STUDIES ON SOME ASPECTS OF NEMATODE INFECTIONS IN ANIMALS OF FOOD VALUE WITH AN EVALUATION OF PLAUSIBLE FACTORS AFFECTING ZOONOTIC INFECTIONS IN MEGHALAYA

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THESIS SUBMITTED IN FULFILMENT OF THE DEGREE OF

DOCTOR OF PHILOSOPHY IN ZOOLOGY

To

THE NORTH-EASTERN HILL UNIVERSITY

SHILLONG (INDIA)

NOVEMBER, 1990

IN MEMORY OF MY

FATHER

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*I certify that the thesis entitled "**Studies on some aspects of nematode infections in animals of food value with an evaluation of plausible factors affecting zoonotic infections in Meghalaya**" submitted by Sri Arun Kumar Yadav for the degree of Doctor of Philosophy in Zoology of the North-Eastern Hill University, Shillong embodies the record of original investigation carried out by him under my supervision. He has been duly registered and the thesis presented is worthy of being considered for the award of the Ph.D. degree. This work has not been submitted for any degree of any other university.*

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CONTENTS

PREFACE

Helminth parasites cause diseases of extreme importance to humans and domestic animals, resulting in great economic losses. This is particularly so in developing countries like India, which is sitting on top of mass of parasites. The need to intensify economic control, of parasites in domestic animals is therefore of prime importance not only from the human health standpoint because of the parasitic zoonoses but from the viewpoint of human nutrition as well, since in the low productivity of livestock and poultry helminth parasites are considered to be among the highly important factors.

Although all pasture animals are parasitized to a greater or lesser degree by various groups of internal parasites such as cestodes, trematodes, and nematodes, etc., the latter, i.e., nematodes pose a more serious threat by emerging as a relatively commonly prevalent group of parasites invading the livestock, particularly in the sub-tropics (Levine, 1980). This is probably because most of the gastrointestinal nematodes have a direct life cycle and do not involve intermediate hosts, which expedites the development and transmission of parasites to these hosts in a very simple manner.

Though extensive studies have been carried out on nematode parasites of domestic animals in different regions of India, there is apparently no work so far done pertaining to helminth parasite infections in livestock animals of Meghalaya, a north-eastern state of India. The state is endowed with a vast potential for animal husbandry. The cattle, goat, sheep, pig, and poultry are the important livestock and pork and beef in particular serve as the main constituent of the diet of local people. Further, it would appear that owing to its altogether different agro-climatic conditions when compared to other regions of India (i.e., a hilly terrain characterized by a high-rainfall and moderate temperature for major part of the year) the region bears a special significance in context of parasitic infections.

The foregoing account points out the need to recognize the full extent of the parasitic problem in livestock and to have the widest possible knowledge about various species of nematodes that affect these animals in the state. The present work is an initial attempt in this direction and explores some of the basic facts related to worm infections in this region of India.

The focal aspects of the study include:

(i) a record of the nematode parasite spectrum of animals of food value, namely cattle, goat, sheep, pig and poultry, with a brief description and remarks of each species recovered from the hosts;

(ii) the surface fine topography with the aid of scanning electron microscope (SEM) of those nematode species for which no information is available so as to elucidate the characters of taxonomic and functional significance;

(iii) seasonal prevalence of parasitic infections, particularly of the species of major importance in the spectrum, based on actual recovery of worms from, and/or faecal egg counts of, slaughtered animals;

(iv) an evaluation of plausible factors of zoonotic importance influenced by which parasitic infections prevail, survive, and are transmitted in this region (parasite-host interactions under diverse environmental circumstances may be locally and regionally important epidemiological determinants of hosts' risk to contracting infection);

(v) ascertaining the anthelmintic activity of an indigenous plant, _Flemingia vestita_ (locally known as Soh-phlong), that is regarded and used by natives as an anthelmintic, as evidenced by the effects of the crude extract of the plant tubers on the histomorphology and mobility of _Ascaris_ worms _in vitro_.

ABBREVIATIONS/SYMBOLS USED IN TABLES

A	Anterior Portion
DB	Distal Blade Part
M	Middle Portion
P	Posterior Portion
PT	Proximal Tubular Part
R	Right
¥	Posterior Portion of Oesophagus/Oesophageal bulb(B)
§	Distance from Anterior Extremity
*	Distance from Posterior Extremity
**	Distance from Cloaca/Anus
§§	Distance from beginning of intestine

CHAPTER I

SPECTRUM OF NEMATODE PARASITES : FAUNISTIC STUDIES

INTRODUCTION

Helminth parasitic fauna of domestic animals because of its underlying veterinary, medical and consequent economic importance has been studied by various workers and considerable information exists about the common parasites of these animals in different regions of the world (Schillhorn et al., 1975; Balbo et al., 1978; Duarte, 1981; Horak, 1981; Soulsby, 1982; Shaikh et al., 1983).

A look into the literature reveals that of the various helminthic infections prevalent amongst the livestock and poultry, nematodes can be considered to be the most prominent and economically significant group of parasites (Levine, 1980; Soulsby, 1982). In India, the work related to the survey and taxonomy of nematodes of domestic animals was started in the early twentieth century and from time to time the parasite material collected in India found its way into the hands of specialists such as Cobbold in England, Railliet in France, Parona in Italy and Linstow in Germany. Gaiger (1910) published a list of nematode parasites of Indian livestock animals principally based on the material collected from domestic animals of the Punjab and further added some more species to this list (Gaiger, 1915). Later, Lane made a number of studies between the years 1914-1923; Stewart (1914), Sheather (1919) and Sheather and Shilston (1920) also made significant contributions. Since that time fascinating and interesting works mainly in collaboration with Zoological Survey of India (Z.S.I.), Calcutta by such pioneers as Baylis and Daubney

(1922-26) and Maplestone (1929a-39) need mention of. Based on various reports Baylis (1936a, 1939) published a treatise entitled **Fauna of British India, Nematoda Vol.I & II** in which diagnoses of families and genera with a description of nematodes occurring in India and its adjacent countries were provided. According to Baylis, nematodes frequently parasitizing Indian livestock are placed in six orders representing twelve families and several subfamilies. Of these, seventeen genera have been reported to occur in cattle, twelve in goats and sheep, ten in pigs and five in fowl. Subsequently, nearly twenty years later Yamaguti (1961) produced a series of treatise entitled **Systema Helminthum** in which nematodes of vertebrates of the world are included. According to Yamaguti, nematodes of mammalian and avian hosts are described under nine orders and forty-four families and of these seven orders and twenty-five families are represented in Indian domestic animals such as cattle, goat, sheep, pig and fowl.

In a comprehensive taxonomic revision of the nematode group Anderson, Chabaud and Willmott (1974-1982; Anderson and Chabaud, 1983 — CIH Keys) have provided a classificatory scheme which is based on nematodes' inter-relationships in addition to judiciously characteristic features of their morphology. Thus keys to the various taxa within Nematoda prepared by these authors seem to provide a more natural classification which is also indicative of their phylogenetic relationships. As a result many a taxon (genera, subfamilies, etc.) finds in these keys a different place than what was assigned by earlier workers.

It may be mentioned here that studies related to nematodes of livestock and poultry in India mainly include comprehensive surveys of individual host types from various regions of the country. Significant contributions in this regard include those of Gupta and Mathur (1968), Gupta and Sood (1968), Gupta and Acharya (1968, 1970a,b), Sood and Kaur (1975), Gupta and Kalia (1978a,b), Soota and Sarkar (1977,1980,1981a,b) and Baruah et al. (1981), to mention a few. However, from time to time many workers have also reported numerous species of nematodes new to science (Sarwar, 1946a,b; Rammanuchari and Alwar, 1952; Fotedar and Bambroo, 1965; Jain et al., 1965; Ali and Deshpande, 1970).

Our knowledge of this group of parasites is still scanty in respect of north-eastern region of India. The present studies were therefore undertaken to fill this gap which especially aimed at identifying, ordering and registering the various parasitic species of nematodes prevailing in the livestock and poultry of Meghalaya, that represents a sub-tropical and high-rainfall area of India. In the present study during a two-year long exploration of the spectrum of nematode parasites of these hosts, namely, cattle, goat, sheep, pig and fowl, from various localities of the state twenty-four species belonging to thirteen families and eighteen genera were recorded. Of these, while majority of the species are also known to occur in other regions of India, it is for the first time that the occurrence of most of them is being reported from north-east India, Meghalaya in particular; the occurrence of Setaria bernardi, Capillaria contorta and Strongyloides sp. is recorded herein for the first time from domestic pigs and fowl, respectively in India.

The present work incorporates a description of all these species with remarks and a mention of deviations, if any, from their earlier description.

Representatives of all the species recorded in the present work have been deposited in the Helminthological Collection of the Eastern Regional Station of Zoological Survey of India at Shillong.

MATERIALS AND METHODS

Study area

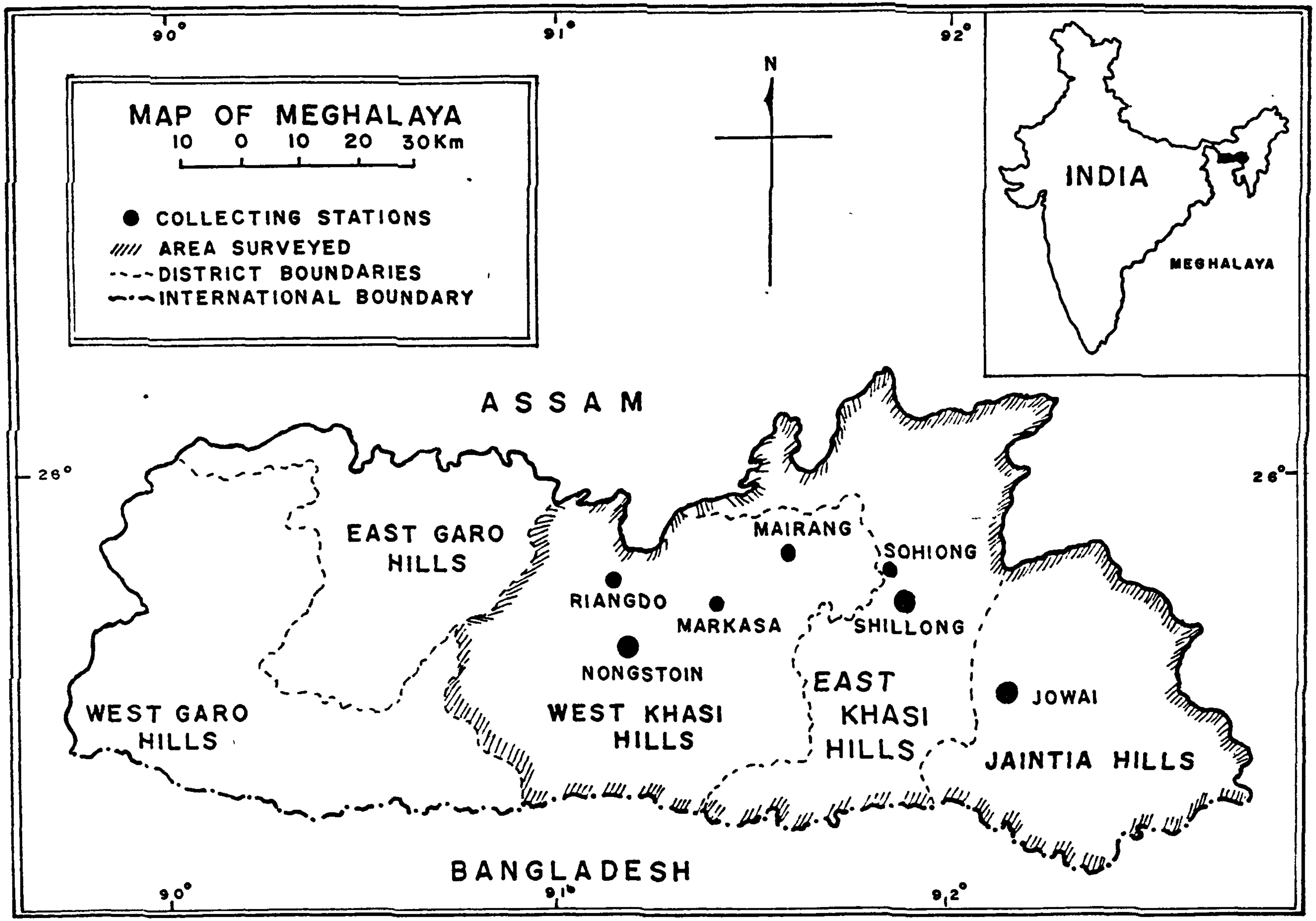
The region under the present study comes under the East and West Khasi Hills and Jaintia Hills districts (with Shillong, Nongstoin and Jowai as the district headquarters, respectively) of Meghalaya state, which covers a total land area of 14,262 sq.km. (24°5'N-26°10'N-90°45'E-92°95'E) and has an altitude range of approximately 400-1600m above sea level (Plate 1.1). The stations from where the materials were collected include Shillong, Sohiong, Mairang,Markasa, Nongstoin, Riangdo and Jowai.

Selecting the survey samples

To determine the nematode parasite spectrum of livestock and poultry, postmortem recovery of worms was made from animals slaughtered during different times of the years at various slaughter houses located in the region; for poultry, the alimentary canal along with associated body organs was procured from local markets. During each collection, a visual examination of body cavity and other organs of slaughtered animals was made for the presence

PLATE 1.1 Map of Meghalaya, showing the area surveyed (hatched) and locations of various collecting stations

PLATE-1·1


90°
91°
92°
26°
26°
MAP OF MEGHALAYA
10 0 10 20 30Km
COLLECTING STATIONS
AREA SURVEYED
DISTRICT BOUNDARIES
INTERNATIONAL BOUNDARY
N
INDIA
MEGHALAYA
ASSAM
EAST GARO HILLS
WEST GARO HILLS
MAIRANG
SOHIONG
RIANGDO
MARKASA
SHILLONG
NONGSTOIN
WEST KHASI HILLS
EAST KHASI HILLS
JOWAI
JAINTIA HILLS
BANGLADESH
90°
91°
92°

of parasites, if any, and further the specimens were recovered from the wash of each and every gastro-intestinal tract handled by the butchers; in addition at least 4-5 gastro-intestinal tracts along with other body organs were subjected to a detailed laboratory examination in order to recover worms from their sites of predilection.

Laboratory procedures

For poultry, the alimentary canals with associated organs were brought to the laboratory. Each of the five portions of the alimentary tract (oesophagus, stomach, small intestine, colon and caecum) of each bird was slit separately along its length and the contents and lining examined for free and/or adhering worms. Other organs such as liver, bronchi, lungs, heart, muscles, ureters, kidneys and associated peri-renal fat were also examined microscopically for any embedded worms.

For cattle, goats, sheep and pigs the gastro-intestinal tract, lungs, heart, liver were removed from the body and brought to the laboratory for further examination. Different parts -. abomasum, small intestine and large intestine were separated, slit opened lengthwise and their contents washed gently in separate buckets. The drained gut contents were passed through a graded series of sieves (diameter - 20.5cm; aperture size - 450, 250 and 150μm, respectively) under running water as described by Reinecke (1984), the worms thus retained on different sieves being collected. Simultaneously, the lungs, liver and heart were also examined for the presence of nematodes by standard laboratory techniques.

The worms thus collected were washed in physiological saline, heat relaxed and fixed in 70% alcohol, cleared in graded series of glycerine to pure glycerine in a desiccator and mounted in glycerine jelly medium (Gelatin 8gm + Glycerol 50ml + Distilled water 50ml). Identifications were made on sexually mature male and female worms according to Baylis (1936a, 1939), Yamaguti (1961) and CIH Keys to the Nematode Parasites of Vertebrates Nos.1-10 (Anderson, Chabaud and Willmott, 1974-1982; Anderson and Chabaud, 1983). The taxonomic positions of the recorded species and the terminology used in the text are in accordance with the CIH Keys. The observations were made under the WILD M5APO Stereo- and Leitz Ortholux-2 microscopes. The line drawings were prepared with the help of camera lucida.

All measurements, taken with the help of ocular and stage micrometers are in millimetres and based on ten specimens of each sex unless otherwise stated; at least 5 eggs from each female specimen were measured.

OBSERVATIONS

Family Ascarididae Baird, 1853

Subfamily Ascaridinae (Baird, 1853) Hartwich, 1974

Genus *Ascaris* Linnaeus, 1758

Ascaris suum Geoze, 1782

(Syn. *A. lumbricoides* Linnaeus, 1758)

(Plates 1.2, 1.3)

A very large number of worms of this species was collected from time to time.

PLATE 1.2 *Ascaris suum*

Fig.1 Anterior end, showing lips and cephalic papillae

Fig.2 Posterior end of male, showing caudal papillae

Fig.3 Posterior end of female, showing opening of anus

Fig.4 Vulvar opening in female

Fig.5 Egg

PLATE-1·2

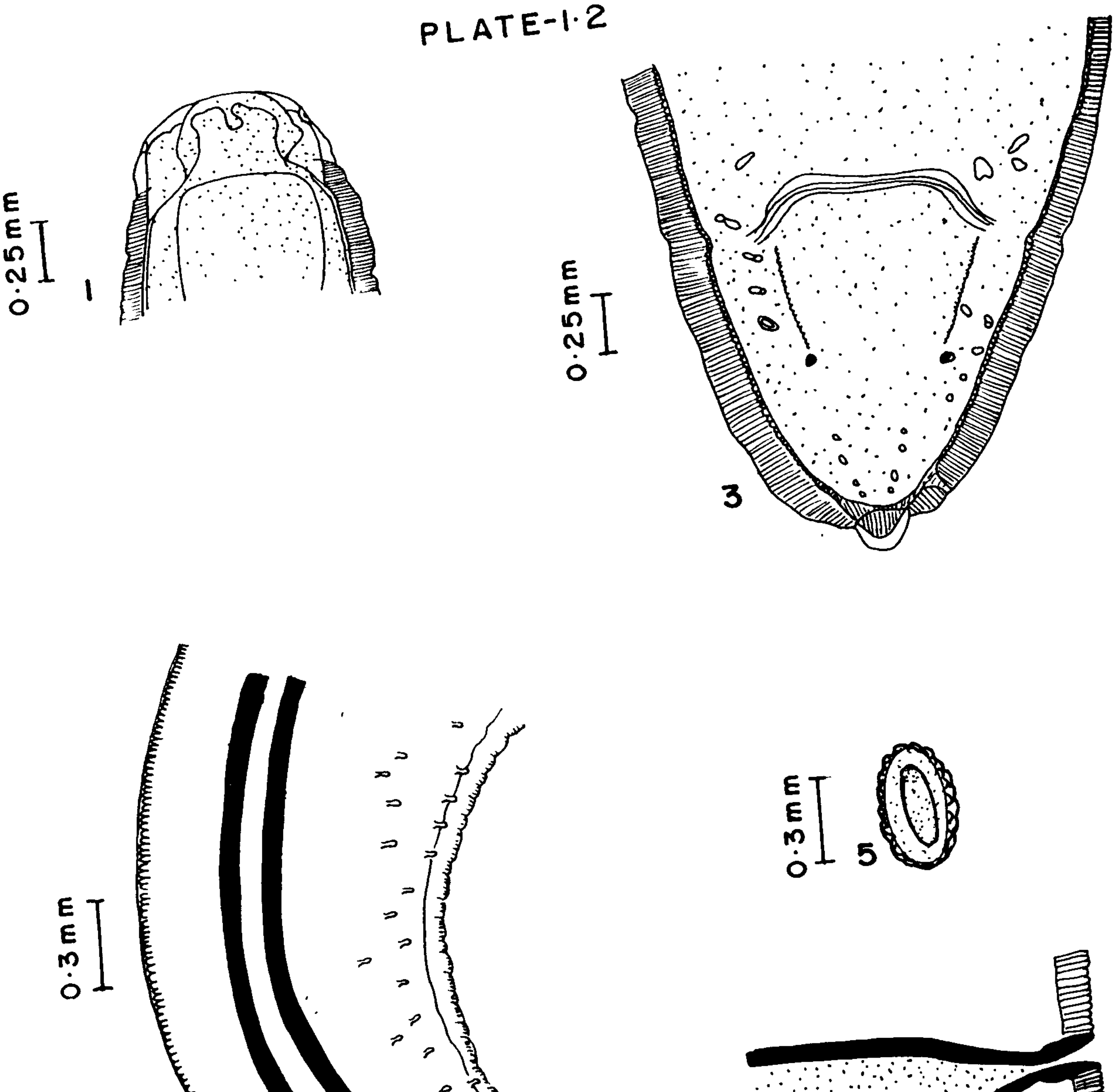


PLATE 1.3 _Ascaris suum_ (Photomicrographs)

Fig.1 Anterior end (scale bar = 0.3mm)

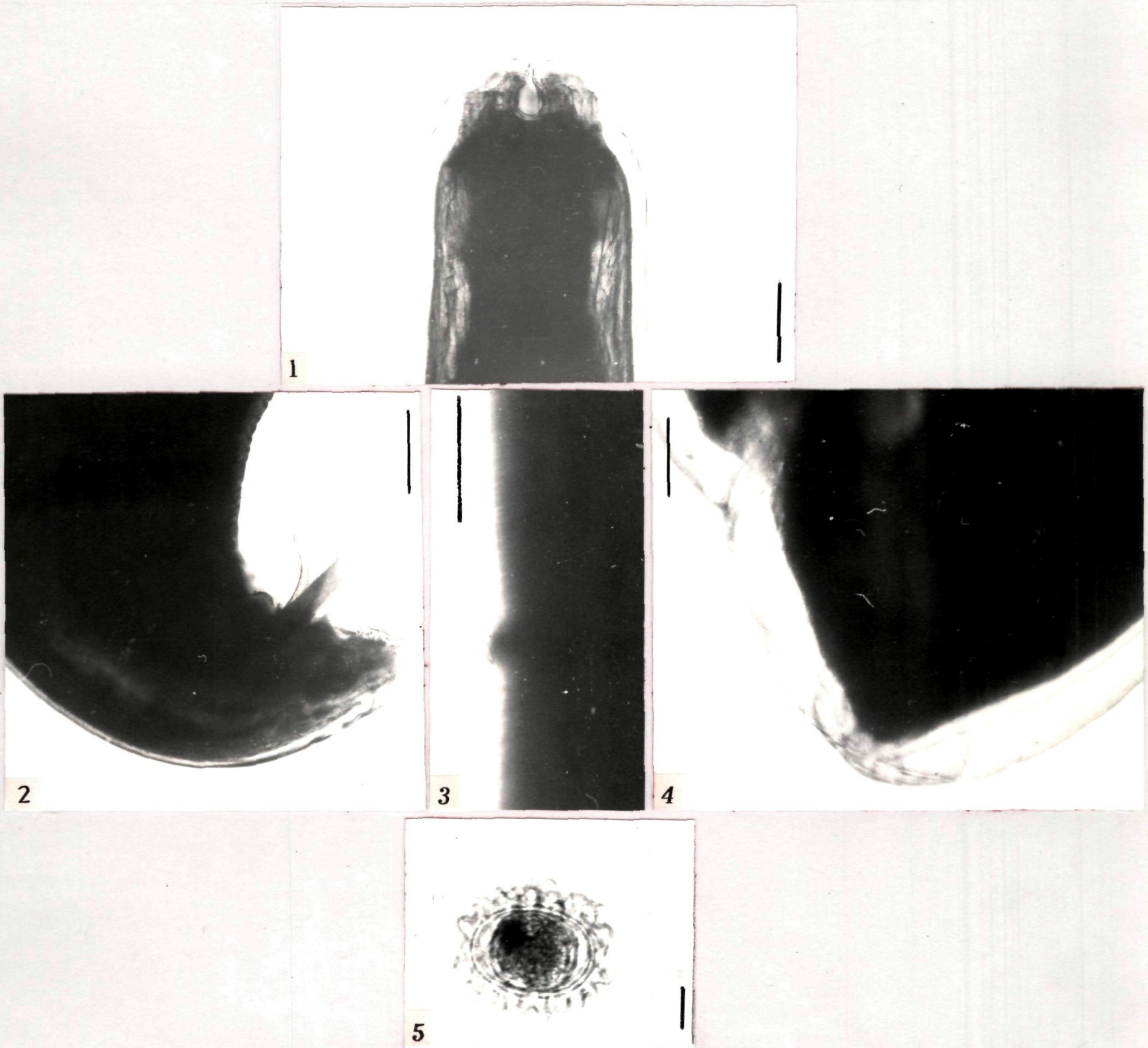
Fig.2 Posterior end of male (scale bar = 0.3mm)

Fig.3 Vulvar region in female (scale bar = 0.2mm)

Fig.4 Posterior end of female (scale bar = 0.3mm)

Fig.5 Egg (scale bar = 0.02mm)

PLATE 1.3



Description

General

Large, yellowish-brown, fairly rigid worms; body tapers gradually towards each end. Cuticle relatively thick with faint transverse striations; cervical alae absent. Anterior end provided with three well-developed semicircular lips, one dorsal, two ventrolateral; dorsal lip bears on its outer surface pair of large lozenge-shaped papillae, with double terminations; each of ventrolateral lips carrying one double papilla ventrally; pulp of each lip produced anteriorly as pair of blunt lobes with shallow groove, additional round median lobe present towards inner surface of lip; inner surface of each lip bearing transverse series of minute dentigerous ridge; interlabia absent. Oesophagus well developed, simple, club shaped, muscular; spherical bulb without internal valve.

Male

Caudal end conical, without alae, almost invariably curled towards ventral side. Caudal papillae 70-75 pairs; five pairs postanal, two anterior pairs large with double terminations, three posterior papillae arranged in triangle on either side; preanal papillae very irregularly arranged, forming single longitudinal row on each side for short distance in front of anus, then several irregular rows, finally at anterior part single row again; pair of double papillae in series at some distance from anus, situated in asymmetrical manner; large, median, cushion-like papilla also present just in front of anal aperture. Spicules equal, broad, dorsoventrally flattened, somewhat widened in their distal half, without alae. Gubernaculum absent.

Female

Tail short, straight, obtusely conoid. Vulva opens near anterior third of body, frequently in shallow annular constriction. Vagina short, running forward for short distance from vulva, then doubling back sharply close to ventral body wall, passing into unpaired portion of uterus which widens gradually giving off two relatively wide uterine branches running back, parallel to each other till short distance from posterior end, where they touch forward and pass into narrower ovarian tubes; these forming several anteroposterior loops, thrown into innumerable secondary loops in transverse direction. Eggs dark brown, thick shelled, albuminous layer bearing prominent projections.

The morphometric measurements of the body and its organs are given in Table 1.1.

Host	Pig
Location	Small intestine
Locality	Shillong, Nongstoin, Markasa, Riangdo, Jowai, Mairang, Sohiong

Remarks

The species has also been recorded from wild boars, man, chimpanzee etc., by Baylis and Daubney (1922) and is cosmopolitan in distribution.

Morphologically similar worms occur very commonly in human hosts as well. The form of human origin has been known as A. lumbricoides Linnaeus, 1758. As early as the work of Rudolphi (1809) A. suum was believed to be

TABLE 1.1 : *Ascaris suum* Goeze, 1782 : morphometric measurements (in mm)

Characters		Male		Female	
		Range	Mean	Range	Mean
Body :	length	185-210	197.6	215-318	264.1
	width	3.0-5.5	4.1	4.0-6.0	5.0
Lips :	length	0.32-0.39	0.35	0.39-0.58	0.51
Oesophagus :	length	7.9-9.5	8.7	7.8-10.0	8.8
	width(B)[¥]	1.1-1.4	1.2	0.91-1.46	1.20
Tail :	length	0.48-0.73	0.62	1.20-1.60	1.40
Spicules :	length	1.39-2.29	1.78	-	-
Vulva[§]		-	-	88.0-130.0	107.4
Eggs :	length	-	-	0.06-0.07	0.06
	width	-	-	0.04-0.05	0.05

a synonym of A. lumbricoides and since then the controversy as to whether or not the two strains are identical has been raised. The early history of this controversy is reviewed by several workers, such as Mozgovoi et al. (1960) and Schwartz (1960). Baylis and Daubney (1922) and Thornton (1924) considered the human and pig forms morphologically identical (further discussion in Chapter II), while Martin (1926) and Caldwell and Caldwell (1926) advocated these to be biologically distinct on experimental and epidemiological grounds. However, biochemical studies performed by Vasilev et al. (1972) and Kurimoto (1974) showed differences between the human and pig forms.

Family Ascaridiidae Travassos, 1919

Genus Ascaridia Dujardin, 1845

Ascaridia galli (Schrank, 1788) Freeborn, 1923

(Syn. Ascaris galli Schrank, 1788; A. gallopavonis Gmelin, 1790; A. hamia Lane, 1914)

(Plates 1.4, 1.5)

The collection comprised several hundred specimens of A. galli.

Description

General

Worms long, semitransparent, with oral opening at anterior end. Cuticle striated, intervals between cuticular striations well marked; lateral alae in cervical region feebly developed, extremely narrow. Sides of anterior end of body bearing pair of distinct cervical papillae. Mouth surrounded by three

PLATE 1.4 Ascaridia galli

Fig.1 Anterior end, showing lips and cephalic papillae

Fig.2 Posterior end of male, showing preanal sucker, anus and caudal papillae

Fig.3 Posterior end of female, showing opening of anus

Fig.4 Vulvar opening in female

Fig.5 Egg

PLATE-1·4

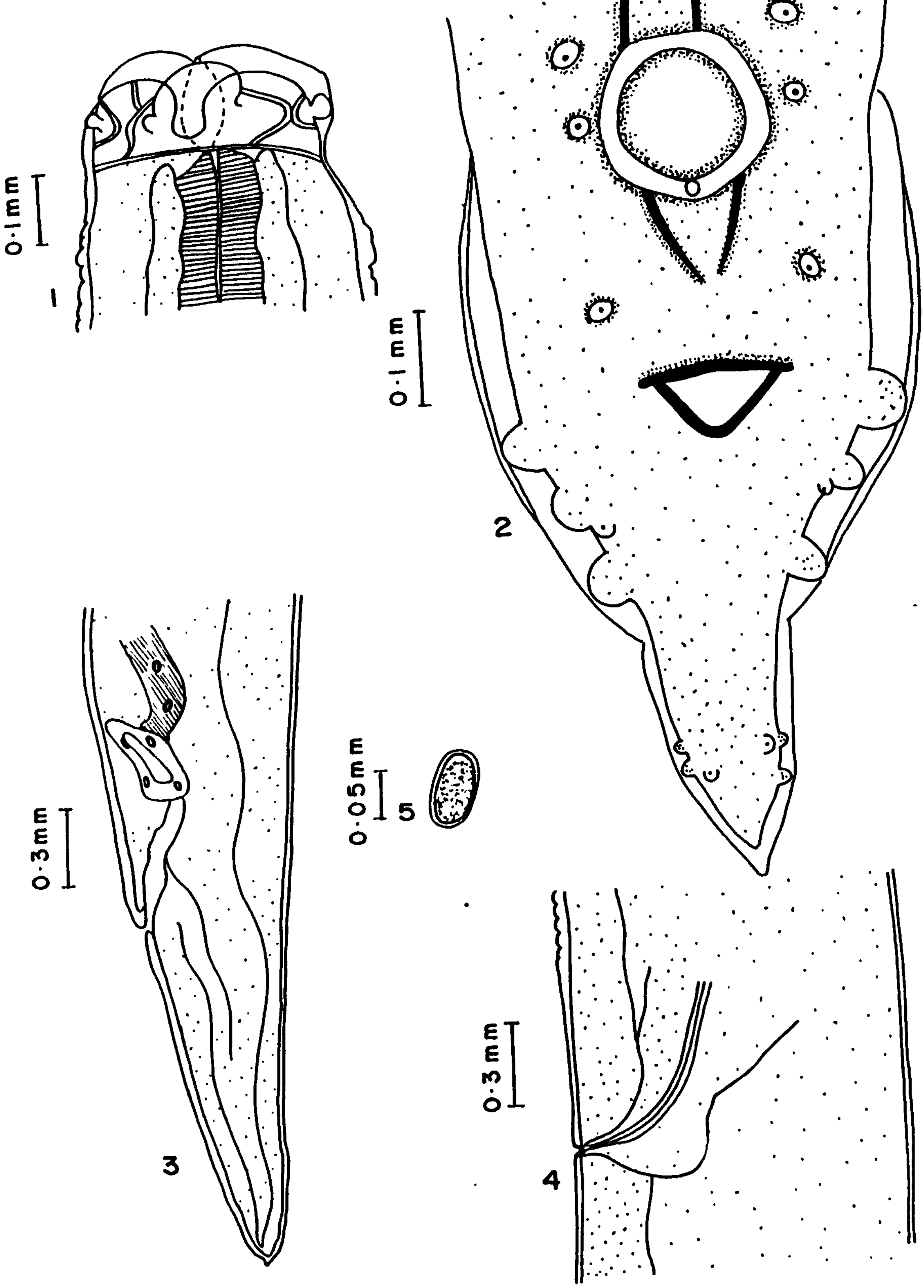


PLATE 1.5 *Ascaridia galli* (Photomicrographs)

Fig.1 Anterior end, showing lips and labial papillae (scale bar = 0.2mm)

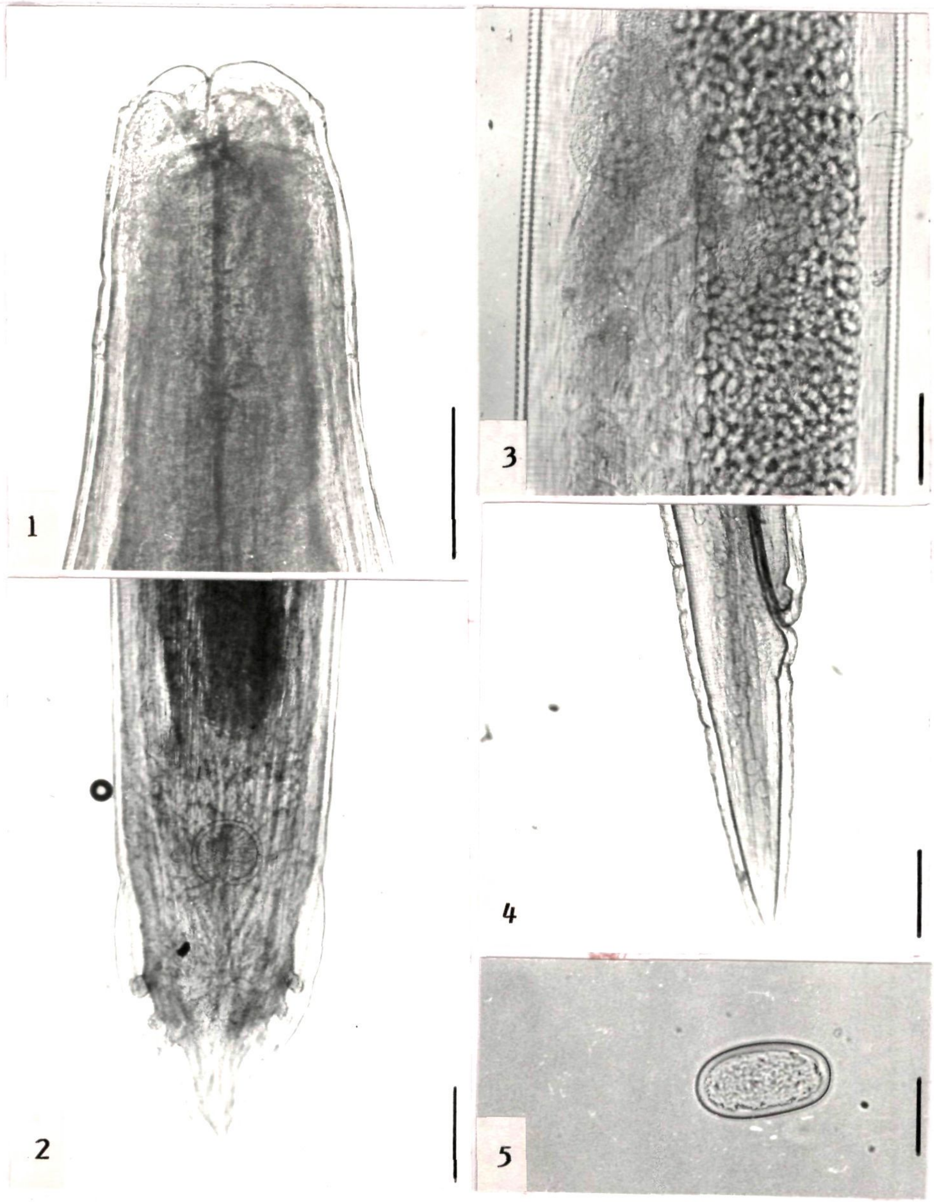
Fig.2 Posterior end of male, showing preanal sucker and caudal papillae (scale bar = 0.3mm)

Fig.3 Vulvar region in female (scale bar = 0.3mm)

Fig.4 Posterior end of female, showing opening of anus (scale bar = 0.3mm)

Fig.5 Egg (scale bar = 0.04mm)

PLATE 1.5



prominent lips, one dorsal, two lateral; each lip divided into three distinct lobes, one median, two lateral; inner surface of median lobe of each lateral lip possessing single dentigerous ridge; dorsal lip broader than lateral lip, provided with pair of distinct large lozenge-shaped papillae in its centre in addition to a large circular papilla. Oesophagus simple, terminating by swelling, without valve.

Male

Slightly smaller, more slender than female. Posterior end obliquely truncated, possessing narrow bursal membrane on each side and concavity on ventral surface of body between anus and tip of tail. Prominent preanal sucker present on ventral side of tail, surrounded by distinct chitinous rim; anus usually appearing as transverse slit; numerous small tubercle-like structures scattered irregularly around anus, extending towards lateral sides. Caudal papillae ten pairs, arranged in distinct groups, i.e., preanal, anal, postanal and subterminal on ventral surface of caudal end; preanals three pairs - first pair anterior to preanal sucker, second at level of preanal sucker and close to the first pair; subterminals three pairs, first smallest of all anal pairs, lying close to second pair, second and third pairs comparatively more prominent, surrounded by small cuticular raised structures giving them rosette-like appearance, lying laterally and ventrally respectively, on extreme tail region of body. Spicules well developed, equal, covered in spicular sheath, protruding out at anal opening.

Female

Larger, stouter and vigorous than male. Tail tapers pointingly posteriorly, possessing pair of papillae just near to its tip. Anus in front of posterior end of body. Vulva near middle of body. Vagina muscular, proceeding anteriorly; uteri opposed. Eggs oval, smooth, thick shelled.

The morphometric measurements of the body and its organs are given in Table 1.2.

Host	Fowl
Location	Intestine and caecum
Locality	Shillong, Mairang, Nongstoin, Jowai

Remarks

This species has been recorded from fowl and other birds from almost all parts of the country. Schrank (1788) described ascarids of poultry as a new species, Ascaris galli. Later Railliet and Henry (1912a) referred this species as Ascaridia lineata (Schneider, 1866). Freeborn (1923) substituted Ascaridia galli (Schrank, 1788) for Ascaris perspiculum (Rudolphi, 1803). Bhalerao (1934a) separated A. lineata from A. galli on the basis of the number of dentigerous ridges. On account of longer spicules, the larger preanal sucker and the presence of lateral alae in A. galli, Neveu-Lemaire (1936) regarded A. lineata as distinct species from A. galli, an opinion also held by Monning (1947) and Kung (1949) and later workers.

Except for some minor variations such as only two dentigerous ridges on the median lobes of lateral lips as against three as described by Bhalerao (1934a), the present observations are in conformity with the earlier descriptions.

TABLE 1.2 : *Ascaridia galli* (Schrank, 1788) Freeborn, 1923 : morphometric measurements

Characters		Male Range	Male Mean	Female Range	Female Mean
Body :	length	50.0-74.0	63.2	68.0-110.0	84.7
	Width	0.50-0.64	0.55	0.648-0.936	0.69
Lips :	length	0.09-0.12	0.10	0.09-0.12	0.09
Interstrial distance		9.2-18μ	14 μ	9-20 μ	12 μ
Oesophagus :	length	2.88-3.24	3.02	2.8-3.3	3.04
	Width	0.28-0.50	0.37	0.32-0.50	0.41
Nerve ring§		0.52-0.68	0.61	0.43-0.63	0.58
Tail :	length	0.48-0.79	0.64	1.17-1.36	1.26
Preanal sucker :	length	0.18-0.25	0.21	-	-
	distance**	0.25-0.50	0.38	-	-
Spicules :	length	0.88-2.52	1.7	-	-
Vulva§	-	-	-	28.6-35.2	31.8
Eggs :	length	-	-	0.05-0.08	0.07
	width	-	-	0.03-0.05	0.04

Family Heterakidae Railliet et Henry 1912a

Subfamily Heterakinae Railliet et Henry, 1912a

Genus Heterakis Dujardin, 1845

Heterakis gallinae (Gmelin, 1790) Freeborn, 1923

(Syn. Ascaris gallinae Gmelin, 1790; H. gallinarum (Schrank, 1788) Madsen, 1949; H. vesicularis Dujardin, 1845)

(Plates 1.6, 1.7)

The collection comprised several hundred specimens of this species.

Description

General

Worms small to medium sized, white coloured; anterior extremity bent dorsally. Cuticular striations extremely fine; two narrow lateral cuticular membranes extending along body length, well developed in cephalic and caudal regions. Pair of cervical papillae present at anterior extremity. Mouth surrounded by three equal-sized rounded lips, two lateral, one dorsal; each lateral lip bearing two papillae, one each at its anterior extremity and towards its base; dorsal lip possessing pair of comparatively small papillae. Oesophagus divided into three parts - short muscular pharynx, cylindrical middle part, and posterior part enlarged to form subglobular bulb with three-sided valvular apparatus. Nerve ring and excretory pore just anterior to cervical papillae.

Male

Tail straight, tapering beyond alae to a fine filament; two quite large,

PLATE 1.6 Heterakis gallinae

Fig.1 Anterior end, showing lips and cervical alae

Fig.2 Posterior end of male, showing prominent preanal sucker, spicules and arrangement of papillae

Fig.3 Posterior end of female, showing opening of anus

Fig.4 Vulvar opening in female

Fig.5 Egg

PLATE-1·6

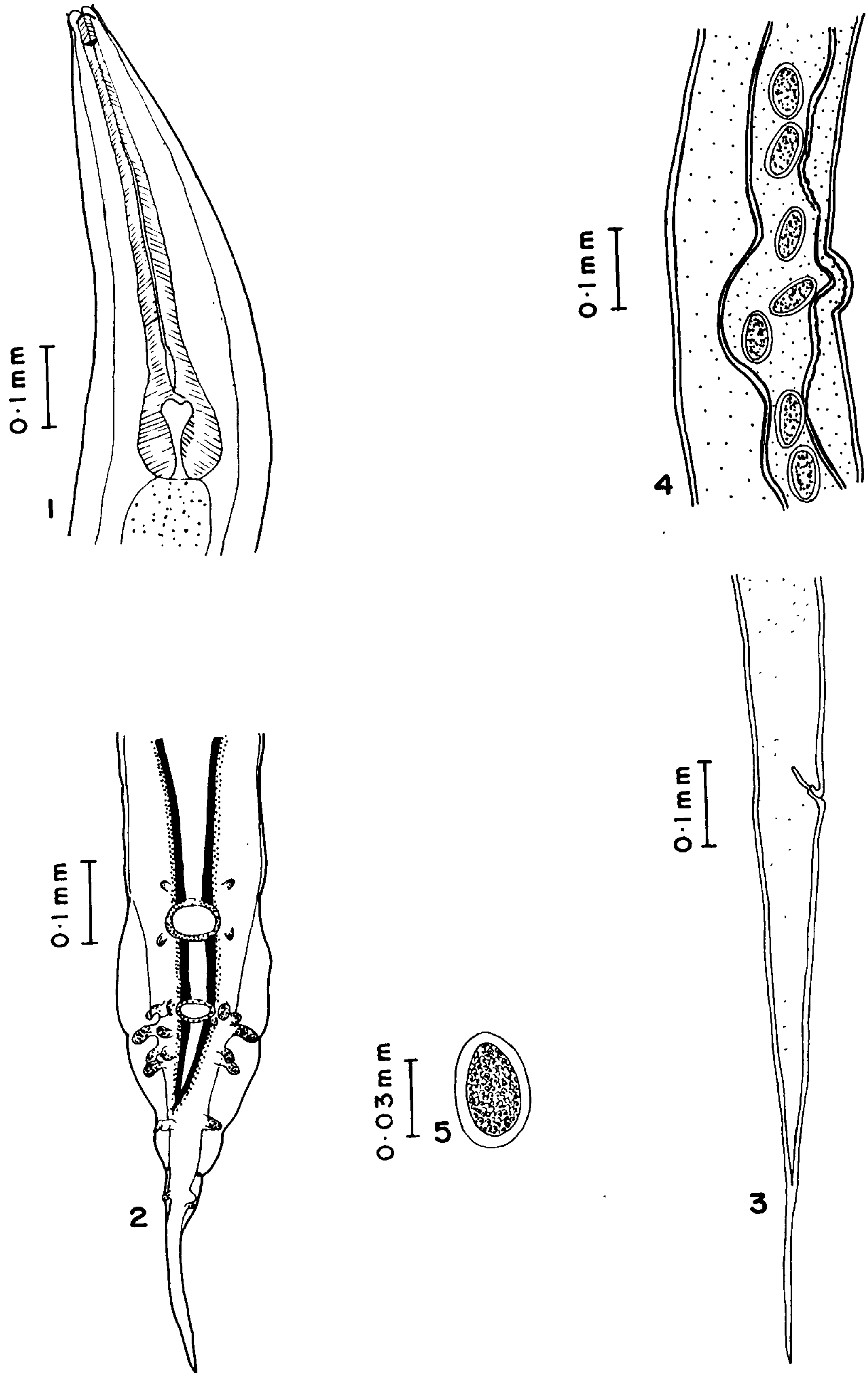


PLATE 1.7 _Heterakis gallinae_ **(Photomicrographs)**

Fig.1 Anterior end (scale bar = 0.2 mm)

Fig.2 Posterior end of the male, showing caudal papillae and spicule (scale bar = 0.2 mm)

Fig.3 Vulvar region in the female (scale bar = 0.2mm)

Fig.4 Caudal end of the female, showing long, slender tail (scale bar = 0.2 mm)

Fig.5 Egg (scale bar = 0.015mm)

PLATE 1.7

subequal lateral bursal wings present on either side of tail, supported by pedunculate papillae. Preanal sucker with chitinous rim, not very close to anus; anal opening oval with definite walls. Caudal papillae twelve pairs, situated on ventral side of caudal extremity; five pairs with long peduncles, projecting into alae; of the remaining pairs four postanals, two sessile adanals, four ray-like adanals, two ray-like preanals; latter at sides of preanal sucker; of adanals, sessile papillae close to anus, second pair of ray-like adanals largest touching outer bursal membrane; of postanals, first pair large, third and fourth pairs overlapping each other. Spicules unequal, dissimilar with prominent alae; right spicule longer with narrower alae and simple conical tip, left spicule possessing very broad alae, its tip forming characteristic double curve. Gubernaculum absent.

Female

Tail tapering posteriorly to sharp point, pair of small, caudal papillae present just near to its tip. Vulva inconspicuous, lying near middle of body. Vagina highly muscular, its terminal portion running posteriorly from vulva. Uterus forming several anteroposterior loops, and disposed in two apparently opposed branches. Eggs thick shelled, ellipsoidal, unsegmented.

The morphometric measurements of this species are given in Table 1.3.

Host Fowl

Location Intestinal caecum, frequently intestinal lumen

Locality Shillong, Mairang, Nongstoin, Jowai

TABLE 1.3 : <u>Heterakis gallinae</u> (Gmelin, 1790) Freeborn, 1923 : morphometric measurements

Characters		Male Range	Male Mean	Female Range	Female Mean
Body :	length	7.5-10.0	8.5	8.5-12.0	10.2
	width	0.22-0.44	0.31	0.26-0.35	0.29
Oesophagus :	length	0.86-1.0	0.92	0.82-0.93	0.88
	width(B)[¥]	0.09-0.12	0.11	0.09-0.12	0.10
Nerve ring[§]		0.25-0.30	0.27	0.25-0.36	0.28
Tail :	length	0.37-0.46	0.43	0.66-0.97	0.79
Caudal alae:	length	0.09-0.12	0.11	-	-
	width	0.09-0.15	0.13	-	-
Preanal sucker :	diameter	0.04-0.07	0.6	-	-
	distance**	0.14-0.19	0.17	-	-
Spicules :	length(L)	0.70-0.81	0.74	-	-
	(R)	1.2-1.7	1.48	-	-
Vulva[§]		-	-	5.4-7.6	7.01
Vagina :	length	-	-	0.25-0.30	0.27
Eggs :	length	-	-	0.05-0.08	0.06
	width	-	-	0.02-0.04	0.03

Remarks

H. gallinae has been recorded from a variety of gallinaceous birds in the Zoological Gardens, Calcutta, by Baylis and Daubney (1922), Chandler (1926), and Maplestone (1932a). Gmelin (1790) first described the parasite and placed in the genus Ascaris (Linnaeus, 1758). Frölich (1791) redescribed it and assigned it to a new genus Heterakis. Zeder (1800) created a genus Fusaria but Gmelin named the type species as gallinae. After Frölich (1791), this worm was considered as H. vesicularis till Freeborn (1923) reintroduced the correct name Heterakis gallinae (Gmelin, 1790).

The present observations are in conformity with those of Baylis (1936a) and Deo (1964) except for minor deviations with regard to the length of the body and tail, and distance of vulva from the posterior end.

Family Kathlaniidae (Lane, 1914) Travassos, 1918

Subfamily Cruziinae (Travassos, 1917) Ortlepp, 1924

Genus Pseudocruzia Wolfgang, 1953

Pseudocruzia orientalis (Maplestone, 1930b) Wolfgang, 1953
(Syn. Cruzia orientalis Maplestone 1930b)
(Plates 1.8, 1.9)

The collection comprised a single male and several female specimens of this species.

Description

General

Medium-sized worms, body thicker in middle, tapering towards either

PLATE 1.8 Pseudocruzia orientalis

Fig.1 Anterior end, showing lips, cephalic papillae, and pharynx containing parallel rows of teeth

Fig.2 The same extended posteriorly to show the diverticulum of intestine

Fig.3 Posterior end of male, showing spicules and arrangement of papillae at caudal extremity

Fig.4 Posterior end of female, showing opening of anus

Fig.5 Vulvar region in female

Fig.6 Egg

PLATE-1·8

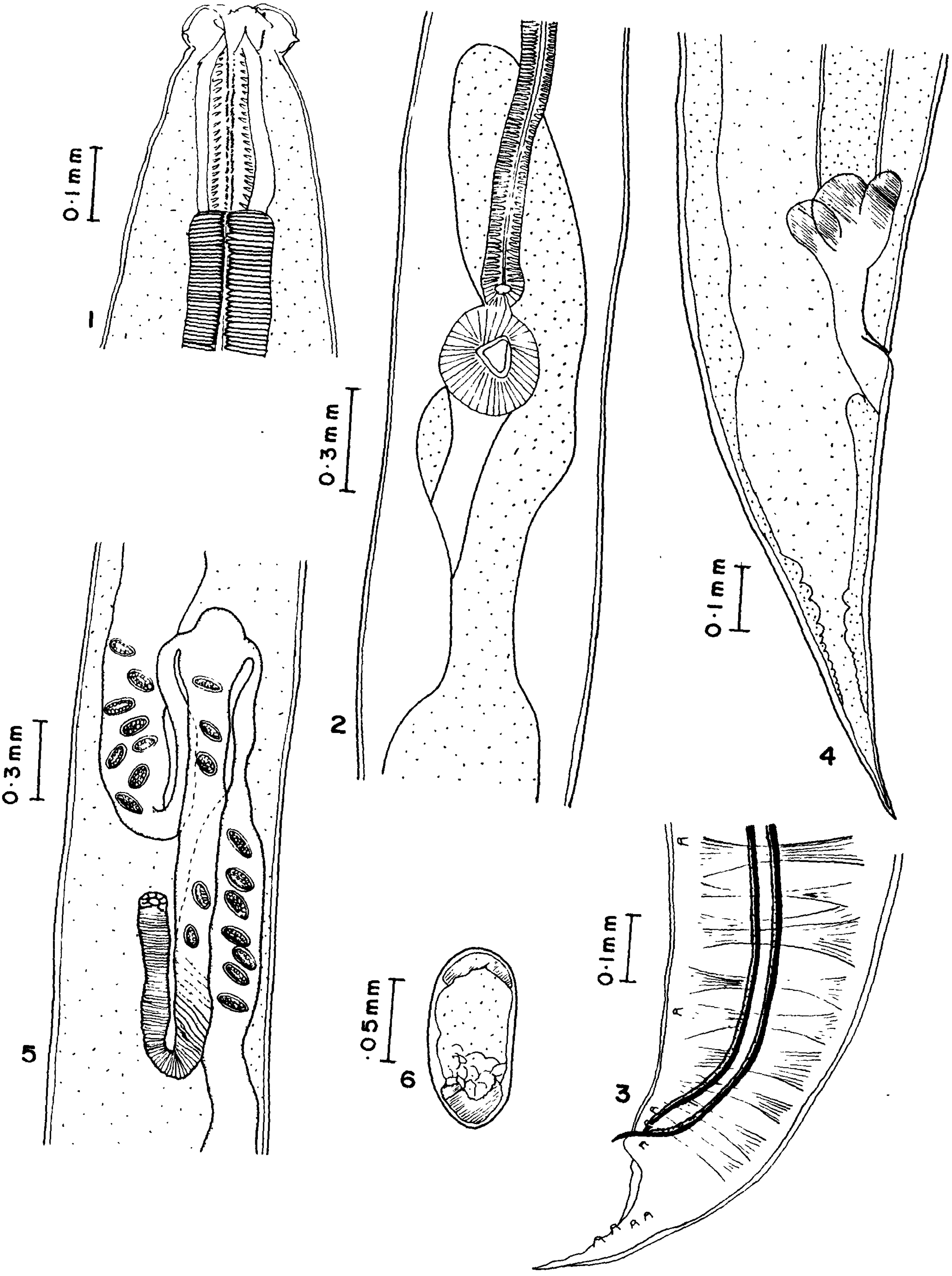


PLATE 1.9 Pseudocruzia orientalis (Photomicrographs)

Fig.1 Anterior end (scale bar = 0.2 mm)

Fig.2 Oesophageal region, showing intestinal diverticulum (scale bar = 0.3 mm)

Fig.3 Posterior end of male, showing caudal papillae (scale bar = 0.2mm)

Fig.4 Vulvar region in female (scale bar = 0.3 mm)

Fig.5 Posterior end of female (scale bar = 0.2mm)

Fig.6 Egg (scale bar =0.05 mm)

PLATE 1.9

ends. Cephalic extremity separated from rest of body by marked constriction. Head with three subtriangular lips separated from one another by subsidiary lobes; lips possessing widely inflated cuticle, double papilliform processes on inner surface at mouth opening, dorsal lip at very prominent lateral angles, ventrolateral lip marked off from body by deep groove. Pharynx three sided, with narrow lumen, strongly chitinized, armed with three rows of about twenty two denticles projecting at right angles into lumen; teeth of same size.

Oesophagus with large spherical bulb and small prebulbar swelling; bulb not constricted off from corpus. Intestine with anteriorly directed diverticulum.

Male

Tail conical, caudal alae very small. Ventral surface of preanal region rugose. Caudal muscles well developed, form oblique bundles, not aggregated into sucker-like organ. Ten pairs of sessile caudal papillae present - four pairs postanal, three pairs adanal, three pairs situated in preanal region. Spicules equal, alate. Large subtriangular gubernaculum present.

Female

Tail tapering gradually to point. Vulva not very prominent, situated slightly in front of middle of body. Uteri opposed. Eggs relatively large, with thick rugose shell.

The measurements of the body and its organs are given in Table 1.4.

TABLE 14 : *Pseudocruzia orientalis* (Maplestone, 1930b) Wolfgang, 1953 : morphometric measurements

Characters		Male	Female Range	Female Mean
Body :	length	15.0	16.2-18.0	16.9
	width	0.72	0.72-0.84	0.76
Pharynx :	length	0.23	0.25-0.27	0.26
Oesophagus :	length	2.25	2.34-2.61	2.50
	Width(B)[¥]	9.14	0.12-0.16	0.13
Intestinal caecum :	length	1.08	1.26-1.69	1.41
Tail :	length	0.28	0.61-0.64	0.62
Spicules :	length	0.72	-	-
Vulva[§]		-	6.48-7.92	7.15
Eggs :	length	-	0.10-0.11	0.10
	width	-	0.05-0.06	0.05

Host Pig

Location Caecum

Locality Shillong, Nongstoin

Remarks

Originally described as Cruzia orientalis by Maplestone (1930b) from pigs in Calcutta, this species was accommodated in Family Kathlaniidae Travassos, 1918 by Baylis (1936a). Later on, it was placed in a new genus Pseudocruzia erected by Wolfgang (1953) and classified under family Cruziidae Yorke et Maplestone, 1926 by Yamaguti (1961). Wolfgang justified the erection of a new genus on the basis of the peculiar cephalic structures and the oesophageal bulb constriction and also suggested that further investigation may establish a reptilian host for Pseudocruzia and show that it is a pseudoparasite for pigs. Chabaud (1978) assigned the genus to the subfamily Cruzinnae under family Kathlaniidae.

It may be mentioned here that following Maplestone's record of 1930, there has been hitherto no report of the occurrence of P. orientalis in suids elsewhere in India or abroad. The original description provided by Maplestone (1930b) has been supplemented herein. The present observations tally with those of Maplestone (1930b) in all respects except for minor deviations with regard to the length of oesophagus, caecum and spicules.

Family Strongyloididae Chitwood et McIntosh, 1934

Genus Strongyloides Grassi, 1879

Strongyloides sp.

(Plates 1.10, 1.11).

The collection comprised only a single female specimen.

Description

Body slender, attenuated anteriorly, 9.0 long. Buccal capsule reduced, without teeth. Oesophagus cylindrical with swelling at posterior end, 0.30 long. Tail tapering to point, 0.14 long, 0.04 in width. Vulva situated at 5.50 from anterior end of body, opening directly into uterine branches; latter opposed. Eggs few, relatively large, oval, thin shelled, segmented, 0.05-0.06 in length; 0.025-0.03 in width.

Host	Fowl
Location	Intestinal caecum
Locality	Shillong

Remarks

On the basis of a short buccal capsule, a markedly elongated and slender oesophagus without a distinct posterior bulb, short and conical tail and characteristic position of the vulva (i.e., posterior half of the body) the specimen was identified as belonging to the genus *Strongyloides*. Only one species, i.e., *Strongyloides avium* is known to represent the genus in fowl (Soulsby, 1982). The specimen under observation differs markedly from *S. avium* in respect of the length of the body and oesophagus, which is 2.2 and 0.7mm, respectively, in the latter species.

