae started moving towards the root-tips after wandering aimlessly for sometime. They reached slightly behind the root cap near meristematic zone. Most of them lay with their head at right angle to the root axis and body parallel to it. Slight movement was noticed in head and after some time it was seen buried in the root tissue. The penetration was intercellular as well as intracellular. In many instances it was noticed that the track left by a larva was often followed by others. The number of larvae at each root tip varied from one to as many as fifteen. The presence of so many larvae in the same region showed that the injury caused by one larva served as passage for many others. While most of the larvae even after 48 hours remained confined to the tip, a few migrated away from the tip. More larvae were observed in the cortical region than in the steler region.

Pathogenicity (Fig. 30; Pl. VI–VIII).—The results of the pot experiments have been summarised in the table 6. Shoot length is significantly low only at such high levels of 1,000 and 10,000 degrees of inoculation from the control plants. Shoot weight (both green & dry), root weight (green) and number of nodes have an effective impact of inoculation at 100 degrees and above levels. But the effect of inoculation for the root length, diameter at first node and total number of roots, is felt even at 10 degree level of inoculation though with varying degrees. Higher the degree of inoculation, greater is the value of each of these characters. In general it can be said that the effect of inoculation is present in all the characters considered. The susceptibility of all the characters to infection is well assured when the inoculation level is at 1,000 degree. The effect of infestation in the pots inoculated with 10,000 larvae was so severe that many plants started dying in 7th–8th week.

Besides the above differences other pathogenic symptoms were observed. Leaves became rugose, dull and mottled. The lower leaves were shed prematurely leaving a small crown of leaves at the top. The top leaf-crown showed close bunching as against fairly open crown in control plants (Pl. VII). The stems were shrivelled. Wilting was observed repeatedly. The whole plant lost its shining green colour and exhibited symptoms of chlorosis. The variegation of leaves was marked by small dot-like yellow spots. In extreme cases their margins curled and started drying.

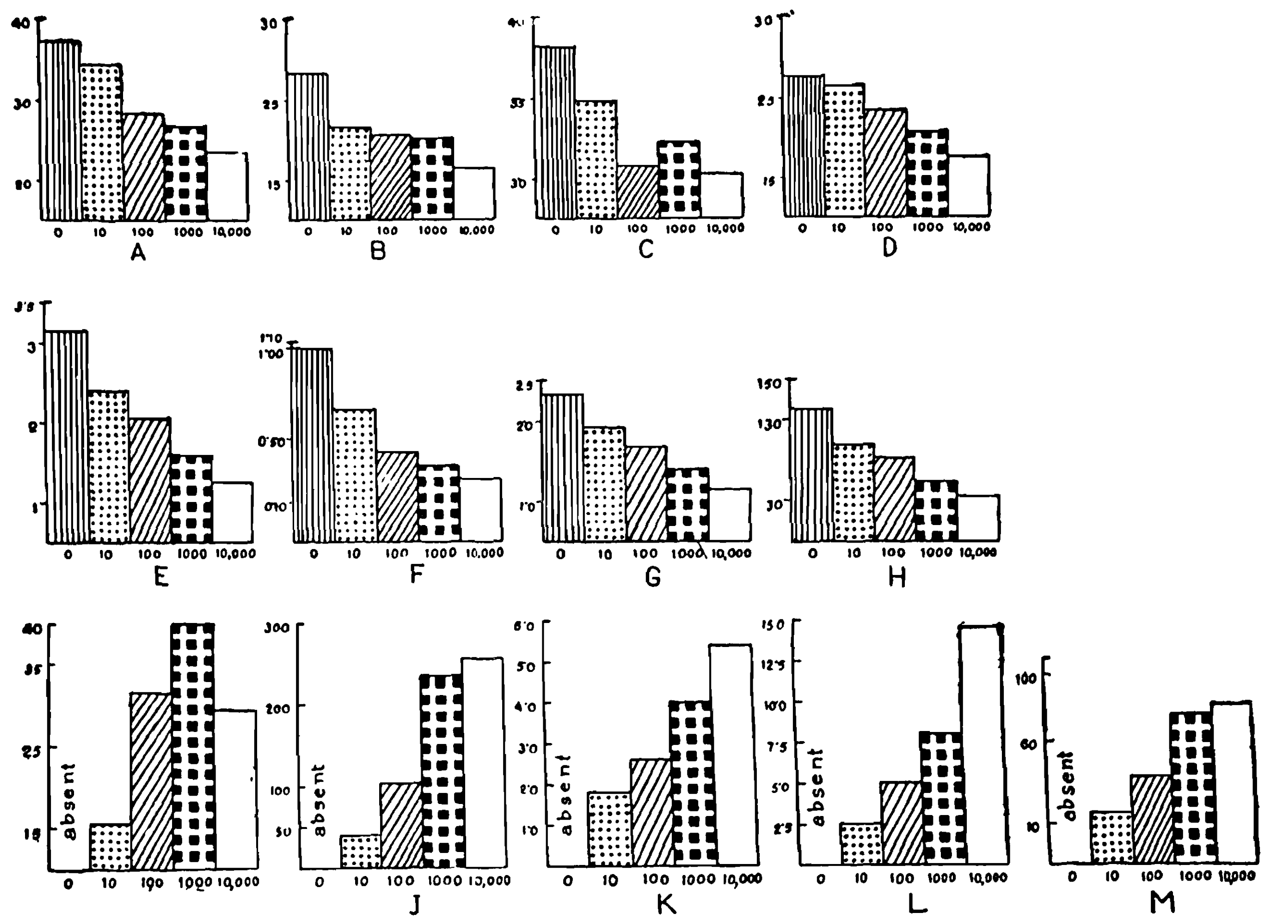

Fig. 30. Histograms depicting morphometric changes in *C. olitorius* var. JRO 632 at different levels of inoculum.—A. Shoot length (cm); B. Root length (cm); C. Diameter at first node (mm); D. Number of nodes; E. Shoot weight (green—in gm); F. Shoot weight (dry—in gm); G. Root weight (green—in gm); H. Total number of roots; I. Number of roots with knots; J. Number of knots; K. Gall size (length—in mm); L. Gall size (width—in mm); M. Root—knot index.

In the below-ground symptoms depletion of the root system occurred. These showed reduced length and number as well as weight. Gall formation took place showing that *C. olitorius* var. JRO 632 was susceptible to *M. javanica*. The number of galled roots and number of total galls on each plant increased with increased number of inoculated nematodes. The knots were simple, enclosing only one or two females, or composite with many females completely buried in it. These were found to be median, apical or axillary in position. Their shapes varied as club-, spindle-or ring-shaped to cylindrical. In many cases apical knots stopped the growth of a root as a result many side branches were seen arising from that point. In simple knots eggs were laid in egg sacs protruding outside plant tissue but in composite knots embedded females laid egg masses within egg sacs enclosed in the plant tissues (Pl. XII). The gelatinous matrix of egg sacs outside plant tissue became tough and brown while those enclosed in plant tissue remained soft and colourless. All these pathogenic symptoms were best developed in plants inoculated with 10,000 nematodes per pot.

Histopathology (Pl. IX–XII).—As the result of infestation by *M. javanica* many histopathological changes were also noticed. After penetration most of the larvae settled themselves in the cortical region. Some of the larvae migrated to steler region through the parenchymatous tissue of the cortex and were found near cambial cells, in parenchyma of the steler region or the xylem cells. While penetrating the steler region, body of the larva remained in the cortex and it was only the anterior part which was embedded in the stele. Fine infested roots stained in acid fuchsin lactophenol showed that when larvae attached themselves to xylem elements, the surrounding xylem tissue assumed a spindle shape and stained dark like the larvae (Pl. IX). When dissected out, these cells of the surrounding tissue could be separated easily just as macerated ones. Their walls were distorted and cytoplasm became dense and stained deeply. Many deeply stained nuclei were also seen. These were the giant cells. The root-sections also showed two to six giant cells around the anteior end of each nematode (Pl. X). The protoplasm in giant cell in the vicinity of the head of the larvae became granular. The cells were enlarged and had many nuclei (Pl. X). The walls of the cells were comparatively thicker. In many cells vacuolated cytoplasm was also noticed. This process of giant cells formation occurred more frequently in the parenchymatous tissue of the cortex than in the steler region. Hypertrophic condition of cells was noticed as early as 48 hours after inoculation. For the formation of giant cells, breaking down of the cell walls and coalescing of their contents was not observed. The thickened cell walls and the nuclei stained dark and could be located easily. A large number of smaller cells indicative of hyperplasia were observed surrounding the giant cells (Pl. XII). However, no mitosis was observed. Overall reaction of the nematode infestation is the swelling of root or galling caused by hypertrophy and hyperplasia. Sections of heavily infested roots showed two cork layers.

