STUDIES ON ORIBATID VECTORS

Thesis submitted in partial fulfilment
of the requirement for the
Degree of Doctor of Philosophy in Zoology

R. SOBHANA AMMA

Division of Acarology
Department of Zoology
University of Calicut
Kerala - 673 635

1997

UNIVERSITY OF CALICUT

Dr. M.A. HAQ
PROFESSOR

DIVISION OF ACAROLOGY
DEPARTMENT OF ZOOLOGY
UNIVERSITY OF CALICUT
CALICUT, KERALA
INDIA - 673 635

TELEX: 804243 UNIC IN
GRAMS: UNICAL
PHONE: 0493 800271 (Off)
0493 800276 (Res)
0493 800505 (Res)
FAX: 0493 800 269

CERTIFICATE

This is to certify that this thesis is a record of the work carried out by **Mrs. R. Sobhana Amma** in the Division of Acarology, Department of Zoology, University of Calicut under my supervision and guidance and that no part thereof has been presented earlier for any other degree.

It is further certified that the candidate has passed the preliminary qualifying examination of the Ph.D. degree of the University of Calicut on 15.10.1993.

5th Nov '97

(Dr. M.A. Haq)

CONTENTS

ACKNOWLEDGEMENT

India is primarily an agricultural country. Its economy depends mainly on agricultural products and livestock. Any organism that hinders the growth of our economy demands serious concern. Oribatid mites are known to affect our cattle wealth considerably, even though their role in increasing soil fertility is not negligible. The present study is intended to highlight the role of these organisms as intermediate hosts and transmitting agents of cestode parasites of domestic animals. In fact it is this particular aspect of the problem that created an interest in me to take up this study.

I should acknowledge most sincerely and gratefully the help and guidance rendered to me by my guide Dr. M.A. Haq, Professor, Department of Zoology, Calicut University for initiating in me a great concern for the significance of the problem. He has been a constant source of inspiration and encouragement to me in carrying out this study. I consider it to be an honour and privilege to work under such an efficient professor who is rightly deemed to be an authority in Acarology, one of the fastest growing branches of Zoology.

I should also express my profuse gratitude to Dr. N. Ramani, Lecturer, Department of Zoology, Calicut University and Dr. K. Sumangala, Lecturer, Department of Zoology, Zamorin's Guruvayurappan College, Calicut for their unstinted co-operation and help in the preparation of this thesis.

The major part of the research work on this study was done in the Department of Zoology, Calicut University. I would like to place on record my sincere thanks to

the Head of the Department of Zoology for providing me with the facilities available in the laboratory for carrying out my work.

Last but not the least I thank everyone who has helped me in the preparation of this dissertation.

R. Sobhana Amma

INTRODUCTION

R. Sobhana Amma “Studies on oribatid vectors” Thesis. Department of Zoology , University of Calicut, 1997

INTRODUCTION

INTRODUCTION

Acarology, one of the fastest growing branches of Zoology, dates back to the early parts of the century with the identification of ticks as obligate haematophagous parasites of vertebrates. Though mites are known as the cousins of ticks, their minute size and clandestine nature had delayed their status over a period of time. Obviously, studies on mites picked up tremendous momentum to attain worldwide recognition during the last few decades of the century. On account of revived recognition, it is now well known that mites exert a profound influence on diverse areas of human interest ranging from microbial proliferation to crime detection.

Acari, one of the subclasses of Arachnida, has a distinct evolutionary path and enjoys a universal distribution. Through their ubiquitous presence, astounding diversity and unique adaptive techniques they have attained an enviable status as the rivals of insects in conquering and colonizing all the available habitats of the biosphere. Their survival potentials have aided them to exploit successfully even hostile environmental conditions. Their domiciles range from the abyssal ocean depths to the mighty mountain peaks and from the deserted polar caps to the warm equitorial regions. These organisms exhibit marvellous dexterity in making even

silent glaziers, desolate deserts, thermal springs and volcanic remnants of subterranian caves as their habitats. A few can thrive well in thermal springs with a temperature of 50.8°C and in highly alkaline waters with a pH of 9.6 which in fact documents their superb adaptability to hostile and formidable environmental conditions.

Mites' association with animals extend from simple phoresy to active ecto and endoparasitism. They are found in the hair follicles and fur of mammals, feathers and quill cavities of birds and the scales of reptiles. The nasal and respiratory cavities of dogs, monkeys, seals, snakes and birds are the abodes of acarine inhabitants. These cryptic organisms habour in the facial follicles, eyelids and the ear canals of human beings and act as agents of devastating and lethal diseases. Household furniture and bed mattresses are not immune to habitation by mites. Certain coprophagous beetles carry large number of mites on their back and the elytra of some beetles and grass hoppers are dwelling grounds of these arthropods. Nests of birds and cages of mammals are post-residential areas of a substantial variety of acarines. With their multifarious activities these minute creatures have succeeded in building up a tremendous influence on man and his environment which in turn has resulted in the ramification of acarology along diverse lines.

Depending on their influence on man and his environment, mites could be classified into two categories namely beneficial and baneful. Their feeding habits coupled with their adaptability to the altering physicochemical and biological conditions of the soil make them capable of influencing the ecosystem to a very large extent. Today they are very effectively being utilized all over the world in biological control programmes, irradication of weeds and improvement of soil fertility and productivity. The extreme sensitivity of mites to the physicochemical characteristics of their immediate surroundings enables them to act as biological indicators of environmental conditions, thereby helping to reveal microclimatic conditions operating in a specific set up. This behavioural pattern of mites is immensely helpful in chartering programmes related to the study of the structural and functional aspects of the ecosystem which would open up new avenues for the optimisation of agricultural practices. Mites could be effectively used in the classification of soil, rating the humification process, analysis of the variation in the microclimatic conditions etc. Further, mites act as bioindicators of soil toxicity owing to pollution and the use of pesticides, levels of radioactivity, industrial emulsions etc.

Analysis of the gut contents and studies on the feeding habits of oribatid mites like *Galumna* and *Scheloribates* have proved beyond doubt their role as

predators of soil nematodes. This again, is another illustrious example of the tremendous potentials of mites in the national agricultural improvement programmes.

The biological control of pests and weeds is becoming increasingly popular owing to the environmental problems caused by the large scale use of insecticides and pesticides which are aptly defined as "ecological narcotics". The biological control of pests/weeds could well be defined as the suppression of undesirable insect pests and plants through the introduction and encouragement of their natural enemies. Its long lasting effect and lack of ecological imbalance have made this, one of the most recognised regulative measures in pest/weed management programmes. Several species of mites play a vital role in this area and have been recognized as successful agents in pest/weed management. For example many species of ground dwelling mites like *Macrocheles muscaedomesticae* are known to feed on the eggs of houseflies and galumnid mites belonging to Oribatida are reported to be effective regulators of noxious weeds like *Eichhornia crassipes* and *Chromolaena odorata*.

Though these microarthropods play a vital role in pest/weed management programmes, they have gained notoriety as pests of an array of agricultural, horticultural and ornamental plants. Mites are the only phytophagous arachnids and

their close association with plants is evident from their availability on herbs,shrubs, deciduous trees, conifers, leaves, stems, barks and roots of many agricultural and ornamental plants. The tetranychid mites have well developed mouth parts which help them to feed voraciously on plant parts. The eriophyid mites dwell in the galls and burrows on leaves, "witches brooms" on trees, cervices in the barks and the like. They feed on plant sap causing malformations like yellowing and russetting, leaf-rolling, blisters and stunted growth, hampering plant life. The large scale attack by mites often leads to a devastating fall in crop-yield. Apart from the direct damage inflicted on crops, certain species of mites act as transmitters of plant pathogens like fungi, bacteria and viruses. In fact they have been reported to be present from paddy to orchids. Thus in an agricultural country like India mites have an enormous impact on the national economy.

The fact that approximately half of the 3000 known species of mites are soil dwellers proves that they constitute the major group among the soil mesofauna. Among these, the group Oribatida is worthy of special mention owing to their vital role in the soil humification process. The microphytophagous group of these mites plays a significant role in the biodegradation process through grazing and disseminating fungal spores, thereby serving as an indispensable link in biodegradation and nutrient cycling. Besides, the complex organic compounds in

plant litter are converted into simple and easily degradable compounds in the guts of mites. The highly humifiable acarine excreta provides a very fertile environment for the growth of roots and the germination of seeds. Further the consumption of dead roots by the detritiphagous mites increases soil porosity and the development of humus rich galleries.

Infestation of stored products provides an increased notoriety to the parasitic nature of mites. Many species of mites lead a luxurious life in stored products like oil seeds, millets, cereals, spices, confectionaries, leather, fishery products, poultry and cattle feeds and vegetables contaminating them with their excreta and dead bodies. They render seeds unfit for sowing by reducing their nitrogen content by feeding on the germ tissues and the surrounding endosperm. Large scale settlement of mites in stored products results in hot spot formation which leads ultimately to microbial infections.

Studies on mites have revealed the influence of these diminutive creatures on animals and human beings as ecto and endoparasites. Acarine parasites of animals are a universal phenomena and diverse types of pathogenic organisms are transmitted by them. Some are known to cause typhus haemorrhagic fever, plague etc. Ectoparasitic mites discovered from animals like bats, armadillos, marsupials, primates, reptiles as well as birds are known to feed on the blood, lymph, sebaceous

secretions and tissue particles of their hosts. *Dermanyssus gallinae*, the chicken mite, *Ornithonyssus sylviarum*, the Northern fowl mite, the mange and scab mites and chiggers of the family Trombiculidae are but a few examples. Ectoparasitic mites on domestic animals and cattle cause loss of vigour and sarcoptic and psoroptic mites cause weeping lesions. Accidental ingestion of live mites by vertebrates might result in a condition called "acariasis" in which mites survive and reproduce in the alimentary canal causing severe vomitting and diorrhea. Dust mites cause severe respiratory problems leading to chronic asthma and associated diseases. Certain other species burrow into the dermis of human skin causing skin diseases like dermatitis, vanilism, copra-itch and grocer's itch. Mites are also responsible for human pulmonary acariasis and rickettsial pox. Some of them even lead to a psychological condition termed as "Acarophoebia" a type of symbiophoebia in man.

Oribatid mites also play very significant and divergent roles in the soil ecosystem as intermediate hosts and vectors of cestode parasites, affecting cattle and sheep and thereby causing a major threat to our rural economy. The injurious effects of oribatid mites not only on plant life but also on animal life were established as early as 1937 by the pioneering work of Stunkard. Subsequent researches in this field have proved that more than fifty species of oribatid mites

belonging to about twenty five families can act as transmitters of atleast twelve species of tapeworms. Among the oribatid mites Scheloribatidae and Galumnidae are the most commonly known vectors. Vector species belonging to the family Galumnidae include four genera namely *Galumna, Pergalumna, Allogalumna* and *Cryptogalumna*. Of these twelve species and a subspecies belong to the genus *Galumna*. Eight species belonging to Scheloribatidae are known to act as vectors of *Moniezia expansa*. Oribatid mites belonging to the families Liacaridae, Carabodidae, Pelopidae, Oribatulidae, Xylobatidae and Haplozetidae have also been reported as vectors of various tape worms.

India being an agricultural country, cattle and cattle products play a very vital role in our national economy. It is but natural that diseases among the cattle have become a problem of utmost magnitude and hence continuous efforts have been made in the last few decades to discover the causative organisms of the diseases and the vectors involved in the transmission of pathogens. Researches in the field have established beyond doubt the abundant presence of oribatids in the pastures and ground vegetation and their ability to harbour different life stages of the common tapeworm. While grazing on oribatid infected vegetation they enter the body of cattle and sheep who serve as the final host. As such the studies on oribatid mites infected with cysticercoides are of very great significance and urgency.

INTRODUCTION

R. Sobhana Amma “Studies on oribatid vectors” Thesis. Department of Zoology , University of Calicut, 1997

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Oribatid mites constitute a prominent group of soil animals exhibiting multiple roles in the soil ecosystem. The impact of their role on a closer grid would reveal various channels of studies converging in the emergence of a great deal of literature. Even within the boundaries of oribatid taxonomy also sufficient literature is available. The present review is, therefore, intended to cover literature pertaining to the taxa comprising vector species included in this study only.

TAXONOMY

Pearse (1906) initiated taxonomic studies of oribatid mites from the Indian subcontinent who recorded 20 species including a new genus *Chaunoproctus* and 8 new species *C. cancellata* and *C. asperulus, Oribata fallax, Liacarus nigrescens, Notaspis hamatus, Amerus speciosus, Neoliodes ocellatus* and *Hoploderma claviger* from Sikkim Himalaya. It was Ewing (1910) who first started taxonomic studies of oribatid mites from South India by surveying the soils of Nilgiris. The same author, later (1916, 1918) prepared a synopsis of the North American genera of oribatid mites and furnished information on the oribatid fauna of Oregon. Subsequently, Sellnick (1925) conducted studies on the oribatid mites of Sumatra and pointed out (1928) the importance of these mites in the maintenance of soil

fertility. Jacot (1933) carried out redescriptions of Ewings' species as *Galumna tessellata* and *G. nilgirica* under the family *Galumnidae*. A new species of *Scheloribates* viz., *S. chauhani* was erected by Baker (1945) from North India. Grandjean (1949) studied the developmental pattern of the genito-anal plates of oribatid mites while tracing the ontogeny of a few species. A new species of oribatid mite from Queensland was reported by Hammer (1953). A formal classification system for oribatid mites was outlined by Grandjean (1954). The occurrence of two species of oribatid mites, viz., *S. madrasensis* and *Galumna* sp. was reported by Anantharaman (1957) from South India.

Balogh (1958, 1959) conducted studies on the oribatid fauna of African soils. Investigations on the oribatid fauna of Andes mountains were made by Hammer (1958). Aoki (1961, 1963) reported several new species of oribatid mites from Japan which included *Zygoribatula truncata, Peloribates acutus, Pergalumna capillaris, P. harunaensis, P. akitaensis, P. intermedia, Galumna cuneata, Phthiracarus clemens, Oppia restata* and *Ceratozetes imperatorus*. The same author (1965a,b) erected 2 new genera, *Sadocepheus* and *Oscesobates* and 4 new species from Japan and provided a preliminary revision of the family Octocepheidae and described 12 new species under the family. Further, he (1965c) performed studies on the oribatids of Thailand and erected 6 new genera and several new

species and subspecies including *G. flabellifera orientalis*. He (1967) erected a new subfamily of Otocepheidae viz., Tetracondylinae and added 12 new species and a new subspecies to the genus *Dolicheremaeus* and a new subspecies to the genus *Fissicepheus*. 4 new genera and 24 new species of oribatid mites were added to science by Balogh and Mahunka (1967) from Vietnam. A list comprising 54 species of oribatid mites associated with cestode parasites was provided by Bulanova-Zachvatkina (1967). Hammer (1967) reported several new taxa of oribatid mites from New Zealand.

During a Hungarian Soil Zoological Expedition to South America, Balogh and Mahunka (1968) erected 4 new genera and 18 new species of oribatid mites. From the oribatid specimens recovered from Calcutta, India, Bhaduri and Chaudhuri (1968) described a new subgenus, *Paralamellobates* under the genus *Lamellobates* and *L. (Paralamellobates) bengalensis* as the type species. Aoki (1968) reported 30species belonging to 25 genera and 16 families including one new genus and 7 new species. Information on the zoogeography of oribatid mites in the Antartic region was provided by Wallwork (1969). 5 species of Liacarid mites were described by Fujikawa and Aoki (1969), of which 3 were new to science. Engelbrecht (1969) enhanced our knowledge on the galumnoid mites by adding a new species to the genus *Galumna* from Africa. While studying the oribatid fauna

of Viti Levu and Fiji Islands, Hammer (1971) collected 83 species, of which 8 represented new genera, 34 formed new species and 6 formed new varieties. Taxonomic studies performed by Kriovolutskij (1971a,b) enabled to erect 3 new genera, *Asiacarus, Arenozetes* and *Mystroppia* from Central Asia and 6 new species belonging to 6 genera from Kirgisia. From Hokkaido, Japan, Fujikawa (1972) reported 106 species of oribatid mites belonging to 76 genera and 47 families which included 9 new species and one new subspecies. During her investigation on the oribatid fauna of Tahiti and the Atoll Rangiroa, Hammer (1972) enlisted 60 species of oribatid mites, of which 4 represented new genera, 36 were new species and 5 were new varieties.

Aoki (1973) described one new genus, 6 new species and a few subspecies of oribatid mites while exploring the oribatid fauna of Iriomote Jima, the southernmost island of Japan. Hammer (1973) provided information on 57 species of oribatid mites including 13 new genera from the Tongatapu, Eua, the Tonga islands and from Upolu, the Western Samoa. Chakrabarti *et al.* (1973) recorded several species of Indian oribatids and erected a new subspecies. A survey on the oribatid fauna of Rhodesia was performed by Mahunka (1973) which yielded several new and interesting taxa. Our knowledge on the Indian oribatids was increased by Bhaduri *et al.* (1974) and Bhattacharya *et al.* (1974) by reporting new

species under Basilobelbidae and Lohmanniidae respectively. A new classification system for the family Oriopodidae was proposed by Aoki and Okkubo (1974). Balogh and Mahunka (1974) provided information on the Malaysian oribatid fauna by illustrating several new taxa. Prasad (1974) supplemented a list of known families of Indian oribatid mites along with a key to the superfamilies.

Four galumnoid species from Korea were described by Aoki (1975) which included a new species of *Pilogalumna* viz. *P. steinmanni*. Two new species of Oribatellidae viz., *Oribatella alami* and *O. kashmiriensis* were reported by Kardar (1975). The oribatid fauna of Central Sahara region of Africa was surveyed by Hammer (1975) who added several new taxa to science. The genus *Scheloribates* was made more elaborate by Biswas and Bhaduri (1976) by adding 3 species viz., *S. albiialatus, S. obtusus* and *S. natalensis* from West Bengal, India. Further additions to the genus from India were made by Kardar (1976) by describing 4 new species viz., *S. bicuspidatus, S. translamellaris, S. baloghi* and *S. rufafulvus*. Mahunka (1976) furnished information on 5 new species from Hongkong. Morphological descriptions of 3 new species viz., *Oppia adoris, Hemileius elongatus* and *Z. quadarramica* were provided by Perez-Innigo (1976a) from Central Spain. The same author (1976b) presented an annotated list of 44 species including descriptions and illustrations of new taxa under Carabodidae, Oppiidae,

Suctobilbidae, Dampfiellidae, Achipteriidae, Mycobatidae, Galumnidae and Oribatulidae. Weigmann (1976) provided information on the oribatid fauna of Acores and he dealt with 42 species along with their distribution data. He further illustrated the characters and validity of genera like *Scheloribates, Topobates* and *Multoribates*. New additions to the family Achipteriidae were made by Nevin (1976) who described new species viz., *Parachipteria travel, Achipteria catskillensis* and *A. clarencei* from the Catskill mountains.

Aoki (1977a,b) provided information on 3 new species of *Eohypochthonius* and 2 new species of *Peloribates* from Central Japan. Seniczak (1977) discussed the systematic position of moss mites of the genus *Anachipteria* in the light of ontogenic studies and established close relationship among 3 genera viz., *Achipteria, Anachipteria* and *Parachipteria*. Haq (1978a) reported several species of oribatid mites from South India. Two new species of Otocepheidae viz. *Pseudotocepheus hammerae* and *P. gobletus* were erected by Chakrabarti *et al.* (1978) from North India. Further addition to Indian fauna was made by Haq (1978) who added 7 new species from South India. An elaborate survey on the oribatid fauna of Mauritius, Reunion and Seychelles, enabled Mahunka (1978) to collect 62 species including 2 new genera under the family Oribatulidae.

An annotated list of 12 oribatid species was given by Chakrabarti *et al.* (1979) from Darjeeling which included 6 new species also. Corpuz-Raros (1979) provided information on 158 species of oribatid mites belonging to 104 genera and 47 families from Philippines, of which 44 species and one subspecies were new to science. The author created 2 new genera to accommodate 4 unique species under the family Otocepheidae and one new subgenus under Haplozetidae. Additional diagnostic data for 20 species of oribatid mites of the family Brachychthoniidae, Eremaeidae, Liacaridae, Suctobelbidae and Oppiidae were presented by Mahunka (1979). The oribatid fauna of Java was studied in detail by Hammer (1979) which enabled her to erect 12 new genera and 101 new species. Haq (1979) erected a new species, *Xiphobelba ismalia* from Kerala. While conducting surveys on the oribatid fauna of Hungary, Bayoumi (1979) described and illustrated 3 new species viz., *Oppia hungarica, Suctobelbella trichosa* and *Z. ziesil*. The same author (1980a) erected a new species of *Perxylobates* under the family Xylobatidae from Egypt. He (1980b) provided an annotated list of 14 species of oribatid mites from Egypt including the illustrations of a new species of *Zygoribatula*.

While surveying the oribatid mites inhabiting the Tunisian soils, Mahunka (1980a) erected 6 species under *Lohmannia, Papillacarus, Eremaeus, Licneremaeus, Zygoribatula* and *Peloribates* and a new subspecies of *O. ornata*.

He (1980) reported 3 new species, 2 of which belonged to *Scheloribates* viz., *S. sikkimensis* and *S. saswatii* and one species of *Chaunoproctus* viz., *C. longisetosus* from Sikkim Himalaya.

A new species of oribatid mite, *Vaghia blascoi* collected from the Palani Hills of South India was reported by Trave (1981). A review on the taxonomy and distribution of oribatid mites in India was furnished by Bhaduri and Chaudhuri (1981). Raju *et al.* (1981) reported a new Indian species of *Pergalumna* viz., *P. andhraensis*. Corpuz-Raros (1981) added 7 new species to the genus *Peloribates* from Philippines. 2 new genera, 27 new species and 5 new subspecies of oribatid mites were collected and described by Balogh and Mahunka (1981). Wallwork (1981) provided data regarding the vertical distribution in oribatid mites. While investigating the oribatid specimens recovered from Bali, Indonesia Hammer (1982) described 84 species including 18 new species. Fritz (1982) erected a new species of *Zygoribatula* viz., *Z. floridana* along with a list of the species in the genus. Balakrishnan and Haq (1982) reported a new species of Porogalumnella viz., *P. setosa* from Kerala. A new genus, *Pelokylla* with *P. malabarica* as the type species was erected by Clement and Haq (1982) from Kerala.

During a Hungarian Soil Zoological Expedition, Mahunka (1983) identified 23 species including 21 new species. Aoki (1984) collected and described one new

genus, *Defectamerus*,20 new species and one new subspecies. Norton (1982) provided illustrations of a new enarthronote mite, *Arborichthonius stylosetosus* from Ontario. Taxonomic and systematic examination of the oribatid materials collected from the eastern part of Ethiopian region was performed by Mahunka (1984) who described 9 new genera and 29 new species along with redescription of 2 species. Okhubo (1984) created 6 new species of *Trichogalumna* along with a new combination. Balakrishnan and Haq (1985) described a new species of *Cryptogalumna* serving as vector for anoplocephaline cestodes from Kerala viz., *C. grandjeani*. The authors also added a new subspecies, *Flagellozetes porosus indicus*. Luxton (1985) provided a concise review on the oribatid mites of New Zealand which comprised 366 species belonging to 160 genera and 58 families. A new genus and 4 new species of oribatuloid mites were described by Balogh (1985) from Hawaii Islands. Mahunka (1985) described 5 new genera and 25 new species from Africa. Balogh and Balogh (1985) erected 15 new species under the genus *Xenillus* from South America. Balogh (1985) added one new genus, 4 new species and one new subspecies of oribatuloid mites from Hawaiian Islands. Data on the distribution records of *Ceratozetes gracilis* in the arctic zones of western North America were provided by Behan (1985). A new genus under the family

Galumnidae viz., *Indogalumna* was added by Balakrishnan (1985) from India to accommodate 3 new species viz., *I. microsculcata, I. undulata* and *I. monticola*.

Balogh and Balogh (1986) described 22 new species and 2 new genera of forest soil oribatids from New Guinea. Aoki and Wang (1986) described a new species of *Zygoribatula* viz., *Z. agareae* discussing its phytophagous habit and another species viz., *Punctoribates manzanoensis* from Japan. Behan (1986a) added new ceratozetid mites from Western North American subarctic. The same author (1986b) described a new genus, *Laminizetes* and 8 new species from the above region. Fujikawa (1986) recorded 14 oribatid species including 2 new species and one new subspecies from a nature farm in Nayoro. Descriptions of 14 new species and 6 new genera from the Republic of South Africa and Tanzania were given by Mahunka (1986). Schuster (1986) erected new taxa of oribatids along with notes on their distribution from lower Saxony and other regions of the Federal Republic of Germany. Addition of one new species each to the genera *Heptacarus, Oppia* and *Ischeloribates* was made by Bayoumi and Alhaufa (1986).

A new species of *Xenillus* serving as intermediate host of *Monoecocestus* spp. was described by Freeman and Woolley (1987) from North central Minnesota. Colloff and Seyd (1987) erected a new species of *Parachipteria* from Northwales. Cancela Da Fonseca and Stamou (1987)while conducting studies on oribatid mites

of Greece described a new species of Achipteriidae, *A. holomoneasis*. Mahunka (1988a) listed 74 species of oribatid mites from Sabah, East Malaysia, of which 39 were new species and 6 were new genera. The same author (1988b) described 15 new species and 3 new genera of these mites from Vietnam. One new genus, one new subgenus and 11 new species of oribatid mites were established from Sri Lanka by Balogh (1988). Balogh and Balogh (1988) revised and redefined the faimily Ceratokalummidae providing identification key for 5 genera and 8 species and descripton of 2 new species. Norton *et al.*(1988a, b) recorded 14 oribatid mite fossils from a terrestrial Devonian deposit in New York and described 2 new species and genera from the fossil collections. Kardar (1988) erected 3 new species viz. *Oribatella arabia, S. Sandiensis* and *S. riyadhensis* from soils of Riyadh. Sanyal and Bhaduri (1988) while reviewing the oribatid genera of Indian subcontinent, listed 132 genera under 57 families.

Mahunka (1989a) erected 10 new species and one new genus, *Ocellotocepheus* from Singapore. He (1989 b) identified 10 new species and 2 new genera, *Sumatrotritia* and *Reteremuloides* from Geneva. The same author (1989 c) described 4 new species of galumnoid mites, 2 each belonging to the genera *Galumna* and *Pergalumna* from Vietnam. Romero *et al.* (1989), reported for the first time in America, a potential vector mite belonging to *Scheloribates* for the

anoplocephaline cestode, *Anoplocephala perfoliata* and discussed the epidemiological aspects of anoplocephalids in horses. Balogh and Balogh (1990) provided identification key to 35 known genera of the family Galumnidae and enumerated 4 new genera and one new subgenus. The same authors (1990 b) prepared an identification key to the oribatid fauna of Neotropical region providing 830 figures in 142 plates. Mahunka (1990) erected 3 new species from the oribatid fauna of Philippines and Indonesia. Taxonomic and ecological studies on Scheloribatidae and Oribatulidae in South West Germany were performed by Wanderle *et al* (1990). Information on 2 new species. *Uracrobates indicus* and *Notogalumna nortoni*, one each representing Ceratozetidae and Galumnidae inhabiting coconut palm in South India was provided by Ramani and Haq (1990a,b).

Mahunka (1991 a) described 2 new genera and 7 new species from East Malaysia. He (1991 b) further recorded 29 species of oribatid mites, including 5 new species from the Cape Verde Islands. 5 new species were erected and 16 new genera and 12 families were recorded by Corpuz Raros (1991) from Visayas Islands of Philippines. 2 new species of Lohmanniid mites viz. *Cryptacarus grandjeani* and *Annectacarus wallworki* were described by Clement and Haq (1991) from Kerala. Ramani and Haq (1992) erected a new species of *Afronothrus* viz. *A.*

arboreus inhabiting coconut palm in Kerala, South India. New additions to the genus *Zygoribatula* were made by Grobler (1993 a,b) from South Africa and Nawar and Borolossy (1993) from Egypt. Subias (1993) extended the knowledge on the galumnoid mites of Spain by adding a new genus, *Iberogalumnella*,3 new species and one new subspecies. Further addition to galumnoid mites was made by Aoki and Hao (1993) by erecting one new genus, 7 new species and 2 new subspecies from the Yunnan Province of Southern China.

Mahunka (1994a) established new genera under Oribatulidae and Halpozetidae from the oribatid materials preserved in Berlese's collection. He (1994 b) further added 2 new galumnid mites and incorporated a new genus, *Bigalumnella* from Thailand. The same author (1994 c) identified 16 species of large winged mites of Parakalummoidea and Galumnoidea from Sabah, of which 14 were new including 3 new genera, *Strabogalumna, Variogalumna* and *Trypogalumnella*. Grobler (1994) created a new species of *Zygoribatula* viz. *Z. contracta* and provided supplementary description of another known species of the genus, *Z. setosa* from South Africa. Perez-Inigo and Pena (1994) examined the oribatid materials collected from Gran-cauaria and erected 2 new genera and 3 new species. A new species of *Annectacarus* viz. A. *aokii* dwelling the forest floors of Silent Valley was described by Jaikumar *et al.* (1944), Coetzee (1995) described a

new species of *Saltatrichus* of the family Zetomotrichidae from South Africa. Haq and Clement (1995) erected two new species of Lohmaniid mites, one each belonging to *Meristacarus* and *Haplacarus* from Kerala. While surveying the oribatid fauna of Uruguay, Perez-Inigo (1995) established 3 new species and a new subgenus. Balogh (1995) described 4 new species of oribatid mites from Brazil with a list of identification and remarks on the distribution of the "Gondwanan species and genera". Stary and Block (1995) reported 21 species of oribatid mites including 3 new species from the Subarctic Island of South Georgia. Description of 6 new species and a new genus of oribatid mites was provided by Perez-Inigo and Baggio (1996) from Brazil. Subias and Arillo (1996) described a new species, *Serratoppia guamicola* from a cave in Central Spain. Miko and Trave (1996) erected a new family Hungarobelbidae based on the type species *Hungarobelba pyrenaica*. A list of oppiid mites collected from the Bonin islands in North Pacific ocean was provided by Okhubo (1996). A new genus and species, *Huilicheremaeus michaii* belonging to the family Licneremaeidae was described by Fernandez *et al.* (1977) from the arid zone of Argentina. Iturrondobeilia and Arillo (1997) provided information on a new species of oppiid mite, *Medioppia producta* inhabiting a cave in Biscay, North Spain. A new species of *Epidamaeus* was described by Tolstikov (1997) from the Tien Shan mountains, Central Asia.