PLATE 1.10 Strongyloides sp. - female worm

Fig.1 Anterior end

Fig.2 Posterior end

Fig.3 Vulvar region

Fig.4 Egg

PLATE-1·10

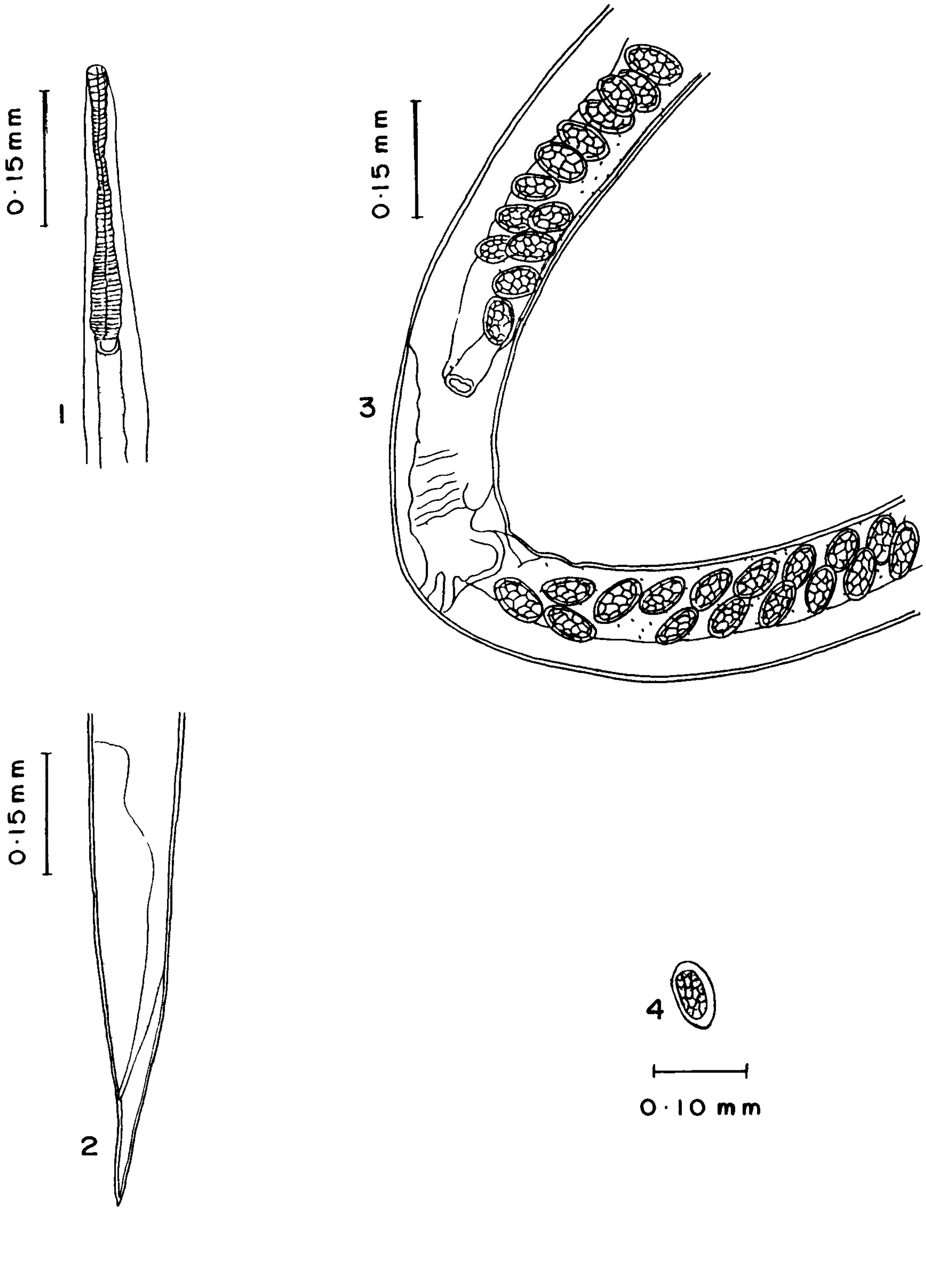


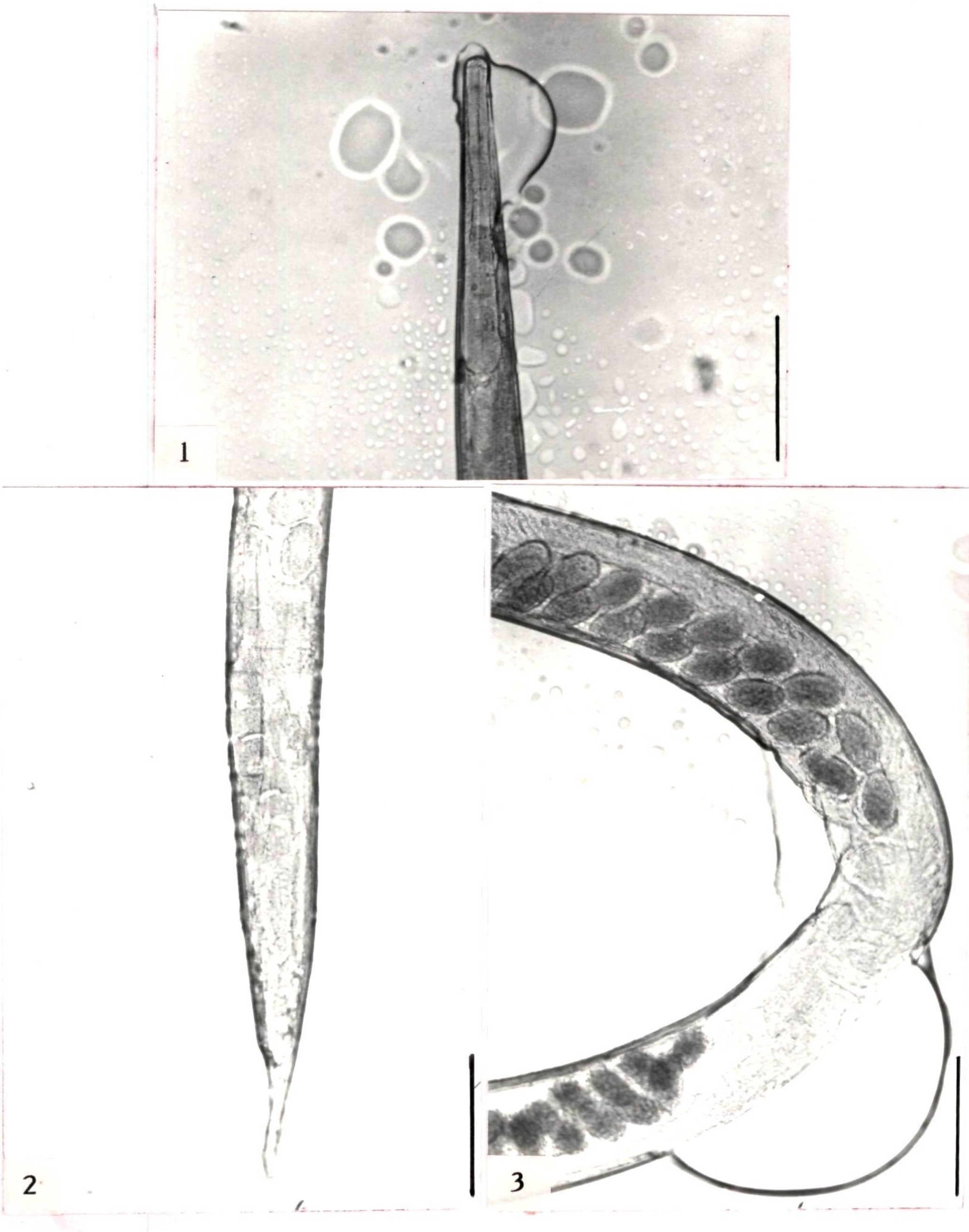
PLATE 1.11 *Strongyloides* sp. - female (Photomicrographs)

Fig.1 Anterior end (scale bar = 0.2 mm)

Fig.2 Posterior region (scale bar = 0.2 mm)

Fig.3 Vulvar region possessing characteristic big-sized eggs (scale bar = 0.2mm)

PLATE 1.11



The identification of the species level has been kept pending for want of more specimens. However, it is the first record of the genus Strongyloides in domestic fowl of India.

Family Chabertiidae (Popova, 1952) Lichtenfels, 1980

Subfamily Oesophagostominae Railliet, 1916

Genus Bourgelatia Railliet, Henry et Bauche, 1919

Bourgelatia diducta Railliet, Henry et Bauche, 1919 (Plates 1.12, 1.13)

The collection comprised several hundred specimens of this species.

Description

General

Small-sized worms, milky white in colour. Mouth directed straight forwards. Cuticle with well marked transverse striations throughout length of body. One pair of cervical papillae symmetrically placed near middle of oesophagus. Two sets of corona radiatae present, external composed of twenty one large pointed elements, internal having same number of bifid elements. Buccal capsule shallow, cylindrical, more wide than deep, its wall thick, composed of two pondions - anterior ring shaped, surrounding basis of leaf crown, posterior more or less continuous with cuticular lining of wide shallow oesophageal funnel. Oesophagus swollen posteriorly with trivalved apparatus at its base.

PLATE 1.12 Bourgelatia diducta

Fig.1 Anterior end, showing corona radiatae and a pair of cervical papillae

Fig.2 Posterior region of male, showing spicules, prebursal papillae and arrangement of rays in bursa

Fig.3 Posterior region of female, showing opening of vulva and anus

Fig.4 Egg

PLATE-1·12

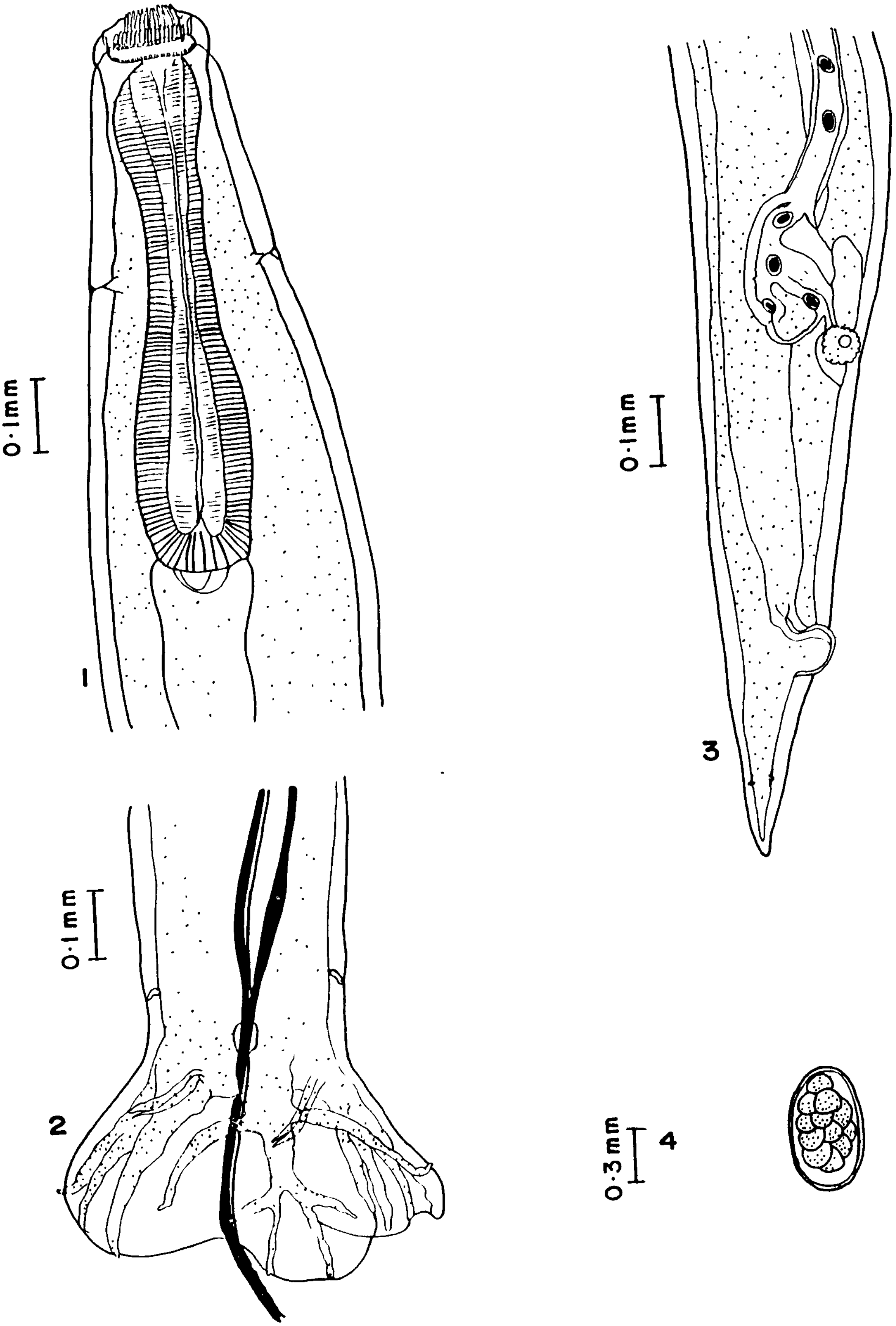


PLATE 1.13 *Bourgelatia diducta* **(Photomicrographs)**

Fig.1 Anterior end (scale bar = 0.2mm)

Fig.2 The same enlarged to show more clearly elements of corona radiata (scale bar = 0.15 mm)

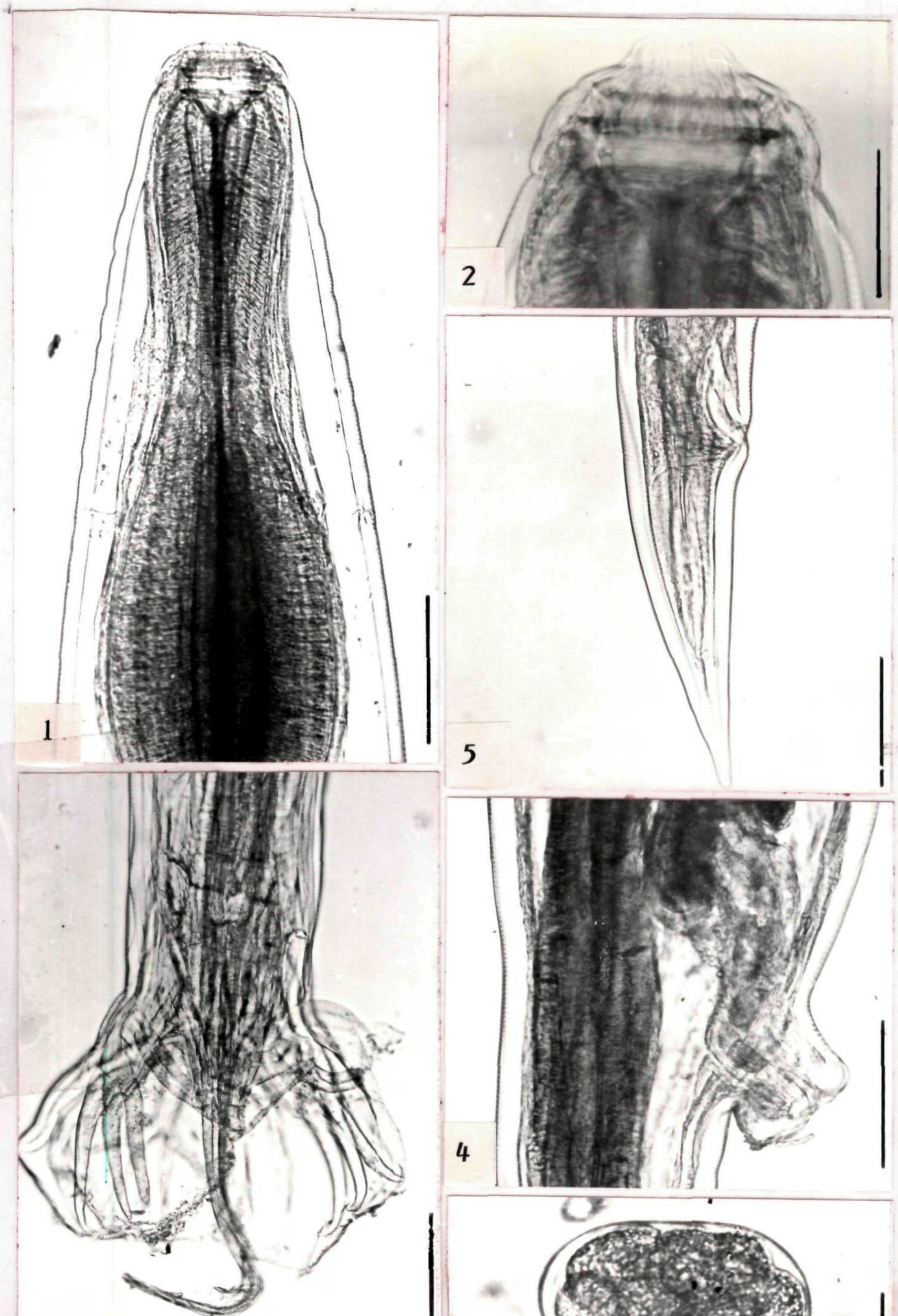
Fig.3 Posterior region of male (scale bar = 0.2 mm)

Fig.4 Vulvar region of female (scale bar = 0.2 mm)

Fig.5 Posterior region of female, showing opening of anus (scale bar = 0.2mm)

Fig.6 Egg (scale bar = 0.02mm)

PLATE 1.13



Male

Bursa well developed, with bursal rays at porterior end of body, incised near tips of ventral rays, giving appearance of a pair of additional lobes; ventral rays cleft to base, parallel and closely applied to each other, antero-lateral ray somewhat shorter than, but not divergent from, remaining lateral rays; externodorsal short, originating high up on main dorsal stem; dorsal short, bifurcated deeper than proximal branches. Genital cone pointed with large papilla on each side of its base, but ill defined. Spicules long, equal, having transverse alae. Gubernaculum indistinct.

Female

Posterior extremity straight, ending in sharp point. Caudal papillae one pair, symmetrically placed near tip. Vulva opening near anus. Vagina short, uterine branches parallel; ovejectors J-shaped, usually laden with three mature eggs. Eggs thin shelled, segmented.

The measurements of the body and its organs are given in Table 1.5.

Host	Pig
Location	Caecum and colon
Locality	Shillong, Nongstoin, Markasa, Mäirang, Sohiong

Remarks

This species was originally recorded from Annam, has also been recorded in other regions of India - from Bengal (Maplestone, 1930a) and Kerala (Thomas and Peter, 1975).

TABLE 1.5 : *Bourgelatia diducta* Railliet, Henry et Bauche, 1919 : morphometric measurements

Characters		Male		Female	
		Range	Mean	Range	Mean
Body :	length	8.0-10.0	9.2	10.0-12.0	10.8
	width	0.41-0.50	0.45	0.46-0.55	0.50
Buccal capsule :	length	0.05-0.06	0.05	0.05-0.07	0.06
	width	0.04-0.08	0.07	0.05-0.07	0.06
Oesophagus :	length	0.64-0.71	0.68	0.73-0.80	0.76
	width(B)[¥]	0.18-0.23	0.19	0.20-0.23	0.21
Cervical[§] papillae		0.43-0.48	0.46	0.44-0.50	0.46
Spicules :	length	1.05-1.17	1.12	-	-
Tail :	length	-	-	0.34-0.41	0.38
Caudal papillae*		-	-	0.11-0.14	0.12
Vulva**		-	-	0.50-0.57	0.54
Eggs :	length	-	-	0.04-0.05	0.051
	width	-	-	0.027-0.036	0.031

The present observations tally more or less with those of Railliet et al. (1919) and Maplestone (1930a), except for minor variation in the position of caudal papillae in females; Railliet et al. (1919) mentioned these to be placed asymmetrically. The species is of rather rare occurrence in pigs of India and is being reported for the first time from north-east India, Meghalaya in particular.

Genus Oesophagostomum Molin, 1861

Subgenus Bosicola Sandground, 1929

Oesophagostomum (Bosicola) radiatum Travassos et Vogelsang, 1932.

(Syn. B. tricollaris Sandground, 1929)

(Plates 1.14, 1.15)

A fairly good number of worms of this species was collected from the hosts.

Description

General

Medium-sized worms; anterior end bent like hook. Cephalic inflation well developed, with narrow annular constriction behind its middle, limited behind by prominent cervical groove which runs completely around neck and extends further back dorsally and ventrally, forming dorsal and ventral cuticular flaps. Lateral alae well developed, beginning at cervical groove, extending throughout almost whole length of body. Cervical papillae quite prominent situated at middle of oesophagus, little behind posterior limit of cephalic -

PLATE 1.14 *Oesophagostomum (Bosicola) radiatum*

Fig.1 Anterior end, showing corona radiata, cervical groove, and a pair of cervical papillae

Fig.2 Posterior end of male, showing spicules emerging from bursa

Fig.3 Posterior region of female, showing opening of vulva and anus

Fig.4 Same enlarged to show a pair of minute papillae near tip of tail

Fig.5 Egg

PLATE-1·14

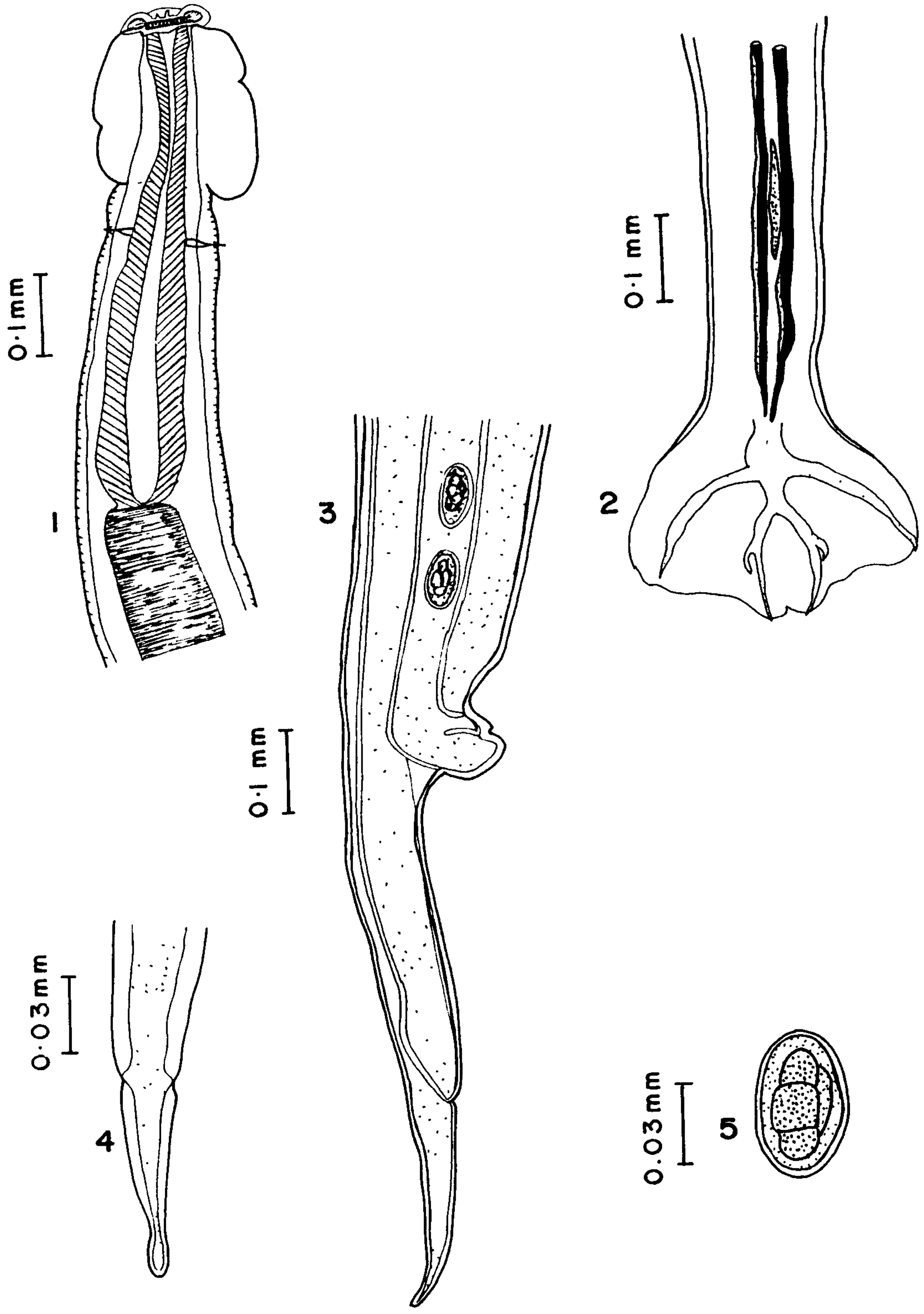


PLATE 1.15 **_Oesophagostomum_ (_Bosicola_) _radiatum_ (Photomicrographs)**

Fig.1 Anterior end (scale bar = 0.15 mm)

Fig.2 Posterior end of male (scale bar = 0.2 mm)

Fig.3 Posterior region of female, showing opening of anus (scale bar = 0.2mm)

Fig.4 Egg (scale bar = 0.02 mm)

PLATE 1.15

PLATE 1.16 Oesophagostomum (Oesophagostomum) dentatum

Fig.1 Anterior end, showing corona radiatae, cervical groove, and a pair of cervical papillae

Fig.2 Posterior end of male, showing spicules, a pair of prebursal papillae and arrangement of rays in bursa

Fig.3 Posterior end of female, showing opening of vulva and anus

Fig.4 Egg

inflation. External corona radiata absent; internal corona radiata comprising about forty elements, represented by a ring of small denticles at anterior border of buccal capsule; buccal capsule shallow, cylindrical, slightly wider in front than behind. Oesophagus club shaped, its funnel well developed.

Male

Bursa well developed; ventral ray cleft; mediolateral and posterolateral rays closely applied to each other, somewhat divergent from anterolateral rays; externodorsal originating high up on main stem of dorsal; dorsal divided into two divergent terminal branches, each of which gives off a short lateral twig. Spicules equal, alate. Gubernaculum present.

Female

Posterior end slightly curved ventrally; tail straight, tapering to sharp point, provided with one pair of small papillae little anterior to its tip. Vulva rather prominent, situated in front of posterior end; uterine branches parallel. Vagina very short, transverse, leading into kidney-shaped vestibule of ovejectors. Eggs thin shelled, segmented.

The measurements of the body and its organs are given in Table 1.6.

Host	Cattle
Location	Small intestine
Locality	Shillong, Nongstoin, Markasa

TABLE 1.6 : Oesophagostomum (Bosicola) radiatum (Rudolphi, 1803) Travassos et Vogelsang, 1932 : morphometric measurements

Characters		Male		Female	
		Range	Mean	Range	Mean
Body :	length	9.7-12.4	11.2	13.2-14.9	13.9
	width	0.20-0.23	0.22	0.29-0.34	0.32
Cephalic vesicle :	length	0.19-0.23	0.20	0.19-0.23	0.20
Oesophagus :	length	0.50-0.55	0.53	0.56-0.63	0.60
	width(B)[¥]	0.07-0.09	0.08	0.11-0.12	0.11
Nerve ring[§]		0.17-0.19	0.18	0.18-0.20	0.19
Spicules :	length	0.46-0.54	0.49	-	-
Tail :	length	-	-	0.27-0.33	0.30
Vulva*		-	-	0.73-0.92	0.83
Eggs :	length	-	-	0.05-0.07	0.06
	width	-	-	0.02-0.03	0.03

Remarks

Agreeing with the subgeneric divisions of the genus by Railliet and Henry (1913), Travassos and Vogelsang (1932) added Bosicola Sandground, 1929 as another subgenus under Oesophagostomum. However, Baylis (1936a) described this species as Bosicola radiatus (Rudolphi, 1803).

The present observations tally with Baylis' (1936a) description in all respects except for some minor variations with regard to the following: the length of body, oesophagus, spicule and tail. According to Baylis' (1936a) description these vary: body length - male 14-17mm, female 16-22mm; oesophagus length 1mm; spicule length 0.7-0.8mm; and tail length 0.3-0.4mm. The cephalic vesicle was found to be more prominent as compare to that of shown in figure by the latter author. This is the first report of the occurrence of this species in north-east India, and Meghalaya in particular.

Subgenus Oesophagostomum Molin, 1861

Oesophagostomum (Oesophagostomum) dentatum (Rudolphi, 1803) Molin, 1861

(Syn. Strongylus dentatus Rudolphi, 1803; O. subulatum Molin, 1861)

(Plates 1.16, 1.17)

A large number of specimens of this species were collected during the present survey of the hosts.

Description

General

Mouth directed straight forwards. Cuticle with well-marked transverse

PLATE 1.16 Oesophagostomum (Oesophagostomum) dentatum

Fig.1 Anterior end, showing corona radiatae, cervical groove, and a pair of cervical papillae

Fig.2 Posterior end of male, showing spicules, a pair of prebursal papillae and arrangement of rays in bursa

Fig.3 Posterior end of female, showing opening of vulva and anus

Fig.4 Egg

PLATE-1·16

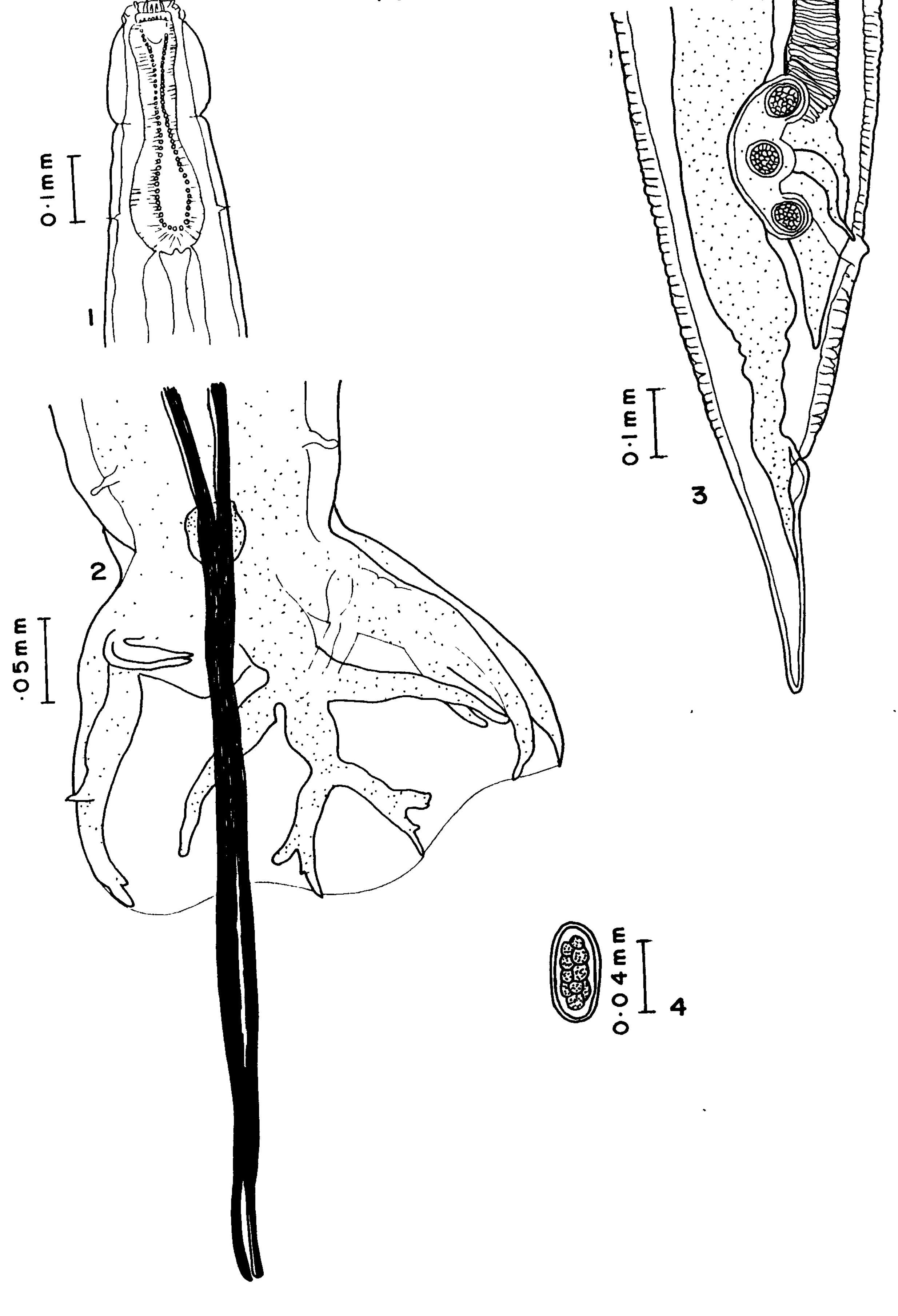


PLATE 1.17 Oesophagostomum (Oesophagostomum) dentatum (Photomicrographs)

Fig.1 Anterior end, dorsal view (scale bar = 0.2 mm)

Fig.2 Same as seen in ventral view (scale bar = 0.3 mm)

Fig.3 Posterior end of male (scale bar = 0.2 mm)

Fig.4 Posterior region of female, showing opening of vulva and anus (scale bar = 0.2 mm)

Fig.5 Egg (scale bar = 0.02 mm)

PLATE 1.17

striations throughout length of body. Cervical or lateral alae absent. Pair of cervical papillae symmetrically placed behind middle of oesophagus, possessing bristle-like terminations. Two corona radiatae present - external projecting beyond oral aperture, with nine elements, one pair displaced on either side of oral aperture, five closely packed together with pointed endings; internal having eighteen elements. Mouth collar with two lateral and four submedian head papillae which project forward conspicuously. Ventral cervical groove near anterior end, extending around ventrolateral aspects of body; cuticle anterior to groove dilated to form prominent cephalic vesicle, anteriorly beginning at base of mouth collar. Buccal capsule shallow, uniformily cylindrical, oesophagus club shaped, with prominent bulb at its posterior end.

Male

Bursa well developed having bursal rays; ventral ray cleft; mediolaterals and posterolaterals fused proximally, somewhat divergent from anterolateral ray; externodorsal arising from common trunk with dorsal ray; latter divided into two divergent terminal branches, each of which gives off a short lateral twig. Spicules equal, alate with blunt tips. Gubernaculum present.

Female

Tail tapering to sharp point. Vulva little anterior to anus. Ovejector single, J-shaped characteristically laden with three mature eggs; uterine branches parallel, entering ovejector at its opposite ends. Eggs thin shelled, segmented.

The measurements of the body and its organs are given in Table 1.7.

TABLE 1.7 : *Oesophagostomum* (*Oesophagostomum*) *dentatum* (Rudolphi, 1803) Molin, 1861 : morphometric measurements

Characters		Male		Female	
		Range	Mean	Range	Mean
Body :	length	8.0-9.5	8.9	8.0-13.0	10.2
	width	0.35-0.45	0.40	0.45-0.62	0.52
Buccal capsule :	length	0.009-0.013	0.011	0.009-0.013	0.011
	width	0.046-0.053	0.050	0.046-0.059	0.051
Cephalic vesicle :	length	0.16-0.19	0.17	0.15-0.20	0.17
Oesophagus :	length	0.34-0.36	0.34	0.36-0.43	0.39
	width(B)[¥]	0.08-0.10	0.09	0.09-0.16	0.12
Nerve ring[§]		0.18-0.23	0.21	0.16-0.22	0.20
Spicules :	length	0.77-1.19	0.96	-	-
Tail :	length	-	-	0.27-0.46	0.34
Vulva**		-	-	0.36-0.42	0.41
Eggs :	length	-	-	0.050-0.055	0.052
	width	-	-	0.027-0.030	0.031

Host Pig

Location Large intestine and colon

Locality Shillong, Nongstoin, Markasa, Riangdo, Jowai

Remarks

The genus Oesophagostomum Molin, 1861 was divided by Railliet and Henry in 1913 into three subgenera, and the present species was accommodated in subgenus Oesophagostomum (Oesophagostomum) Molin, 1861 mainly on the basis of the shape and degree of development of the oesophageal funnel.

The species closely resembles in general appearance with O. quadrispinulatum (Marcone, 1901) Alicata, 1935 also parasitizing the same host in India, only the shape of the oesophagus (oval) and the tail length (comparatively short) differentiate the present species from the latter species, in which the oesophagus has a small but distinct swelling at its anterior end.

The present description supplements Baylis' (1936a) by position providing the position of nerve ring and length of cephalic vesicle.

Subgenus Proteracrum Railliet et Henry, 1913

Oesophagostomum (Proteracrum) columbianum (Curtice, 1890) Railiet et Henry, 1913

(Syn. Oesophagostoma columbianum Curtice, 1890)

(Plates 1.18, 1.19)

The collection comprised several hundred specimens of O. columbianum from different localities of the state.

PLATE 1.18 Oesophagostomum (Proteracrum) columbianum

Fig.1 Anterior end, showing corona radiatae, cervical groove, and a pair of cervical papillae

Fig.2 Posterior end of male, showing spicules, a pair of prebursal papillae and arrangement of rays in bursa

Fig.3 Posterior end of female, showing opening of vulva and anus

Fig.4 Egg

PLATE-1·18

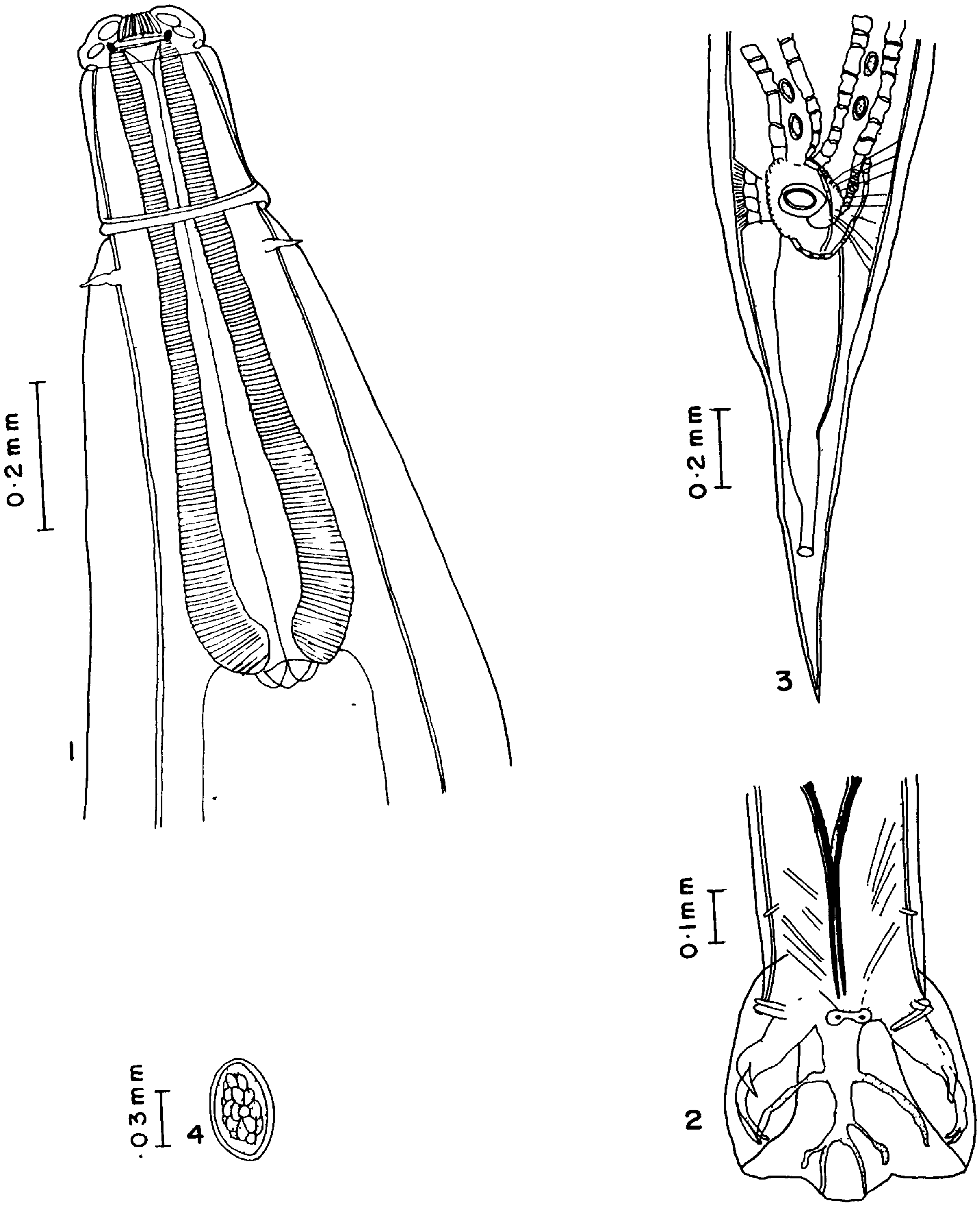


PLATE 1.19 *Oesophagostomum (Proteracrum) columbianum* (Photomicrographs)

Fig.1 Anterior end (scale bar = 0.2 mm)

Fig.2 Posterior end of male (scale bar = 0.2 mm)

Fig.3 Vulvar region of female (scale bar = 0.2 mm)

Fig.4 Posterior region of female, showing opening of anus (scale bar = 0.2 mm)

Fig.5 Egg (scale bar = 0.02 mm)

PLATE 1.19

Description

General

Anterior end curved dorsally into a hook. Cuticle forming mouth - collar in form of truncated cone separated from rest of body by constriction; cervical groove extending around ventral surface of lateral aspects of body, cuticle anterior to this groove inflated to form cephalic vesicle. Lateral alae taking origin immediately behind cervical groove, extending almost whole length of body except for little distance in caudal region; anterior extremities of lateral alae pierced by cervical papillae. Buccal capsule shallow external corona radiata consisting of 20-24 elements, internal having two small elements to each of external. Oesophagus club shaped, with oesophago-intestinal valve, encircled by nerve ring at its anterior end.

Male

Bursa well developed; of bursal rays - ventral ray cleft, mediolateral and posterolateral rays fused proximally, externo-dorsals arising from common trunk with dorsal, latter divided into two divergent terminal branches, each of which gives off short lateral twig. Pair of prebursal papillae present. Spicules equal, alate with blunt tips. Gubernaculum not distinct.

Female

Tail tapering to fine point, bearing pair of tiny papillae just near its tip. Vulva slightly prominent, opening little anterior to anus. Vagina very short; transverse, leading into kidney-shaped vestibule of ovejectors. Eggs thin shelled, segmented.

The measurements of this species are given in Table 1.8.

TABLE 1.8 : Oesophagostomum (Proteracrum) columbianum (Curtice, 1890) Railliet et Henry, 1913 : morphometric measurements

Characters		Male Range	Mean	Female Range	Mean
Body :	length	12.0-15.0	13.6	17.0-20.0	18.1
	width	0.44-0.52	0.47	0.52-0.62	0.58
Buccal capsule:	length	0.04-0.05	0.045	0.04-0.05	0.046
	width	0.07-0.08	0.075	0.06-0.09	0.08
Cephalic vesicle:	length	0.21-0.27	0.24	0.23-0.29	0.25
Oesophagus :	length	0.72-0.90	0.79	0.77-0.86	0.81
	width(B)¥	0.18-0.21	0.19	0.18-0.021	0.20
Spicules :	length	0.75-0.93	0.86	-	-
Tail :	length	-	-	0.41-0.48	0.43
Vulva*		-	-	1.1-1.2	1.17
Eggs :	length	-	-	0.064-0.069	0.068
	width	-	-	0.02-0.04	0.03

Host Goat, Sheep

Location Caecum, large intgestine

Locality Shillong, Nongstoin, Sohiong, Markasa

Remarks

This species is ubiquitous in occurrence and has been reported from time to time from different parts of the Indian Sub-Continent (Bhalerao, 1934b, 1935; Khera, 1954; Bhatia and Pande, 1961). On the basis of relatively short spicules and vagina, and the position of cervical papillae in relation to the oesophageal expansion, it was assigned to the subgenus Proteracrum by Railliet and Henry (1913). The species has occasionally been recorded from cattle (Baylis, 1936a). Except for the gubernaculm which could not be observed clearly in the male specimens all other observations tally closely with the description provided by Baylis (1936a). Meghalaya forms a new locality record for this species.

Subgenus Hysteracrum Railliet et Henry, 1913

Oesophagostomum (Hysteracrum) aspersum Railliet et Henry, 1913

(Syn. O. aspersum Railliet et Henry, 1913)

(Plates 1.20, 1.21)

The collection comprised several hundred specimens of the (O.) (H.) aspersum from different localities of the state.

PLATE 1.20 Oesophagostomum (Hysteracrum) aspersum

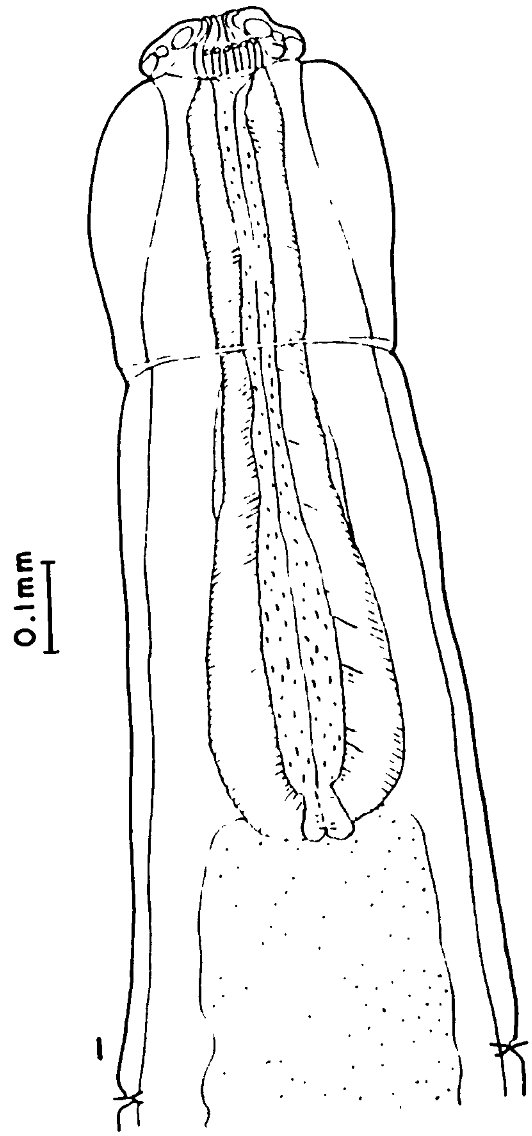
Fig.1 Anterior end, showing corona radiatae cervical groove, and a pair of cervical papillae (behind the oesophagus)

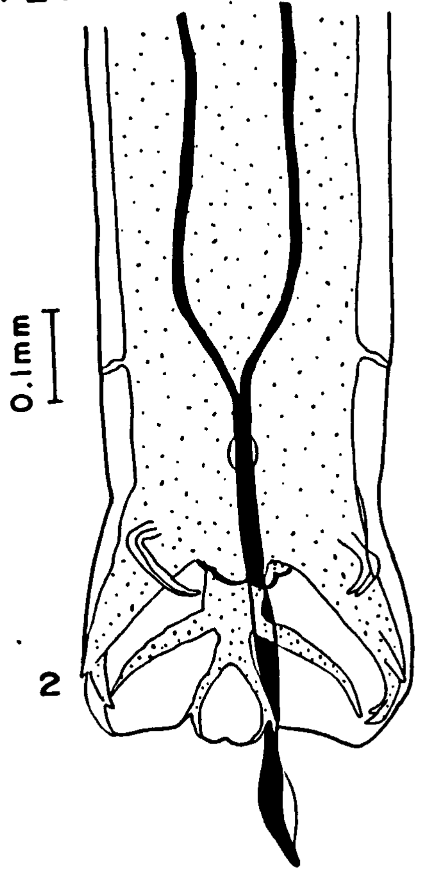
Fig.2 Posterior end of male, showing spicules, a pair of prebursal papillae and arrangement of rays in bursa

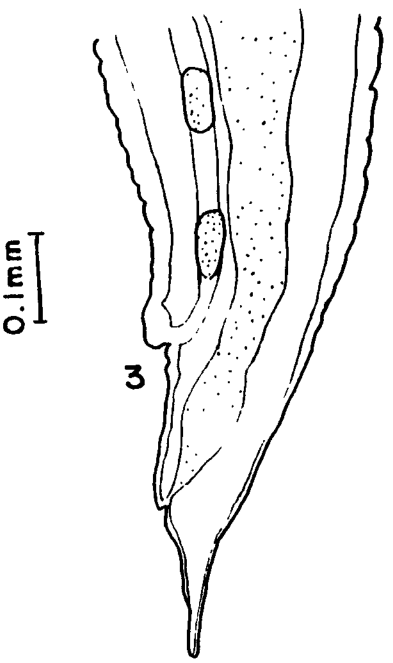
Fig.3 Posterior region of female, showing opening of vulva and anus

Fig.4 Egg

PLATE-1·20







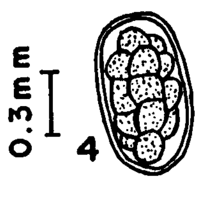


PLATE 1.21 Oesophagostomum (Hysteracrum) aspersum (Photomicrographs)

Fig.1 Anterior end (scale bar = 0.2 mm)

Fig.2 Posterior end of male, dorsal view (scale bar = 0.2 mm)

Fig.3 The same as seen in ventral view (scale bar = 0.2 mm)

Fig.4 Posterior region of female, showing vulva and anal opening (scale bar = 0.2 mm)

Fig.5 Egg (scale bar=0.02 mm)

PLATE 1.21

Description

General

Mouth-collar in form of truncated cone, marked off by a well-defined groove posteriorly. Cephalic inflation of cuticle very well developed. Pair of cervical papillae situated little behind oesophago-intestinal valve. Cervical groove well marked ventrally , extending little behind lateral line. External corona radiata consisting of twelve bluntly rounded elements, internal crown having twenty four small elements. Buccal capsule shallow, its base at level of posterior limit of mouth-collar. Oesophagus club shaped, possessing oesophago-intestinal valve. Nerve ring lying just behind cervical groove.

Male

Bursa well developed, with following arrangement of rays in it : ventral ray cleft; mediolateral and posterolaterals fused proximally, externodorsals arising from common trunk with dorsal; latter divided into two divergent branches, each of which gives off a short lateral branch. Pair of prebursal papillae present in front of bursa. Spicules paired, equal. Accessory piece present, handle of shovel missing or sometimes represented by small, rounded knob.

Female

Tail tapering abruptly, bearing pair of very small papillae just near its tip. Anus rather prominent. Vulva situated at little distance from posterior end of body. Vagina long, opening into relatively anteriorly placed ovejectors. Eggs oval, thin shelled.

The morphometric mesurements of this species are given in Table 1.9.

Host Goat, Sheep

Location Caecum and large intestine

Locality Shillong, Nongstoin, Jowai, Markasa, Riangdo

Remarks

Railliet and Henry (1913) erected a subgenus Hysteracrum for the reception of this species based on the length of spicules and vagina and the position of cervical papillae in relation to the oesophageal expansion. This parasite has earlier been described from several states in India (Thapar 1956; Alwar and Lalitha, 1961; Bhatia and Pande, 1961; Patnaik, 1964). The species, namely O. indicum Maplestone, 1930a from sheep and deer, and O. bhandari Rao et Bhatavadekar, 1958 from goat are considered synonym of O. aspersum (see Sarwar, 1957; Patnaik, 1964).

Except for minor morphometric and structural variations, such as the absence of cervical papillae and gubernaculum in few specimens, the observations tally closely with those provided by Bayllis (1936a). Meghalaya forms a new locality record for this species.

TABLE 1.9 : *Oesophagostomum (Hysteracrum) aspersum* Railliet et Henry, 1913 : morphometric measurements

Characters		Male Range	Male Mean	Female Range	Female Mean
Body :	length	11.0-14.0	12.5	15.0-17.0	15.8
	width	0.39-0.46	0.43	0.46-0.50	0.48
Buccal capsule :	length	0.04-0.05	0.05	0.05-0.06	0.06
	width	0.05-0.08	0.07	0.06-0.07	0.07
Cephalic vesicle :	length	0.27-0.34	0.28	0.27-0.36	0.31
Oesophagus :	length	0.66-0.74	0.69	0.75-0.85	0.79
	width(B)[¥]	0.16-0.19	0.18	0.18-0.23	0.21
Cervical papillae[§]		0.91-0.10	1.01	1.10-1.19	1.16
Spicules :	length	1.30-1.72	1.49	-	-
Tail :	length	-	-	0.14-0.17	0.16
Vulva*		-	-	0.34-0.37	0.35
Caudal papillae*		-	-	0.06-0.07	0.06
Eggs :	length	-	-	0.06-0.08	0.07
	width	-	-	0.03-0.04	0.04

Family Syngamidae Leiper, 1912

Subfamily Stephanurinae Railliet, Henry et Bauche, 1919

Genus Stephanurus Diesing, 1839

Stephanurus dentatus Diesing, 1839

(Syn. Sclerostomum renium Drabble, 1922)

(Plates1.22, 1.23)

A large number of specimens of this species were collected. The worms were found sticking with perirenal fat.

Description

General

Medium-sized worms, body relatively stout, curved ventally at anterior end. Cuticle transparent, internal organs partly visible through it. Mouth circular, directed straight forwards provided with external corona radiata consisting of about fifty to fifty five small elements; cuticle surrounding mouth reflected externally to form six thickenings - epaulettes, two median, four submedian, dorsal and ventral thickenings most prominent. Buccal capsule well developed, cup shaped, thick walled, with six variable sized teeth at its base. Oesophagus club shaped. Intestine considerably longer than body, in convoluted form.

Male

Bursa in degenerate form, very short, subterminal; busal rays short, stout; ventral rays cleft; externodorsal arising separately from dorsal; dorsal divided distally into two bidigitate limbs; lateral rays closely applied to each

PLATE 1.22 Stephanurus dentatus

Fig.1 Anterior end, showing buccal capsule containing teeth inside

Fig.2 Posterior end of male, showing spicules and a poorly developed bursa

Fig.3 Posterior region of female, showing opening of vulva and anus

Fig.4 Egg

PLATE-1·22

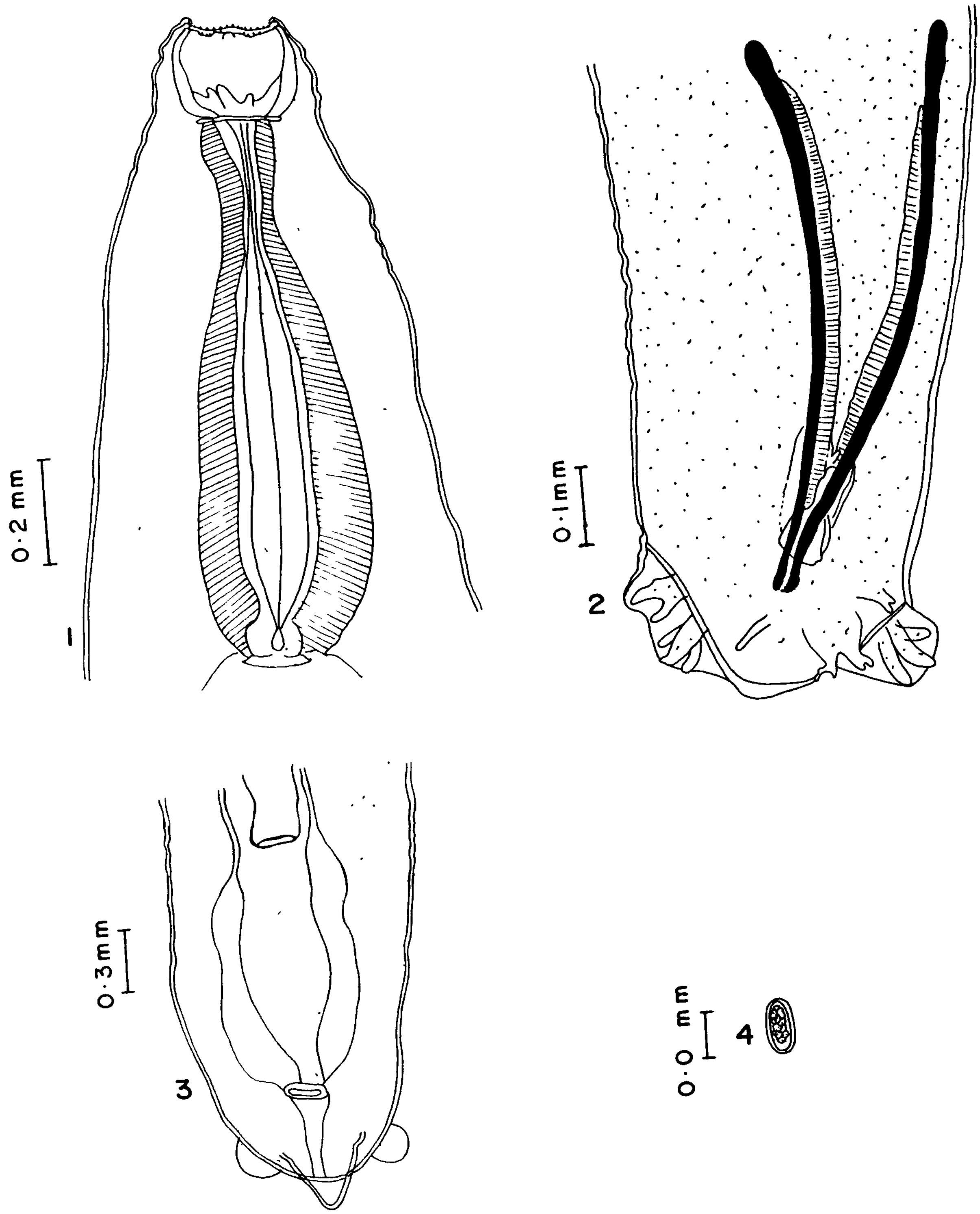


PLATE 1.23 Stephanurus dentatus (Photomicrographs)

Fig.1 Anterior end (scale bar = 0.3 mm)

Fig.2 Posterior end of male (scale bar = 0.3 mm)

Fig.3 Posterior region of female, showing opening of vulva and anus (scale bar = 0.3 mm)

Fig.4 The same, showing cuticular inflations (scale bar = 0.3 mm)

Fig.5 Egg (scale bar = 0.05 mm)

PLATE 1.23

other; posterolateral ray thicker than other two. Spicules equal, with transversely striated alae, slightly swollen at tips. Gubernaculum flattened, heart shaped.

Female

Body bent ventrally, almost at right angle, behind vulva. Tail short, abruptly attenuated behind anus, bearing pair of globular lateral cuticular processes. Vulva little in front of anus. Vagina very short, leading into paired uterine branches, latter opposed at first, posterior branch turning forward almost at once to run parallel with other. Eggs ellipsoidal, thin shelled.

The measurements of the body and its organs are given in Table 1.10.

Host	Pig
Location	Renal and perirenal tissues
Locality	Shillong, Nongstoin, Mairang, Jowai

Remarks

Only a single species viz. S. dentatus is known to represent the genus. According to Baylis (1936a) the Indian origin of the specimens recorded as S. dentatus in the collection of the Zoological Survey of India by Baylis and Daubney (1923) is doubtful as this material was supposed to have come from some other place. However, the species has been reported in domestic pigs of Madhya Pradesh and Kerala (Shrivastav and Shah, 1968; Thomas and Peter, 1975) and Meghalaya forms a new locality record for this species.

TABLE 1.10 : *Stephanurus dentatus* Diesing, 1839 : morphometric measurements

Characters		Male Range	Male Mean	Female Range	Female Mean
Body :	length	22.0-28.0	25.6	29.0-42.0	36.0
	width	1.29-1.44	1.36	1.60-1.87	1.76
Buccal capsule :	length	0.15-0.17	0.16	0.14-0.17	0.16
	width	0.14-0.17	0.16	0.15-0.17	0.16
Oesophagus :	length	0.98-1.39	1.23	1.19-1.49	1.40
Spicules :	length	0.93-1.0	0.97	-	-
	width	0.03-0.07	0.05	-	-
Tail :	length	-	-	0.51-0.60	0.55
Vulva*		-	-	1.43-1.89	1.70
Eggs :	length	-	-	0.08-0.09	0.09
	width	-	-	0.05-0.06	0.05

Family	Ancyclostomatidae (Looss, 1905) Lichtenfels, 1980
Subfamily	Ancylostomatinae Looss, 1905
Genus	Globocephalus Molin, 1861

Globocephalus connorfilii Lane, 1922

(Plates 1.24, 1.25)

The collection comprised several hundred specimens of this species.

Description

General

Small-sized worms; body rather stout, curved at both ends in living worms. Cuticle with marked transverse striations. Cervical papillae verruciform, lying at level of nerve ring. Mouth directed anterodorsally. Buccal capsule deep, somewhat funnel shaped, supported anteriorly by external chitinoid ring. Pair of triangular teeth present, of variable size, arising from posterior part of ventral wall of capsule; posterior border of tooth running to extreme posterior end of capsule, fused with its wall some distance anterior to its junction with oesophagus. Oesophagus club shaped. Dorsal oesophageal gutter prominent, extending almost near collar-like area surrounding mouth.