DISCUSSION

Penetration.—The attraction of *Meloidogyne* towards plant roots and their penetration has been studied by many workers like Godfrey and Oliveira (1932), Christie (1936), Linford (1939), Wieser (1955, 1956), Bird (1959, 1962) and Peacock (1961). The larvae usually penetrate the roots near apical meristem. However, they can enter through other regions too. They can penetrate the roots in as short a time as three to four hours (Loewenberg *et al.*, 1960) or six hours (Godfrey and Oliveira, 1932). The larvae may take even 12 to 24 hours for penetration (Loewenberg *et al.*, 1960) repeatedly penetrating the epidermal cells with the stylet. The present studies showed that larvae penetrated the roots of jute within 12 hours. After penetration they could stay in that region or continued to migrate up to three days before becoming sedentary (Godfrey and Oliveira, 1932). In the jute plant, after penetration, most of the larvae remained contained to the tip even after 48 hours and only a few migrated to other parts. Piercing of cortical parenchyma in jute appears easier than of the cells of the steler region because larvae feeding on cortical cells were larger in number than in the steler region.

Pathogenic effects.—The results of pot experiments showed that *M. javanica* is pathogenic on *C. olotorius* var. JRO 632, under the climatic conditions of West Bengal. Above the ground symptoms showed the stunted growth, crinkled and variegated leaves, shrivelled stem and chlorotic appearance. The roots were found heavily galled. The stunting in case of jute is a very serious phenomenon since it is a fibre crop. The short length of the fibre results in a grading considered inferior commercially. Further, the thin and pale stem gives a poor yield.

Histopathology.—The formation of galls and giant cells or syncytia are essential parts of host-parasite relationships of nematodes of the genus *Meloidogyne*. In different species of host plants infested with different species of *Meloidogyne*, size, number and shape of galls vary. Reynolds (1955) failed to detect any gall on lucerne roots infested with *Meloidogyne*. On the other hand Steiner *et al.* (1934) recorded galls up to 2 feet in diameter on roots of *Thumbergia laurifolia*. Besides *Meloidogyne*, some other nematodes e.g., *Ditylenchus radicicola*, (Kuiper, 1953);

Heterodera rostochiensis, (Doncaster, 1953, and Widdowson *et al.*, 1958); *Hemicycliophora* spp., (van Gundy, 1957, Zuckerman, 1961); *Nacobbus batatiformis*, (Thorne and Schuster, 1956); *Xiphinema diversicaudatum*, (Schindler, 1957) are also known to cause gall formation.

As stated earlier, Treub (1886) was the first person to describe giant cell formation in *M. javanica*. Since then many workers like Molliard (1900), Nemec (1910), Christie (1936), Crittenden (1958), Krusberg and Nielsen (1958), Mildenberger and Wartenberg (1958), Davis and Jenkins (1960), Dropkin and Nelson (1960), Owens and Novotny (1960), Bird (1961, 1962) and Siddiqui and Taylor (1970) have contributed to the study of histopathology in general and the gall formation in particular.

It has been established that the gall formation and giant cell formation are two different phenomena. The galling can be effected even by mere surface feeding (Loewenberg *et al.*, 1950). This suggests that the substances secreted into the cell during feeding are responsible for the cellular changes i.e., hypertrophy and hyperplasia in the course of gall formation. The giant cell formation, however, usually takes place in vascular tissue, it requires much longer period and results in complex structural alteration of the root cells.

Owen and Specht (1964) proposed two probable causes of hypertrophy, (i) mechanical pressure exerted by the enlarging nematode and (ii) lateral movement of growth substances (auxins like indol-acetic acid, etc.) around the cavity created by the growth of the nematode. However, the mechanical pressure theory does not explain the gall formation without actual entry of the larvae in the root; hence the second possibility seems more plausible. It seems that nematode secretion may induce gall formation by one or more of the following processes: (a) changes in cell wall permeability causing accumulation of nutrients, resulting in accelerated growth of cells, (Kostoff and Kendall, 1930), (b) excretory products of nematodes cause gall formation (Myers and Krusberg, 1965, Endo and Veech, 1969), (c) some secretions produced by the interaction of nematode and plant tissue act as growth substances or in collaboration with other growth regulating substances caused hyperplasia (Ustinov, 1951; Myuge, 1956; Mountain, 1960; Balasubramanian and Rangaswami, 1962; Bird, 1962; Setty and Wheeler, 1968; Viglierchio and Yu, 1968; and Dropkin *et al.*, 1969).

The giant cells or syncytia are shown to be the sites of high metabolic activity upon which the nematodes depend. The activity includes protein synthesis and enzymatic reactions (Endo and Veech, 1969; Veech and Endo 1969). There are two theories as regards formation of giant cells. The first theory, as evidenced by the work of Kostoff and Kendall (1930), Christie (1936), Krusberg and Nielsen (1958), Dropkin and Nelson (1960), Bird (1961), Owens and Specht (1964) and Littrell (1966), postulates dissolution of cell walls and coalescing of their contents. The second theory is of Haung and Maggenti (1969a, b); they did not observe any cell wall dissolution and proposed that multinucleate condition is the result of mitosis without cytokinesis. In the present experiment, although there was a distortion of the cell wall, in no case was the breakdown of the latter observed. It seems, therefore, that in jute plant giant cells are formed by the process proposed by Huang and Maggenti (*loc. cit.*). Similar observations had been made by Tischler (1902); Nemec (1910) and Davis and Jenkins (1960); however, not much attention was paid to their observations at that time. Syncytial formations appear to be beneficial to the nematode enabling it to obtain nutrients from the plant and to develop and reproduce without causing so much dysfunction that the plant is killed.

Summing up the various views there are three ways by which a giant cell can achieve polynuclear state: (i) mitosis without cytokinesis, (ii) amitosis or nuclear fragmentation and (iii) the collection of nuclei from several cells that coalesce following the cell wall disolution. It is possible that under different conditions (including different hosts) or under different stages of giant cell development the polynuclear condition is attained by one or more of the aforementioned processes.

The polyploidy in giant cell nuclei has also been studied by Dropkin (1965) and Huang and Maggenti (1969a, b). The cytochemical studies by Bird (1961); Rubinstein and Owens (1964) and Dropkin (1965) have shown that DNA synthesis was much higher in giant cell nuclei, being 2–11 time of a normal plant cell. The chemical nature of nematode secretion inducing series of changes in plant tissue, has been investigated by Rubinstein and Owens (1964) and Bird and McGuire (1966). However, its exact composition still remains unknown. According to Bird (1968) it contains basic protein with some of the properties of histones as well as glyco-proteins and/or mucopolysaccharides, responsible for the development, control and maintenance of giant cells.

TABLE 6. Values of various morphometric characters of *C. olitorius* inoculated with *M. javanica* and comparison between control and others.