BIOECOLOGY

Oribatid-cestode relationship represents an important interdisciplinary aspect serving a connecting link between acarology and veterinary biology. Cestodes constitute a group of parasites affecting ruminants throughout the world. Existence of an intermediate host in the life cycle of anoplocephaline cestodes was proved by the classic study of Stunkard (1934) on cestodes of rabbits, which paved the way for the search of intermediate hosts of this group of parasites. Further investigation by the same author (1937) revealed the role of the soil oribatid mites in the transmission of anoplocephaline cestodes among ruminants. Stoll (1938) confirmed the role of *Galumna* spp. in the transmission of monieziasis. The mode of infection of *Moniezia expansa* in oribatid mites and pattern of its development within the body of the mite was investigated by Stunkard (1939). Studies of Krull (1939) on this aspect could establish vector role played by *G. emarginata* in cestode transmission. Larval development of the tapeworm infecting primates, *Bertiella studeri* in 4 species of oribatid mites, namely *A. coleoptrata, S. laevigatus, Scutovertex minutus* and *Galumna* sp. was proved by Stunkard (1940 a,b) through experimental infection of these mites.

Potemkina (1941) disclosed the occurrence of the larvae of *M.expansa* and *M. benedini* in *G. obvia* and *S. laevigatus* in Russia. Investigations by Stunkard

(1941) on the larval development of cestode parasites of European rabbits, revealed *A. coleoptrata, Allopelops planicornis, A. tardus, G. obvia, Liebstadia similis, Cepheus cepheiformis, Liacarus coracinus, S. laevigatus, S. minutus, Trichoribates incisellus* and *Xenillus tegeocranus* as intermediate hosts for these parasites. Anantaraman (1943) experimentally transmitted *Moniezia* infection to lambs by feeding them with naturally infected *S. madrasensis* in India. Larval development of *M. expansa* and *M.benedini* in *S. madrasensis* was studied by the same author in the following year (1944). Potemkina (1944 a, b) traced the larval development of *M.benedini* in *G.obvia* and *S.laevigatus* and that of *Thysaniezia ovilla (T. giardi) in S. laevigatus* and *S. latipes* in Russia. Stunkard (1944) estimated the duration of life cycle of *Galumna* sp., an intermediate host of *M. expansa.* Developmental duration and longevity of 3 species of vector oribatids, viz., *S. laevigatus, S. latipes* and *G. obvia* were investigated and correlated with cestode development by Soldatova (1945). Runkel and Kates (1947) added a new member *Protoschelobates seghetti* to the list of vectors of *M. expansa* from the United States. Rajski (1947) reported the incidence of anoplocephaline larva in the oribatid species, *S. minutus* from Scotland. The same author (1948) analysed the distribution, ecology and cysticercoid capacity of the oribatid vectors in pasture plots in United States. Duration and sequence of development of the larva of *M. expansa* in *S. madrasensis* was traced by Anantaraman (1951) in India.

Potemkina (1951) added 17 species of oribatid mites to the list of vectors of *M. expansa* from USSR.

Larval development of 3 species of tapeworms namely; *A. magna, A. perfoliata* and *Paranoplocephala mamilliana* in the oribatid vectors was investigated by Spaskii (1951, 1952), who recorded *G. elimata, P. nervosa, Achipteria* sp. and *Ceratozetes* sp. as their intermediate hosts. Transmission of *A. perfoliata* by *Carabodes* sp. and *Scheloribates* sp. was confirmed by Wardle and McLeod (1952). While studying the biology of the porcupine tapeworm species, *Monoecocestus americanus* and *M. variabilis* in Canada, Freeman (1952) observed *G. higer, Liacarus itascensis, Neoribates quadrisetosus* and *Ceratoppia biplis spinipes* as their vectors under natural conditions. Melvin (1952) recorded the larval stages of the tapeworm, *M. sigmodontis* of rats in various oribatid species like *G. banksi, G. minutum, Oribatula minuta, P. seghetti, Belba* sp. and *Liacarus* sp. The role of *G. virginiensis* as vector of *M.expansa* was confirmed by Edney and Kelly Jr. (1953). Studies on the life cycle of *M.benedini* in Australia by Roberts (1953) indicated *Z. longiporosa* as the lone intermediate host of the parasite. Shaldybina (1953) identified *Liacarus* sp. as a new vector of *M. expansa* in the USSR. In a review of the studies on oribatid-cestode relationship, Rajski (1959) listed 12 families, 25 genera and 32 species of these mites as

confirmed secondary hosts of anoplocephaline cestodes. Experimental infection of *Protoschelobates* sp. with *M.expansa* and *M.benedini* carried out by Nadakal (1960 a) yielded 90% infection among the mites. The same author (1960 b) fed eggs of *Avittelina centrepunctata* to *Protoschelobates* sp. and *Trichobates* sp. and recovered partially developed oncospheres from the former species.

Zivkonic and Frank (1964) succeeded in infecting 7 species of oribatid mites, namely *A. punctata, P. nervosa, Phenopelops planicormis, Protoribates lophotrichus, P. seghetti, Punctoribates punctatum* and *Galumna* sp. with *M. expansa.* Frank (1965) listed 15 species of oribatid mites as vectors of *M. expansa* in Bonia and Herzogovina. Durrani and Hameed (1967a,b) reported *Scheloribates* sp. as the only intermediate host of *M. expansa* and *M. benedini* from Pakistan. Prokopic (1967) revealed that the duration of larval period of *M. benedini* in *G.elimata, G. obvia, S. laevigatus* and *Liacarus* sp. as 150 days. Natural and experimental infection of *M. expansa* was recorded in *Unguizetes reticulatus* and *S.perforatus* by Gaber and Gruel (1969). While investigating the larval development of *M. expansa* and *M. benedini* in *S. laevigatus*, Kuznetov (1970) observed that these tapeworms require 64-69 days for larval development in the USSR during summer. Field and laboratory observations on the life cycle of *M. expansa* and *M. benedini* by Nazarova (1970) disclosed the influence of seasonal

changes on the development of these parasites and recorded a range of 58-75 days to attain the cysticercoid stage within oribatid mites.

First experimental evidence for the completion of larval development of *A. lahorea* in oribatid species *S. laevigatus* and *S. fimbriatus* was provided by Narasapur (1974 a). The same author (1974 b) carried out ecological and biological studies on the oribatid fauna of Bombay region with due stress on their role as intermediate hosts for cestode parasites. Occurrence of seasonal variations in the rate of infection by *M.expansa* in the sheep in USA was reported by Worley *et al.* (1974). In a review of oribatid mite-cestode interaction, Sengbusch (1976) reported the vector role of oribatid mites in the transmission of 14 species of tapeworms of the family Anoplocephalidae. Caley (1976) conducted electron microscopic studies on the cysticercoids of *M. expansa* recovered from experimentally infected *Platynothrus pettifer, Xenillus tegeocranum* and *Euzetes globulus*. Cysticercoids of *Hymenolepis asymmetrica*, a parasite of *Microtus arvalis* were recovered from oribatid mites from the alpine region by Ebermann (1976 a). The same author (1976 b) recorded natural infection of *Trichoribates incisellus* by *Cittotaenia pectinata (C. marmotae)*, a parasite of *Marmota marmota*. First report on the role of *S. fimbriatus* as the intermediate host of *M. benedini* was made by Narasapur (1976), who recorded the period of larval development of the

parasite as 38 to 48 days in this mite. The same author (1977) later studied the larval development of *M. expansa* in *S. fimbriatus.*

An interesting fact on the development of the rodent tapeworm *Hymenolepis fraterna* was revealed by Ebermann (1979) who identified oribatid mites as potential vectors of this parasite, which generally develop in insects. Artificial infection of 6 species of oribatid mites with eggs of tapeworms made by Gleason and Bucke (1979) yielded 0.78% to 1.38% infection among the mites. Influence of temperature on the larval development of *M. expansa* in different oribatid hosts was studied by Narasapur and Prokopic (1979). During survey on the oribatid hosts of anoplocephaline cestodes in farmlands of S. India, Balakrishnan and Haq (1984) made new records of natural infection in *Hypozetes imitator* and *G. flabellifera orientalis* and also noted the incidence of infection in *S. laevigatus*, a previously known vector mite. Infection rate among the three species ranged from 0.44 % to 1.2%.

Akbaev (1985, 1986) carried out extensive studies on the pathogenicity of *M. expansa* on the ruminant hosts. Survey on the natural infection of oribatid mites by cestode parasites in the pasture lands carried out by Schuster (1988) yielded less than 3% infection among the oribatid fauna. Haq (1988) discussed the role of oribatid mites in cestode transmission under Indian conditions along with an

updated list of 73 speceis of vector mites. While investigating the vector role of oribatid mites, Balakrishnan and Haq (1989) made new records of natural cestode infection in 2 species namely, *P. intermedia* and *C. grandijeani*. Murai (1989) reported the development of the larvae of hymenolepid cestode, *Vampirolepis asymmetrica* in *Ceratozetes gracilis*. During their studies on the cestode parasite *A. perfoliata* infecting horses in Argentina, Romero *et al.*, (1989) recorded the developing stages of the parasite in *Scheloribates* sp. Five species of oribatid mites were added to the list of intermediate hosts of cestode parasites by Haq (1990). The new vector species recorded were *Pilobates pilosellus, Xylobates seminudus, S. rectus, Ischedribates lanceolatus* and *P. bimaculata*. The same author (1991) reported 4 more new records of natural infection of cestodes on oribatid mites, such as *S. fijiensis*, *P. laevipunctatus*, *Eupilops claviger* and *G. longiporosa*.

Seasonal variation of oribatid mite populations and their relationship to cestodiasis in Argentina was studied by Denegri and de Alzuet (1992). In an extensive review of oribatid - cestode interactions, Denegri (1993) listed 127 species of these mites as intermediate hosts of 27 tapeworm species belonging to the family Anoplocephalidae. Artificial infection experiments on *Scheloribates* spp. with *M. expansa*, carried out by Schuster (1995) yielded 62 to 82% reduction in the survival rate of the infected mites.

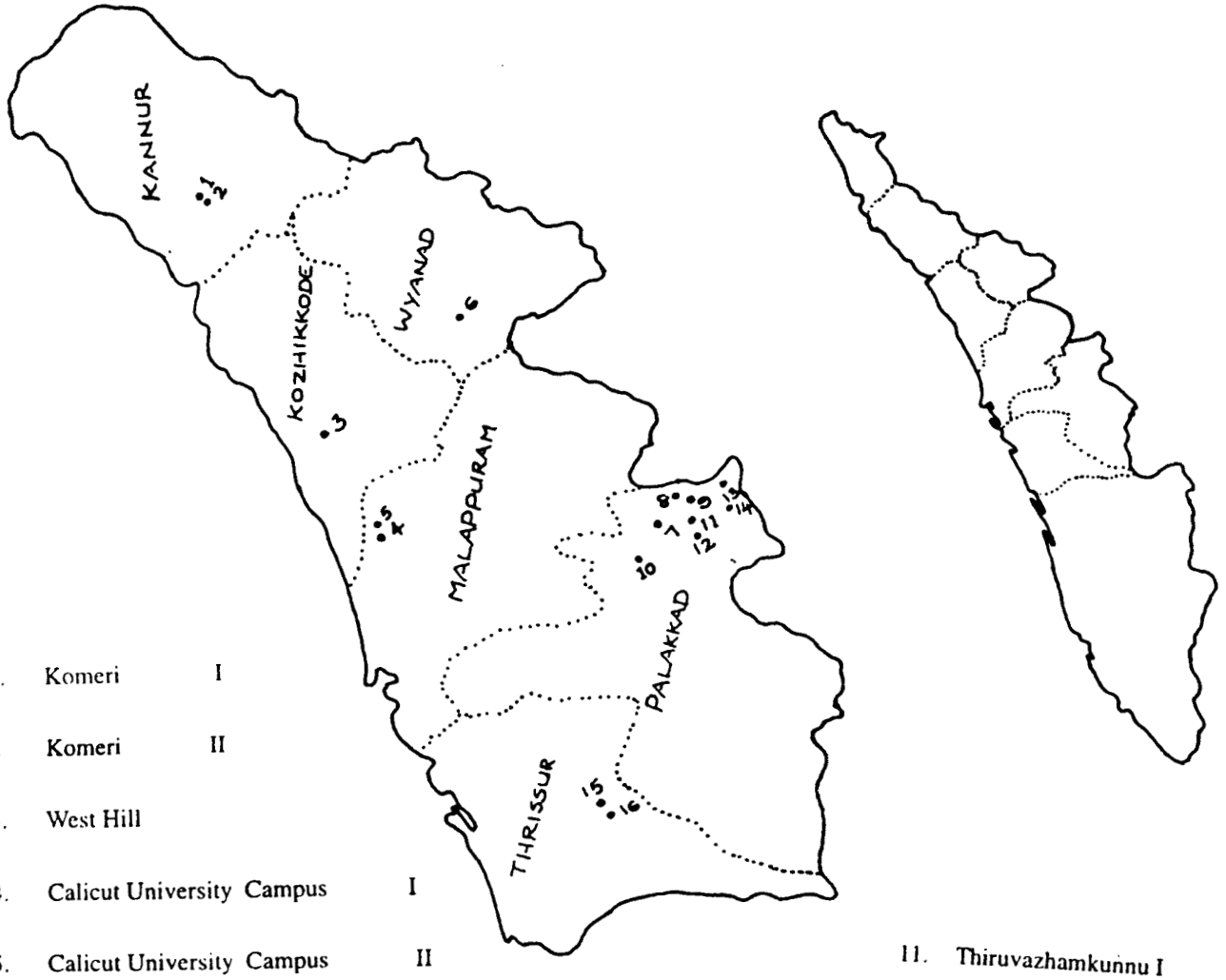
MATERIALS AND METHODS

R. Sobhana Amma “Studies on oribatid vectors” Thesis. Department of Zoology , University of Calicut, 1997

MATERIALS AND METHODS

MAP OF KERALA

NORTHERN KERALA SHOWING COLLECTION SITES



1. Komeri I
2. Komeri II
3. West Hill
4. Calicut University Campus I
5. Calicut University Campus II
6. Wyanad
7. Silent Valley
8. Vadakottuthara - I
9. Vadakottuthara - II
10. Mannarghat
11. Thiruvazhamkunnu I
12. Thiruvazhamkunnu II
13. Attappadi - I
14. Attappadi - II
15. Mannuthy - I
16. Mannuthy - II

forest in Kannr district. This grassland stretches over an area of about 8 hectares. The major portion of the soil is formed of black type fringed with red loam. Seasonal temperature of the site ranged from 22 to 30°C and relative humidity varied considerably, between 50-85%. About half of the site represents plain grassy ecosystem where goats of the farm are allowed to graze (Fig. 1) whereas the other half includes uneven soil of heaps and cracks. *Eulalia trispicata, Apocopis mangaloorensis* and *Ischaemum tumidum* represent the predominant grasses and herbs growing at this site.

2. Komeri II: This site represents part of the Kannavam forest, which merges with the open grassland area (Fig. 2). The locality chosen for sampling during the present study includes an area of about 15 hectares adjacent to the open grassland site mentioned above. Soil of this area is similar to that of the first site, mentioned above. However, temperature showed a slight reduction of 2-3°C whereas RH showed an increase of 3 to 8% normally. The area constitutes a sloping lateritic zone with intermittent rocks. Vegetational components include trees like *Macaranga peltata, Cassia fistula* etc. The lower tier of the flora includes wild herbs forming bushes and a few twiners. Some of the common species include *A. mangaloorensis, I. goebellii, Morinda umbellata,* etc. The ground level is occupied by wild grasses forming a continuous cover. *E. trispicata* and *Heteropogon contortus* include the most abundant species among grasses. Goats

represent the major grazing animals. The grazing activity persists irrespective of seasonal changes during all seasons. Contrary to the open grassland area, this site experiences human interference like felling of trees and collection of fire wood. Soil profile structure of this area has recorded an average litter accumulation of about 1-3 cm.

3. West Hill: The collection site considered for the study at West Hill forms the suburban part of Calicut township, about 28 km North of Calicut city. The site comprises an open grassland with an area of about 6 hectares. The entire area constitutes a plain plateau of red laterite soil. Seasonal temperature and RH of the site ranged from 30 to 34°C and 50 to 80% respectively. Annual grasses such as *Arthraxon quartinianus*, *Digitaria longiflora* and *Chloris barbata* constitute the vegetational components. Other types of plants are almost absent except few coconut palms. Soil profile on examination revealed practically no litter accumulation (Fig. 3). Major grazing animals of this field are cattle. The area is under continuous grazing during the monsoon and post monsoon periods from June to September, when grass is available at the site. During summer months, the area is almost barren. This locality experiences persistent human interference on account of athletic activities, cycling etc.

4. Calicut University Campus - I: Calicut University Campus comprises a vast

area of around 1000 hectares of land located in the western part of Malabar, about 24 km south of Calicut City. The first collection locality from the campus considered for the study constitutes the stadium ground of the University, situated at the northern region of the campus. The area was originally, a rocky terrain, which was later converted into plain ground by removing soil along with rocky material to a depth of about 20 feet. The site comprises an open ground without any canopy. Soil of the area is red laterite with a temperature of 30 to 34°C and RH of 60 to 80%. At present, annual grasses and herbaceous plants represent the only type of flora occupying the area. *Sporobolus piliferus, C. barbata, D. ciliaris, D. bicornis, Dactylopium aegypticum* etc. represent the prominent plant species. Profile examination of the soil revealed negligible litter accumulation. Similar to the grassland at West Hill, presence of grass in this field is limited to the period from June to September. During the rest of the year, the region turns to a barren land. Being a stadium, the area is under persistent human interference by way of athletics and other sports activities. Cattle constitute the dominant group of grazing animals of this site (Fig. 4). However, goats also graze at this ground occasionally. Their presence in the site can be witnessed throughout the year, eventhough active grazing occurs only during the monsoon and post-monsoon periods of the year owing to the availability of grass.

5. Calicut University Campus II: This area represents a vast mixed cultivation land comprising more than 50 hectares, intermittent with buildings, roads, gardens, plantations, forests, streams, ponds, paddy fields, etc. This discontinuous stretch of grassy area available for grazing comprises an uneven ground with red laterite soil (Fig. 5). Temperature and RH of the region are almost similar to those of the stadium ground site. However, this locality harbours diverse floral components. *Annona squamosa, Mangifera indica, Anacardium occidentale, Artocarpus integrifolia, Cocos nucifera, Strychnos nux-vomica, Holigarna arnothiana, M. indica, M. peltata* etc., represent the major tree species of this site. Other floral components include herbs, bushes and twiners, *Morinda coreia, Crotalaria* spp., *Lablab purpureus, Clitoria ternatia, Ixora coccinea, Pavetta indica, Heteropogon contortus, Digitaria* spp., *Calicopteris floribunda, Chromolaena odorata* etc. The soil profile at various regions of this site recorded 1 to 5 cm of litter accumulation. Grazing animals of the area include cattle and goats (Fig. 6). Most parts of this area is under human intervention by way of construction and plantation activities, collection of firewood, harvesting of cultivated trees, etc.

6. Wyanad: Sampling was made from an area of about 20 hectares of virgin forests at Muthanga region of Wyanad. Temperature of the site ranged from 16 to 30^0C while its RH varied from 70 to 85%. Wild trees constitute the dominant

group of floral components of the area. Most of the trees are evergreen type such as *Alstonia scholaris, Calophyllum* sp., *M. indica, S. nux-vomica, Mesua* sp. *A. integrifolia* and *Xylia xylocarpa*, while a few are deciduous trees like *Bambusa* spp. *Phyllanthus emblica, Ceiba pentandra, Casia fistula, Careya arborea* etc. The lower strata is occupied by wild herbs and twiners. Giant bamboo groves of *Bambusa gigantia* represent one of the common floral components of the area. Thick growth of grasses intermittent with forest (Fig. 7) and soil containing an accumulation of litter reaching to an average thickness of 3 to 6 cm are prominent characters of the site. Grazing animals of the area include cattle and buffalloes straying on the region occassionally. Human interference is moderate and is limited to the period of cutting and collection of bamboos.

7. **Silent Valley**: An area of about 15 hectares forming part of the Silent Valley National Park has been surveyed for its oribatid fauna during the present study. The area is locally known as Sairanthri and is situated about 27 km from Mukkali, the foothill area of the high ranges. Soil of this site is of laterite type with great proportion of humus. Temperature ranged from 16 to 22^0 C and RH from 70 to 85%. Vegetation of the area is predominated by tall wild trees with abundant shrubs and twiners. However, small patches of grasslands are seen (Fig. 8) amidst this thick forest. Such areas often harbour wild grasses and bushy plants. A novel feature of this site is the presence of the hill stream 'Kunthipuzha' flowing along

the heart of the site. The area recorded high litter accumulation, upto 20 cm. However, it is low at regions of patches of grasslands. Being a virgin forest area, the site harbours no domestic grazing animals except the wild animals. Very rarely few cattle are found in this site. Human intervention is almost absent in this locality. The important plant species of this site include the following:

Trees: *Calophyllum polyanthum, Mesua ferrea, Terminalia bellerica, A. inegrifolia, M. indica, X. xylocarpa, A. scholaris, Xanthophyllum arnottianum, Tectona grandis etc.*

Herbs: *Argostemma courtallense, Mycetia acuminata, Phyrynium rheedi, Bambusa* spp. etc.

Climbers: *Smilax zeylanica, Toddalia asiatica, Miquelia devitata, Adenia hondala* etc.

Grasses: *A. castratus, Cymbopoyon flexuousus, H. contortus J. commutatus* etc.

8. Vadakkottuthara - I: This site consists of an open grassland with an area of about 18 hectares. This pasture field borders the evergreen and semievergreen forests of the western ghats (Fig. 9) at the eastern boundary of Kerala. The grass land includes slopes of about 6-8 hectares and the remaining region constitutes

areas of low land and uneven terrains. Low land area at certain region is fringed with small streams which flow down to join the main stream. Soil type of the area is lateritic loam. Temperature and RH of this locality ranged from 25 to 32 ^{0} C and 56 to 80% respectively. Litter accumulation is alomost nil and goats are the dominant group of grazing animals. Human intervention in the site is moderate, which includes agricultural and other domestic activities of the people of tribal settlements.

Vegetation

Herbs: *Abelmoschus* spp., *Crotalaria* spp., *Sida* spp. etc.

Grasses: *Dendrocalamus strictus, Ottochola nodosa, Eragrostis nigra, H. contortus* etc.

9. Vadkottuthara - II: This collection locality represents a portion of the virgin forest, comprising about 25 hectares. This region is the area adjacent to the pasture field mentioned above. This forest terrain constitutes the upland area of the hills. Canopy of this site consists of thick forest intermittent with patches of grassy areas. Soil type of this area is similar to that of the adjacent open grassland area. Cows and buffaloes appear to be the dominant groups of grazing animals. However, few goats are also seen occasionally. Slow moving hill streams fringed the area here and there. Litter accumulation on the ground surface measured about

12 cm thickness. Human interference is moderate with activities of the tribals. Major vegetational components include the following:

Trees: *B. ceiba, Bridelia retusa, Dillenia pentaggua, Butea monosperma, Haldamia cordifolia, Tremia nudiflora, Bambusa* spp. etc.

Herbs: *Clerodendrum serratum, C. odorata, Neurocalyx* sp. etc.

Climbers: *Ancistrocladus heyneanus, T. asiatica, Tetrastigma leucostaphylium* etc.

Grasses: *Rottboellia exaltata, H. contortus, Coix gigantia, C. aquatica* etc.

10. Mannarghat: This site is an open grassland of about 4 hectares, on the banks of Kunthipuzha river (Fig. 10) south of Mannarghat town. This is a plain merging with the river by a slope. Soil is of sandy nature with a lot of pebbles and intermittent rocks. Availability of direct sun light enables the luxuriant growth of wild grasses such as *C. aquatica, C. lacryma-jobi, D. bicornis* and herbs like *Mimosa pudica*. Grazing cattle from nearby houses is a common scene throughout the monsoon and post-monsoon periods. Soil of the site at several regions eroded to the river profusely resulting in cracks and crevices. Litter accumulation is

practically absent. Being a river bank, the site experiences RH of 80 to 90% and temperature range of 24 to 34^0 C.

11. Thiruvazhamkunnu - I: This site represents an area of 6 hectares of plain grazing land (Fig. 11) from a vast stretch of open grassland maintained by the cattle breeding centre (Fig. 12) of Kerala Agricultural University. Soil of the region is of loamy clay nature with abundant grass stumps throughout. Temperature and relative humidity of the region ranged from 22 to 31^0 C and 55 to 75% respectively. This was originally a coconut garden later converted into a grassland. Therefore coconut trees are common in the site. Among the grasses cultivated, species like *Andropogon giganus* and signal grass constituted the major groups in the area. Apart from the grassland, soil samples were also collected from the backyard of the cowshed (Fig. 13) where instances of occurrence of tapeworm proglottids in cow dung were reported earlier. Soil of this area is very rich in organic content.

12. Thiruvazhamkunnu - II: This represents a forest area adjacent to the grassland site mentioned above. It extends over an area of several hectares, of which 2 hectares where extensive grazing by cattle is being allowed. It is a mixed forest land harbouring trees like *X. xylocarpa, A. integrifolia, M. indica* etc., shrubs such as *Canthium parthflorum, Morinda umbellata*, etc. Herbs like *I. coccinea, Vicoa indica,* etc. and grasses like *Brachiaria seigera, Setaria pallida-fusca,*

Pennisetum polystachyon etc. Being a forest, sun light rarely reaches the ground and litter accumulation of the site is about 3 to 4 cm. Soil of this region is characterized by patches of rocky remnants which often create difficulty during sampling. Sampling was carried out occassionally. Temperature ranged from 24 to 32° C and RH ranged from 60 to 82%.

13. Attapadi - I: This site lies by the side of the main forest of Attapadi and comprises an area of 3-4 hectares of land. The region is a plain marshy area with fertile soil. Vegetation of the site includes different species of grasses such as *Calophyllum* spp. *Cassia siamea, M. peltata, Alianthus* sp. etc. along with shrubs like *I. malabarica, I. coccinea* etc.

A prominent feature of the site is the deposition of some quantity of litter from the upland forests. Humification of such litter is often evident at waterlogged regions. Temperature and relative humidity of the region ranged from 30 to 32° C and 80 to 88%. Domesticated goats (Fig. 14) of tribal colonies and private goat farms are let free for grazing in this region.

14. Attapadi - II : This collection locality forms a small region of about 5 hectares of a vast forest of the Nilambur region. The region is a hill slope with rocky loam type of soil. The area experiences a temperature of 26 to 30°C while RH of the region varied from 84 to 90%. This site harbours a rich vegetation including all

groups of plants like grasses, herbs, shrubs, climbers and trees (Fig. 14). The vegetation is characterised by the abundance of climbers. Some of the prominent species of plants of the site are the following:

Grasses: *C. lacryma-jobi, C. gigantia, R. exaltata, H. contortus, Peretis indica* etc.

Herbs: *Borreria rofea, V. indica, X. strumarium*, etc.

Shrubs: *I. malabrica, C. parviflorum.*

Climbers: *M. umbellata, I. malabarica, Ichnocarpus frutescens*, etc.

Trees: *X. xylocarpa, Bompax ceiba, Mitragyna* sp., *Phyllanthus emblica, A. scholaris, Aphancemixis* sp., *Olea dioica, S. nux-vomica*, etc.

Goats from the adjacent open grasslands often move to this shaded region during hot days.

15. Mannuthy - I: This site is an open grassland area (Fig. 15) of about 6 hectares forming the base of a hillock at the goat farm of the Kerala Agricultural University. The soil is of black loamy type with abundant pebbles. Temperature and RH varied from 28 to 32°C and 60 to 80% respectively. This area is a continuous stretch of grassland with goat sheds, fodder house, and other buildings of the farm unit. Vegetation is dominated by grasses like *E. trispicata, D. longiflora, S. piliforus* etc. In addition to this, few annual herbs such as *I. goebelli, D. ciliaris* etc. also occur

along with grasses. The region experiences continuous human interference due to farming and construction activities of the farm workers.

16. Mannuthy - II: The shaded grassland site forms the hill slope and upland region of the hillock at the farm land of the Kerala Agricultural University. Soil type and temperature of this site are similar to that of the open grassland area described above. However, marked difference is seen in the vegetational components. This site harbours more complex vegetation including all types of plants (Fig. 16) from grasses to trees. The tall grasses such as *Pennisetum polystachyon* and *Socciolepis interrupta* dominated the ground surface. Herbs and twiners are seen intermittently with the grasses. They include *X. struminarium, D. ciliaris, J. frutescens, Parsonsia alboflavescens* etc. Other plants include trees like *C. pentandra, Ficus callosa M. peltata, Mallotus philippensis* etc. On comparison with the open grassland area, human intervention in this site is much low. Goats are the major grazing animals of both these sites. However, cattle are also let to graze on these areas occassionally.

c) Collection of Samples

Collection of soil samples from the study sites at various localities was carried out mainly with two intentions. The first intention involves collection of soil samples for extraction of mites to locate natural infection by cestode parasites in

them, their identification, and also qualitative and quantitative assessment. Secondly collection of soil samples for frequent extraction of mites for biological studies was required. For collection of mites to serve the first, a rectangular iron sampler was used whereas for the second an iron scoop was used. Usually sampling was made during early hours of the day. The collected samples were transferred to clean polythene bags, labelled and transported immediately to the laboratory for the extraction of its fauna.

d) Extraction of Soil Samples

The samples collected were extracted under a series of Berlese Tullgren-funnel apparatus made locally for the purpose (Fig. 17). The frame of this rectangular unit (168 cm x 90 cm x 190 cm) is made of steel and rests on four legs. The bottom and the top of the unit are covered by steel sheets. Three rows of wooden planks with ten holes are provided for holding the funnel. Each row has ten units arranged in two parallel series of five each. Thus the apparatus has a total of thirty units. Each unit comprises three parts namely, (1) Heat sources (2) Sample container and (3) Collecting unit.