Male

Bursa well developed, having following arrangement of rays in it - ventral ray cleft for almost all length; laterals emerging from common trunk, abruptly slender at distal end; externodorsal arising from trunk of dorsal ray; dorsal bifurcated at about middle, each branch terminating in three-pronged processes, of which central process is somewhat longer. Prebursal

PLATE 1.24 Globocephalus connorfilii

Fig.1 Anterior end, showing buccal capsule containing teeth, and a pair of cervical papillae

Fig.2 Posterior end of male, showing spicules and arrangement of rays in bursa

Fig.3 Posterior end of female, showing opening of anus

Fig.4 Vulvar opening in female

Fig.5 Egg

PLATE-1·24

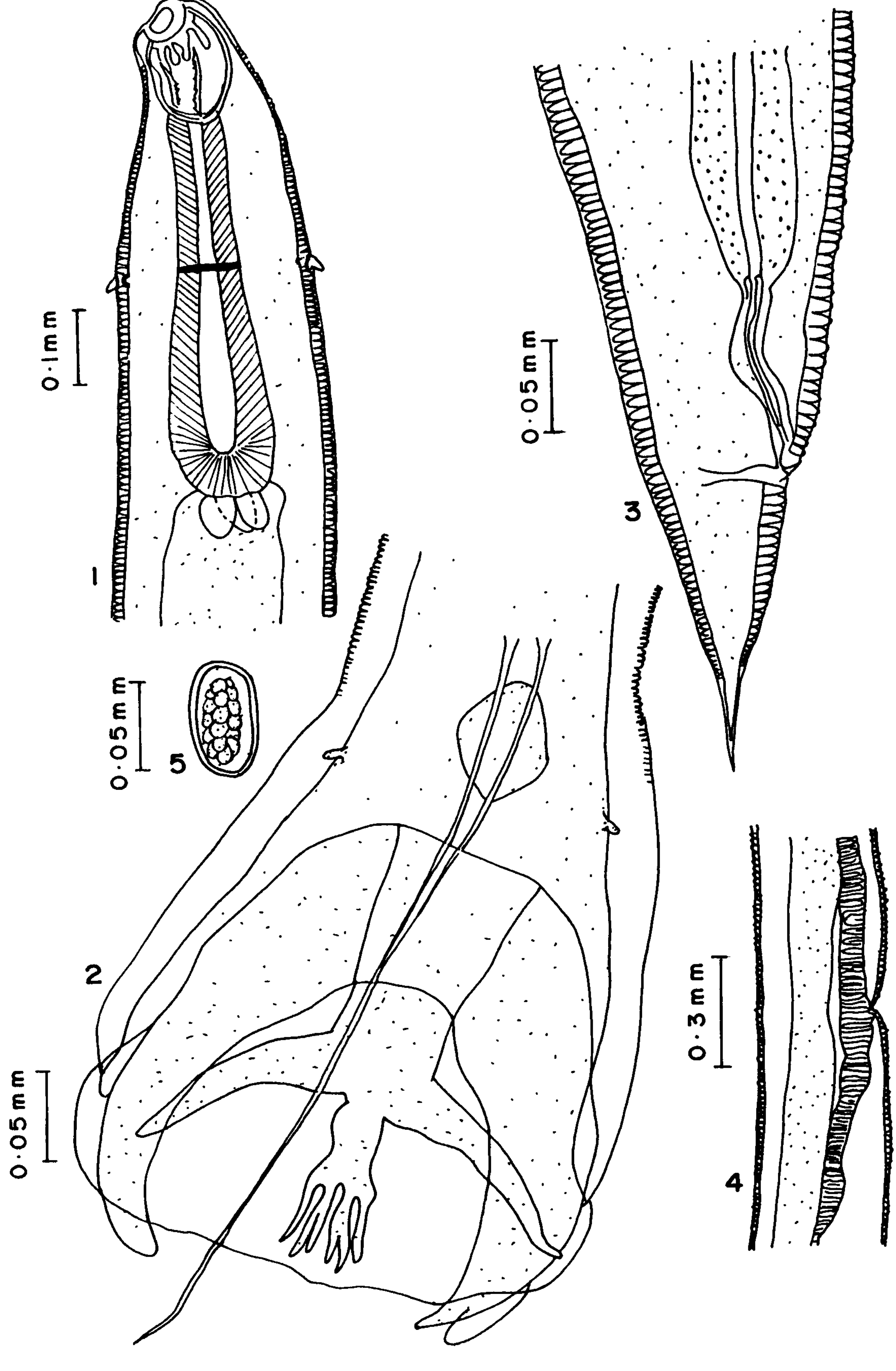


PLATE 1.25 Globocephalus connorfilii (Photomicrographs)

Fig.1 Anterior end,dorsal view (scale bar = 0.2 mm)

Fig.2 The same as seen in ventral view (scale bar = 0.2 mm)

Fig.3 Posterior end o male, lateral view (scale bar = 0.2 mm)

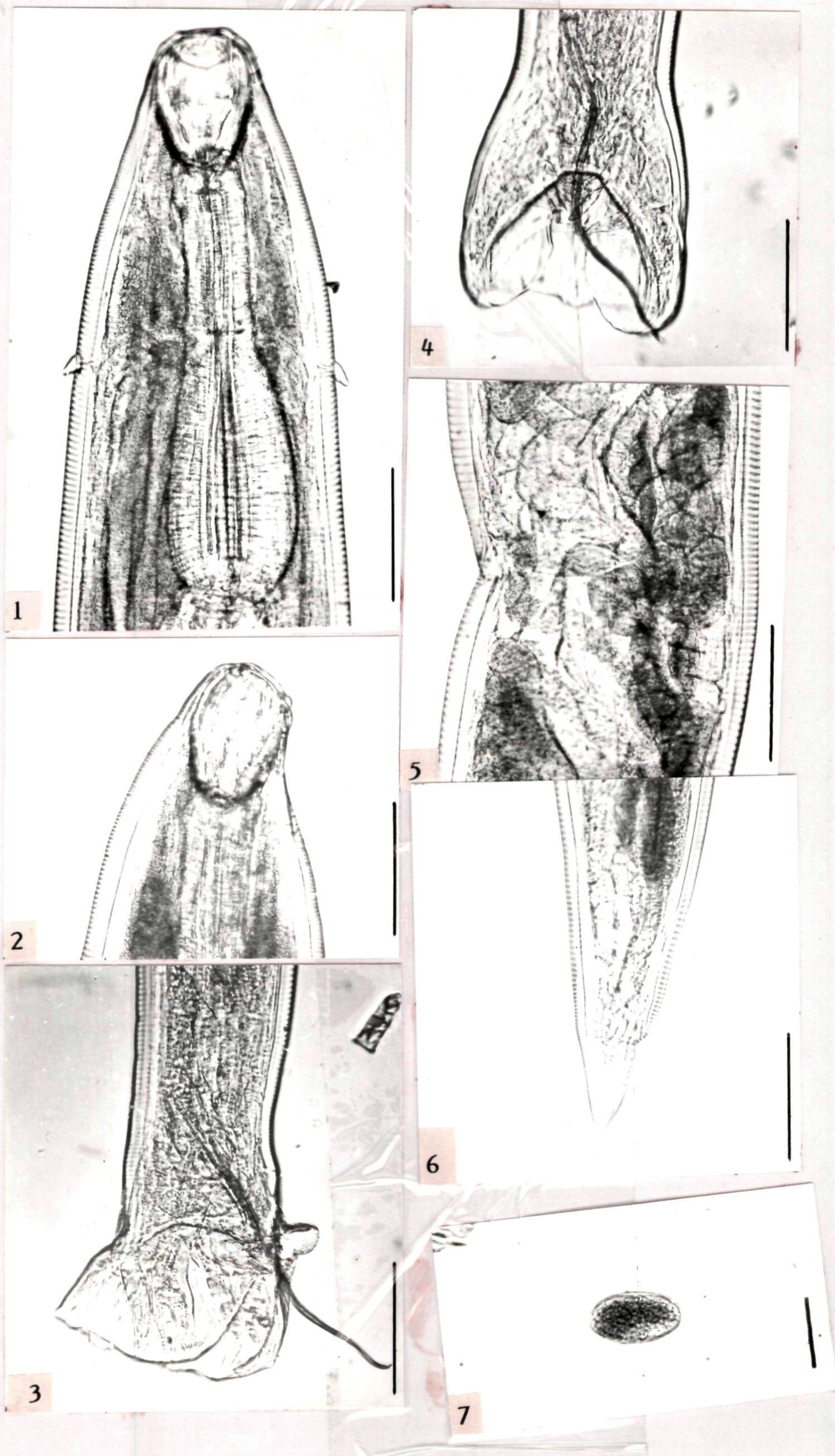
Fig.4 The same as seen in ventral view (scale bar = 0.2 mm)

Fig.5 Vulvar region in female (scale bar = 0.2 mm)

Fig.6 Posterior end of female, showing opening of anus (scale bar = 0.2 mm)

Fig.7 Egg (scale bar = 0.04 mm)

PLATE 1.25



papillae conspicuous. Spicules slender, equal, curved dorsally at their tips, elongated. Accessory piece present.

Female

Tail tapering, pointed, bearing pair of small papillae just near its tip. Vulva not very prominent, opening slightly posterior to mid-body. Uterine branches opposed. Eggs oval, thin shelled.

The measurements of the body and its organs are given in Table 1.11.

Host	Pig
Location	Upper Small intestine
Locality	Shillong, Nongstoin, Riangdo, Sohiong

Remarks

Lane (1922) originally described this species based on the material collected from the small intestine of pig in Samoa. Later, Yamaguti (1961) considered this species a synonym of G. urosubulatus Allessandrini, 1909. However, Maplestone (1930b) regarded the two as distinct species.

Only three species of Globocephalus are represented in Indian swine. These are G. urosubulatus Alessandrini, 1909; G. samoensis Lane, 1922 and G. connorfilii, all recorded from domestic pigs in Calcutta by Maplestone (1930b). The nature of the buccal lancets is the only main feature to distinguish the three species from one another. In G. samoensis the buccal lancets are bicuspid, whereas in the other two these are triangular; however in G. urosubulatus the lancets reach up to the posterior part of the buccal capsule but do not do so in G. connorifilii.

TABLE 1.11 : *Globocephalus connorfilii* Lane, 1922 : morphometric measurements

Characters		Male Range	Male Mean	Female Range	Female Mean
Body :	length	3.8-4.8	4.3	4.2-7.2	6.2
	width	0.30-0.36	0.33	0.39-0.45	0.42
Buccal capsule :	length	0.11-0.18	0.15	0.12-0.18	0.15
	width	0.06-0.09	0.07	0.07-0.13	0.09
Oesophagus :	length	0.45-0.81	0.59	0.48-0.81	0.55
	width(B)[¥]	0.12-0.16	0.14	0.14-0.18	0.16
Cervical papillae[§]		0.43-0.46	0.45	0.43-0.49	0.46
Spicules :	length	0.42-0.46	0.44	-	-
Tail :	length	-	-	0.16-0.21	0.19
Vulva*		-	-	1.9-2.1	2.0
Eggs :	length	-	-	0.05-0.06	0.05
	width	-	-	0.03-0.036	0.03

This species is being reported for the first time from north-east India, Meghalaya in particular.

Subfamily Bunostominae (Railliet et Henry, 1909) Looss, 1911

Genus Bunostomum Railliet, 1902

Bunostomum trigonocephalum (Rudolphi, 1808) Railliet 1902

(Syn. Strongylus trigonocephalus Rudolphi, 1808; B. kashinathi Lane, 1917a)

(Plates 1.26, 1.27)

The collection comprised several hundred specimens of this species.

Description

General

Worms considerably big in size. Anterior end bent dorsally, so that buccal capsule opens anterodorsally. Buccal capsule relatively large, infundibular, bearing at its base strong dorsal tooth, with large cone projecting into buccal cavity; dorsal gutter running along tooth, carrying duct of dorsal oesophageal gland; ventral margins of capsule bearing pair of chitinous plate ; lancets comprising two pairs, one ventral, other subventral, former pair lying near opening of oesophagus, latter in lateral walls of capsule. Oesophagus club shaped. Cervical papillae little behind anterior end of body. Nerve ring at level of cervical papillae.

Male

Bursa well developed with asymmetrical dorsal lobe; right externodorsal

PLATE 1.26 *Bunostomum trigonocephalum*

Fig.1 Anterior end, showing buccal capsule and a pair of cervical papillae

Fig.2 Posterior end of male, showing spicules and arrangement of rays in bursa

Fig.3 Posterior region of female, showing opening of anus (a pair of papillae is also visible just near to tip)

Fig.4 Vulvar opening in female

Fig.5 Egg

PLATE-1·26

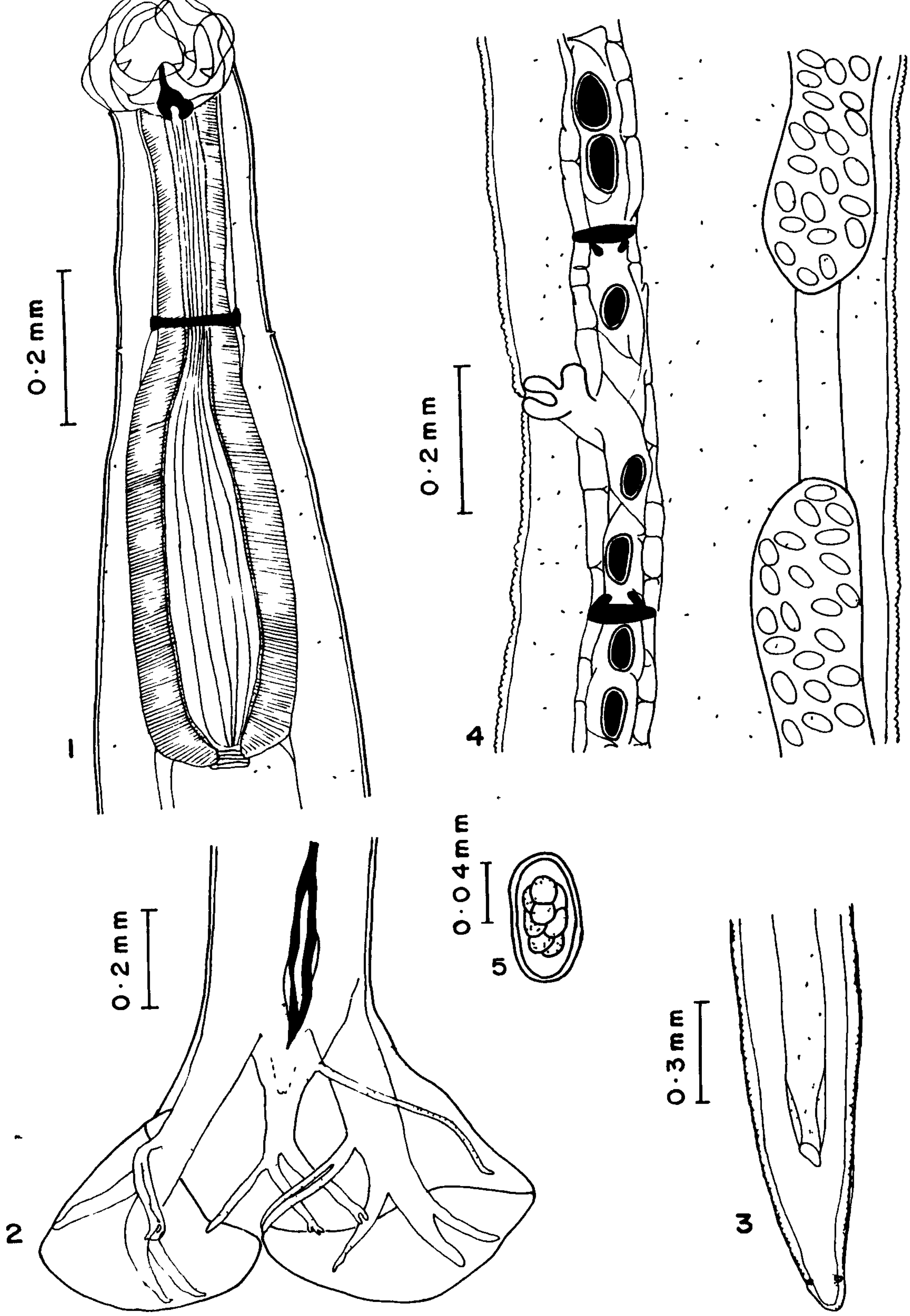


PLATE 1.27 ***Bunostomum trigonocephalum*** **(Photomicrographs)**

Fig.1 Anterior end (scale bar = 0.2 mm)

Fig.2 Posterior end of male (scale bar = 0.2 mm)

Fig.3 Vulvar region of female (scale bar = 0.3 mm)

Fig.4 Posterior end of female (scale bar = 0.2 mm)

Fig.5 Egg (scale bar = 0.04 mm)

PLATE 1.27

ray long, slender, arising high up on main dorsal stem; left externodorsal much shorter, arising at about level of bifurcation of dorsal ray; dorsal ray with tridigitate terminations; posterolateral and mediolateral rays fused in their terminal portions, separated distally; ventral, externodorsal and lateral rays arising from large common trunk; ventral ray cleft. Spicules slender, alate, slightly twisted. Gubernaculum absent.

Female

Tail tapering to point, bearing pair of papillae just little short of its tip. Vulva not so prominent, lying little ahead of middle of body. Vagina short, followed by uterine vagina forming part of ovejector; sphincter present at junction of uterine vagina and ovejector. Eggs with bluntly rounded ends.

The measurements of the body and its organs are given in Table 1.12.

Host	Goat
Location	Small intestine
Locality	Shillong, Nongstoin, Jowai, Markasa, Sohiong

Remarks

Lane (1917a) described a new species B. kashinathi, from goats in Darjeeling district of Bengal and differentiated it from B. trigonocephalum only on the basis of the shape of the buccal capsule. However, Yorke and Maplestone (1926) considered B. kashinathi a synonym of B. trigonocephalum.

The present observations tally closely with the description provided by Baylis (1936a) except for minor difference in the length of spicules.

TABLE 1.12 : *Bunostomum trigonocephalum* (Rudolphi, 1908) Railliet, 1902 : morphometric measurements

Characters		Male Range	Male Mean	Female Range	Female Mean
Body :	length	12.0-16.0	14.6	18.0-26.0	22.9
	width	0.36-0.41	0.39	0.57-0.68	0.61
Buccal capsule :	length	0.14-0.21	0.18	0.18-0.25	0.21
	width	0.14-0.18	0.16	0.14-0.19	0.17
Oesophagus :	length	0.72-1.0	0.88	1.17-1.26	1.21
	width(B)[¥]	0.16-0.21	0.17	0.18-0.28	0.23
Nerve ring[§]		0.55-0.73	0.58	0.57-0.80	0.58
Cervical papillae[§]		0.48-0.55	0.51	0.54-0.75	0.62
Spicules :	length	0.54-0.64	0.57	-	-
Tail :	length	-	-	0.27-0.36	0.30
Vulva*		-	-	5.7-8.1	7.3
Eggs :	length	-	-	0.06-0.08	0.07
	Width	-	-	0.04-0.05	0.04

Family	Trichostrongylidae (Leiper, 1908) Leiper, 1912
Subfamily	Haemonchinae (Skrjabin et Schulz, 1937) Skrjabin et Schulz, 1952
Genus	Haemonchus Cobb, 1898

Haemonchus contortus (Rudolphi, 1803) Cobb, 1898

(Syn. Strongylus contortus Rudolphi, 1803; H. cervinus Baylis et Daubney 1922)

(Plates1.28, 1.29)

A bulk collection of specimens of this species was made from the hosts.

Description

General

Medium-sized worms, more or less filiform. Anterior tip of body with numerous symmetrically arranged longitudinal cuticular ridges of more or less equal height. Cervical papillae prominent, spine like, almost equidistant from anterior end. Head relatively large, without cuticular dilation. Head papillae inconspicuous. Buccal cavity small, containing inconspicuous slender tooth originating from its base. Oesophagus club shaped. Nerve ring little anterior to cervical papillae.

Male

Live specimens with even reddish colour, distinguishable from females. Bursa very well developed, with large symmetrical lateral lobes, small dorsal lobe placed symmetrically on left side of median line; ventroventral and latero-ventral rays fused proximally, separated distally; externodorsal long, thin,

PLATE 1.28 Haemonchus contortus

Fig.1 Anterior end, showing a pair of prominent cervical papillae

Fig.2 Posterior end of male, showing spicules and arrangement of rays in bursa

Fig.3 Posterior region of female, showing opening of anus

Fig.4 Vulvar region of linguiform female, showing tongue-shaped flap

Fig.5 Knob-shaped flap on vulva in knobbed pnehotype

Fig.6 Egg

PLATE-1·28

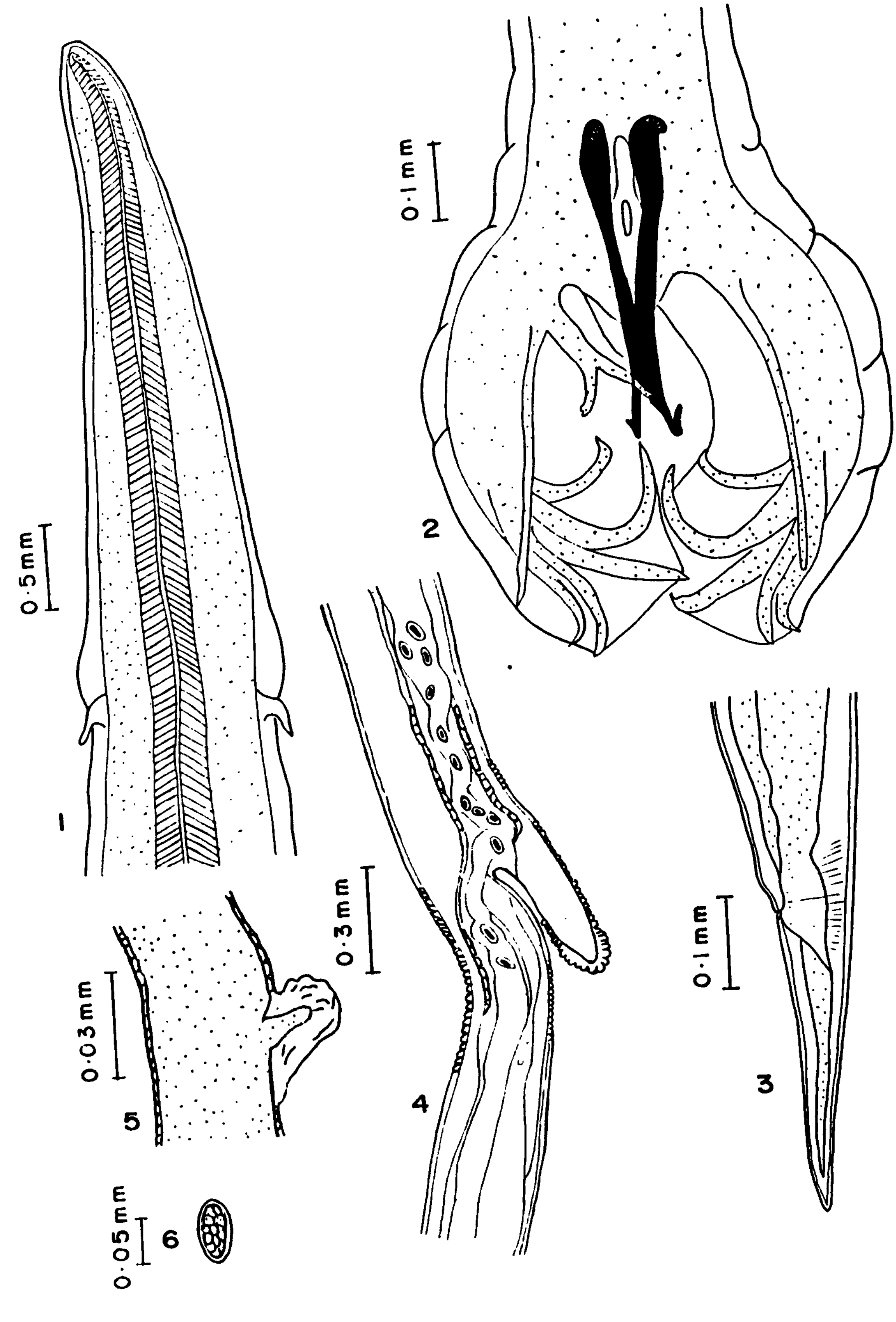


PLATE 1.29 Haemonchus contortus (Photomicrographs)

Fig.1 Anterior end (scale bar = 0.2 mm)

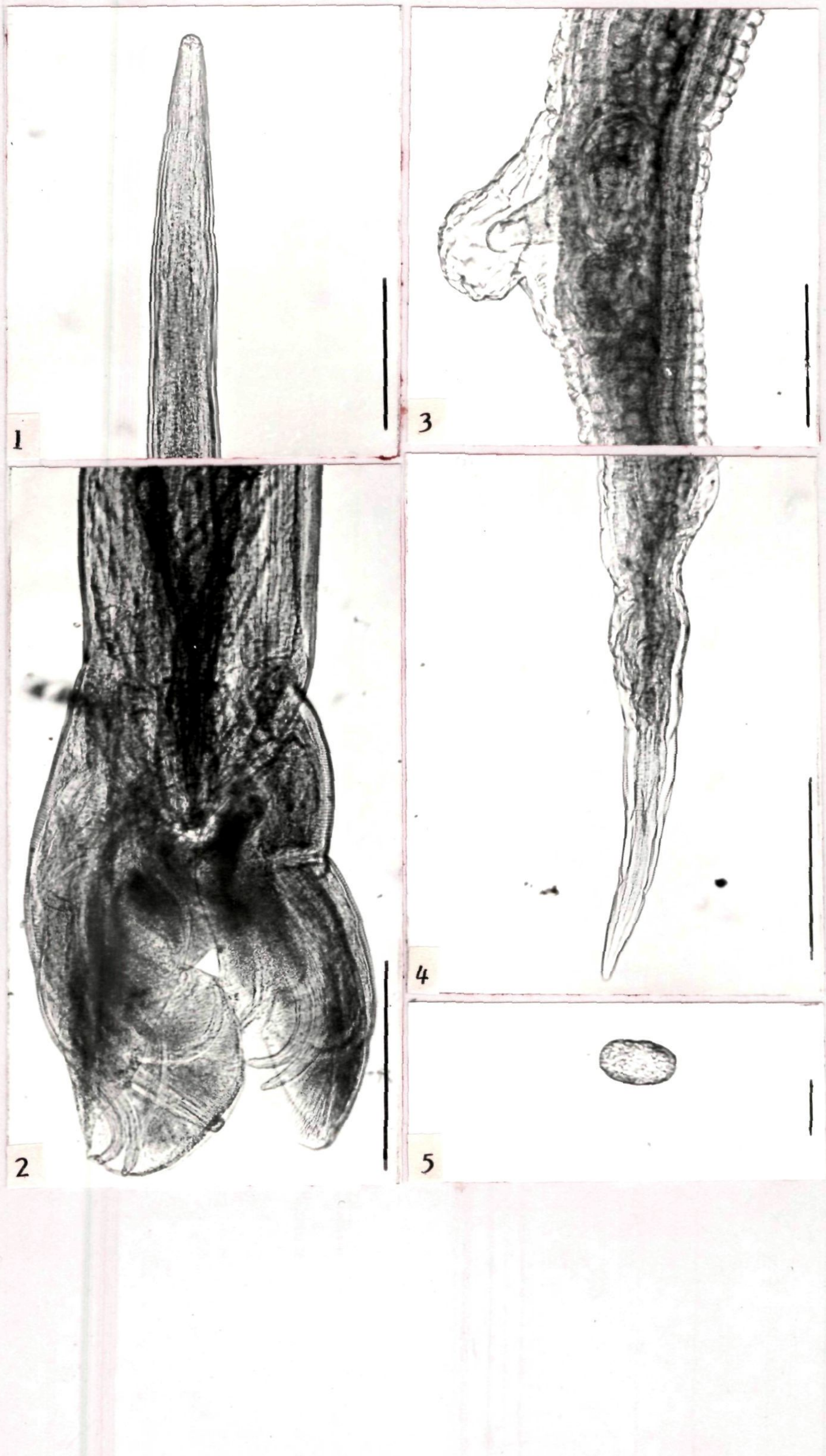
Fig.2 Posterior end of male (scale bar = 0.2 mm)

Fig.3 Vulvar region of linguiform female (scale bar = 0.2 mm)

Fig.4 Posterior end of female, showing opening of anus (scale bar = 0.2 mm)

Fig.5 Egg (scale bar = 0.04 mm)

PLATE 1.29



arising separately from dorsal ray, curving slightly dorsally; dorsal ray stout, bifurcated each limb bidigitate taking its origin from left side near externo-dorsal ray; mediolateral and posterolateral thicker than other lateral rays; anterolateral more or less straight; widely divergent from other two lateral rays; latter parallel, curved dorsally. Prebursal papillae close to bursa, not prominent. Spicules relatively short, thick, unbranched, dark brown, each provided with small barb on its outer surface. Gubernaculum present, its edges not so distinct.

Female

Both linguiform and knobbed phenotypes occurring in single population. Tail slender, sharply pointed, bearing a pair of papilae just near its tip. Vulva situated in posterior part of body, covered by prominent flap, projecting caudally (linguiform); in few specimens instead of a flap, a reduced small knob-like structure present at opening of vulva (Knobbed). Vagina small, runs anteriorly from vulva. Eggs segmented, thin shelled.

The measurements of the body and its organs are given in Table 1.13.

Host Goat, sheep, cattle

Location Stomach

Locality Shillong, Nongstoin, Jowai, Markasa, Riangdo

Remarks

Variations in the shape of the vulvar region were noted in a few specimens; the same was linguiform with a flap in some and in others knob-like and/or not as conspicuous as noted in the majority of the worms.

TABLE 1.13 : *Haemonchus contortus* (Rudolphi, 1803) Cobb, 1898 : morphometric measurements

Characters		Male Range	Male Mean	Female Range	Female Mean
Body :	length	15.0-18.0	16.2	18.0-26.0	20.7
	width	0.24 -0.29	0.25	0.25-0.34	0.30
Head :	diameter	20-27μ	20μ	20-27μ	25μ
Oesophagus :	length	1.20-1.50	1.32	1.30-1.60	1.40
	width(B)[¥]	0.10-0.11	0.10	0.08-0.15	0.11
Nerve ring[§]		0.27-0.32	0.29	0.29-0.35	0.32
Cervical papillae[§]		0.36-0.39	0.38	0.37-0.42	0.39
Spicules :	length	0.42-0.48	0.44	-	-
	barb(L)	0.020-0.027	0.024	-	-
	barb(R)	0.040-0.046	0.044	-	-
Tail :	length	-	-	0.44 -0.51	0.46
Caudal papillae*		-	-	0.08-0.11	0.09
Vulva*		-	-	3.20-4.14	3.56
Eggs :	length	-	-	0.050-0.069	0.059
	width	-	-	0.02-0.04	0.031

Baylis and Daubney (1922) recorded female specimens only (though one male specimen, too, but badly damaged) from spotted deer (Cervus axis) and described the same under the name Haemonchus cervinus. Whereas Le Roux (1929) and Das and Whitlock (1960) considered H. cervinus as a species inquirenda due to the absence of male's description, Baylis (1936a) and Gibbons (1979) regarded it as synonym of H. contortus.

H. contortus has been reported from an array of hosts including man and a fresh water fish Wallago attu by Sahay (1966) in India. Vulvar configuration in H. contortus populations has been considered to be of taxonomic significance and a variety of subspecies were described by several workers principally on the basis of variations in the morphology of the vulvar region. H. contortus populations in sheep and goats from Orissa were described as var. utkalensis (Das and Whitlock 1960). Fotedar and Bambroo (1965) added H. contortus var. kashmirensis from Kashmir. Similarly the forms collected from sheep at Bangalore were designated as var. bangalorensis by Rao and Rahman (1967). However, Gibbons (1979) considered the earlier two as synonym of H. contortus and the latter as species inquirenda.

In the females of H. contortus three phenotypes have been reported in India (Sood, 1981) : these include linguiform, knobbed and smooth. Sood and Kaur (1976) found a greater percentage of knobbed and less of linguiform females from Ludhiana. Rao and Rahman (1967) however, found large number of linguiform and less of knobbed forms in sheep from Bangalore (Karnataka). According to Sood (1981) variations in vulvar form among the various populations are due to geographical and climatic factors. Daskalov (1972; 1974) asserted that the host species is largely responsible for this phenomenon and further suggested it to be associated with the reproductive activity of the mature forms. He thus concluded that the vulvar flaps are rather age related and have no taxonomic value. Gibbons (1979), in view of the dependence of vulvar configuration on several factors, stated that these cannot be relied upon for specific differentation and rejected the valadily of subspecies of Haemonchus.

The buccal tooth and the gubernaculum could not be seen distinctly in many of the specimens examined in the present study. Meghalaya forms a new locality record for this species.

Genus Mecistocirrus Railliet et Henry, 1912 b

Mecistocirrus digitatus (Linstow, 1906) Railliet et Henry, 1912 b

(Syn. Strongylus digitatus Linstow, 1906; M. tagumai Morishita, 1922; Nematodirus digitatus Railliet et Henry, 1909; N. gibsoni Railliet et Henry, 1912 b

(Plates 1.30, 1.31)

The collection comprised many specimens of this species.

Description

General

Worms red to dark reddish in colour; body markedly attenuated, tapered anteriorly. Slight vesicular swelling present at anterior end. Cervical papillae quite conspicuous, spine like, present laterally on each side of body after

PLATE 1.30 *Mecistocirrus digitatus*

Fig.1 Anterior end, showing buccal tooth and a pair of cervical papillae

Fig.2 Posterior end of male, showing spicules, gubernaculum and arrangement of rays in bursa

Fig.3 Posterior region of female, showing opening of vulva and anus

Fig.4 Egg

PLATE-1·30

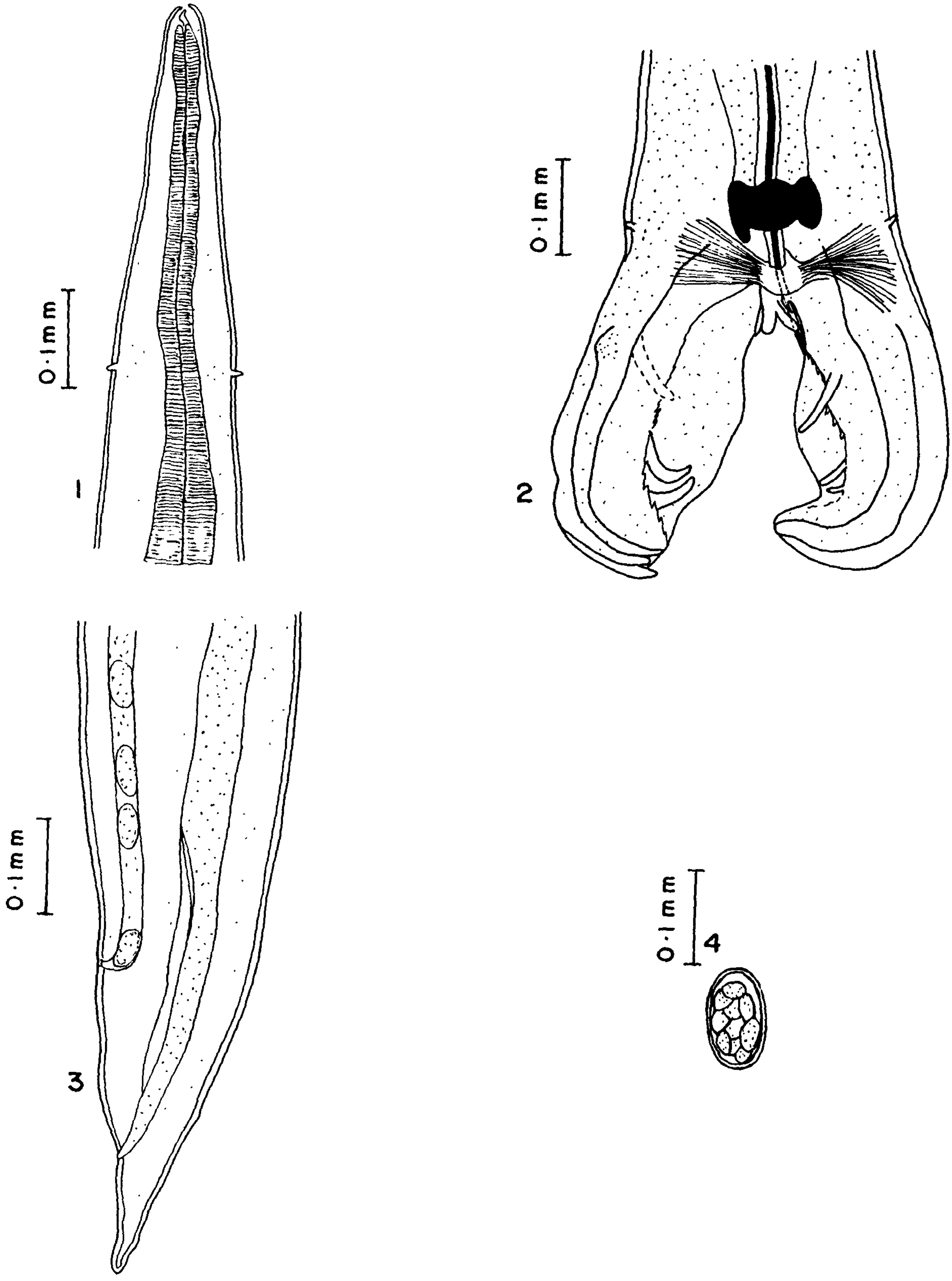


PLATE 1.31 *Mecistocirrus digitatus* (Photomicrographs)

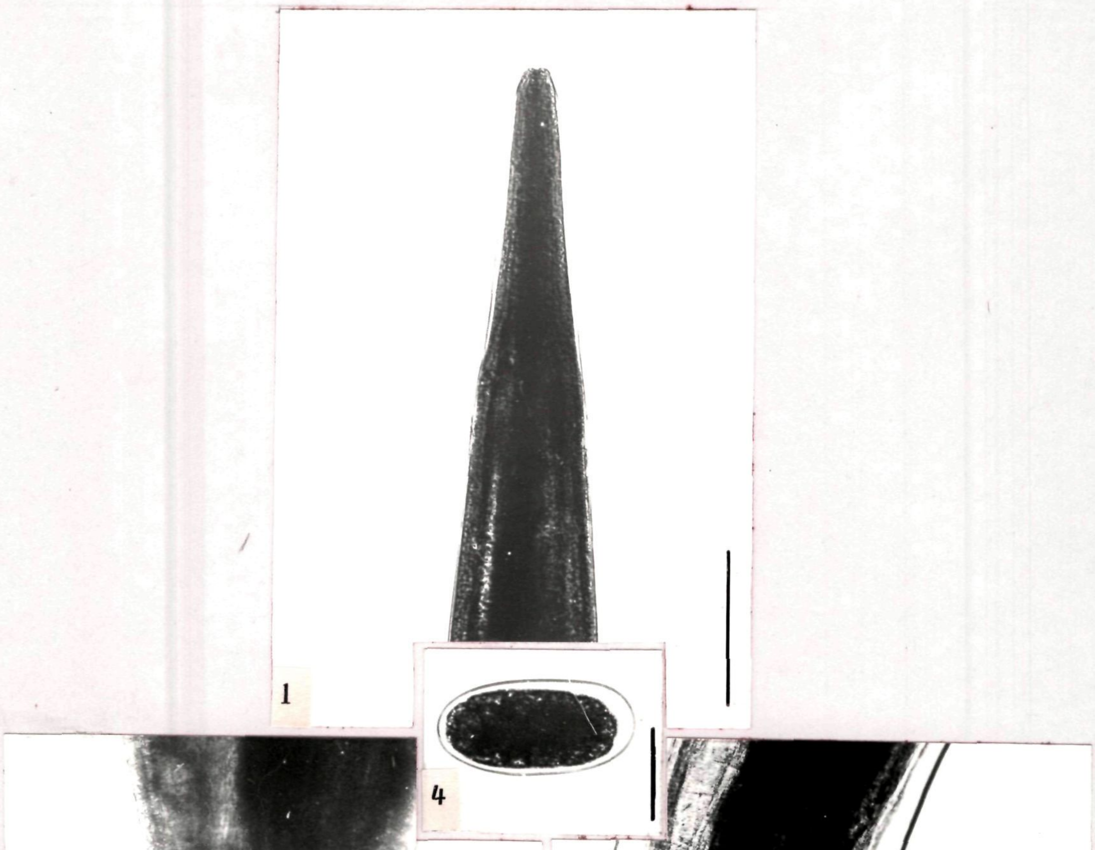
Fig.1 Anterior end (scale bar = 0.2 mm)

Fig.2 Posterior region of female, showing opening of vulva and anus (scale bar = 0.2 mm)

Fig.3 Posterior end of male (scale bar = 0.2 mm)

Fig.4 Egg (scale bar = 0.04 mm)

PLATE 1.31



excretory pore. Mouth subterminal, slightly inclined dorsally. Body cuticle with fine transverse striations, bearing about thirty longitudinal ridges. Buccal capsule very small, possessing large, lancet-like curved tooth. Oesophagus club shaped. Nerve ring at about anterior quarter of oesophagus.

Male

Bursa well developed comprising two lateral, one small but distinct symmetrical dorsal lobes; ventrolateral ray short, slender, widely divergent from lateroventral ray; latter and anterolateral rays close together except at tips, conspicuously longer than other rays; remaining rays, all slender; externodorsal arising separately from dorsal ray; latter short, bifurcated distally, each branch ending in three terminal papillae. One pair of conspicuous pre-bursal papillae present. Spicules very long, slender, united for almost whôle of their length, tip of spicule enclosed in spicular membrane with prominent funnel-shaped head. A structure resembling gubernaculum present.

Female

More robust, longer in size than males. Tail conical, without terminal spine. Vulva near posterior extremity, close to anus, with chitinoid lips. Vagina very long, running anteriorly from vulva. Ovaries wound spirally around intestine; ovejectors opposed. Posterior branch of uterus immediately turning forward to run parallel with anterior branch, filled with numerous eggs. Eggs relatively large, oval, thin shelled, segmented.

The measurements of the body and its organs are given in Table 1.14.

TABLE 1.14 : Mecistocirrus digitatus (Linstow, 1906) Railliet et Henry, 1912b : morphometric measurements

Characters		Male Range	Male Mean	Female Range	Female Mean
Body :	length	17.0-19.0	17.7	16.0-40.0	24.0
	width	0.36-0.43	0.38	0.36-0.54	2.12
Oesophagus :	length	1.44-1.62	1.50	1.44-1.83	1.68
	width	0.12-0.16	0.14	0.16-0.21	0.17
Cervical papillae[§]		0.37-0.43	0.39	0.36-0.50	0.40
Nerve ring[§]		0.39-0.50	0.45	0.36-0.50	0.41
Spicules:	length	5.58-5.76	5.70	-	-
Tail :	length	-	-	0.12-0.18	0.15
Vulva*		-	-	0.32-0.48	0.39
Vagina :	length	-	-	2.48-2.73	2.57
Eggs :	length	-	-	0.09-0.11	0.10
	width	-	-	0.05-0.059	0.05

Host Cattle

Location Abomasum

Locality Shillong, Nongstoin, Riangdo, Jowai, Markasa

Remarks

This species was originally described by Linstow (1906) from stomach of zebu (Bos indicus) at Colombo, Ceylon. In India, it was first recorded by Sheather (1919) from calves. The present observations tally closely with the description provided by Baylis (1936a) except for the gubernaculum which was reported to be absent by earlier workers. The species is being reported for the first time from north-east India, Meghalaya in particular.

Family	Onchorercidae (Leiper, 1911) Anderson and Bain, 1976
Subfamily	Setariinae Yorke et Maplestone, 1926
Genus	Setaria Viborg, 1795

Setaria digitata (Linstow, 1906) Railliet et Henry, 1911

(Syn. Filaria digitata Linstow 1906; S. buxi Bhalerao 1933; S. labiato-papillosa Bhalerao, 1933)

(Plates 1.32, 1.33)

The collection comprised several hundred specimens of this species.

Description

General

Body several centimetres long, milky white, tapering towards hind end, latter spirally coiled. Cuticle smooth, rather thick with fine transverse striations, without lateral alae. Mouth opening round, surrounded by raised dorsoventrally elongate peribuccal ring with notched dorsal and ventral prominences; processes notched at apex so as to give two more or less prominent angular points. Cephalic papillae less prominent; four submedian, four sub-lateral, two lateral papillae, all lying behind peribuccal crown. Oesophagus divided into anterior short, thin muscular portion and posterior long, thick, glandular portions. Tail provided with pair of tiny lateral appendages near its end.

Male

Posterior extremity attenuated, coiled spirally to ventral side, with pair of small lateral cuticular appendages near tip of tail. Caudal alae absent.

PLATE 1.32 *Setaria digitata*

Fig.1 Anterior end of female, lateral view, showing opening of vulva and cephalic papillae

Fig.2 Anterior end of male, dorsal view, showing peribuccal crown

Fig.3 Posterior end of male, showing spicules and arrangement of papillae

Fig.4 Posterior region of female, showing opening of anus and a pair of caudal appendages

PLATE-1·32

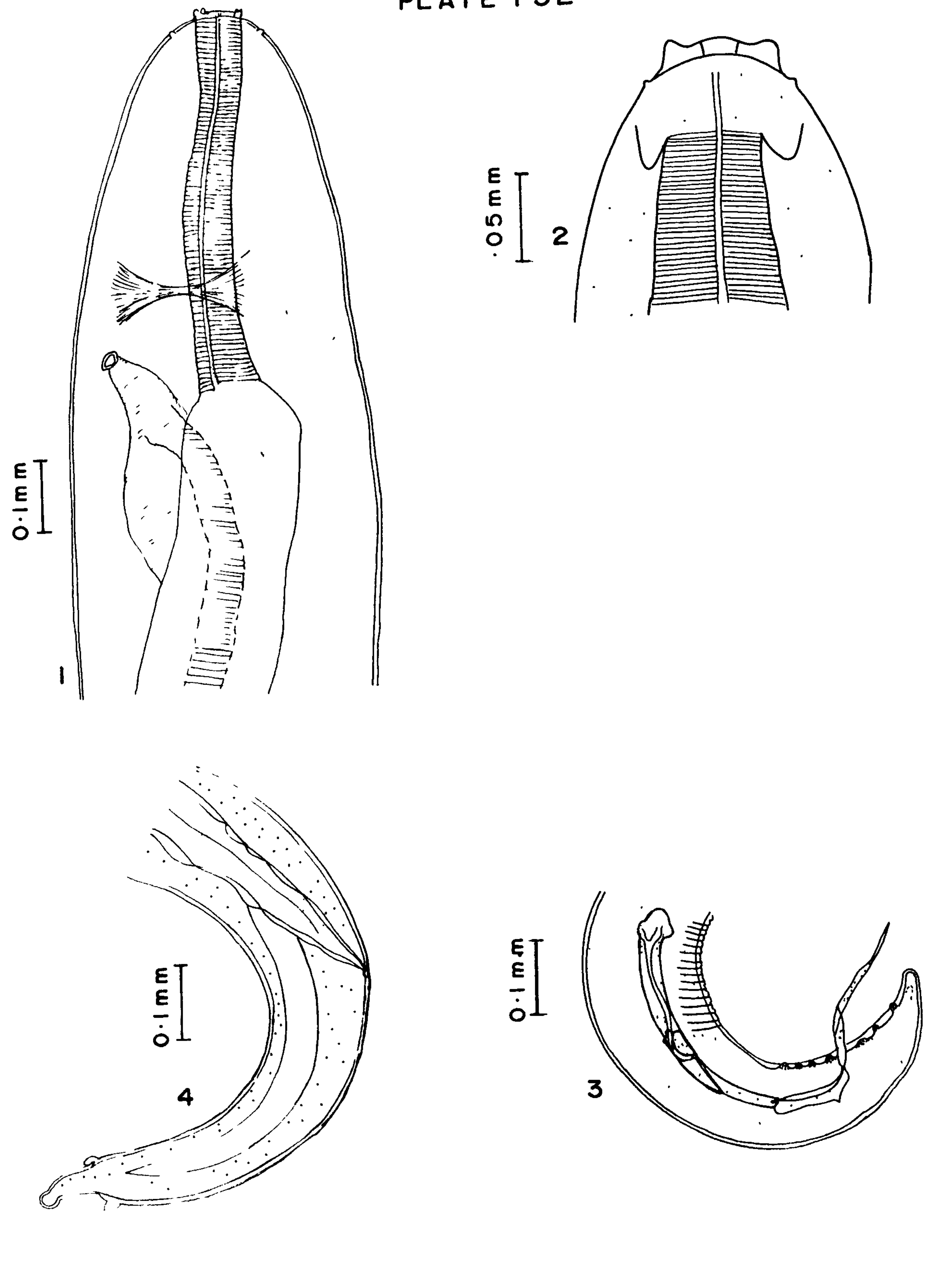


PLATE 1.33 ***Setaria digitata*** **(Photomicrographs)**

Fig.1 Anterior end of male (scale bar = 0.2 mm)

Fig.2 Anterior end of female (scale bar = 0.2 mm)

Fig.3 Posterior end of male, showing a protruding spicule and caudal papillae (arrows) (scale bar = 0.2 mm)

Fig.4 Posterior region of female showing opening of anus (scale bar = 0.2 mm)

Fig.5 Egg (scale bar = 0.1 mm)

PLATE 1.33

Tail possessing four pairs of preanal, three pairs of postanal papillae arranged in subventral rows. Cuticle forming transverse folds, which expand laterally in front of preanal papillae on spiral part of body. Spicules very unequal, dissimilar, alate; left spicule longer, with tubular proximal portion, distal membranous portion extending to a cuticular blade; right spicule short, stout, somewhat boat shaped, slightly curved ventrally, with tip directed backwards.

Female

Tail bent dorsally into loose spiral, terminating in spherical terminal knob, bearing 1-2 circlets of spikes, pair of well-developed small rounded appendages just near its tip. Vulva projecting slightly above body surface, lying in oesophageal region. Vagina highly muscular situated at level of union of two parts of oesophagus, forming 'S'-shaped strucutre, bifurcates into two uteri occupying large part of body cavity; in sexually mature individuals anterior part of uterus filled with microfilarae. Eggs thin shelled, containing coiled microfilara.

The measurements of the body and its organs are given in Table 1.15.

Host Cattle

Location Peritoneal cavity

Locality Shillong, Nongstoin, Sohiong, Mairang, Markasa, Jowai

Remarks

This species was originally described as Filaria digitata on the basis of nematodes obtained from Bos indicus in Sri Lanka, and in 1911 transferred

TABLE 1.15 : Setaria digitata (Linstow, 1906) Railliet et Henry, 1911 : morphometric measurements

Characters		Male Range	Male Mean	Female Range	Female Mean
Body :	Length	42.0-52.0-	48.2	72.0-96.0	86.5
	width	0.41-0.51	0.51	0.45-0.57	0.49
Peribuccal lips :	depth	18-36µ	28µ	17-36µ	32µ
Oesophagus :	length(A)	0.39-0.50	0.44	0.46-0.63	0.54
	(P)	4.3-5.4	4.75	4.7-6.5	5.86
Nerve ring§		0.126-0.216	0.178	0.20-0.25	0.22
Tail :	length	0.162-0.252	0.198	0.46-0.57	0.53
Spicules :	length(L_{PT})	0.234-0.262	0.249	-	-
	length(L_{DB})	0.174-0.197	0.187	-	-
	(R)	0.124-0.142	0.133	-	-
Caudal appendages:	length	18-27µ	20µ	17-36µ	33µ
	distance*	72-90µ	79µ	90-108µ	99µ
Vulva§		-	-	0.45-0.59	0.52
Vagina :	length	-	-	0.28-0.36	0.32

in the genus Setaria by Railliet and Henry. Boulenger (1921) redescribed the female of this species, indicating its morphological differences from the female of S. labiatopapillosa (Alessandrini, 1838). Schwartz (1926) and Thwaite (1927) also expressed the same view. However, Purvis (1931) and Baylis (1936b) considered S. digitata a synonym of S. labiatopapillosa. In the same year Baylis (1936b) synonymized it with S. cervi. Later on, other workers such as Sarwar (1946a) and Skryabin and Shikhobaleva (1945) did not agreed with the opinions of Purvis and Baylis, and considered the species S. digitata an independent one. Yeh (1959), while revising the genus Setaria studied a collection of Setaria from cattle of various countries of south-east Asia. He came across a coinfection of these animals by nematodes of the species S. labiatopapillosa and S. digitata which he reported to be quite different in morphology. The two species can be distinguished by the shape of the mouth opening - round (in S. digitata) against oval (in S. labiatopappillosa) and presence or absence of bosses on the tail of female. Shoho (1959) also pointed out that the two species are distinct and valid. Desset (1966) was also of the same view and pointed out that the absence of bosses on the caudal end in S. digitata or their presence in S. labiatopapillosa may be considered the only reliable difference listed by Yeh. The present species can also be differentiated from S. cervi, commonly reported from Bovidae in India, as the tail terminates in a bell-shaped thickening and the cephalic crown appears with four odontoid cuticular outgrowths protracted in dorsoventral direction in the latter species.

Except for the variation in the number of caudal papillae and the terminal knob of tail, which sometimes appeared simple, all other charactes tally with the description provided by Yeh (1959); the latter author mentioned eight pairs of caudal papillae.

Setaria bernardi Railliet et Henry, 1911

(Syn. S. congolensis Railliet et Henry, 1911; Artionema bernardi (Railliet et Henry, 1911) Yeh, 1959)

(Plates 1.34, 1.35)

The collection comprised only a single male and six female specimens of this species.

Description

General

General appearance of worms like that of S. cervi (described earlier). Peribuccal chitinous crown oblong, slightly elongated dorsoventrally; four corners of crown pointed, directed outwardly in dorsal and ventral views; denticles distinctly separate, appearing bifurcate in median view. Four pairs of submedian papillae lying just below head end, arranged in two levels; pair of lateral amphids lying at nearly same level. Oesophagus differentiated into short anterior, long posterior portions.

Male

Posterior extremity weakly spiraled. Pair of tiny lateral appendages present very near to tail tip. Tail bearing four pairs each of pre- and postanal papilae, one central papilla in front of cloaca, pair of small papillae near its end; of preanal papillae first two pairs arranged symmetrically, third asymmetrically, last pair symmetrically very near to cloaca; postanal arranged quite asymmetrically, except last pair symmetrically close to tail end. Spicules markedly unequal; left spicule long, consisting of tubular proximal, distal membranous portions; right spicule small, stout.

PLATE 1.34 Setaria bernardi

Fig.1 Anterior end of female, dorsal view, showing opening of vulva

Fig.2 Anterior end of male, lateral view, showing dissimilar spicules and arrangement of papillae

Fig.3 Posterior region of female, showing opening of anus and a knobbed terminal end consisting of circlet of spikes; a pair of caudal appendage is also seen just near to tip of tail

Fig.4 Egg containing coiled microfilaria

Fig.5 Microfilaria

PLATE-1·34

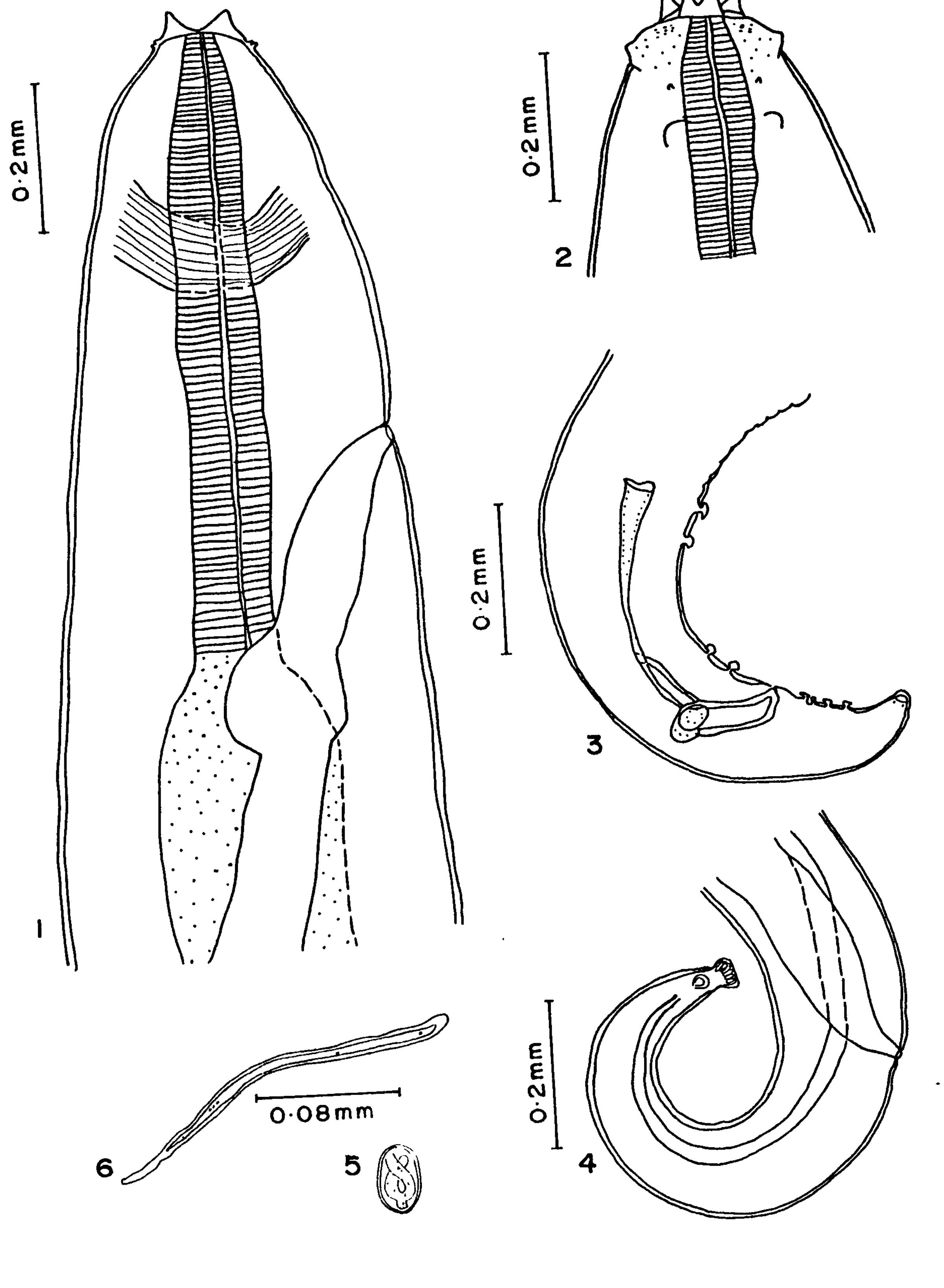


PLATE 1.35 Setaria bernardi (Photomicrographs)

Fig.1 Anterior end of male, showing oval peribuccal crown (scale bar = 0.2 mm)

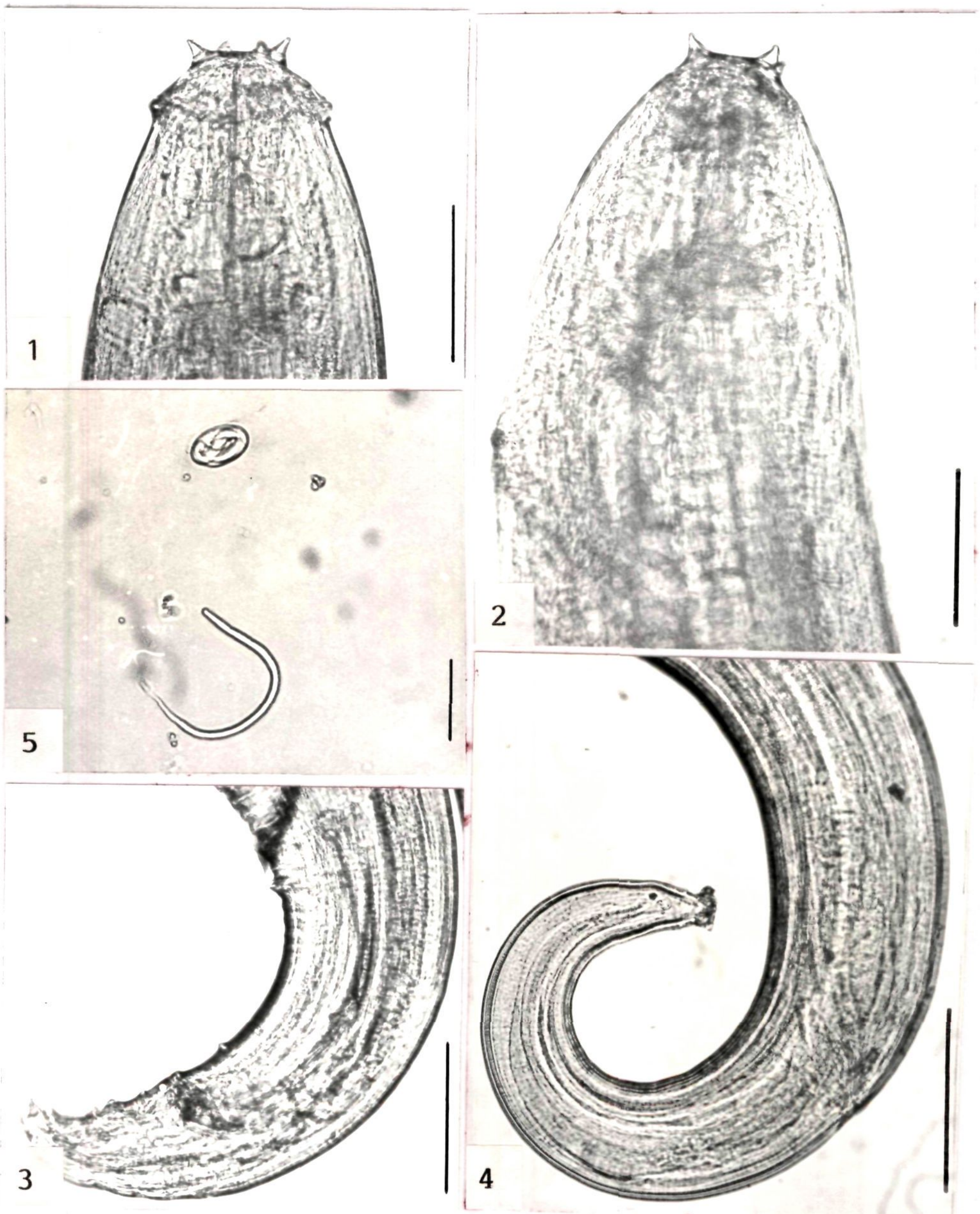
Fig.2 Anterior end of female, showing opening of vulva (scale bar = 0.2 mm)

Fig.3 Posterior end of male, showing caudal papillae (scale bar = 0.2mm)

Fig.4 Posterior end of female, showing opening of anus and a circlet of spikes (scale bar = 0.2 mm)

Fig.5 Egg and microfilaria (scale bar = 0.1 mm)

PLATE 1.35



Female

Tail coiled spirally, having many short spines; in some specimens terminating in bulbous dilation. Caudal appendages small, rounded very close to tip. Vulva opening in oesophageal region; sphincter stretching little distance behind. Vagina fusiform, highly muscular; ovejectors divided into two uteri. Eggs oval, thin shelled, containing coiled microfilaria.

The measurements of the body and its organs are provided in Table 1.16.

Host	Pig
Location	Peritoneal cavity
Locality	Shillong, Nongstoin

Remarks

Bernard and Bauche' (1911) recovered a filariid in the abdominal cavity of domestic pigs of Vietnam and described it as Filaria sp. Ralliet and Henry (1911) also described a species Setaria congolensis from wild pigs in Africa and stated that the parasites discovered by Bernard and Bauche though belonged to the genus Setaria, represent a distinct species, for which these workers proposed the name Setaria bernardi. However, the non-availability of the original description led some workers to doubt the validity of the species. Sandground (1933), after studying Setaria from Indo-China, concluded that S. bernardi should be treated as a synonym of S. congolensis. However, Yeh (1959) and Desset (1966), after studying the type specimens of the two species, reached to a conclusion that they are two independent and valid species.