Number of larvae per inoculum	Range	Mean±S.E.	S.D.±S.E.	't' test
(1)	(2)	(3)	(4)	(5)
		1. Shoot length (in cm)		
0	31.00–48.00	37.12±2.92	6.52±2.06	—
10	30.60–38.00	34.21±1.60	3.57±1.13	NS
100	24.30–31.00	28.15±1.18	2.63+0.83	NS
1,000	24.80–30.00	26.75±0.89	1.99±0.63	**
10,000	21.20–25.00	23.56±0.63	1.42±0.45	**
		2. Root length (in cm)		
0	24.00–34.00	28.06±1.87	4.17±1.32	—
10	19.00–25.00	21.66±1.10	2.46±0.78	*
100	19.00–24.00	20.46±0.92	2.06±0.65	**
1,000	17.60–23.00	20.12±1.06	2.38±0.75	**
10,000	13.60–21.00	16.24±1.33	2.98±0.94	**
		3. Diameter at 1st node (in mm)		
0	3.60–4.00	3.81±0.06	0.143±0.045	—
10	3.30–3.80	3.48±0.09	0.205±0.065	*
100	2.76–3.33	3.08±0.12	0.277±0.087	***
1,000	2.68–3.60	3.23±0.17	0.387±0.122	*
10,000	2.70–3.30	3.02±0.10	0.217±0.069	***

Number of larvae per inoculum	Range	Mean±S.E.	S.D.±S.E.	't' test
(1)	(2)	(3)	(4)	(5)
		4. Number of nodes		
	26.00–32.00	27.60±1.12	2.50±0.79	—
10	25.00–29.00	26.40±0.68	1.51±0.48	NS
100	20.00–29.00	23.20±1.53	3.42±1.08	*
1,000	19.00–23.00	20.60±0.75	1.67±0.53	***
10,000	14.00–20.00	17.60±1.03	2.30±0.73	***
		5. Shoot weight (green—in gm)		
0	2.50–4.50	3.13±0.37	0.830±0.262	—
10	2.16–2.66	2.39±0.09	0.193±0.061	NS
100	1.60–2.33	2.04±0.14	0.318±0.100	*
1,000	1.00–2.00	1.59±0.20	0.440±0.139	**
10,000	0.66–1.66	1.26±0.17	0.385±0.122	**
		6. Shoot weight (dry—in gm)		
0	0.64–1.70	1.06±0.18	0.395±0.125	—
10	0.40–1.64	0.69±0.24	0.530±0.168	NS
100	0.28–0.51	0.41±0.04	0.092±0.029	**
1,000	0.26–0.37	0.33±0.02	0.041±0.013	**
10,000	0.12–0.39	0.25±0.04	0.097±0.031	**
		7. Root weight (green—in gm)		
0	2.00–2.60	2.32±0.11	0.244±0.077	—
10	1.60–2.33	1.91±0.14	0.310±0.098	NS
100	1.00–2.00	1.68±0.19	0.415±0.131	*
1,000	1.00–1.83	1.39±0.17	0.372±0.118	**
10,000	0.83–1.66	1.15±0.15	0.338±0.107	***
		8. Total number of roots		
0	128–160	143.80±6.47	14.46±4.57	—
10	93–106	10.00±2.61	5.83±1.84	***
100	73–91	81.20±3.14	7.01±2.22	***
1,000	32–76	53.40±9.23	20.63±6.53	***
10,000	28–45	35.00±3.03	6.78±2.14	***

Number of larvae per inoculum	Range	Mean±S.E.	S.D.±S.E.	't' test
(1)	(2)	(2)	(4)	(5)
	9. Number of roots with knots			
0	absent	—	—	—
10	5.00–26.00	15.40±3.67	8.20±2.59	—
100	14.00–45.00	31.60±5.47	12.24±3.87	—
1,000	27.00–57.00	39.80±6.16	13.77±4.36	—
10,000	22.00–37.00	29.20±2.56	5.72±1.81	—
	10. Number of knots			
0	absent	—	—	—
10	11.00–62.00	39.00± 8.79	19.66±6.22	—
100	38.00–173.00	103.40±23.81	53.25±16.84	—
1,000	193.00–266.00	234.84±12.99	29.05±9.19	—
10,000	204.00–305.00	255.80±16.40	36.67±11.60	—
	11. Gall size (length—in mm)			
0	—	—	—	—
10	1–3	1.80±0.374	0.837±0.265	—
100	2–3	2.60±0.245	0.548±0.173	—
1,000	3–5	4.00±0.316	0.707±0.224	—
10,000	5–6	5.00±0.245	0.548±0.173	—
	12. Gall size (width—in mm)			
0	—	—	—	—
10	1–4	2.60±0.510	1.140±0.361	—
100	3–7	5.00±0.707	1.581±0.500	—
1,000	4–13	8.00±1.643	3.674±1.162	—
10,000	9–18	14.60±1.631	3.647±1.153	—
	13. Root—knot index			
0	absent	—	—	—
10	5.30–24.70	15.12±3.44	7.69±2.43	—
100	18.10–52.90	38.44±5.93	13.27±4.20	—
1,000	67.50–90.62	75.96±4.15	9.28±2.93	—
10,000	78.57–86.66	83.39±1.41	3.15±0.99	—

ABBREVIATIONS:—

S.D.	Standard deviation
S.E.	Standard error
N.S.	Not significant at 5% level of probability
*	Significant at 5% level of probability
**	Significant at 1% level of probability
***	Significant at 0.1% level of probability

OVOVIVIPARITY IN *MELOIDOGYNE INCOGNITA* (KOFOID & WHITE, 1919) CHITWOOD, 1949,

Introduction

Nematodes usually deposit eggs either uncleavaged or in two or four cell stage. Some species are known in which intra-uterine development of eggs takes place up to prehatch larval stage. There are still other species which are viviparous (actually ovoviviparous). Exceptions occur as a rule in nature and cases have been reported of intra-uterine development or *Endotokia matricida* even in the species laying un-segmented or 2–4 cell stage eggs. The cases of viviparity also are not unknown in the ovipositing species of nematodes. The phenomenon of *endotokia matricida* has been reported frequently in ectoparasitic tylenchids and in free-living forms, specially rhabditids. But so far it was unknwon in root-knot nematodes except in *Meloidogyne acornea* Coetzee, (1956) in which it is considered as a regular and distinctive feature of the species. The present communication deals with occurrence of ovoviviparity in the two populations of *Meloidogyne incognita* in which it was observed for the first time.

Christenson (1950) cites many species of animal parasitic nematodes in which ovoviviparity occurs so frequently. Naupas (1899) stated that intra-uterine development is widespread in all the species of *Rhabditis*. Cobb (1920) reported the embryonated eggs in the females of *Tylenchus mahagoni*. Lordello (1951) observed *endotokia matricida* in *Rhabditis* sp. Paetzold (1958) and Dropkin *et al.* (1958) observed the same phenomenon in different species of plant parasitic nematodes. Loof (1959, 1960) and Sanwal (1959) reported the phenomenon in some tylenchids like *Pratylenchus coffeae* and a panagrolaimid nematode respectively. Loos (1962) in *Radopholus similis* and Ivanova (1962) in *Anguina scopoli* observed intra-uterine development. Jairajpuri (1964) considered the phenomenon as a common feature in a population of *Aphelenchus avenae* from Simla, H.P., India. Seshadri (1964) and Yuen (1964, 1965) noticed developing larvae in the body of the mother in *Criconemoides xenoplax* and *Helicotylenchus* spp., respectively. Clark (1967), while studying the life history of *Nacobbus serendipiticus*, observed intra-uterine development in the species. Krall (1967), while reporting on hibernation in *Paranguina agropyri*, also recorded *endotokia matricida*. Gupta and Swarup (1968) not only observed the intra-uterine development in *Anguina tritici* but also reported the occurrence of adult males inside uterus of the females. Poinar (1969) described a new species, *Praecocilenchus rhaphidophorus* parasitising on palm weevils in which he reported intra-uterine development as a common character and observed mating of two sexes within the body of the motehr.

Scott & Whittaker (1970), while investigating upon *Pelodera strongyloides*, studied the phenomenon in laboratory population and discussed probable factors involved. Lam & Webster (1971) recorded intra-uterine development in *Panagrolaimus tipuael* and Wehnut & Edwards (1971) in *Pratylenchus coffeae*. In 1974 the phenomenon was observed in *Pratylenchus mulchandi* by Nandakumar and Kheta and in a free-living species *Chiloplacus lentus* by Roy. Jatala (1975) for the first time observed hatching out of larvae in the uterus of a *Xiphinema* sp.

Observations

While studying nematodes associated with jute crop we came across two populations of *M. incognita* which showed intra-uterine development of eggs. The details are given below.