(1) Heat Source: The heat source in each unit is provided by an electric bulb, the intensity of which is decided by the thickness and moisture conent of the sample. The distance between the bulb and the sample is normally 12 cms. But it

could be increased or reduced by raising or lowering the wooden planks with the help of screws provided at the corners. During summer when the samples are dry 40 and 60 watt bulbs are used and during rainy season they are replaced by 100 watt bulbs. For procuring larval and nymphal stages an automatic electric dimmerstat is used to regulate the heat intensity.

(2) Sample Container Unit: The sample container unit consists of a circular vessel, resting shield and a funnel, all made up of brass (Fig. 18). The sample container is a circular brass vessel measuring 15 cm in diameter and 10 cms in height. The bottom of the container consists of a fine wire mesh of 0.8 mm size and a diameter of 15 cm. There is a gap of one cm between the base and the lower rim of the sample container. Below the sample container is a rounded resting shield also made of brass and having a diameter of 19 cm with a large mesh size of .5 cm. Two vertical rods are attached to either side of the shield, the tips of which are provided with hooks. The sample container with the resting shield could be removed and replaced by lifting the rod without disturbing the sample.

The brass funnel which contains the resting shield and the sample container has a length of 20 cm and mouth diameter of 16 cm. The tail region has only a diameter of 2 cms. It is conical in shape with steep and smooth inner sides. The

upper rim of the funnel is well flattened into a platform with raised edges to accommodate the resting shield and the sample container.

(3) The Collection Unit: It consists of collection vials and a spring fixed on a metal block. The vials measuring 6 cm in length and 3 cm in diameter are made of glass or plastic. These vials are placed below the tail ends of the funnels with the help of the above springs, which fix them tightly to the lower end of the funnel. The collected samples are placed in the container without any disturbance in an inverted position and the bulbs are switched on.

The extraction technique, employed here is based on the principles of Berlesee's original funnel apparatus modified by Tullgren using heat to desiccate the sample gradually thereby enabling to drive out the fauna. The animals move deeper into the sample, reach the fine mesh screen and finally fall into the collecting vials through the funnel. Mites for taxonomical and ecological studies were collected in 70% alcohol. However for biological studies mites were collected in live condition. In order to obtain mites in live condition, litter from the habitat of the mites was collected, dried and powdered. A small quantity of this was then moistened and transferred to separate collecting vials before they were springed to funnel bases. Care was taken to moisten the powdered litter as and when necessary by observing small portions under stereomicroscope. Oribatid mites found moving

were then transferred to culture cells, consisting of plastic containers based with 3:1 mixture of plaster of paris and animal charcoal. Individual species of mites after separation through routine collection were transferred to different culture vials. Sufficient number of mites in such culture vials were maintained in the laboratory under controlled conditions for further use.

e) Clearing and Mounting

Mites for preservation and taxonomic studies were collected in 70% alcohol and upgraded in series of alcohol and transferred to clearing medium containing absolute alcohol and lactic acid in 1:1 ratio. The cleared mites were mounted temporarily in glycerine and examined under a microscope for the identification of the mite. Permanent slides were prepared in Hoyer's medium (Baker and Wharton, 1952).

Hoyer's medium

Gum arabic	-	30 gms
Chloral hydrate	-	200 gms
Distilled water	-	50 ml
Glycerine	-	20 ml

50 ml of distilled water was taken in a beaker. 30 gms of gum arabic and 200 gms of chloral hydrate were added and mixed thoroughly. To this 20 ml of glycerine was added and mixed at room temperature. This mixture was filtered and used for making permanent slides.

The mites mounted on slides were examined under a Leitz Ariskoplan microscope. Drawings were made using a camera lucida and measuremnts were made by an ocular micrometer.

f) Culturing

Culturing of the mites in the laboratory was carried out in specific culture cells (Fig. 19) as per Haq (1978). The base of the culture cells was frequently moistened and moisture level was noted with the help of a hygrometer (Fig. 19). RH was regularly maintained at 80% throughout the investigation. Litter of various plants, known species of fungi, bacteria, algae, moss, lichens and other materials like live and dead arthropods, nematodes and eggs of cestode parasites were offered as food for these mites. Preferred food items of individual species of mites was recorded through food choice test.

g) Food Choice Test

In order to get a general idea of the food and feeding habits of the mites

continuous observation was made in the laboratory to record their response towards each of the food items provided. Most of these food items were isolated from the natural habitats of the mites and ready stocks were maintained (Fig. 19) before the initiation of the experiment. Simultaneously, two different food items were introduced sufficiently apart from one another in the culture cell. Feeding responses of the mites to the different food items provided were noted by specific methods. Total rejection of the mites of a particular food item and the consequent absence of faecal pellets were considered to be indicative of the rejection by the mites of certain items of food. Occasional movement of the mites on the food material and production of a few faecal pellets were considered to be instances of consumption. Presence of the mites in or on the food substance during most of the time and continuous production of large number of faecal pellets were taken as a token of preference. Selective consumption of a particular food item enabling the mites to complete their life-cycle was regarded as proof for reproductive success.

Isolation of Fungi

Soil samples from the study area were mixed thoroughly and one gram of the mixture was dissolved in 100 ml of sterile water in a conical flask. The solution was diluted by mixing with sterile water at suitable ratio. One ml of the diluted soil solution was pipetted out into a set of sterile petridishes. 20 ml of cooled potato

dextrose agar (PDA) medium (Booth 1971) was poured over the soil solution in each petridish. The petridishes were swirled and incubated in the dark for 4-5 days. Colonies of fungi formed were examined and marked. Spores from these colonies were inoculated on fresh PDA medium and the process was repeated till pure colonies of individual species of fungus were raised. Pure cultures of the fungi were transferred to fresh PDA slants in test tubes and stored at low temperature. All inoculations were done under sterile conditions. Portions of the fungal colonies in the test tubes were removed along with the agar base under asceptic conditon using sterile spatula introduced to the culture cells for feeding the mites. Ten species of fungi such as *Cladosporium oxysporum, Alternaria alternata, Curvularia geniculata, Trichoderma viride, Fusarium solani, Penicillium citrinum, Phoma glomerata, Pestalotiopsis versicolor, Pestalotia* sp. and *Botryodiploidia theobromae* could be isolated from the soil of the study area and cultured in the laboratory.

Isolation of Bacteria

One ml of the previously prepared diluted soil solution was pipetted out into a set of petridishes. 15 ml of freshly prepared cooled nutrient broth medium (Harrigan and Margaret, 1966) was poured over the soil solution in each petridish, swirled and incubated for 24 hrs. From the bacterial colonies developed, pure

cultures of individual species were prepared by repeating the process. *Serratia marcescens, Bacillus subtilis, Flavobacterium* sp.I and *Flavobacterium* sp. II were cultured in the laboratory for experimental purpose.

Collection of Algae

Protococcus sp. of alga growing on the trunks of *Artocarpus indicus* and *Spheroplea* sp. from nearby pond were collected and offered to the mites.

Collection of Moss

The common moss *Funaria* sp. from trunks of *M. indica* and *A. integrifolia* and from moist walls of buildings were collected and offered to the experimental mites in cultures for feeding observation.

Collection of Lichen

Lichen growing on trees and in soil in the Botanical garden of the Calicut University were removed and brought to the laboratory for feeding experiments.

Collection of Tapeworm Eggs

Frequent visits were made to slaughter houses and mature worms of *M. expansa* were collected. The specimens were brought to the laboratory and the gravid proglottids were removed carefully. The eggs of the tapeworm were

removed by dissecting the proglottids and offered to the mites in culture cells. Excess eggs were preserved in cow dung and normal saline mixture for future use.

Collection of Soil Arthropods

Live and dead microarthropods were procured from the stock cultures maintained in the laboratory.

Collection of Nematodes

Nematodes of the species *Radopholus similis* were obtained from fresh soil samples.

All the above items of food materials maintained in the laboratory were tested with each species of mites and the response of individual species was assessed. Data obtained were analysed for arriving at conclusion.

h) Post-embryonic Development and Longevity of Oribatid Mites

The duration and pattern of the development of the oribatid mites, which confirmed their vector role were studied in the laboratory by daily observation of the cultures. The number of days required for the completion of individual instars, total duration for attaining adult stage, and ovipositional behaviour of each species were studied in detail. Longevity of the adult mites was tested by rearing the laboratory bred mites till their death.

i) Artificial Infection of the Mites by *Moniezia expansa*

During the present study the cestode parasite *M. expansa* was used for experimental infection of oribatid mites. The species of mites which exhibited feeding affinity towards cestode eggs during their food choice test were considered for artificial infection. Known number of eggs of *M. expansa* were offered to the mites along with their preferred food items in the culture cells. Routine observation of the culture cells was made to confirm the consumption of the eggs by the mites. Several such experimental sets were maintained in the laboratory. Random samples of mites within a period of three months was made from the cultures during the course of the experiment. The mites were picked up, fixed, dehydrated, cleared and examined to ascertain the stages of the development of the parasite within the body cavity of the mites.

j) Recovery of the Cestode from the Body Cavity of the Mites

The individual mites fed upon the eggs of *M. expansa* in the culture chambers were fixed in 70% alcohol, dehydrated by passing through 80% absolute alcohol for sufficiently longer duration. The dehydrated specimens were later transferred to clearing medium and ratained therein till attaining sufficient clarity for observation. The well cleared specimens were mounted in glycerine and examined under stereomicroscope for the presence of any stage(s) of the cestode

larva. The cysts inside the body cavity of the mites were stained using 70% borax carmine in alcohol. Anal plates and genital plates of the specimens were removed prior to staining in order to facilitate the entry of the stain in to the body cavity of the mite. The shape, size, number and stages of the larvae in individual mite specimens were noted and the duration required to attain specific stages of development by the cestode egg was thus traced.

The mite specimens were then treated with acid alcohol for 2-3 weeks to dissolve the cyst wall of the parasite. By gently tapping the notogaster of the mite, larvae of the tapeworm were forced to slide through the anal aperture of the mites. The number, size and shape of the suckers along with other identifying characters of the larvae were studied to ascertain the developmental stages of the cestode.

Table 1. **Characteristics of the sampling sites**

Sl. No.	Locality	District	SITE DESCRIPTION						
			Ecosystem	Area	Soil type	Tempera-ture & RH	Major vegetational components	Litter accumulation	Major grazing animals
1	Komeri - I (KOM-I)	Kannur	Open grassland	8 hectares	Black cotton soil	25 - 32°C 60 - 80%	Grasses, wild herbs and shrubs	Nil	Goat
2	Komeri - II (KOM-II)	Kannur	Shaded grassland	15 hectares	Black cotton soil	23 - 30°C 66 - 88%	Grasses, herbs, shrubs, climbers and few trees	1 - 3 cm	Goat
3	West Hill (WHILL)	Kozhikode	Open grassland	6 hectares	Red laterite	30 - 34°C 50 - 80%	Grasses, herbs and few trees	Nil	Cattle
4	Calicut University Campus - I (CUC-I)	Malappuram	Mixed cultivation	40 hectares	Red laterite	28 - 33°C 60 - 80%	Grasses, wild herbs, climbers, shrubs and few trees	0.5 cm	Goat & cattle
5	Calicut University Campus - II (CUC-II)	Malappuram	Mixed cultivation	40 hectares	Red laterite	28 - 33°C 60 - 80%	Grasses, wild herbs, climbers, shrubs and few trees	0.5 cm	Goat & cattle
6	Wyanad (WYD)	Wyanad	Virgin Forest	20 hectares	Laterite soil	16 - 22°C 70 - 85%	Evergreen and deciduous trees, shrubs, wild herbs, climbers and grasses	20 cm	Cattle
7	Silent Valley (SVY)	Palakkad	Virgin Forest	15 hectares	Laterite soil	15 - 20°C 70 - 90%	Evergreen and deciduous trees, shrubs, wild herbs, climbers and grasses	20 cm	Cattle
8	Vadakottuthara-I (VTR-I)	Palakkad	Open grassland	18 hectares	Laterite soil	25 - 32°C 56 - 80%	Grasses, herbs	Nil	Goat

9	Vadakottuthara-II (VTR-II)	Palakkad	Virgin forest	25 hectares	Laterite soil	22 - 30°C 60 - 82%	Evergreen trees, deciduous trees, wild herbs, grasses	12 cm	Cattle
10	Mannarghat (MNG)	Palakkad	Open grassland	4 hectares	Rocky loam	28 - 34°C 80 - 90%	Grasses, herbs	Nil	Cattle
11	Thiruvazham-kunnu-I (TVK-I)	Palakkad	Open grassland	6 hectares	Loamy clay	22 - 31°C 55 - 75%	Grasses, coconut trees	Nil	Cattle
12	Thiruvazham-kunnu-II (TVK-II)	Palakkad	Shaded grassland	2 hectares	Rocky loam	24 - 32°C 60 - 82%	Fodder trees, legumes, grasses	6 - 8 cm	Cattle
13	Attapadi - I (ATPD-I)	Palakkad	Open grassland	3 - 4 hectares	Marshy soil	30 - 32°C 80 - 88%	Grasses, shrubs	Nil	Goat
14	Attapadi - II (ATPD-II)	Palakkad	Shaded grassland	5 hectares	Rocky loam	26 - 30°C 84 - 90%	Wild trees, grasses, herbs, shrubs, climbers	Nil	Goat
15	Mannuthy - I (MNTY-I)	Thrissur	Open grassland	6 hectares	Black loam	28 - 32°C 60 - 80%	Grasses, herbs	Nil	Goat
16	Mannuthy-II (MNTY-II)	Thrissur	Shaded grassland	8 hectares	Black loam	28 - 32°C 60 - 80%	Wild trees, bushes, grasses	2 - 3 cm	Goat

PLATE I

Fig. 1. Komeri open grass site where goats are seen actively grazing.

Fig. 2. A scene of the grass land site at Komeri merging with Kannavam forest.

Fig. 3. A closer view of the West Hill site without any litter accumulations.

Fig. 4. Calicut University Stadium site with grazing cattles and goats.

Fig. 5. Calicut University mixed cultivation site showing uneven terrain with plenty of wild grasses and cultivated plants.

Fig. 6. Red laterite soil at the Calicut University Site II showing animal and human intervention.

Fig. 7. Wynad site showing luxurient growth of grass among the forest.

Fig. 8. Patches of grass lands amidst the evergreen forest ecosystem of Silent Valley site.

PLATE I

PLATE II

Fig. 9. Vadakkottuthara grassland site with adjacent semievergreen forest and goats.

Fig. 10. Mannarghat grassland site at the banks of Kunthipuzha river.

Fig. 11. Open grassland site at Thiruvazhamkunnu with background forest.

Fig. 12. A close up view of a farm cow from the cattle breeding centre at Thiruvazhamkunnu.

Fig. 13. Collection of soil samples from the backyard of the cattle shed at the cattle Breeding Centre, Thiruvazhamkunnu

Fig. 14. A view of Attapady sites I and II showing vegetation and goats.

Fig. 15. Open grassland site at Mannuthy showing actively grazing goats.

Fig. 16. Shaded grassland at Mannuthy farm with complex vegetational set up.

53F

PLATE II

16

PLATE III

Fig. 17. Extraction unit comprising series of Berlese-Tullgren funnels used for the extraction of mites.

Fig. 18. Close up view of the extraction funnel, sample container and wire mesh.

Fig. 19. A view of the food chambers and culture chambers used for biological studies.

Fig.20. A microscopic view of the oribatid mites collected from Komeri.

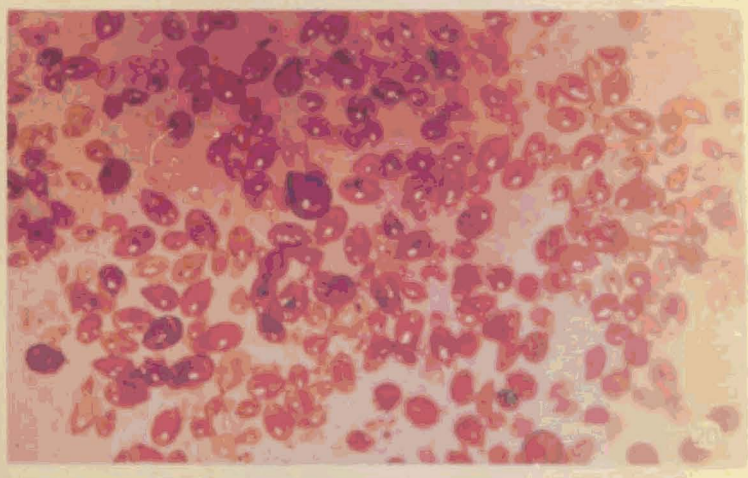
Fig.21. A closer view of galumnoid mites from the Calicut University Campus.

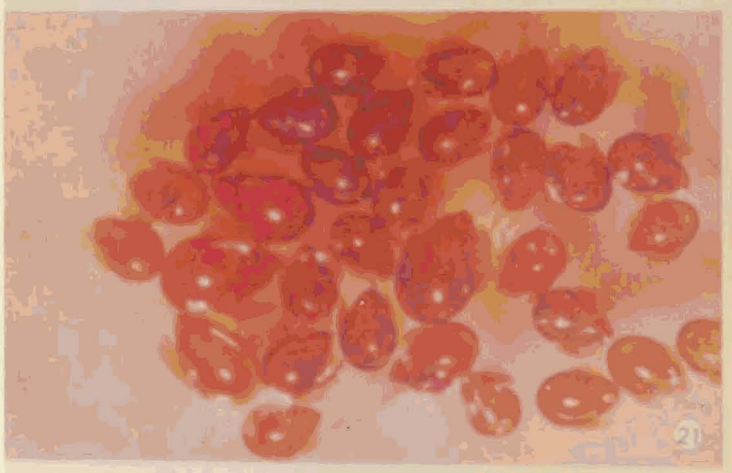
Fig.22. A closer view of Scheloribatid mites from the Calicut University Campus.

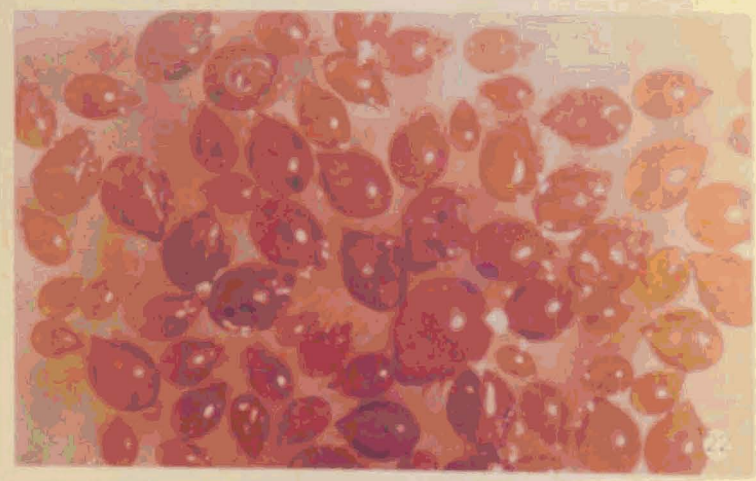
Fig. 23. *Scheloribates praeincisus* var. *interruptus* showing eggs of cestode.

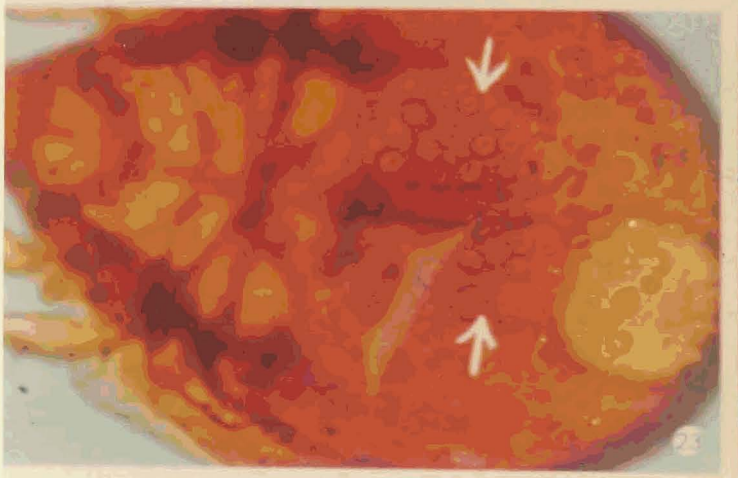
Fig. 24. *S. latipes* showing onchosphere in the body cavity.

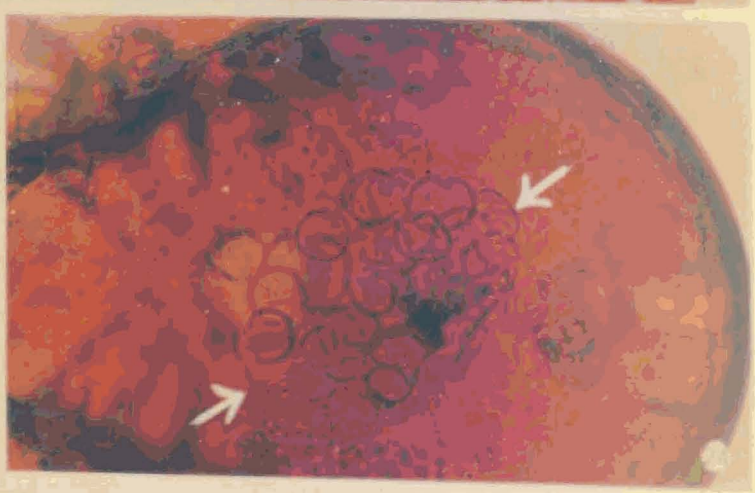
PLATE III









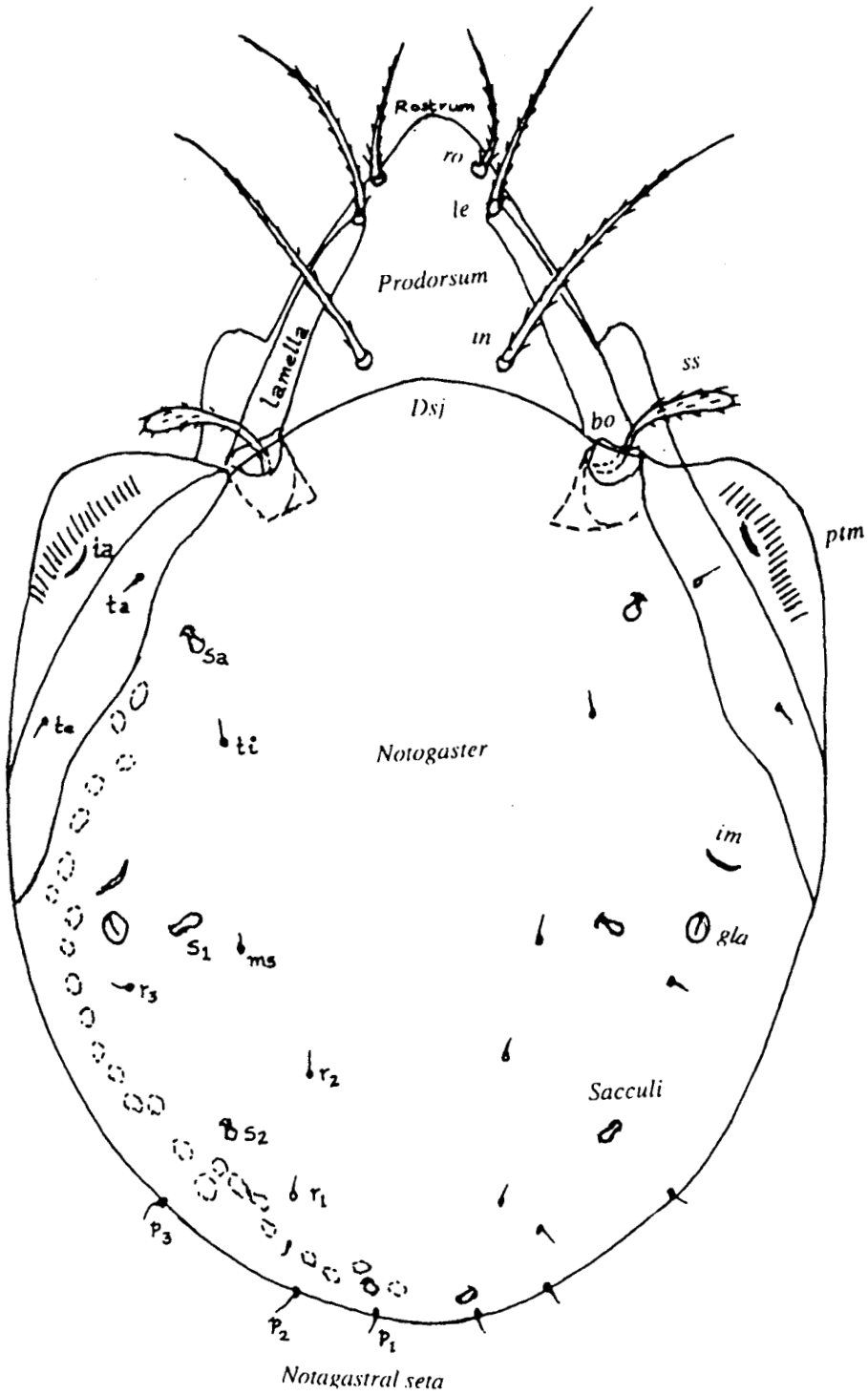


IDENTIFICATION OF ORIBATID MITES

R. Sobhana Amma “Studies on oribatid vectors” Thesis. Department of Zoology , University of Calicut, 1997

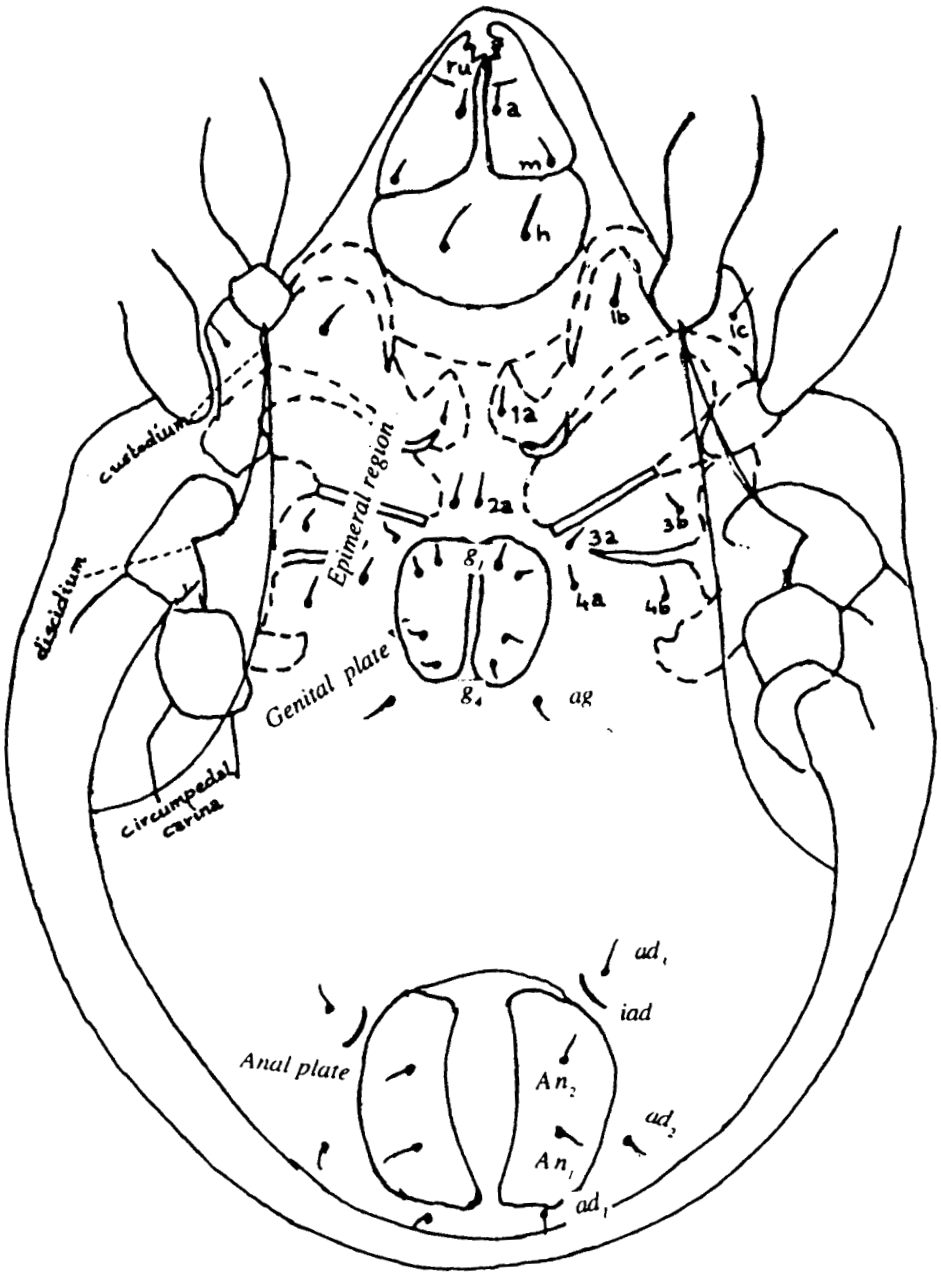
IDENTIFICATION OF ORIBATID MITES

FIG. A



EXTERNAL CHARACTERS OF ORIBATID MITE
DORSAL VIEW

FIG. B



EXTERNAL CHARACTERS OF ORIBATID MITE

VENTRAL VIEW

IDENTIFICATION OF ORIBATID MITES -

TERMINOLOGICAL SURVEY

(Figs. A & B)

Oribatid mites, the so called beetle mites or moss mites are characterized by heavy sclerotization and high degree of diversity with regard to their morphological features. A basic knowledge on the terminology used is necessary for the identification of oribatid mites. The terminology used here is mainly drawn from Balogh (1972), Wallwork (1965), Balogh and Mahunka (1983) and Woolley (1988).