TABLE 1.16 : *Setaria bernardi* Railliet et Henry, 1911 : morphometric measurements

Characters		Male	Female Range	Mean
Body :	length	95.0	105.0-120.0	114.0
	width	0.63	0.82-0.99	0.89
Peribuccal lips :	depth	23 μ	23-27μ	23μ
Oesophagus :	length(A)	0.77	0.93-1.04	0.99
	(P)	10.12	9.54-10.47	10.08
	width(A)	0.09	0.09-0.12	0.10
	(P)	0.21	0.18-0.21	0.19
Nerve ring§		0.23	0.23-0.26	0.24
Tail :	length	0.18	0.49-0.73	0.59
Caudal appendages:	length	13 μ	9-18 μ	11 μ
	distance*	50 μ	41-59μ	51 μ
Spicules :	length(L)	0.33	-	-
	(R)	0.18	-	-
Vulva§		-	0.61-0.64	0.63
Vagina :	length	-	0.34-0.38	0.37

In possessing an oblong peribuccal crown and in general features of the posterior end of the body, the specimens under the present study are identified as S. bernardi and differ from other species of Setaria reported from Suidae, viz., S. thomasi, S. congolensis and S. castroi. The morphometric measurements of the present specimens tally closely with those described by Shoho and Machida (1979) from Japan except for minor variations in the length of the body, i.e., male 95.0 and female 105.0-220.0mm as compared to 66.0-78.0 and 88.0-165.0mm, respectively by the latter authors.

The genus Setaria is found to be of relatively less common occurrence in the members of the Suidae (Yamaguti, 1961). So far only four species of thegenus are known from these hosts elsewhere in the world. While several species occur in Indian ungulates, there is apparently no report of the genus Setaria in Indian swine. The present study contributes to the first record of the genus in domestic pigs in India and forms a new locality record for S. bernardi.

Family Spirocercidae (Chitwood et Wehr, 1934) Chabaud, 1975.

Subfamily Ascaropsinae Alicata et McIntosh, 1933

Genus Ascarops Beneden, 1873

Ascarops strongylina (Rudolphi, 1819) Alicata et McIntosh, 1933

(Syn. Spiroptera strongylina Rudolphi, 1819; Ascarops minuta Beneden, 1873)

(Plates 1.36, 1.37)

The collection comprised numerous specimens of this species.

PLATE 1.36 Ascarops strongylina

Fig.1 Anterior end

Fig.2 Posterior end of male

Fig.3 Posterior end of female

Fig.4 Vulvar region of female

Fig.5 Egg

PLATE-1·36

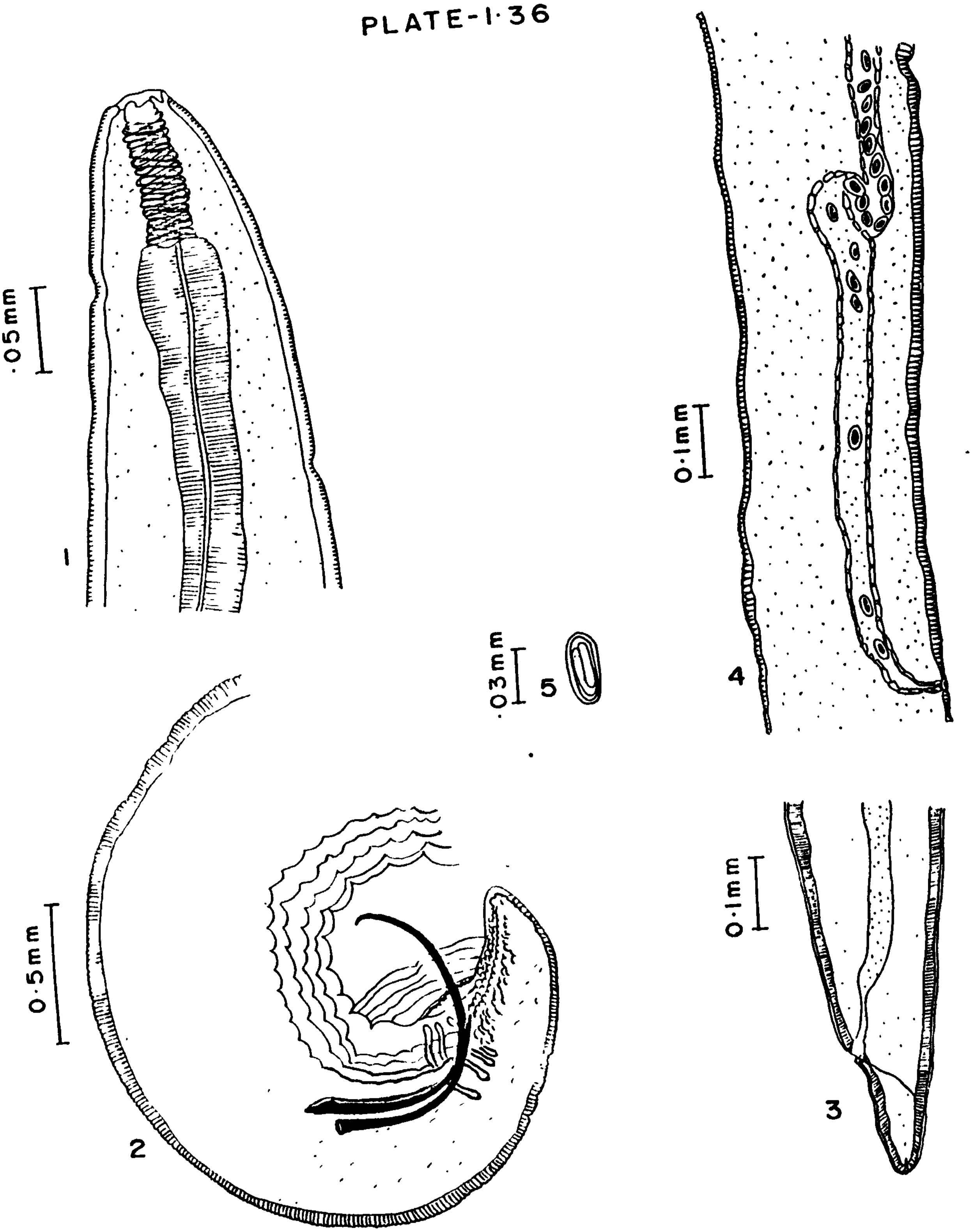


PLATE 1.37 Ascarops strongylina (Photomicrographs)

Fig.1 Anterior end, showing spiral thickenings of pharynx (scale bar = 0.2 mm)

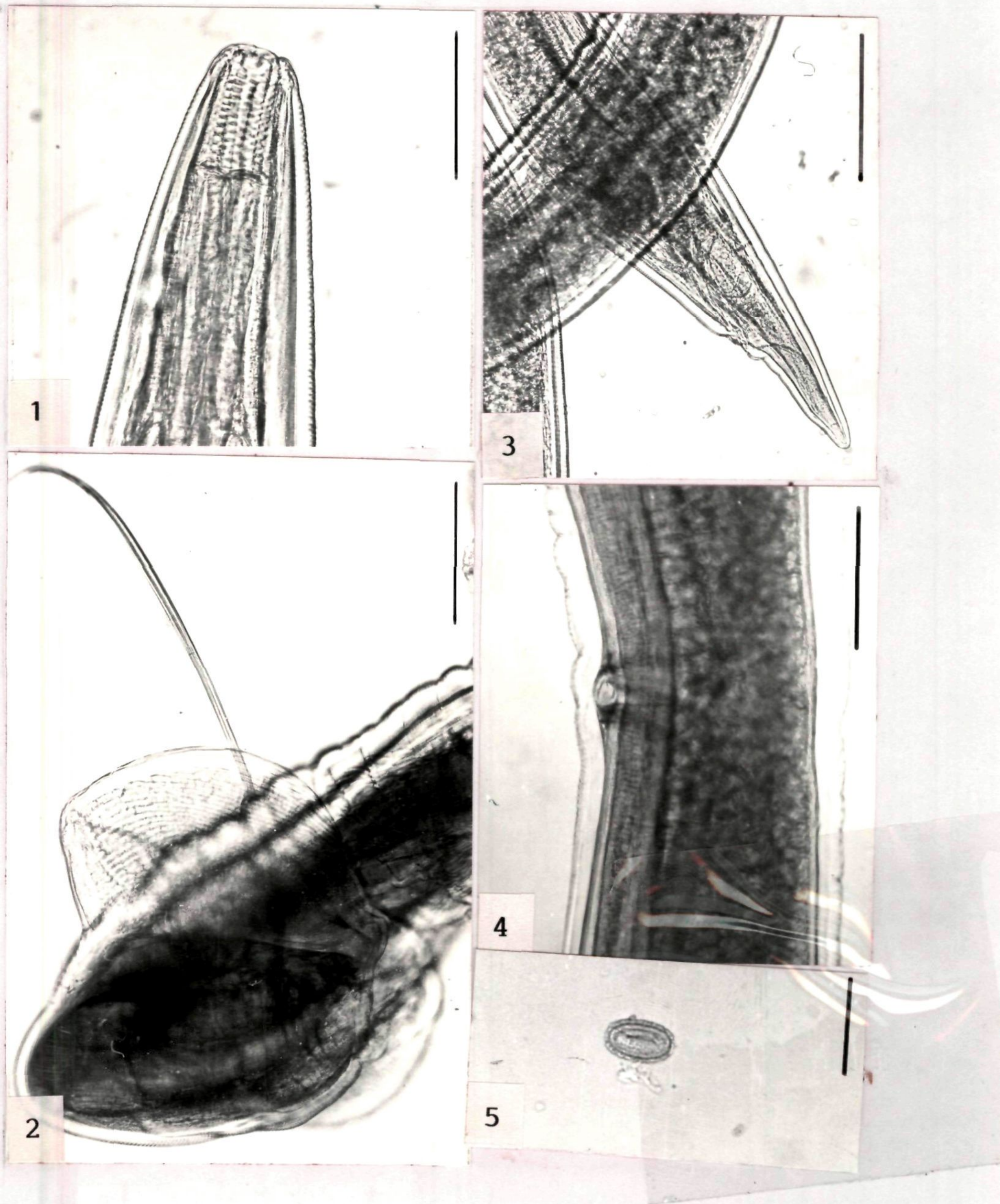
Fig.2 Posterior end of male (scale bar = 0.2 mm)

Fig.3 Posterior end of female, showing opening of anus (scale bar = 0.2 mm)

Fig.4 Vulvar region of female (scale bar = 0.2 mm)

Fig.5 Egg (scale bar = 0.05 mm)

PLATE 1.37



Description

General

Body slender, reddish white. Cervical ala present only on left side of body. Cervical papillae situated asymmetrically. Mouth with two lateral trilobed lips, each bearing two submedian papillae externally and one tooth on each side internally, projecting into oral cavity. Pharynx straight, its wall strengthened by thickenings in form of triple or quadraple spirals. Oesophagus long, consisting of two parts, anterior much shorter.

Male

Tail coiled, with asymmetrical alae; right ala about twice as wide as left. Caudal papillae four pairs, long, pedunculate; of these three pairs preanal, one adanal; papillae on right side almost at same level, those on left side placed irregularly, additional pair of pedunculate papilae present in postanal region; five pairs of postanal small sessile papillae present on prominent raised area of cuticle with serrated margin near cloaca. Spicules unequal, dissimilar; left long, slender, finely pointed; right shorter, stout, blunt.

Female

Tail bluntly pointed. Vulva in front of middle of body, displaced towards left side, opening just ventrally to lateral ala; constriction in region of vulva present. Vagina at first running transversly between cuticle and muscular layer of body wall, then posteriorly within body cavity. Uterine branches opposed; posterior branch doubling forward at distance of few millimeters, its ovary situated in oesophageal region; anterior branch doubling back at similar distance as posterior branch from its origin, its ovary lying in posterior region of body. Eggs oval, of irregular outline, operculate at poles, embryonated.

The measurements of the body and its organs are given in Table 1.17.

Host	Pig
Location	Stomach, small intestine
Locality	Shillong, Nongstoin, Jowai

Remarks

Only two species of the genus are so far represented in the suids of the world. These, namely A. strongylina and A. dentata are distinguished from each other mainly on the basis of the body length which is up to 15mm and 22mm in males and females of the former species and upto 35mm and 55mm, respectively in males and females of the latter species. Accordingly the material under the present study was also identified as A. strongylina. Due to its extreme coiledness of the posterior end the caudal structures in most of the male worms could not be easily discerned.

In the description given by Baylis (1939) and Shoho and Machida (1979) there is no mention of the triangular raised area of cuticle surrounding the cloaca, as noticed in the male specimens under present investigation. The gubernaculum reported to be present by the latter authors could not be seen. However, in all other major respects the present observations are in accordance with that of Baylis (1939) and Shoho and Machida (1979).

TABLE 1.17 : <u>Ascarops strongylina</u> (Rudolphi, 1819) Alicata et McIntosh, 1933: morphometric measurements

Characters		Male Range	Male Mean	Female Range	Female Mean
Body :	length	10.0-14.0	12.8	17.0-22.0	18.7
	width	0.33-0.38	0.36	0.30-0.53	0.43
Pharynx :	length	0.07-0.09	0.08	0.076-0.083	0.077
	width	0.034-0.038	0.033	0.064-0.072	0.066
Oesophagus :	length	2.96-3.47	3.145	3.03-3.84	3.40
Cervical papillae§ :	(L)	0.15-0.16	0.16	0.21-0.24	0.23
	(R)	0.30-0.32	0.31	0.45-0.52	0.49
Tail :	length	0.13-0.18	0.14	0.19-0.24	0.22
Spicules :	length(L)	2.47-2.73	2.57	-	-
	(R)	0.40-0.51	0.45	-	-
Vulva§		-	-	5.40-8.51	6.85
Eggs :	length	-	-	0.041-0.045	0.043
	width	-	-	0.022-0.024	0.023

Ascarops dentata (Linstow, 1904) Alicata et McIntosh, 1933

(Syn. *Spiroptera dentata* Linstow, 1904)

(Plates 1.38, 1.39)

A large number of specimens of this species was collected during the present study.

Description

General

Relatively small sized worms. Cervical ala present only at left side of body, begins at short distance from anterior extremity. Cervical papillae placed asymmetrically. Pharynx cylindrical containing several spiral rows of cuticular thickenings, guarded at its entrance by dorsal and ventral tooth. Oesophagus long, consisting of two parts, anterior much shorter.

Male

Tail coiled, with asymmetrical alae. Ventral surface of tail and caudal alae possessing several longitudinal rows of elongated cuticular thickenings. Caudal papillae five pairs with relatively small peduncles, of these four pairs preanal, asymmetrical; one pair postanal symmetrical; additionally five pairs of small, asymmetrical sessile papillae present between last pair of pedunculate papillae and tip of tail. Cloacal aperture surrounded by somewhat triangular elevated structure, latter with serrated margin at right side. Spicules dissimilar, left long; right short, stout.

Female

Tail short, conical, curved dorsally. Vulva not so distinct, opening far

PLATE 1.38 Ascarops dentata

Fig.1 Anterior end, showing the pharynx consisting of several rows of spiral thickenings

Fig.2 Posterior end of male, showing characteristic cuticular foldings, spicules, and arrangement of papillae at caudal extremity

Fig.3 Posterior end of female, showing opening of anus

Fig.4 Vulvar region of female

Fig.5 Egg containing coiled larva

PLATE-1·38

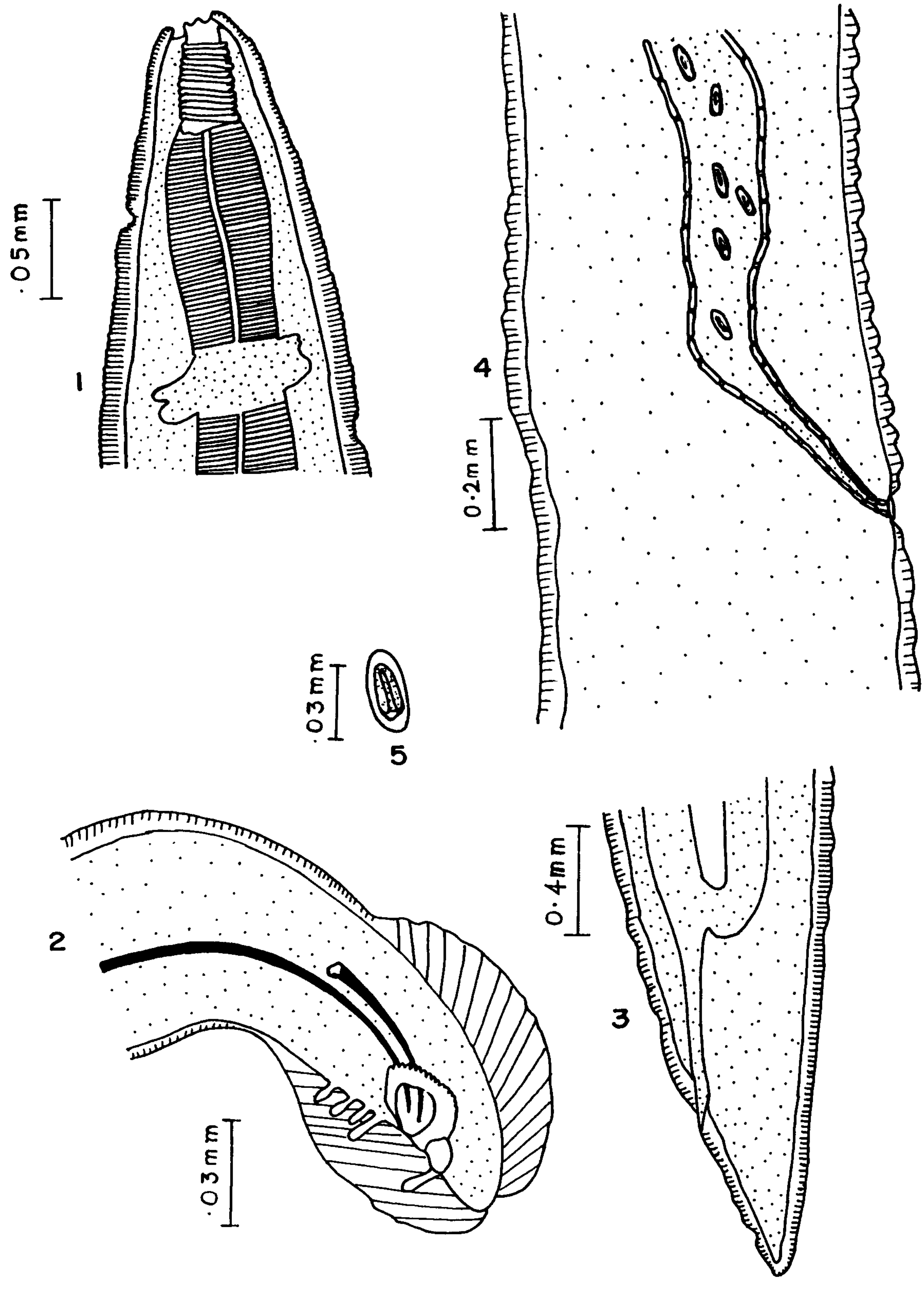


PLATE 1.39 Ascarops dentata (Photomicrographs)

Fig.1 Anterior end showing pharynx (scale bar = 0.2 mm)

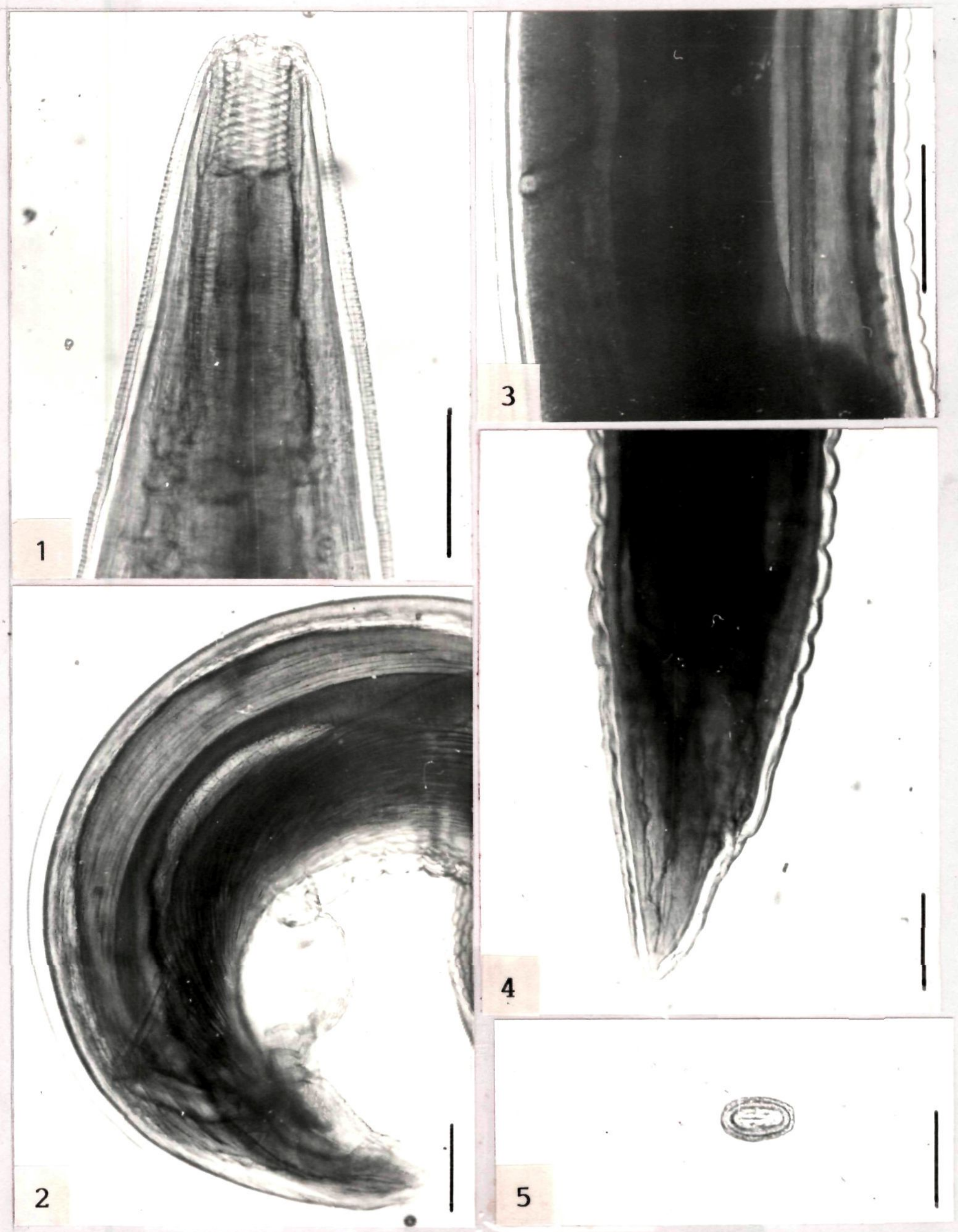
Fig.2 Posterior end of male (scale bar = 0.3 mm)

Fig.3 Posterior end of female, showing opening of anus (scale bar = 0.2mm)

Fig.4 Vulvar region of female (scale bar = 0.3 mm)

Fig.5 Egg (scale bar = 0.05 mm)

PLATE 1.39



behind middle of body. Eggs elliptical, thick shelled, containing coiled larva inside.

The measurements of the body and its organs are given in Table 1.18.

TABLE 1.18 : Ascarops dentata (Linstow, 1904) Alicata et McIntosh, 1933 : morphometric measurements

Characters		Male Range	Male Mean	Female Range	Female Mean
Body :	length	20.0-25.0	22.6	25.0-38.0	33.0
	width	0.70-0.82	0.76	0.93-1.08	1.03
Pharynx :	length	0.10-0.12	0.11	0.12-0.14	0.13
	width	0.04-0.06	0.05	0.05-0.06	0.06
Oesophagus :	length	4.14-4.44	4.25	4.88-6.36	5.87
Cervical papillae§ :	(L)	0.22-0.24	0.23	0.53-0.58	0.55
	(R)	0.45-0.52	0.49	0.26-0.30	0.28
Tail :	length	0.42-0.47	0.45	0.42-0.55	0.52
Spicules :	length (L)	3.62-4.14	3.96	-	-
	(R)	0.55-0.62	0.61	-	-
Vulva§		-	-	14.98-23.9	20.39
Eggs :	length	-	-	0.034-0.038	0.037
	width	-	-	0.019-0.022	0.021

Host Pig

Location Small intestine

Locality Shillong, Nongstoin

Remarks

A. dentata closely resembles A. strongylina in general appearance. The length of the body could differentiate these two speices; however, the width of the body, pharynx and tail and also the length of the spicule (relatively more in A. dentata) could be taken as supporting characters in the differentiation of the two species. Besides, in males of A. dentata the triangular elevation present surrounding the cloaca appeared to be less prominent than that in A. strongylina.

This species is being reported for the first time from north-east India, Meghalaya in particular.

Genus Physocephalus Diesing, 1861

Physocephalus sexalatus (Molin, 1860) Diesing, 1861

(Syn. Spiroptera sexalata Molin 1860; S. strigis (Linstow, 1878) Seurat, 1915; S. strongylina suis labiati (Molin, 1860).

(Plates 140, 141)

The collection comprised only few female specimens of this species.

Description

General

Medium-sized worms. Anteriorly, portion of body in oesophageal region

PLATE 1.40 *Physocephalus sexalatus* - female

Fig.1 Anterior end, showing pharynx, and lateral alae

Fig.2 Posterior end showing opening of anus

Fig.3 Opening of vulva

Fig.4 Egg, containing larva inside

PLATE-1·40

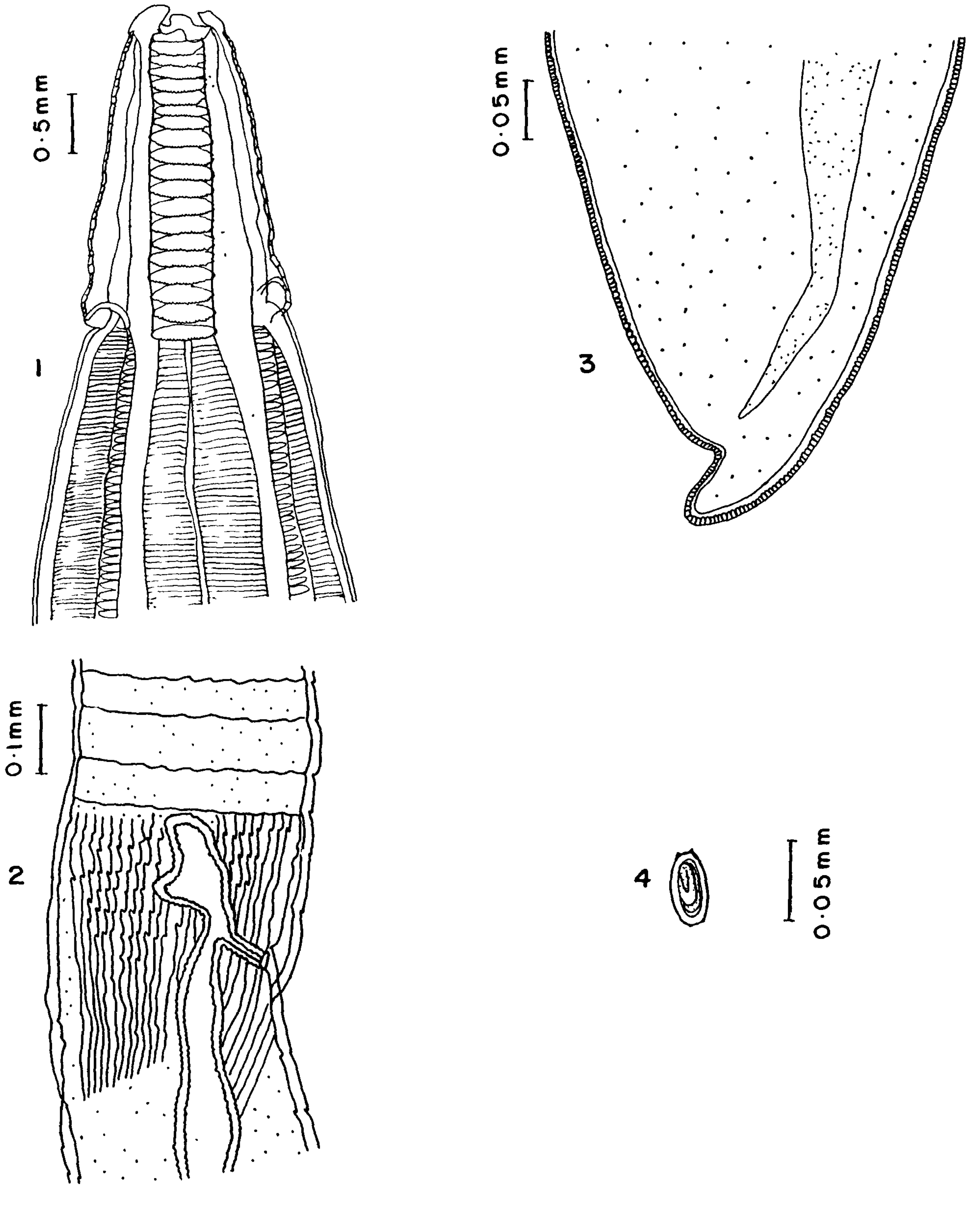


PLATE 1.41 Physocephalus sexalatus - female (Photomicrographs)

Fig.1 Anterior end showing spiral thickenings of pharynx (scale bar = 0.2 mm)

Fig.2 Posterior end (Scale bar = 0.2 mm)

Fig.3 Vulvar region (scale bar = 0.2 mm)

Fig.4 Eggs (scale bar = 0.05 mm)

PLATE 1.41

showing striated cephalic cuticular extension; latter ending into two pocket-like structures, each looking like head of sign '?'. Three lateral alae present just behind cuticular extensions; middle ala well developed, completely striated; internal ala thickely striated; external one with none or few striations restricted to half of its width. Cuticle striated, striations markedly distinct behind lateral alae up to posterior end of body. Cervical papillae very asymmetrically situated, apparently only single papilla situated on left side on middle lateral ala, just in front of nerve ring. Mouth with two trilobed lateral lips, joined to form two lateral masses; each lip bearing three pappilae externally, without teeth internally. Pharynx relatively long; its wall strengthened by single spiral thickening which breaks up in to complete rings in middle portion. Oesophagus long, straight, divided into two parts, anterior much shorter, less wide than posterior.

Female

Tail constricted little behind anus, its tip bent ventrally. Vulva behind middle of body, number of small cuticular thickenings present in form of interrupted longitudinal ridges adjacent to it. Vagina running posteriorly from vulva; ovaries situated at opposite ends of body. Eggs elliptical, slightly flattened at poles, containing larva.

The measurements of the body and its organs are given in Table 1.19.

Host	Pig
Location	Stomach, small intestine
Locality	Shillong, Nongstoin, Markasa

TABLE 1.19 : Physocephalus sexalatus (Molin, 1860) Diesing, 1861 : morphometric measurements

Characters		Female Range	Mean
Body :	length	18.0-22.0	20.0
	width	0.39-0.46	0.43
Cephalic inflation :	length	0.18-0.23	0.20
	width	0.05-0.06	0.055
Lateral alae :	width (A)	0.046-0.05	0.04
	(M)	0.035-0.040	0.036
	(P)	0.025-0.028	0.024
Pharynx :	length	0.28-0.32	0.29
	width	0.05-0.07	0.06
Oesophagus :	length	3.06-3.42	3.28
Tail :	length	0.11-0.12	0.11
Vulva§		11.0-14.0	12.3
Eggs :	length	0.03-0.04	0.03
	width	0.01-0.02	0.01

Remarks

This species has been reported from pigs of Calcutta (Maplestone, 1930b), and Punjab (Gupta and Sood, 1968) in India. The present description is based on female specimens only, as males could not be collected during the survey. The observations reported herein are in conformity with the descriptions provided by Baylis (1939) and Gupta and Sood (1968). The occurrence of P. sexalatus is being reported herein for the first time from Meghalaya.

Family Gnathostomatidae Railliet, 1895

Subfamily Gnathostomatinae (Railliet, 1895) Baylis et Lane, 1920

Genus Gnathostoma Owen, 1836

Gnathostoma doloresi Tubangui, 1925

(Plates 142, 143)

The collection comprised only two male and four female specimens of this species. The worms were found sticking with their forebodies into the gastric wall of the host.

Description

General

Body stout, cuticle of posterior two-thirds of body considerably inflated whereby anterior third appearing relatively slender. Pair of blunt cervical papillae present. Lips large, trilobed, having cuticle of their inner surfaces thickened and raised into longitudinal tooth-like ridges interlocking with those of opposite lip. Globular cephalic bulb present following lips; latter separated from body, armed with eight to nine rows of backwardly directed spines (all

PLATE 1.42 *Gnathostoma doloresi*

Fig.1 Anterior end, showing posteriorly directed cuticular spines

Fig.2 Posterior end of male, showing spicules and caudal papillae

Fig.3 Vulvar opening in female

Fig.4 Caudal extremity of female

Fig.5 Egg

PLATE-1·42

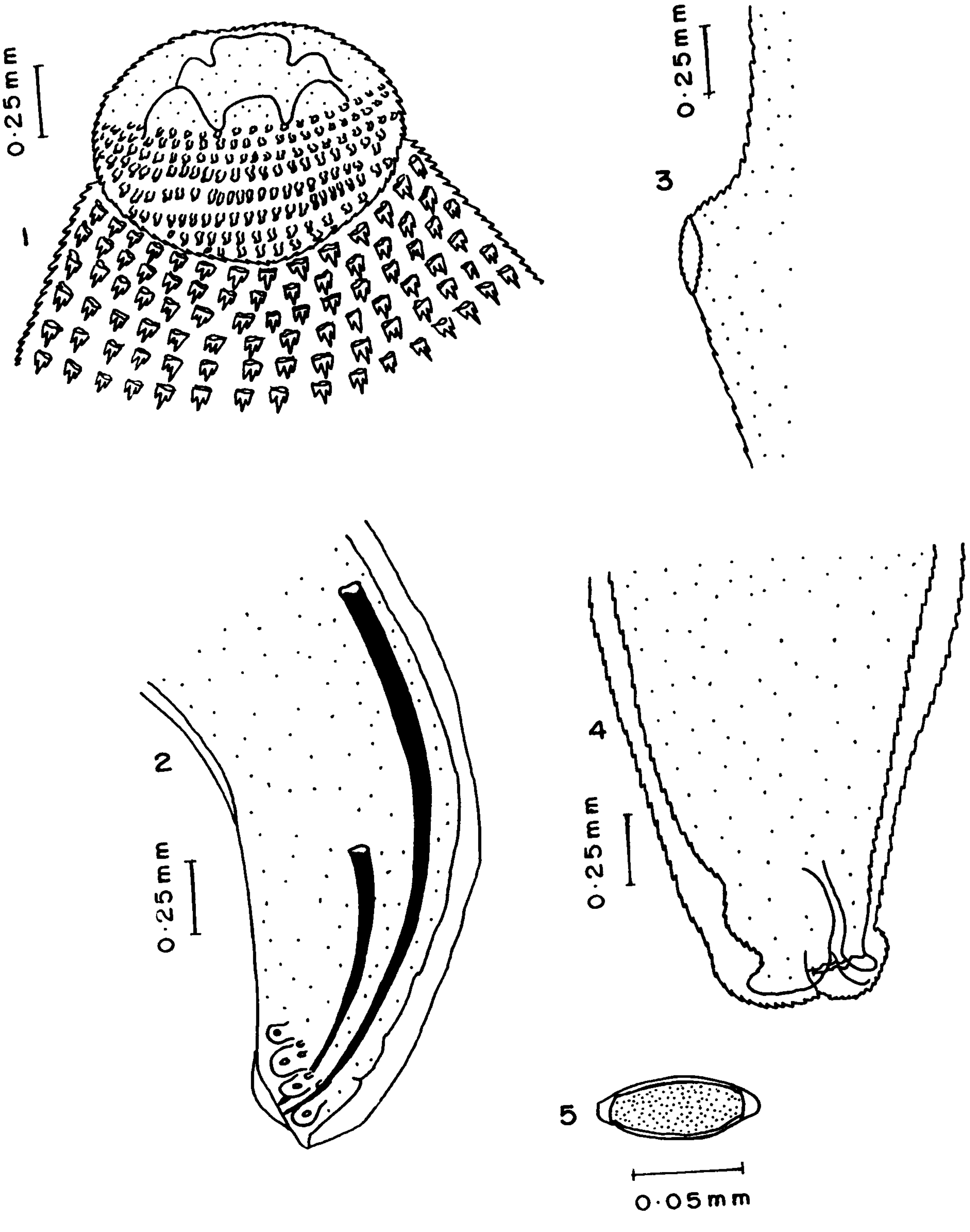


PLATE 1.43 *Gnathostoma doloresi* (Photomicrographs)

Fig.1 Anterior end, showing cephalic bulb armed with backwardly directed transverse rows of cuticular spines (scale bar = 0.3 mm)

Fig.2 *En face* view, showing large trilobed pseudolabia (scale bar = 0.3 mm)

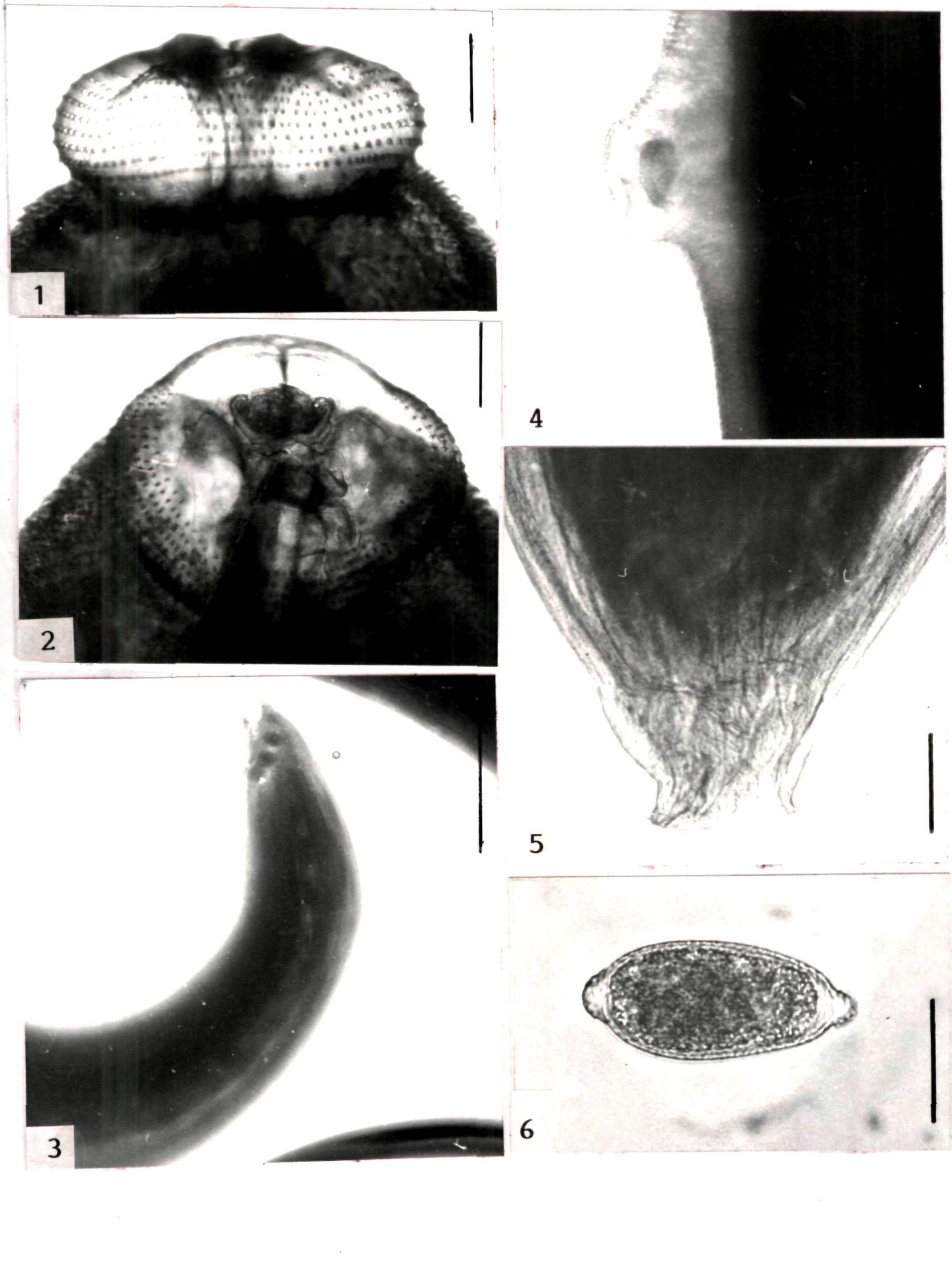
Fig.3 Posterior end of male (scale bar = 0.15 mm)

Fig.4 Vulvar region of female (scalr bar = 0.3 mm)

Fig.5 Caudal end of female, showing opening of anus (scale bar = 0.3mm)

Fig.6 Characteristic bipolar egg (scale bar = 0.03 mm)

PLATE 1.43



rows not evident in one view). Entire surface of body provided with numerous transverse rows of backwardly directed cuticular spines; latter in anterior rows broad, short, with several unequal teeth; posteriorly spines slender, each bearing three sharp teeth - middle tooth conspicuously longer than lateral two; succeedingly, spines becoming gradually smaller, with two teeth each; posterior two-thirds of body densely covered with single-pointed spines, which becomes smaller posteriorly.

Male

Tail with papillae like termination. Cuticle of caudal end much inflated dorsally and ventrally. Four pairs of large stout lateral caudal papillae present; first pair preanal, rest three pairs postanal; between first and second, second and third pairs, from posterior end present two pairs of smaller subventral papillae. Spicules unequal, stout, curved, tapering evenly from root to tip.

Female

Tail blunt, surrounded by large cuticular inflation. Vulva projecting slightly above body surface, opening behind middle of body. Vagina muscular, long, running forward from vulva, extending as far as posterior end of oesophagus, turning posteriorly again. Eggs oval, with wart-like caps at each pole, their surface finely granulated.

The measurements of the body and its organs are given in Table 1.20.

Host	Pig
Location	Gastric mucosa
Locality	Shillong

TABLE 1.20 : Gnathostoma doloresi Tubangui, 1925 : morphometric measurements

Characters		Male Range	Male Mean	Female Range	Female Mean
Body :	length	26.0-28.0	27.0	30.0-44.0	37.0
	width	1.2-2.0	1.6	2.20-4.50	3.05
Head bulb :	length	0.75-0.90	0.82	0.86-1.02	0.94
	width	0.28-0.32	0.30	0.41-0.46	0.44
Oesophagus :	length	2.52-2.55	2.53	5.40-5.99	5.61
Cervical papillae§		0.75-0.82	0.79	0.86-1.18	1.04
Cervical sacs:	length	1.47-1.51	1.49	1.65-1.80	1.74
Spicules :	length(L)	1.71-1.76	1.73	-	-
	(R)	0.43-0.50	0.46	-	-
Tail :	length	-	-	0.36-0.39	0.37
Vulva*		-	-	12.0-15.0	13.25
Eggs :	length	-	-	0.07-0.08	0.07
	width	-	-	0.03-0.04	0.03

Remarks

This species was originally described by Tubangui (1925) on the basis of female worms collected from domestic pigs in the Philippines. Later on, Maplestone (1930a) provided the description of both sexes from parasites collected from slaughtered pigs in Calcutta.

There are three species of Gnathostoma reported in India : G. spinigerum Owen, 1836 from carnivores and G. hispidum Fedchenko, 1872 and G. doloresi Tubangui, 1925 from domestic pigs (Sus scrofa domestica) (Baylis, 1939). These species are distinguishable from one another by reference to the distribution of body spines and/or the shape of the eggs. While in G. spinigerum only the anterior two-thirds of the body has spination, in the other two species the spines cover the whole body; in G. hispidum the eggs are with wart-like cap only at one pole, and not on both as in G. doloresi. The present description tallies with that of Maplestone (1930a), except for the number of rows of spines on the cephalic bulb; in the original description, 10 rows of spines are mentioned, while 8-9 rows were obsered in the present material.

Meghalaya forms a new locality record for this species.

Family Trichuridae (Ransom, 1911) Railliet, 1915

Subfamily Trichurinae Ransom, 1911

Genus Trichuris Roederer, 1761

Trichuris globulosa (Linstow, 1901) Ransom, 1911

(Syn. Trichocephalus globulosus Linstow, 1901)

(Plates 1.44, 1.45)

The collection comprised several hundred specimens of this species.

PLATE 1.44 *Trichuris globulosa*

Fig.1 Anterior end, showing inflated cuticle at head

Fig.2 Posterior end of male, showing spicule projecting from sheath, globular at its tip (note the size of spines, those on proximal end are smaller as compared to those on distal globular portion)

Fig.3 Posterior end of female, showing opening of anus

Fig.4 Vulvar opening in female

Fig.5 Egg

PLATE-1·44

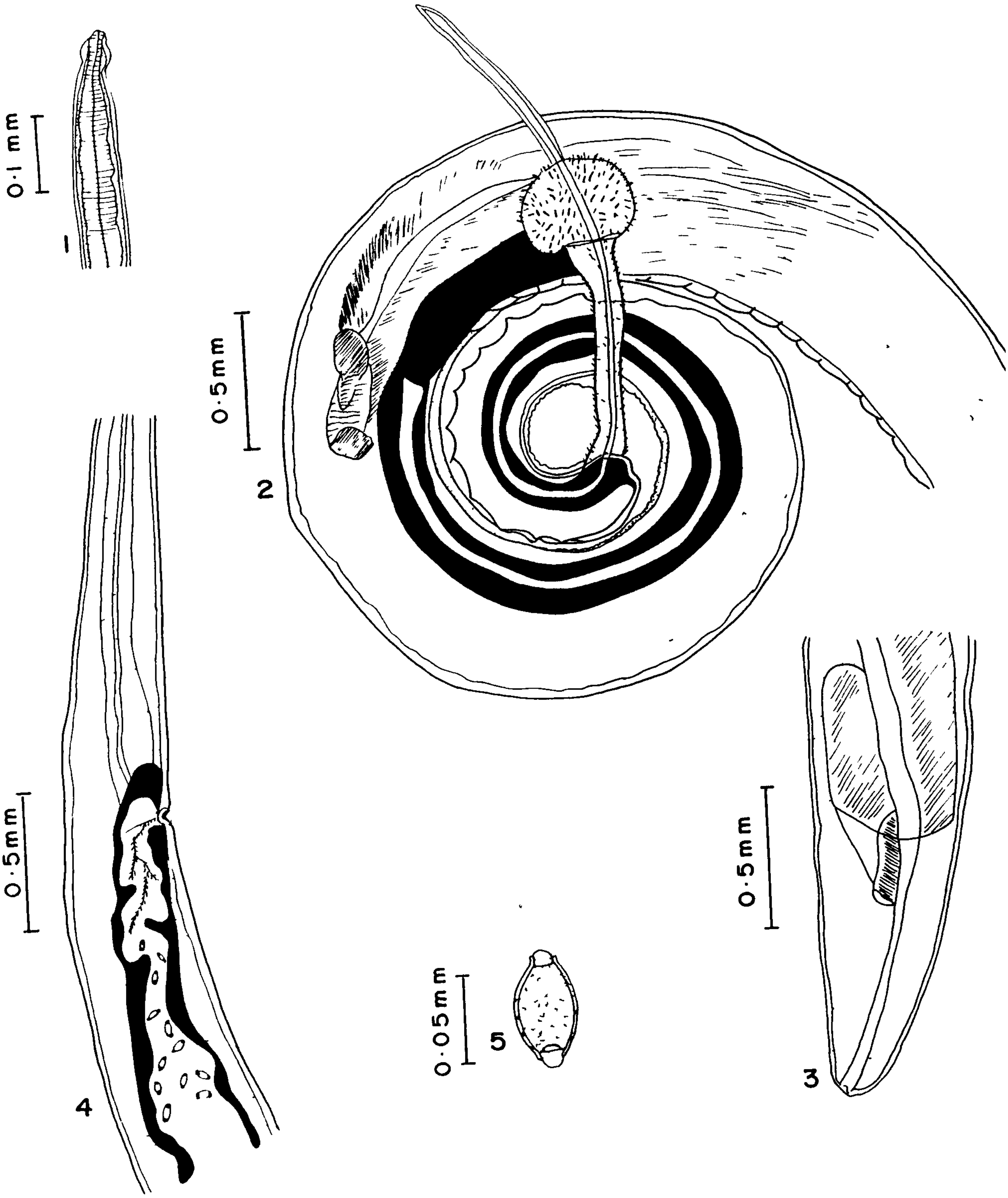


PLATE 1.45 Trichuris globulosa (Photomicrographs)

Fig.1 Anterior end with inflated cuticle at head (scale bar = 0.2 mm)

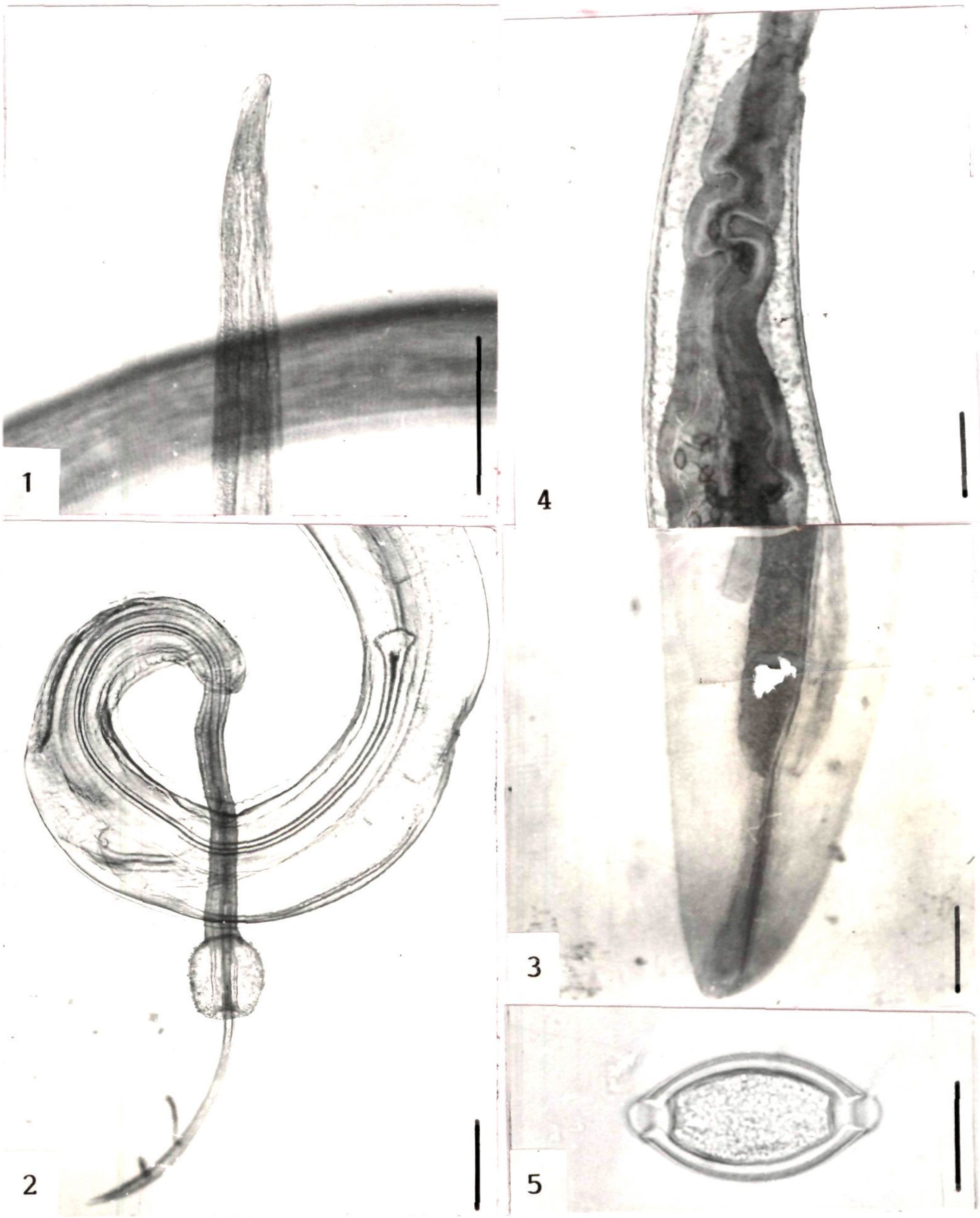
Fig.2 Posterior end of male, showing globular expansion of spicule sheath (scale bar = 0.3 mm)

Fig.3 Vulvar region in female (scale bar = 0.3 mm)

Fig.4 Posterior end of female (scale bar = 0.3 mm)

Fig.5 Characteristic bipolar egg (scale bar = 0.03 mm)

PLATE 1.45



Description

General

Body with slender anterior oesophageal portion constituting about two-thirds to three-quarters of its length, markedly thickened short posterior portion containing reproductive organs. Mouth simple, without definite lips. Cuticle slightly inflated to give tiny vesicle -like structures one on either side of head. Ventral longitudinal bacillary band present in oesophageal region, composed of numerous unicellular subcuticular glands with rod-like processes projecting through cuticle.

Male

Proximal end pointed, hind end spirally coiled, bearing single expanded spicule. Latter with broad proximal end, spicule sheath when fully everted bearing globular expansion at distal end, whole sheath covered with closely set spines; latter on distal expansion longer than these on remaining portion. Cloacal wall thick, muscular anterior to point of entry of spicule, thinner posterior to it.

Female

Posterior extremity bluntly rounded. Anus terminal. Vulva prominent, lying at junction of anterior slender and posterior stout portions. Vagina relatively short, stout, muscular; lumen of its distal portion lined with large spines, thrown into 4 sharp angular bands; portion of vagina immediately behind this region forming ventrally concave narrow duct which extends suddenly into large eggs reservoir with folded cuticular lining. Eggs with thick brown cells, barrel shaped, with transparent plug at either pole.

The measurements of the body and its organs are given in Table 1.21.

TABLE 1.21 : *Trichuris globulosa* (Linstow, 1901) Ransom, 1911 : morphometric measurements

Characters		Male Range	Male Mean	Female Range	Female Mean
Body :	length	58.0-72.0	63.8	60.0-78.0	66.0
	width (P)	0.68-0.86	0.72	0.63-1.0	0.76
Head :	diameter	0.01-0.02	0.01	0.01-0.02	0.018
Spicules :	length	3.34-4.66	3.74	-	-
	width (A)	23.0-28.0	23.46	-	-
	(M)	32.0-55.0	43.70	-	-
	(P)	0.83-110.0	97.5	-	-
Spicule sheath :	length	0.72-0.90	0.83	-	-
	width	0.09-0.12	0.10	-	-
Globular expansion :	length	0.21-0.48	0.29		
	width	0.32-0.46	0.36		
Vulva*		-	-	12.3-13.2	12.7
Eggs :	length	-	-	0.059-0.069	0.063
	width	-	-	0.027-0.036	0.032

Host Goat, sheep

Location Caecum

Locality Shillong, Nongstoin, Jowai

Remarks

Trichuris globulosa originally described from dromedary, has been reported from cattle, sheep, goats, and in European elk. According to Baylis (1939) the specimens named Trichocephalus alcocki by Linstow (1906) from a thameng (Cervus eldi) in the Zoological Gardens, Calcutta, belonged partly to this species.

The cuticle near the head end was found to be slightly inflated - a feature not mentioned by Baylis (1939). The rest of the present observations are in agreement with those of the latter author.

This species is being reported for the first time from Meghalaya.

Trichuris ovis (Abildgaard, 1795) Smith, 1908
(Syn. Trichocephalus ovis Abildgaard, 1795)
(Plates 146, 147)

The collection comprised many specimens of this species.

Description

General

In general appearance and most of the body characters T. ovis closely resembles T. globulosa.

Male

Posterior end bearing single spicule, latter slightly proximally expanded, pointed at distal end; spicule sheath bearing slightly stretched globular expansion at its distal end; sheath covered with closely set spines, those on distal expansion of sheath larger than the rest.

PLATE 1.46 Trichuris ovis

Fig.1 Anterior end

Fig.2 Posterior end of male, showing spicule and sheath

Fig.3 Vulvar opening in female

Fig.4 Posterior end of female, showing opening of anus

Fig.5 Egg

PLATE-1·46

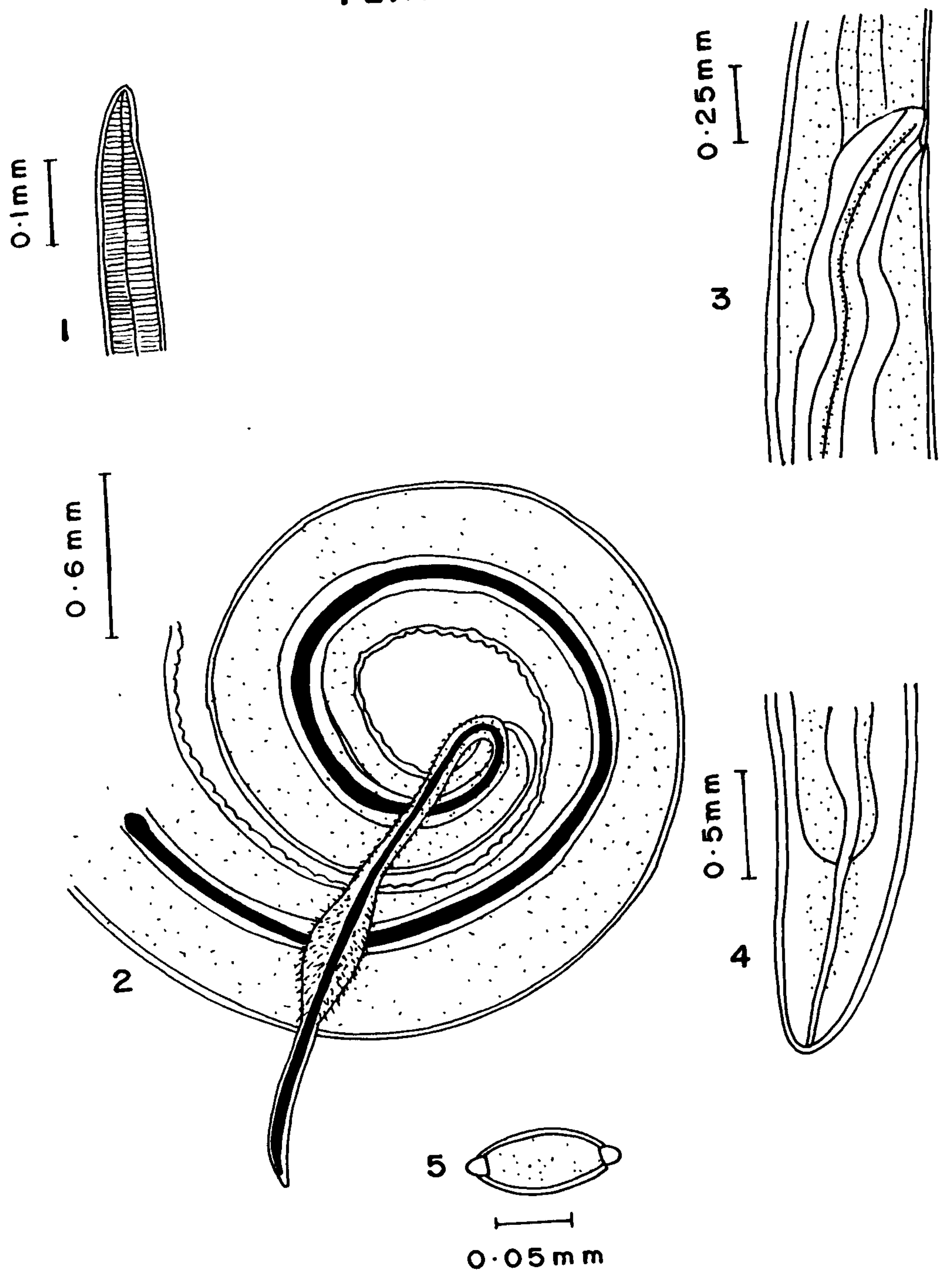


PLATE 1.47 Trichuris ovis (Photomicrographs)

Fig.1 Anterior end (scale bar = 0.2 mm)

Fig.2 Posterior end of male showing spicules protruding from sheath (scale bar = 0.2mm)

Fig.3 Vulvar region in female (scale bar = 0.2 mm)

Fig.4 Posterior end of female (scale bar = 0.2 mm)

Fig.5 Egg (0.03 mm)

PLATE 1.47

Female

Vulva opening at junction of anterior oesophageal and posterior stout reproductive portions. Vagina long, slender; its lumen widening gradually posteriorly; lumen of distal portion lined with small spines for a little distance. Eggs barrel shaped with polar plugs; latter do not project well beyond the proteinous coat.

The meausrements of the body and its organs are given in Table 1.22.

Host	Goat
Location	Caecum
Locality	Shillong, Nongstoin, Jowai

Remarks

Baylis (1939) differentiated _T. ovis_ and _T. globulosa_ on the basis of the size of the spines on the distal expansion of the everted spicule sheath (those on the distal expansion of the sheath being larger than the rest in _T. globulosa_ and vice versa in _T. ovis_) and by the topography of vagina (long and slender with its lumen widening gradually in _T. ovis_, whereas short and stout with its lumen forming angular bends and opening suddenly into an egg chamber in _T. globulosa_). However, no size difference was observed in the spines of the spicule sheath in the male specimens of _T. ovis_ examined herein. The males of the two species could be differentiated by reference to the shape of the proximal end of the spicules and also of the distal expansion of the everted spicule sheath. Except for above-mentioned minor variations, the present observations tally closely with the previous account provided by Baylis (1939). However, no cuticular inflation was noticed near the head end, as recorded by Gupta and Mathur (1968).