Burdwan population (Plate XIII, A). The females were recovered by dissecting out roots of jute, *Corchorus olitorius* Linn. collected in June, 1972 from Burdwan, West Bengal. The root-knot infestation was moderate. Knots were simple enclosing single or 2–3 females only.

Dimensions: ♀♀ (5): Length=0.466–0.476 mm, width=0.266–0.322 mm, eggs=70–91 × 35–45 μm.

The females were pyroid in shape, without any neck. Cuticle was thin, smooth, rather soft and colourless. Their bodies were filled with eggs, many of which enclosed fully developed larvae. Uteri could not be seen clearly. General morphological characters were same as described for the species by Whitehead (1968).

Barasat population (Plate XIII, B). The roots of *C. olitorius* Linn. were collected from Barasat, 24-Parganas, West Bengal in October, 1971. The plants were heavily infested and roots showed enormous size galls. The females were dissected out from composite knots in which many females lay embedded in root tissue.

Dimension: ♀♀ (7): Length=0.536–0.823 mm, width=0.280–0.595 mm, neck=0.070–0.298 mm, eggs=88–98 × 39–53 μm.

Female body pyroid or saccate in shape. Most of the females had a long neck. Cuticle was thick, specially in posterior region, more tough and coarse than in Burdwan population. In most of the cases cuticle appeared dirty white or with a pale tinge. Body was filled with embryonated eggs. One of the females showed emergence of a larva through genital pore (Plate XIII, C). A few uncleavaged eggs were also seen in the anterior part of body.

DISCUSSION

Whitehead (1968) and Franklin (1971) have considered deposition of uncleavaged or early cleavage stage eggs in gelatinous matrix, as a character which distinguishes the genus *Meloidogyne* from all other genera of *Heteroderidae*. The only exception is *M. acornea* Coetzee, 1956 in which embryonated eggs are laid.

Although several workers have reported occurrence of *endotokia matricida* in different genera and species of nematodes, but very few of them have attempted to throw light on the factors responsible for this phenomenon. It is obvious that this phenomenon involves processes like development of eggs, their hatching and expulsion of eggs. Therefore, factors governing these processes may be held responsible. indirectly, for inducing intra-uterine development.

Triffit (1930) showed that larvae of *Heterodera rostochiensis* did not emerge from cysts in the absence of oxygen. Wallace (1955) observed similar results in *H. schachtii*. Wallace (1958) and Shepherd & Clarke (1971) showed that in *Heterodera* spp. hatching was stimulated by some root exudates. Crofton (1966) found that hatching might depend upon a special stimulus which could just be a rise in the environmental temperature.

Rogers (1960) suggested that moulting and hatching of free-living nematodes were controlled and co-ordinated by some internal mechanism in the animal. In parasitic species part of this mechanism might be lost so that the parasite would depend on host to replace it. The host might provide a stimulus which induced the nematode to produce the internal secretions or it might provide substances which replaced the missing internal secretions.

Loos (1962) postulated that intra-uterine development was due to disturbances like, change of environment or damage of the female. However, in none of the cases reported so far damaged females have been mentioned.

Cobb (1929) stated that gravid adult females of *Mermis subnigrescens* regulated oviposition by blue light. Christie (1937) and Croll (1966) found that oviposition was arrested or greatly reduced in the dark and resumed on illumination. These observations were made in the laboratory and it is questionable how far light can affect the nematode life in their natural habitat i.e. soil or plant (root) tissue.

Gupta & Swarup (1968) stated that temperature had an important bearing on releasing eggs by females. The old age of females was also considered a factor by them. Their view was further supported by Roy (1974). However, Roy (*loc. cit.*) attached more importance to old age as the temperature in his laboratory experiments remained constant.

Scott & Whittaker (1970) observed the formation of vaginal plug in very young females of *Pelodera strongyloides* after fertilization. For expulsion of eggs lysing of vaginal plug is essential, which involves an enzymatic mechanism. The factors like irradiation of ancestral culture may disturb the enzymatic reaction resulting in non-expulsion of eggs.

From the above facts it is obvious that the factors so far considered responsible for *endotokia matricida* may be categorised as: (1) environmental, (2) physiological and (3) old age of the females. As regards the first category it can be said that nematodes are sensitive to environmental factors such as temperature and moisture. The ontogenic processes of each species are modified by certain threshold reactions to these factors. However, in present case temperature cannot be considered responsible for inducement of intra-uterine development since one population was collected in June and the other in October of different years. The second category of factors like enzymatic secretions inside the nematode body or physiological changes resulting from host-parasite relationships act as important factors in moulding many life processes.

As regards the third factor, viz. the old age of females, it is suggested that mere old age cannot induce the intra-uterine development. This is proved from the fact that this phenomenon was observed in old as well as young females. It is assumed that under certain environmental or physiological conditions the females may lose the tonicity of muscles of certain parts of body such as vulva, vagina and uterus, responsible for ejection of eggs.

Turlygina (1961) reported that "each uterus of *Meloidogyne* spp. may contain up to 30 synchronus eggs which grow and develop intensively, passing into the uterus at the same rate as the division in the germinal zone and also correlated with the development in the growth and maturation zones" On the basis of above it can be said that the movement of oöcytes from multiplication zone, through growth zone, towards uterus must be creating some pressure helpful in expulsion of eggs. Lack of multiplication of oocytes under unfavourable conditions and resultant reduced pressure may also be considered a factor towards failure of the female to eject.

The intra-uterine development provides increased chances of nematode survival because the animal is developed to such a stage, which, immediately after birth, can migrate through the soil or host tissue. As the phenomenon offers opportunity for better survival it can be considered a step in the evolutionary process. This is supported by the fact that many species have adopted it as a common mode of development (Sanwal, 1959; Poinar, 1969; Waerebeke & Remillet, 1974).

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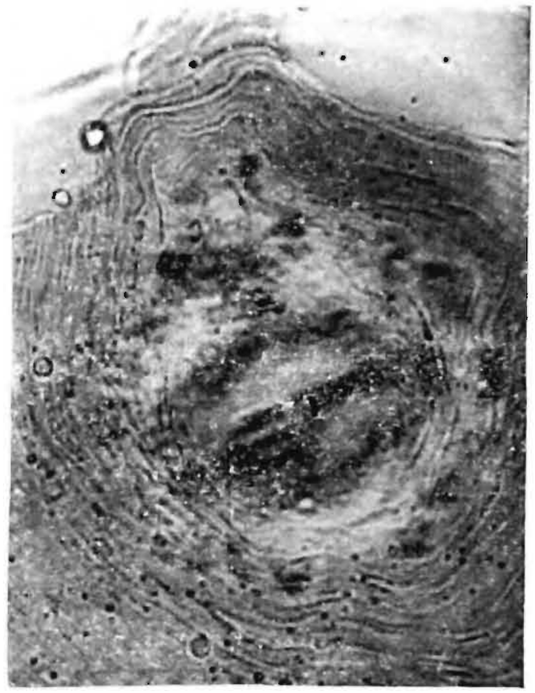
A

B

Plate I

Hoplolaimus dubius n.sp.—A. Attached to jute root; B. Anterior region embedded in root tissue