The body size of oribatid mites varies from 100 μm to more than 1000 μm in length. They are generally dorsoventrally flattened, but sometimes they may be cylindrical or laterally compressed. The body is covered by thin and hard cuticle and the degree of sclerotization varies considerably from species to species.

The body of an oribatid mite consists of two parts (1) an anterior prosoma or propodosoma, the dorsal covering shield of which is termed prodorsum and (2) a posteriorly situated hysterosoma or opisthosoma, the dorsal covering shield of which is knwon as notogaster. In most oribatids the prodorsum and the notogaster are separated by a suture termed as the dorsosejugal suture which may be interrupted or completely absent in some cases.

Prodorsum: It represents the cuticular shield of the anterior part of the body and it covers the propodosoma. In primitive oribatids the propodosoma can be folded like the blade of a pen knife to the hysterosoma. In higher forms it is movable but not foldable to the hysterosoma or it is firmly fused to it. Prodorsum is almost triangular in shape and the anterior extremity of it is called the rostrum. Prodorsum carries four to six pairs of setae at different regions and they are (1) sensilli (*ss*) or pseudostigmaic organs (*bo*) (2) Interlamellar hairs (*in*) (3) lamellar hairs (*le*) (4) rostral hairs (*ro*) (5) anterior exostigmatal hairs (*exa*) and (6) posterior exostigmatal hairs (*exp*). Higher oribatids generally have only a single pair of exostigmatal hairs and in some others it may be absent. The sensilli are present in cup shaped invaginations called bothridia (bo) or pseudostigmata. The sensilli, the organs of perception are present in all oribatid mites but they may either be absent or very small in some groups. They may be of various shapes like setiform, fusiform, lamelliform, clavate, pectinate, spathulate etc. The rostral setae may arise from below or above the rostrum. The lamellar setae are generally located in the vicinity of the lamellar apex or lamellar cuspis. Interlamellar setae are usually situated in the interbothridial region in between the lamellar base or they may be located near to the dorsosejugal suture. Anterior and posterior exobothridial setae

originate from the anterior and the posterior sides of the bothridium respectively. The shape and size of all prodorsal setae may vary from species to species.

Extending from the base of the bothridium towards the rostrum, there is usually an appendage or outgrowth. If these organs are flat, lath shaped or lamelliform they are defined as lamellae. If they are only rib-like and projecting from the level of prodorsum, and not lamellate they are called costulae. The lamellae are frequently connected by a translamella. The apical portion of the lamella is the cuspis. In addition to the above, the prodorsum usually carries reticulations of various size and shape as well as punctations of different nature.

Notogaster: The notogaster which lies posterior to the prodorsum covers the hysterosoma. The notogaster may be elongated, oval, round, flat, pentagonal or hexagonal. The posterior portion of the notogaster may be sometimes broader than the anterior part. The notogaster is usually undivided. In certain cases it is divided by 1-3 transversal sutures, into 2-4 parts. Primitive oribatids have six notogastral segments arranged one after the other in the order c, d, e, f, h and Ps. These segments carry setae arranged in different positions. Primitive oribatids have 16 pairs of setae whereas higher oribatids possess 15 or 10-14 setae. While naming the setae, it is customary to name the segment first followed by a number indicating the relative position of the setae.

The notation of primitive oribatids with 16 pairs of setae

row 1: c_1, c_2, c_3

row 2 : d_1, d_2, d_3

row 3: e_1, e_2

row 4 : f_1, f_2

row 5 : h_1, h_2, h_3

last row : ps_1, ps_2, ps_3

The notation of higher oribatids with 14 or 15 pairs of setae

The homologies of the setae of the first row and the last two rows are certain. They are denoted as in the primitive oribatids. The homology of the six pairs of setae situated in the middle is uncertain and they are named according to their relative positions into three transverse rows. Accordingly the notation is as follows:

row 1	:	c_1, c_2 c_3
anterior row	:	*da, la*
median row	:	*dm, lm*
posterior row	:	*dp, lp*
row 5	:	h_1, h_2, h_3
last row	:	ps_1, ps_2, ps_3

Here 'd' indicates dorsal, 'l' lateral 'a' anterior 'm' median and 'p' posterior regions.

The notation of higher oribatids with 10 pairs of setae

Here only four rows are found and they are named as te, ms, r and p. The setae in the first row are named by three small letters of the alphabet viz. a, e, and i. The setae in the second row are designated as ms and there is only one seta in this row. The setae in the last two rows are designated using serial numbers viz. 1,2, and 3. Thus the notation is as follows.

First row : *ta, te, ti*

Second row : *ms*

Third row r : r_1, r_2, r_3

Fourth row p : p_1, p_2, p_3.

Here the letter 'a' stands for anterior 'e' for exterior and 'r' for interior. Some primitive oribatids have more than 16 pairs of setae. They differ from the normal ones and are called neotrichal setae and the condition is known as neotrichy.

In addition to setae, notogaster also carries other structures like condyles having different shapes, glands, respiratory structures like area porosae, sacculi and pores. The area porosae are portions thinner than usual of the notogaster and are

supplied with fine pores or tubes. In higher oribatids the usual number of circular area porosae is eight and hence Grandjean called them octotaxic organ. They are porosae adalares *(Aa)* and area porosae mesonoticae 1-3 (A_1, A_2, A_3). Apart from these, certain species bear a pair of area porosae on the dorsosejugal suture, area porosae doroejugales *(Ad)*, area porosae laterals *(Al)* in the side of the prodorsum and area porosae post anuales *(App)* behind the anal plates. The sacculi are small sacs sunken below the cuticle with only a slit or dot like opening to the surface. Their position and number correspond to those of the area porosae and are designated as S_a, S_1, S_2 and S_3. Pori are immersed sacs diminished to a punctiform pore and they are designated as P_a, P_1, P_2 and P_3. Lyrifissures are slit like openings and a maximum of severn pores can be distinguished. They are designated as *ia, ip, ih, ips, iad* and *iam*. Opening of the oil gland *gla* is seen at the middle or posterior region of the notogaster. Anteriolaterally on the shoulders of the notogaster there are characteristic wing like expansions called pteromorphae in many of the higher oribatids. Four types of pteromorphae are distinguished. They are immovable, eupterous, oxypterous and umbellate.

Lateral side

In certain higher oribatids, a chitinous longitudinal ridge called tutorium (*tu*) is present on the lateral side. The bases of the legs are partly covered and protected

by certain structures called pedotecta. The bases of the IVth leg are protected by lateral projections of the ventral plate called discidia. A wedge shaped crista called custodium projects from leg IV in certian oribatids.

Ventral region

Comprises the gnathosoma, the epimeral region and the ano-genital region.

Gnathosoma

It is located in an anterior cavity called camerostome and includes the mouth parts. It consists of an infracapitulum, paired palps and paired chelicerae. The palps have 2-5 segments. The chelicerae may be wide chewing type or elongated piercing type. The infracapitulum consists of an unpaired mentum, a dorsal neck or cervix, the paired genae and their continuation in the rutellum. The articulation between the mentum and genae is called labiogenal articulation and it may be of the following four types.

(1) Anarthric type : Without any special articulation

(2) Stenarthric type : Labiogenal artiulation is directed posteriorly and mentum appears triangular.

(3) Diarthric type : With transverse labio-genal articulation and mentum is quadrangular.

(4) Suctorial type : With united mento-genal plate.

The infracapitulum bears three pairs of setae one pair called *h* on the mentum and two pairs *a* and *m* on genae. Two setae *cha* and *chb* are present on the chelicerae. Pedipalps bear 2 to 5 segments and the setation varies with species.

Epimeral region

The ventral side of the propodosoma delimited anteriorly by the infracapitulum, bilaterally by the coxae of the legs and poseriorly by the genital plate is called the epimeral region. This region is covered by four epimeral plates ep_1, ep_2, ep_3 and ep_4. The epimeral plates are borderd by chitinous thickenings called apodemata and there are five apodemata apo_1, apo_2, apo_3, apo_4 and apo_5 (Apodemata sejugales). The epimeral setae are designated by a formula of four figures. The setae are counted in each epimeral plate from the middle towards the margin.

Genito-anal region

This is the region behind the epimeral region occupied by the genital and anal plates. In primitive oribatids or Macropyline type, the genital and anal plates touch each other and occupy the entire length of the genito-anal region. In higher oribatids ie., in the Brachypyline type the genital and anal plate do not meet each other and are situated on distinct ventral plates. There is a pair of small triangular aggenital plates lying laterally below the genital plate. In between the genital and

anal plates, a pre-anal plate is present. Lateral to the anal plate, a pair of longitudinally placed adanal plate is also present which may be either fused with the anal plate or may lie separate. Except preanal plate, all the other plates carry setae. In primitive oribatids the genital plate is divided by a transverse suture and bears 10 pairs of genital setae. The anal plate bears 2 and adanal plate bears 4 pairs of setae. In higher oribatids the most frequent chaetotaxy consists of 6 or 4 pairs of genital setae, 1 pair of aggenital setae, 2 pairs of anal setae and 3 pairs of adanal setae.

Legs

Adult mite possesses four pairs of legs and each leg has five segments, viz., trochanter, femur, genu, tibia and tarsus. The chaetotaxy of the legs vary from species to species as well as from leg I to IV. The tarsus is the longest segment of the leg and it bears the maximum number of setae including the fundamental and accessory setae. The tarsal segment of leg I is characterized by the presence of various setiform organs which include the eupathedia, famuli and solenidia. Tip of the tarsus bears 1-3 claws depending on the species.

Eupathedia

In oribatids eupatheds are restricted to the tarsi and are found most often on tarsus I rarely on tarsus II and never on tarsus III and IV. These are modified setae

with a hollow central canal penetrating a small root and a large alucolus. They are devoid of any ornamentation and are sensory in function.

Famuli

Famuli are found only on the tarsal segments. It is hollow and resembles the solenidion or eupathed but can be distinguished from them by the presence of actinochitin. The internal surface is not striated but somewhat rugosed.

Solenidea

They are hollow, thin walled setae without actinochitin and are seen on the genu, tibia and tarsus. They are tactile in function. Grandjean has grouped them into four types (1) Baculiform, when they are having the same diameter throughout (2) Ceratiform, when they are tapering towards the tip but still visibly rounded. (3) Piliform, when they are elongated with a fine tip and (4) Tactile, when they are very long and flagellate. Solenidia are smooth yellow coloured and circular or oval in cross-section. They seem to have striations which are caused by the helicoid ridges on the internal wall.

DESCRIPTION OF VECTOR SPECIES OF ORIBATID MITES

Superfamily : **Eremuloidea Grandjean, 1965**

Family : **Damaeolidae Grandjean, 1965**

Genus : ***Fosseremus* Grandjean, 1954**

***Fosseremus silensis* sp. nov. (Figs 1-2)**

Colour : Light brown

Measurements: Length : 221 µm (Range: 212 - 221 µm)

Width : 129 µm (Range: 120 - 129 µm)

Dorsal region (Fig. 1)

Prodorsum

Prodorsum somewhat conical with wavy lateral margins. Rostrum more or less pointed. Seta *ro* smooth, slender and curved medially, inserted on the lateral wall, beyond the rostral tip. *ro* forms the longest of prodorsal setae measuring 22µm. Seta *le* also smooth, slender, directed anteriorly, inserted on the tip of the costula and measures 20µm in length. Costulae slender and wavy, the apices of which connected by a transverse translamella. Seta *in* small, thin, smooth, measures, 7 µm and with prominent insertion points. *in* of the two sides inserted

close together. Bothridial cup with wide opening and the sensillus characteristically long, is stalk being slender and smoooth while the head gradually dilated with a hyaline, separated apical part. A single pair of short, thin exostigmatic setae (*ex*) inserted anterolateral to the bothridial cup-prodorsal surface smooth.

Notogaster

Notogaster elongated and oval in appearance. Anterior border almost straight while the poserior border more or less conical. 11 pairs of smooth setae of varying lengths arranged on the notogaster as represented in figure. Notogaster characteristic in having an H-shaped zone, delimiting 4 depressed areas of various shapes, one anterior, one posterior and two lateral depressions. The depressed areas devoid of setae. Fissure *im* shifted more posteriorly. Surface of notogaster possesses closely set linear to wavy markings.

Ventral region (Fig. 2)

Labiogenal articulation diarthric. Rutellum less sclerotised. 2 pairs of infracapitular setae located, *a* longer and thicker than *h*, *m* absent. Mentum smooth. Epimeral boundaries distinct. Setal formula of epimerata 3-1-2-2, all setae smooth and thin. Setae *1a*, *2a*, *3a*, *3b* and *4b* minute. Apodemes 2, 3 and sejugal one clearly discernible, the latter the longest. . A transverse arched ridge present at the

sternal region, connecting the fourth epimeral boundries of the two sides. Genital plates elongated bearing 6 pairs of smooth setae, 2 anterior pairs placed close together linearly, on the anterior compartment of the genital plate. The remaining 4 pairs arranged on the posterior compartment vertically, one below the other. Genital plates smooth. 3 pairs of smooth slender aggenital setae placed posterolateral to the genital plates. Anal plates somewhat rectangular bearing 2 pairs of smooth setae, just above and below the median level. Anal plates carry a well developed wavy ridge, arranged vertically. Adanal setae 3 pairs, all slender and smooth, ad_1 post-anal while ad_2 and ad_3 para-anal in position. Exterior to the adanal plates fissure *ip* located, the latter placed vertically, at the level of seta an_2. Fissure *iad* distantly placed lateral to the anal plates, above seta ad_3. Ventral plate smooth.

Legs: All legs monodactylous.

Materials examined: Holotype: $\hat{O}$, Paratypes: $1\hat{O}\hat{O}$ collected from the open grasslands at Mannarghat, Palakkad (Dt.); $1\hat{O}$ collected from the shaded grassland at Mannuthy on 11.8.1993 and 1O from the virgin forest floor of Silent Valley, Palakkad (Dt.) on 22.6.1994.

Remarks: *Fosseremus* represents a cosmopolitan genus erected by Grandjean (1954) based on the type species *Damaeosoma laciniatus* (Berlese, 1905). The

genus currently includes 6 species viz. *F. laciniatus* (Berlese, 1905), *F. saltaensis* Hammer, 1958, *F. pistillifera* Balogh, 1958, *F. africanus*, Balogh, 1958, *F. quadripertitus* Grandjean, 1965, *F. sculpturatus* Mahunka, 1982. Of the 6 species compared, the new species shows some resemblance to *F. saltaensis* erected by Hammer (1958) from Argentina in nature of translamella, prodorsal hairs, and nature of nologastral setae. However, the new species can be separated from the above species by the possession of following characters.

1. Nature of sensillus
2. Absence of curved ridges on the prodorsum.
3. The characteristic ornamentation of notogaster instead of the reticulation of *F. sultaensis* and
4. Presence of 6 pairs of genital setae instead of the 4 pairs of *F. saltaensis*.

Superfamily : **Otocepheioidea Balogh, 1972**
Family : **Otocepheidae Balogh, 1961**
Genus : ***Nesotocepheus*, Hammer, 1972**

***Nesotocepheus hauseri* Mahunka, 1980c (Figs. 3-4)**

Colour : Dark brown

Measurements: Length : 580 µm (Range: 570 - 593 µm)
Width : 271 µm (Range: 258 - 285 µm)

Dorsal region (Fig. 3)

Prodorsum

Rostrum elongate with a blunt anterior margin. *Seta ro* dentate unilaterally, curved and inserted along the lateral border. Seta *le* also curved, weakly barbed and inserted at the lamellar apex. Lamellae with undulating inner margin, almost parallel and reach the base of pseudostigmatic organ. Seta *in* inserted far above the bothridial cup, thick, roughened and with blunt tip. Bothridial cup small, from which protrudes the smooth, curved stalk of the sensillus bearing a spined, fusiform head. Area between the bothridia of the two sides possess linearly arranged rectangular foveoles with bristles, arranged in two rows. The foveoles bordered by semilunar markings and porose integument. Area anterior to seta *in* ornamented with round to semilunar foveoles.

Notogaster

Notogaster oval with somewhat straight dorsosejugal suture, anteriorly interrupted by two pairs of notogastral condyles. 10 pairs of roughened thick setae of varying lengths arranged on the notogaster. Linearly arranged foveoles at the posterior half of the lateral portion of the notogaster present a beaded or chain like appearance. Anterior to the foveolae, a vertical chitinous ridge runs along the interal border, up to the base of the lateral condyle. Apart from the porose nature,

notogaster at various regions exhibits the possession of semilunar markings, disclosing a regose nature.

Ventral region (Fig. 4)

Infracapitulum with diarthric articulation. 3 pairs of smooth setae present on the gnathosoma. Mentum ornamented with foveoles and porose nature while the genae smooth. Epimeral area also porose with a chaeototaxy of 3-1-2-3; seta *lc* barbed and the remaining setae smooth. Sejugal apodeme the longest. Genital plates more sclerotised than the surrounding ventral plate. 3 pairs of smooth setae present on the genital plates. Aggenital setae a single pair, thick and smooth. Anal plates well sclerotized bearing 2 pairs of setae, an_1 barbed and longer than an_2, the latter small and smooth. 3 pairs of adanal setae present, ad_1 and ad_2 long and smooth, ad_3 short and smooth. Fissure iad horizontally placed at the anterolateral corner of the anal plate, between ad_2 and ad_3. Ventral plate appears porose medially and with slit like ornamentation laterally.

Legs: All legs monodactylous.

Materials examined: 2 ♂♂s and 2 ♂♂s collected from the shaded grassland at Mannuthy on 4.6.94 and 3 ♂♂s and 1 ♀ collected from the virgin forest at Silent Valley on 12.9.94.

Remarks: The specimen agrees with *N. hauseri* erected by Mahunka, 1980 from Argentina. However, the prodorsal and notogastral ornamentation observed in the present specimen do not agree with that of the type species.

Superfamily : **Oribatuloidea Woolley, 1956**

Family : **Oribatulidae Thor, 1929**

Genus : ***Zygoribatula* Berlese, 1917**

***Zygoribatula lineata* Hammer, 1979 (Figs. 5-6)**

Colour : Light brown

Measurements: Length : 267 µm (Range: 248 - 281 µm)

Width : 166 µm (Range: 161 - 175 µm)

Dorsal region (Fig. 5)

Prodorsum

Prodorsum broader than longer with a well pointed rostrum. Setae *ro* slender, feebly barbed and curved medially. Seta *le* barbed, thicker but shorter than *ro*, and with blunt tip. Seta *in* the shortest among the prodorsal setae and provided with short barbs. Costulae oriented anteromedially and converging with well developed cuspis for the insertion of seta *le*. Costulae of the two sides connected by a thin translamella. Area porosae (*A1*) present at the outer border of the lamellae. Exterior to the lamellae, on either side a vertical line present which meets the prodorsal border below the insertion level of seta *ro*. Another faint semicircular ridge covering the entire prodorsal region present above the anterior border of the

lamellae. Bothridial cups directed laterad. Seta *exa* present, thin and barbed. Sensillus (*ss*) with a short, smooth stalk and a clavate head of spined nature. Integument of prodorsum smooth throughout.

Notogaster

Notogaster oval and highly convex in appearance with maximum breadth at the middle region. 14 pairs of notogastral setae with short barbs present. 4 pairs of area porosae of various size and shape discernible on notogaster. *Aa* elongate while A_1, A_2 *and* A_3 somewhat oval. Fissure *ia* placed far anteriorly, below seta *ta*. Fissure *in* situated slightly below the middle of notogaster. Aggregated muscle scars detected along the lateral and posterior borders of the notogaster.

Ventral region (Fig. 6)

Diathric type of articulation present on infracapitulum. 3 pairs of infracapitular setae, all barbed. Mentum smooth. Epimeral surface foveolated medially. Apodemata 2, 3 and the sejugal one detected. Sejugal apodemes of the two sides meeting medially, forming a broad, band like structure. Epimeral setal formula 3-1-3-3. Faint reticulations seen on the fourth epimere. Circumpedal carina well developed. Genital plates broader anteriorly and narrower posteriorly, each plate carrying 4 smooth setae. Ventral plate encircling the genital aperture more sclerotized and thickened. A single pair of short, smooth aggenital setae

inserted posterior to the genital plates. Anal plates carry two pairs of smooth setae, an_1 anterior to and an_2 posterior to the middle of each plate. 3 pairs of short, smooth setae located at the adanal region, ad_1 post-anal, ad_2 para-anal and ad_3 pre-anal in position. Fissure *iad* seen at the anterolateral corner of the anal plate.

Legs: All legs tri and heterodactylous. Central claw thicker than the two lateral ones.

Materials examined: 5 ♂♂ and 2 ♀♀ collected from the open grassland at Mannarghat, Palakkad (Dt.) on 22.7.93 and 2 ♀♀ collected from Silent Valley virgin forest on 5.11.93.

Remarks: The specimen agrees with *Z. lineata* created by Hammer (1979) from Java excluding the following dissimilarities: presence of translamella, elongated nature of *Aa*, absence of sculpture on the ventral plate and the smooth nature of adanal setae.

Superfamily : **Oribatuloidea Woolley, 1956**

Family : **Scheloribatidae Grandjean, 1933**

Genus : ***Scheloribates* Berlese, 1908**

***Scheloribates laevigatus* (C.L. Koch, 1836) (Figs. 7-8)**

Colour : Light brown

Measurements: Length : 368 µm (Range: 368 - 382 µm)

Width : 221 µm (Range: 212 - 225 µm)

Dorsal region (Fig. 7)

Prodorsum

Prodorsum broad basally and narrowing apically ending in a round rostrum. Seta *ro* barbed unilaterally. Seta *le* longer than *ro*, barbed and erect. Lamella narrowing anteriorly, bearing seta *le* at its apex. Seta *in* also with few barbs, shorter than *le*. Bothridial cup sunken from which protrudes the sensillus, the latter with a short, smooth, curved stalk and a somewhat clavate head bearing short spines. Apex of head pointed. Prodorsal region smooth.

Notogaster

Notogaster with an arched anterior margin and looks oblong in appearance. Anterolateral margins with partly developed pteromorphae carrying striae. 10 pairs of small setae distributed on the notogaster, 2 of which on each pteromorph. 4 pairs of small sacculi also detected near setae *ti*, *ms*, r_1 and between r_2 and r_3. Lyriffisure *ia* placed on the pteromorph while *im* more or less medially located. Notogastral surface smooth. Muscle scars aggregated along the lateral border of notogaster.

Ventral region (Fig. 8)

Diarthric type of infracapitulum carrying 3 pairs of smooth setae. Rutellum with 3-4 sclerotised notches. Mentum and genae smooth. Epimeral surface with

irregular foveolae and beset with small setae following the order 3-2-1-2. Genital plates carry 4 pairs of setae, 2 pairs on the anterior half and the other 2 pairs on the posterior half. Single pair of aggenital hairs located. Anal plates with 2 pairs of setae, both smooth and short. Adanal setae 3 pairs, ad_1 at the posterolateral border, ad_2 lateral and ad_3 anterolateral in position. Fissure *iad* vertical and placed near seta ad_3. Ventral plate smooth.

Legs: All legs carry 3 claws, of which central one stout and lateral ones thin.

Materials examined: 4 ♂♂s and 1 ♀ collected from Vadakottuthara, Palakkad (Dt.) on 22.8.95 and 2 ♂♂ collected from Mannuthy, Trichur (Dt.) on 12.9.95.

Remarks: The specimen resembles *S. laevigatus* described by C.L. Koch (1836) in all characters.

***Scheloribates latipes* (C.L. Koch, 1841)**

(Figs. 9-10)

Colour : Light brown

Measurements: Length : 299 µm (Range: 290 - 308 µm)

Width : 212 µm (Range: 207 - 225 µm)

Dorsal region (Fig. 9)

Prodorsum

Prodorsum broader than longer with a rounded rostral apex. Seta *ro* unilaterally barbed and directed anteriorly. Seta *le* with small barbs and inserted at the lamellar apex. Seta *in* the longest of prodorsal hairs and resembles *le* in nature. Lamellae broader basally and narrowing towards apex. Bothridial cup opens anterolaterally. Sensillus with a short, thin, smooth stalk and a clavate head bearing few spines. No ornamentation seen on the prodorsal surface.

Notogaster:

Dorsosejugal suture highly arched. Pteromorph with a round anterior border bearing few closely set striae. 10 pairs of small setae present, 2 pairs of which located on the pteromorphae. Fissure *ia* obliquely placed on pteromorph. 4 pairs of sacculi also found on notogaster as represented in figure 9. Fissure *im* placed medially while *ip* situated more posteriorly. Muscle scars seen scattered along the lateral border of notogaster.

Ventral region (Fig. 10)

Labiogenal suture transverse. Seta *h* longer than *m* and *a*, all setae smooth. Mentum and mentotectum smooth. Epimeral surface also smooth bearing setae of

various length; setal formula of the epimeres 3-1-2-2. Sejugal apodeme the longest and apodeme 2 the shortest. Genital plates with 4 pairs of smooth setae. Aggenital setae also smooth. Anal plates with 2 pairs of setae, situated more or less medially. 3 pairs of adanal setae, all smooth and small, inserted at the adanal area, ad_1 pre-anal and ad_2 and ad_3 para-anal in position. Fissure *iad* vertically aligned at the anterolateral border, inner to seta ad_3. Ventral plate including the anogenital plates smooth.

Legs: All legs tridactylous with heterodactyly. Tarsus 1 carries 3 solenidia and a famulus.

Materials examined: 2 ♂♂ and 4 ♀♀ collected from the virgin forest at Vadakottuthara, Palakkad (Dt.) on 20.8.92.

Remarks: The specimen resembles *S. latipes* described by C.L. Koch (1841) except in the absence of a prolamellar line.

***Scheloribates praencisus* var. *interruptus* Berlese, 1916**

(Figs. 11-12)

Colour : Dark brown

Measurements:	Length	: 478 µm (Range: 460 - 483 µm)
	Width	: 368 µm (Range: 359 - 382 µm)

Dorsal region (Fig. 11)

Prodorsum

Prodorsum broader than long with a conical rostrum. Seta *ro* barbed, inserted slightly below the apex. Seta *le* thick, stout, barbed and acutely pointed. Lamellae broad basally and narrowing towards the tip. Translamella absent, but remnants of a translamellar line present, one on either lamellae. Seta *exa* also barbed weakly, placed at the level of bothridium and forms the shortest among the prodorsal hairs. Seta *in* resembles *le* in appearance and directed anterolaterally. Bothridial cup (*bo*) directed laterad from which sprouts the smooth stalk of *ss*, the head of *ss* clavate and spined. Prodorsal surface smooth.

Notogaster:

Dorsosejugal suture medially arched. Notogaster oval, broad and produced in to well discernible pteromorphae. The pteromorphae slightly concave medially and provided with serially arranged striations. 10 pairs of short, smooth setae located on the notogaster, 2 pairs of which on the pteromorphae. 4 pairs of sacculi also present on the notogaster, the arrangement of which shown in the figure. Large number of isolated and aggregated muscle scars noted along the lateral boundaries of the notogaster. The integument of the notogaster smooth.

Ventral region (Fig. 12)

Labiogenal articulation diarthric. Rutellum with 3-4 well secterotized notches. Infracapitular, setae 3 pairs, all barbed. Mentum, genae and mentotecum smooth. Epimeral boundaries well marked. Apodemes 2,3 and sejual apodeme, the latter the longest. Both discidium and custodium detected. Epimeral surface bears weakly developed foveoles. Epimeral setal formula 3-1-2-3, all setae short and smooth. Genital plates broad anteriorly and narrow posteriorly bearing 4 pairs of smooth setae, 2 pairs inserted anteriorly and the other 2 pairs posteriorly. A pair of aggenital setae (*ag*) present-posterior to the genital plates. Anal plates broader posteriorly bearing 2 pairs of smooth setae, inserted on the middle. 3 pairs of adanal setae detected, ad_1 posterior to the anal plate, ad_2 posterolateral and ad_3 anterior to the anal plates. Fissure *iad* seen at the anterolateral corner of the anal plates.

Legs: Legs tridactylous with unequal laws. Central claw stouter than the lateral ones. Tarsus I with 3 solenidia and a famulus apart from the tactile setae. Solenidiotaxy of leg - I : 0-0-1-2-3.

Materials examined: 4 $\overset{\uparrow\uparrow}{\mathrm{OO}}$ and 7 $\underset{++}{\mathrm{QQ}}$ collected from the open grassland at Mannarghat, Palakkad (Dt.) on 22.7.93.

Remarks: The specimen resembles *S. praeincisus* var. *interruptus* described by Berlese (1916). However, the pseudostigmatic organ in the present specimen is more clubbed than that of the type specimen. Moreover, the epimeral setal formula of the present specimen is 3-1-2-3 unlike the 3-1-3-3 of the type species.

Scheloribates rectus Hammer 1958

(Figs. 13-14)

Colour : Light brown

Measurements: Length : 414 μm (Range: 414 - 428 μm)

Width : 285 μm (Range: 281 - 290 μm)

Dorsal region (Fig. 13)

Prodorsum

Prodorsum broader at base. Rostrum narrow. Seta *ro* unilaterally barbed and curved medially. Seta *le* longer and thinner than *ro* and set with small bristles. Lamella broadest slightly below apex and narrow basally. Seta *in* resembles *le* in nature and erect in position. Bothridial cup almost sunken. Sensillus with a thin, smooth stalk and with a lanceolate, spined head with a pointed tip. Sensillus directed outwards and backwards The inner margin of sensillus head smooth.

Prodorsal surface smooth. Prolamellar line distinct while translamellar line interrupted medially.

Notogaster

Dorsosejugal suture arched. Pteromorphae slightly rounded at the anterior free end, below which a slight impression present, thereby imparting a triangular appearance. Pteromorphae bear striae, 2 pairs of setae (*ta, te*) and the fissure *ia*. The other 8 pairs of setae arranged on the notogaster as represented in figure. 4 pairs of sacculi also noted on the notogaster apart from lyrifissures *im* and *ip*. Integument of notogaster smooth.