Meghalaya forms a new locality record for this species.

TABLE 1.22 : *Trichuris ovis* (Abildgaard, 1795) Smith, 1908 : morphometric measurements

Characters		Male Range	Male Mean	Female Range	Female Mean
Body :	length	44.0-78.0	66.0	58.0-85.0	74.3
	width (P)	0.50-0.93	0.81	0.72-0.82	0.76
Oesophagus :	length	32.0-60.0	51.8	46.0-56.0	49.9
Head :	diameter	0.01-0.02	0.01	0.01-0.02	0.02
Interstrial distance .		4.60-9.20µ	7.30µ	4.60-9.20µ	6.90µ
Spicules :	length	4.50-6.75	5.48	-	-
	width (M)	0.02-0.03	0.02	-	-
Spicule sheath :	length	0.10-0.12	0.11	-	-
	width	0.03-0.04	0.03	-	-
Vulva*		-	-	12.0-18.0	15.2
Eggs :	length	-	-	0.064-0.073	0.069
	width	-	-	0.032-0.041	0.037

Subfamily Capillarinae Railliet, 1915

Genus Capillaria Zeder, 1800

Capillaria contorta (Creplin, 1839) Travassos, 1915

(Syn. Trichosoma contortum Creplin, 1839; Thominx-contorta (Creplin, 1839) Travassos, 1915)

(Plates 148, 149)

The collection comprised several hundred specimens of this species. The worms were found to be entangled each other in the content of the caecum.

Description

General

Body thread like, long. Mouth very simple. unadorned with bacillary bands. Cuticle striated transversely. Oesophageal portion shorter, only slightly thinner than post-oesophageal portion. Oesophagus gradually increasing in size posteriorly.

Male

Caudal end straight. Anus terminal with thin muscular wall at anterior and posterior to points of entry of spicule. Two prominent inflations present on either side of tip of tail. Spicule long, slender with blunt tip, enveloped in sheath covered with fine hair-like processes.

Female

Posterior end bluntly rounded. Anus opening terminally. Vulva close behind junction of oesophagus and intestine, its anterior lip slightly prominent and protruding outwardly. Ovary, uterus single, both simple in nature; latter

PLATE 1.48 *Capillaria contorta*

Fig.1 Anterior end

Fig.2 Posterior end of male, showing spicule protruding from sheath

Fig.3 Posterior end of female, showing opening of anus

Fig.4 Vulvar opening in female

Fig.5 Egg

PLATE-1·48

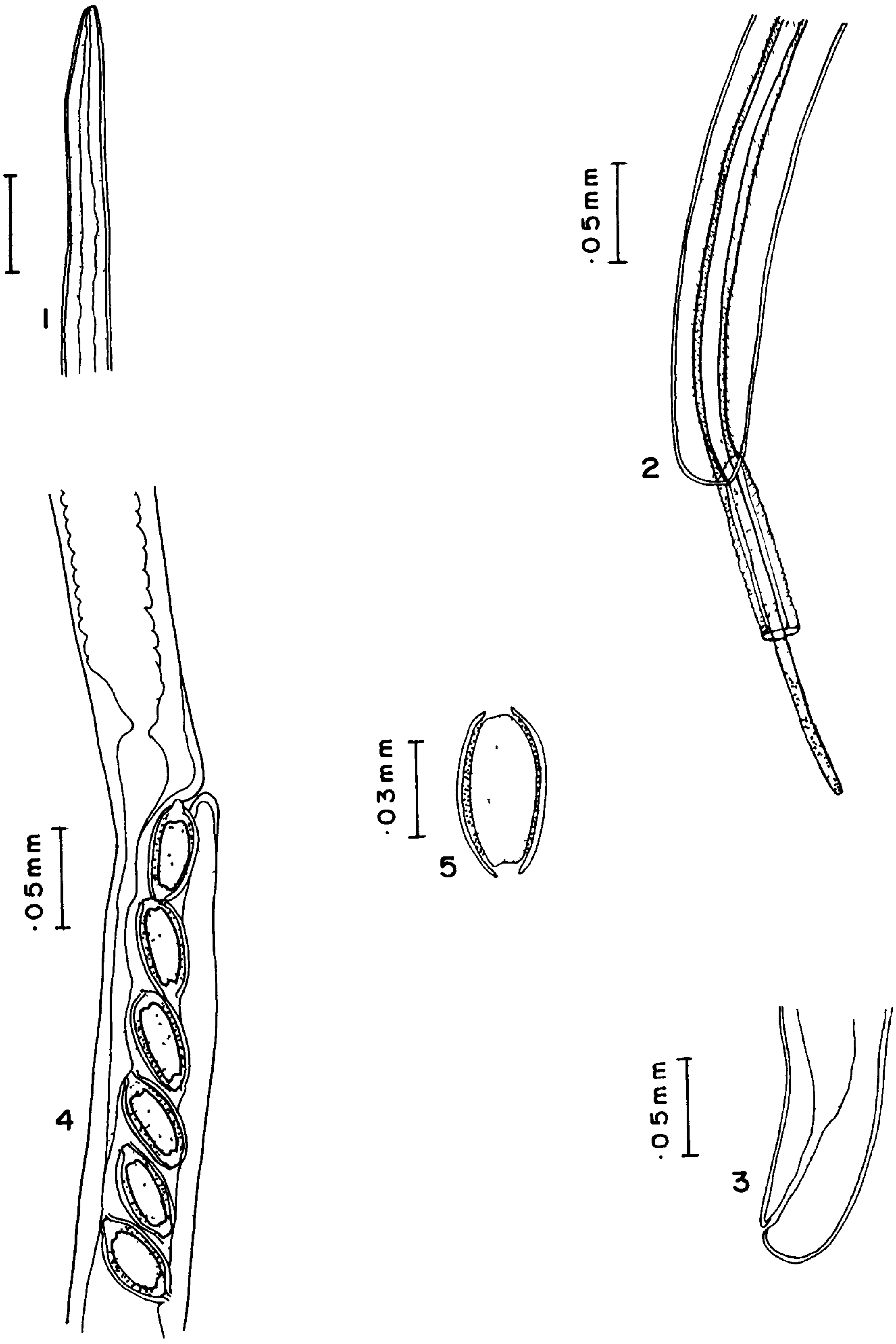


PLATE 1.49 Capillaria contorta (Photomicrographs)

Fig.1 Anterior end (scale bar = 0.2 mm)

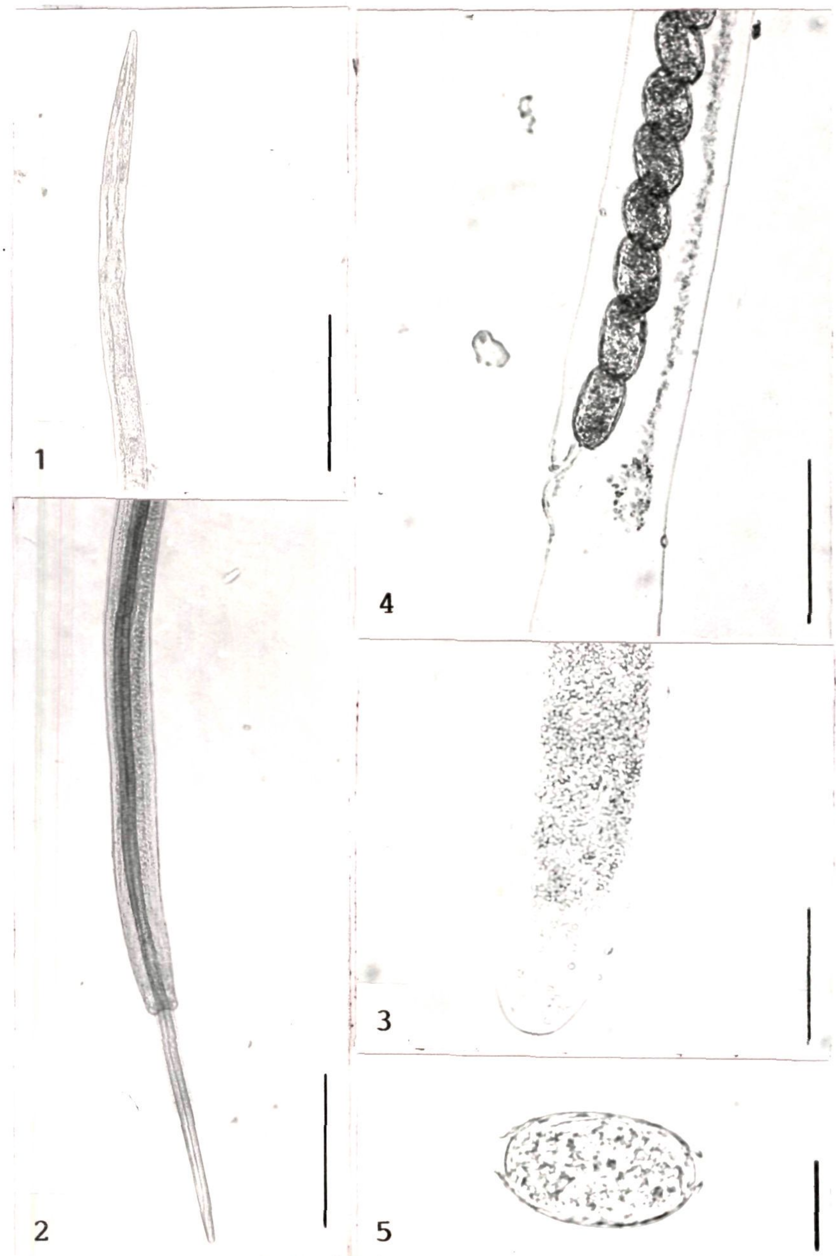
Fig.2 Posterior end of male with spicule protruding from sheath (Scale bar = 0.2 mm)

Fig.3 Posterior end of female, showing opening of anus (scale bar = 0.1 mm)

Fig.4 Vulvar opening in female (scale bar = 0.1 mm)

Fig.5 Egg (scale bar = 0.02 mm)

PLATE 1.49



leading to vagina. Eggs elliptical, smooth shelled.

The measurements of the body and its organs are provided in Table 1.23.

Host Fowl

Location Intestinal caecum

Locality Shillong, Nongstoin, Mairang

Remarks

There is perhaps no other group of nematodes, particularly among those of birds, in which the existing description of the species so inadequate as in Capillaria. This is probably because of the simple organization and thread-like form of the worms which pose a problem in examination and thus inaccurate identification of the species. In most of the body characters C. contorta closely resembles other species of the genus, such as C. annulata and C. columbae, known to occur in the caecum of domestic fowl (Deo, 1964). However, these species could be best separated from one another mainly on the basis of the male reproductive structures; C. contorta possesses a protrusible spicule sheath which is beset with fine hair-like spines throughout its length; C. columbae also possesses a similar spicule sheath but lacks the spines on its surface; in C. annulata the sheath is reported to be lacking the spicule (Wassilkowa and Gouchanskaja, 1930); additionally the cuticle at the anterior extremity forms a characteristic swelling in the latter, which is absent in C. contorta.

In context of India, only C. columbae has been recorded in fowl of Bombay and Uttar Pradesh (Bhalerao and Rao, 1944). This is the first report of the occurrence of Capillaria contorta in domestic fowl of India.

TABLE 1.23 : *Capillaria contorta* (Creplin, 1839) Travassos, 1915 : morphometric measurements

Characters		Male Range	Male Mean	Female Range	Female Mean
Body :	length	8.0-11.2	9.7	18.0-52.0	37.6
	width	0.05-0.06	0.06	0.10-0.14	0.12
Oesophagus :	length	3.3-3.9	3.7	7.4-8.3	7.0
Spicule :	length	0.79-0.90	0.83	-	-
	width	0.013-0.018	0.015	-	-
Spicule sheath :	length	0.16-0.21	0.18	-	-
	width	0.023-0.029	0.025	-	-
Vulva §§		-	-	0.14-0.16	0.15
Eggs :	length	-	-	0.046-0.055	0.050
	width	-	-	0.018-0.023	0.020

The present description tallies closely with that of Travassos (1915), except for some minor variation in the spicule length; in the original description the spicule is mentioned to be 0.8mm long.

CHAPTER II

SURFACE FINE TOPOGRAPHY

INTRODUCTION

In the past several years scanning electron microscopy (SEM) has become a useful tool that has aided in clarifying the fine surface structures of nematode body and has helped taxonomic interpretations (Hirschmann, 1983). A scrutiny of the literature reveals that many morphological characters, which were not identifiable by light microscopy (LM), have been resolved by SEM and have added to the list of useful taxonomic characters, which may provide reliable specific distinctions and phylogenetic clues among related species (Sprent, 1952; Kikuchi, 1975, 1976a,b; Shoho and Uni, 1977; Barus et al., 1981; Malan et al., 1986). In addition, the use of SEM has also been utilized by numerous investigators to assess the arrangement of various structures, particularly pertaining to the sensory and feeding mechanisms of several nematode species, which may provide an insight into their probable functions and role in the microenvironment offered by the host (Ward et al., 1975; Mclaren, 1976; Wright, 1977; Marchiondo and Sawyer, 1978; Singhvi and Johnson, 1989). With regard to the nematodes of medico-veterinary significance many reports are available that provide the details of the microtopographic features of the head and tail regions of various parasitic species (Madden et al., 1970; Sprent et al., 1973; Wiese, 1973; Ansel et al., 1974; Setasuban, 1974; Kikuchi et al., 1974a,b,c; Yoshida et al., 1974a,b; Uni and Takada 1975; Madden and Tromba 1976; Wang and Fujita, 1976; Kikuchi and Oshima, 1977; Wong and Brummer, 1978). During the past decade studies related to nematode parasites of vertebrates hosts include those of Barus et al. (1979a,b), Kikuchi et al. (1979), Rahman and Waddell (1979), Tiekotter (1981), Uni and Takada (1981), Kazacos and Turek (1982), Gibbons and Khalil (1983a,b), Blanchard et al. (1985), Malan et al. (1986) and Snyder (1989). Recently Gibbons (1986) provided a comprehensive account of SEM of about one hundred forty species including representatives of each of the superfamilies of nematode parasites of vertebrates.

In the present investigation, while a few species of nematodes have been studied by SEM for the first time, the description has been supplemented in the case of others. In view of their significance in systematic nematology, the surface fine features, particularly of the anterior and posterior extremities, in both sexes are described and illustrated.

MATERIALS AND METHODS

The nematode species studied by SEM in the present study include Setaria digitata recovered from the peritoneal cavity of cattle; Ascaris suum, Bourgelatia diducta, Globocephalus connorfilii, and Ascarops dentata from the small intestine, Gnathostoma doloresi and Stephanurus dentatus from the gastric and ureter wall, respectively of pig; and Oesophagostomum aspersum and O. columbianum from the small and large intestine, respectively, of goat.

Live worms were collected from freshly slaughtered hosts in 0.9% physiological saline, washed several times with additional changes of the same solution and finally in 10% acetic acid in order to remove any mucus or host debris. They were then killed in warm water at 50-60°C. The whole worms or in the case of big sized specimens 5-10mm long cut pieces of their cephalic and caudal ends and also of the middle portions of the body, were fixed in 2% buffered neutral formalin (pH 7.0-7.2) for 24 hr washed several times in phosphate buffer (pH 7.0-7.2) and stored in the same buffer at 4°C (changing the buffer at 7-10 days interval) till further processing. Before final processing for SEM, the specimens were washed several additional times in the buffer and dehydrated in graded series of acetone with two changes of 15 min in each, followed by a change of dry acetone at 30 min. In lieu of the critical point drying technique the acetone-dried specimens were treated with Tetramethylsilane (TMS), - an organo-silicon compound having a low surface tension (10.2 dynes/µ m at 20°C) and low boiling point (26.3°C) (obtained through Alfa Products, USA) as described by Dey et al. (1989). The TMS solution was added to the dehydrating tubes, immediately after removing the dry acetone. The tubes were left covered with a screw cap for 10 min at 4-6°C and then placed without the cap in an oven at 24°C or at room temperature till liquid evaporation. The specimens were mounted and positioned on the stubs, coated with a thin layer of gold in a Fine Coat Ion Sputter JFC-1100 and observed under a Jeol-JSM 35 CF Scanning Electron Microscope, operating at electron accelerating voltages of 10-15 KeV. The important regions were chosen and micrographs were taken on ORWO/Indu 125 ASA B/W 120 roll films. Until otherwise indicated, the observations for each of the species were made on at least 4 specimens of each sex.

OBSERVATIONS

Ascaris suum (Plate 2.1)

The body cuticle is thrown into narrowly placed transverse striations. The mouth possesses three, prominent semicircular lips; one dorsal and two subventrals. The upper and inner surfaces of lips are separated by a single row of dentigerous ridge. The denticles are less conspicuous, smaller and with concave edges.

Male

The tail terminates into a knob. Adjacent to the anus there lies

PLATE 2.1 Scanning electron micrographs of <u>Ascaris suum</u>.

Fig.1 Anterior extremity bearing one dorsal and two ventral lips (scale bar = 10 μm).

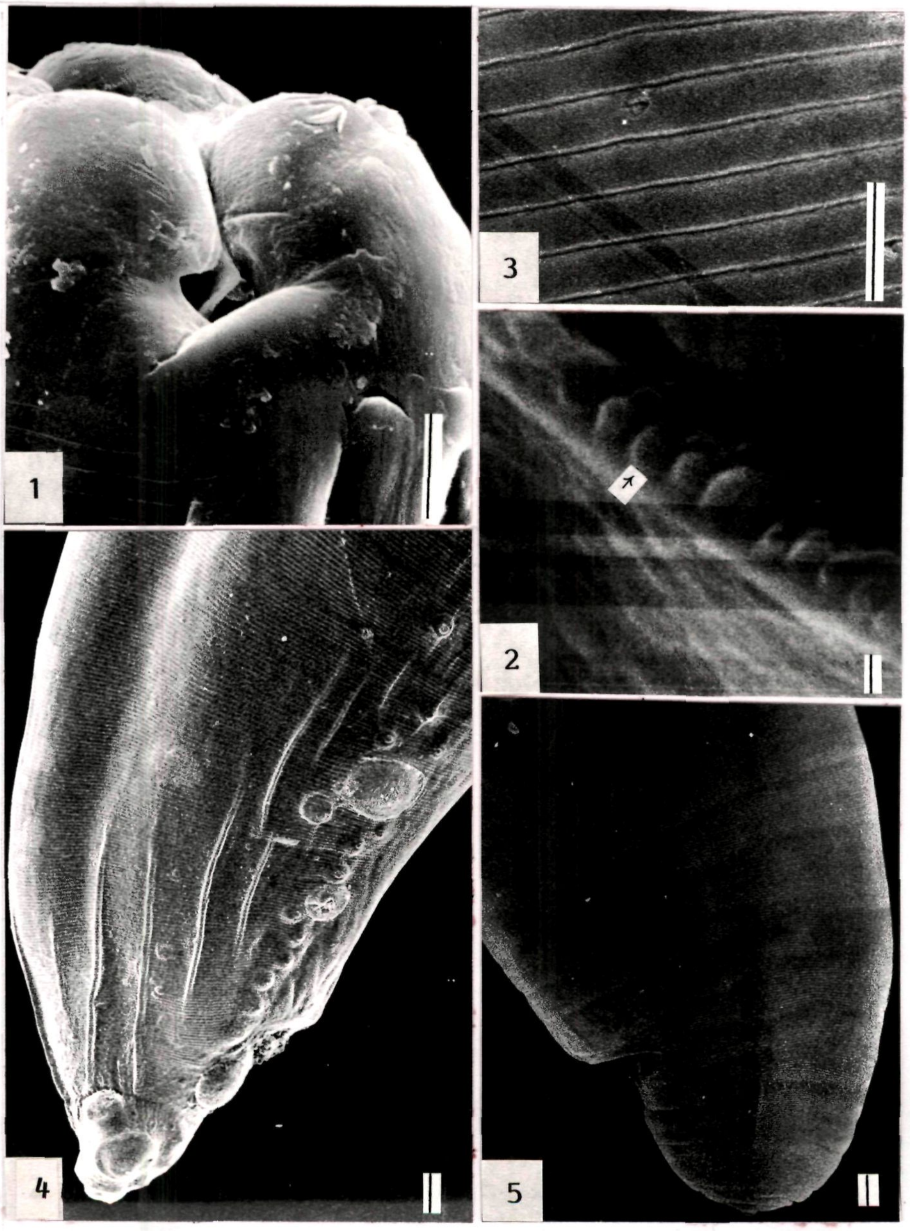
Fig.2 An enlargement of a section of the dentigerous ridge positioned at the outer margin of internal surface of a single lip exhibiting inconspicuous, small and concave edged denticles (arrowed) (scale bar = 1μ m).

Fig.3 Pattern of cuticle at anterior extremity of body (scale bar = 10μ m).

Fig.4 Caudal extremity of male, showing distribution of papillae (scale bar = 100 μm).

Fig.5 Caudal extremity of female showing opening of anus and button-like terminal knob (scale bar = 100μ m).

PLATE 2.1



a row of 5-6 small preanal papillae, preceding which are present one large, circular and two relatively small papillae. In addition there are present many small papillae scattered irregularly and extending towards the anterior extremity of the body. Of the postanal papillae, there occur a large central papilla and an aggregation of 3-4 small papillae very near the tail tip.

Female

The conoid, short tail ends in a button-like knob. The anal opening is slit like and subterminal in position.

Bourgelatia diducta (Plates2.2-2.4)

The anterior end of the worm is broad with a buccal capsule which has a ring of tentaculate structures forming the leaf crown at its rim. The external corona radiata is composed of 21 large, broad and leaf-shaped elements; cephalic papillae situated at the outer periphery of the mouth; these appear as raised cushions of tissue on the body surface. The surface cuticle has almost regularly gapped transverse striations throughout, both on the dorsal as well as the ventral aspects of the body.

Male

The bursa is marked off by notches into long dorsal and slightly shorter lateral lobes. The proconus, an element of the genital cone, appears as a pointed structure with a pair of papillae (not seen clearly in the photographs) near its base; these papillae appear dome shaped with a rugose surface of cuticular folds. The various bursal rays appear as bead projections on the surface; of these the externodorsal and anterolateral are more prominent. The long filiform spicule seen emerging from the bursal lobes is curved at

PLATE 2.2 Scanning electron micrographs of <u>Bourgelatia</u> <u>diducta</u>

Fig.1 Anterior extremity, showing a small caphalic vesicle (between the arrows) restricted to the anterior extremity (scale bar = 10 μm).

Fig.2 Side *en face* view, showing the mouth opening, elements of external corona radiata and a circle of six cephalic papillae (*) (scale bar = 10 μm).

Fig.3 An enlarged view of oral end (scale bar = 10μ m).

Fig.4 Transverse ridges of cuticle (scale bar = 10 μm).

PLATE 2.2

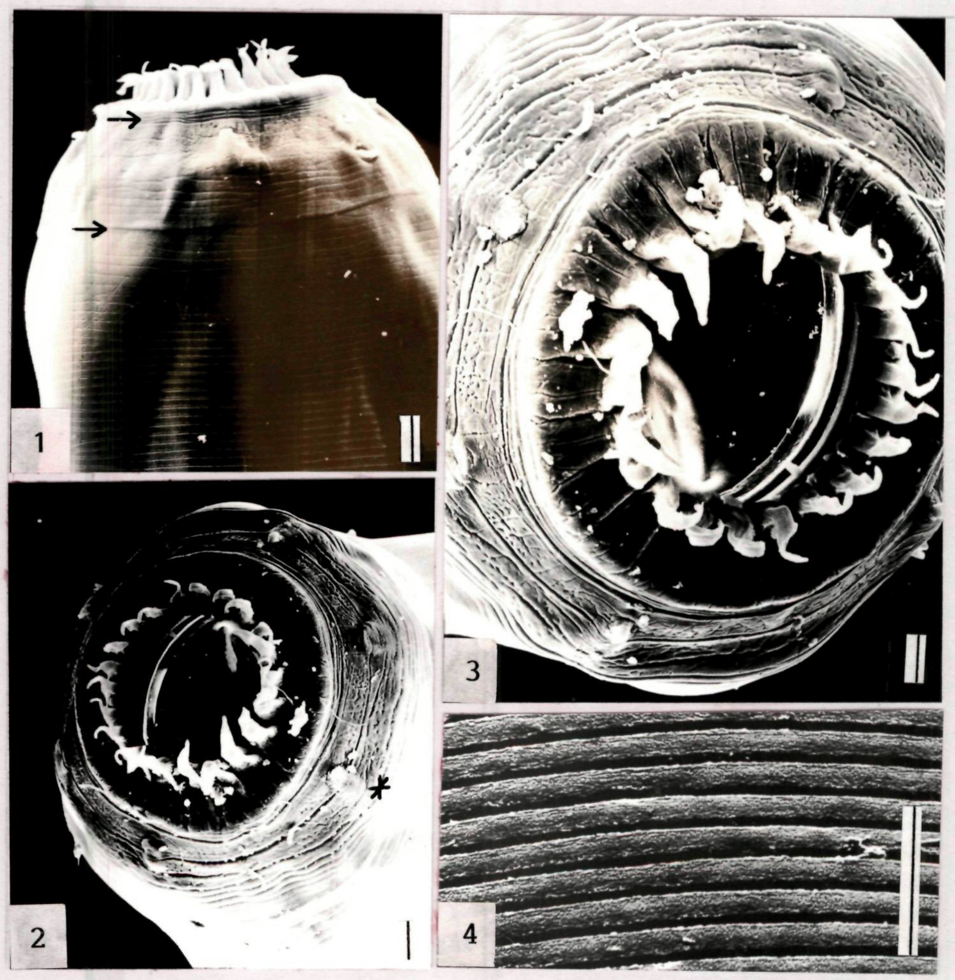


PLATE 2.3 Scanning electron micrographs of *Bourgelatia diducta*

Figs.1-2 Caudal end of male, showing 1. proconus (*) of genital cone and long filiform spicules curved at tips 2. prominent externodorsal (numbered 8) and anterolateral (numbered 4) rays at lateral lobe of bursa (scale bar = 100 μm)

Fig.3 A caudal papilla in an enlarged view (scale bar = 1μ m)

Fig.4 Pattern of cuticle at bursa with serrated margins (scale bar = 10 μ m)

PLATE 2.3

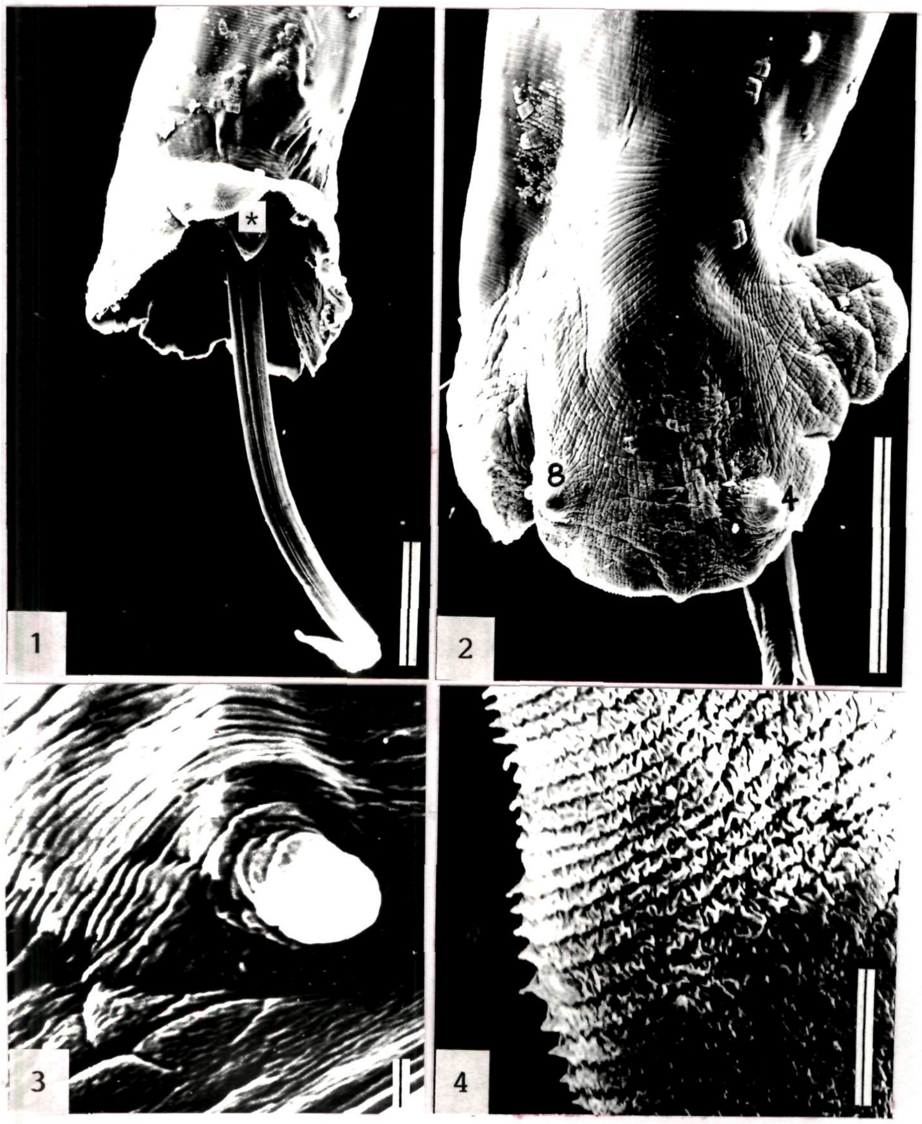


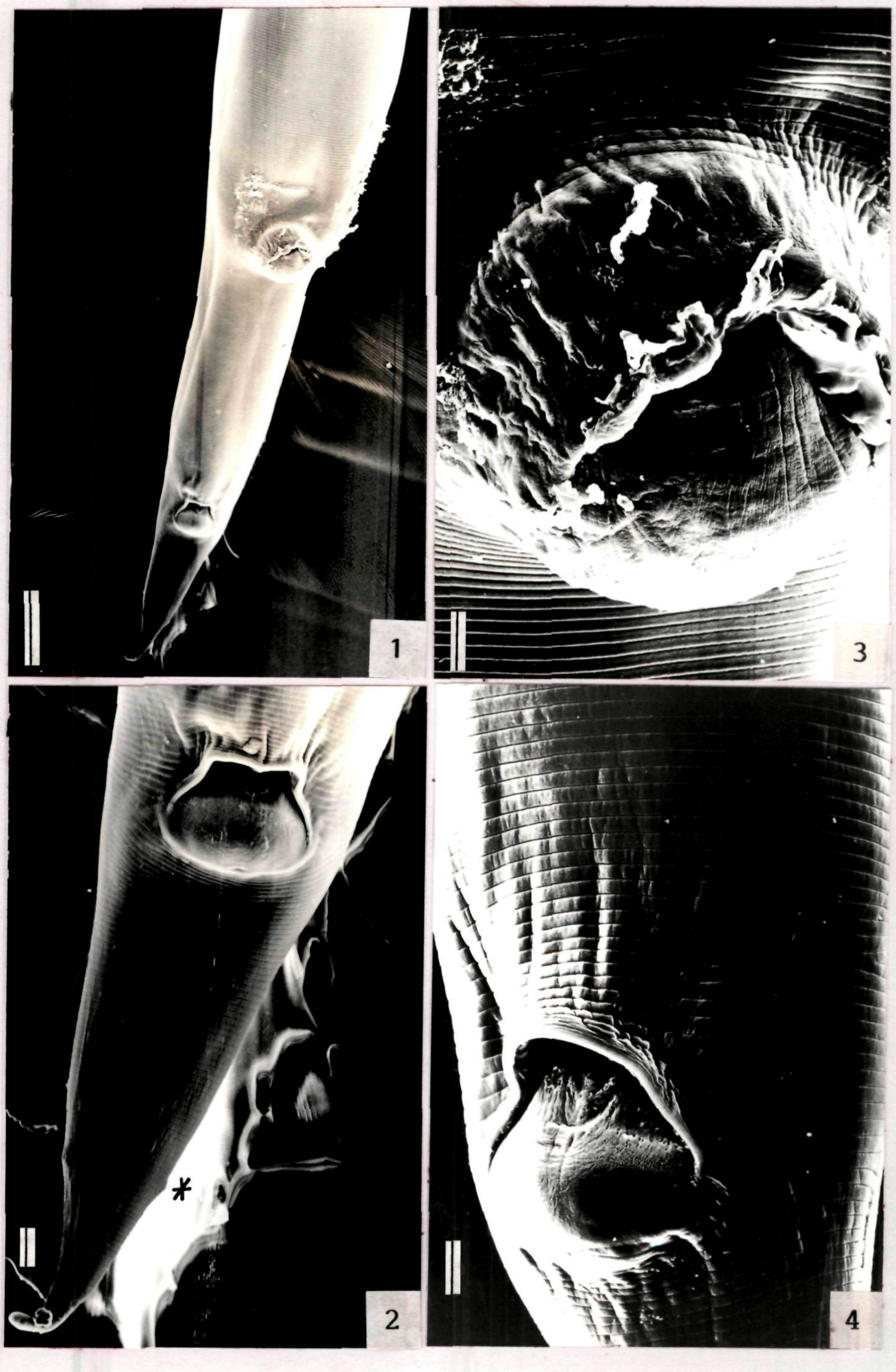
PLATE 2.4 Scanning electron micrographs of <u>Bourgelatia</u> <u>diducta</u> - female

Figs.1-2 Caudal end, showing positions of - 1. vulva and anus (scale bar = 100 μm) 2. a pair of caudal papillae (*) and the phasmidial pores (arrowed) (scale bar = 10μ m)

Fig.3 Vulva as seen in enlarged view (scale bar = 10μ m)

Fig.4 A closer view of anal region (scale bar = 10 μm)

PLATE 2.4



the tips. The cuticle of the bursa exhibits a pattern of fine wrinkles in between the transverse striations and the lateral margins of the body also show a serrated nature.

Female

The short tail gradually tapers to a blunt point and bears a pair of caudal papillae, one on either lateral side, at a little distance from the posterior end. The vulva is prominent, circular opening situated at a little distance in front of the anus, the latter also being a quite prominent semi-circular opening with a thick rim. The phasmidial pores are conspicuous, situated a little in front of the posterior termination of the body.

Oesophagostomum columbianum (Plates 2.5, 2.6)

The anterior end of the worm is bent dorsally in a hook-like manner. The cuticle of the cephalic region is inflated to form a distinct cephalic vesicle. A prominent cervical groove is evident extending around the ventrolateral aspects of the anterior extremity. A pair of cervical papillae (seen feebly in the photographs) is located at the region where cervical groove ends. The cuticular transverse striations are evident throughout the dorsal aspect of the body, whereas the cuticle on the ventral side is smooth. The lateral alae are well developed, originating immediately posterior to the cervical groove and extend for most length of the body forming a marked dorsal curvature which is interrupted at intervals. The mouth collar is in the form of a truncated cone, markedly separated from the rest of the body. A pair of amphids is seen lying one on either lateral side of the mouth cone; these appear as deep circular pits. Long and prominent cephalic papillae, four in number, are arranged peripherally on the mouth cone. The cuticle immediately surrounding the oral

PLATE 2.5 Scanning electron micrographs of _Oesophagostomum columbianum_

Fig.1 Anterior extremity bent dorsally in a hook-like manner, showing lateral ala and a large cephalic vesicle (between arrows) marked behind by cervical groove (scale bar = 100μ m)

Figs.2-4 Cephalic region enlarged 2. in ventral view, showing elements of external corona radiata raised upward 3. in dorsal view showing amphidial opening (arrowed) cephalic papillae (*) on mouth cone 4. in _en face_ view, showing circular oral opening and 20 leaf-shaped elements of external corona radiata (scale bar = 10μ m)

PLATE 2.5

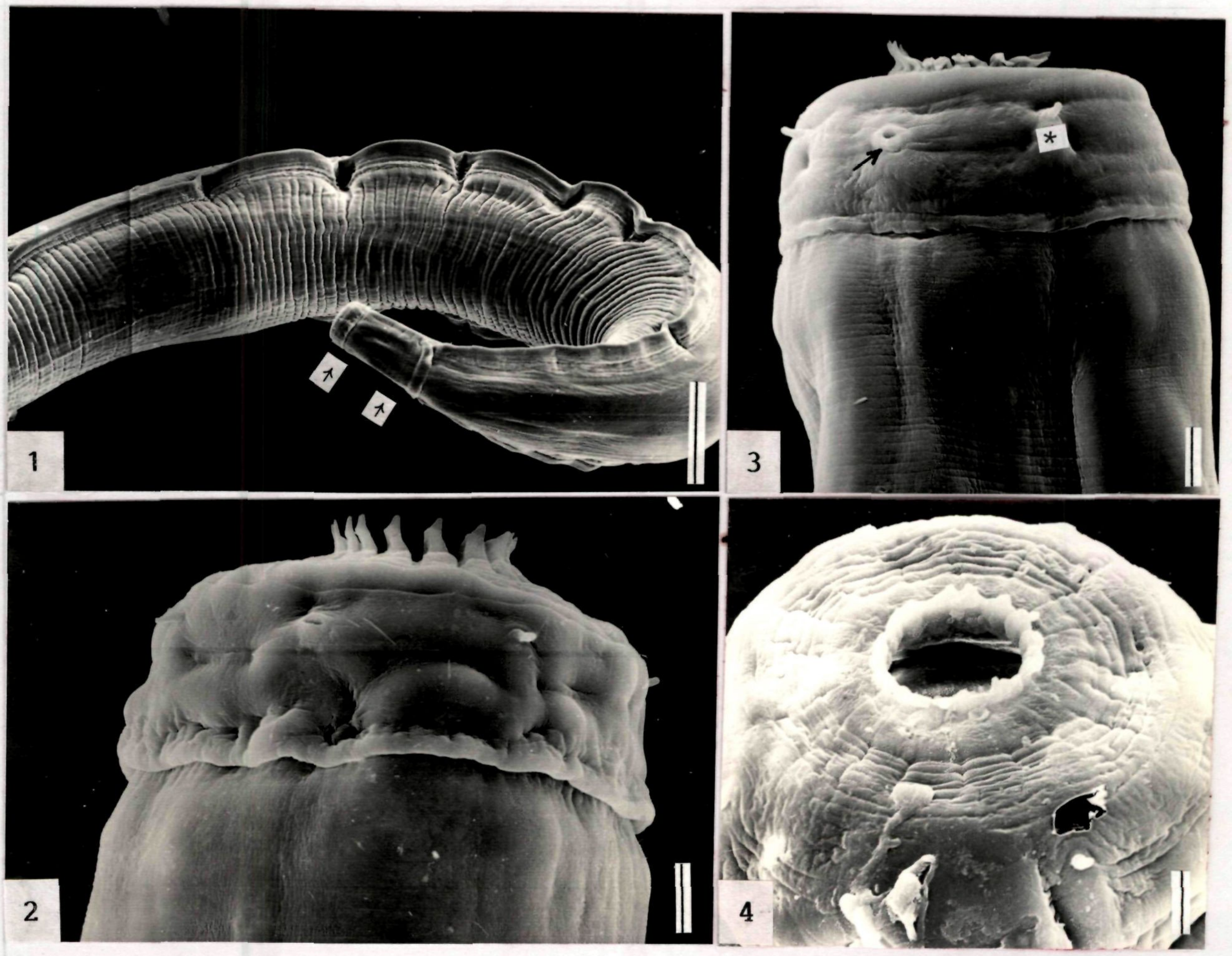
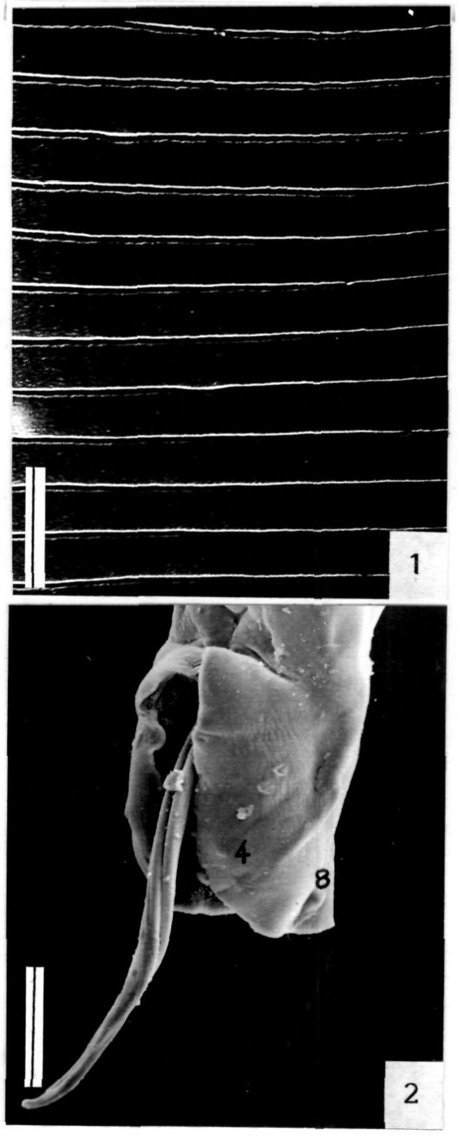


PLATE 2.6 Scanning electron micrographs of Oesophagostomum columbianum

Fig.1 Transverse striations on dorsal aspects of body (scale bar = 10 µm)

Fig.2 Caudal end of male with a bell-shaped bursa, showing externo-dorsal (numbered 8), anterodorsal (numbered 4) rays at lateral lobes and long twisted spicules (scale bar = 100 µm)

PLATE 2.6



aperture has radially extending corrugations and nearing the anterior edges of the mouth collar forms 8-10 regular concentric rings of ridges. The external corona radiata comprises 20 long leaf-shaped elements.

Male

The bursa is bell shaped with two large lateral lobes. The antero-lateral and externodorsal rays are seen bulging on the bursal surface. The spicules are long and twisted upon each other and are seen extending beyond the bursal lobes.

Oesophagostomum aspersum (Plates 2.7-2.9)

The anterior end of the body is somewhat rounded with a cuticular inflation or vesicle that is limited behind by a well defined cervical groove. The mouth-collar is in the form of a truncated cone. Two oval amphidial apertures are visible, one on either lateral side of the cone. There is present one small papilla on either anterolateral aspect and one on the middle of the cephalic vesicle. The cuticle of the anterior region (behind the cephalic vesicle) is thrown into conspicuous ridges forming 2-3 consecutive tiers; however, posteriad these ridges transform into fine annular striations. The oral cavity is circular with its rim having an evenly placed row of projections that form a leaf crown; the external corona radiata consisting of 12 bluntly rounded elements is quite conspicuous. The cephalic papillae are seen situated peripherally on the mouth-cone.

Male

The posterior end of the worm is expanded to form a well-developed bursa copulatrix, with large dorsal and slightly shorter lateral lobes. There is

PLATE 2.7 Scanning electron micrographs of Oesophagostomum aspersum

Figs 1-4 Anterior extremity, showing 1. characteristic cephalic vesicle and amphidial aperture (arrowed) 2. circular oral opening and elements of external corona radiata 3. Cephalic papillae on mouth cone 4. changing pattern of cuticular ridges posteriad (scale bar = 100 μm)

PLATE 2.7

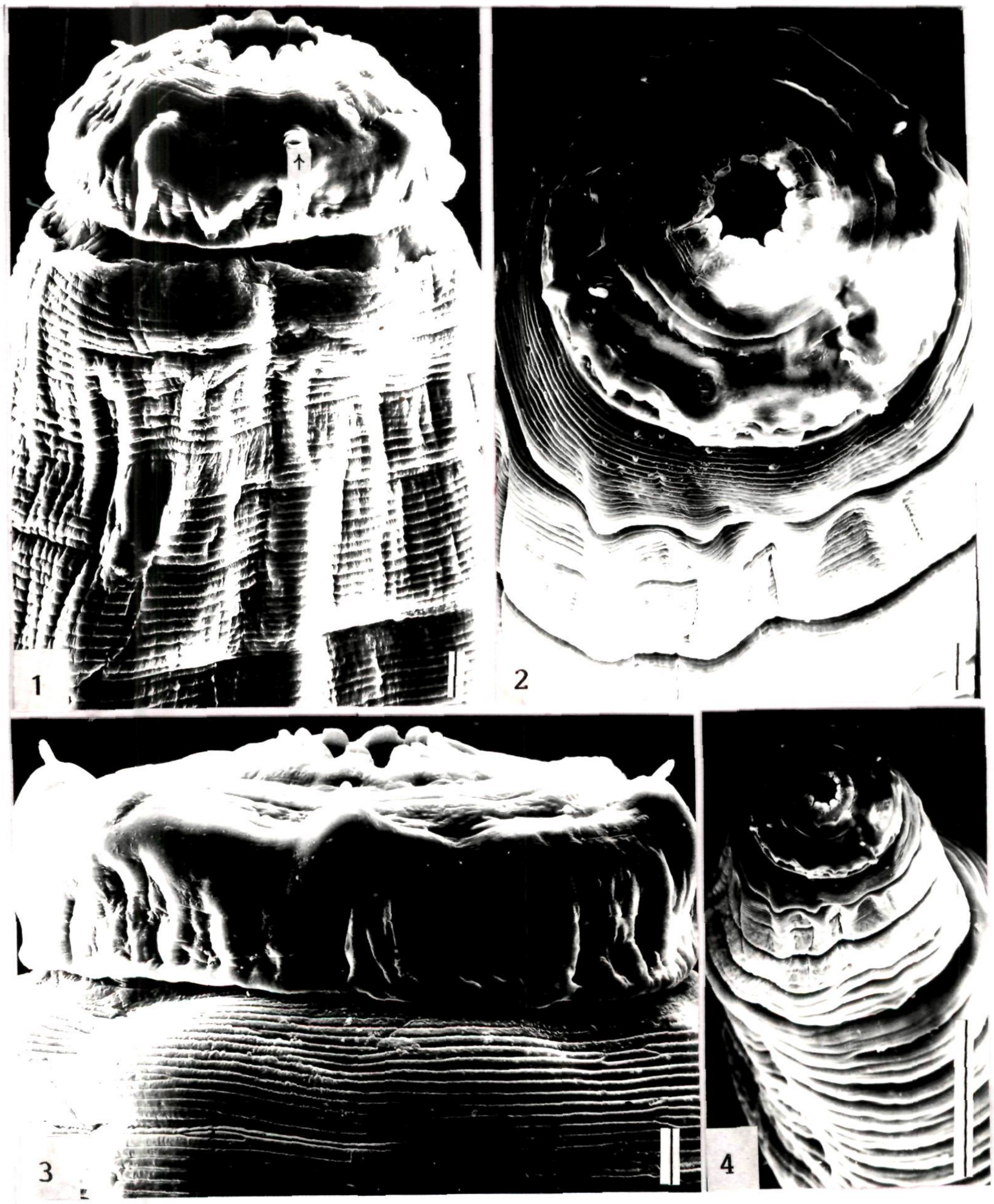


PLATE 2.8 Scanning electron micrographs of Oesophagostomum aspersum

Figs.1-2 Patterns of cuticle at 1. Anterior extremity 2. Middle region of body (scale bar = 10 µm).

Fig.2 Posterior extremity showing position of vulva and short tail with sub-terminal anus (scale bar = 100 µm)

Fig.4 Vulva, in a closer view (scale bar = 10 µm).

PLATE 2.8

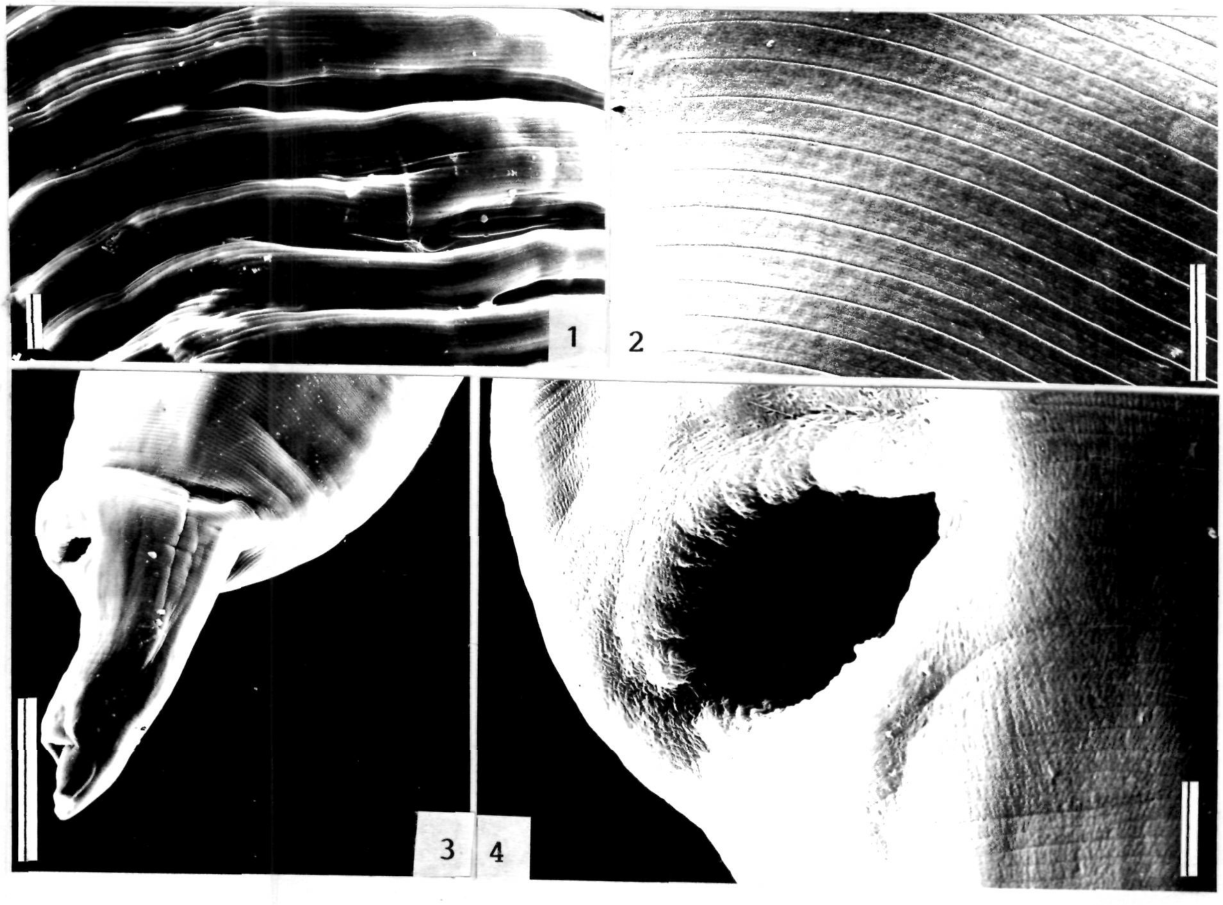


PLATE 2.9 Scanning electron micrographs of Oesophagostomum aspersum - male

Fig.1 Caudal end, showing bursa, a prebursal papilla (numbered 1) and curved distal end of slender pointed spicules (scale bar 100 μm)

Fig.2 Bursa in an enlarged view, showing prominent externodorsal (numbered 8) dorsal (numbered 9) and other bursal rays (arrowed) (Scale bar = 10 μm)

PLATE 2.9

present a pair of small prebursal papillae just in front of the bursal lobes. The bursal rays show their presence as raised bead-like projections on the surface of bursa. The long filiform spicule, seen emerging from the bursal lobes, is curved at the tip.

Female

The tail tapers to a blunt point. An abrupt constriction, a little in front of the posterior extremity, marks off a conical terminal end which lodges the vulva and anal opening. The vulva appears as a simple, somewhat transversly elliptical opening without any cuticular ornamentation in its vicinity. The anus lying relatively close to the posterior tip looks like a triangular opening.

Stephanurus dentatus (Plates 2.10, 2.11)

The hexagonal mouth opening is directed straight forwards with thick cuticular rim. The latter bears a rudimentary corona radiata containing about 80-85 small elements. The cuticle surrounding the mouth is reflected externally into six raised thickenings, of which the dorsal and the ventral are more prominent. Four prominent seta-like cephalic papillae are present in the circumoral region. Emerging from the base of the buccal capsule are visible six tongue-shaped teeth which are both bi- and tri-cuspid types and have uniform edges devoid of any ridges.

Male

The bursa is small and thick walled; the bursal rays are short and stout, and always terminate in rounded, relatively wide tips; the dorsal ray is small and bifurcated into two branches each of which is in turn trifurcated

PLATE 2.10 Scanning electron micrographs of *Stephanurus dentatus*

Fig.1 Anterior extremity, showing reduced elements of corona radiata situated at a thick cuticular rim and seta-like cephalic papillae (arrowed) (scale bar = 10 µm)

Fig.2 Same showing elements of corona radiata more clearly (scale bar = 10 µm)

Fig.3 *En face* view, showing oral opening and teeth inside the buccal cavity; a circle of six thickenings of cuticle, and four cephalic papillae are also visible (scale bar = 10 µm)

Fig.4 Caudal end of male, showing circumcloacal papillae (arrowed) and various bursal rays numbered as dorsal (8,9), posterolateral (6) medio-lateral (5), anterolateral (4), posteroventral (3) and anteroventral (2) (scale bar = 10 µm)

PLATE 2.10

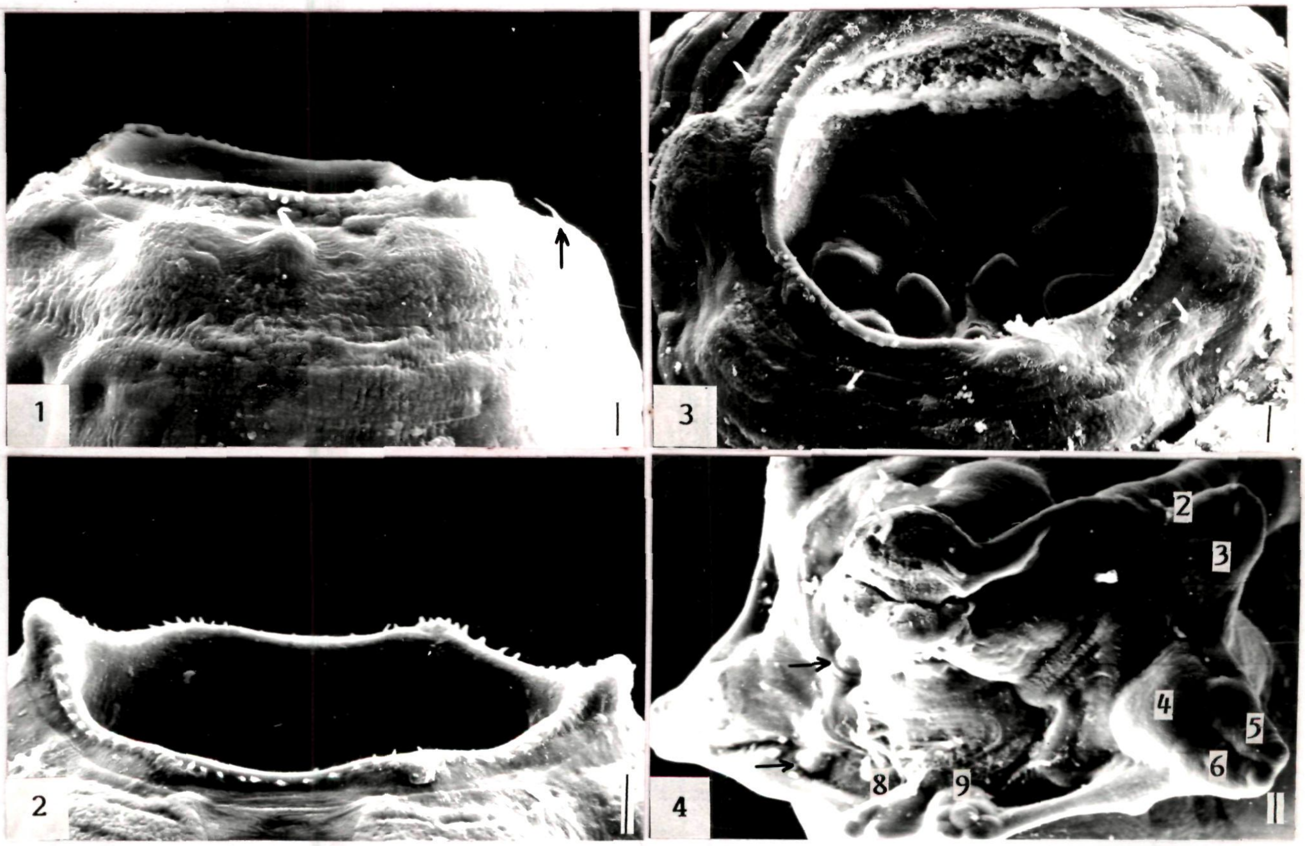


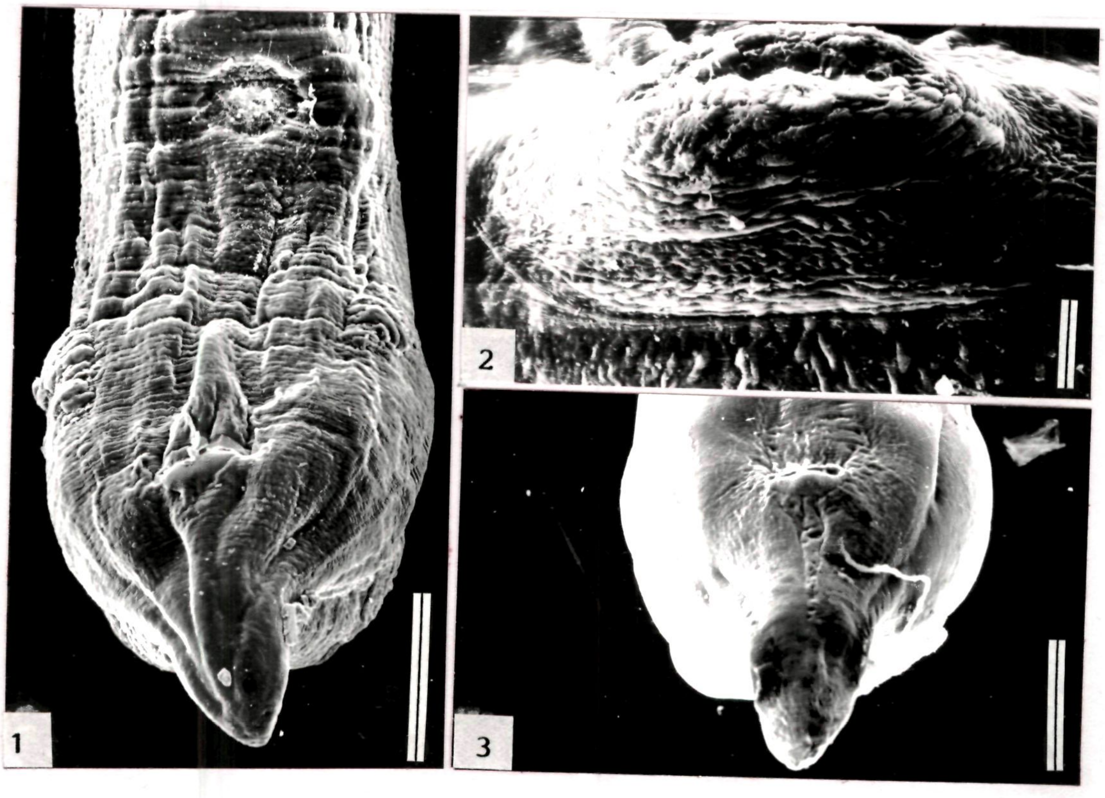
PLATE 2.11 Scanning electron microscopy of *Stephanurus dentatus*

Fig.1 Posterior extremity of female, showing opening of vulva and anus (scale bar = 100µm)

Fig.2 Vulvar region, enlarged to show ornamentation at vicinity (scale bar = 10µm)

Fig.3 Posterior extremity of female, showing the characteristic conical tail (scale bar = 100 µm)

PLATE 2.11



at its tip; the lateral rays are massive, closely applied to one another, the posterolateral being thicker than the other two; the ventral rays are also applied to each other and are of same size. The cloacal aperture appears as slit like, situated subventrally between the lateral processes of the bursa. There are present two pairs of circumcloacal papillae (papillae of right side are not clearly seen in the photographs), each with a rounded, slightly protruding tip. The spicules are swollen distally bearing a minute pore-like opening at their tip.

Female

The posterior extremity is bent ventrally. The tail is conical, bearing a circular opening of the anus quite close to the tip. The vulva is situated a little in front of the anus, with cuticular ornamentation surrounding it.

Globocephalus connorfilii (Plates 2.12-2.14)

The anterior end of the worm is bent dorsally with a small circular oral cavity. Along the whole length of the body the cuticle is transversely striated with almost an equal interstrial distance throughout. A prominent verruciform cervical papilla is situated on either side of the body some distance away from the posterior tip.

Male

The bursa is formed by a small dorsal and two large lateral lobes, and possesses genital cone inside. The cuticle of the bursal region has a finely corrugated appearance. A pair of prebursal papillae is markedly observed in front of the bursal lobes; these appear somewhat elliptical in shape. The externodorsal ray appears as a papilla-like elevation at the edge of the lateral lobe.