A

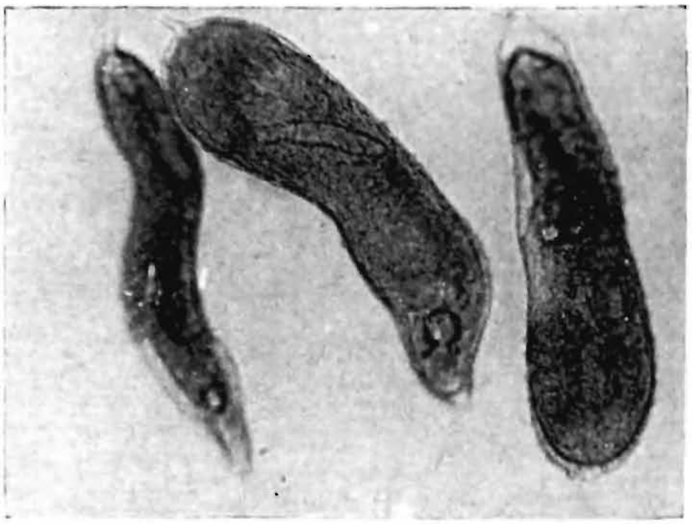


B

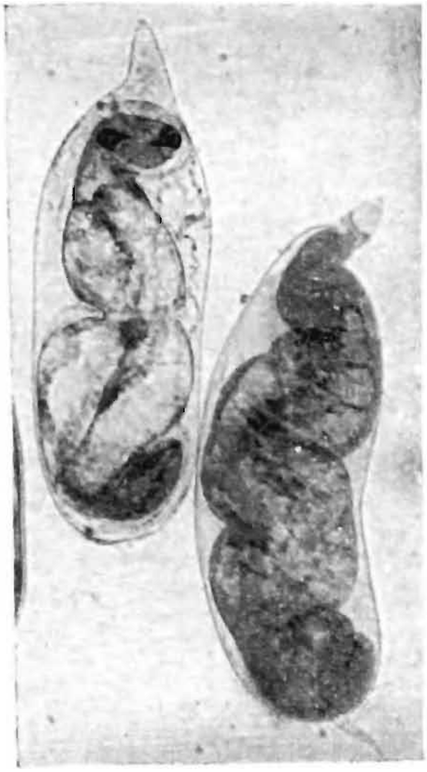
C

Plate II

(A–B) *Meloidogyne incognita*—A. Perineal Pattern—"*incognita* type"; B. Perineal pattern—"*acrita* type"; C. Perineal pattern of *M. javanica*.



A



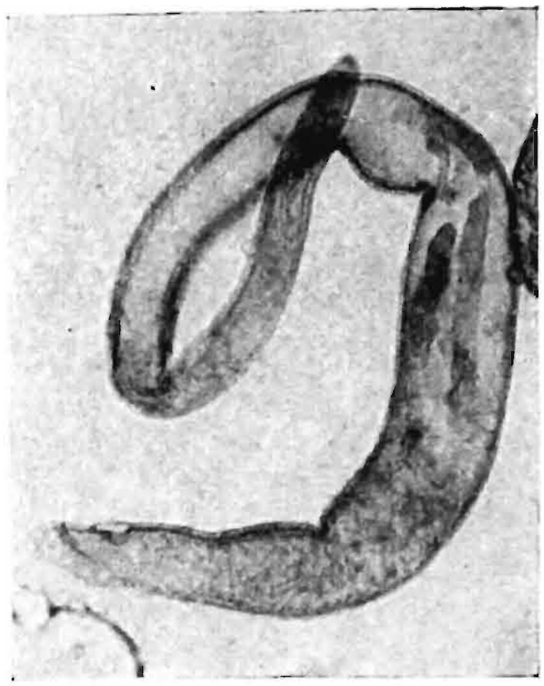
B

C

Plate III

M. javanica—A. Female larva three stages of development; B-C. Male larva - three stages of development.

A



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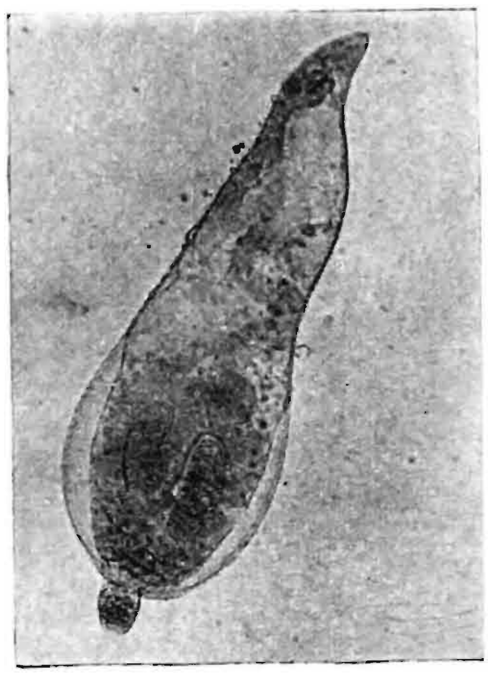


C

Plate IV

M. javanica—A. An adult intersex with vulva and spicules; B. A young intersex with *two testes*, incipient vulva and spicules; C. Female with gelatinous matrix and eggs in uteri on 14th day after inoculation.