Ventral region (Fig. 14)

Labiogenal suture transverse. Rutellum with 3 sclerotized notches. 3 pairs of infracapitular setae detected, all barbed. Mentum smooth. Epimeral surface with a setal formula of 3-1-2-2. Apodemes 2, 3 and sejugal apodeme developed. Discidium and circumpedal carina distinct. Genital plates with 4 pairs of smooth setae, 2 pairs inserted anteriorly and 2 pairs posteriorly. Aggenital seta located at the posterolateral corner of genital plate. Anal plates with 2 pairs of setae; an_1 medially placed while an_2 posterior in position. Adanal setae 3 pairs, ad_1 post-anal, ad_2 para-anal and ad_3 pre-anal in location. Fissure *iad* vertical, seen below seta ad_3, along the lateral border of the anal plate. Ventral plate smooth.

Legs: Legs tridactylous. Central claw on all legs stouter than the lateral claws.

Materials examined: 2 ♂♂ and 3 ♀♀ collected from the open grassland at Mannuthy, Palakkad (Dt.) on 12.7.95.

Remarks: The specimen resembles *S. rectus* described by Hammer (1958) from Bolivia in all characters except in the absence of chitinous pores on the notogaster.

Genus : *Ischeloribates* Corpuz-Raros, 1980

***Ischeloribates lanceolatus*, Aoki, 1984**

(Figs. 15-16)

Colour : Light brown to dark brown.

Measurements: Length : 368 μm (Range: 350 - 382 μm)

Width : 258 μm (Range: 239 - 271 μm)

Dorsal region (Fig. 15)

Prodorsum

Prodorsum broader than longer with a conical rostrum. Rostral apex blunt. Seta *ro* weakly barbed, inserted far beyond the rostral apex. Seta *le* longer than *ro*, feebly barbed and inserted at the lamellar apex. Lamellae broader basally and narrowing towards the apex, the latter curved mediad. Remnants of translamellar

line present, which interrupted medially. A thin prolamellar line connects the lamella with the anterolateral prodorsal border, at the insertion of seta *ro*. Seta *in* thicker, but shorter than *le*, sparsely barbed. Prodorsal surface smooth. Sensillus with a slender curved smooth stalk and a lanceolate head bearing barbs. Borthridial cup partly sunken and directed anterolaterad.

Notogaster

Notogaster more or less oval with an arched dorsosejugal suture anteriorly. Pteromorphae partially developed bearing closely set striations, 2 pairs of setae *ta* and *te* and fissure *ia*. The remaining 8 pairs of setae distributed on the notogaster as shown in figure 15. All setae small and smooth. Fissure *im* oblique and located more or less medially. Notogaster bears 4 pairs of sacculi also in close association with setae *ti*, *ms*, r_1 and r_3. Notogastral integument smooth.

Ventral region (Fig. 16)

Labiogenal articulation diarthric. 3 pairs of infracapitular setae present, *h* the longest and *a* the shortest, all being smooth. Mentum smooth. Epimeral setal formula 3-1-3-2, all setae smooth. Apodemes 2, 3 and the sejugal one detected, the latter being the longest. Genital plates bear 5 pairs of smooth setae, g_1 and g_2 anterior to the middle of each plate g_3 medially situated while g_4 and g_5 posteriorly inserted. A pair of smooth aggenital setae (*ag*) located posterior to the genital

plates. Anal plates carry 2 pairs of short and smooth setae as represented in figure. Of the 3 pairs of adanal setae ad_1 post-anal, ad_2 para-anal and ad_3 pre-anal in position ad_1 the longest and ad_3 the shortest. Fissure *iad* closely aligned at the anterolateral border of the anal plates, in between ad_2 and ad_3. Ventral surface also smooth, without bearing any ornamentation.

Leg: Legs monodactylous. Pedotecta of legs 1 and 2 well developed. Leg 1 carries solenidia on genu, tibia and tarsus. The tarsal segment bears a famulus also.

Materials examined: 6 ♂♂ and 8 ♀♀ collected from the open grassland at West Hill, Kozhikode (Dt.) on 23.9.94.

Remarks: The specimen resembles *I. lanceolatus* erected by Aoki (1984) from Japan with two character differences such as possession of an epimeral setal formula of 3-1-3-2 and the kidney shaped nature of the sacculi.

Superfamily : **Oribatuloidea Woolley, 1956**
Family : **Haplozetidae Grandjean, 1936**
Genus : ***Peloribates* Berlese, 1908**

***Peloribates levipunctatus* Aoki, 1984 (Figs. 17-18)**

Colour : Dark brown to black.

Measurements: Length : 474 µm (Range: 460 - 483 µm)
Width : 396 µm (Range: 391 - 409 µm)

Dorsal region (Fig. 18)

Prodorsum

Prodorsum triangular with a pointed rostrum. Anterolateral border of the prodorsum produced into a sharp tooth, just beyond the insertion of seta *ro*. The latter heavily barbed, curved forwards and inserted beyond the rostral apex. Lamella broad basally and narrows towards apex. Seta *le* inserted on the lamellar apex, barbed and longer than seta *ro*. Seta *in* the longest among the prodorsal hairs, inserted just above the dorsosejugal suture, barbed and sharply pointed. Bothridial cups directed laterad and partly sunken from which sprouts the curved, smooth stalk of the sensillus (*ss*), the head of sensillus clavate and spined. Prodorsal integument ornamented with round foveoles, which lack any distinct arrangement.

Notogaster

Dorsosejugal suture slightly arched. Posterior border of the notogaster clearly spherical. Anterolateral corners produced into movable pteromorphae. Closely set striations present on the pteromorphae. 14 pairs of elongate sparsely barbed setae inserted on the notogaster, the length of which show variation. All setae tapering towards the apex. 4 pairs of sacculi also located on the notogaster, as represented in figure 17. Fissure *ia* placed obliquely on the pteromorph. The anterior region of the notogaster, inner to the pteromorphae ornamented with few

circular to semilunar foveoles, set in aggregation. Fissure *im* seen medially. Notogaster ornamented with sparsely distributed small round foveoles. Pteromorphae also carry foveoles. Notogastral foveoles smaller than the prodorsal foveoles.

Ventral region (Fig. 18)

Rutellum with 2-3 notches; labiogenal suture transverse. Infracapitular setae 3 pairs, barbed, *a* short while *h* and *m* almost of equal length. Epimeral area also foveolated. Epimeral setal formula 3-1-3-2; all setae barbed. Circumpedal carina well developed. Genital plates longer than broader bearing 4 pairs of barbed setae. Small foveoles present on the genital plates. A single pair of barbed aggenital setae (*ag*) located posterolateral to the genital plates. Anal plates elongate carrying 2 pairs of smooth setae. Small foveoles also detected on each anal plate. 3 pairs of smooth adanal setae seen, ad_1 the longest while ad_2 and ad_3 almost of equal length. Fissure *iad* para-anally placed near to ad_3. Ventral plate exterior to the genital and anal plates also foveolated.

Legs: Legs tridactylous, the central claw being the stouter one while the two lateral claws thinner. All legs carry both tactile and sensory setae.

Materials examined: 3 ♂♂ and 1 ♀ collected from the open grassland at Komeri, Kannur (Dt.) on 14.8.92.

Remarks: The present specimen resembles *P. levipunctatus* created by Aoki (1984) from Japan. However, the larger size of body, the plumose nature of seta *ro*, presence of foveoles on prodorsum and pteromorph, pointed nature of notogastral setae and the absence of rectangular area on pteromorph are the differences observed in the present specimen.

Superfamily : **Oribatuloidea Woolley, 1956**

Family : **Haplozetidae Grandjean, 1936**

Genus : ***Pilobates* Balogh, 1960**

***Pilobates pilosellus Balogh*, 1960 (Fig 19-20)**

Colour : Pale yellow

Measurements: Length : 377 μm (Range: 363-382 μm)

Width : 161 μm (Range: 147 - 167 μm)

Dorsal region (Fig. 19)

Prodorsum

Prodorsum broader than longer. Rostral apex somewhat round. Seta *ro* inserted slightly behind the rostral apex, barbed and directed forwards. seta *le* shorter than *ro*, curved medially and inserted below the level of lamellar tip, medially. Seta *in* curved backwards, barbed and longer than seta *le*. Lamellae

broad medially and narrow apically. Apex of the lamella connected to the base of seta *ro* by a faint ridge. Prodorsal surface with feeble functation. Bothridial cup overlapped by a flange. Sensillus long and setaceous with a slightly thickened head, short barbs present on 2/3 rd the length of *ss*, on the apical region.

Notogaster

Dorsosejugal suture highly convex and medially arched. Humeral region expanded to immovable pteromorphae, the lateral border of which flexed ventrad. Fisure *ia* oblique and located on the pteromorph. Notogaster elongate and cylindrical. 14 pairs of small, smooth setae present on the notogaster, 2 pairs of which inserted on the pteromorphae. Notogaster also carries 4 pairs of sacculi. Lyrifissures *im* and *ih* clearly visible. Feeble punctations present on the notogaster which often agregated into foveoles.

Ventral region (Fig. 20)

Infracapitulum with diarthric type of articulation. Mentum, mentotectum and genae smooth. 3 pairs of setae visible on the infracapitulum, all smooth and short. Epimeral setal formula 3-1-2-1, all setae minute. Apodemes 2,3 and the sejugal apodeme detected, the latter being the longest. Epimeral surface foveolated weakly. Circumpedal carina and discidium clearly visible. Genital plates more or less rectangular, bearing 6 pairs of smooth setae. g_1 and g_2 inserted anteriorly

followed by g_3 and g_4 while g_5 and g_6 inserted posteriorly. 3 pairs of minute aggenital setae located, one pair posterolateral and the remaining 2 pairs posteriorly inserted. Anal plates elongated bearing 2 pairs setae of smooth nature. 3 pairs of adanal setae detected, all smooth, ad_1 post-anal while ad_2 and ad_3 para-anal in position. Fissure *iad* vertical and aligned laterally along the middle of the anal plates. Ventral plate smooth.

Legs: Legs tridactylous, central claw thicker than the lateral ones.

Materials examined : 1 ♂ and 3 ♀♀ collected from Silent Valley virgin forest floor, Palakkad (Dt.) on 25.9.94.

Remarks: The present specimen resembles *P. pilosellus* described by Balogh (1960) from Congo Belge in most respects except in the notogastral ornamentation.

Family : Haplozetidae Grandgeian, 1936

Genus : *Xylobates* Jacot, 1929

***Xylobates seminudus* Hammer, 1971 (Figs. 21-22)**

Colour : Dark brown

Measurements: Length : 423 µm (Range: 419 - 442 µm)

Width : 244 µm (Range: 235 - 258 µm)

Dorsal region (Fig. 21)

Prodorsum

Prodorsum conical with a blunt rostrum. Seta *ro* inserted far beyond the rostral apex, barbed and curved forwards. Seta *le* also barbed and inserted at the lamellar cuspis. Lamellae broadest medially and tapering anteriorly. Seta *in* inserted slightly above the dorsosejugal suture, barbed and erect. Bothridial cup opens anterolaterally, posterior rim of each cup produced into a short spine. Sensillus with a somewhat lanceolate head bearing barbs on the anterior border. The head of the sensilus round at the anterior border, while the posterior border straight. Small bristles present on 2/3 rd length of the stalk also. Prodorsal surface porose.

Notogaster

Dorosejugal suture arched.. Notogaster oval in appearane with anterolateral pteromorphae. Pteromorph bent ventrad along the anterolateral border. Anteriorly, each pteromorph bears a district concavity. Pleurophragma and dorsophragma well developed. 10 pairs of very minute setae with prominent insertion points present on the notogaster, 2 pairs of which inserted on the pteromorph. Fissure *ia* also located on the pteromorph. Fissures *im* and *in* also well discernible. 4 pairs of area porosae of varying size arranged on the notogaster near setae *ti*, *ms*, r_2 and p_2. Aggregations

of muscle scars arranged along the lateral notogastral border. Integument of notogaster smooth.

Ventral surface (Fig. 22)

Rutellum with 3-4 sclerotised notches. Diarthric type of articulation present on the infracapitulum. Seta *m* barbed while *h* and *a* smooth. Mentotectum porose. Epimeral surface porose medially. Irregular foveoles also present on epimeres. Apodemes 2,3 and sejugal apodeme distinct. Epimeral setal formula 2-2-1-2, all setae smooth. Genital plates with 5 pairs of small, smooth setae, g_1 and g_2 *a*nteriorly, g_3 medially and g_4 and g_5 posteriorly placed. A single pair of aggenital setae noted, which appears small and smooth. Anal plates possess 2 pairs of smooth setae and punctation. Adanal setae 3 pairs, of which ad_1 and ad_2 long while ad_3 short. Fissure *iad* aligned laterally, between ad_2 and ad_3. Ventral plate between the genital and anal plates porose.

Legs : All legs *tri* and heterodactylous. Central claw stronger than the lateral claws. Femora with well developed ventral keels.

Materials examined: 3 ♂♂ and 6♀♀collected from the virgin forest at Wynad on 22.7.92 and 3 ♀♀ collected from Silent Valley Virgin forests on 21.8.92.

Remarks : The specimen resembles *X. seminudus* erected by Hammer (1971) from Viti Levu islands except in the porose nature of prodorsum.

***Xylobates triangularis* Hammer, 1971 (Figs. 23-24)**

Colour : Golden yellow to light brown.

Measurements: Length : 308 μm (Range: 290 - 317 μm)

Width : 166 μm (Range: 156 - 175 μm)

Dorsal region (Fig. 23)

Prodorsum

Prodorsum truncate, rostrum prolonged into a round snout. Seta *ro* inserted on the anterolateral border of rostrum, slightly beyond the snout. Seta *le* inserted inner to the lamella, slightly below the lamellar apex, smaller than *ro* and possesses a few barbs on the surface. Lamella tapering towards the tip and occupies most of the lateral wall of the prodorsum. Seta *in* barbed, thicker and longer than *le* and curved laterad. Bothridial cup with anterolateral opening, the posterior boundary pointed. Sensillus elongate with thin stalk which widens into a flattened head. The anterior border of the head round while the posterior border straight. Small bristles also present on the outer border of the entire head and the distal 1/3rd of the stalk. Prodorsal surface smooth.

Notogaster

Dorsosejugal suture arched. Notogaster oval with anterolateral pteromorphae. Anterior borders of pteromorphae with a deep incision, thereby giving a triangular appearance, characteristic of the species. 10 pairs of small setae present on the notogaster, 2 pairs of which inserted on the pteromorphae. Pteromorph also carries fissure *ia*. 4 pairs of area porosae of varying dimensions also located on the notogaster, near the setae *ti*, *ms*, r_2 and p_1. Fissure *im* seen somewhat medially, above the level of A_1 while fissure *ip* displaced posterolaterally. Small foveoles and faint punctations ornament the notogastral surface.

Ventral region (Fig. 24)

Labiogenal articulation diarthric. Rutellum heavily sclerotized with 3-4 notches. All the 3 pairs of infracapitular setae small. Mentum and genae smooth. Epimeral surface irregularly foveolated Setal formula of the epimere 3-1-2-2, all setae minute. Apodemata 2,3 and the sejugal one developed. Genital plates longer carrying 5 pairs of setae. g_1, g_2 and g_3 inserted anterior to the middle of the genital plate while g_4 and g_5 inserted posteriorly. Aggenital setae represented by a single pair of alveoli. Ventral plate lying around the posterolateral regions of the genital plate with scattered, minute foveoles. Anal plates carry 2 smooth, short setae, an_1 inserted medially while an_2 placed posteriorly 3 pairs of short adanal setae seen, ad_1

posterior to anal plates, ad_2, at the posterolateral corner while ad_3 pre-anal in position. Fissure *iad* aligned vertically above the level of an_1.

Legs: All legs monodactylous Tarsus *I* with 2 solenidia, w_1 thin and long while w_2 thick and short. Femur *I* with a ventral keel.

Materials examined: 5 ♂♂ and 2 ♀♀ collected from the mixed cultivation site at the Calicut University Campus, Malapuram (Dt.) on 31.8.94.

Remarks: The specimen resembles *X. triangularis* described by Hammer (1971) from Viti Levu islands with the exception of characters like the absence of dark spot behind the base of seta *le*.

Superfamily : **Ceratozetoidea Balogh, 1961**

Family : **Ceratozetidae Jacot, 1995**

Genus : ***Hypozetes* Balogh, 1959.**

***Hypozetes imitator* Balogh, 1959, (Figs. 25-26)**

Colour : Dark brown

Measurements: Length : 359 µm (Range: 345 - 373 µm)

Width : 276 µm (Range: 267 - 290 µm)

Dorsal region (Fig. 25)

Prodorsum

Prodorsum conical with lateral teeth. Rostral apex provided with two lateral teeth on either side. Seta *ro* inserted far beyond the rostral apex, inner to the lateral prodorsal tooth, heavily barbed and directed forwards. Seta *le* inserted on the lamellae, weakly barbed and longer than *ro*. Lamella sheath like and connected anteriorly by the translamella, the latter with an inner median notch directed posteriorly. Seta *in* the longest and thickest of the prodorsal hairs and possesses barbs on the surface and inserted on the dorsosejugal suture. Bothridial cup almost completely sunken from which sprouts the curved, smooth stalk of the sensillus bearing a clavate barbed head. Prodorsal surface smooth.

Notogaster.

Dorsosejugal suture distinctly convex. Anterolateral regions of notogaster produced into immovable pteromorphae, anterior border of which concave. Pteromorphae possess closely set striations, a lyrifissue (*ia)* and a seta (*ta)* . A total of 10 pairs of setae present on the motogaster, all roughened. Just behind the dorsosejugal suture the integument of notogaster porose, the remaining part smooth.

4 pairs of sacculi also located on the notogaster, near *ti*, *ms*, r_2 and r_3. Fissure *im* obliquely placed slightly behind the middle of the notogaster.

Ventral region (Fig. 26)

Rutellum with 3-4 highly sclerotised notches. Infracapitular setae smooth. Epimeral surface with irregularly distributed foveoles, often arranged in reticular fashion. Chaetotaxy of epimerata 2-1-2-1. Circumpedal carina well developed. Genital plates broader anteriorly carrying 5 pairs of setae, seta g_2 inserted inner to and between g_1 and g_3, all setae smooth. A single pair of aggenital setae also located at the posterolateral corners of the genital plates. Anal plates broad posteriorly, 2 pairs of smooth setae present on the anal plates. 3 pairs of adanal setae detected, all smooth. Fissure *iad* vertical and located anterior to ad_3.

Legs: Legs tridactylous with a thick central claw and 2 thin lateral claws.

Materials examined: 5 ♂♂ and 2 ♀♀ collected from the open grassland at West Hill, Kozhikkode (Dt.), on 22.8.94.

Remarks: The specimen resembles *H. imitator* described by Balogh (1959) from Eastern Africa except in the nature of seta *le*, nature of pteromorph and in the possession of translamella.

Superfamily : **Oribatelloidea Woolley, 1956**

Family : **Achipteriidae Thor, 1929**

Genus : ***Anachipteria* Grandjean, 1935**

***Anachipteria globatus* sp. nov. (Figs. 27-28)**

Colour : Dark brown

Measurements: Length : 285 µm (Range: 276 - 299 µm)

Width : 225 µm (Range: 212 - 230 µm)

Dorsal region (Fig. 27)

Prodorsum

Prodorsum broad and short with two lateral teeth, one at the rostral apex and the other slightly beyond the rostral tip. Rostrum appears dipartite owing to the presence of the rostral teeth. Seta *ro* barbed, directed forwards, measures 44 µm in length and inserted just above the lateral tooth. Lamellae prominently developed, occupying more than 3/4 of the prodorsum and broadest medially. Seta *le* inserted along the inner border of the lamellae, barbed, erect and measures 66 µm. Seta *in* inserted on the dorsosejugal suture, barbed and measures 73 µm. Bothridial cup

broad with thicker wall and sunken. Sensillus with a short, slender, smooth stalk and a clavate roughened head. Prodorsal surface smooth.

Notogaster

Dorsosejugal suture convex. Anterolateral corners of the notogaster produced into immovable pteromorphae, which partly bent ventrad. Closely set striations present on the pteromorph. Integument of notogaster lying just below seta *le* appears porose. 10 pairs of smooth, slender setae and 4 pairs of small area porosae detected on the notogaster. Fissure *ia* located inner to the pteromorphal boundary. Foveoles of semilunar to elongate nature aggregated at the anterolateral regions of notogaster as shown in figure 27. Fissure *im* vertically placed below seta r_3. along the lateral border. Punctations also distributed on the notogastral surface.

Ventral region (Fig. 28)

Rutellum with 3 sclerotised notches. Mentum and mentotectum smooth. Infracapitular setae 3 pairs, all smooth and of varying length. Epimeral area also smooth bearing short, smooth setae; setal formula of the epimerata 3-1-2-2. Apodemata 2,3 and sejugal one detected, apodemae 2 bifurcated. Sejugal apodeme the longest. Discidium and circumpedal carina well developed. Custodium short. Genital plates with 6 pairs of setae, g_1, g_2 and g_3 inserted along the anterior border,

g_4 just above the middle and g_5 and g_6 inserted posteriorly. Aggenital setae represented by a single pair, smooth and longer than the genital hairs. Anal plates broader posteriorly bearing 2 pairs of smooth setae. 3 pairs of adanal setae located, ad_1 post-anal while ad_2 and ad_3 para-anal in location. Fissure *iad* vertical and placed along the posterolateral boundary of the anal plate, above the level of insertion of seta an_1. Ventral plate smooth.

Legs: All legs tridactylous possessing heterodactyly.

Materials examined: Holotype : ♂ Paratypes 2 ♂♂ and 1 ♀ collected from the open grassland at Thiruvazhamkunnu, Palakkad (Dt.) on 20.9.93.

Remarks: The holarctic genus *Anachipteria* was erected by Grandjean, 1935 from South America based on the type species *A. deficiens.* Later additions to the species were made as redescriptions such as *A. signata* (Banks, 1895), *A. latitecta* (Berlese, 1908), *A. achipteroides* (Ewing, 1913) and *A. alpina* (Schweizer, 1922). Later, Balogh (1959) added a new species viz. *A. kittenbergeri* from Eastern Africa. Further expansion of the genus was made by Aoki, 1961 who erected *A. grandis* from Japan.

The present new species, *A. globatus* on comparison with the other known species of the genus, was found exhibiting similarities in some characters with two species, viz. *A. kitenbergeri* and *A. grandis* such as the nature of notogastral setae,

arrangement of area porosae and number of genital, anal and adanal setae. However, the present species appears unique in the possession of the following characters which keeps its identity separate from the above two taxa.

1. Globular shape of notogaster
2. Barbed, clavate head of sensilus
3. Porose nature of the anteromedian surface of notogaster
4. Barbed nature of the prodorsal hairs and
5. Arrangement of genital hairs.

Superfamily : Galumnoidea Balogh, 1961

Family : Parakalummidae Grandjean, 1936

Genus : *Protokalumma* Jacot, 1929

***Protokalumma erecta* Balogh and Mahunka, 1969 (Figs 29-30)**

Colour : Dark brown to black

Measurements: Length : 460 µm (Range: 442 - 474 µm)
Width : 299 µm (Range: 290 - 313 µm)

Dorsal region (Fig. 29)

Prodorsum

Prodorsum broader than longer and conical. Seta *ro* barbed, inserted far

beyond the rostral apex. Seta *le* also barbed, longer than *ro* and inserted on the lamellar cuspis. Seta *in* the longest of the prodorsal hairs reaching beyond the rostral apex. Lamellae broad basally, the apex produced into remnants of translamella. Bothridial cup opened laterally. Sensillus with a slender, smooth stalk and a lanceolate head bearing few barbs. Integument of prodorsum devoid of any ornamentation.

Notogaster

Notogaster elongate and demarcated from the prodorsum by a convex dorsosejugal suture. Anterolateral regions of the notogaster expanded into two movable wing like pteromorphae bearing ornamentations like reticulations and foveoles of different nature. The inner borders of pteromorphae bear notches also. 10 pairs of very minute setae located on the notogaster as represented in figure 29. 4 pairs of sacculi also detected on the notogaster. Semilunar foveoles found aggregated on either sides of notogaster, anterolaterally. Fissure *im* placed medially in an oblique fashion.

Ventral region (Fig. 30)

Labiogenal articulation diarthric. Gnathosomal setae 3 pairs, minute.

Mentum, mentotectum and genae smooth. Epimeral area foveolated irregularly. Apodeme 2 very small, sejugal apodeme elongate, other apodemes not detected. Epimeral setal formula 1-1-2-1. Genital plates broader anteriorly, 5 pairs of smooth setate inserted on the genital plates, 3 pairs on the anterior half and 2 pairs on the posterior half. Distance between g_3 and g_4 greater. Anal plates more or less rectangular bearing 2 pairs of setae. 3 pairs of adanal setae present, ad_1 posterior, ad_2 posterolatral and ad_3 anterior to the anal plate. Fissure *iad* vertical and closely apposed to the lateral border of each anal plate.

Legs : All legs tridactylous and heterodactylous. Tarsus-1 possesses the maximum setal compliment.

Materials examined: 2 ♂♂ collected from the open grassland at Mannarghat, Palakkad (Dt.) on 22.7.93 and 1 ♂ ad 1 ♀ collected from the shaded grassland at Attapadi, Palakkad (Dt.) on 12.8.93.

Remarks: The specimen resembles *P. erecta* erected by Balogh and Mahunka (1969) from South America. However certain character deviations could be observed in the present specimen such as the nature of setae *le* and *in*, absence of chitinous rings surrounding prodorsal setae and presence of pteromorphal ornamentation.

Superfamily : **Galumnoidea Balogh, 1961**

Family : **Galumnidae Jacot, 1925**

Genus : ***Galumna* Von Heyden, 1826**

***Galumna flabellifera orientalis* Aoki, 1965c (Figs 31-32)**

Colour : Light brown

Measurements: Length : 229µm (Range: 285 - 308 µm)

Width : 212µm (Range: 202 - 216 µm)

Dorsal region (Fig. 31)

Prodorsum

Prodorsum broad with a blunt snout. Seta *ro* slender, smooth and curved forwards. Seta *le* resembles *ro* in appearance and inserted between lines L and S. Seta *in* the shortest of prodorsal setae, slender and smooth in appearance. Bothridial cup opens laterad. Sensillus with a curved, smooth stalk and a clavate head bearing barbs on the anterior and apical border. Prodorsum smooth.

Notogaster

Dorosejugal suture slightly concave medially. Posterior border of notogaster spherical in appearance. Humeral region produced into well expanded and movable

pteromorphae bearing notches and veins. 10 pairs of notogastral setae located as shown in figure 31. Notogaster possesses 5 pairs of area porosae also, which show variation in shape and size. *Ad* slender, elongate and located on the dorsosejugal suture. *Aa* the largest, and situated at the humeal region. A_2 the smallest. Fissure *ia* seen on the pteromorph. Fissure *im* placed almost vertically, slightly below the middle of the notogaster. Anteriorly, notogaster carries reticulations at restricted sites as represented in figure 31. Muscle scars also present along the lateral border of notogaster.

Ventral region (Fig. 32)

Labiogenal suture highly convex. Infracapitulum carries 3 pairs of setae, of which *a* and *m* barbed. Seta *h* minute and often represented by the alveolus. Mentum and menotectum smooth. Epimeral setal formula 1-1-1-2; all setae minute. Apodemes 2,3 and sejugal apodeme developed, the sejugal one the longest. Genital plates broad anteriorly and narrow posteriorly, carrying 5 pairs of smooth setae. Setae g_1, g_2 and g_3 inserted on the anterior border while g_4, far below followed by g_5. Aggenital setae located on the posterolateral corner of each genital plate. Anal plates broader posteriorly carrying 2 pairs of minute smooth setae. 3 pairs of adanal setae detected, ad_1, post-anal while ad_2 and ad_3 lateral in location. Fissure *iad* obliquely placed, just above the insertion of ad_3. Ventral plate smooth.

Legs : All legs tridactylous with unequal claws. Central claw thicker than the lateral ones. Tarsus 1 bears 3 solenida and one famulus. The number of setae on the leg segments shows variation.

Materials examined: 7 ♂♂ and 3 ♀♀ collected from the open grass land at West Hill, Kozhikkode (Dt.) on 22.8.94.

Remarks: The specimen resembles *G. flabellifera orientalis* erected by Aoki (1965) from Thailands. However, the possession of notogastral ornamentation and an epimeral setal formula of 1-1-1-2 are the character deviations observed in the present specimen.

***Galumna triquetra* Aoki, 1965c (Figs. 33-34)**

Colour : Dark brown

Measurements: Length : 285µm (Range: 276 - 299 µm)

Width : 198 µm (Range: 189 - 202 µm)

Dorsal region (Fig. 33)

Prodorsum

Prodorsum more or less conical with a broad, blunt rostrum, Seta *ro* small,

thin and barbed. Seta *le* thicker and longer than *ro*, barbed and inserted between lines *L.* and *S.* A distinct curved transverse line connects the lamellar apex of the two sides. Seta *in* shorter than *le* and erect. Bothridial cups partly sunken. Sensillus with a curved, smooth stalk and with a slightly dilated barbed head. Prodorsal area smooth.

Notogaster

Dorsosejugal suture medially interrupted. Pteromorphae well expanded with a median notch. Venation poorly developed. Each pteromorph carries fissure *ia* and seta *ta*. 10 pairs of setae, all minute inserted on notogaster as shown in figure 33. 5 pairs of area porosae also detected with varying size. *Aa* the largest and A_3 the smallest. *Ad* located on the dorsosejugal suture. Lyrifissure *im* placed below the middle, between A_1 and A_2. *ip* displaced more posteriorly. Few reticulation also detected at the anterior region,near *Aa*. Other areas of notogaster smooth.

Ventral region (Fig. 34)

Labiogenal articulation highly convex. Infracapitular setae 3 pairs, all smooth. Mentum and mentotectum smooth. Epimeral region with a setal formula of 1-0-3-1. Genital plates with 6 pairs of setae, g_1, g_2 and g_3 arranged along the anterior border, the other 3 pairs arranged in a vertical line. Aggenital seta minute. Anal plates carry 2 pairs of short setae, an_1 anterior and an_2 somewhat medial in

location. 3 pairs of adanal setae present, ad_1 and ad_2 post-anal while ad_3 para-anal. Area porosae *Apa* elongated and arranged below the anal plates, one an either side. Ventral plate smooth.