PLATE 2.12 Scanning electron micrographs of Globocephalus connorfilii

Fig.1 Anterior extremity, bent dorsally showing circular oral opening (scale bar = 100 μm)

Fig.2 Same in ventral view, showing a pair of verruciform cervical papilla (scale bar = 10 μm)

Fig.3 Somatic region, showing large cervical papillae extending over surface and cuticular striae (scale bar = 100 μm)

Fig.4 Transverse striae of cuticle, in magnified view (scale bar = 10 μm)

PLATE 2.12

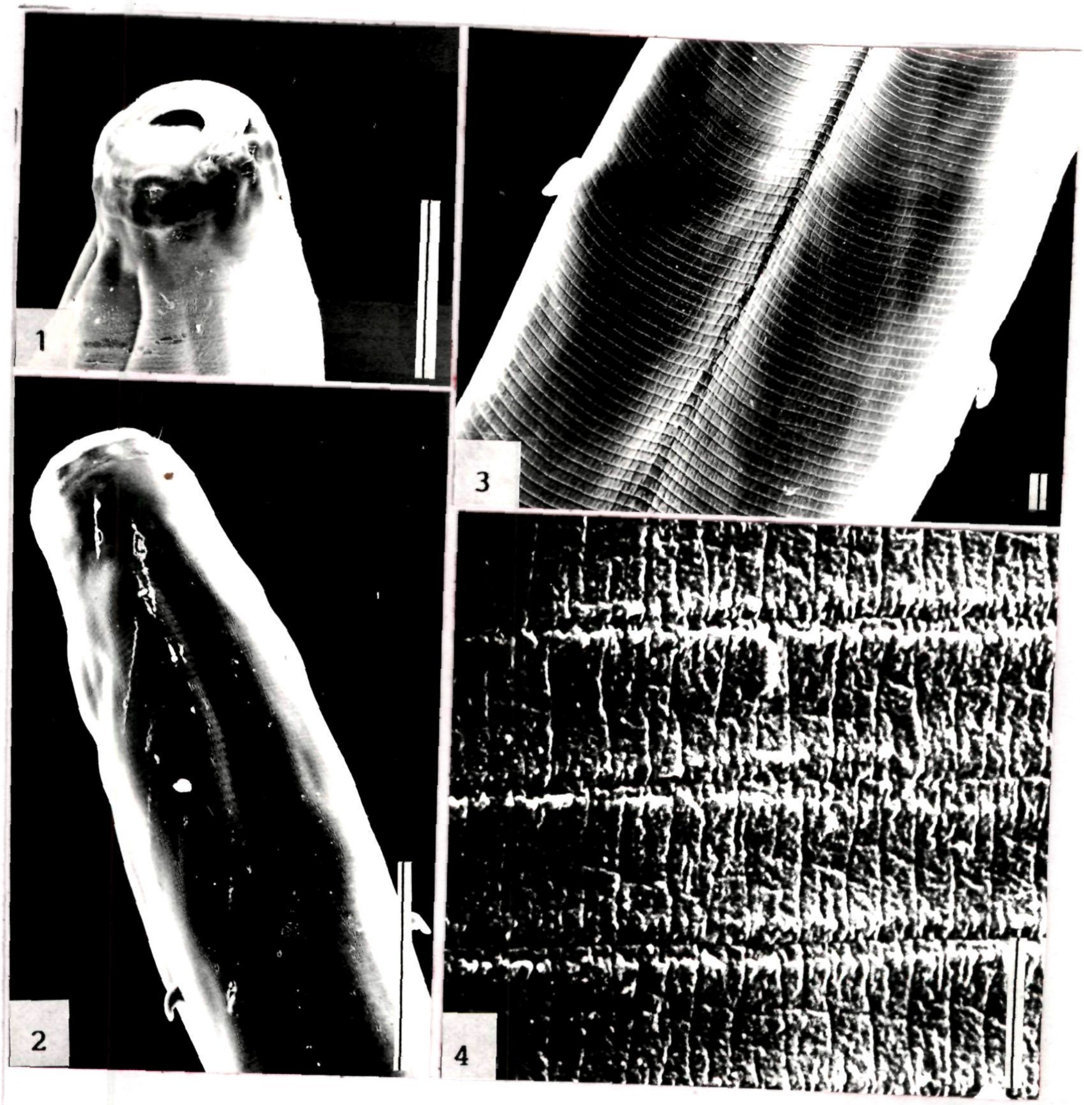


PLATE 2.13 Scanning electron micrographs of _Globocephalus connorfilii_

Fig.1 Caudal end of male, showing bursa and a pair of prebursal papillae (numbered 1) (scale bar = 10 µm)

Fig.2 The same enlarged, showing genital cone (scale bar = 10 µm)

Fig.3 A prebursal papilla in a closer view (scale bar = 1 µm)

Fig.4 Cuticular pattern of bursa (scale bar = 10 µm)

PLATE 2.13

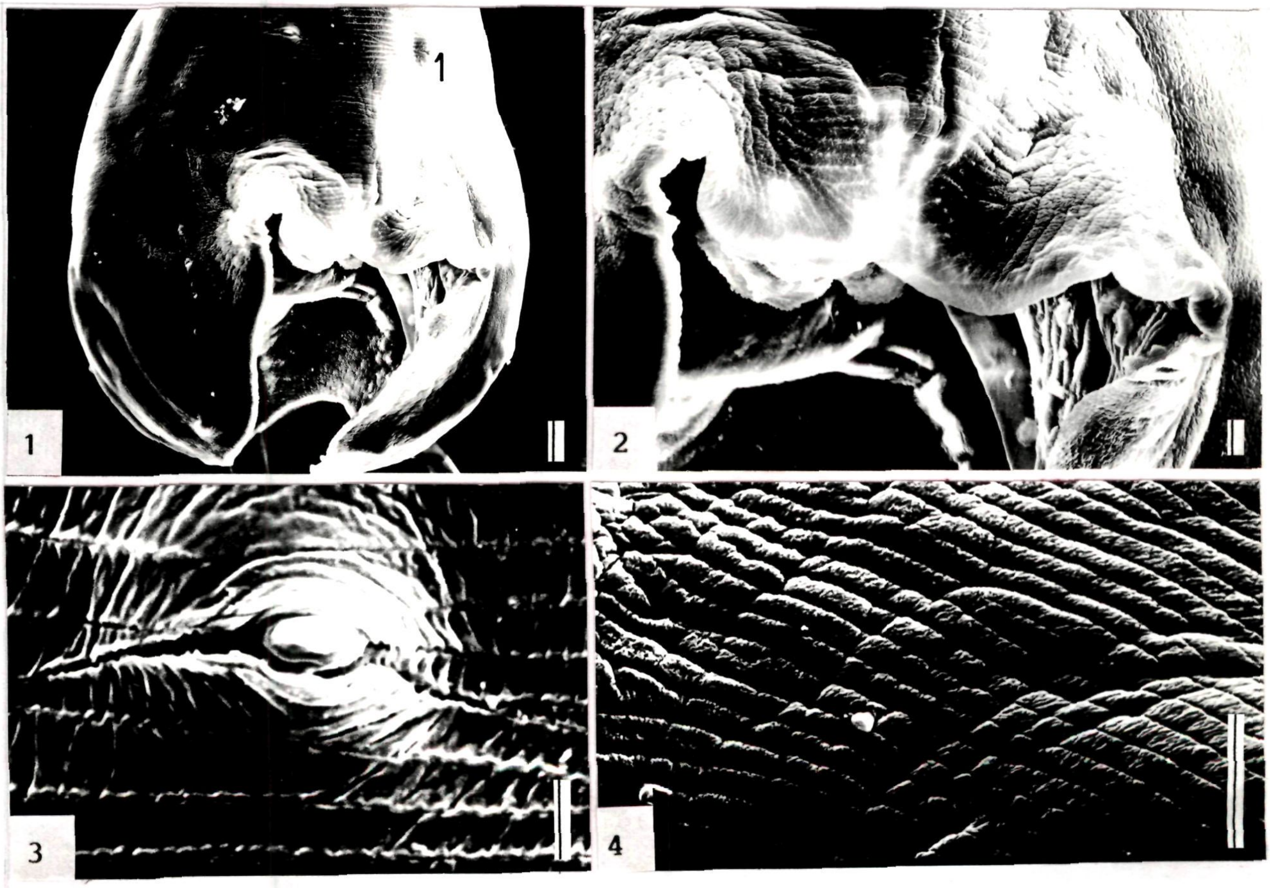


PLATE 2.14 Scanning electron micrographs of Globocephalus connorfilii

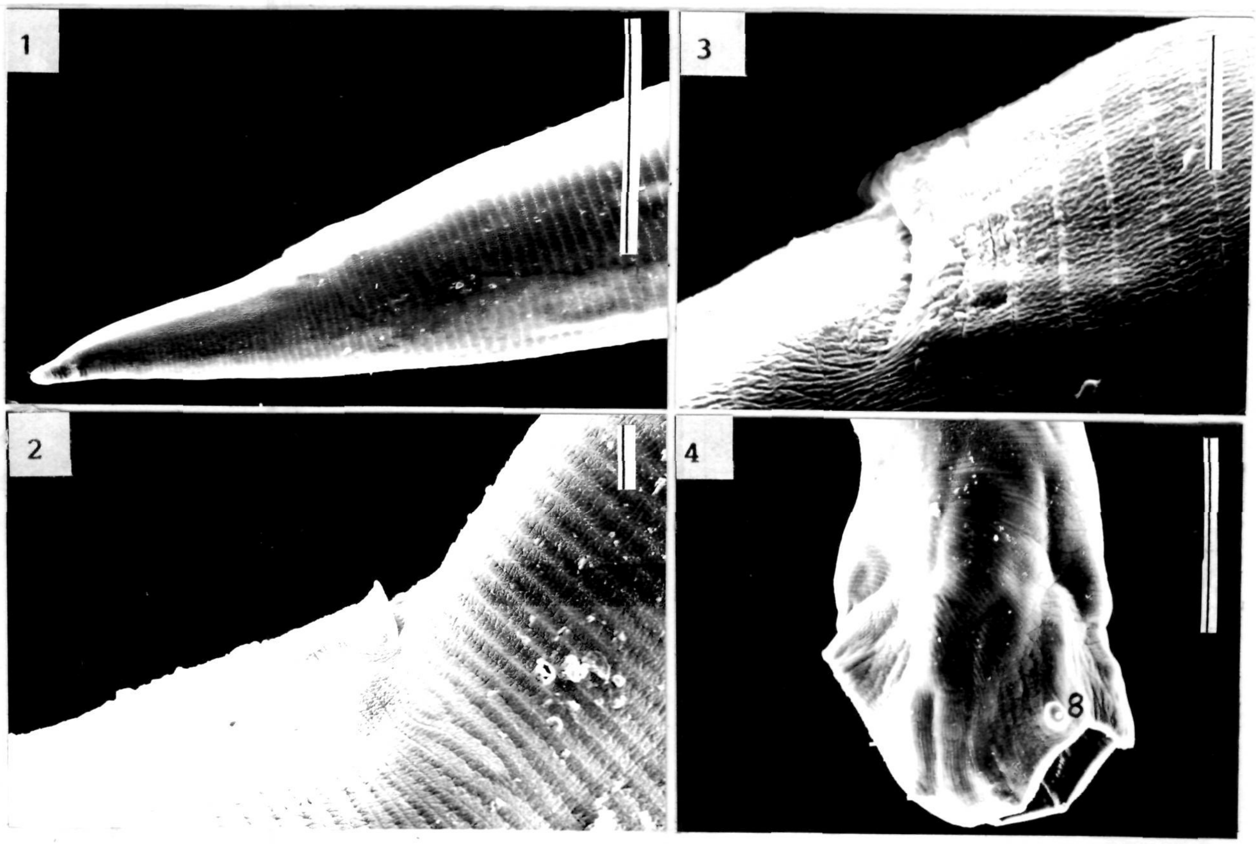
Fig.1 Caudal end of female, showing tapering tail with a blunt distal tip (scale bar = 100 µm)

Fig.2 Opening of vulva guarded by a small flap (scale bar = 10 µ m)

Fig.3 Anus, as a slit-like opening (scale bar = 10 µ m)

Fig.4 Caudal end of male, showing externodorsal ray (numbered 8) at lateral lobe of bursa (scale bar = 100 µm)

PLATE 2.14



Female

The cuticle shows a contour similar to that in male worms. The tail tapers posteriorly behind the anus, with a blunt distal tip. The anus apepars as a slit-like opening, lying quite close to the posterior end. The vulvar opening situated in the posterior half of the body is guarded by an everted flap of cuticle.

Setaria digitata (Plates 2.15-2.17)

The characteristic form of the oral opening surrounded by a raised cuticular area of peribuccal ring is clearly revealed by SEM observations. The latter possesses a pair of cuticular elevations notched at the apex. A pair of tiny pore is recognizable at the upper armpit of the lateral appendages in both the sexes; the appendages have the shape of a long papilla.

Male

The posterior extremity is curved spirally. The ventral bands, visible in the region anterior to the cloaca, have a characteristic ornamentation of cuticular striations; strips of transversely running ridges are regularly intercepted by narrower strips of longitudinal ridges. Of the caudal papillae there are three pairs of precloacal, a pair of adcloacal and three pairs of postcloacal papillae, all arranged laterally on either side of the tail, plus a central papilla which is elongated dorsoventrally and situated in front of the cloaca. Additionally there are present two pairs of tiny papillae anterior to the lateral appendages (not depicted clearly in the photographs). A single tongue-shaped spicule is seen projecting from the cloacal orifice.

PLATE 2.15 Scanning electron micrographs of *Setaria digitata*

Fig.1 Anterior extremity, *en face* view, showing oral opening surrounded by a raised cuticular area of peribuccal ring (scale bar = 10 μm)

Fig.2 Anterior extremity in dorso-lateral view, showing lateral lips of peribuccal crown (scale bar = 10μm)

Figs.3-4 Cuticular pattern ornamentation of ventral bands; note the strips of transversely striated cuticle alternating with those having longitudinal striations (scale bar, Fig.3 = 10 μm; Fig. 4 = 1 μm)

PLATE 2.15

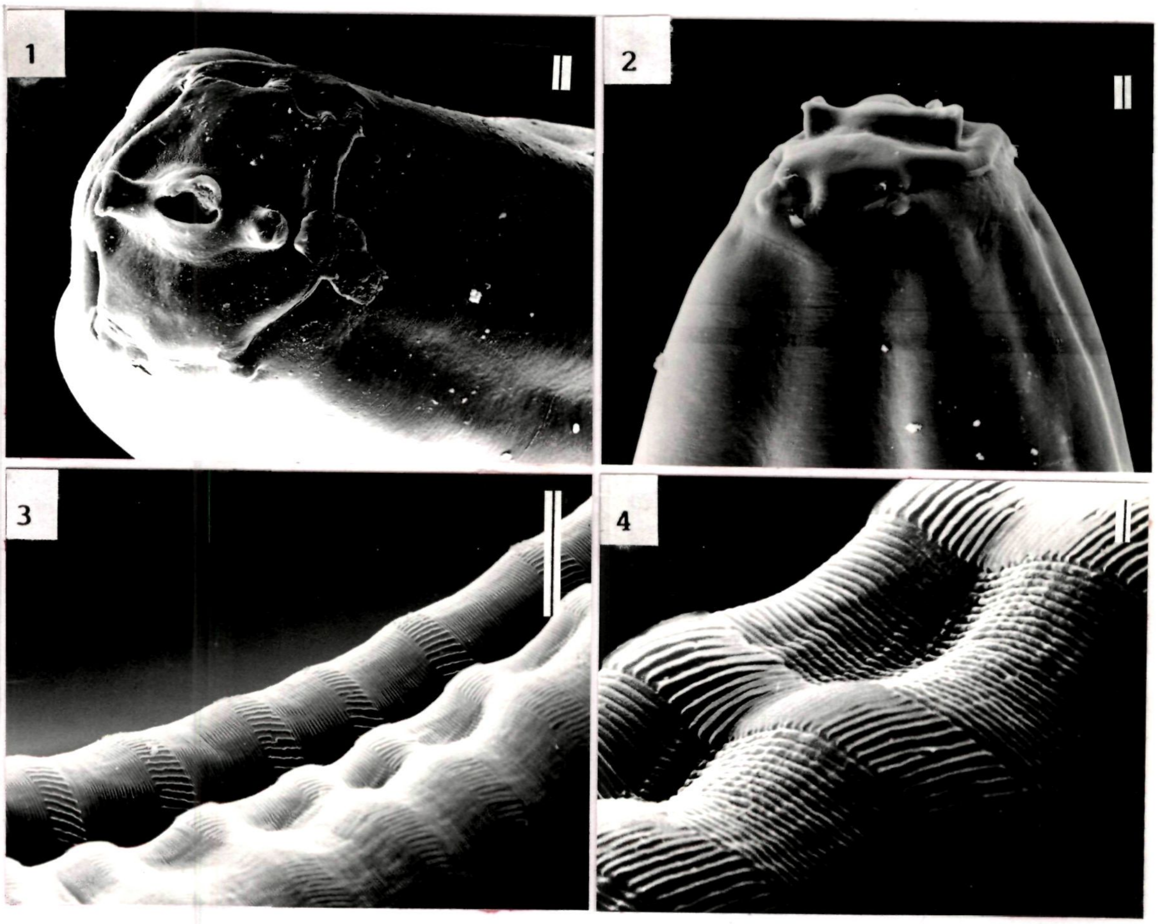


PLATE 2.16 Scanning electron micrographs of Setaria digitata

Fig.1 Caudal end of male, showing arrangement of papillae (scale bar = 100 µm)

Fig.2 Same in a diferent and enlarged view (Scale bar = 10µ m)

Fig.3 Caudal end of male, showing the broad spicule emerging from anus and a central papilla (*) (scale bar = 10µ m)

Fig.4 Caudal end of female, showing small lateral appendages (arrow) (scale bar = 10 µm)

PLATE 2.16

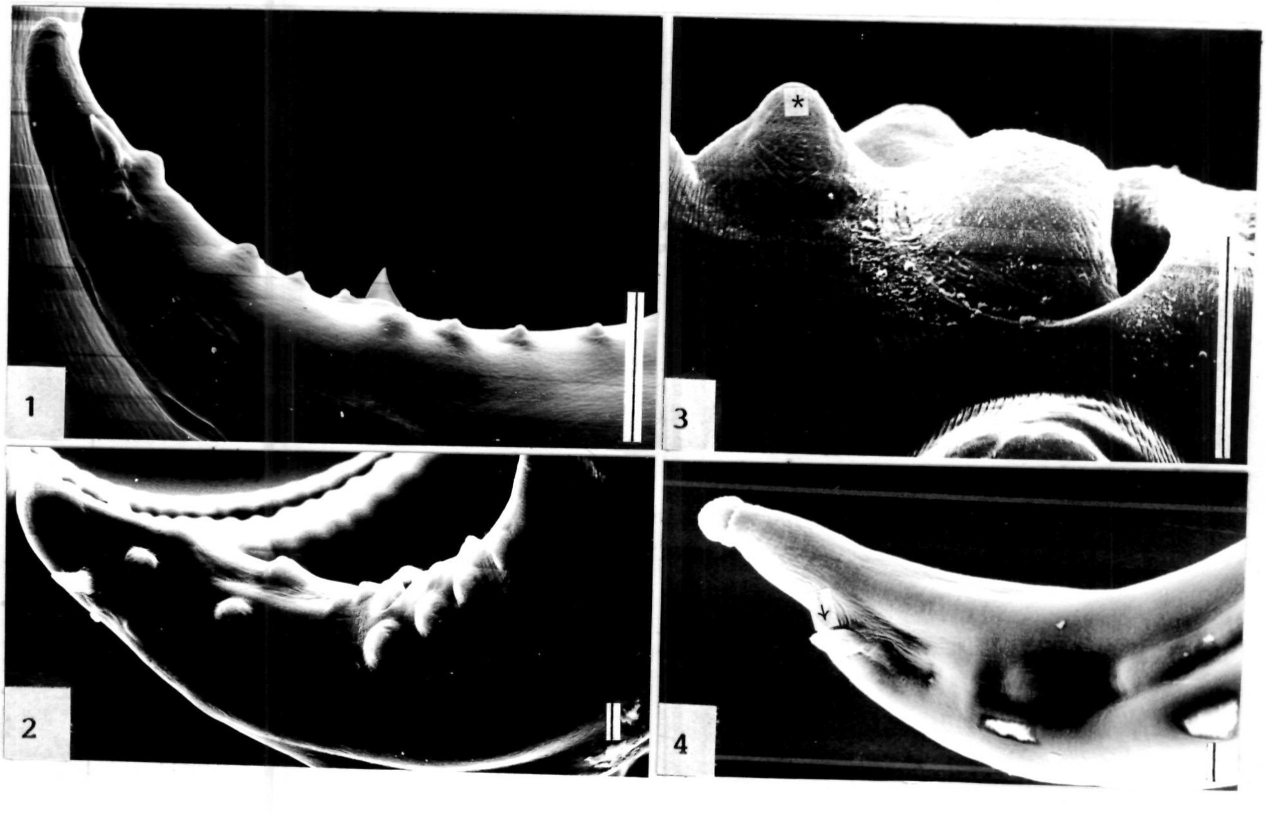


PLATE 2.17 Scanning electron micrographs of *Setaria digitata*

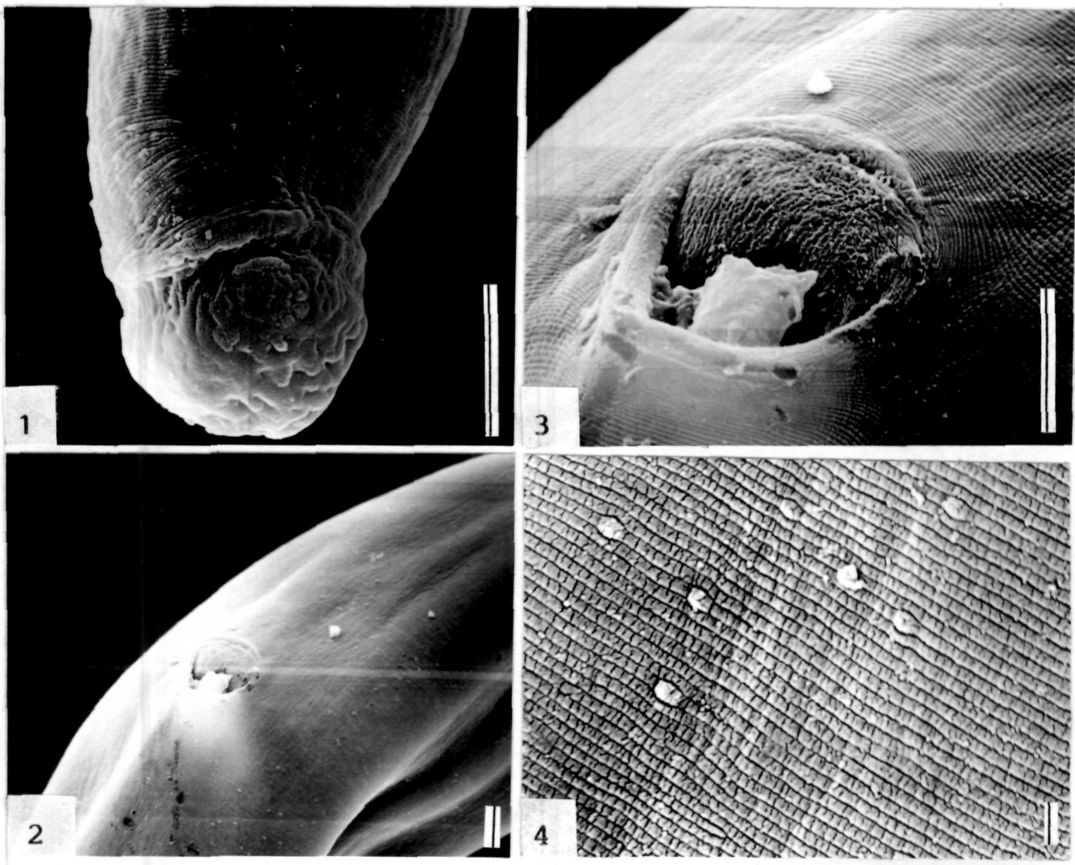
Fig.1 Posterior end of female, showing a terminal rounded knob in an enlarged view (scale bar = 10 μm)

Fig.2 Postdeirid positioned near posterior extremity of male (scale bar = 10 μm)

Fig.3 Same in an enlarged view (scale bar = 10 μm)

Fig.4 Transverse bands composed of longitudinally running micro-striation; note the presence of tubercles throughout the surface (scale bar = 1 μm)

PLATE 2.17



Female

In between the cuticular striations are present scantly and irregularly scattered very minute papillate structures. The posterior extremity terminates in a rounded knob.

Ascarops dentata (Plates 2.18-2.21)

The anterior end of the worm is provided with a pair of oppositely directed pseudolabia. The latter are trilobed and originate separately at a little distance from the anterior extremity, forming a longitudinal slit that divides the anterior extremity into two lateral parts; the slit represents the length of the pharynx. Each labium throws a well-developed buccal tooth from its middle lobe into a large and terminal oral cavity. There are present two distinct submedial cephalic papillae, one on each outer lobe of the lip. The papillae are relatively stout, prominent and oval. At higher magnification it is revealed that the papillae do not possess a central pore and their tip is smooth. The amphidial openings are prominent large circular pits anterior to the submedian cephalic papillae at the middle lobe; a minute pore-like opening was observed markedly anterior to the papillae on the lateral side of the outer lobe of each pseudolabium.

The cuticle covering the head part is non-striated, whereas throughout the major length of the body (except for the caudal region) it has a pattern of almost regular transverse striations. The latter are not as wide at the anterior region of the body as in the posterior; the dorsotransverse and ventro-transverse striations of the anterior region end at the lateral alae in an alternating manner, while those at the posterior end remain continuous.

Male

The caudal extremity is bent on to its left side almost at a right

PLATE 2.18 Scanning electron micrographs of *Ascarops dentata*

Figs.1-3 Anterior extremity in different views, showing submedian cephalic papillae, amphidial aperture (arrowed), and circular oral openings; note a minute pore-like opening at outer lobe of each pseudolabium (scale bar = 10 μm)

Fig.4 Pseudolabium showing a submedian cephalic papilla (scale bar = 1 μm)

PLATE 2.18

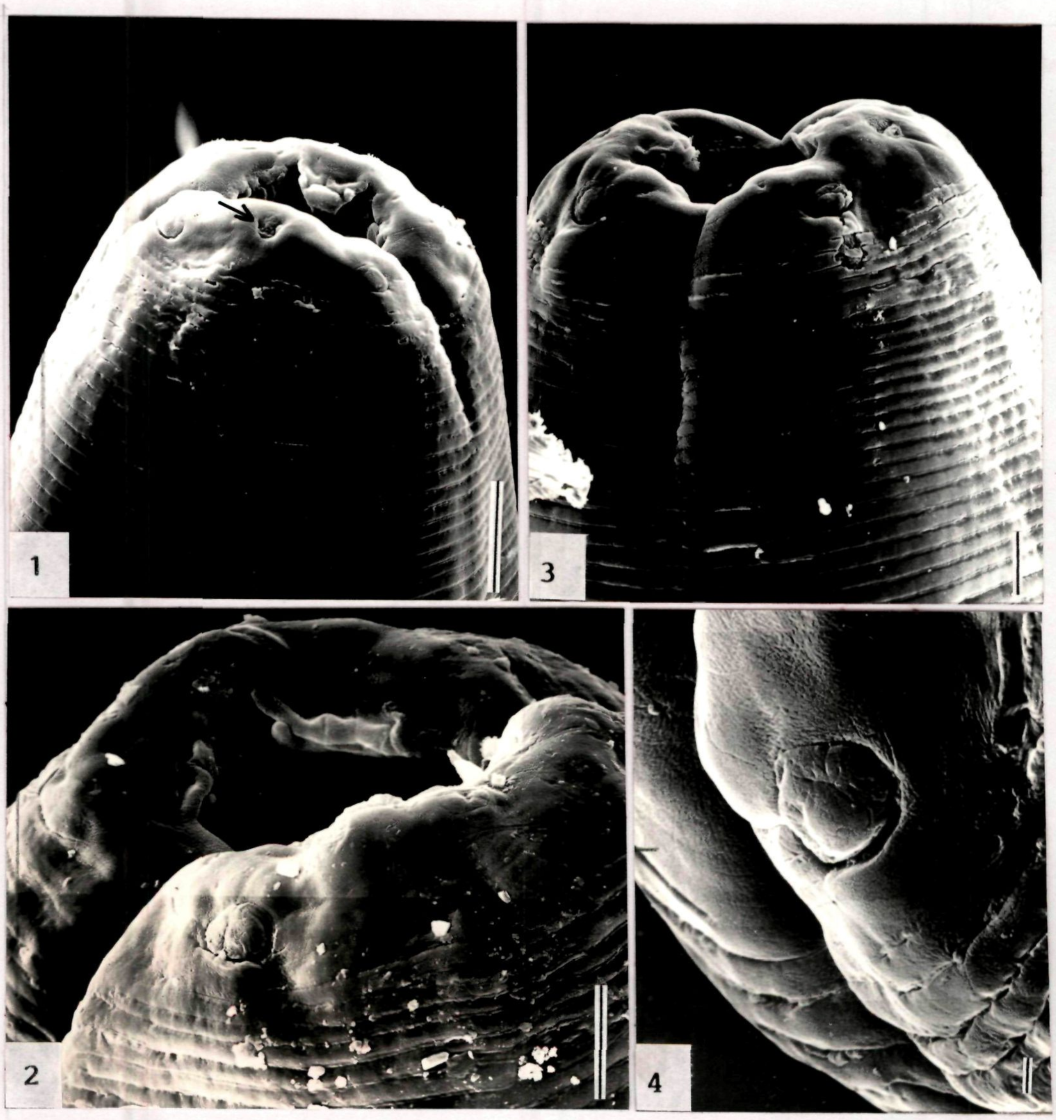


PLATE 2.19 Scanning electron micrographs of *Ascarops dentata*

Fig.1 A submedian cephalic papilla in enlarged view (scale bar = 1 μm)

Figs.2-4 Patterns of cuticular ridges - 2. at the anterior extremity (scale bar = 10 μm) 3. at the middle region (scale bar = 10μ m) 4. at the posterior region (scale bar = 100 μm)

PLATE 2.19

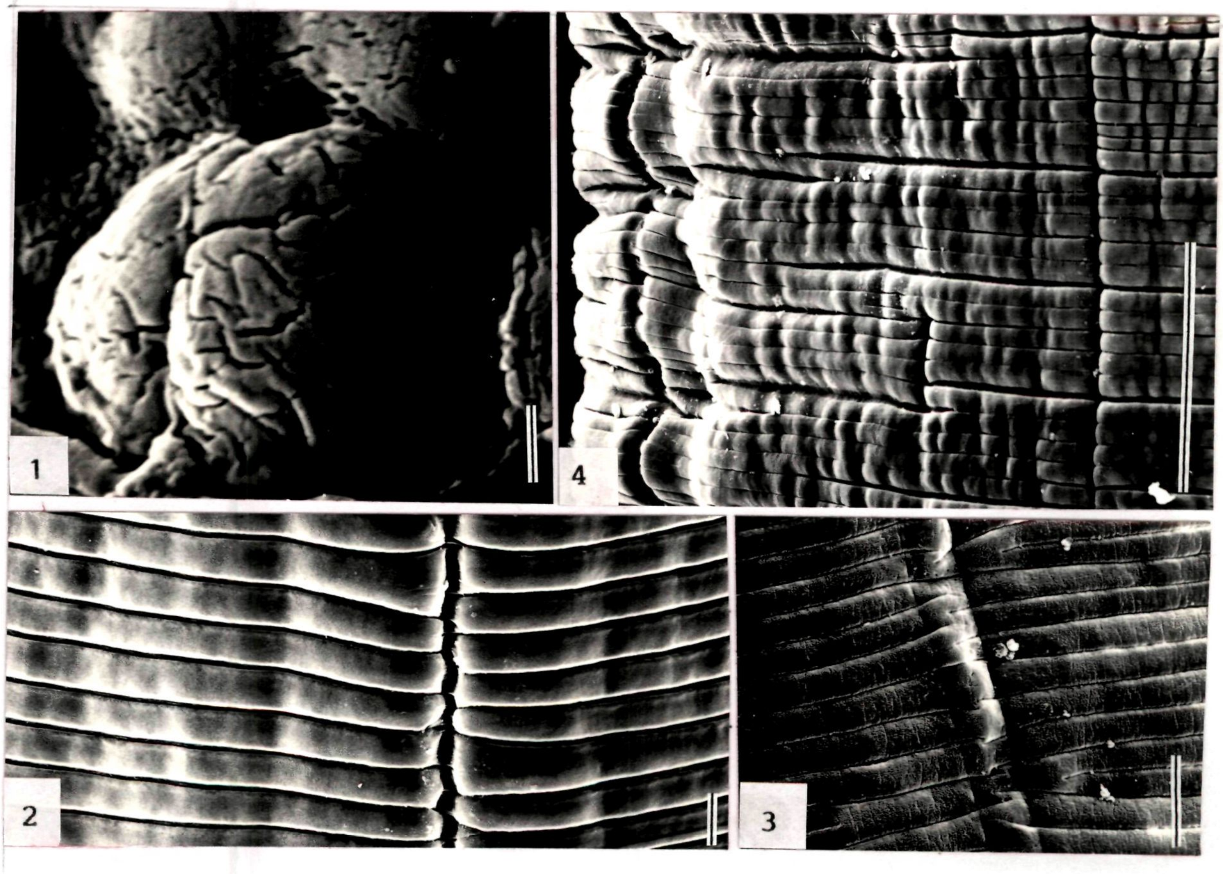


PLATE 2.20 Scanning electron micrographs of *Ascarops dentata* - male

Fig.1 Caudal end curved spirally, note the changing pattern of cuticle posteriad (scale bar = 100 µm)

Fig.2 Same enlarged to show the caudal ala extended markedly to right side and a phasmidial pore (arrowed) (scale bar = 100 µm)

Fig.3 Same in ventral view, showing unequal spicules extending from the cloacal orfice and ornamentations of cuticle (scale bar = 100 µm)

Fig.4 Cuticular ornamentation in a closer view (scale bar = 10 µm)

PLATE 2.20

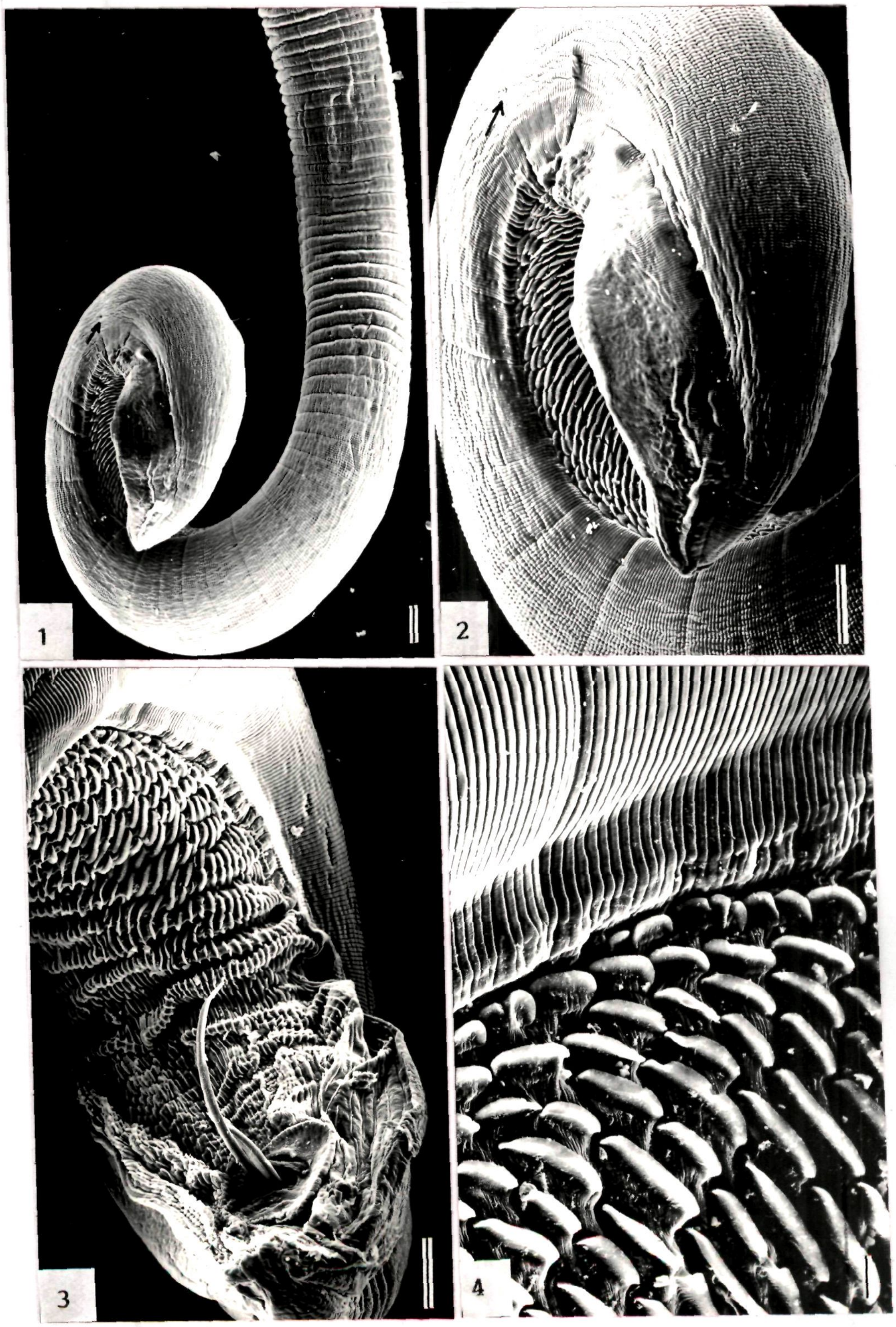


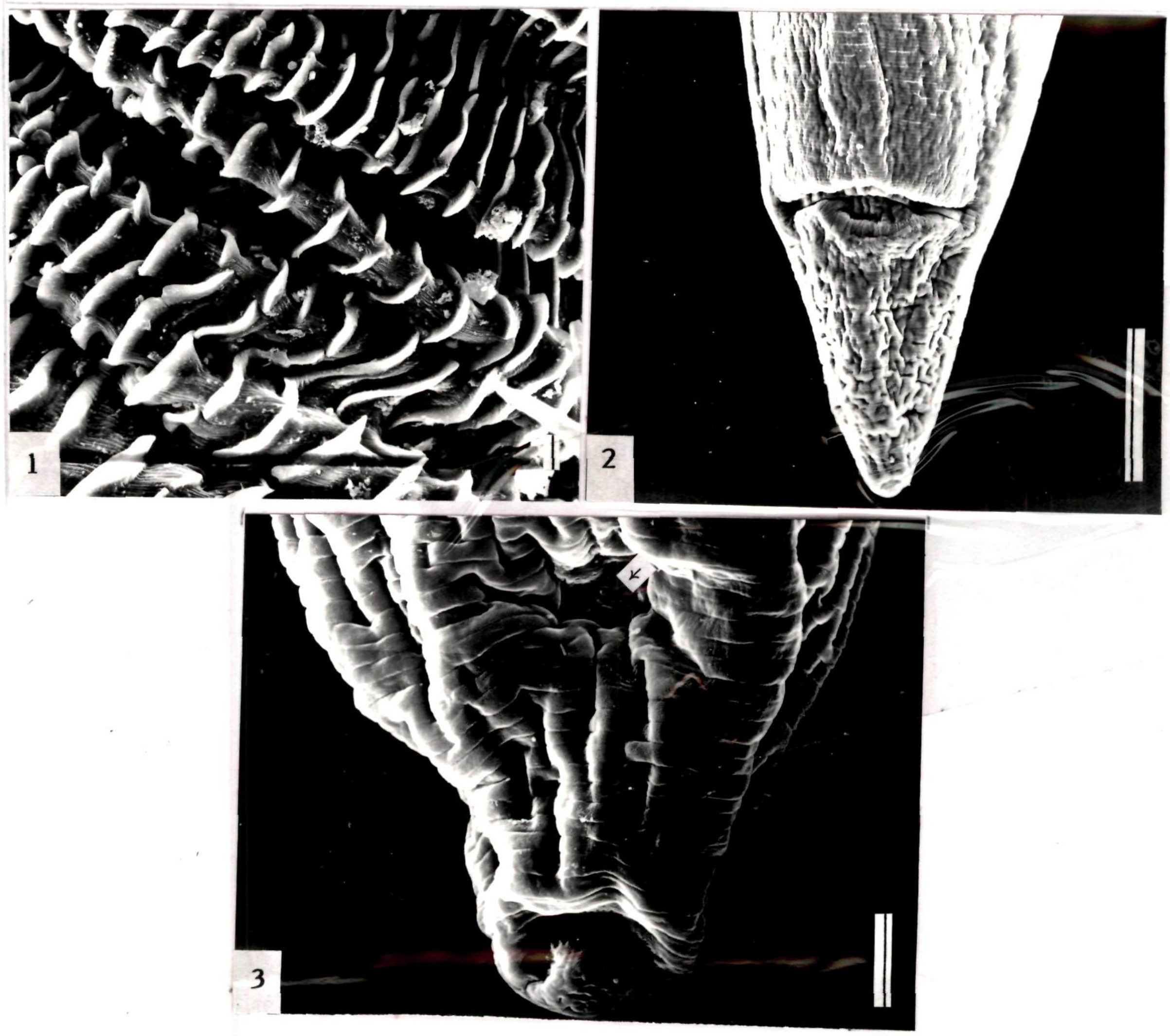
PLATE 2.21 Scanning electron micrographs of *Ascarops dentata*

Fig.1 Cuticular pattern at posterior extremity of male (scale bar = 10 µm)

Fig.2 Caudal end of female, showing slit-like anus and a conical tail (scale bar = 100µm)

Fig.3 Terminal end of female, showing pattern of cuticle and phasmidial opening (arrowed) (scale bar = 10 µm)

PLATE 2.21



angle, giving the posterior end an appearance of the numeral 6 upside down ('9'). The cuticle of the caudal region is covered with pronounced but fine transverse ridges, the latter nearing the posterior extremity being rather narrowly placed. The minute phasmidial pores are situated on the lateral aspects of the region immediately before the caudal alae. The caudal alae are extended markedly to the right side of the tail and appear as triangular pieces. The ventral surface of the caudal end has a dense aggregation of mushroom-like cuticular thickenings, with their bases overlapping sideways and distal ends forming smooth narrow surfaces, arranged in somewhat recognizable longitudinal rows. The unequal spicules are seen emerging out of a smooth subterminal disc-like plate. The tail ends bluntly.

Female

The tail is comparatively shorter than in the male worm and is pointed bluntly. The anus appears as a prominent opening near the tip. The cuticle in the preanal region has more or less regular transverse striations, whereas in the postanal region it is thrown into a pattern of irregular folds and ridges. A small but prominent depression, observed among these folds on the lateral aspects and quite close to the tip of the tail, appears to be the phasmidial opening of the right side.

Gnathostoma doloresi (Plates 2.22, 2.23)

The anterior end of the worm is provided with a distinct globular cephalic bulb. Two large pseudolabia guard the oral opening; the cuticle of each labium on its inner facet is thickened and raised into a tooth-like ridge which encounters its fellow of the opposite side as if forming a macerating device. The cephalic bulb is armed with backwardly directed spines arranged

PLATE 2.22 Scanning electron micrographs of *Gnathostoma doloresi*

Fig.1 Anterior extremity, showing cephalic bulb separated off from rest of body, and backwardly directed cuticular spines throughout its surface (scale bar = 100 µm)

Fig.2 *En face* view showing trilobed pseudolabia, submedian cephalic papillae (*) and amphidial opening (arrowed) (scale bar = 100 µm)

Fig.3 Magnified *en face* view, showing the lips edges and cephalic papillae (arrowed)(scale bar = 10µ m)

Fig.4 Cephalic bulb, showing transverse rows of backwardly directed spines (note the fibrous interconnections between the spines) (scale bar = 100 µm)

PLATE 2.22

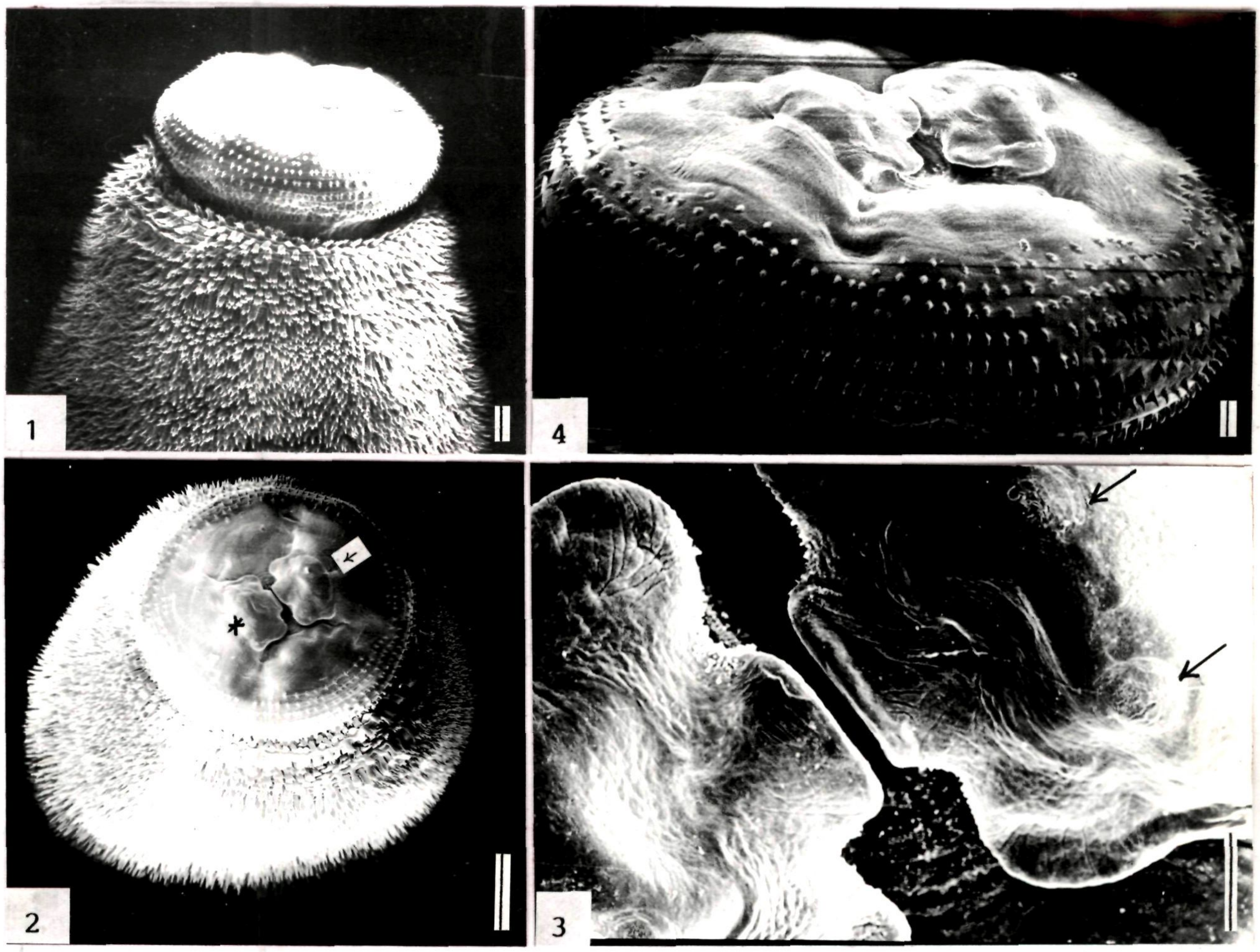


PLATE 2.23 Scanning electron micrographs of Gnathostoma doloresi

Fig.1 Spination on the head bulb (scale bar = 10 m)

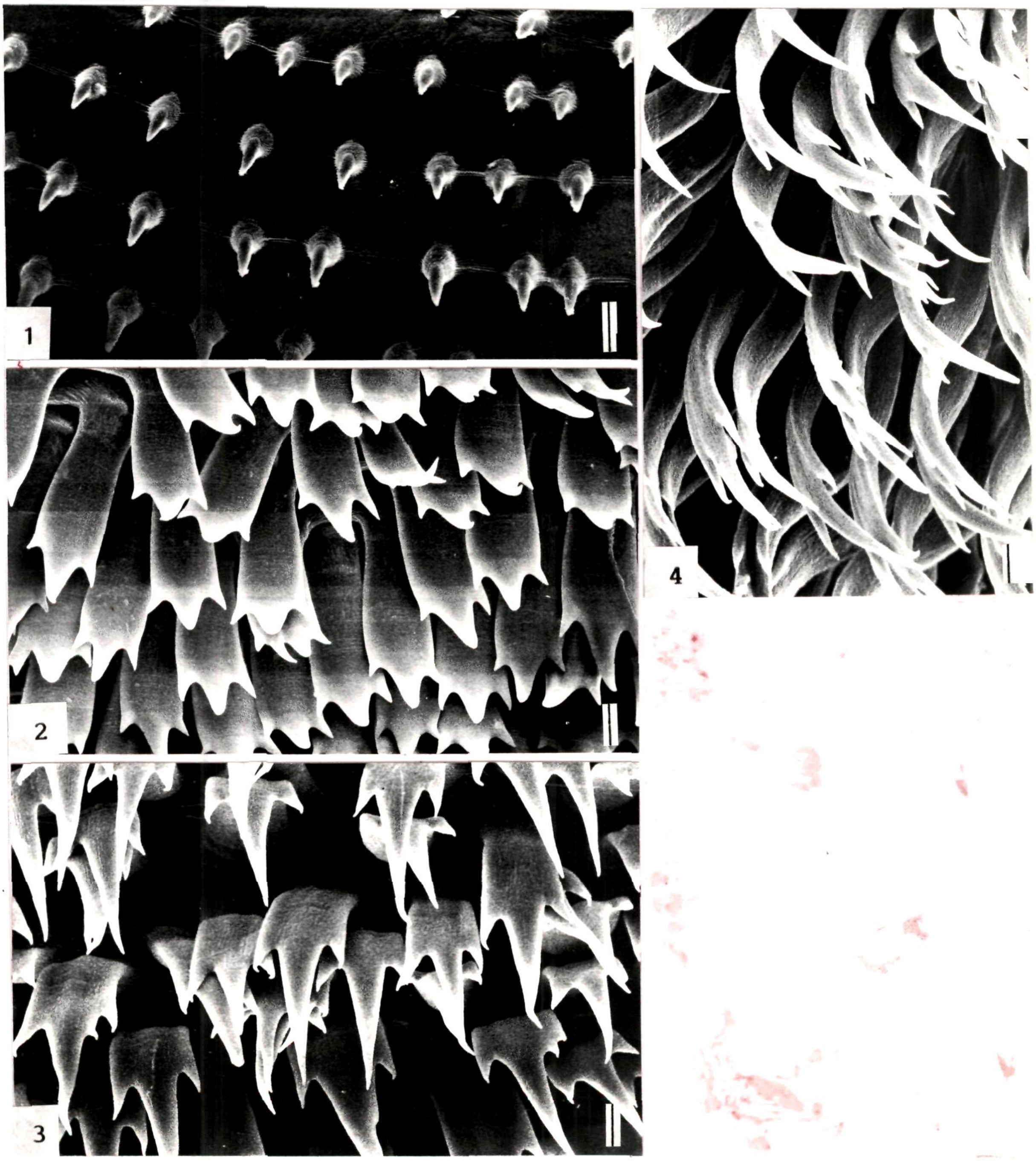
Fig.2 Three-pronged spines, densely distributed on the cuticle in the anterior region of body (scale bar = 10 µm)

Fig.3 Spination on the mid body region (scale bar = 10 µm)

fig.4 Spination on the posterior region of body (scale bar = 10 µm)

Fig.5 Amphid, opening as a deep circular pit at the cephalic bulb (scale bar = 10 µm)

PLATE 2.23



in 8-9 regular circular rows. These spines are exhibited as emerging from a globular cuticular base and the cuticle in between the spines of a row shows transverse fine wrinkles, probably reflecting the underlying fibrous elements. The amphids revealed as a deep circular pit situated laterally on each labium. There are present four submedian cephalic papillae. The whole body surface, posterior to the cephalic bulb, is densely covered with backwardly directed cuticular spines. The latter show a gradual change in their contour and density from anterior to posterior end of the body. Those abounding in the anterior region are scale like or foliate, showing a densely overlapping pattern and having characteristically 3-pronged distal edges; the median of the three prongs is slightly longer and bluntly tapering, while the lateral prongs are short and have pointed ends. The cuticular spines in the middle region of the body are seen to have relatively short base but their trident distal edge have a conspicuously long median prong that tapers to sharp narrow points. Towards the posterior end the spines retain their trident contour but appear more slender and elongated than those of the rest of the body. At the extreme posterior extremity the spination reduced to mere points protruding beyond the striations of the cuticle.

DISCUSSION

The present study illustrates a detailed account of fine surface structures of nine species representing eight superfamilies of nematode parasites of vertebrates.

The dentigerous ridges are characteristic of several genera of the superfamily Ascaridoidea (Gibbons, 1986). The size and topography of the denticles forming the ridge have been used by previous workers as taxonomic criteria for differentiating the apparently identical species, A. suum from pigs and A. lumbricoides from humans. Sprent (1952) indicated a convincing morphological difference between the human and pig strains, i.e., the denticles on the lips of the pig forms are equilateral triangles with straight edges, and those of the human form are less conspicuous, smaller and have concave edges. However, according to Lýsek (1963) the denticles in both forms varied considerably and lacked any reliable distinguishing feature. Little (1968) admitted that same difference were infact, apparent when comparing worms of a similar size, since the denticles increase in size as the worms grow. While Madden et al. (1970) supported Sprent's observations, Ubelaker and Allison (1972) noted variations in shape even in the specimens originating the same host. Ansel and Thibaut (1973) claimed that there were difference between the two forms in the size and shape of the denticles from the central part of lips. Madden and Tromba (1976) found the shape of the denticles of the pig form varying with the angle from which they were viewed and their size varying not only in different worms but also in the same specimen, the average size being dependent on the age of the worm. These workers also stated that any distinction between the denticles of the worms of human and pig origin will remain questionable until similar age-related studies are done with the human form. Lýsek (1980) also doubted the taxonomic significance of denticles' size and density, in view of their variation in the material from pigs.

In general, the topography of the anterior end of A. suum as revealed herein is similar to that reported by Wiese (1973) and Madden et al. (1975). However, these authors reported the presence of two dentigerous ridges dividing the lip into a upper and a lower part, whereas only one dentigerous ridge was found to be present and the denticles appeared to be less conspicuous with concave edges in the specimens studied herein. These observations, in conformity with those of Sprent (1952) would lead to identification of worms under study as A. lumbricoides! Thus a possibility of Ascaris worms of porcine and human origins being conspecific may not be eliminated.

Based on a combination of head, tail, and body structures the SEM has been successfully used for species separation within the family Strongyloidae. B. diducta studied herein resembles closely the other strongylids like Oesophagostomum spp. (which also inhabit the same site in the host) in possessing the characteristic mouth opening with leaf-shaped elements forming the crown; it is also similar to Cylicocerus catinatus (subfamily Cyathostominae) in having a wide saucer-shaped anterior end with a shallow constriction separating the head capsule from the body (Rahman and Waddell, 1979); papillae not earlier visualized by LM, appear as raised cushions of tissue situated at the periphery of the mouth opening and have suggestedly a mechanoreceptive functions (Gibbons, 1986). The exact number of the elements constituting the crown, now determined, removes any further confusion related to their number. The genital cone, an organ of the male tail in bursate nematodes is also illustrated in B. diducta. In the past it has been largely overlooked in the systematics and taxonomy of bursate nematodes. However Gibbons and Khalil (1983a) discussed its value as a supportive taxonomic characters. The presence of genital cone has also been demonstrated in the trichostrongylid Ostertagia ostertagia (see Gibbons and Khalil, 1983b). The characteristically shaped vulva and anus are illustrated herein at higher magnification; earlier these were recognized merely as simple openings by LM. Besides, several more features are visualized through SEM, which earlier were not discernable in LM studies. These include a pair of smooth caudal papillae and the phasmidial pores. No such caudal papillae were reported to be present in Ostertagia ostertagia males. The papillae with a pore are considered to be more involved with chemoreception than with tactile reception (McLaren, 1976). Therefore, the absence of a visible pore in the papillae is suggestive of a tactoreceptive function. The location of the phasmidial pores observed in this species seems to be comparable with that shown in the female tail end of the ascarid, Parascaris equorum (see Snyder, 1985).

Members of the genus Oesophagostomum are primarily identified on the basis of the characteristic mouth cone and the number and shape of the elements in the coronae radiatae; the latter are often not accurately countable in LM studies. In O. asperum, as illustrated herein, the external corona radiata is found to comprise 12 blunt leaf-like elements and the general morphology of the anterior end considerably resembles that reported in other strongylids such as Cylicodontophorus sagitattum (see Rahman and Waddell, 1979). Zaman (1983) also illustrated similar features in Oesophagostomum sp., though the cephalic papillae appear less prominent than in O. aspersum. The three-dimensional view of the anterior end of O. columbianum confirms the LM observations that the anterior extremity curved like a hook, is provided with a prominent cephalic vesicle marked behind by a cervical groove and a pair of cervical papillae (Baylis, 1936a). The mouth collar and the cervical groove are more prominent in this species than in O. aspersum. The definite number of elements of the external corona radiata is found to be 20, whereas earlier the elements were mentioned as varying between 20 and 24 (Baylis, 1936a).

The presence of oval amphidial apertures, one at each lateral edge of the mouth-cone is visualized through SEM for the first time in both the Oesophagostomum spp. studied herein. Amphids similar in form, one at each lateral side of the oral opening have been described in other bursate nematodes as well (Gibbons, 1986). The elongated spicules projecting from the bursal lobe and observed as joined together throughout their length in O. aspersum resemble those of Necator americanus (see Zaman, 1983). The absence of any cuticular ornamentation around the anus and vulva in female O. aspersum, has also been observed in Haemonchus contortus and B. phlebotomum (see Gibbons, 1986; Malan et al., 1986). Further, in O. aspersum the tail is short with subterminal anus, however in O. columbianum the anus is placed far in front of the posterior extremity and the tail tapers sharply posterior to the anus (Gibbons, 1986).

The cuticular pattern may be taken as an additional supportive character in differentiation of various Oesophagostomum species. While cuticular transverse striations are evident only at the dorsal aspect of the body in O. columbianum, in O. aspersum these are present on both the surfaces. The characteristic lateral alae of O. columbianum could clearly be seen originating from the cervical groove and extending along almost the entire length of the body. The lateral alae may provide a degree of longitudinal stiffening and allow for changes in the worm's diameter; these remain in contact with the substrate and therefore increase the efficiency of locomotion by increasing friction and preventing rolling (Lee, 1969).

In S. dentatus the SEM provides the characteristic three dimensional view of the hexagonal oral opening endowed with six cuticular peripheral thickenings, leaf crown, revealed the presence of seta-like cephalic papillae 80-85 elements in the leaf crown and six teeth originating from buccal cavity. The hexagonal nature of the oral cavity in S. dentatus is implicated to represent six rudimentary lips (Chitwood and Chitwood, 1977), and supplements the previous observations made by LM. Almost identical cephalic papillae with same number have also been recorded in Murshida hamata, also belonging to the superfamily (Gibbons, 1986). Baylis (1936b) earlier had mentioned to the presence of about 50 reduced elements of the leaf crown at the periphery of the mouth, whereas their number was found to vary between 80-85 in the present study. Almost similar elements of crown have also been elucidated in Chabertia ovina a strongylid (Gibbons, 1986). Teeth have also been reported to occur in several other animal parasitic nematodes such as, Syphacia spp., Rictularia jodhpurensis, etc. (Wiger et al., 1978; Mezaros et al., 1978; Singhvi and Johnson, 1989). The morphology of the teeth varies greatly and they have been divided into two groups based on their point of origin, those transformed from the labial region, referred to as 'odontia' (e.g. Physaloptera sp., Abbreriata spp. and Ancylostoma spp.) and those originating posteriorly and associated with the oesophagus, referred to as 'onchia' (e.g. as in many species belonging to the super families Strongyloidea and Trichostrongyloidea, namely Haemonchus contortus, Strongylus vulgaris and S. asini (see Gibbons, 1986); Stephanurus seems to represent the latter type; however unlike the Syphacia and Rictularia spp. no ridges were found to be present surrounding the teeth. The topography of the teeth observed in S. dentatus is very much comparable to that of Strongylus vulgaris.

The arrangement of rays and the topography of the bursa could clearly be visualized with the aid of SEM. The general morphology of the bursal rays resembles closely that in Trichinella spp. (see Barus et al., 1981b). The blunt tip of the spicule with a minute pore at the distal end is comparable to that in Onchocerca sp. (see Gibbons, 1986). The perineal cuticular ornamentation in Stephanurus appears similar to that in Bourgelatia diductia and

Oesophagostomum sp. (see Zaman, 1983). The features, such as the rudimentary corona radiata and degenerated bursa, support the concept advocated by Lichtenfels (1980) that Stephanurus represents a primitive strongylid form.