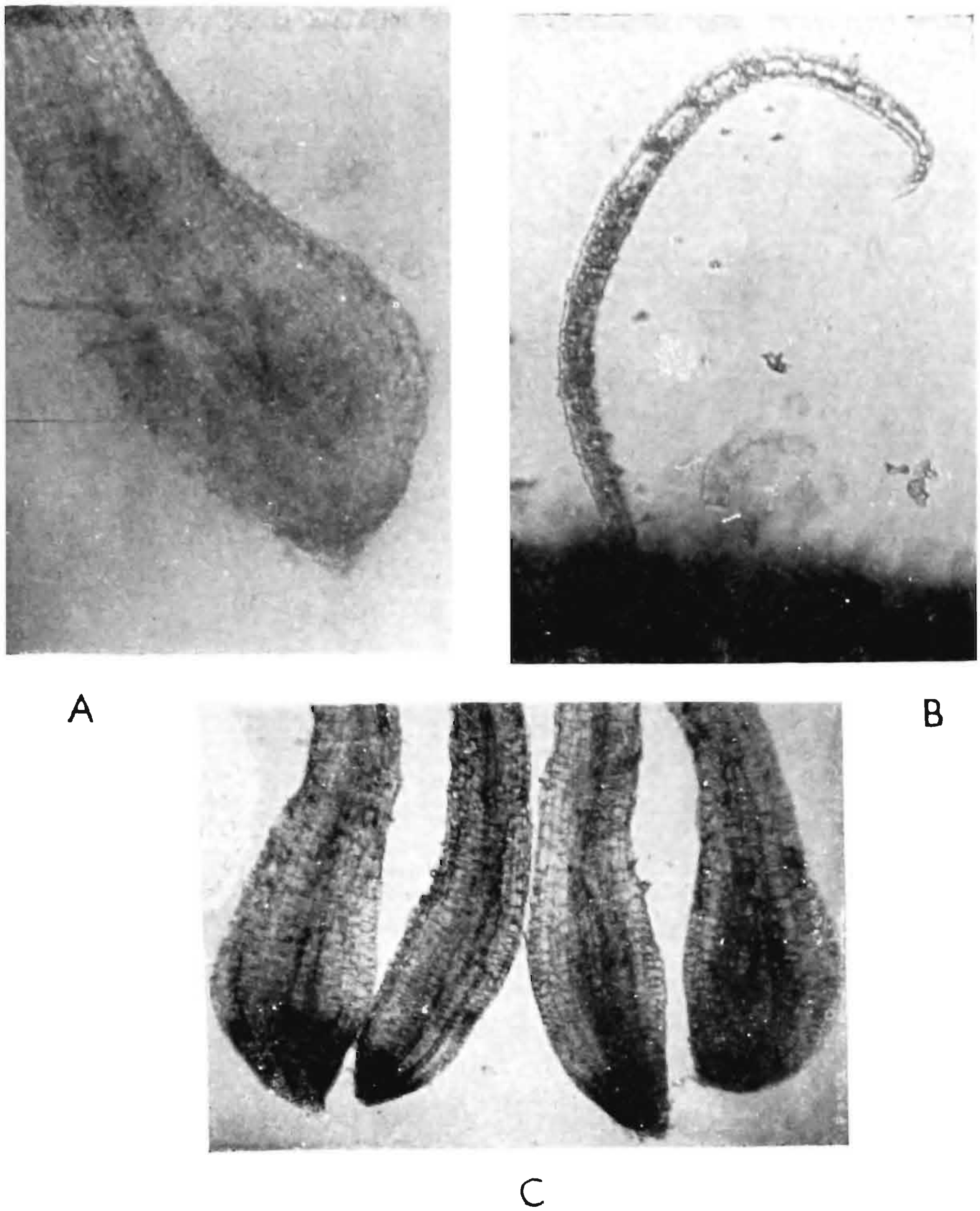
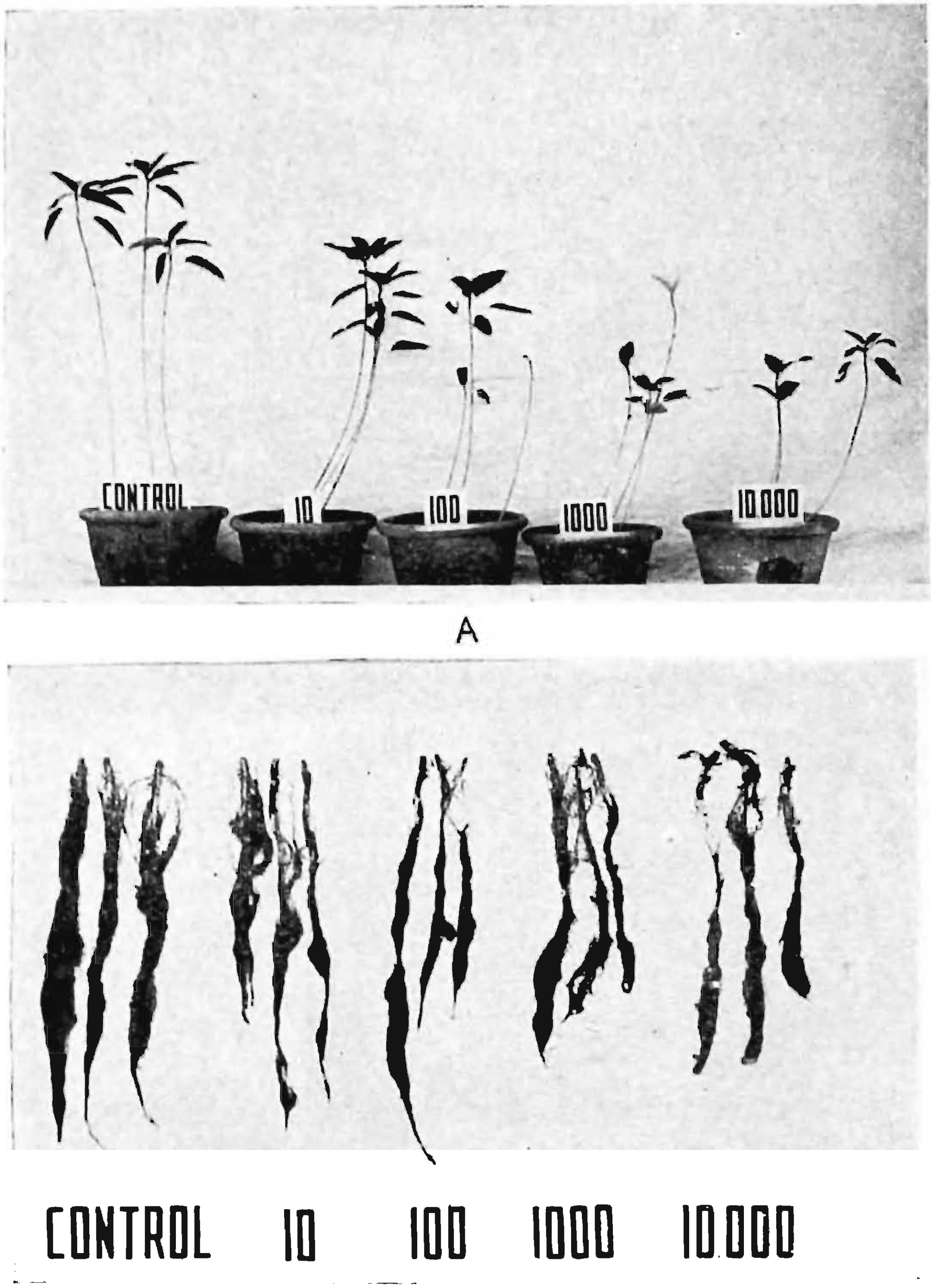


Plate V

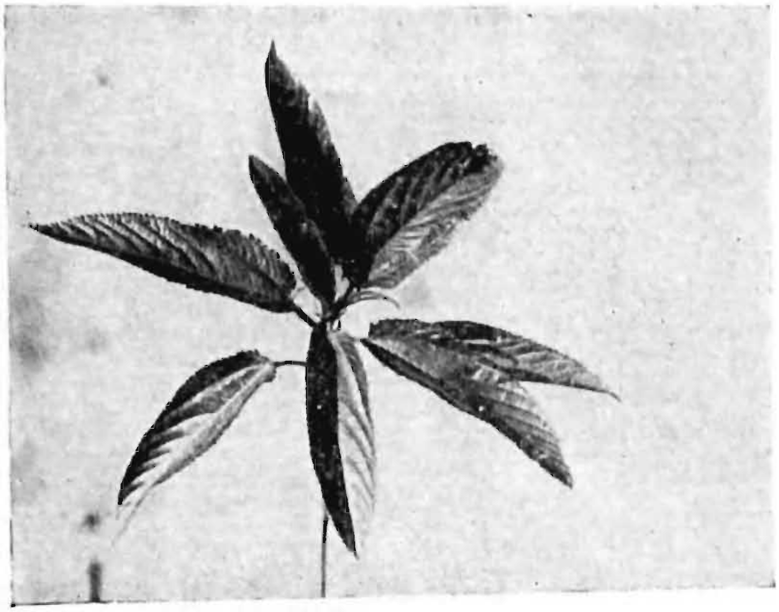
A. A root from pot showing penetration by *M. javanica* larvae; B. *M. javanica* larvae penetrating the roots of *C. olitorius* grown in agar plates; C.D. Pr. Root tips after 24 hours of inoculation showing most common site of infestation.



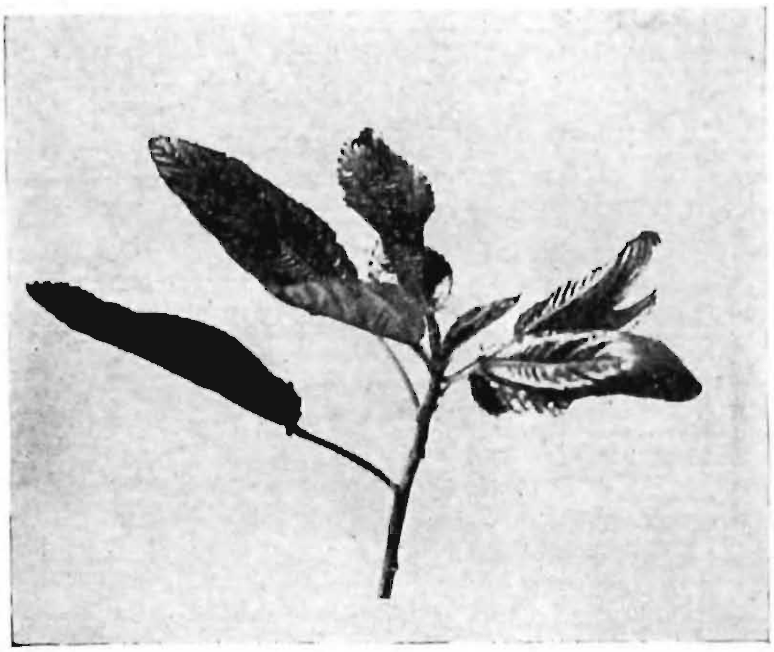
B

Plate VI

Effect of *M. javanica* at different levels of inoculum on the growth of *C. olitorius*—A. Shoot length; B. Root length.