Legs: Legs tridactylous with 3 unequal claws, central claw thicker than the lateral ones.

Materials examined: 2 ♂♂ and 3 ♀♀ collected from the open grassland at West Hill, Kozhikkode (Dt.) on 22.8.94.

Remarks: The present specimens agree with *G. triquetra* described by Aoki (1965) in all characters except in the possession of an epimeral setal formula of 1-0-3-1. In the type specimen, the epimeral setal formula is 1-0-2-1.

Galumna longipluma (Berlese, 1904) (Figs. 35-36)

Colour : Dark brown to black.

Measurements: Length : 405 µm (Range: 396 - 414 µm)

Width : 221 µm (Range: 212 - 221 µm)

Dorsal region (Fig. 35)

Prodorsum

Prodorsum broadly triangular with a round rostrum. Seta *ro* smooth and inserted beyond the rostral apex. Seta *le* also smooth, longer than *ro* and originates between lines *L* and *S*. Seta *in* thick, barbed and with a blunt tip. Sensillus long and setaceous, with a curved proximal end. Apical 2/3 rd of the stalk armed with small bristles. Prodorsal surface smooth.

Notogaster

Dorosejugal suture slightly arched. Pteromorphae with very faint venation. Medially , a well developed notch present on the pteromorph. Fissure *ia* and seta *ta* also located on pteromorph. A total of 10 pairs of setae distributed on notogaster, all minute and often represented by alveoli. Fissures *im* and *ip* also clearly discernible. 4 pairs of area porosae present with varying dimensions. Surface of notogaster smooth.

Ventral region (Fig.35)

Labiogenal articulation highly convex. All the 3 pairs of gnathosomal setae barbed. Rutellum with well sclerotised notches. Epimeral surface raised with

irregular concave regions. Epimeral setal formula 1-0-1-1, setae minute. Apodemes 2, 3 and sejugal apodeme well developed. Genital plates with 6 pairs of smooth setae arranged as shown in figure 35. A single pair of smooth aggenital setae seen at the posterolateral corners of the genital plates. Anal plates with broader posterior margin, bearing 2 pairs of smooth setae. 3 pairs of adanal setae located, ad_1 and ad_2 post-anal while ad_3 pre-anal in location. Fissure *iad* obliquely placed along the lateral border of anal plate near to seta ad_3. Ventral surface smooth.

Legs: All legs tridactylous with three unequal claws. Femur 1 with a ventral ridge and porose areas.

Materials examined: 6 ♂♂ and 5♀♀ collected from the open grassland at West Hill, Kozhikkode (Dt.) on 22.8.94.

Remarks: The specimen resembles *G. longipluma* (Berlese, 1904) in all characters except in the nature of seta *in* and in the possession of a more or less straight dorsosejugal suture.

Galumna discifera Balogh, 1958 (Figs. 37-38)

Colour : Light brown

Measurements: Length : 285 μm (Range: 281 - 294 μm)

Width : 207 μm (Range: 193 - 212 μm)

Dorsal region (Fig. 37)

Prodorsum

Prodorsum narrow and triangular with a blunt rostrum. Seta *ro* minute, roughened and directed forwards. Seta *le* also slender, roughened and oriented anteriorad. Lines *L* and *S* well developed. Seta *in* vestigial. sensillus with a curved, smooth stalk and a clavate head bearing short barbs. Prodorsal integument porose.

Notogaster

Notogaster clearly spherical posteriorly. Dorsosejugal suture slightly arched. Pteromorphae with an anterolateral concavity and an inner curved ridge. Linear to semilunar ornamentation and punctations visible on each pteromorph. Seta *ta* and fissure *ia* also situated on the pteromorph. The remaining 9 pairs of notogastral setae arranged as shown in figure 37. 5 pairs of area porosae of varying

size and shape located on the notogaster. *Ad* situated on the dorsosegugal suture. *Aa* largest and some what oval in appearance. A_1 and A_2 spherical while A_3 elongated. Opening of the lateroabdominal gland clearly visible. Fissures *im* and *ip* also deteted. Notogastral surface lying just below the dorsosejugal suture porose. Reticulations of various types scattered on the notogaster, more prominently on the anteromedian and anterolateral aspects of the notogaster.

Ventral region (Fig. 38)

Rutellum with 3 notches. Labiogenal articulation highly convex. Infracapitular setae 3 pairs, minute and smooth. Epimeral setae also minute, following a chaetotaxy of 2-0-1-1. Apodeme 1 and the sejugal apodme developed, others not located. Circumpedal carina present. Genital plates broader anteriorly and narrower posteriorly bearing 6 pairs of setae, 4 pairs on the anterior and 2 pairs on the posterior halves of the genital plates. A single pair of aggenital setae inserted posterior to the genital plates. Anal plates broader posteriorly bearing 2 pairs of minute setae. 3 pairs of minute adanal setae present, ad_1 post-anal while ad_2 and ad_3 para-anal in position. Fissure *iad* vertically aligned along the lateral border of the anal plates, at the level of seta ad_3. A single area porosa, *Apa* present posterior to the anal plates, which appears elongated. Ventral plates smooth.

Legs: Legs tridactylous with unequal laws, central claw being the stouter one.

Materials examined: 2 ♂♂ and 3 ♀♀ collected from the open grassland at West Hill, Kozhikkode, (Dt.) in 20.9.95.

Remarks : The specimen resembles *G. discifera* described by Balogh (1958) except in the nature of seta *in*, possession of notogastral ornamentation and arrangement of genital setae.

***Galumna alata* (Hermann, 1804) (Figs 39-40)**

Colour : Dark brown to black

Measurements: Length : 459 µm (459 - 497 µm)

Width : 293 µm (293 - 319 µm)

Dorsal region (Fig. 39)

Prodorsum

Prodorsum broader with a round rostral apex. Seta *ro* unilaterally barbed and inserted on the lateral wall. Lines *L* and *S* distinct. Seta *le* also unilaterally barbed, longer than *ro* and inserted between lines *L* and *S*. seta *in* the longest reaching beyond the rostral apex, barbed and directed anterolaterally. Bothridial cups sunken. Sensillus with a long, slender stalk and a lanceolate head bearing barbs. Tip of the sensillus pointed.

Notogaster

Dorsosejugal suture complete. Pteromorphae bear a notch and few foveoles. Seta *ta* and fissure *ia* also located on each pteromorph. 10 pairs of minute setae, often represented by alveoli present on the notogaster. Notogaster also bears 5 pairs of area porosae which show slight variation in size. *Ad* placed on the dorosejugal suture. Surface of notogaster provided with faint foveoles irregularly. Anteromedian surface exhibits a reticulated appearance also.

Ventral region (Fig. 40)

3 pairs of infracapitular setae present, all smooth. Mentum, menotetcum and genae smooth. Rutellum with 2-3 sclerotised notches. Epimeral surface with irregular foveoles. Chaetotaxy of epimeral region 1-0-2-1, all setae minute. Circumpedal carina and discidium well developed. Genital plates with 6 pairs of setae, all smooth. A single pair of minute aggenital seta located posterior to the genital plates. Anal plates broad posteriorly and narrow anteriorly bearing 2 pairs of setae, an_1 anterior and an_2 posterior in location. 3 pairs of adanal setae, all short and smooth detected. ad_1 posterior to anal plates, ad_2 posterolateral and ad_3 somewhat anterolaterally placed. Fissure *iad* aligned vertically, near to seta ad_3. Ventral plate smooth.

Legs: Legs tridactylous with unequal claws. Tarsal segment of leg-1 with 2 solenidia and a famulus.

Materials examined: 3 ♂♂ and 5 ♀ collected from the open grassland at West Hill, Kozhikkode (Dt.) on 16.9.95.

Remarks: The species characteristics observed in the present specimen closely resemble that of *G.alata* (Hermann, 1804). However, few minor character deviations also could be detected such as the pointed tip of the sensillus and the presence of foveoles on the notogaster.

***Galumna obvia* (Berlese, 1915) (Figs. 41-42)**

Colour : Dark brown to black

Measurements: Length : 644 µm (Range: 620 - 644 µm)

Width : 565 µm (Range: 532 - 565 µm)

Dorsal region (Fig. 41)

Prodorsum

Prodorsum conical with a round rostrum. Seta *ro* slender, smooth and inserted at rostral apex. Seta *le* also smooth, longer than *ro* and inserted between lines *L* and *S*. Seta *in* plumose and inserted slightly above the dorsosejugal suture.

A faint transverse line connects lines *L* of both sides. Bothridial cup sunken. Sensillus with a curved, smooth stalk, head appears setaceous. Prodorsal surface with scattered foveoles.

Notogaster

Dorsosejugal suture complete and flattened. Pteromorphae with a notch, faint veins and well developed foveoles, seta *ta* located on the pteromorph in addition to the lyrifissure *ia*. A total of 10 pairs of minute setae distributed on the notogaster as shown in figure 41. 5 pairs of area porosae of varying shape and size located. *Ad* somewhat elongate and placed on the dorsosejugal suture. *Aa* the largest and sole-shaped, A_1 round and large while A_2 oval and smaller than A_1, A_3 elongated and located more posteriorly. Punctations ornament the entire surface of notogaster.

Ventral region (Fig. 42)

Infracapitulum smooth bearing 3 pairs of glabrous setae. Epimeral surface irregularly foveolated. Apodemes 2,3 and the sejugal one developed. Setal formula of epimerata 1-1-2-1, all setae minute. Genital plates with longitudinal striae. Each plate carries 5 pairs of setae, all smooth. Aggenital setae represented by a single pair of alveoli. Anal plates smooth and carry 2 pairs of setae. 3 pairs of

adanal setae present, ad_1 post-anal while ad_2 and ad_3 para-anal in position. Ventral plate smooth.

Legs : Legs tri and heterodactylous.

Materials examined: 5 ♂♂ and 7 ♀♀ collected from the open grass land at Mannuthy, Trichur (Dt). on 16.10.95.

Remarks: The specimen described above shows close similarity to *G.obvia* erected by Berlese, 1915 in most of the characters except in certain minor alterations. Plumose nature of seta *in*, elongated nature of A_3 and the presence of *Ad* are the differences exhibited by the present specimen.

Superfamily : Galumnoidea, Balogh, 1961

Family : Galumnidae Jacot, 1925

Genus : *Pergalumna* Grandjean, 1936.

***Pergalumna nervosa (Berlese, 1915)* (Figs. 43-44)**

Colour : Dark brown

Measurements: Length : 490 µm (Range: 480 - 490 µm)

Width : 345 µm (Range: 331 - 345 µm)

Dorsal region (Fig. 43)

Prodorsum

Conical prodorsum with a blunt, round rostrum. Seta *ro* slender and smooth and inserted well below the rostral apex. Seta *le* also slender, smooth and inserted far above line *L*. Both lines *L* and *S* distinct. Seta *in* the longest of prodorsal hairs and resembles *le* in nature. Sensillus smooth and setaceous and without any demarcation of head and stalk. Prodorsal surface smooth.

Notogaster

Dorsosejugal suture slightly arched. Posterior surface clearly spherical. Pteromorphae well developed bearing a notch and varying ornamentation comprised of curved lines. Seta *ta* and fissure *ia* present on the pteromorph. The remaining 9 pairs of setae distributed at specific sites of notogaster as represnted in figure 43, all setae minute and often represented by alveoli. 5 pairs of area porosae detected with varying shape and dimensions. *Ad* the smallest and located at the basal region of the dorsosejugal suture, *Aa* more less rectangular with a broad anterior border and a narrow posterior border and placed obliquely. *Al* and A_2 clearly circular, the former larger than the latter. A_3 slightly oval and shifted more posteriorad. Anterolateral corners of notogaster surrounding *Aa* ornamented with semilunar sculptures, the rest of the notogastral surface smooth.

Ventral region (Fig. 44)

Mentum and mentotectum ornamented with slit like structures. Rutellum with highly sclerotized notches. Infracapitular setae 3 pairs, represented by alveoli. Epimeral boundaries clear. Apodemes 2,3 and sejugal apodeme well discernible. Epimeral setae minute and arranged in the order 1-0-2-1 'Genital plates with 6 pairs of setae, all slender and smooth. Aggenital setae represented by a single pair of minute setae inserted posterolateral to the genital plates. Anal setae 2 pairs, represented by alveoli, one on each anterior and posterior half of anal plate respectively. Adanal setae also represented by 3 pairs of alveoli, ad_1 and ad_2 post-anally placed while ad_3 para-anal. Fissure *iad* vertically placed at the mediolateral border of each anal plate, slightly above seta ad_3, ventral plate smooth.

Legs: Legs tridactylous possessing heterodactyly.

Materials examined: 3 ♂♂and 5 ♀♀ collected from the shaded grassland at Mannuthy, Trichur (Dt.) on 27.8.95.

Remarks : The specimen resembles *P. nervosa* erected by Berlese, 1915 in most of the specific characteristics. However, the setaceous nature of the sensillus of the present specimen does not agree with the slightly fusiform head of the sensillus in Berlese's specimen.

Pergalumna intermedia Aoki, 1963 (Figs 45-46)

Colour : Dark brown to black.

Measurements: Length : 405 µm (Range: 405 - 460 µm)

Width : 340 µm (Range: 331 - 350 µm)

Dorsal region (Fig. 45)

Prodorsum

Prodorsum broad and triangular in appearance. Rostrum with blunt apex. Seta *ro* smooth, slender and inserted far beyond the rostral apex. Seta *le* thicker and longer than *ro*, barbed and inserted far anterior to lines *L* and *S*. Setae *in*, sparsely barbed and longer than *le*. Bothridium with lateral opening. Sensillus setaceous and plumose except at the basal region. Prodorsal integument rugose.

Notgaster

Notogaster broadly spherical, anteriorly merging with the prororsum owing to the absence of a dorsosejugal suture. Anterolaterally, notogaster produced into two movable pteromorphae bearing well developed notches and veins. Anterolateral border of each pteromorph marked with a characteristic concavity. Both pteromorphae rugose, particularly along the lateral borders. Seta *ta* and

fissure *ia* also located on the pteromorph. Apart from the 10 pairs of small, smooth setae, notogaster carries 4 pairs of area porosae also with varying size and shape. A_1 the largest and A_3 the smallest. Fissure *im* placed slightly below the middle of the notogaster, slightly above the insertion of seta *in*. Surface of notogaster possesses three types of ornamentations represented by foveolae, punctations and rugose nature as shown in figure 45.

Ventral region (Fig. 46)

Labiogenal suture convex. Gnathosomal setae represented by 3 pairs of minute, smooth hairs. Mentotectum exhibits a rugose nature. Epimeral surface punctate medially. Setal formula of epimeres 2-0-1-2. Apodemes 2,3 and sejugal one detected Circumpedal carina and discidium discernible. Genital plates elongated and punctated bearing 5 pairs of setae, setae being smooth. Aggenital setae single pair and smooth. Anal plates broad posteriorly, being broadest, beyond the middle. Resembling the genital plates, anal plates also punctated. Of the 2 pairs of anal setae, an_2 inserted slightly below the middle of the anal plate while an_1 shifted far anteriorly. Adanal setae 3 pairs, ad_1 and ad_2 post-anal and ad_3 para-anal in alignment. Fissure *iad* vertical, closely apposed to the lateral border of anal plate, above the insertion of seta ad_3. Ventral plate lying between the genital and

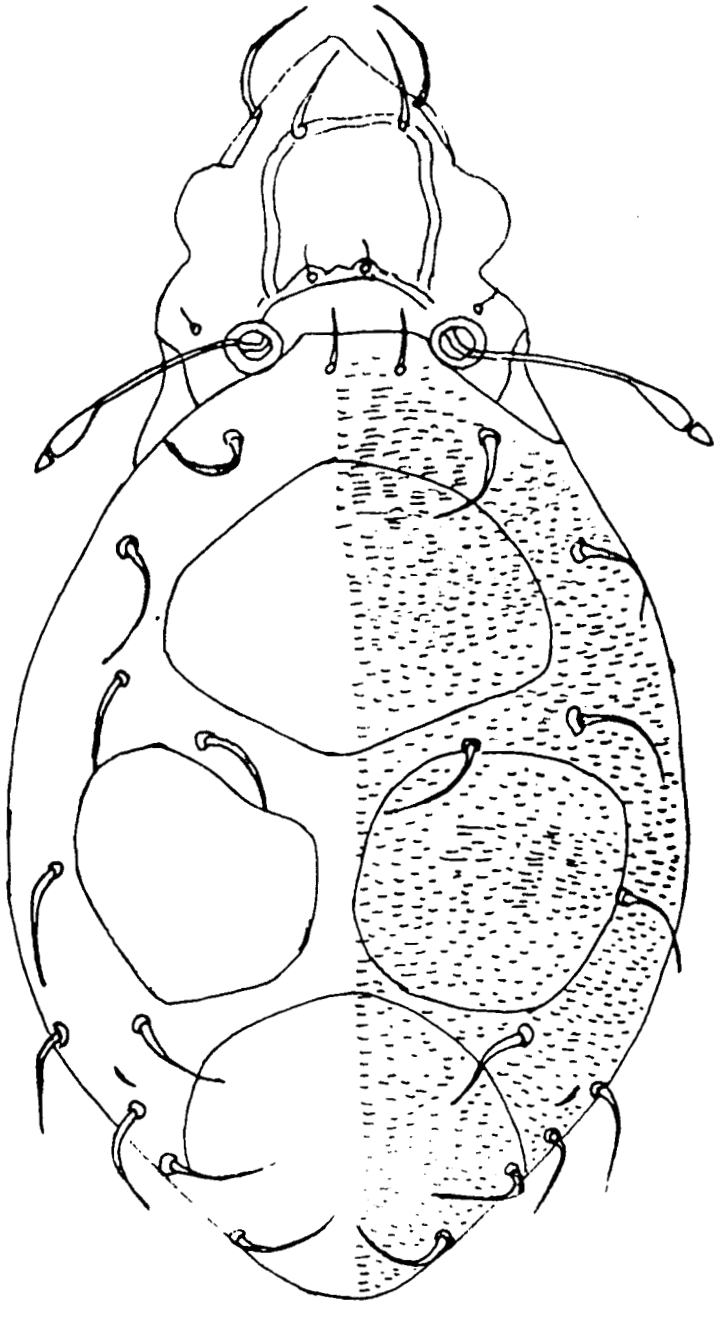
anal plates punctated. Lateral regions of the ventral plate and area posterior to the anal plates rugose.

Legs: All legs heterodactylous with 3 unequal claws. Central claw thicker than the lateral ones.

Materials examined: 5 ♂♂ and 7 ♀♀ collected from the virgin forest at Silent Valley, Palakkad (Dt) on 28.9.95.

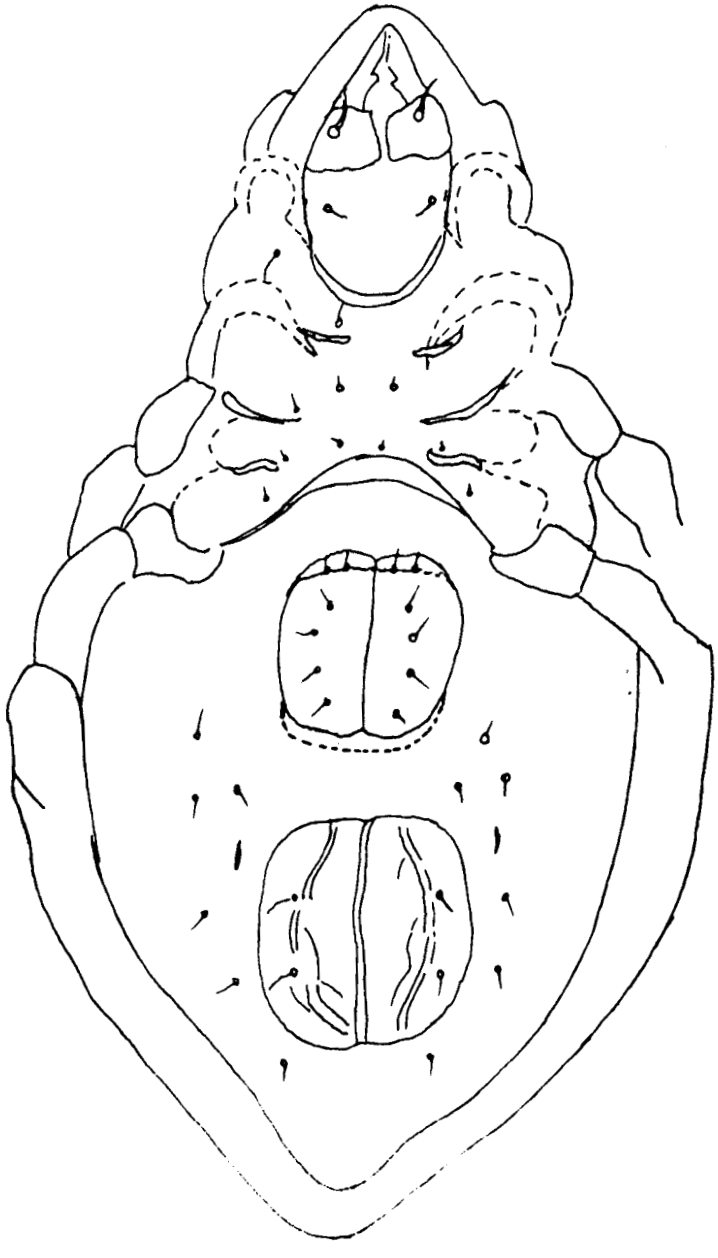
Remarks : The specimen resembles *P. intermedia* described by Aoki (1963) except in the prodorsal and notogastral ornamentation.

FIG. 1 **Fosseremus silensis sp.nov.**



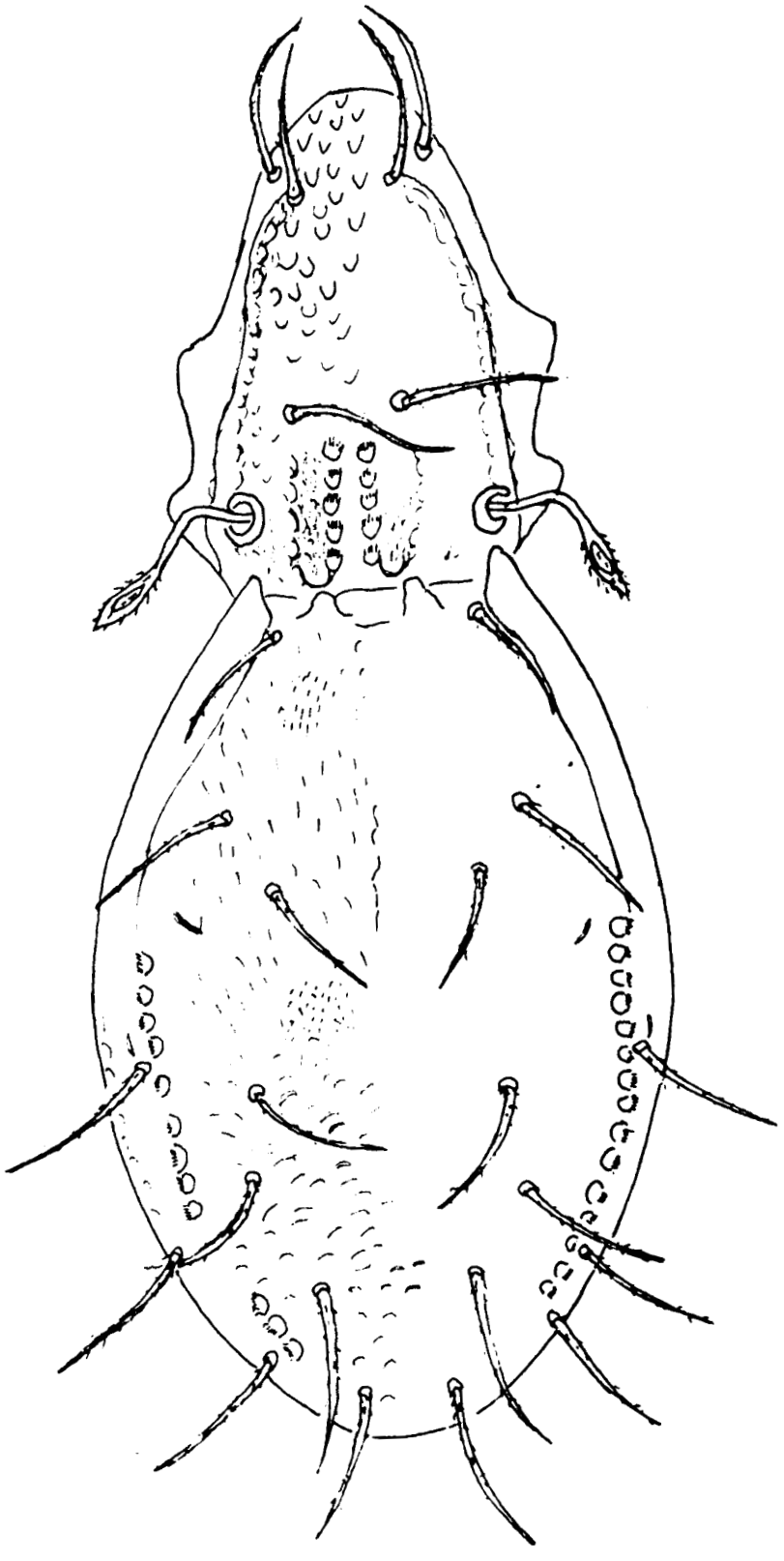
DORSAL VIEW

FIG. II **Fosseremus silensis sp.nov.**



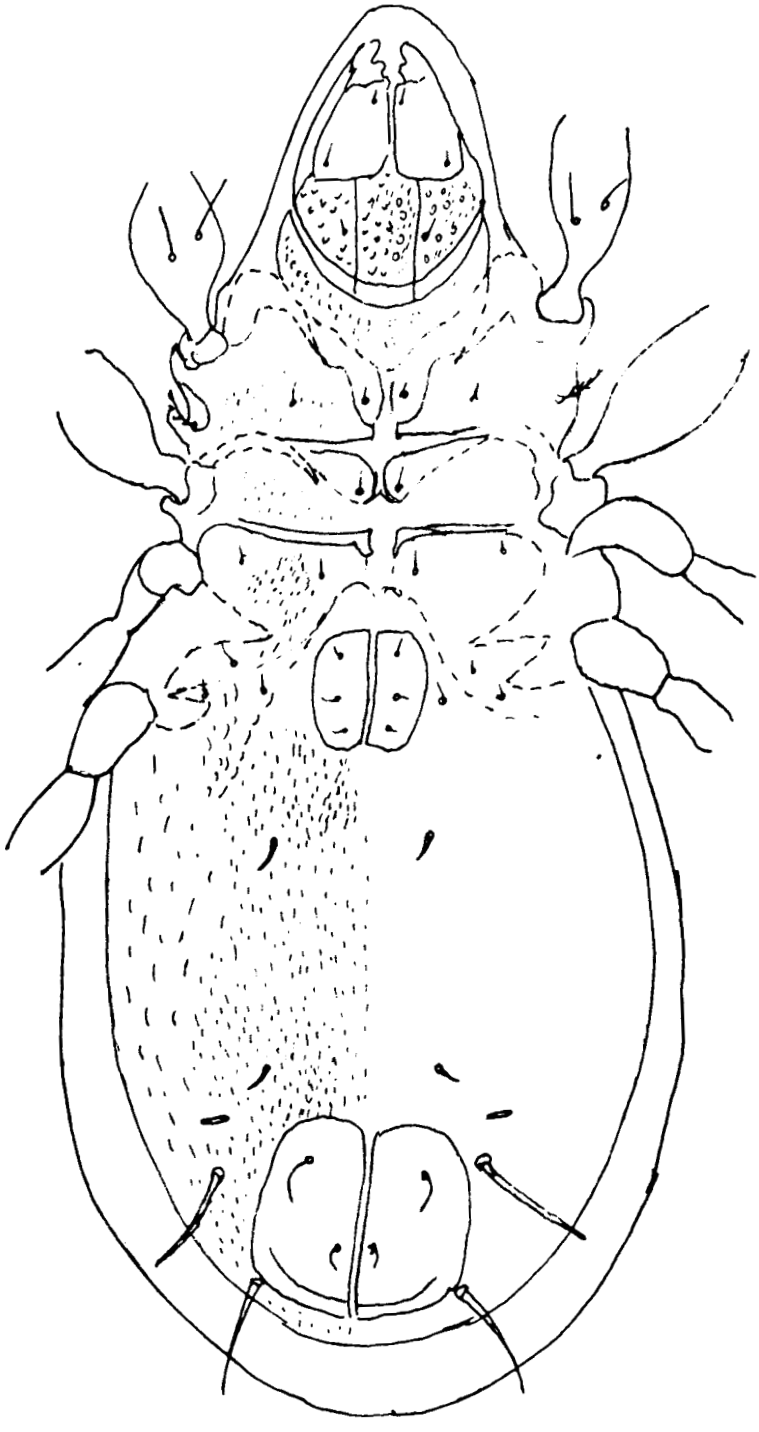
VENTRAL VIEW

FIG. III **Nesotocepheus hauseri Mahunka, 1980**



DORSAL VIEW

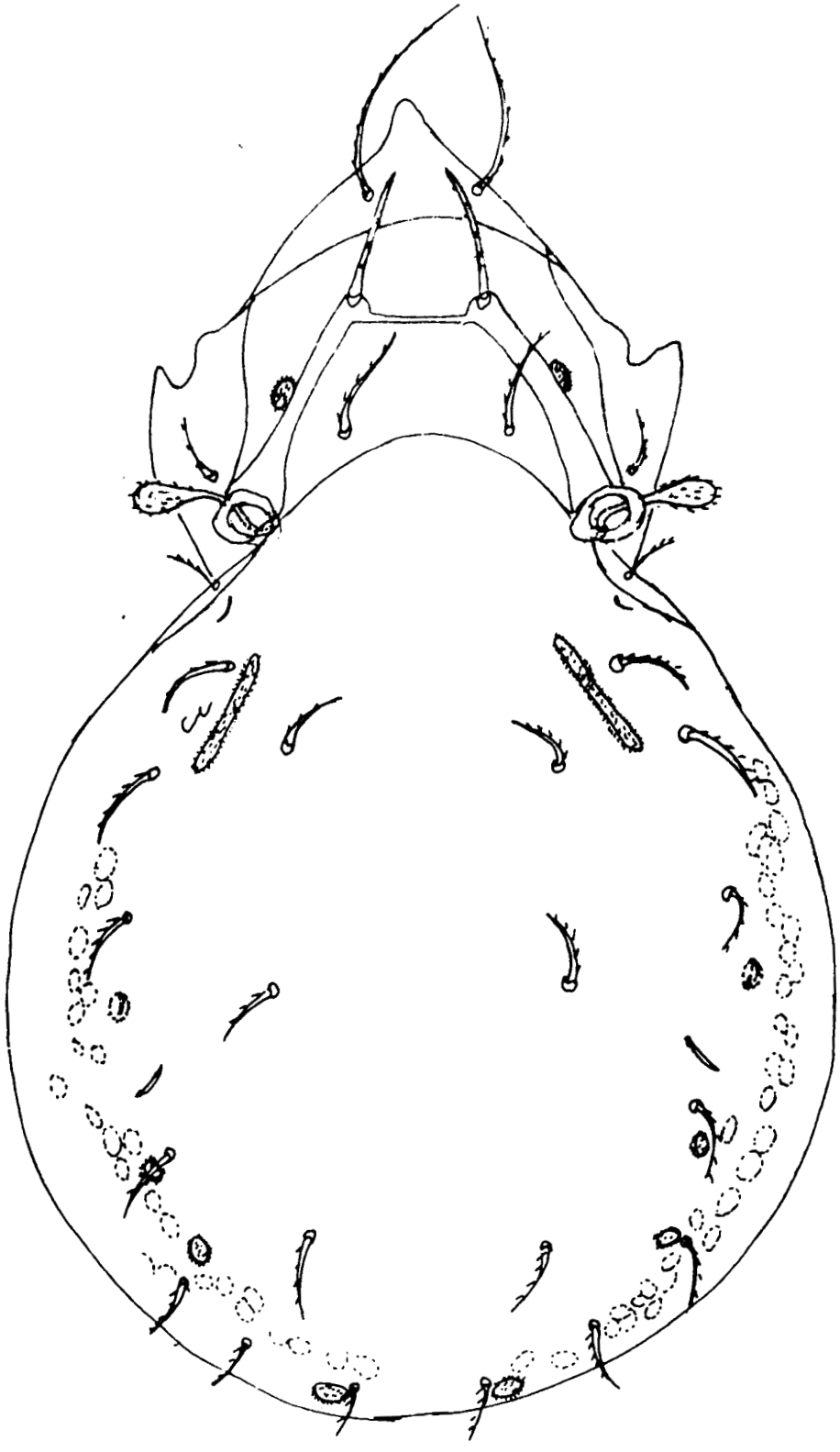
FIG IV **Nesotocepheus hauseri Mahunka, 1980**