The application of SEM to Globocephalus connorfilii reveals many characters of specific identification. The functionally important surface annulations are present as transverse markings on the dorsal and ventral surfaces and are absent at the middle region of the body. Annulations enable the nematodes to change shape and the cuticle to flex during dorsoventral contractions (Wharton, 1986). The absence of cephalic papillae and the small buccal cavity are features comparable to those made on the trichostrongylid, Ollulanus tricuspis (see Blanchard, 1985). The dorsally bent anterior end resembles that of Bunostomum phlebotomum (see Malan et al., 1986). According to Lichtenfels (1980) the orientation of oral opening could be taken as a tool to separate tribes within the family Ancylostomatoidea. The characteristic striated cuticle, the presence of prominent cervical papillae and the topography of the vulva are the features which may be of significance in identification of the species. The SEM observations on the morphology of G. connorfilii particularly the cervical papillae and male bursa (with a dorsal and two lateral lobes) supplement in general the available information reported for the other hookworm species (Setasuban, 1974; Yoshida et al., 1974a,b; Malan et al., 1986). The semi expanded postion of the dorsal and ventral lobes of the male bursa may not represent a natural condition. The topography of the distal tip of the female tail could differentiate G. connorfilii from an identical appearing species G. urosubulatus. In the former the tail ends with a blunt tip, whereas in the latter it is observed to finish in a prominent terminal spine (Gibbons, 1986). The posterior extremity of female in G. connorfilii in general appears similar to that of Necator americanus, also belonging to the same family. The presence of a flap or the opening of vulva observed in this species has also been illustrated in the trichostrongylid, Paracooperia nodulosa by Gibbons and Khalil (1983a).

Shoho and Uni (1977) and Wong and Brummer (1978) used SEM for differentiation of adult filarial worms within the same genus. With regard to Setaria digitata, studied herein, the SEM has provided useful information about some structures which could be profitable in clarifying difficult taxonomic situations in the genus Setaria which includes a wide spectrum of species. A series of cephalic papillae arranged circum-orally could be seen in the specimens examined herein. The amphidial opening that has not been recognized earlier by LM is seen situated on the lateral side of the peribuccal ring. The position and external appearance of the amphidial opening resemble closely that illustrated for Setaria marshalli pandei (see Shoho and Uni, 1977). The phasmidial pores are demonstrated in the present investigation as lying close to the lateral appendages. The post-deirid which has often been overlooked in LM studies was first observed in Setaria nelsoni by Shoho (1976) among all Setaria spp., it is also demonstrated clearly in S. digitata. The latter species is distinguishable from S. marshalli on the basis of the general appearance of the post deirid; in S. marshalli, it appears as a trifurcated needle-like formation. (Shoho and Uni, 1977), situated on an elevated mass, whereas in S. digitata it is simple and uniform, not divided at the tip and emerges from a deep wide tip. The pattern of finer longitudinal microstriations comprising the ventral bands may be species specific and thus could be helpful in differentiation of various Setaria spp. These microstriations were first illustrated by Helle and Blix (1973) with the aid of SEM in Dipetalonema spirocauda. The characteristics microstriations consisting of regular rows of spherical bands are also reported to be present in male specimens of *S. labiato-papillosa* and *Brugia pahangi*, at a little distance from cloaca, thought not neatly arranged (Shoho and Uni, 1977; Aoki *et al.*, 1980). It is noteworthy here that somewhat similar kind of ornamentation, the so-called "spines", has also been illustrated in the region approximating cloaca in male *Baylisascaris procyonis*, an ascarid (Snyder ,1989). According to Gibbons (1986) the region possessing these bands known as area rugosa, is an essential feature of the superfamily Filariodea. Snyder is of the view that these structures perform some sensory function in the copulatary process. The exact number and position of caudal papillae visualised herein removed all controversy regarding the same in *Setaria* spp. Gupta and Kalia (1978a) pointed out that *S. digitata* possesses 3-4 pairs of preanal and 4 pairs of postanal papillae. The arrangement of caudal papillae and general appearance of the caudal end of male specimens of *S. digitata* observed herein resemble more or less *Dirofilaria* spp. (see Wong and Brummer, 1978). The caudal papillae localized in the vicinity of the cloacal region of male suggestedely assist in positioning of the male cloaca with the female vulva during copulation (McLaren, 1976). However, the reasons as to why various filarids adopt different arrangement and number of male caudal papillae is not known. Additional information may be obtained when these papillae are examined more closely with the aid of transmission electrón microscopy.

The caudal end of *S. digitata* is found to be rounded and knobbed with a pair of long, leaf-shaped caudal appendages. Howver, in SEM illustrà-tions of *S. marshalli* provided by Shoho and Uni (1977) the posterior extremity appearas as having a distinct circlet of spikes, with the lateral appendeges lying closer to the tip as compared to *S. digitata*, further the caudal appendages are also shorter and stouter in *S. marshalli*. The minute papillate structures abounding on the cuticular surface in S. digitata seem comparable to those illustrated in the filarid, Brugia malayi by Zaman (1983). Small tubercles were also demonstrated in the tail region of females of Wuchereria bancrofti and Brugia species (Buckley, 1952; Buckley et al., 1958; Schacher, 1962), the male worms of Brugia being entirely devoid of these tubercles.

The anterior end of A. dentata is provided with a pair of lateral trilobed pseudolabia which are not distinctly separated from the rest of the body as in the ascarids and other members of the order Spirurida e.g. Physaloptera spp. (see Madden et al., 1970; Madden and Tromba 1976; Tiekotter, 1981). It appears that in A. dentata the anterior extremity of the body represents a transitional phase of modifying into well-developed lips and thus a primitive condition, from which more and more specialized zooparasitic nematodes such as Ascaris, Toxocara and Parascaris have evolved. The present hypothesis gains support from the fact that in contrast to rather specialized cutting surfaces such as dentigerous ridges present in Ascaris spp. (see Wiese, 1973; Gibbons, 1986), Ascarops possesses a pair of well-developed buccal teeth, which guard the aral cavity. The buccal teeth observed herein seem comparable to those of Physaloptera spp., where these appear rather prominent and extend from the middle lobe of the pseudolabia (Tiekotter, 1981). The pair of dome-shaped submedian cephalic papillae presumably of mechanoreceptive function, in A. dentata resemble those observed in other spirurids, such as Physaloptera spp. and Paracuaria sp. (see Gibbons, 1986), but unlike those in the latter spices these lack the central pit at their tips. The amphids, revealed as large circular openings in the species studied herein resemble those in Paracuaria and differ from the ellipsoidal ones in Physaloptera species. In Heterakis gallinae, the amphids open on subventral lips and appear slit-like with margins like a lip

(Wright, 1977). Studies have shown the presence of acetylcholinesterase in the amphidial pit secretion of a number of animal parasitic numatodes, which either alters the permeability of the host membrane or acts as a biochemical holdfast by dampening down the peristaltic movements of the host gut (Mclaren, 1976). The presence of a minute pore-like opening of unknown function at the outer lobe of each pseudolabium in A. dentata has also been observed sporadically in lip-possessing nematodes (Tiekotter, 1981; Snyder, 1985). The characteristic large buccal cavity and the cuticle - smooth on the head and transversely striated on the rest of the body, in A. dentata tally closely with the observations made on Oxyuris equi; in the latter the lips are rudimentary and the characteristic lamellar organs are reported to function as inner lips (Barus et al., 1979a). The body cuticle of A. dentata exhibits a series of transverse striations which are not only wider posteriorly than at the anterior end, but also appear distinctly different, i.e., the dorsotransverse and the ventro-transverse striations terminate at the lateral alae where they may alternate as seen at the anterior extremity or may remain continuous, as appearing in the middle region of the body; their characteristic nature could thus be of significance in the species identification.

The tail of male A. dentata is with well-developed caudal alae and shows a variety of beautiful cuticular ornamentations at its ventral surface. Similar ornamentations of mail tail have also been elaborated in Cyathospirura seurati, another member of the family Spirocercidae (see Gibbons, 1986). It is speculated that the caudal alae act to clasp the female during copulation, and the cuticular structures aid in increasing the friction of mail tail to female vulva (Maggenti, 1981).

The SEM further reveals the structures such as the phasmidial pore, two unequal spicules originating at a smooth disc placed at cloacal orfice and the transverse slit-like anal opening in A. dentata. The characteristic anal opening and cone-shaped tail are similar to those of Parascaris equorum (see Snyder, 1985).

Members of the genus Gnathostoma exhibit a relatively narrow morphological diversity and appear to be very similar apparently (Baylis, 1939). The species like G. hispidum and G. doloresi have often been misidentified and confused with each other (Miyazaki, 1968). The use of SEM has introduced few additional characteristics which may be helpful in differentiation and identification of Gnathostoma spp. i.e. G. hispidum, G. doloresi, and G. spinigerum The 3-pronged cuticular spines and their distribution seem characteristic of G. doloresi. The amphids, not located earlier by LM, appear as circular pits opening laterally on the cephalic bulb. The presence of a pair of submedian cephalic papillae on each labium in G. doloresi is comparable with that of Physaloptera spp., where these are assumed to function as mechanoreceptors (Gibbons, 1986). However, in some members of the family Oxyuridae, such as Oxyuris equi, there are present three pairs of cephalic papillae (Barus et al., 1979a).

In general the enface view of G. doloresi as seen by SEM, closely resembles that of Metathelazia capsulata, also belonging to the order Spirurida, which possesses an oval oral opening partly covered by two lateral lobe-like, and four submedian small tooth-like structures (Wertheim and Chabaud, 1977). The shape and surface topographical features of the cephalic bulb and the general body surface are indicative of some adaptations to the parasite's habitat; the armed cephalic bulb apparently functions as a holdfast, collapsing when the anterior end is inserted into the gastric mucosa and thereafter getting inflated (Chitwood and Chitwood, 1977).

CHAPTER III

PREVALENCE AND SEASONAL FLUCTUATION

INTRODUCTION

In formulation of successful control strategies for worm parasites the very first need is to look into the epidemiological pattern of the parasitic groups perpetuating infections in an area, which varies very often from place to place and at different times in the same area (Banerjee, 1987). Helminth parasites which have a direct tie with the external environment respond significantly with the season and its annual rhythms. It is now generally accepted that temperature is the prime single extrinsic factor that influences the parasites, though humidity and rainfall are also considered to be of fundamental importance, which together exert a strong influence on the type, spread and intensity of parasitic infections, nematodes in particular which mostly exhibit a direct life cycle. In certain areas of the world the use of these data has enabled the prediction of outbreaks of parasitic infections with reasonable accuracy (Gordon, 1948).

During the past two decades, a considerable work has been undertaken in a number of advanced countries that have tropical or sub-tropical zones in their territories (Australia, South Africa, U.S.A.) and also those with temperate climates (United Kingdom, New Zealand, etc.) towards the control of helminth infections of livestock, investigating into the epidemiology of infection (Armour, 1980; Brunsdon, 1980; Morley and Donald, 1980; Herd et al., 1984). In most of the reports useful informations related to control have been derived mainly from the results obtained on the parasitic species composition, their incidence and seasonal distribution either as monitored by faecal worm egg counts at necropsy (Swan, 1970; Riche et al., 1982; Altaif and Issa, 1983) or with more accurate total worm counts in slaughtered animals (Brundsdon, 1970; Southcott et al., 1972; Allonby and Urquhart, 1975; Horak, 1977, 1978). It is true that some of the results of research from advanced countries bear some relevance to the solution to the problems in developing countries, but there are a number of problems which are location specific and can only be dealt with in the region where they occur.

Of the individual host types from the livestock, numerous studies have been carried out pertaining to the prevalence and seasonal change of nematode parasitic infections of goats and sheep under varying climates of several regions of the world (Joshi, 1978; Assoku, 1981; Grant, 1981; Specht, 1982; Islam, 1984; Lutu, 1984; Rose et al., 1984; Okafor, 1987). By providing meteorological data most workers demonstrated the key role of temperature and rainfall in regulating the population of parasites in the host. Similar aspects have also been studied from several parts of India (Bali, 1973, 1976; Sinha and Sahai, 1973; Misra et al., 1974; Bali and Singh, 1977; Katiyar et al., 1981; Dhar et al., 1982; Dubey et al., 1983; Gupta et al., 1987). In general, while most of these studies emphasized on the prevalence of various nematode species with particular stress on those of economic importance in various localities of India, in few of these reports the occurrence of a particular parasite species is correlated with the prevailing climatic conditions in a particular region. The species which were found to be of quite common occurrence among sheep and goats include Haemonchus contortus, Bunostomum trigonocephalum and Oesophagostumum spp. in various regions of India.

With regard to the nematodes of pigs, many reports are available which record an array of parasite species and mainly conclude that the helminth infections show regular epidemiological patterns and despite the wide variety of species involved there occurs a distinct periodicity of the parasites' occurrence in these hosts (Bindseil, 1974; Kendall, 1974; Mikhailov et al., 1981; Morris et al., 1984; Marti and Hale, 1986). Studies in this direction in India include those by Shrivastav and Shah (1968), Misra et al., (1974) and Varma et al., (1978, 1979). Verma (1983) listed Ascaris suum as the commonest infection in pigs of Manipur. Likewise, Sarma and Gogoi (1986) reported six species, with A. suum as the most prevalent species, in pigs of Kamrup district of Assam. However, the literature pertaining to the seasonal prevalence of infections in India is very scanty.

The studies related to the prevalence of nematode parasites in cattle have been made in different regions of the world (Williams et al., 1983; Zoocoller, 1983; Hunter and Heath, 1984; Hayashi et al., 1985; Vercruysee et al., 1986; Bianchin and Honer, 1987). In India those who contributed in this direction include Bhopale et al., (1971), Chauhan et al. (1973), Prasad et al., (1978), Verma and Kalra (1978), Baruah et al. (1981), Gupta and Pruthi (1982), Borkakoty et al. (1984), and Gupta et al. (1988); most of these studies pertain to northern states of India that represent a tropical climate.

The investigations on similar lines pertaining to domestic fowl have been carried out by a number of workers based on actual recovery of worms at necropsy in various regions of the world (Ssenyonga, 1982; Hayat and Hayat, 1983; Vattanodorn and Singh, 1984; Zaldivar et al., 1984; Samad et al., 1985) including India (Alavi and Ansari 1973; Gogoi, 1974; Hedge et al., 1977; Misra et al., 1980; Muralidharam and Venkataratnam, 1980; Matta and Ahluwalia, 1981; Malhotra, 1983; Srinivas et al., 1983; Malhotra and Capoor, 1984; Fotedar and Khateeb, 1986; Deb et al., 1986; Ghosh, 1986).

The state of Meghalaya, being a hilly region with green forages, is endowed with a vast potential for animal husbandry. The pigs, goats, sheep, cattle and poultry form a substantial source of animal protein for the people of the state. In the production of these animals, a problem frequently encountered is the parasitic gastroenteritis, which is supposed to be caused by nematode parasites (Okafor, 1987). The consequences are serious losses of animals, reduced productivity and loss of vitality. Despite this fact, there is meagre information available about the nature of nematode parasitic infections of livestock and poultry in the state. A stray likelihood is that considerable variations may occur in the pattern of parasitic prevalence and incidence in this area due to the diversity of physiographic and climatic conditions when compared to other regions of the world.

A study was therefore undertaken to identify the major nematode species prevalent and their seasonal variations in the food animals i.e., goats, pigs, cattle and domestic fowl of Meghalaya. It is hoped that this first phase report would provide data of value in formulating schemes for prophylaxis of parasitic infections in the region. Since the frequency of slaughter of sheep is very low in the state, these hosts are not included in the study. Further, in respect of cattle the observations are confined to only prevalence and seasonal fluctuations of the latter are not studied in view of their being of mixed geographical origin.

MATERIALS AND METHODS

Study area

The region under the East and West Khasi Hills districts (with Shillong and Nongstoin as the district headquarters, respectively) is geographically situated in the eastern and central parts of the state of Meghalaya, and lies between 25°5'N-26°10'N and 90°45'E-90°15'E (Plate 3.1) at an altitude range of 400-1600m ASL. In the present study this region was divided into two areas; a low-altitude region (400-750m) and a high-altitude region (750-1600m). The region experiences a sub-tropical monsoon climate. During the 18-month period of study (i.e., March 1986 to August 1987)the mean maximum and minimum monthly temperatures during summer were 25°6. (23.9-27.6) and 21.2°C(18.7-22.2), and during winter 17.0°C(16.5-20.1) and 10.8°C (9.6-13.4), respectively. The mean daily relative humidity at 8.30 hr was 67.4% (40-86) and at 17.30 hr, 79.5% (37-91). The rains are well distributed throughout most of the year with a very short dry season, but are comparatively heavier between April and mid-October. The average annual rainfall of the region is 400cm but in certain parts it reaches 1143cm, as recorded around Cherrapunji and Mawsynram, the world's rainiest spots (Rao and Neogi, 1980). The data for mean maximum and minimum monthly temperatures, average relative humidities and total rainfall for the study area pertaining to the survey period were procured through the meteorological station of the Indian Meteorological Department and are shown in Plate 3.2.

Animals

The investigation made between March 1986 to August, 1987 was carried out on a total of 532 domestic fowl (*Gallus domesticus* L. - mixed lot of Leghorn and Rhode Island Red breeds), 1228 goats (*Capra hircus* L.) of Assam hilly breed, 1496 domestic pigs (*Sus scrofa domestica* L.) of mostly desi breed, and 778 cattle (*Bos indicus* L. - mixed breed and of 4-6 years age group), of both sexes slaughtered (fowl procured from markets) at local abattoirs in the state.

PLATE 3.1 Study area (shown as hatched) in the state of Meghalaya

PLATE- 3.1

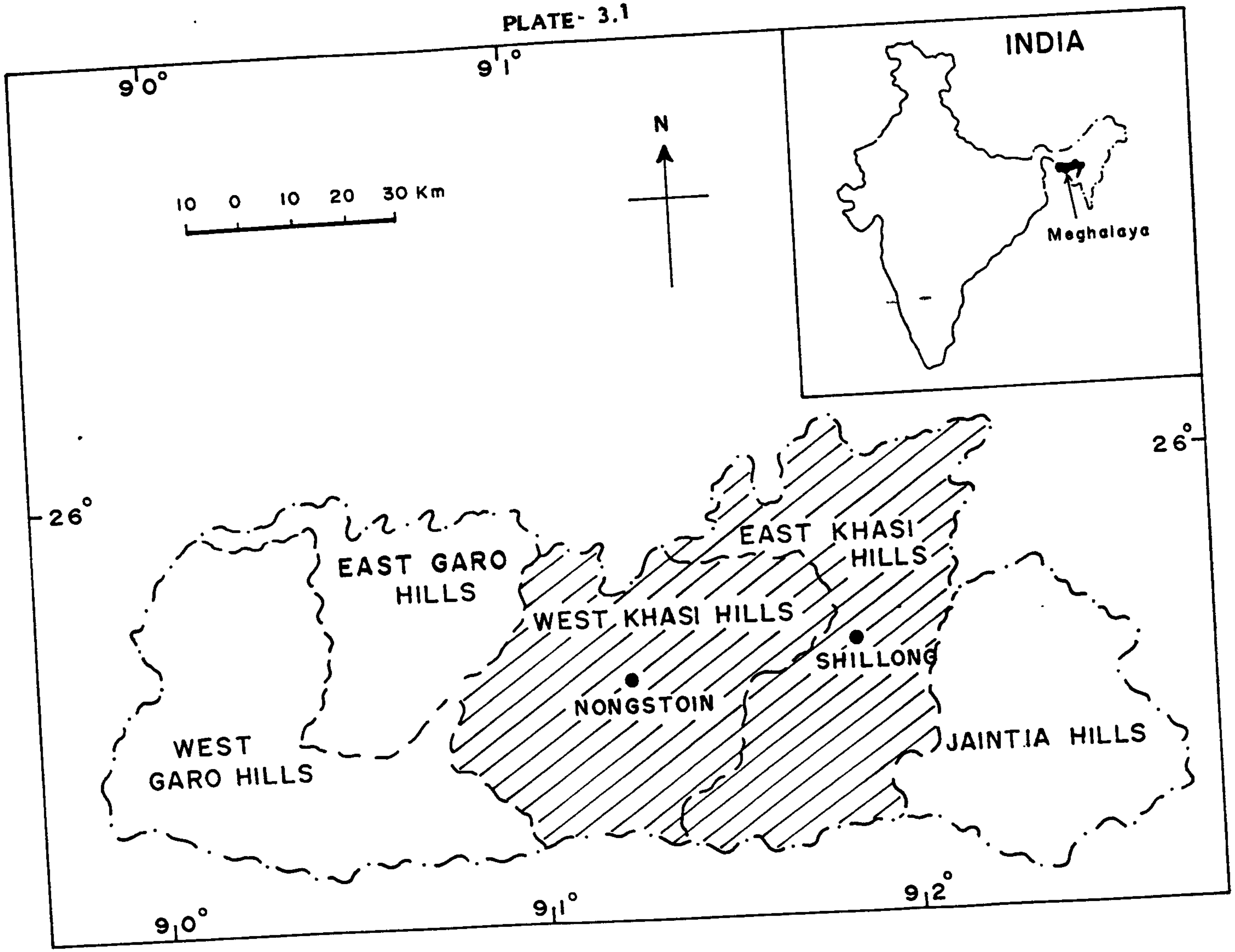
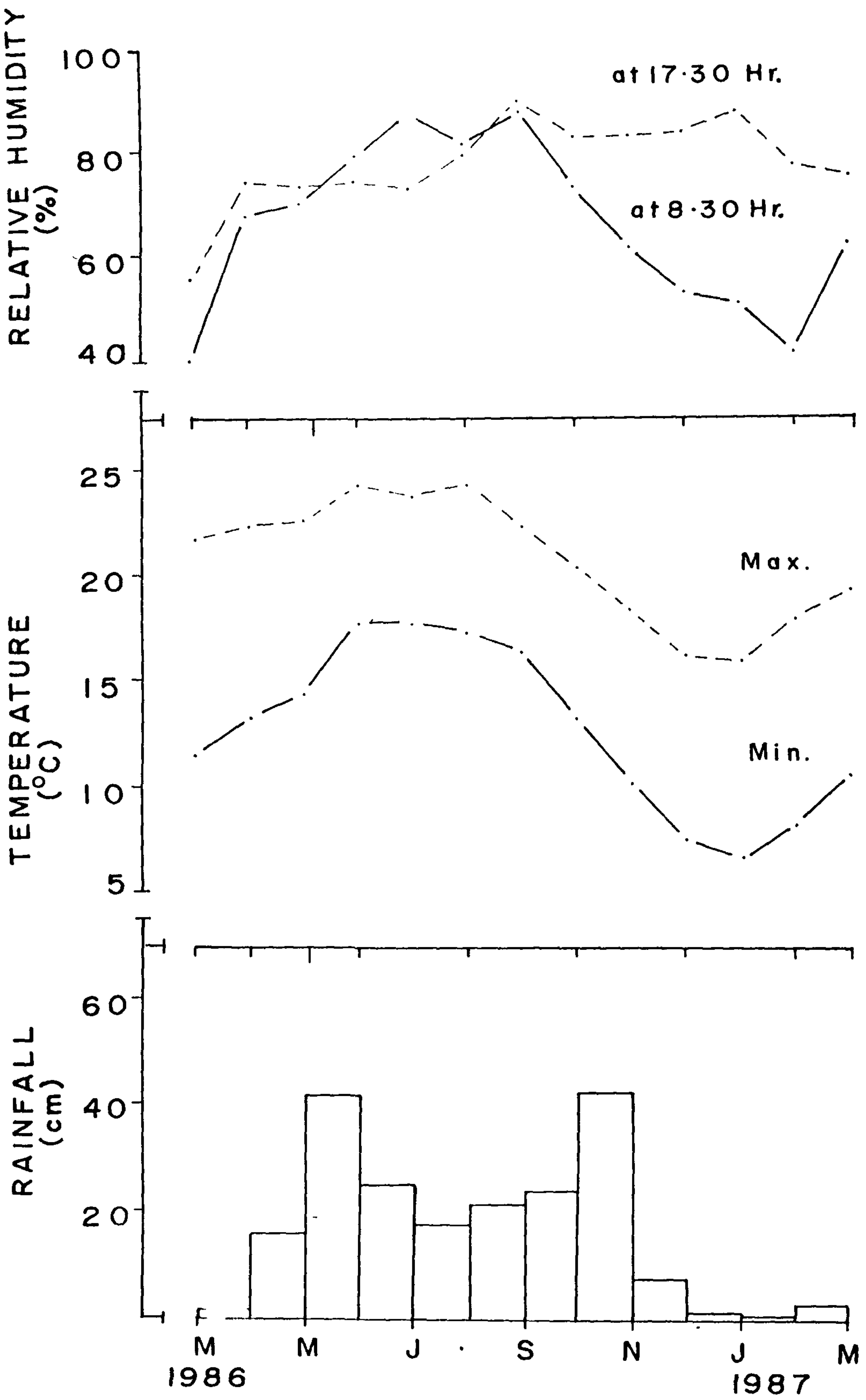

INDIA
Meghalaya
N
10 0 10 20 30 Km
9'0°
9'1°
9'2°
26°
EAST GARO HILLS
WEST GARO HILLS
WEST KHASI HILLS
EAST KHASI HILLS
JAINTIA HILLS
NONGSTOIN
SHILLONG

PLATE 3.2 Average relative humidities at 8.30 and 17.30 Hrs., mean monthly maximum and minimum temperatures and total rainfall at Shillong during the study period

PLATE- 3.2


RELATIVE HUMIDITY (%)
100
80
60
40
at 17·30 Hr.
at 8·30 Hr.
TEMPERATURE (°C)
25
20
15
10
5
Max.
Min.
RAINFALL (cm)
60
40
20
M
M
J
S
N
J
M
1986
1987

Of the mentioned animals the pigs and fowl are extensively raised by natives for meat purposes, generally on a free range system and receive very little attention from their owners. Similarly, the majority of goats slaughtered at these abattoirs are those reared by natives for food purposes; however, the stock of a mixed geographical origin is occasionally slaughtered when animals are brought from the neighbouring state of Assam to meet the increased demand. Of the cattle examined during the present study, the majority comprised those brought from the plains of Assam, while only a small section was of the locally reared animals.

Survey samples and laboratory techniques

Postmortem recovery of worms was made from the hosts as described in Chapter I. The parameters taken into consideration to analyse the data are prevalence and mean intensity, defined as per the recommendations made by an ad hoc committee of the American Society of Parasitologists (Margolis et al., 1982) as follows:

Prevalence — Number of individuals of a host species infected with a particular parasite species divided by number of hosts examined (not synonymous to the term 'Incidence', which means number of new cases of a disease or infection appearing in a population within a given period of time divided by number of uninfected individuals in the population at the beginning of the time period).

Mean intensity — Mean number of individuals of a particular parasite species per infected host in a sample.

To study the seasonal fluctuations of infections, for pigs and fowl the data were collected and analysed on the basis of the recovery of the adult worms from the hosts, while in the case of goats the study on the seasonal variation was based on the faecal worm egg counts, carried out during different times of the year. Fresh faecal samples or those collected from the rectum of the hosts were brought to the laboratory and stored at 4°C until further analysis. The examination of samples was generally performed within 48 hr of collection using a modified McMaster's salt floatation technique (Anonymous, 1977) — 3gm of sample faeces was well mixed with 42ml of distilled water and 45 glass balls in a bottle; to this added 45ml of saturated sodium chloride solution and the bottle was shaken vigorously to mix the contents; in order to remove coarse faecal material the mixture was strained through a sieve of 0.15mm aperture size; the filtrate is collected, stirred well, and sufficient drawn off with a graduated pipette in two shifts and run into two counting chambers (of 0.15ml capacity each) of McMaster slide filling all the spaces. The number of eggs per gram of faeces (EPG) is obtained by multiplying the total number of eggs counted in the two separate centimetre squares by 100. (wherever necessary a correction factor was used according to the consistency of the faeces as recommended by Soulsby (1982), i.e. initial quantity of faeces taken as per ratio of : 2gm of normal faeces, 2.5gm of soft faeces, 3gm of medium soft stool, 5gm of pultaceous stool and 7gm of watery stool). Nematode eggs recorded in the present study were exclusively strongylids.

RESULTS

Pigs

Of the 1496 domestic pigs examined, 1023 (68.38%) were found infected with one or more species of nematode parasites. No sex related prevalence was noted during the study; therefore, the prevalence of all the species recorded in this survey is presented together in Table 3.1. The most commonly occurring species in the region was Ascaris suum, followed by Oesophagostomum dentatum, Bourgelatia diducta and Stephanurus dentatus in receding order. The least prevalent species were Gnathostoma doloresi, Setaria bernardi, and Pseudocruzia orientalis which were present in <2% of the hosts examined. Ascarops stronglylina, A. dentata, Physocephalus sexalatus and Globocephalus connorfilii showed a prevalence of betwen 2.0 and 8.22%. The prevalence and seasonal fluctuations of various species recorded were also studied with regard to low- and high-altitude regions and show an inverse relationship with the altitude. The overall infection rate was considerably higher in the low altitude region than in the high-altitude region. With respect to the individual nematode species, the prevalence of some species, namely A. suum, O. dentatum, B. diducta, G. connorfilii and A. dentata was markedly higher in the low altitude region (Table 3.1). Little variation in the prevalence rate of infection between the two regions was noted in case of the other species, namely A. strongylina, S. dentatus and S. bernardi. G. doloresi was only present in the low altitude region and its rate of infection was very low.

The seasonal variations in the overall infection rate were monitored by recording the number of animals infected with one or more nematode species per quarter during one calendar year (Table 3.2). The highest level of infection was noted during autumn and the lowest in winter. Observations were also made monthwise for major contributing species in the spectrum, i.e., A. suum, O. dentatum and B. diducta (Plate 3.3). A. suum showed highest peaks in its prevalence during early summer and autumn. B. diducta also revealed almost a similar pattern during summer, following which the prevalence declined gradually to a low level during winter. In the case of O. dentatum the prevalence

TABLE 3.1 : Prevalence of nematode parasites of domestic pigs of Meghalaya

	Animals examined in the whole region (n=1496) Δ		Animals examined in low altitude region (n=632) Δ		Animals examined in high altitude region (n=864) Δ	
	No. infected	Percentage of infection	No. infected	Percentage of infection	No. infected	Percentage of infection
	1023 ΔΔ	68.38	483	76.42	540	62.50
Location/species-wise prevalence						
Stomach						
Ascarops strongylina	34	2.27	20	3.16	14	1.62
A. dentata	52	3.47	34	5.37	18	2.08
Gnathostoma doloresi	4	0.26	4	0.63	-	-
Physocephalus sexalatus	68	4.54	42	6.64	26	3.00
Small intestine						
Ascaris suum	773	51.67	422	66.77	351	40.62
Globocephalus connorfilii	123	8.22	93	14.71	30	3.47
Pseudocruzia orientalis	17	1.13	16	2.53	1	0.11
Large intestine						
Bourgelatia diducta	324	21.65	142	22.46	182	21.06
Oesophagostomum dentatum	413	27.60	303	47.94	110	12.73
Perirenal fat & ureter wall						
Stephanurus dentatus	146	9.75	51	8.06	95	10.99
Peritoneal cavity						
Setaria bernardi	12	0.80	10	1.58	2	0.23

Δ Number of animals examined.
ΔΔ Each animal may be infected with more than one nematode species.

TABLE 3.2 : Seasonal prevalence of overall nematode parasite infections in domestic pigs of Meghalaya

Season	No. of animals examined	No. of animals infected	Percentage of infection
Winter (Nov. - Jan.)	346	218	63.0
Spring (Fep. - Apr.)	428	298	69.6
Summer (May - July)	386	261	67.6
Autumn (Aug. - Oct.)	336	246	73.2

PLATE 3.3 Seasonal variations in prevalence of major nematode species infections of pigs -

Fig.1 Ascaris suum

Fig.2 Oesophagostomum dentatum (solid line); Bourgelatia diducta (broken line)

PLATE-3·3

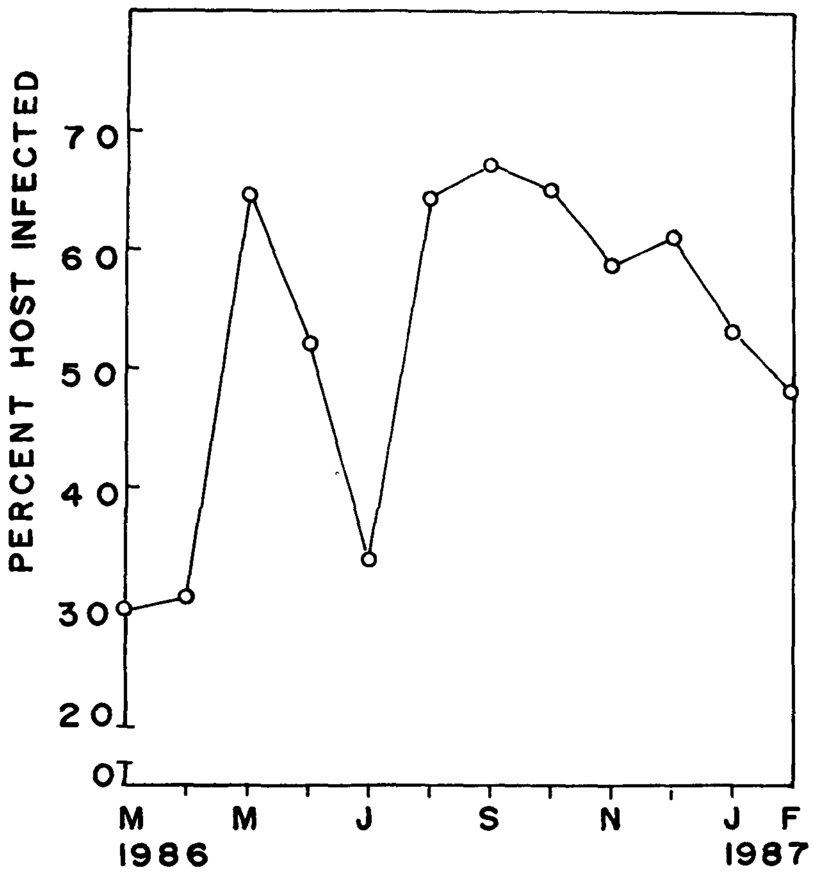


FIG.1.

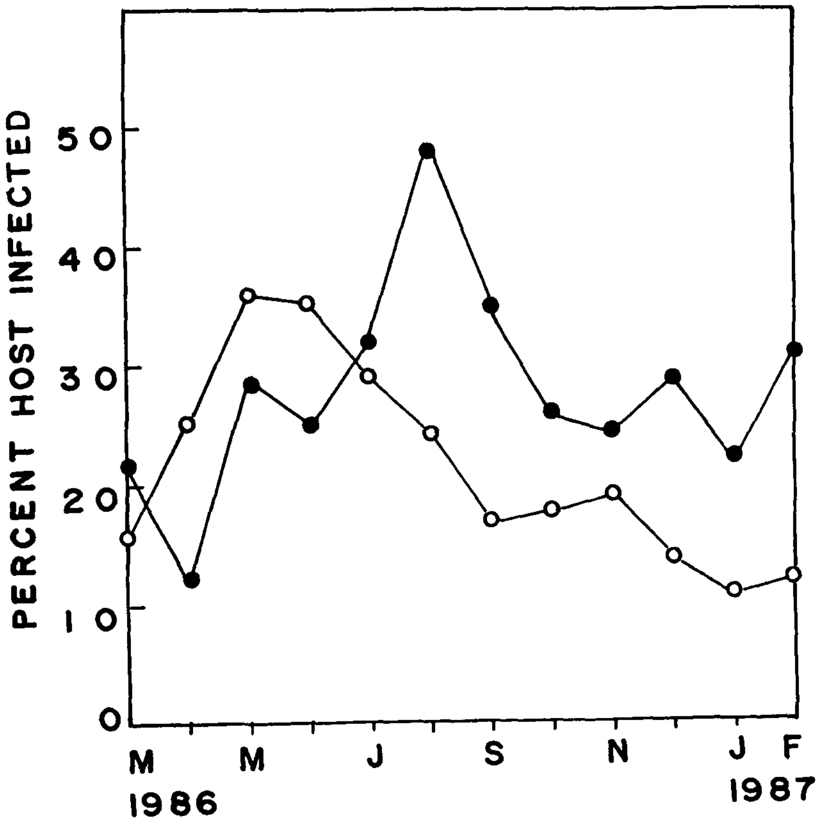


FIG.2.

registered a rising trend from the start of summer with its peak during early autumn (August), following which again a declining trend was evident reaching to its minimum value during late wintẹr (January).

Goats

Of the total of 1228 goats examined during this study, 1066 (86.8%) were found to be infected with one or more species of nematode parasites (Table 3.3). The survey recorded the presence of a total of 6 nematode species, which arranged in descending order of their prevalence are Haemonchus contortus (52.7%), Bunostomum trigonocephalum (41.7%), Oesophagostomum columbianum (384%), Trichuris globulosa (24.3%), O. aspersum (19.6%) and T. ovis (3.5%).

The observations on seasonal fluctuations of prevalence (percent positive samples) and the mean monthly faecal egg counts for the 12-months period are summarised in Table 3.4.

The maximum value for prevalence (92%) and the overall mean EPG (4800) were recorded in October, i.e., after the period of heavy rains was over. With the beginning of the winter season from November onwards, the mean total egg count fell to a low level, steadily falling to a minimum of 150 EPG in May; it then rose sharply with the increase in rainfall. The prevalence did not show a marked seasonal pattern in the present study. However, it was at a minimum (47%) during May at the onset of summer season and higher levels were recorded during late autumn and early winter months.

Fowl

Of the total of 532 domestic fowl examined during this study, 418 (78.57%) were found to be infected with one or more species of nematode

TABLE 3.3 : Prevalence of nematodes parasites in goats (n=1228) of Meghalaya

Location /Species	No. of animals infected	Percentage of infection
Abomasum		
Haemonchus contortus	647	52.7
Small Intestine		
Bunostomum trigonocephalum	512	41.7
Large Intestine		
Oesophagostomum columbianum	472	38.4
O. aspersum	241	19.6
Trichuris globulosa	298	24.3
T. ovis	43	3.5

TABLE 3.4 : **Monthly EPG of gastro-intestinal nematodes in goats of Meghalaya**

Month	Number examined	Percent positive	Mean EPG	Range of Mode
March 1986	192	56	200	200-500
April 1986	135	60	400	200-500
May 1986	120	47	150	100-200
June 1986	136	58	550	300-600
July 1986	129	60	1100	700-1000
August 1986	102	52	1800	1600-2000
September 1986	142	60	2500	2100-5000
October 1986	120	91	4800	2000-5000
November 1986	126	88	2600	2000-5000
December 1986	128	80	1000	800-1000
January 1987	130	64	450	200-500
February 1987	178	58	300	200-500

parasites. The prevalence and intensity of various species infecting fowl are presented in Table 3.5.

A total of 4 nematode species was recorded. These, arranged in descending order of their prevalence are Ascaridia galli (60.5%), Heterakis gallinae (40.9%), Capillaria contorta (25.1%) and Strongyloides sp. (0.1%).

To study the impact of various seasons on nematode infections, observations were made monthwise on the prevalence and mean intensity of infection for two major component species of the spectrum, i.e., A. galli and H. gallinae, during one annual cycle (Plate 34). Both the species exhibited highest peaks in their prevalence and intensity during summer. However, in the case of Ascaridia while the prevalence showed a rise and declining trend at monthly intervals, the intensity of infection declined gradually to a low level during early autumn (August). In the case of Heterakis both prevalence and intensity declined gradually, reaching a minimum during late autumn (September-October), following which again a rise was evident with another peak during winter (December).

Cattle

Of the total of 778 cattle examined, 376 (48.32%) were found to be infected with one or more species of nematode parasites (Table 3.6). Four species of nematodes were recovered during this study. The filarid, Setaria digitata, was the most commonly occurring species followed by Oesophagostomum radiatum and Mecistocirrus digitatus, which occurred at a low profile and were present in 1.54% and 0.77% of the hosts examined, respectively. Haemonchus contortus was the rarest species which occurred in 4 (0.51%) of the hosts examined.

TABLE 3.5: Prevalence and intensity of nematode species in domestic fowl (n=532)$^{\Delta}$ of Meghalaya.

Location / Species-wise prevalence	No. of birds infected			Percentage of infection	Intensity $^{\Delta\Delta}$	
	Pure	Mixed	Total		Mean ± S.E.	Range
Intestine						
Ascaridia galli	69	253	322	60.5	11±0.68	1-68
Heterakis gallinae	21	197	218	40.9	16±1.72	1-126
Caecum						
Capillaria contorta	8	126	134	25.1	6±0.47	1-18
Strongyloides sp.	-	1	1	0.1	1±0	1

$\Delta\Delta$ Number of worms per infected bird.

PLATE 3.4 Seasonal variations in prevalence (P, solid line) and mean intensity (I, broken line) of major nematode species infections in fowl

Fig.1 Ascaridia galli

Fig.2 Heterakis gallinae

PLATE-3·4

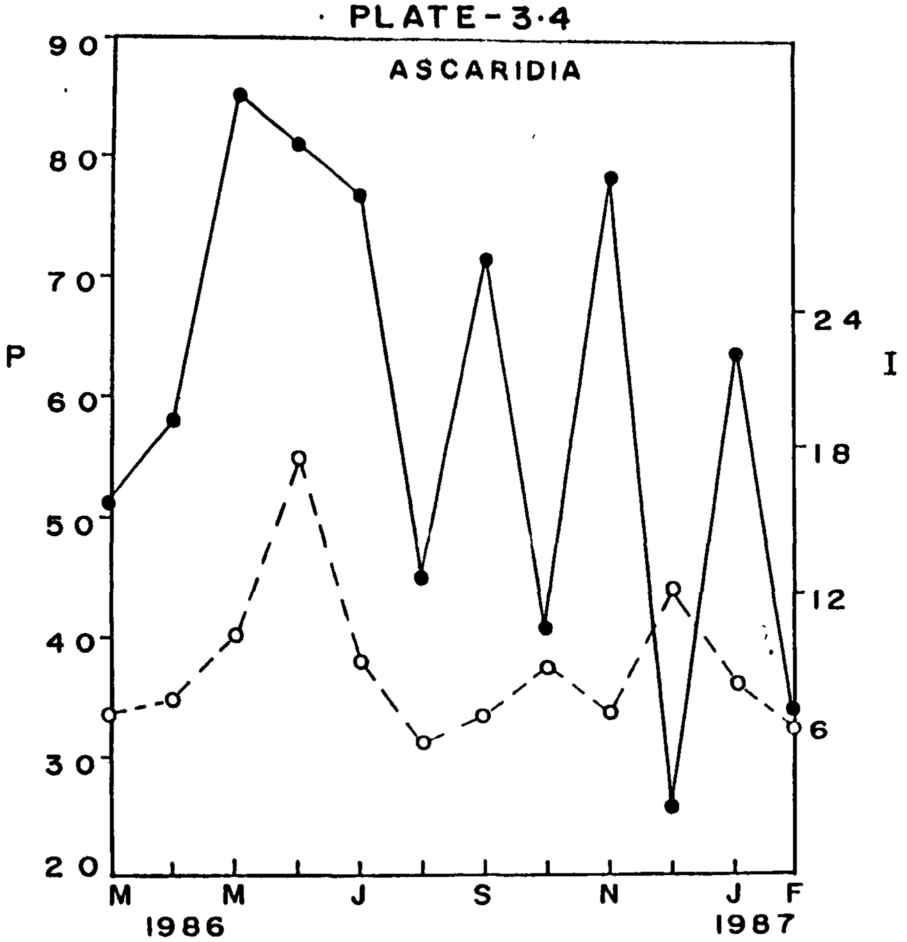


FIG.1.

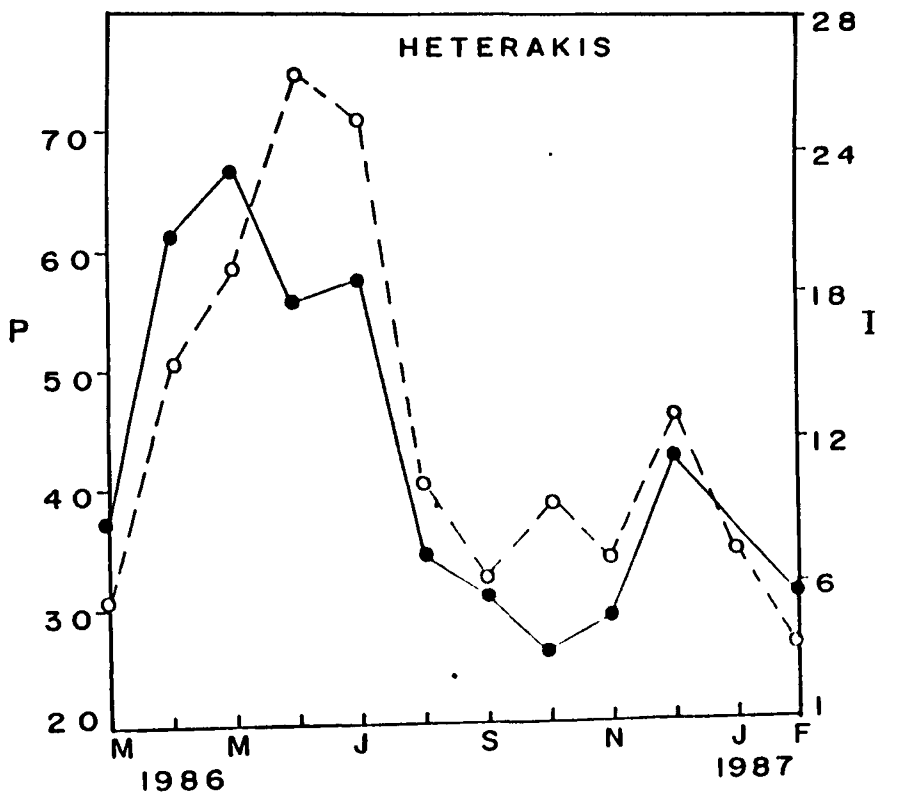


FIG.2.

TABLE 3.6: Prevalence of nematode parasites of cattle (n=778)$^{\Delta}$ of Meghalaya.

Location/species-wise prevalence	No. of animals infected	Percentage of infection
Small intestine		
Oesophagostomum radiatum	12	1.54
Mecistocirrus digitatus	6	0.77
Haemonchus contortus	4	0.51
Peritoneal cavity		
Setaria digitata	372	47.81

DISCUSSION

This study was aimed at determining the prevalence of nematode parasite species and also to record seasonal fluctuations in infections as monitored by faecal eggs and/or adult worm counts in the animals of food value under the climatic conditions of Meghalaya, a sub-tropical and high-rainfall area of India. The kind and nature of nematode parasite infections in the respective hosts, i.e., pig, goat, poultry and cattle and the seasonal patterns of infections in the former three hosts are discussed separately in the following account:

Pigs

During the present survey eleven species of nematodes were found, ten of which have previously been reported, while S. bernardi is reported herein for the first time from domestic pigs in India. Of the other species, although P. orientalis and G. doloresi have been earlier reported from Calcutta (Maplestone, 1930b), recent surveys pertaining to several regions fo the country do not indicate their occurrence in these hosts (Varma et al., 1977, 1979; Verma, 1983; Sarma and Gogoi, 1986). It is worth mentioning here that P. orientalis, G. doloresi, G. connorfilii and B. diducta were not encountered during earlier screenings of pigs for helminth parasites in the neighbouring state of Assam (Endrejat, 1964; Sarma and Gogoi, 1986), whereas certain other species, such as Simondsia paradoxa and Trichuris suis were recorded by these workers. These differences may be due to the climatic differences of the two regions. The findings of the present survey are close to those of Shoho and Machida (1979), who reported the nematode parasites of wild boars from Japan. Except for Capillaria riukiuensis, all the other species recorded by them have also been encountered in pigs of the region under the present study. The findings of the present study are also in agreement with those of Misra et al. (1972) and Morris et al. (1984) who studied the gastro-intestinal parasitism in Bhubaneswar (India) and Oklahoma swine and found Ascaris spp. and or O. dentatum to be the most prevalent worm types in their helminth spectrum, respectively.

In the present investigation the overall nematode infection rate was found to be 68.38%, which is more than that reported by Sarma and Gogoi (1986) for pigs in Kamrup district of Assam, representing a temperate climate. These workers also found A. suum to be the most prevalent helminth infection, although its infection rate was lower (33.8%) than that prevailing in the present study. In the pigs of Madhya Pradesh and Haryana states, A. strongylina was found to be the most prevalent helminth species (with a 87% and 100% infection rate, respectively) and P. sexalatus also constituted a fairly common infection (Shrivastav and Shah, 1968; Varma et al., 1979). However, both these species presented a low profile in the present study. The pigs of Kerala, a coastal state of India representing a rainy humid climate, were found to be infected with 14 species of nematodes (Thomas and Peter, 1975) and except for Gnathostoma doloresi and P. orientalis almost all the species encountered in the present study are also mentioned in the report of the latter authors.

The high frequency of nematode parasite infections (68.38%) in the pigs of the area under study is an indication of both a favourable environment for survival and development of pre-infective stages of nematodes and the limited veterinary care of these animals in the region. The high-rainfall in the region coupled with very short dry season results in the persistent high humidity in the environment, which satisfies the optimum requirements needed for the development of nematode eggs and, by ensuring a prolonged survival of eggs and/or larvae in the soil, enhances the possibility of host infection.

To some extent the feeding habit of pigs is also one of the factors for such a high infection rate of nematodes, Ascaris in particular, in these hosts. Information collected from various medical agencies of the region indicated a high prevalence of ascariasis in the human population of the region. As is known, establishment of cross-infections with A. suum in human hosts is possible (Takada, 1951; Kofie and Dipeolu, 1983); pigs thus appear to act as reservoir hosts for disseminating human ascariasis in the region. Furthermore, the presence in pigs of G. doloresi, which is of public health significance, is also noteworthy.

The seasonal pattern of overall nematode infections observed in the investigation is attributable to one factor - the presence of larvae in the soil during the wet season (July-September). A climate with warmth and wetness is most congenial for the majority of nematode parasites (Rogers, 1962). During the wet season there is sufficient moisture for development of the pre-parasitic stages of nematodes. Thus in the present study the highest level of infection was noted in autumn (August-October). Relatively low infections recorded during winter could be associated with the absence of or low level of infection. However, the overall seasonal pattern of prevalence of infection did not show a wide fluctuation (i.e., remained between 63.0% and 73.2%) in the present study which may be due to little variations, in the ambient temperature and widely spread rains all the year round in this area.

With regard to the seasonal patterns of dominant species in the spectrum, species of Oesophagostomum, Bourgelatia, and Ascaris could conveniently be placed broadly into two life history groups : the former two with 3 free-living larval stages, and the latter having the second larval stage within the egg which then becomes infective. The larval development in both these groups is determined by extrinsic factors such as temperature and humidity, but the difference in basic requirements for larval development and infective stage susceptibility may influence the epidemiological pattern of parasites (Levine, 1978). In case of Oesophagostomum and Bourgelatia the development requires moisture and warmth; the optimum temperature is 10-25°C (Thomas and Ferber, 1985) and so the development would be limited between April and October in this area. This probably may explain the rise and higher rates of prevalence of these species during summer and early autumn. In the context of Ascaris the moisture requirement is reported to be less vital but the optimum temperature required, the minimum being 15°C is 17-30°C (Jackson et al., 1977). Consequently, the development would be limited to a short period from June to August and this probably accounts for a comparatively high prevalence of Ascaris infection August onwards in this study.

Goats

The present study revealed that the nematode parasites spectrum of goats comprise only a few species. All the six species encountered in goats of the region are those which have commonly been reported by several workers in goats and sheep of different climatic areas of the world (Srivastava et al., 1980; Grant, 1981; Soota and Sarkar, 1981a,b; Specht, 1982; Chermette, 1983; Rose et al., 1984). However, the species of Trichostrongylus, Ostertagia, Cooperia and Strongyloides which have been reported as commonly occurring in these hosts from several parts of the world (Assoku, 1981; Grant, 1981; Chermette 1983; Islam, 1984), and also from other regions of India (Bali, 1976; Dhar et al., 1982) were not encountered in the present study.

The overall nematode infection rate of goats in the present study was found to be 86.8%, which is more than that reported by Islam (1984) for goats in Zambia (53.8%) and is quite close to that recorded in goats of Nigeria

(77.9%) by Okafor (1987). The deviation in the prevalence rate could be attributed to the differences in the climatic conditions and animal management practices of the concerned regions. H. contortus emerged as the most prevalent species (52.7%) in the region under the present study with B. trigonocephalum and O. columbianum also being common (41.7% and 38.4%, respectively). These findings are in conformity with those of Grant (1981), Specht (1982), Vercruysee (1983) and Okafor (1987) who studied the nematode parasites of goats and sheep in Zimbabwe, South Mozambique, Senegal and Nigeria, respectively. The present findings are also close to those of Bali and Singh (1977) and Katiyar et al. (1981) who reported H. contortus and B. trigonocephalum as the most common species in goats of Hissar (Haryana), and sheep of Sikkim, respectively which represent a subhumid tropical climate. It is stated that heavy infections of H. contortus in sheep are dependent on a total monthly rainfall of 50mm and a monthly mean temperature above 18°C (Gordon, 1950). In this region of the country such conditions prevail from May onwards and further, a relatively short generation interval probably enable H. contortus to take rapid advantage of favourable climatic conditions (Grant, 1981), as manifested by its high prevalence in the present study. The warm, moist summer experienced in the region seems to be well suited to the development and survival of free-living stages of the other two species namely B. trigonocephalum and O. columbianum.

A high frequency of overall nematode infections in goats of the area under study could be explained by the fact that the rains received almost throughout the year result in a high humidity in the environment because of the moderate temperature that prevails in the region. Animal parasites are favoured in such a climate (Williamson and Payne, 1978).

Seasonal fluctuations of nematode infections were monitored by faecal worm egg counts of strongylids. In the present investigations, the mean egg counts and the recovery of adult worms at necropsy indicate towards H. contortus and B. trigonocephalum being the most predominant species infecting goats in this area. It is generally considered that heavy infections (2000-3000 adult worms) of H. contortus are particularly favoured by an adequate rainfall and a high mean monthly temperature and are very common in rainy season (Levine, 1963; Vercruysse, 1983; McCulloch et al., 1986). In this region of the country, such condition prevail from March onwards. In the case of O. columbianum, 200-300 adult worms constitute a severe infection, which is more common in late wet season (Grant, 1981). It is likely that the higher egg output of these worms contributes to an increase in the overall mean EPG value from July to November (late wet season). It is assumed that in these hosts infestation builds up slowly with the onset of favourable micro-environmental conditions from May onwards and reached a peak during October (EPG 4,800). The comparatively low mean EPG value observed from January to June might be correlated with the beginning of a drier season (the worms remaining in an arrested stage during the adverse dry environmental conditions and resuming their development in spring) and/or more possibly with the self-cure phenomenon stimulated by the host (Soulsby, 1982). Specht (1982) also observed that H. contortus and B. trigonocephalum are the most prevalent worm species in sheep and goats of south Mozambique, which contributed significantly to a rise in EPG with the onset of rainy season and then showed a declining trend, with the start of a drier season.

Fowl

During the present survey 4 species of nematodes were recorded, three of which have commonly been reported from poultry in several other regions of India (Gogoi, 1974; Fotedar and Khateeb, 1986) and of the world (Bavia *et al.*, 1980; Ssenyonga, 1982; Vattanodorn and Singh, 1984; Samad *et al.*, 1985), while *Capillaria contorta* is reported herein for the first time from domestic fowl in India. The investigation revealed a significantly high rate of overall infection in domestic fowl of the region. This agrees with the findings of Gogoi (1974) who reported 74.3% overall prevalence of helminths in fowl of the neighbouring state of Assam, which represents a humid to temperate climate. *A. galli* and *H. gallinae* emerged as the major species of the spectrum in fowl of this region. On the contrary a relatively low prevalence (46.0%) of *A. galli* with no occurrence of *H. gallinae* is reported from Rajasthan, a semi-arid zone of India (Saxena and Nama, 1976). In sub-humid areas like Garhwal and Allahabad while *Ascaridia* is not reported to occur, *H. gallinae* was found to have almost similar profile as that in the present study (Malhotra *et al.*, 1982; Malhotra, 1983; Gogoi (1974) also found *A. galli* and *H. gallinae* to be the commonest species of the spectrum, though the percentage infection of the latter species was lower (27.3%) that recorded in the present study.

The influence of climate on helminth infections in domestic fowl has been reviewed by several workers (Malhotra and Capoor, 1984; Fotedar and Khateeb, 1986). As stated earlier also, the possible factors for a relatively high prevalence of nematode infections may be high rainfall and moderate temperature for most part of the year in this area, resulting in a constantly high humidity in the environment. Under these conditions the survival rate of exogenous forms of the parasites is increased and dense populations of the infective stage rapidly build up on the ground. This probably enhances the possibility of host infection.

Though the present study was not intended to investigate into the impact of nematode parasites on fowl population, yet a few comments in this context seem in order. Of all the species encountered in the region, A. galli is among the serious pathogenic parasites of poultry (Soulsby, 1982) and therefore, of considerably ecological importance. A mean worm burden of 11 worms per infected host by this parasite was noted in mid summer. The presence of 15-20 worms in young hens is reported to be fatal, and even a small number of worms may lead to the weakened condition of the host (Deo, 1964). Frequent intestinal obstruction by a large number of Ascaridia worm entangled in a mass was observed at several occasions during the study. Of equal concern is also H. gallinae, the principal importance of which lies in its role as a carrier of the protozoan, Histomonas meleagridis, the causal agent of the black-head disease of poultry.

The prevalence and intensity of the two major nematode species studied herein did not show a wide fluctuation and a relatively constant level of prevalence of infection was maintained for most part of the year. The region lacks the extreme climatic condition (where the monthly maximum and minimum temperatures do not fluctuate much) which possibly accounts for the continous recruitment and simultaneous loss of worms round the year and hence a steady rate of infection, as observed in the present study. However, A. galli and H. gallinae (both having a direct life cycle) exhibited highest peaks in their prevalence and intensity during summer. This seems to be related to the commencement and maximum recruitment of infection due to more optimum climatic conditions available during that period. The present finding gains support from Malhotra and Capoor (1984) who reported a higher prevalence of nematode infections during summer in poultry of Garhwal. Fotedar and Khateeb (1986) also reported the first peak in nematode infections during summer and another in winter in fowl of Kashmir, as recorded in the present study as well. While the Ascaridia infections showed a sporadic trend of prevalence throughout the year, their intensity showed yet another peak during winter. Heterakis also exhibited a sharp peak both for prevalence and intensity during the same period. This observation agrees closely with that of Malhotra (1983), who found almost a similar seasonal trend for Heterakis sp. infections in poultry of Garhwal (Uttar Pradesh). Factors like feeding behaviour, physiology, sex and age of the host may have a role in influencing the recruitment of infection and the periodicity of parasites occurrence (Malhotra, 1983).

Cattle

From the results of the present work it appears that the nematode fauna of cattle in this area is characterized by only a few species. With the exception of S. digitata, which was found to be the most prevalent species, the other species recovered during the survey have been reported to be of common occurrence in cattle from various other regions of India (Bhopale et al., 1971; Soota and Sarkar, 1981a, Borkakoty et al., 1984) and of the world Hendorson and Kelly, 1978; Hayashi et al., 1985; Bianchin and Honer, 1987), though with a different prevalence rate. Of more significance in this region was a high prevalence of the filarid Setaria, species of which are serious pathogen of livestock animals. The present finding is in conformity with that of Endrejat (1964) who reported Setaria sp. as the most common parasite in cattle of Assam; however, other species such as those of Bunostomum, Trichuris, Trichostrongylus and Dictyocaulus recorded by latter author were not recorded in cattle of the region under present study. This may be due to the climatic differences of the two regions. The present findings do not match with recent reports of Borkakoty et al. (1984) pertaining to the incidence of gastro-intestinal parasitic infections in cattle of Kamrup District of Assam. The latter authors recorded an infection with ten species of nematodes with Haemonchus, Cooperia and Mecistocirrus being the common elements of the spectrum.

It is worth mentioning here that among the natives of the state, rearing of cattle is rather a very uncommon practice. The cattle slaughtered at various places in the state mainly represent a mixed population, originating from different ecological zones, such as plains of Assam, Bihar and Uttar Pradesh. This probably may explain as to why the cattle examined in this area harboured only a few species of nematode parasites. Of more interest and importance in this context seems the role of cattle imported from these places as reservoirs of infection for the animals of indigeneous stock. The cattle brought from outside are slaughtered according to the demand in the market and therefore are maintained for months together in close association with local animals. Rivera et al.(1983) stated that the most of the nematodes infecting cattle develop better in temperatures from 10 to 25°C and rainfall close to 50mm per month, the climatic conditions which prevail in this region also for major part of the year. It seems a fair possibility that faecal pollution by the imported cattle in this area may contribute to the source of infection to the animals of the local stock.

In conclusion, it is apparent that in the humid sub-tropical environment of India, following are the major nematode parasite infections which could be the main constraints to the production of livestock and poultry in the humid areas: A. suum, O. dentatum, and B. diducta in pigs; H. contortus,

B. trigonocephalum, and O. columbianum in goats; S. digitata in cattle; and A. galli and H. gallinae in fowl. As a sequal of the present studies investigation into their transmission dynamics in prevailing climatic conditions needs to be undertaken in detail.