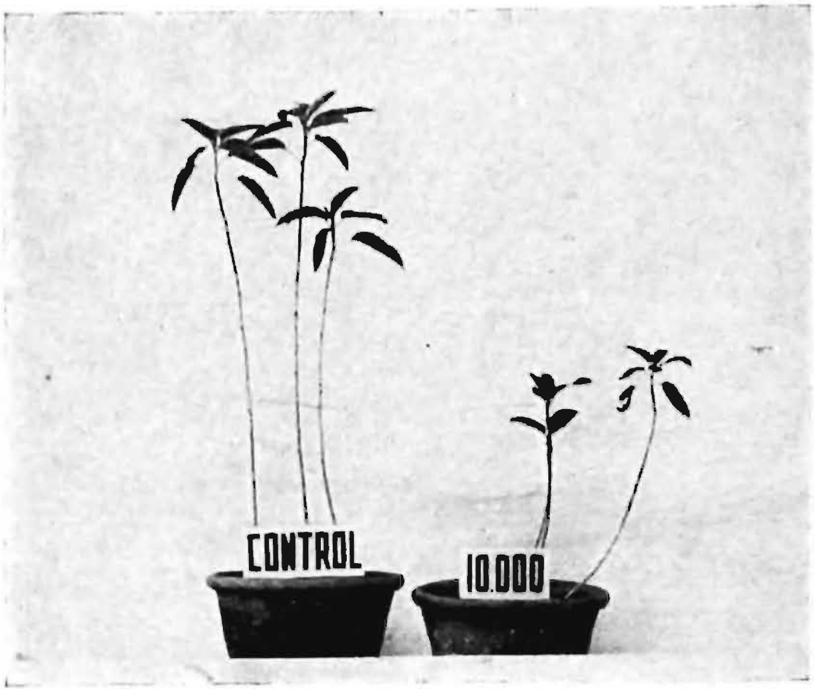
A



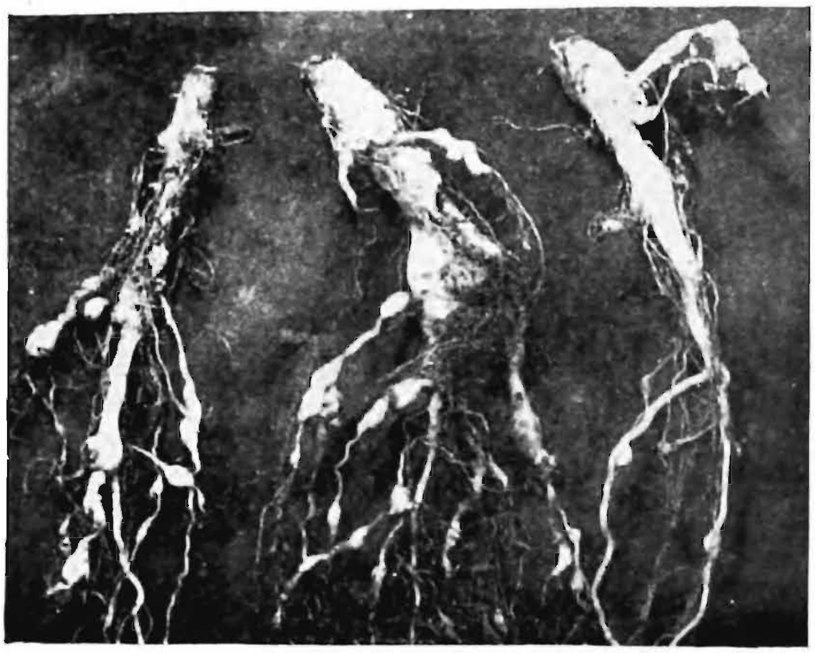
B

Plate VII

A. Leaf crown of a control plant; B. Leaf crown of a plant with 10,000 inoculum.



A



B

Plate VIII

A. Plants of control and 10,000 inoculum series; B. Roots from 10,000 inoculum series showing galls.

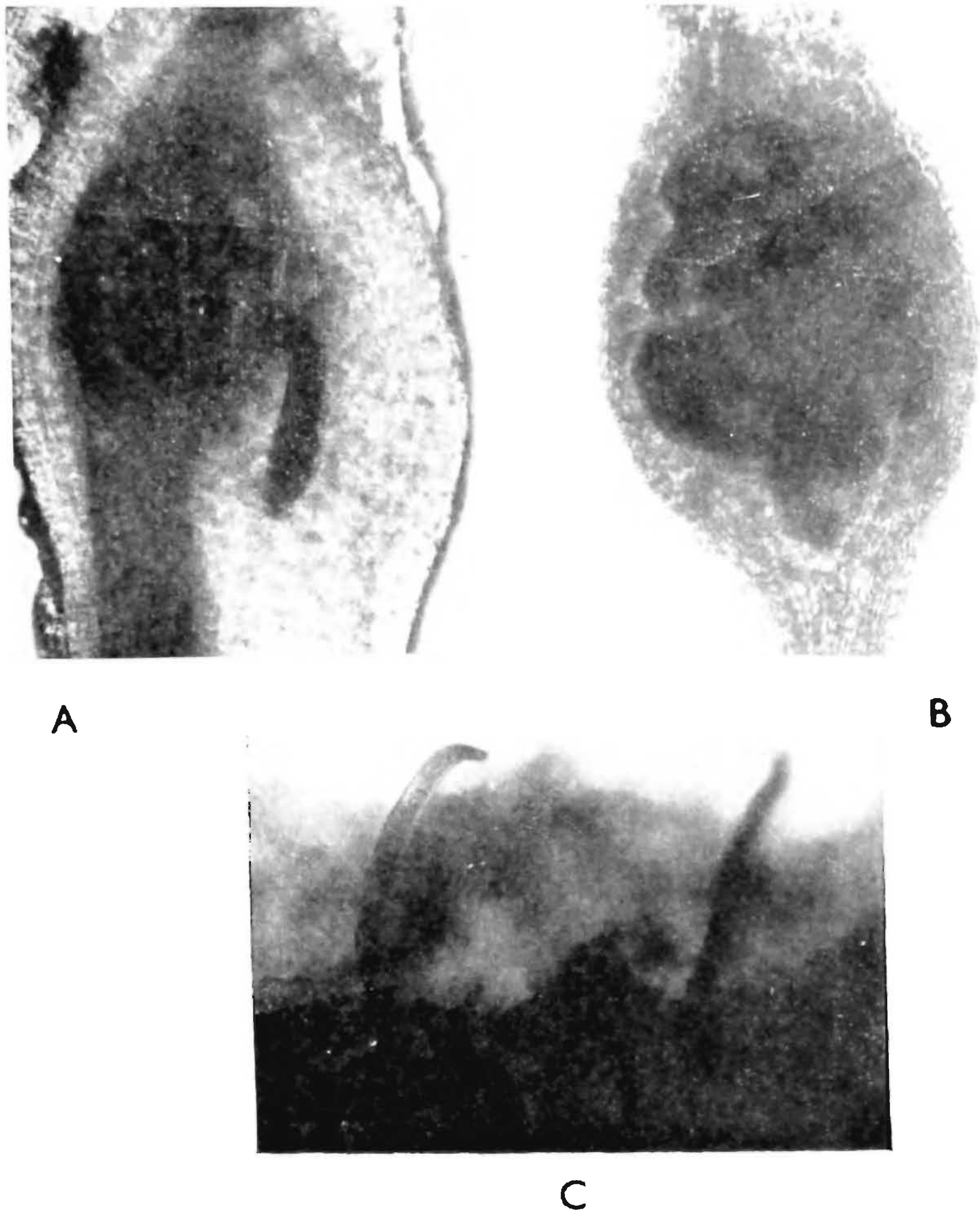


Plate IX

A. Root-piece showing a larva attached to stele and swelling in steler tissue; B. Root-piece showing giant cell in steler region; C. A dissected gall showing males of *M. javanica* inside the root.