VENTRAL VIEW

FIG V

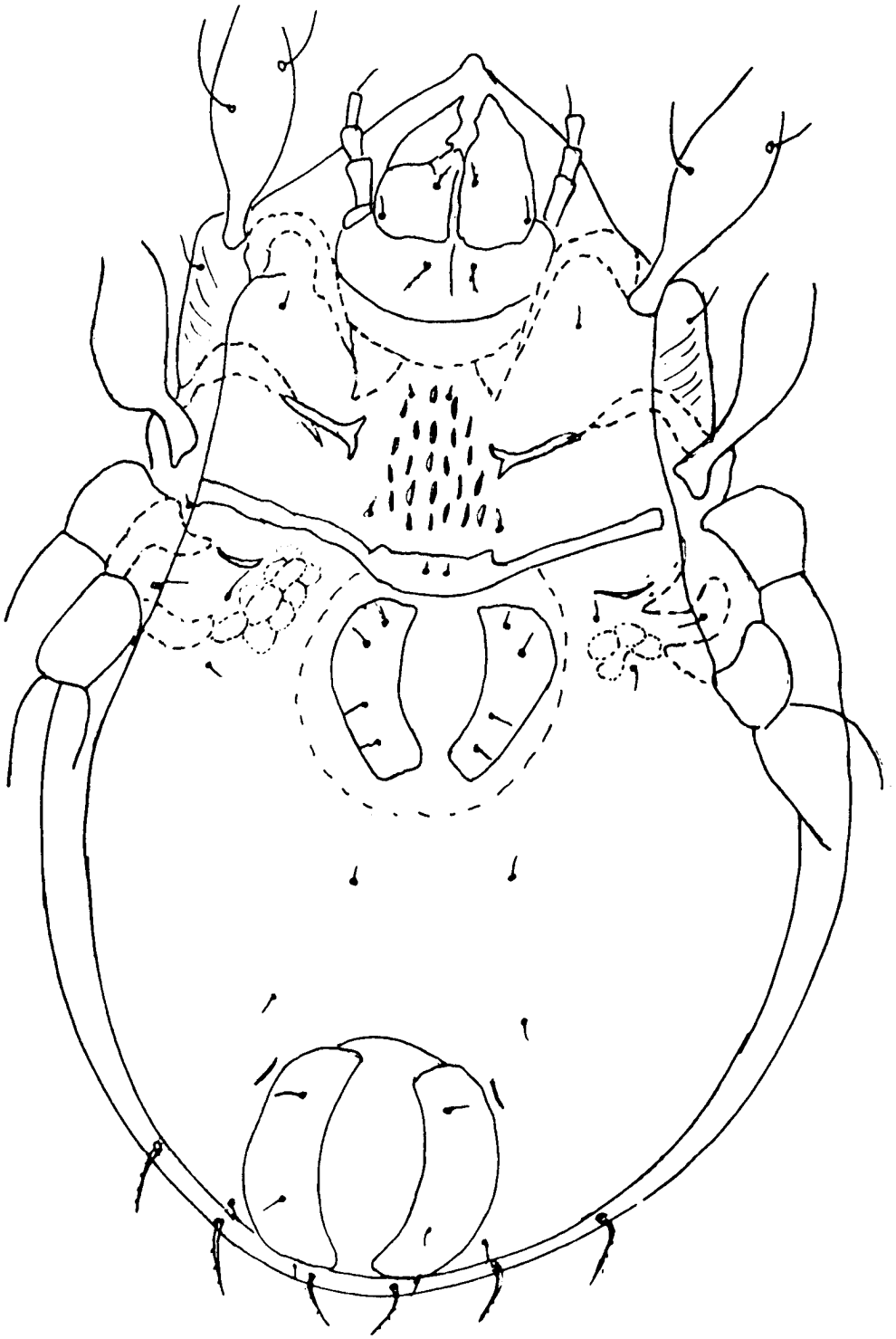
Zygoribatula lineata Hammer, 1979



DORSAL VIEW

FIG VI

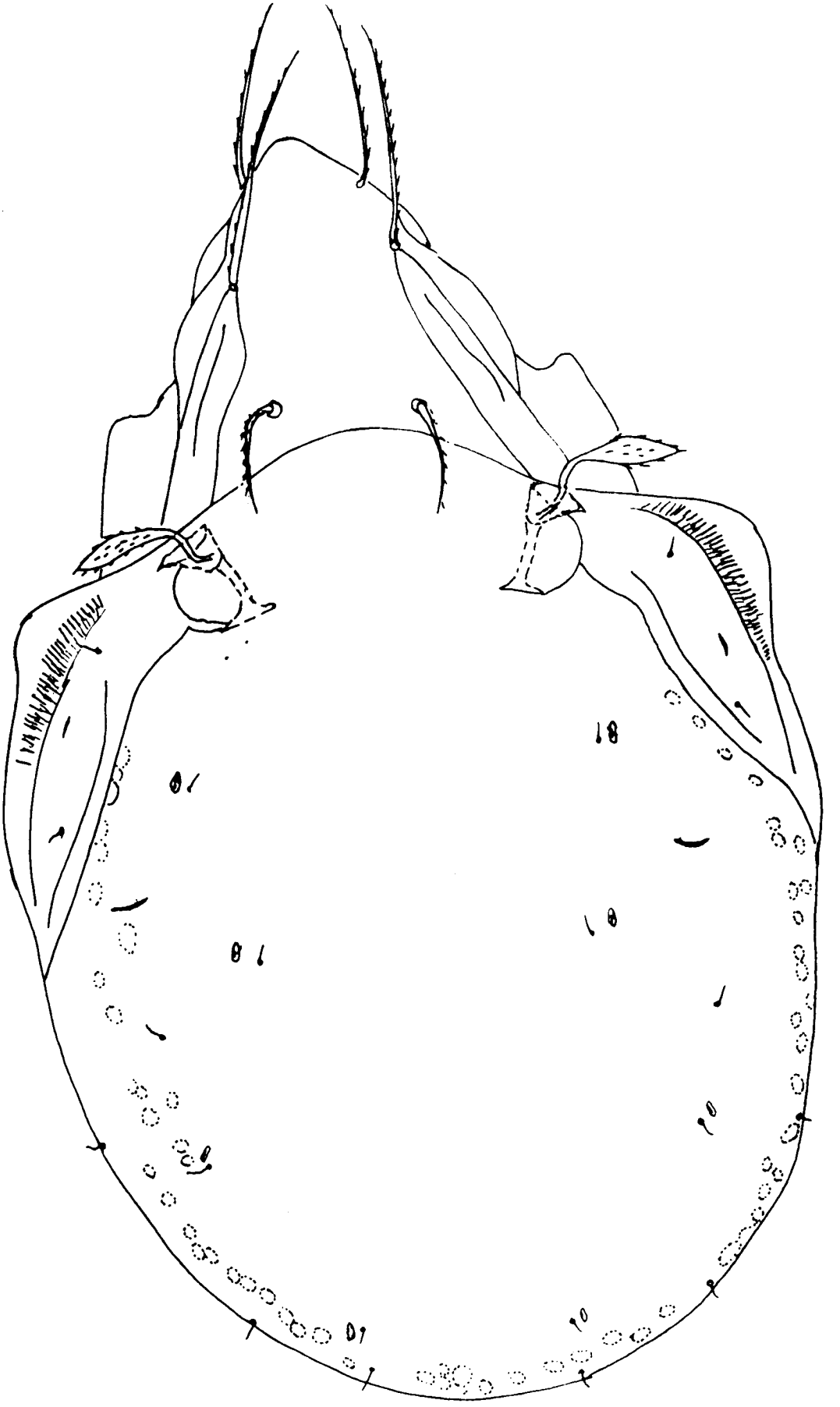
Zygoribatula lineata Hammer, 1979



VENTRAL VIEW

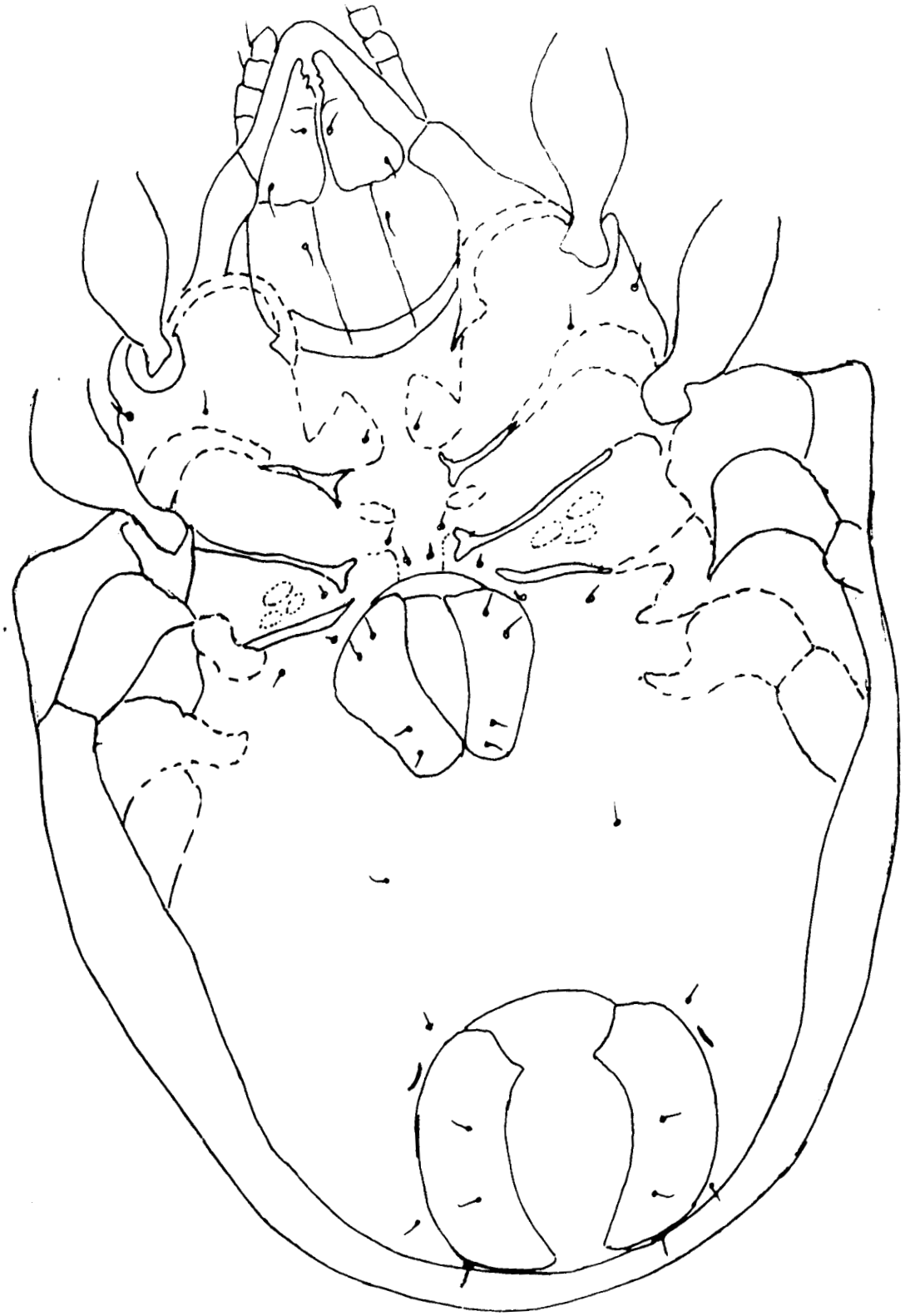
FIG VII

Scheloribates laevigatus (C.L.Koch,1841)



DORSAL VIEW

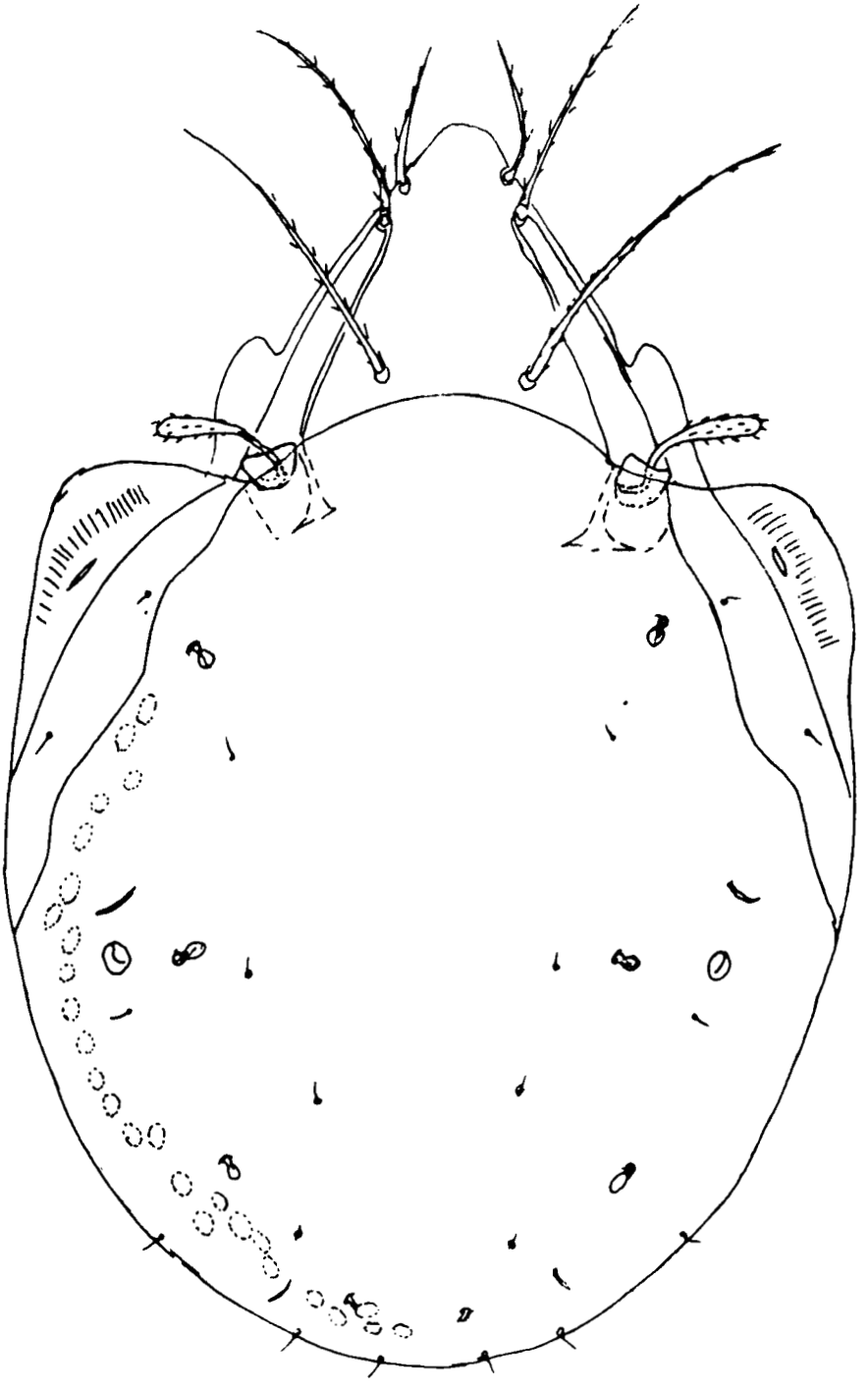
FIG VIII **Scheloribates laevigatus (C.L.Koch, 1841)**



VENTRAL VIEW

FIG IX

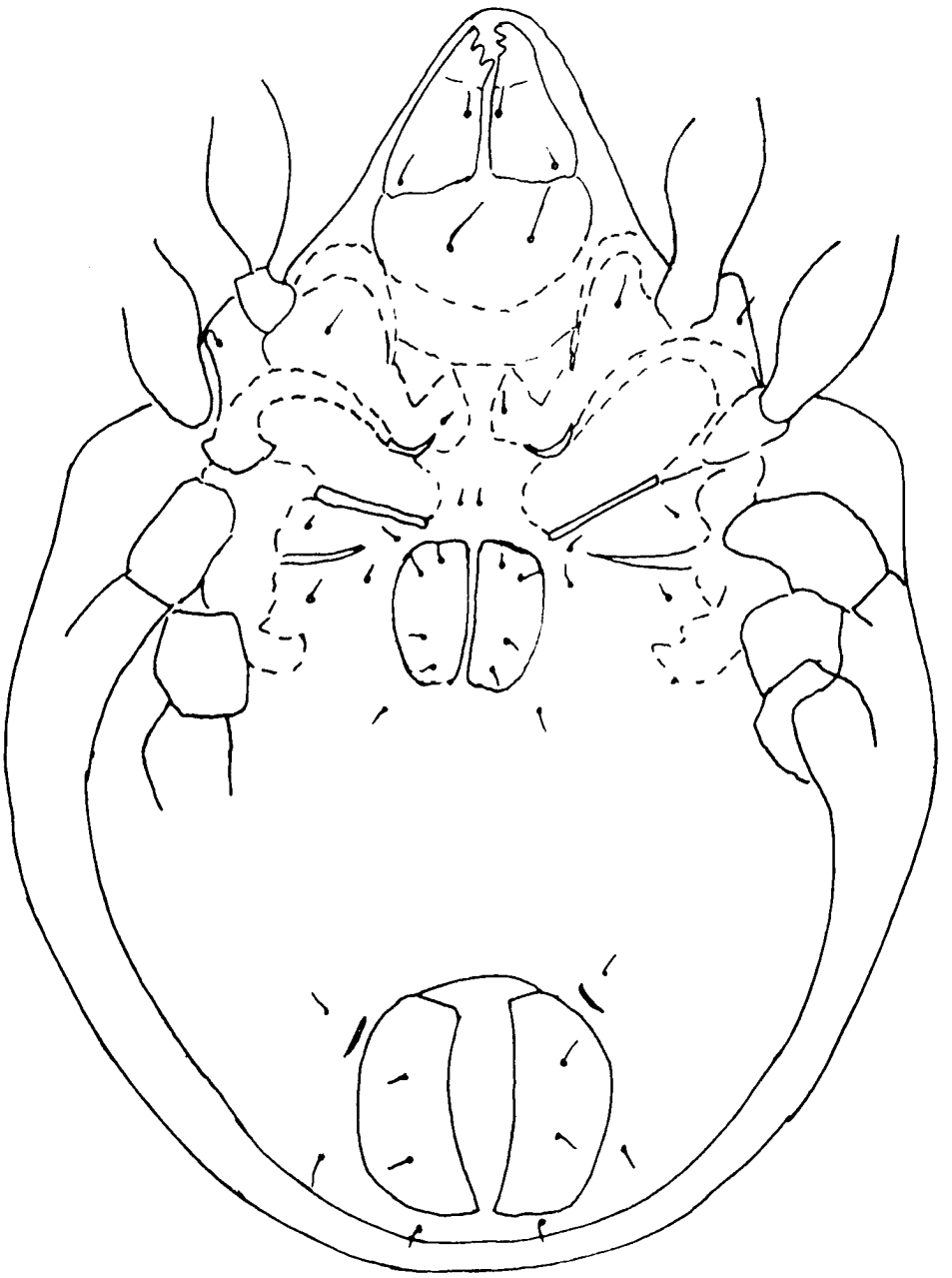
Scheloribates latipes (C.L.Koch,1841)



DORSAL VIEW

FIG X

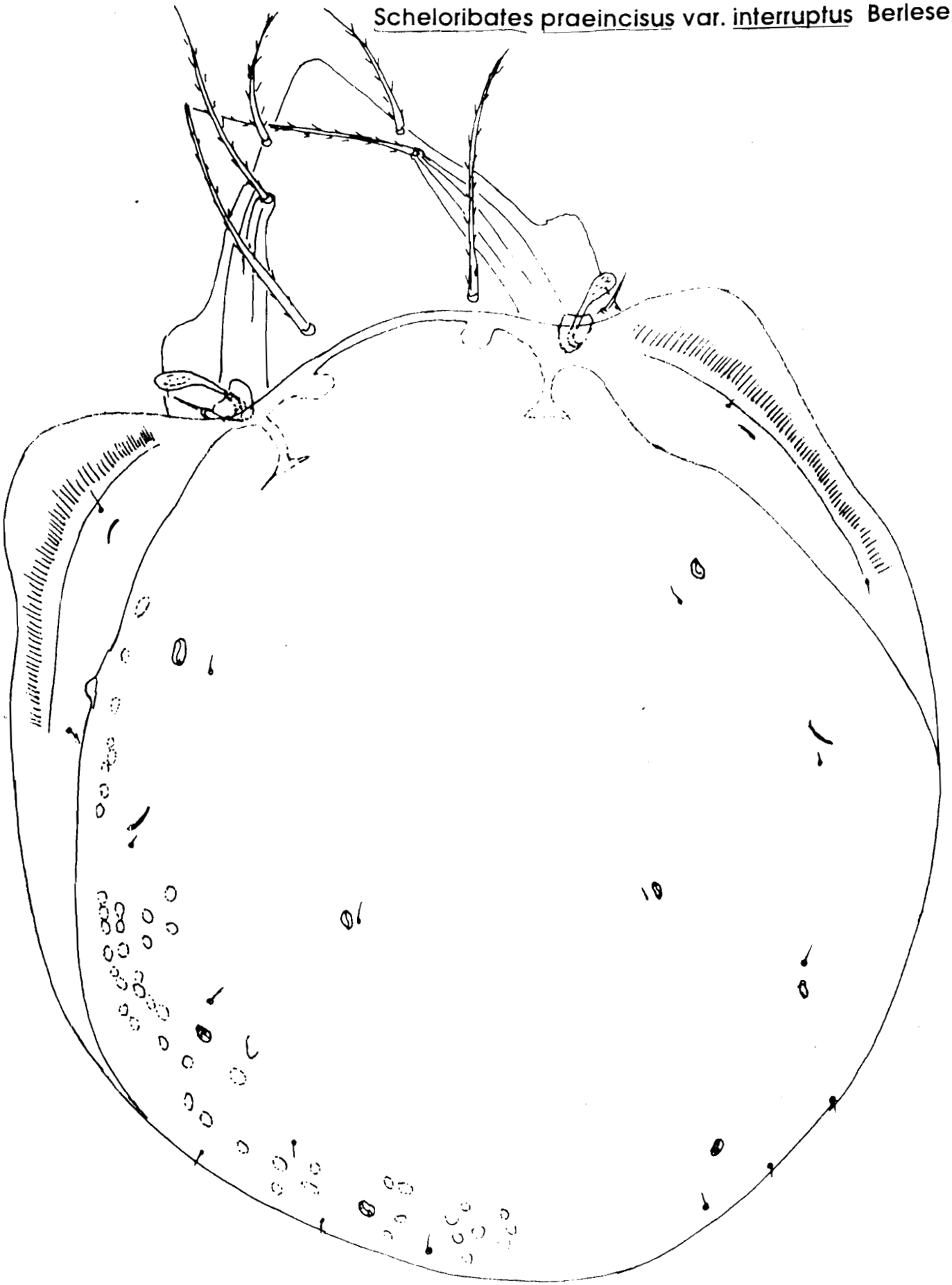
Scheloribates latipes (C.L.Koch,1841)