CHAPTER IV

PLAUSIBLE FACTORS OF ZOONOTIC IMPORTANCE

INTRODUCTION

The problem of helminthozoonoses as such has drawn considerable attention of workers in recent years and is now emerging as a major dread of risk to which mankind is exposed. There is a chain of factors — of host, causative agent and the environment, that interplay and influence the endemicity and transmission of parasitic zoonoses within a geographical area.

Animals such as pigs, dogs and cattle (that form a part of biocoenosis) act as definitive hosts for a variety of helminth parasites which, in turn, also identify these animals as potential reservoirs of parasitic infections of public health significance (Gualazzi et al., 1986). A perusal of the literature reveals that sufficient importance has not been ascribed to these parasites both from epidemiological and zoonotic points of view in India. Recent surveys of human helminthiasis in the country indicate a fairly good involvement of helminths of zoonotic importance (Das et al., 1981; Paul et al., 1982; Raina et al., 1984).

Most parasitic nematodes carry on their life cycle by the passage of their eggs or larvae in the faeces of their host, and thus contaminate the environment with many millions of their progeny. As a consequence, environmental objects, soil and vegetables in particular, act as transmitting media for parasitic infections (Marzochi, 1977a,b; Khizhhyak and Romanenko, 1979; Woodruff et al., 1981; Dunsmore et al., 1984). Studies made in this direction revealed a positive involvement of the soil in the epidemiology of zoonotic helminthiasis (Ghadirian et al., 1976; Chieffi and Müller, 1976; Dada and Lindquist, 1979; Paul et al., 1988). Studies related to parasitic contaminants on green vegetables have established these as potent transmitters of helminth infections to human hosts (Bhatia et al., 1978; Lee et al., 1978; Lin et al., 1980; Rude et al., 1984). Hookworm infections in India are reported to occur from direct contact with the polluted soil and by eating vegetables that are grown using night soil (Geldreich, 1972).

To a great extent climatic factors, such as temperature, rainfall and humidity etc., exert a strong influence on parasite eggs' development and survival and thus favour the occurrence of a particular parasitic species within a geographical area. In juxtapose when there exists a susceptive host population, too, there occurs a strong likelihood of completion of life cycle of the causative agent of parasitic zoonoses (Arambulo and Moran, 1980). In the field, several climatic factors exert their effect concurrently, which leads to an uncertainity in ascribing any effect to a specific factor. However, in the laboratory these factors can be dealt with individually to provide a reliable evidence of their influence. It is in this context that the studies pertaining to the role of climatic factors on the development have been carried out and their optimum range for egg development worked out in a variety of nematode species in many regions of the world (Perez et al., 1981; Velichkin and Burzyanstev, 1981). The egg development of ascarids was studied and the survival of infective ova also tested at various temperature regimes under laboratory conditions (Orbulescu et al., 1981; Velichkin and Troyan, 1984; Barnard et al., 1987).

Similarly, the components of socio-economic and socio-cultural environment, such as housing, occupation, food habits, age, sex etc. of human subjects have been found among the main determinants of parasite transmission and persistence (Nelson, 1972; Cravioto and Delicardie, 1976; Kochar et al., 1976; Nwosu, 1973). In India, studies made in this direction include mainly the surveys undertaken by teams of workers of Indian Council of Medical Research (ICMR), New Delhi (Biswas et al., 1978, 1980; Das et al., 1981; Datta et al., 1981; Paul et al., 1982) and reported the said factors as of great importance in the acquisition of various parasitic infections by human population. Recent country studies from south-east Asia have established that cultural and dietary habits are responsible for different prevalence of ascariasis among Indians (Crompton et al., 1985).

The present study tends to investigate into the factors that are/or could be associated with the problem of zoonoses in the state. Though preliminary in nature, the study presents a first-hand information pertaining to the problems of directly transmitted worm infections in the human population and explores the possibility of further detailed investigation into these aspects in the region.

MATERIALS AND METHODS

The bulk of the study was performed in the vicinities of Shillong and Nongstoin towns. These localities are mostly inhabited by tribal people. Use of open areas for defecating and use of paper, not water, for self cleaning are common practise among people, children in particular, of low socio-economic groups. Facilities of potable water supply are by and large very poor and the water demand is fulfilled by nearby streams. Pig raising is widely practised, and cats and dogs are kept as common pets by the natives. In addition, there exists a growing population of stray dogs in the area.

The meterological data pertaining to the study period are provided in Plate 3.2 (Chapter III).

Survey details/Laboratory procedures

To determine the prevalence of parasites of public health significance the investigation was carried out between March 1986 and June 1988. An autopsy examination of the animal hosts was done at abbattoirs in the area; besides faecal samples of dogs were collected in 3% formalin. The latter were examined by simple salt floatation technique (Wills method as described in Soulsby (1982). Two sets each of about 1gm of faecal sample were shaken well with 10-20ml of saturated sodium chloride solution in a measuring cylinder. The mixture was allowed to stand for sedimentation of coarse material; the supernatant was centrifuged at 4000 rpm for 10 min and the tubes were then taken out and filled to the top with the same solution. A clean cover slip was slid over the mouth of the tube, so that it is in contact with the liquid. It was allowed to stand for about 1 hr, following which the cover slip was picked up carefully, placed on a glass slide and examined for the presence of nematode eggs.

Ninty-eight samples of soil were collected from children parks, house yards and places near piggeries. A total of 72 vegetables which are commonly eaten raw (i.e., salad vegetables, like cabbage, lettuce, carrot, spinach) were collected, mostly directly from fields, a few samples also procured from the local markets. The procedure for the detection of eggs/larvae was almost similar to that followed in the case of faecal samples. Of the soil samples collected from each locality 2 replicates were processed by mixing one part of soil with 10 parts of water; for vegetables, the leaves were brush-scrubbed in approximately 200ml of distilled water; the soil suspension/vegetable wash was processed further for salt floatation technique. The eggs/larvae were identified according to morphological criteria (Soulsby, 1982).

To observe the effect of climatic factors prevailing in the region on the parasite's egg development, Ascaris suum was chosen as the model material. The fertilized eggs collected from the specimens obtained through freshly slaughtered pigs were suspended in 0.5 N NaOH containing 10% sodium hypochlorite for about 24 hr at 30°C (Cleeland and Lauren, 1962); eggs were then washed gently in physiological saline and incubated in petri dishes, containing sand sterilized at 60°C for 48 hr in a climatic chamber at various temperature and relative humidity (r.h.); two sets of temperature and humidity conditions (i.e., 13±1°C/64±1% r.h. and 20±1°C/83±1% r.h.) used for incubation of eggs in general represent the average conditions prevailing in the region between the second and third (April-September), and the last and first quarters (October-March), respectively of the year. One set of eggs kept at 28±1°C/90±1% r.h. served as control. To investigate the influence of soil pH on egg development pH values of 5.0-9.0 were maintained using phosphate buffers, and the temperature was kept controlled at 28±1°C. The process of egg development was observed at 2-3 days interval by taking a little amount of sand and separating the eggs under development by simple falt floatation technique as described earlier. Whenever necessary a small amount of water was showered to keep the sand moist; eggs were aerated by rotating the sand in petri dish daily.

In order to determine the possible relationship between the prevalence of infection and the socio-economic status of the people, for a period of three months data were collected for Ascaris infections among persons visiting the Civil Hospital, Nongstoin for treatment of possible worm infections. Stool samples of these individuals were examined by the direct smear method (Paul et al., 1982). The variables taken into account include the age, sex, occupation, and place of living of the subjects.

OBSERVATIONS

The nematode parasites of zoonotic importance recorded during the survey with their prevalence rate are listed in Table 4.1. Toxocara canis was the most prevalent species; though the prevalence of Ascaris suum, Gnathostoma spinigerum and Ancylostoma caninum was also considerably high (Plate 4.1).

The findings related to the survey of soils and vegetables for nemic eggs/larvae are summarised in Tables 4.2 and 4.3. Of the soil samples, 63 (64.3%) were found to contain one or more nematode eggs. The most prevalent contamination was by the eggs of Ascaris, followed in receding order of prevalence by the eggs of Toxocara, Ancylostoma and Enterobius, and Strongyloides larvae. Among the various localities surveyed the prevalence of Ascaris, Strongyloides and Enterobius egg and/or larvae was highest in soils of the places near piggeries, while Toxocara and Ancylostoma eggs were the most common contaminants in soils of children's parks. Of the vegetable samples monitored, nematodes eggs were detected in 73.6%. Ascaris eggs were the most commonly occuring contaminants followed in receding order of prevalence by the species of Strongyloides (larvae), Toxocara, Ancylostoma and Enterobius.

The findings of the effect of various climatic factors with regard to the development/survival of Ascaris eggs are summarised in Tables 4.4 and 4.5 (Plates 4.2 and 4.3).

The eggs incubated at 28±1°C/90±1% r.h. (control) showed formation of infective L-3 stage between 22-25 days. In context of the prevailing climatic conditions, eggs incubated at 20±1°C and 83±1% r.h. showed infective stages between 48-52 days, whereas those at 13±1°C and 64±1% r.h. failed to reach the L-3 stage and degenerated between 60-80 days. Similarly, for eggs incubated

TABLE 4.1: Prevalence of nematode parasites of public health significance in domestic animals of Meghalaya.

Host	Parasite	Percentage prevalence*
Pig	*Ascaris suum*	51.67
	Gnathostoma doloresi	0.26
Dog	*Toxocara canis*	69.0
	Ancylostoma caninum	47.2
	Gnathostoma spinigerum	50.9
	Ascaris sp.	5.4
Fowl	*Strongyloides* sp.	0.1

Percentage prevalence of infection in pigs and fowl based on 1496 and 532 autopsies, respectively and that of dogs based on 9 necropsies and 46 faecal samples.

TABLE 4.2: Prevalence of nematode eggs/larvae of significance to public health in soil samples (n=98)ΔΔ of Meghalaya.

Eggs/ larvaeΔΔ	No. (%) of positive samples	No.(%) positive in children's parks (n=31)Δ	No.(%) positive in house yards (n=34)Δ	No.(%) positive in places near piggeries (n=33)Δ
Ascaris sp.	36 (36.7)	7 (22.6)	12(35.3)	17 (51.5)
Toxocara sp.	16 (16.3)	8 (25.8)	4(11.8)	4 (12.1)
Ancylostoma sp.	14 (14.3)	6 (19.3)	4(11.8)	4 (12.1)
Enterobius sp.	11 (11.2)	3 (9.7)	3(8.8)	5 (15.1)
*Strongyloides*ΔΔ sp.	10 (10.2)	3 (9.7)	1(2.9)	6 (18.2)

Δ Number of samples examined.

TABLE 4.3: **Prevalence of nematode eggs/larvae of significance to public health in vegetable samples (n=72)$^{\Delta}$ of Meghalaya.**

Eggs/larvae $^{\Delta\Delta}$	No. of samples positive	Percentage of infection
Ascaris sp.	45	62.5
Strongyloides$^{\Delta\Delta}$ sp.	12	16.7
Toxocara sp.	10	13.9
Ancylostoma sp.	8	11.1
Enterobius sp.	7	9.7

PLATE 4.1 **Nematodes eggs/larvae* of significance to public health recovered in soil and vegetable samples of Meghalaya (Photomicrographs)**

A. _Ascaris_ sp. B. _Ancylostoma_ sp.

C. _Toxocara_ sp. D. _Strongyloides_* sp.

E. Enterobius sp. (scale bar = 0.05mm)

PLATE 4.1

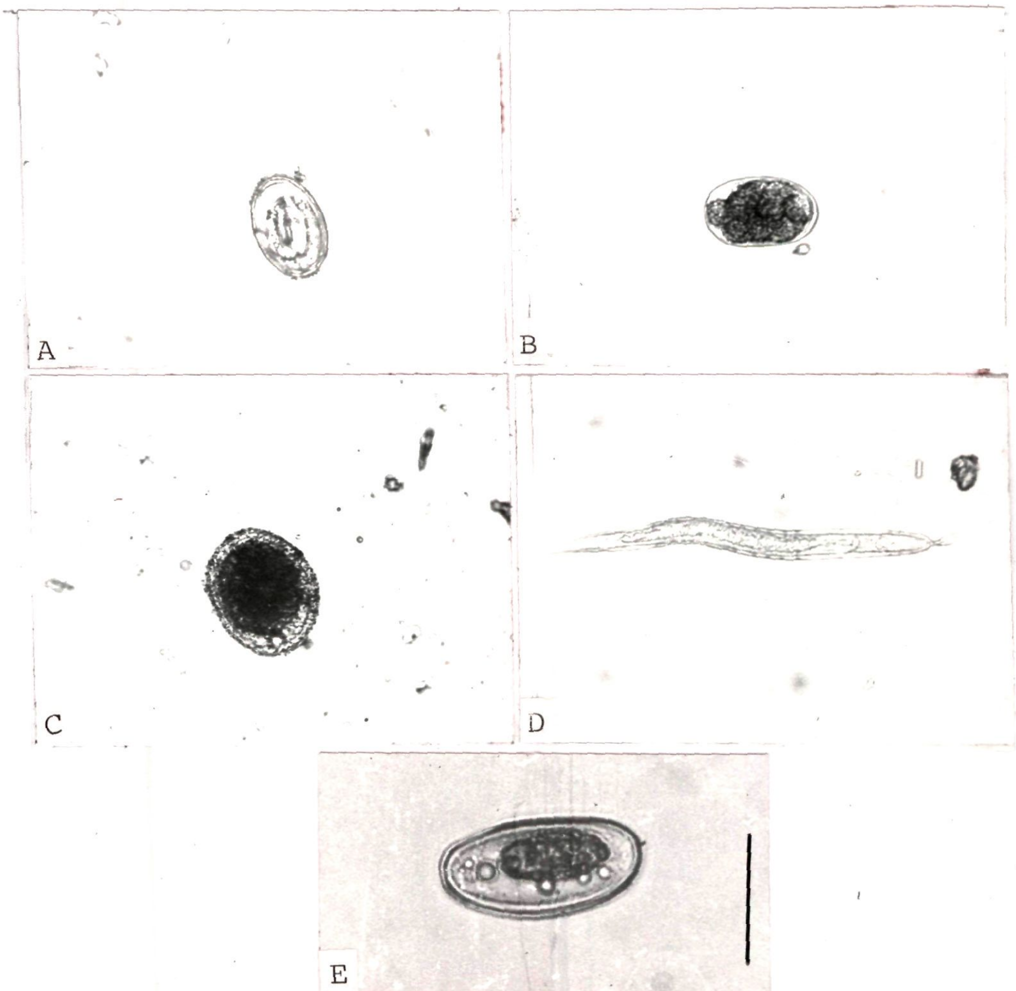


TABLE 4.4: Length of time take by *Ascaris* egg to reach infective stage at various climatic conditions.

Parameters	Time taken (in days)
Temperature/Relative humidity	
28±1°C / 90±1%	22 - 25
20±1°C / 83±1%	48 - 52
13±1°C / 64±1%	-*
Relative humidity (±1%)**	
40	-*
60	-*
80	26 - 27
100	30
Soil pH ***	
5.0	26 - 30
7.0	29 - 34
9.0	30 - 42

TABLE 4.5: Survival of infective *Ascaris* eggs at various relative humidities**

Relative humidity (±1%)	Survival (in days)
40	4 - 5
60	7 - 10
80	-§
100	-§

* No development, eggs degenerated after 40-80 days.
** Incubating temperature 28°1°C
***Incubating temperature and relative humidity 28±1°C and 90±1%, respectively.

§ No mortality till 120 days.

PLATE 4.2 **Patterns of egg development of <u>Ascaris suum</u>**

Fig.1 Development stages

A. Fertilized egg B. Two-cell stage
C. Four-cell stage D. Eight-cell stage
E. Early morula stage F. Late morula stage
G. Gastrula stage H-I. Eggs containing L_1 and L_3 stages
J. Infective L_3 stage (scale bar = 0.05mm)

Fig. 2 Various Degeneration stages

A. Vacuolar formation B. Granular degeneration
C. Degeneration noticed at early development stages (scale bar = 0.05mm).

PLATE 4.2

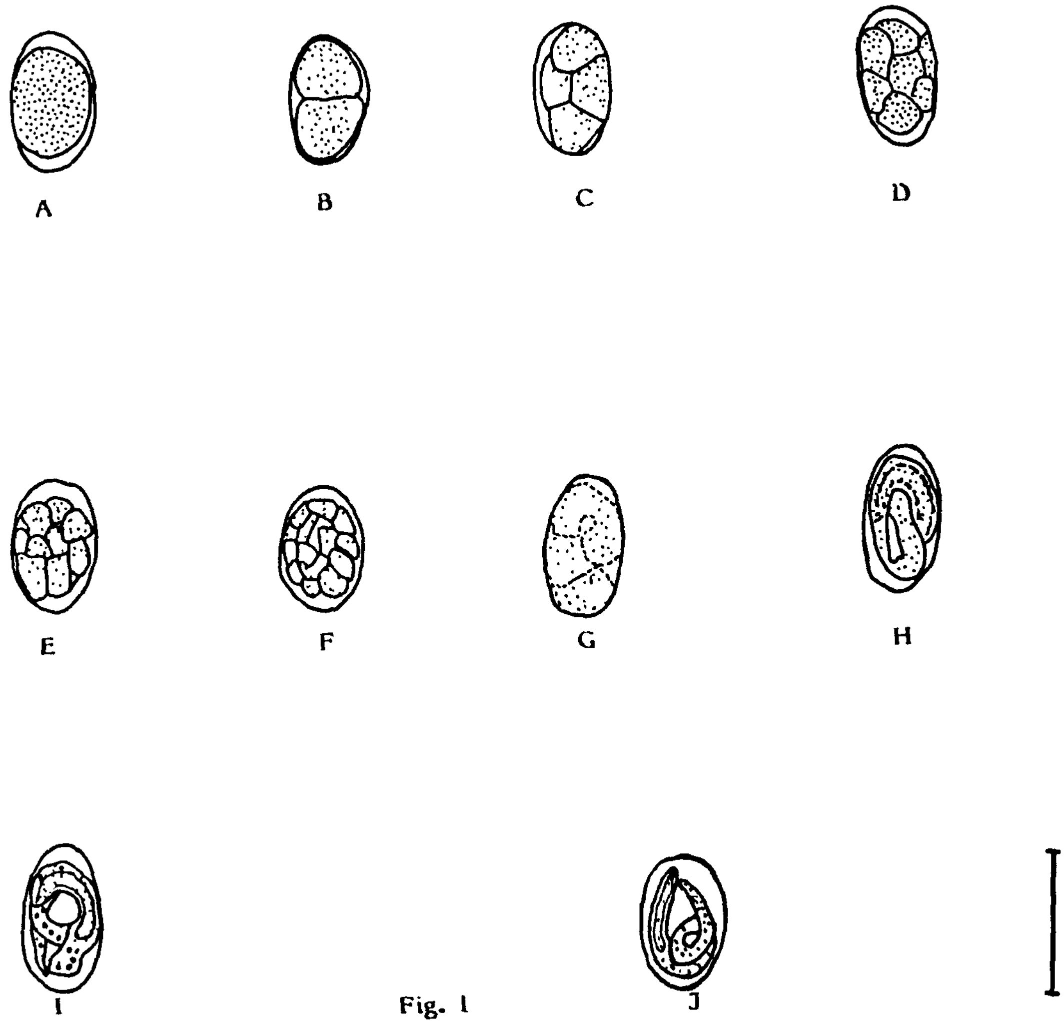


Fig. 1

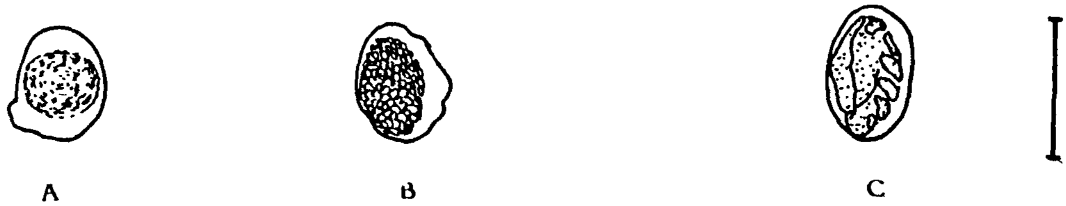
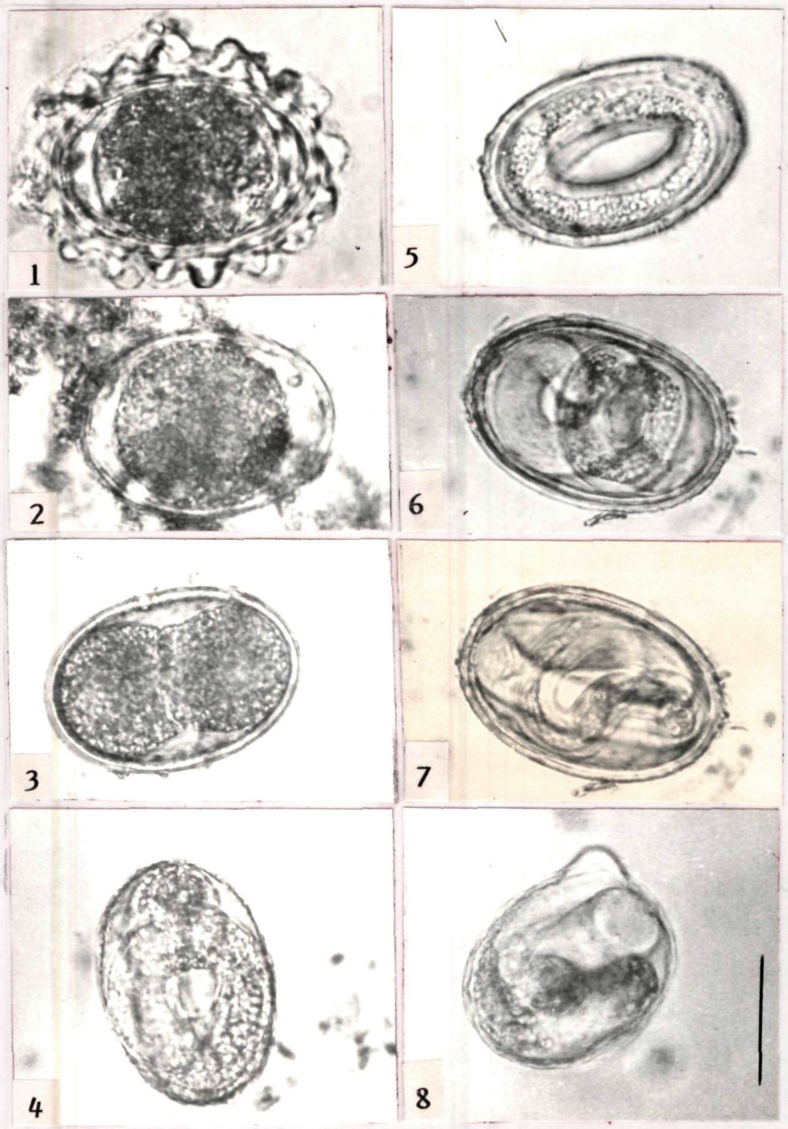


Fig. 2

PLATE 4.3 Patterns of egg development of _Ascaris suum_ (Photomicrographs)

1. Fertilized egg. 2. An initial embryonation stage.
3. Two-cell stage 4. Early morula stage
5. Late morula stage 6. L_1 stage
7. Infective egg containing L_3 stage
8. Degeneration noticed at an early development stage
(Scale bar = 0.03 mm)

PLATE 4.3



at different r.h. keeping the temperature constant, eggs could not develop to infective stage at r.h. 40-60% and degenerated between 40-80 days, whereas those incubated at 80±1 and 100% r.h. did develop to this stage within 26-27 and 30 days, respectively. With variations in pH of soil, the infective stages was attained relatively early (26-30 days) by eggs kept in acidic soil (pH 5.0), though not much variation was noticed in the time taken to reach infectivity at other pH of soil.

The survival of infective eggs was monitored at various r.h., i.e., 40, 60, 80 and 100%. The infective eggs exposed to 40±1% and 60±1% r.h. could survive only for 4-5 and 7-10 days, respectively, whereas no mortality was noticed in case of those kept at 80±1% and 100%, till a period of 120 days (when observations were discontinued).

The data pertaining to the distribution trend of Ascaris infections in human subjects in relation to the various socio-ecological factors, are presented in Table 4.6. Of the 226 persons who reported to the hospital, 220 were found to be containing Ascaris ova in their stools.

DISCUSSION

The investigation revealed the presence of seven nematode species having zoonotic potential in the domestic animals of the state. All of these are known to cause mild to serious clinical harms when infecting man (Faust et al., 1975; Rao, 1979). However, a significantly high prevalence of species such as Ascaris, Toxocara, and Ancylostoma recorded herein is of special interest because the contaminative mode of their infection may make their transmission rather easy to human population.

TABLE 4.6: Relationship between *Ascaris* infections and socio-economic status of human subjects in Meghalaya* (n=226) $^{\Delta}$

Variables	Category : Number infected	
Sex	Male: 77 (n=81)	Female: 143 (n=145)
Community	Rural: 196 (n=199)	Urban: 24 (n=27)
Occupation	Agriculture: 132 (n=133)	Govt. Service: 88 (n=93)
Age (years)	0-10 : 188 (n=194)	11+ : 32 (n=32)

* Based on data obtained from subjects reporting for treatment of possible worm infections at health centre.

Δ Number of subjects examined.

The data collected show that soils in places of frequent human exposure and vegetables of the area seem to be potential sources of infections to the inhabitants. It seems to be of serious concern, as recent reports pertaining to the prevalence of intestinal parasites mention a common occurrence of these infections in human population of several regions of India (Paul et al., 1982; Raina et al., 1984). The prevalence rate of various nematode species encountered in the present study is either comparable to or higher than that reported in different parts of the world. Silva (1984) found Ascaris eggs as the most common parasitic contaminants in 39% of the soil samples, followed by Ancylostoma and Toxocara (in 26% and 17% samples, respectively) collected from public squares in Rio de Janeiro (Brazil). In the area under the present study also, Ascaris, the most common parasitic contaminant, was detected in 36.7% of the soil samples followed by Toxocara (16.3%) and Ancylostoma (14.3%). A considerably high prevalence of Ascaris eggs as indicated in the present data may be related to a high rate of ascariasis (51-67%) in domestic pigs of the region. Cross infection with the infective stages of Ascaris of swine origin seems a possibility, particularly when the data collected through medical agencies (detailed above) of the area revealed a very high prevalence of ascariasis in human subjects. Of the various localities surveyed, the prevalence of Toxocara was highest (25.8%) in soils of children's parks, which seems to be associated with a markedly high prevalence (64.0%) of this infection in stray dogs of the area. However, Dada and Lindquist (1979) and Paul et al. (1988) found Toxocara eggs in 20.6 and 13.7% of soil samples collected from public places and parks, respectively in the USA. The ingestion of infective stages of Toxocara and Ancylostoma spp. by children may lead to visceral or cutaneous larva migrans, respectively in them (Faust et al., 1975). Suggestedly, dogs and perhaps cats, too which act as reservoir hosts for these parasites, would play an important role in disseminating helminthozoonoses.

Of the vegetable samples, 76.3% were found to be positive for eggs of one or more nematode species in contrast to this, Bhatia et al. (1978) reported 37.6% of vegetable samples as positive for parasite eggs from a hot tropical climatic zone. Ascaris was the predominant egg type (62.5%) in vegetabgle samples examined in the present study. Rude et al. (1984) observed only 2.0-5.0% prevalence of the same in green vegetables examined in the USA. The use of human night soil is a common practice in vegetable farming of Shillong, and this probably explains the observed difference in the level of contamination in the mentioned localities. The nemic eggs of other species encountered in vegetable samples of the area are those that are reported as common contaminants of vegetables in several regions of the world with a prevalence high enough to pose a serious public health problem (Marzochi, 1977; Bhatia et al., 1978; Lin et al., 1980). The recovery of infective stages of parasites in vegetable samples indicates a distinct possibility of infection to consumers, their transmission involving an ingestive mode.

In order to determine the possible role of climatic factors characteristic of the region on the development and survival of Ascaris eggs it revealed that the eggs could complete their development only at 20±1°C/83±1% r.h.; the time taken to reach the infective stage being 48-52 days. Greberkin (1982) reported the optimum range for in vitro egg development of Ascaris to be between 16-32°C, with the lower and upper thresholds being 14.5°C and 34.0°C, respectively. From the present findings theoretically it may be speculated that under the ambient climatic conditions of the region, Ascaris eggs deposited on the soil during June to early July could complete the development and attain the infective stage in 48-52 days (i.e., later half of July-August), and such eggs would play an important role in the recruitment of infection to the community people; the eggs voided July onwards would bear no epidemiological significance since these could not complete their development during that period. In a semi-field condition study, Krasnonos and Zhakangirov (1981) by constructing nomograms, provided an account of forecast of development of *Ascaris* eggs in 8 districts of the Samarkand region, USSR; the minimum and maximum time for egg development were established between 27 and 40 days in the foothills, and between 173 and 178 days in the plain zones, respectively. In another similar kind of investigation made at Herts (U.K.), Stevenson (1979) found that the eggs introduced in the soil during summer could reach to infective stage in as short a period as 14 days; however, the development of eggs was possible only between mid-June to August (i.e., for 75 days). It is worth mentioning here that in an experiment of the influence of embryonation - temperature on the viability of infective *Ascaris* eggs, Arne (1986) reported that the larval viability and ability to penetrate the tissue *in vitro* remained maximum when eggs were incubated at 22±1°C - a temperature almost comparable to that found suitable for egg development in the region under the present study.

With regard to the influence of relative humidity the present data indicate that the eggs could attain the infective stage within 26-30 days only at r.h. 80 and 100%, Grebenkin (1982) reported that at optimum temperature, *Ascaris* egg development is possible only at r.h. between 80-90%. Similarly, Perez *et al.* (1981), while studying the development of *Heterakis* eggs, found that the same failed to reach infective stage at r.h. < 80%. In the region under the present study the mean relative humidity normally is recorded above 80% for major part of the year which is suggestive of considerably long period of favourable conditions for Ascaris egg development. No mortality of eggs at r.h. above 80% seems significant and is indicative of viable infective eggs being available in the environment for a long time.

The soil pH does not seem to have much influence on the egg development in the present study. No reports are available regarding the effect of pH on in vitro egg development. However, the hatch rate of Necator americanus was reported to be maximum at pH 6.0 (Udonsi and Alata, 1987). These authors asserted that apart from a suitable pH some other factors such as available food and the presence of certain electrolytes govern the hatching mechanism of eggs. The practical significance of the finding of relatively rapid development of eggs at pH 5.0 in the present study is that it corresponds very closely with the pH of soil (5.0-6.0) found in the area under this study (Zimba, 1986).

In view of the foregoing account it appears that though the development of Ascaris eggs is possible for a relatively short period (of about 2 months) in this region, what emerges of prime importance is the survival of eggs developed during such a short period. The prevailing temperature and humidity conditions in this region could allow for a long survival of infective eggs which in turn would increase the possibilities of infections among community people.

The study related to the prevalence of ascariasis in human subjects aimed at identifying the possible role if any, some of the socio-ecological factors in the epidemiology of directly transmitted worm infections in the state. Since the data were collected from the subjects reporting to the hospital for treatment of suspected worm infections, the findings reported herein do not reflect a real survey based on random sampling of the subjects. Because of the topography of the study area, i.e., the scattered and isolated settlements, it was not practically feasible to undertake a random survey covering a large area. However, in view of the apparently high rate of ascariasis and possibilities of cross-infection of Ascaris between human and swine population, it appeared to be of interest and importance to collect some basic informations related to the socio-economic status of infected population.

Of the 226 persons who attended the hospital for treatment of possible worm infections, 220 were found to be positive for Ascaris ova in their stools. Of the infected population, 143 were females and 77 males; a large section (196) of the infected subjects were agriculturists by occupations and belonged to the rural community and only 24 were employed in government services of urban community. Similarly of all the positive cases, markedly more (132) were agriculturists, whereas only 88 were employed in government services. Further, the majority of the infected subjects (188) were of the age group 0-10 years, while only 33 were 11+ years old.

With certain limitations, the findings of the present investigation present an overall similar pattern of infection as reported through randomly made studies on the prevalence of intestinal parasitic infections in various regions of India. In areas characterized by hilly terrains, such as Sikkim and Arunachal Pradesh the prevalence of A. lumbricoides was found to be more in younger age-group (Maitra, 1970; Paul et al., 1982). Personal hygienic habits of children are generally poor and they also consume eatables that are quite often exposed to dust and flies; thus there is more chances of their exposure to infection. Besides, change in the behavioural and occupational patterns, and possibly the immune response provoked due to previous infections in adults may be the reasons for higher prevalence of infection. Longer periods exposure in the fields also may lead to easier acquisition of parasitic infections, which may explain the extent of infection among the rural subjects. Further, the factors like lack of sanitary latrines, non-availability of safe drinking supply, and poor personal hygiene may also have some impact on the degree of infection noticed in the present study.

The case history reported herein ran over only three months duration. It is likely that many more subjects positive for Ascaris infections would have escaped diagnosis during this study. Hence, more authentic and meaningful conclusions could be derived by performing a random survey so as to assess the precise role of various socio-ecological factors in disseminating worm infections in the area.

CHAPTER V

ANTHELMINTIC EFFICACY OF *FLEMINGIA VESTITA*

INTRODUCTION

There are a number of problems associated with the endemecity and the transmission of food-borne parasitic zoonoses. Thus besides environmental circumstances, human dietary practices also perpetuate a variety of helminthic zoonoses (Arambulo and Moran, 1980). However, the same also incorporate several indigeneous methods of getting rid of worm infections. For example, in many parts of India, especially those inhabited by aboriginal tribal populations, there persists a rich folk-lore regarding the vermicidal and vermifugal properties of many foods of plant origin (Chopra et al., 1956). In Meghalaya, the natives, particularly those rural areas, follow the practice of consuming parts of several wild plants believing them to be efficacious against worm infections (Rao, 1981).

A scrutiny of the literature reveals that from time to time many plants have been put to scientific investigations for their anthelmintic efficacy either in vitro or in vivo conditions; in a few cases, their efficacy has also been compared with the synthesized anthelminics (Kirtikar and Basu, 1935; Chopra et al., 1956; Dhar et al., 1965; Arslanov and Serov, 1983). Of several hundred plants screened for their biological activity at the Central Drug Research Institute (CDRI), Lucknow (U.P.) against various helminth parasites, only a countable few, namely, Ammonum aromaticum (churampha), Anthocephalus indicus (kadam), Calamintha umbrosa (jangli pudina) and Dalbergia latifolia (itli), showed activity against Ascaridia galli, the common round worm of poultry, though in vitro (Dhar et al., 1968). Similarly, plants viz., Cynara scolymus, Nigella sativa and Cythocline lyrata cass were found to be effective against many helminths (Agarwal et al., 1979; Gakhniyan and Dzhambazon, 1979; Shrivastava, 1979). Mortality effects of the plant Lysimachia clethroides in vitro on several nematode and trematode parasites have been reported by Soh et al. (1980). Judging by clinical trials Sahu (1980) found the seeds of Butea monosperma (palsa) to be effective against Ascaris and hookworm infections in man. Ghafghazi et al. (1980-81) gave an account of activity of the aqueous extract of stem and leaves of Trigonella foenum graceum (fenugreek) in vitro against Hymenolepis nana, Syphacia obvelata, and Moniezia expansa. By estimating the faecal egg counts at necropsy, Adewunmi and Akubue (1981) reported the effectiveness of aqueous extract of Calliandra portoricensis in rats. In another study, Charoenlarp et al. (1981) found the crude extract of Artocarpus lakoocha wood effective against tapeworm infections in human populations of Thailand. Similarly, the activity of plants such as Aganosma dichotoma, Centatherum anthelminticum, Artemesia herba-alba, Butea frondosa, Carica papaya, and Aristolochia bracteata against many parasitic worms is note worthy (Sen and Datta, 1982; Irdis et al., 1982; Rao and Krishnaiah, 1982). Singh et al. (1982) tested the bark extracts of Zanthoxylum alatum (tejbal) against Ascaris lumbricoides, Fasciolopsis buski and H. nana in vitro and reported the maximum activity of the ether extract, particularly against H. nana. Garg and Kasera (1983) and Singh et al. (1983) investigated the anthelmintic effects of the essential oils of Callistemon viminalis and seeds of Aegle marmelos, respectively against several helminth parasites. An account of the efficacy and safety of Caesalpinia crista seed extracts in water and methanol against natural Neoascaris vitulorum in buffalo calves has been provided by Akhtar et al. (1985). Very recently Kalyani et al. (1989) found in vitro anthelmintic activity of an essential oil from the fruits of Zanthoxylum limonella against tape worms and hook worms and reported it to be better than that of piperazine phosphate. Most of the mentioned studies deal with the effects on the mortality and/or expulsion rate of parasitic worms; however none of these provide any information regarding the effect of the plant material on the morphology and/or histology of the worm parasite.

Flemingia vestita Benth & Hooker, locally known as soh-pholong under which name the root tubers are sold in the markets of the Khasi Hills District of Meghalaya) is used by the Meghalayan local people for curing intestinal worm infections. As a matter of fact many of its uses are not known outside the tribal community. Thus a laboratory trial seemed desirable to scientifically authenticate the plant's efficacy as anthelmintic. The present study was therefore undertaken with a view to evaluating and comparing the effectiveness of the tubers of this plant in in vitro conditions. Changes in the motility and histomorphology based on LM and SEM studies, are reported herein after in vitro exposure of the worms to varying concentrations of the crude extracts of the root tubers.

MATERIALS AND METHODS

Plant material

Flemingia vestita, a trailing herb with hirsute stem of around 80-100cm height, is considered to be a lesser known leguminous crop, which has been brought under cultivation by native population of Meghalaya. The portion of the plant that is eaten is the soft, fleshy tuberous root just below the crown. The skin of the tuber is considered to be effective against the tape worms (Singh and Arora, 1973).

Extraction and Isolation

Fresh tubers of Flemengia vestita were purchased from the local markets, washed gently with deionized water and peeled off thickly with the knife. The peel along with the fleshy pulp was heated with deionized water constantly at 50°C in a conical flask. The solution obtained in this manner was centrifuged at 5000 rpm for 30 min. The supernatant was collected and extracted with ethyl acetate. The extract was then concentrated by evaporation with sodium sulfate (anhydrous) using a hot water bath at 50-80°C. The concentrate was reduced to semi-solid state by keeping in an oven at 30-40°C for about 48 hr and then transferred into a small vial and refrigerated until testing.

Testing

Live Ascaris worms were collected in 0.9% physiological buffered saline (PBS) from pigs slaughtered at local abattoirs. The worms were washed several times in PBS and maintained in a climatic chamber at 37± 1°C as follows: six worms were distributed to each of the two petri dishes containing 100ml of medium. Dilutions of the crude extract were prepared in DMSO in PBS since 1% DMSO alone did not exhibit any activity alone (Ahmad and Nizami, 1983), and added to the medium to give final concentrations of 0.06. 0.18, and 0.36 mg/ml. 1000gm of fresh material (tubers and peel) yielded 600mg of crude concentrated extract, the concentration of which used in this study, i.e., 0.06% (0.6mg/ml), 0.18% (1.8mg/ml), and 0.36% (3.6mg/ml) represent 100, 300, and 600 gm of the fresh tubers. For comparison of the activity of the plant extract, Mebex^R (Mebendazole), a broad spectrum anthelmintic, was used as a reference substance. The latter was also dissolved in 1% DMSO and tested at concentrations similar to those of the plant extract. For each such concentration one petri dish containing 1% DMSO in the medium served as control.

The activity of the material was evaluated in terms of motility and histomorphological changes of the worm. Time taken for complete inactiveness (paralysis) of the worm was recorded and death was confirmed by dipping such worms in slightly warm water (50-55°C) which induced movements in worms still alive. Soon after the worms got paralysed, a set of those treated with 0.36% plant extract and also the controls were fixed in Bouins solution and 5% buffered neutral formalin. The Bouins-fixed material was processed for microtomy; and serial paraffin sections were cut at 6-7 µm thickness and stained with haematoxylin and eosin, whereas the specimens fixed in neutral formalin were subjected to SEM studies as described in Chapter II.

OBSERVATIONS

Motility and physical activity

The worms maintained in PBS without the tuber extract showed physical activity till a period of 78-102 hr and thereafter they became immobilized and/or died. In contrast the worms incubated in the medium containing 0.06%, 0.18%, and 0.36% tuber extracts became paralysed at 43-50, 16-18, and 5-8 hr of incubation, respectively (Table 5.1). Worms incubated in Mebendazole concentrations similar to those of plant extract showed considerably faster acquisition of paralytic state (Table 5.1).

Histomorphological studies

The surface fine topography of the worms maintained in the control medium seemed to be normal (Plate 5.1 : Figs.1,2) - the 3 prominent lips have a smooth cuticle and appearing anchoring to one another quite closely as if in a grasping state; the cuticle of the anterior extremity of the body reveals

TABLE 5.1 Effect of *Flemingia vestita* tubers extract and Mebex^{R} (Mebendazole) on motility of *Ascaris* worms *in vitro*.

Treatment	Paralysis*(in hr)	
	Flemingia vestita	Mebex^{R}
0.06%	43-50	4-6
0.18%	16-18	3-4
0.36%	5-8	2

* Worms incubated in control medium (without tuber/drug extracts) showed physical activity till 78-102 hr.

PLATE 5.1 **Anthelmintic efficacy of tuber extract of *Flemingia vestita* on *Ascaris suum*, *In vitro*.**

Figs.1-4 Scanning electron micrographs

Fig.1 Untreated worm, anterior end showing three lips in grasping stage (scale bar = 100 µm)

Fig.2 Anterior end of tuber extract treated worm, showing collapsed surface of lips and wrinkled cuticle posterior to lip region (scale bar = 100 µ m)

Fig.3 Untreated worms, pattern of cuticular ridges at anterior extremity (scale bar = 10µ m)

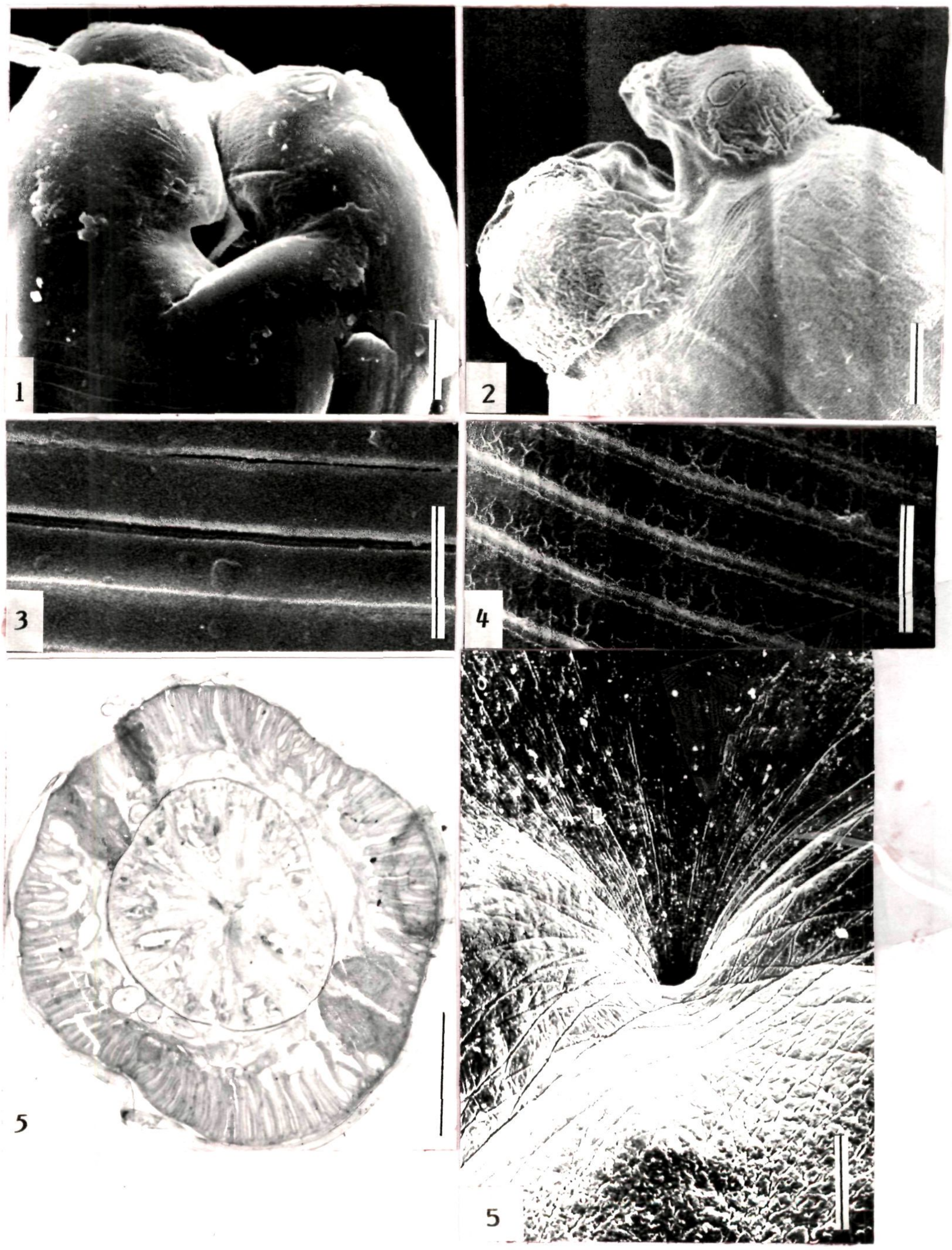
Fig.4 Treated worm, cuticular pattern at anterior extremity, distinct cracks and disorganization of transverse striations are noticed (scale bar = 10µ m)

Figs. 5-6 Light photomicrographs

Fig.5 Normal transverse section through pharyngeal region (Scale bar = 0.5mm)

Fig.6 Transverse section of the extract treated worm; note an irregular disorganization of the muscular layer (scale bar = 0.5 mm).

PLATE 5.1



quite distinct and neatly arranged regular *transverse striations. In contrast,* in the worms incubated with 0.36% concentration of tuber extract the lips appear separated from each other and loosely compresed (Plate 5.1; Figs. 3,4) with prominently wrinkled surface; at the anterior extremity the cuticle shows cracks and somewhat disorganization of the cuticulat striations. Marked difference was noticed in the histology of the worms treated with 0.36% of the extract when compared to those of the control as an irregular disorganization of the muscle layer was noticed in the former (Plate 5.1; Figs.5,6).

DISCUSSION

*Though in vivo trials carried out for preliminary screening for anthel-*mintic efficacy of plants bear more practical significance, the in vitro tests are considered to be equally useful in this regard (Ghafghazi et al., 1980-81).

In the present investigation, since an early paralysis of worms was noticed with the tuber extract concentration of 0.36%, the same concentration was selected for subsequent studies. A remarkable decrease of motility and contraction confined to the anterior extremity and lips observed after incubation for 3-7 hr with 0.36% of the tuber extract indicate that the Flemingia vestita tubers affect the motility and bring about changes in the body surface, especially of the lip and cephalic regions of Ascaris worms and thus may function as anthelmintic. Disorganization of the muscle layer and vacuolization of the intestinal epithelium have also been reported for adult Haemonchus contortus exposed in vitro to dl tetramisole (Kaur and Sood, 1983). Also, in a SEM study Grzywacz (1980) reported the appearance narrower cracks in the cuticle and wrinkles on lips of Ascaris suum treated in vitro with piperazine.

During the present investigation it was found that the worms treated with various concentrations of plant extract became paralysed through they did not show any mortality for some time to follow. The extract suggestely exerts a reversible action on the neuromuscular system of the worm (Croll and Matthews, 1977). The action of piperazine is also found to be reversible and it is believed that the paralysis lasts long enough for the worms to be swept out of the host (Cox, 1982). It may be presumed that *in vivo* under the effect of the plant tuber the paralysed/immobilized worms are easily evacuated by host's gut movements. It thus appears that the tuber extract of *Flemingia vestita* acts as vermifugal. However, to establish its precise mechanism of action further study needs to be undertaken to separate and identify the active principles responsible for anthelmintic activity.

SUMMARY

1. A two-year long survey undertaken to establish the nematode parasite spectrum of animals of food value, namely pigs, goats, sheep, cattle and fowl, in Meghalaya revealed that twenty-four species of nematodes belonging to thirteen families and eighteen genera parasitize these animals in the State. The nematode spectrum in pigs comprised eleven species viz. *Ascaris suum*, *Pseudocruzia orientalis*, *Bourgelatia diducta*, *Oesophagostomum (Oesophagostomum) dentatum*, *Stephanurus dentatus*, *Globocephalus connorfilii*, *Setaria bernardi*, *Ascarops strongylina*, *A. dentata*, *Physocephalus sexalatus* and *Gnathostoma doloresi*; six species viz. *O. (Proteracrum) columbianum*, *O. (Hysteracrum) aspersum*, *Haemonchus contortus*, *Trichuris globulosa*, *T. ovis* and *Bunostomum trigonocephalum* in goats and the former four also in sheep; four species viz. *O. (Bosicola) radiatum*, *H. contortus*, *Mecistocirrus digitatus* and *S. digitata* in cattle; and four species, namely *Ascaridia galli*, *Heterakis gallinae*, *Strongyloides* sp. and *Capillaria contorta* in fowl. A brief description is provided for all the species recorded. While majority of these are also known to oc̆cur in other regions of India, it is for the first time that their occurrence is reported herein from north-east India, Meghalaya in particular. *S. bernardi* in domestic pigs and *C. contorta* and *Strongyloides* sp. in fowl form the first records from India.

2. Scanning electron microscopic studies on the surface fine topography of nine nematode species representing seven families revealed several structures of taxonomic and functional significance not visualized previously by light microscope studies.

In *A. suum* the anterior end is found to possess three distinct lips, each with a single dentigerous ridge bearing conspicous and concave-edged denticles. In strongylids -- *B. diducta*, *O. columbianum* and *O. aspersum* the number, shape and size of elements in the corona radiatae are ascertained. The cephalic, cervical and caudal papillae are found to vary in their number and topography; the phasmidial and amphidial openings and patterns of cuticle also show inter-specific variations. In *B. diducta* the bursa is marked off by notches into long dorsal and short lateral lobes, while in *O. columbianum* it appears bell shaped. In *B. diducta* the vulva appears to be a prominent circular opening, whereas in *O. aspersum* it is a simple elliptical opening without any cuticular ornamentation in its vicinity. *S. dentatus* exhibits a hexagonal mouth opening with 80-85 small elements and four prominent cephalic papillae; six tongue-shaped teeth protrude from the oral cavity; in males the bursa is found to have short and stout rudimentary bursal rays; in females the vulva and the anus are situated quite closely, the latter also showing cuticular ornamentation around it.

G. connorfilii reveals dorsally bent anterior end; prominent cervical papillae are distinct on either side of the body; the bursa has a small dorsal and large lateral lobes and a pair of prebursal papillae, and the vulva shows a prominent flap. S. digitata shows a rasied cuticular peribuccal crown at anterior extremity; in males the ventral aspect of the posterior end reveals neatly arranged ventral bands, whereas in females the cuticle has scantily and irregularly scattered minute papillae; three pairs of precloacal, one pair of adcloacal and three pairs of postcloacal papillae are evident in males. A. dentata exhibits a pair of oppositely directed trilobed pseudolabia, the middle lobe of each of which is seen throwing a buccal tooth towards the oral cavity; two distinct submedian cephalic papillae and a minute pore-like opening are visible on each pseudolabium; the male worm has a curved tail bearing dense aggregation of mushroom - like cuticular thickenings arranged in somewhat longitudinal rows; the female has a shorter tail than that of the male; the anus appear as a prominent opening very near to the posterior tip. G. doloresi shows a distinct globular cephalic bulb bearing two large pseudolabia and submedian cephalic papilae; 8-9 regular rows of backwardly directed cuticular spines are present on a cephalic bulb; posteriorly the whole body is densely adorned with backwardly directed cuticular spines; the latter showing a gradual change in their contour along the body length.

3. The prevalence of nematode parasite species and the seasonal fluctuation of those of major importance in the spctrum were studied by means of faecal eggs and/or adult worm counts of the animals slaughtered at the abattoirs, under the characteristic sub-tropical and high rainfall conditions of the region. In the case of pigs, the highest level of infection

was noticed during autumn and lowest in winter. A. suum, O. dentatum and B. diducta were the commonly occurring species. A. suum exhibited higher peaks in its prevalence during summer and autumn. A higher prevalence of B. diducta was also noticeable in summer; O. dentatum registered a high prevalence from the start of summer with a peak during early autumn.

In goats, the strongylids emerged to be the most prevalent species. Hence the seasonal fluctuation in the prevalence of infection was monitored by estimating faecal worm egg counts of strongylids; the maximum values for prevalence and overall mean EPG were noticed after the period of heavy rainfall and remained at a relatively high level from July to December.

In fowl A. galli and H. gallinae occurred as the predominant infections. On the basis of actual recovery of worms at necropsy it emerged that the rate of infection was more or less at a constant level for most part of the year, with slightly higher peaks during summer.

For cattle, the study aimed at establishing the prevalence of various nematode species only and the filariid, S. digitata emerged to be the most commonly occurring species in this region.

4. With a view to ascertaining the occurrence of zoonotic infections in the region, a screening of domestic animals, also including dogs, revealed 7 species as having zoonotic potential. These are — A. suum, G. doloresi, Toxocara canis, Ancylostoma caninum, G. spinigerum, Ascaris sp. and Strongyloides sp.

A survey was made to assess the level of contamination of the environment with the nemic eggs/larvae of public health significance which revealed soils of various localities and vegetables to be highly contaminated with eggs/larvae of one or more of the five nematode species — Ascaris, Toxocara, Ancylostoma, Enterobius, and Strongyloides. Of these, Ascaris eggs were the most common contaminants, though those of Toxocara and Ancylostoma were also involved with a profile enough to pose a risk of infection to the inhabitants.

In order to evaluate the role of environmental conditions on the epidemiology of ascariasis, the development of Ascaris eggs was monitored at various sets of temperature, humidity and pH conditions similar to those existing in the region. Under the existing climatic conditions of the region the eggs deposited on the soil during June and early July could complete their development to infectivity in 48-52 days. Similarly, keeping the temperature constant eggs incubated at 80-100% r.h. showed complete development in 28-30 days. Slightly acidic soil showed comparatively rapid development of eggs. It appeared that the temperature and humidity experienced in this region would favour a prolonged survival of infective eggs in the environment, which could pose a risk of recruitment of infection among community people for most part of the year.

A study made to understand the possible role of socio-econogical factors in contributing Ascaris infection in human subjects showed a positive involvement with the age, sex, place of living, and occupation of the subjects.

5. The anthelmintic efficacy of Flemingia vestita root tubers, consumed by natives for curing worm infections, was investigated against Ascaris suum, in vitro. Taking motility and histmorphology as the parameters, it emerged that the worms treated with 0.36% of the crude extract of plant tubers became paralysed within 5-8 hr; they showed wrinkles and cracks on lips and body cuticle, and also perceptible disorganization of the somatic muscle layer. In comparison, incubation with similar concentration of the reference drug Mebendazole in the medium resulted in much faster acquisition to a paralytic state. It appears that the plant bears good anthelmintic activity and suggestedly has a vermifugal effect.

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APPENDIX

Host-parasite list of nematodes of livestock and poultry of Meghalaya

Host(s)	Nematode Species Recovered
Pig	
(Sus scrofa domestica L.)	Ascaris suum Pseudocruzia orientalis Bourgelatia diducta Oesophagostomum (Oesophagostomum) dentatum Stephanurus dentatus Globocephalus connorfilii Setaria bernardi Ascarops strongylina A. dentata Physocephalus sexalatus Gnathostoma doloresi
Goat	
(Capra hircus L.)	Oesophagostomum (Proteracrum) columbianum Oesophagostomum (Hysteracrum) aspersum Bunostomum trigonocephalum Haemonchus contortus Trichuris globulosa T. ovis
Sheep	
(Ovis aries L.)	O. (P) columbianum O. (H.) aspersum H. contortus T. globulosa
Cattle	
(Bos indicus L.)	Oesophagostomum (Bosicola) radiatum H. contortus Mecistocirrus digitatus Setaria digitata
Fowl	
(Gallus gallus domesticus L.)	Ascaridia galli Heterakis gallinae Strongyloides sp. Capillaria contorta

SYSTEMATIC ACCOUNT OF NEMATODES OF LIVESTOCK AND POULTRY OF MEGHALAYA

Following is the detailed systematic account of the various nematode species recorded in this study from their respective host(s):

Family I. ASCARIDIDAE Baird, 1853

Subfamily Ascaridinae (Baird, 1853) Hartwich, 1974

Genus Ascaris Linnaeus, 1758

A. suum Goeze, 1782
Host : Pig

Family II. ASCARIDIIDAE Travassos, 1919

Genus Ascaridia Dujardin, 1845

A. galli (Schrank, 1788) Freeborn, 1923
Host : Fowl

Family III. HETERAKIDAE Railliet et Henry 1912a
Subfamily Heterakinae Railliet et Henry, 1912a
Genus Heterakis Dujardin, 1845

H. gallinae (Gmelin, 1790) Freeborn, 1923
Host : Fowl

Family IV. KATHLANIIDAE (Lane, 1914) Travassos, 1918
Subfamily Cruziinae (Travassos, 1917) Ortlepp, 1924
Genus Pseudocruzia Wolfgang, 1953

P. orientalis (Maplestone, 1930b) Wolfgang, 1953
Host : Pig

Family V. STRONGYLOIDIDAE Chitwood et McIntosh, 1934
Genus Strongyloides Grassi, 1879

Strongyloides sp.
Host: Fowl

Family VI. CHABERTIIDAE (Popova, 1952) Lichtenfels, 1980
Subfamily Oesophagostominae Railliet, 1916
Genus Bourgelatia Railliet, Henry et Bauche, 1919

B. diducta Railliet, Henry et Bauche, 1919
Host: Pig

Genus Oesophagostomum Molin, 1861
Subgenus Bosicola Sandground, 1929

O. (B.) radiatum (Rudolphi, 1803) Travassos et Vogelsang, 1932
Host: Cattle

Subgenus Oesophagostomum Molin, 1861

O. (O.) dentatum (Rudolphi, 1803) Molin, 1861
Host: Pig

Subgenus Proteracrum Railliet et Henry, 1913

O. (P.) columbianum (Curtice, 1890) Raillet et Henry, 1913
Host: Goat, sheep

Subgenus Hysteracrum Railliet et Henry, 1913

O. (H.) aspersum Railliet et Henry, 1913
Host: Goat, sheep

Family VII. SYNGAMIDAE Leiper, 1912
Subfamily Stephanurinae Railliet, Henry et Bauche, 1919
Genus Stephanurus Diesing, 1839

S. dentatus Diesing, 1839
Host: Pig

Family VIII. ANCYLOSTOMATIDAE (Looss, 1905) Lichtenfels, 1980
Subfamily Ancylostomatinae Looss, 1905
Genus Globocephalus Molin, 1861

G. connorfilii Lane, 1922
Host : Pig

Subfamily Bunostominae (Railliet et Henry, 1909) Looss, 1911
Genus Bunostomum Railliet, 1902

B. trigonocephalum (Rudolphi, 1808) Railliet, 1902
Host : Goat

Family IX. TRICHOSTRONGYLIDAE (Leiper, 1908) Leiper, 1912
Subfamily Haemonchinae (Skrjabin et Schulz, 1937) Skrjabin et Schulz, 1952
Genus Haemonchus Cobb, 1898

H. contortus (Rudolphi, 1803) Cobb, 1898
Host : Goat, Sheep, Cattle

Genus Mecistocirrus Railliet et Henry, 1912b

M. digitatus (Linstow, 1906) Railliet et Henry, 1912b
Host : Cattle

Family X. ONCHOCERCIDAE (Leiper, 1911) Anderson et Bain, 1976
Subfamily Setariinae Yorke et Maplestone, 1926
Genus Setaria Viborg, 1795

S. digitata (Linstow, 1906) Railliet et Henry, 1911
Host : Cattle

S. bernardi Railliet et Henry, 1911
Host : Pig

Family XI SPIROCERCIDAE (Chitwood et Wehr, 1934) Chabaud, 1975
Subfamily Ascaropsinae Alicata et McIntosh, 1933
Genus Ascarops Beneden, 1873

A. strongylina (Rudolphi, 1819) Alicata et McIntosh, 1933
A. dentata (Linstow, 1904) Alicata et McIntosh, 1933
Host : Pig

Genus Physocephalus Diesing, 1861

P. sexalatus (Molin, 1860) Diesing, 1861
Host : Pig

Family XII. GNATHOSTOMATIDAE Railliet, 1895
Subfamily Gnathostominae (Railliet, 1895) Baylis et Lane, 1920
Genus Gnathostoma Owen, 1836

G. doloresi Tubangui, 1925
Host : Pig

Family XIII. TRICHURIDAE (Ransom, 1911) Railliet, 1915
Subfamily Trichurinae Ransom, 1911
Genus Trichuris Roederer, 1761

T. globulosa (Linstow, 1901) Ransom, 1911
Host : Goat, sheep
T. ovis (Abildgaard, 1795) Smith, 1908
Host : Goat

Subfamily Capillariinae Railliet, 1915
Genus Capillaria Zeder, 1800

C. contorta (Creplin, 1839) Travassos, 1915
Host : Fowl

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Yadav, A.K. and Tandon, V. (1989) Nematode Parasite Infections of Domestic Pigs in a sub-tropical and High-rainfall Area of India. Veterinary Parasitology, 31: 133-139.

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