A

B

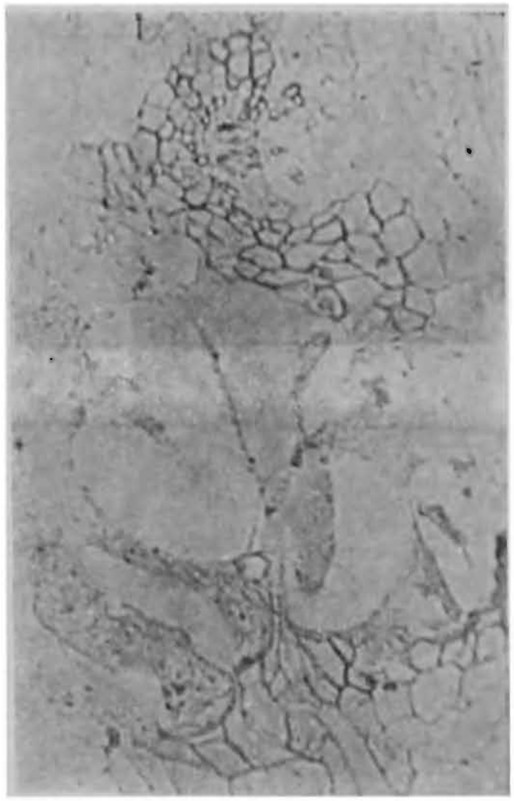
C

D

Plate X

A. Transverse section of root showing nematode infestation in cortex and stele; B. Transverse section of root showing many giant cells in cortex, and head attached to giant cell; C. Transverse section of root showing many giant cells in cortex, and a female attached to vacuolated giant cell; D. Transverse section of root (magnified) showing polynucleate and vacuolated giant cell, and a female attached to it.

A



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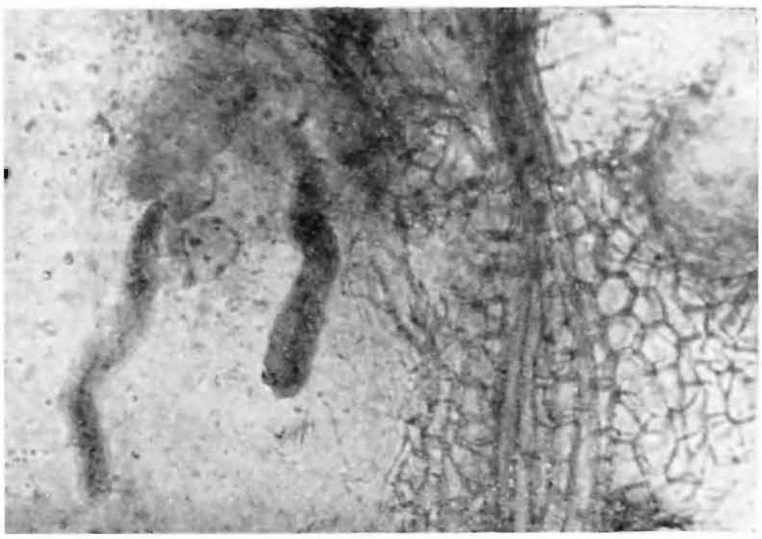
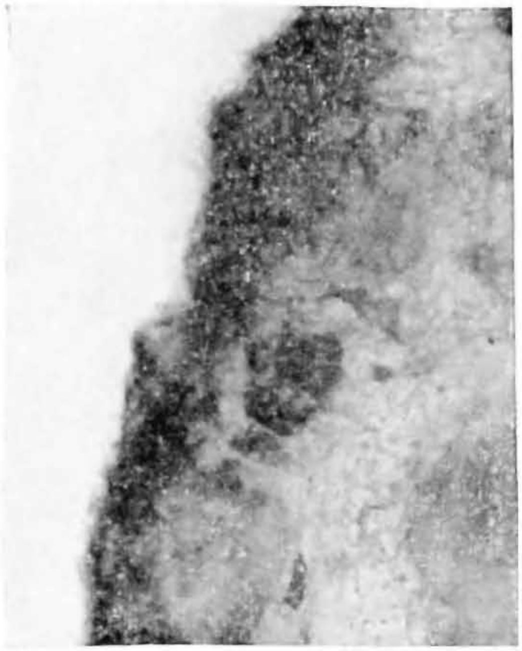


C

Plate XI

A. Longitudinal section of root showing several larvae attached to giant cell in cortex and stele; B. Longitudinal section of root (magnified) showing giant cells distorting xylem elements and hypertrophy of cells; C. Longitudinal section of root showing larvae attached to giant cell and distortion of xylem elements.



A

B

C

D

Plate XII

A. Transverse section of root showing a female and egg mass beneath epidermis; B. Transverse section of heavily infested root showing two cork layers; C. Transverse section of root showing a female with egg sac completely enclosed in root tissue; D. Transverse section of root showing a larva and several smaller cells near it, formed due to hyperplasia.

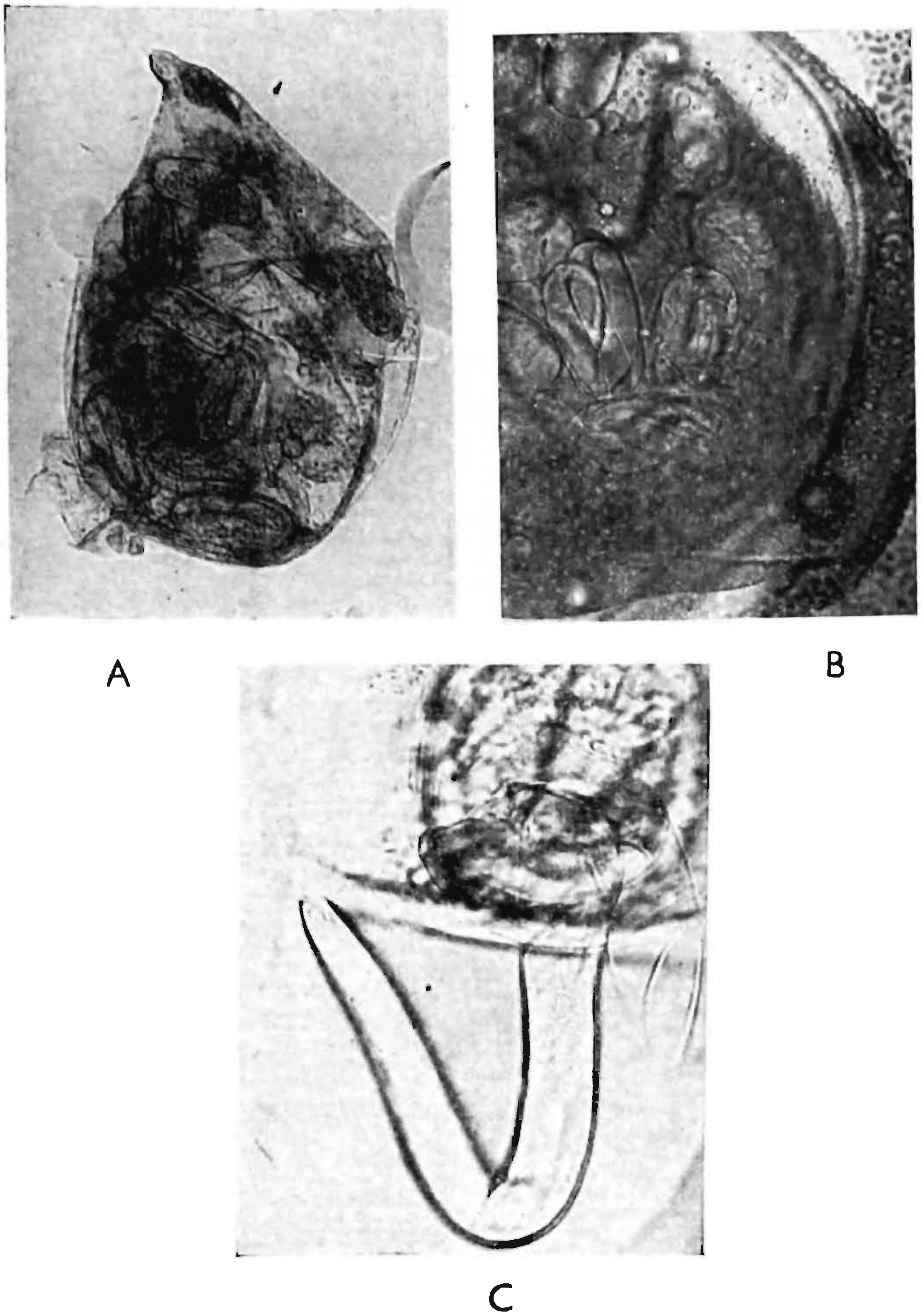


Plate XIII

Meloidogyne incognita—A. A young female with embryonated eggs inside; B. An older female (body in part) with embryonated eggs inside; C. A larva coming out through vulva.