VENTRAL VIEW

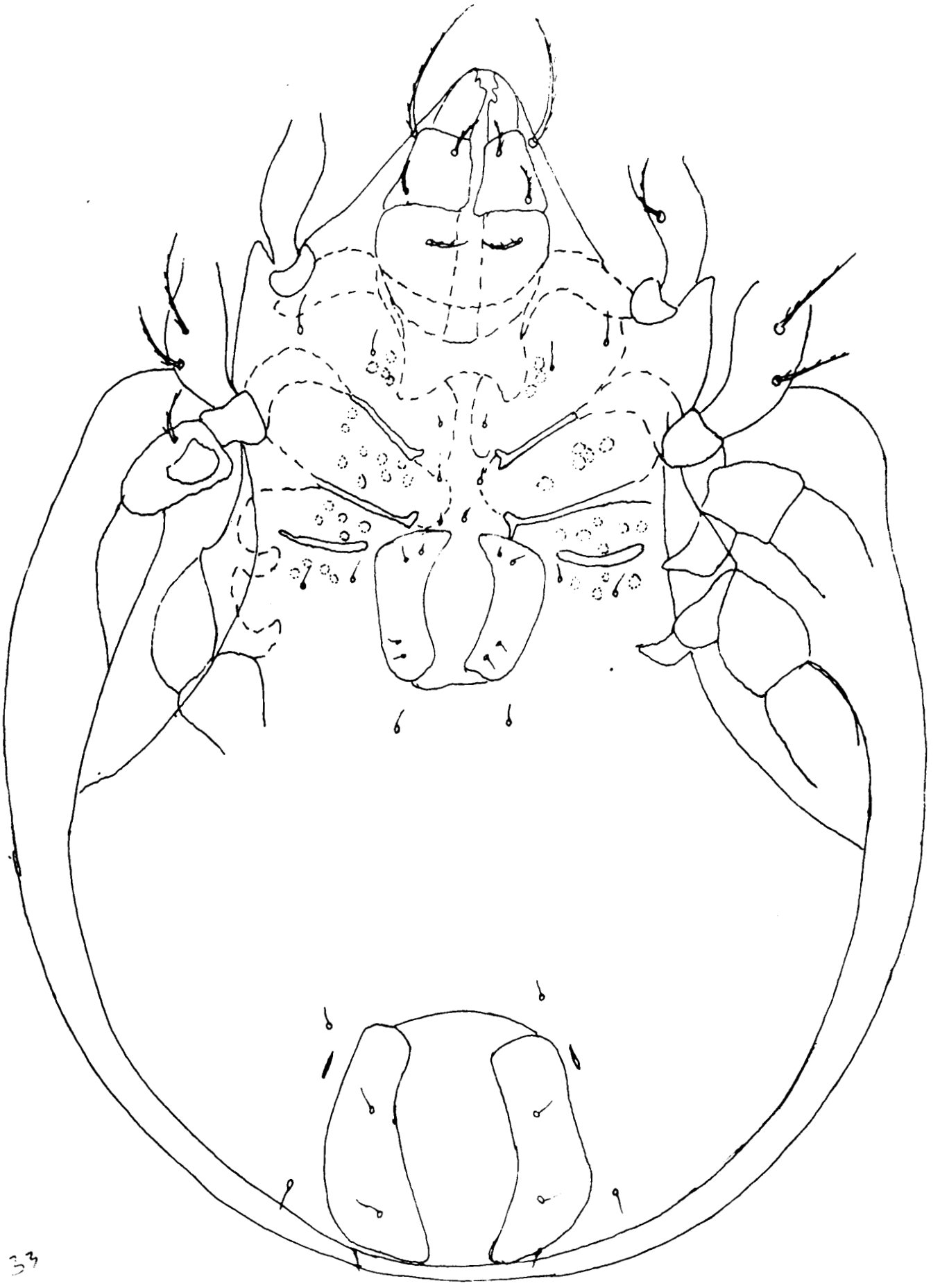
FIG XI

Scheloribates praeincisus var. interruptus Berlese, 1



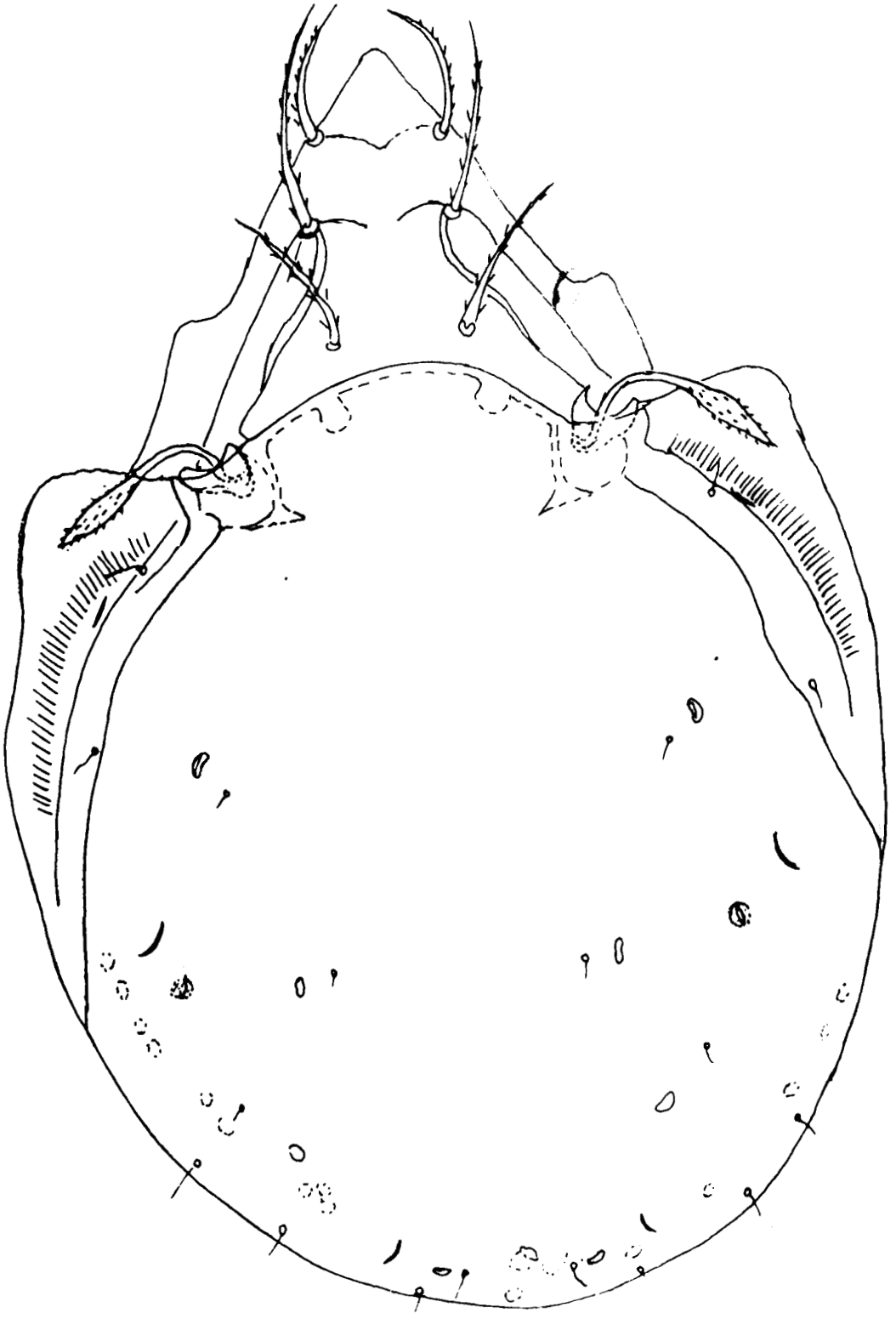
DORSAL VIEW

FIG XII **Scheloribates praeincisus var. interruptus Berlese, 1916**



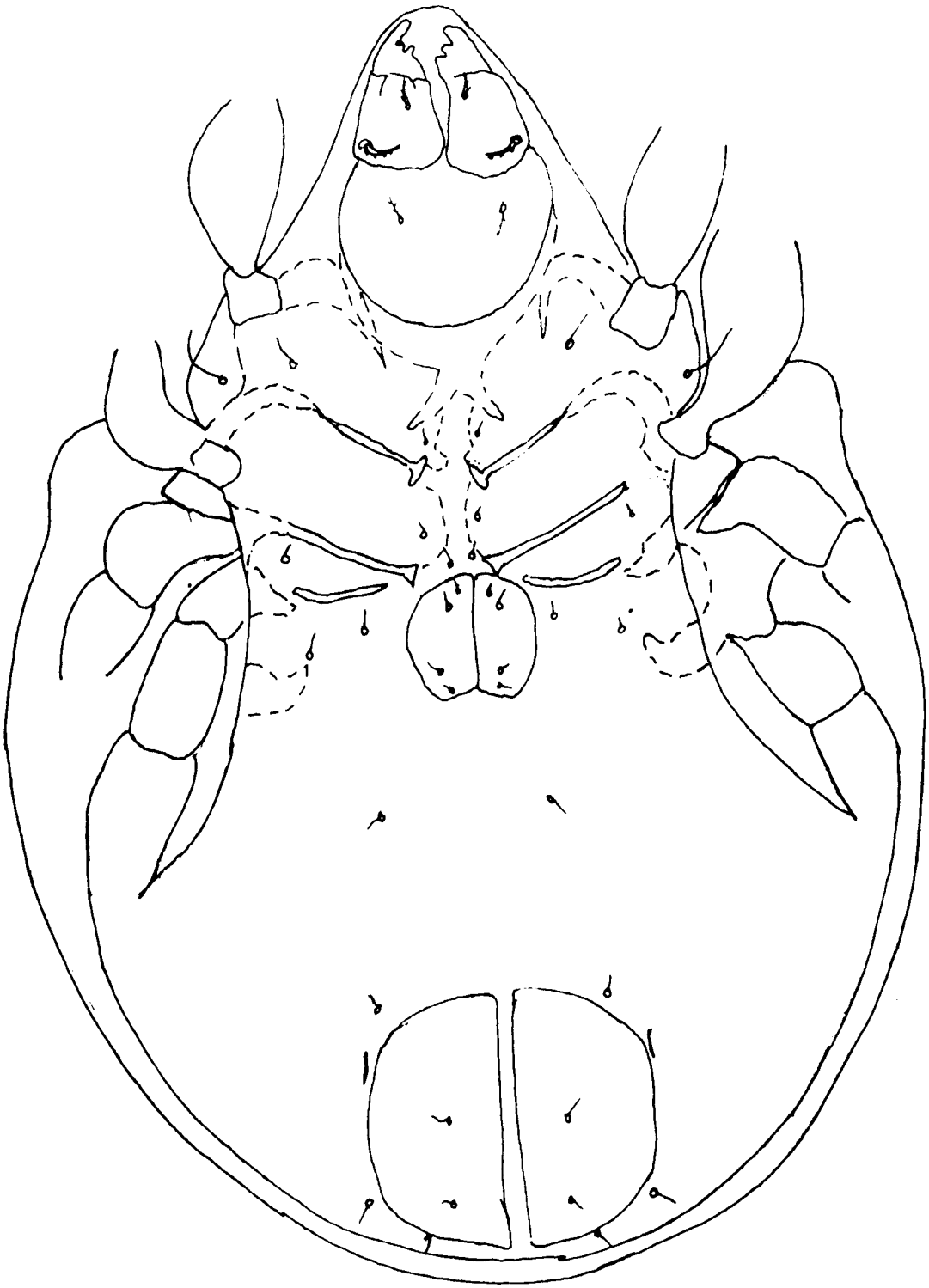
VENTRAL VIEW

FIG XIII **Scheloribates rectus Hammer 1958**



DORSAL VIEW

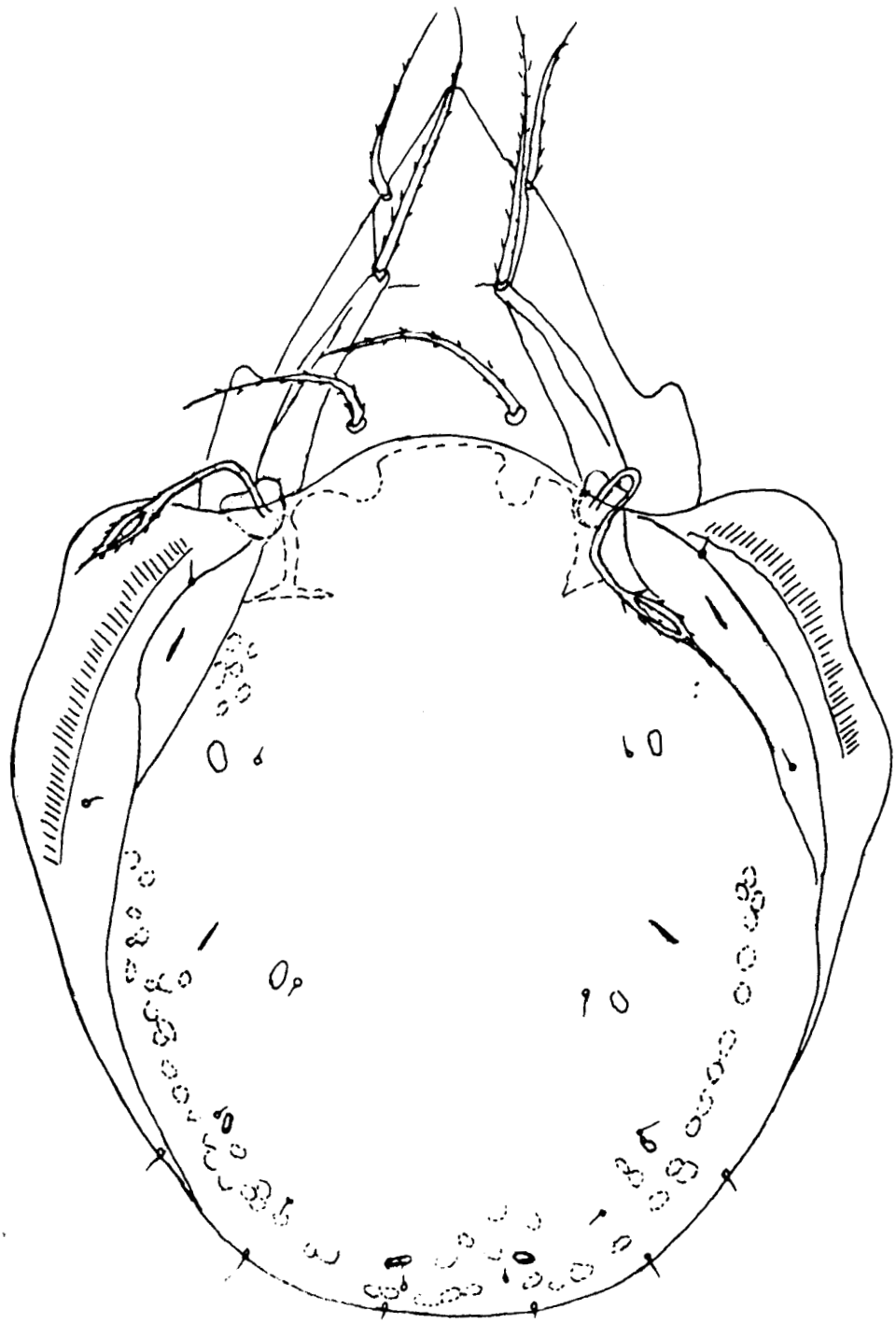
FIG XIV Scheloribates rectus Hammer 1958



VENTRAL VIEW

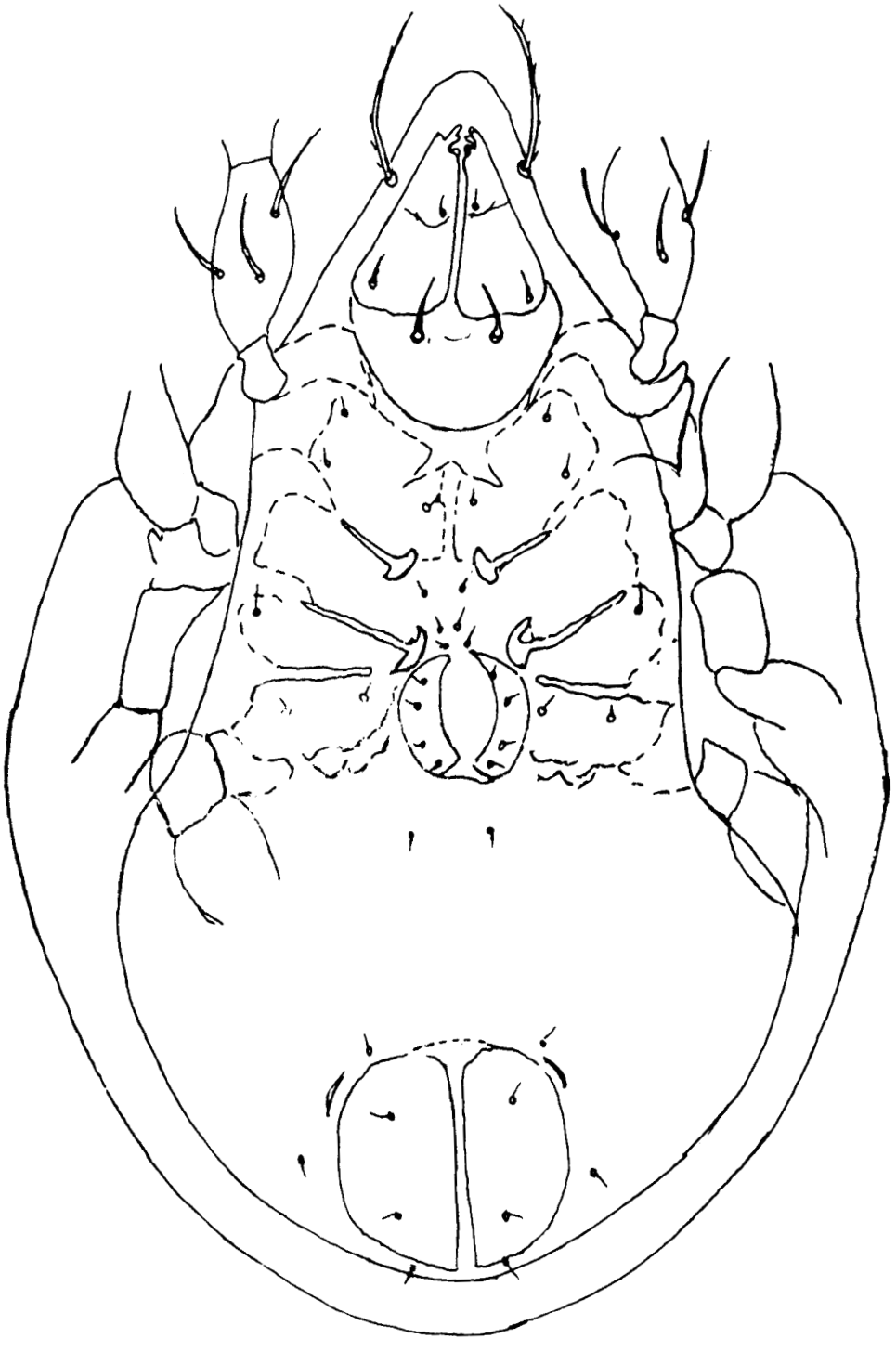
FIG XV

Ischeloribates lanceolatus, Aoki, 1984



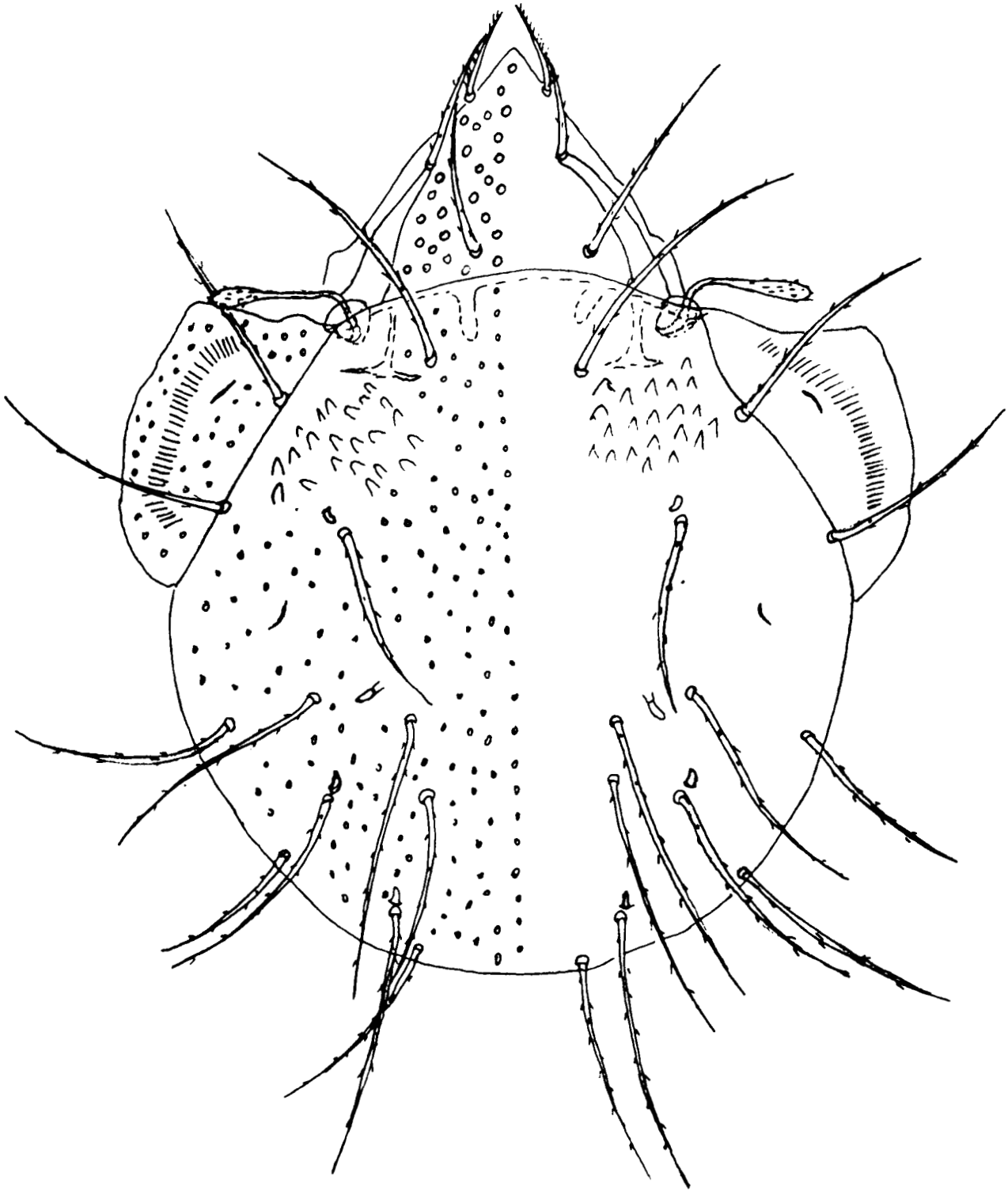
DORSAL VIEW

FIG XVI **Ischeloribates lanceolatus, Aoki, 1984**



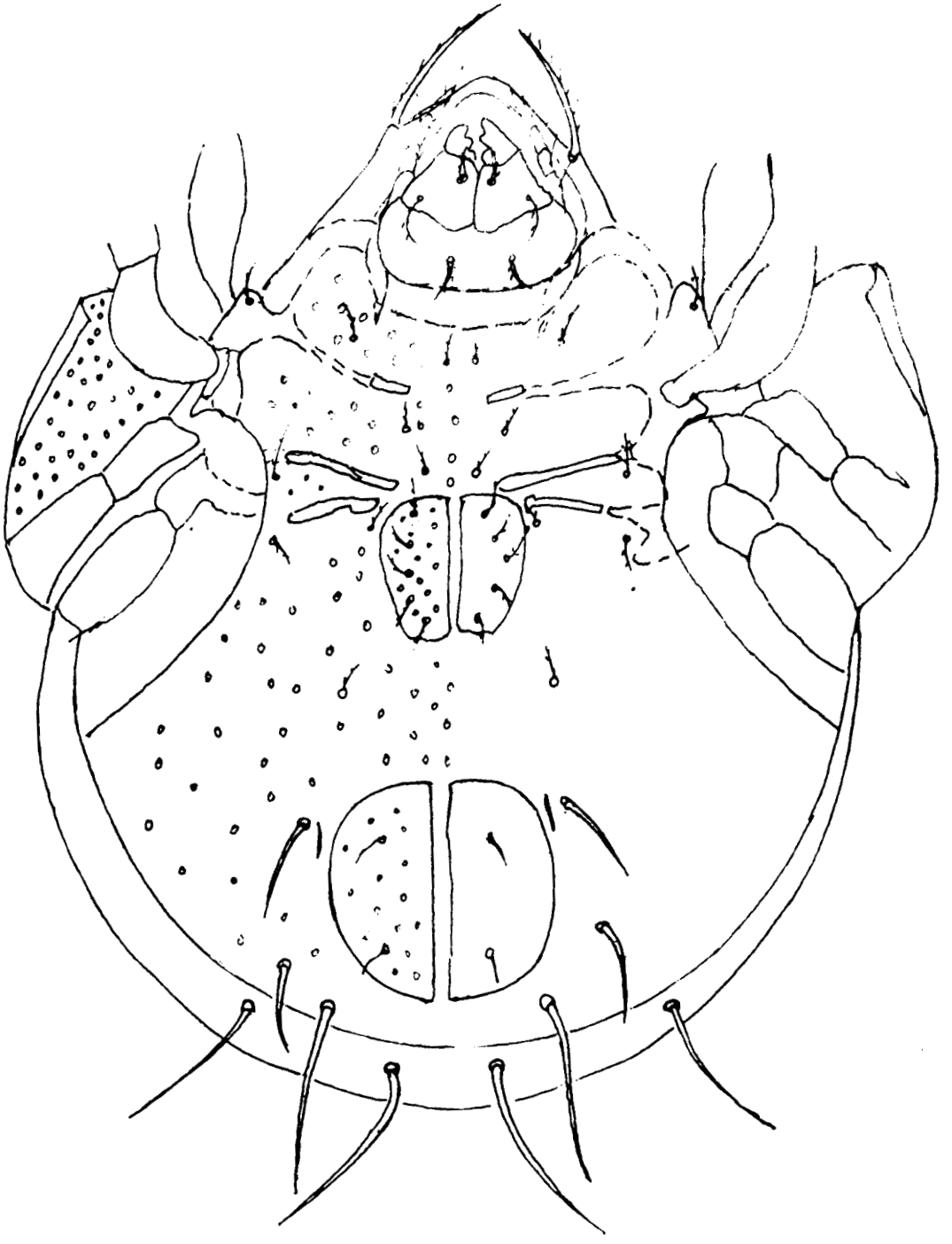
VENTRAL VIEW

FIG XVII **Peloribates levipunctatus Aoki, 1984**



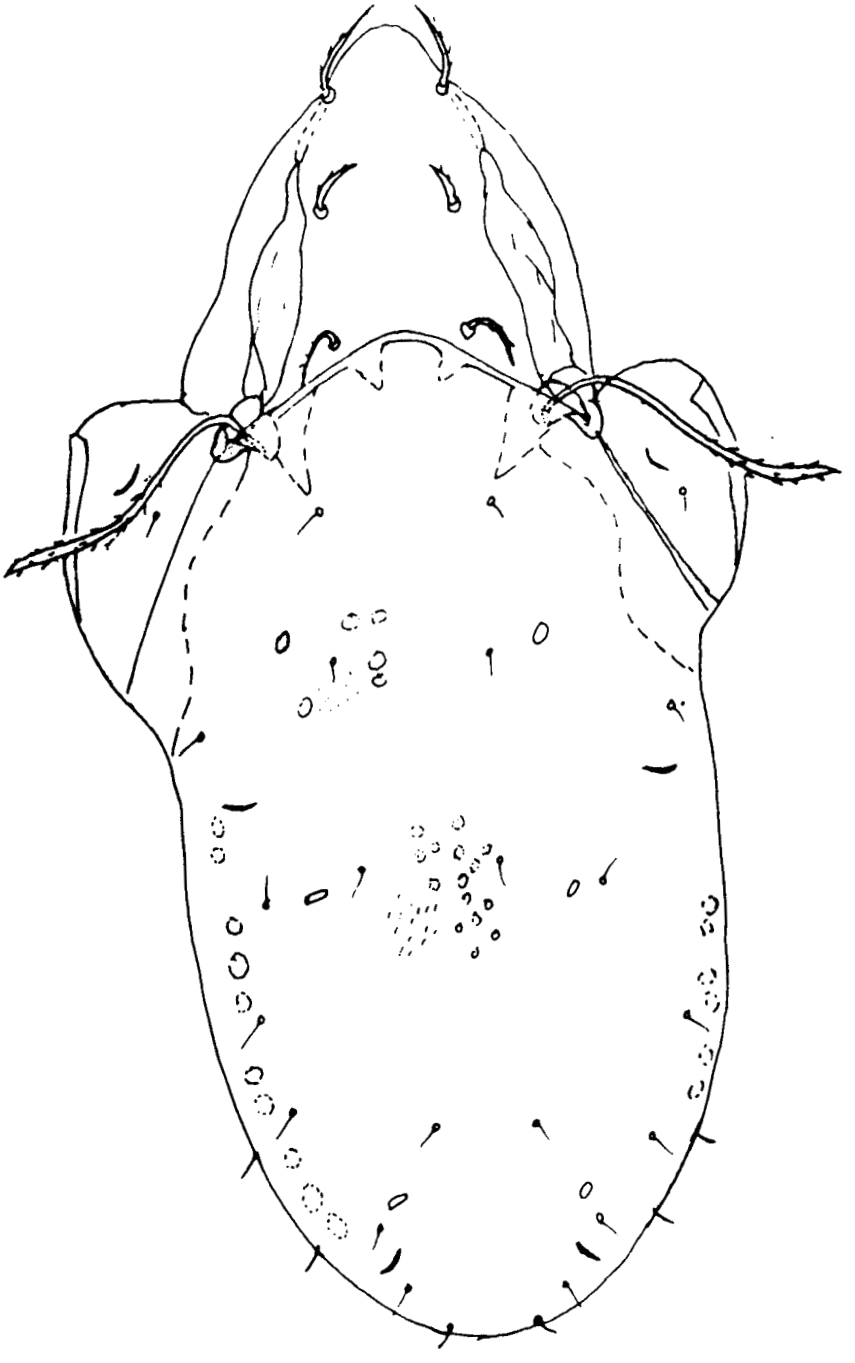
DORSAL VIEW

FIG XVIII **Peloribates levipunctatus Aoki, 1984**



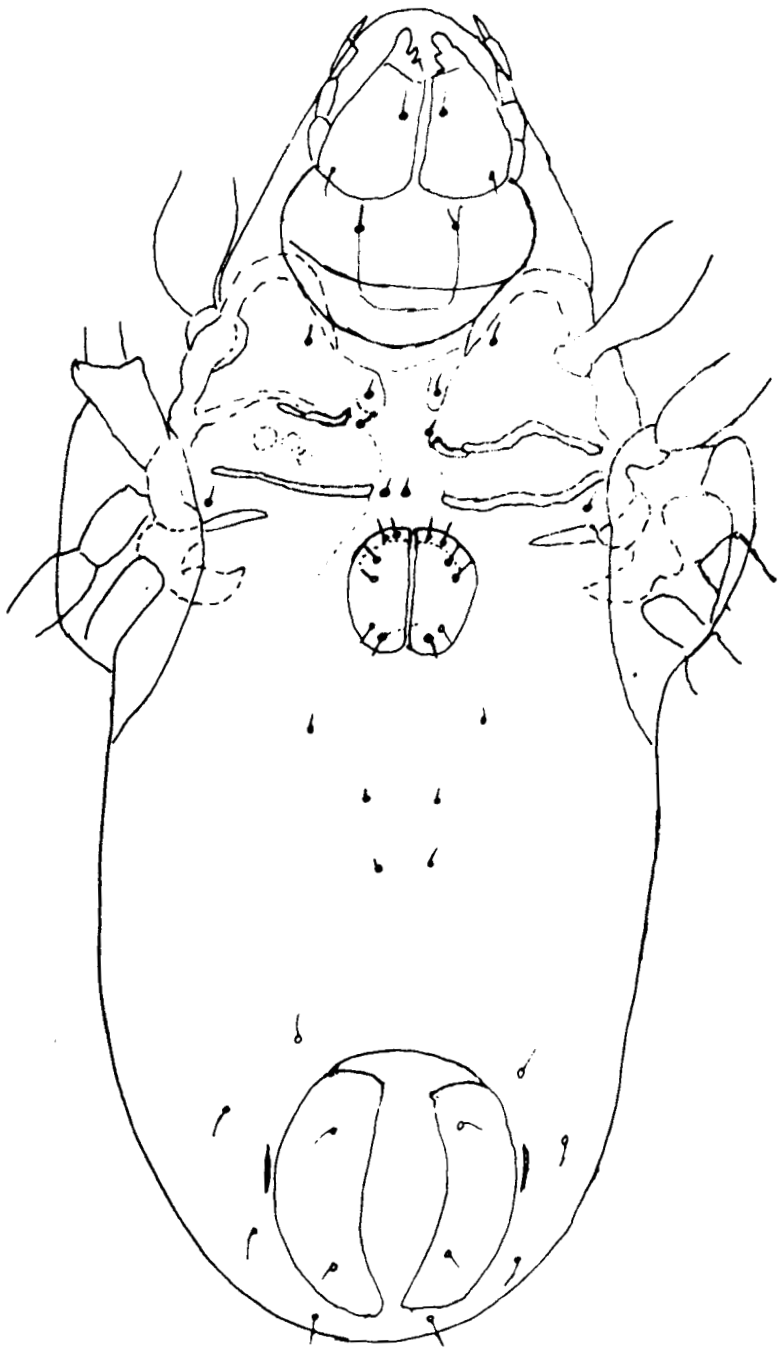
VENTRAL VIEW

FIG XIX **Pilobates pilosellus Balogh, 1960**



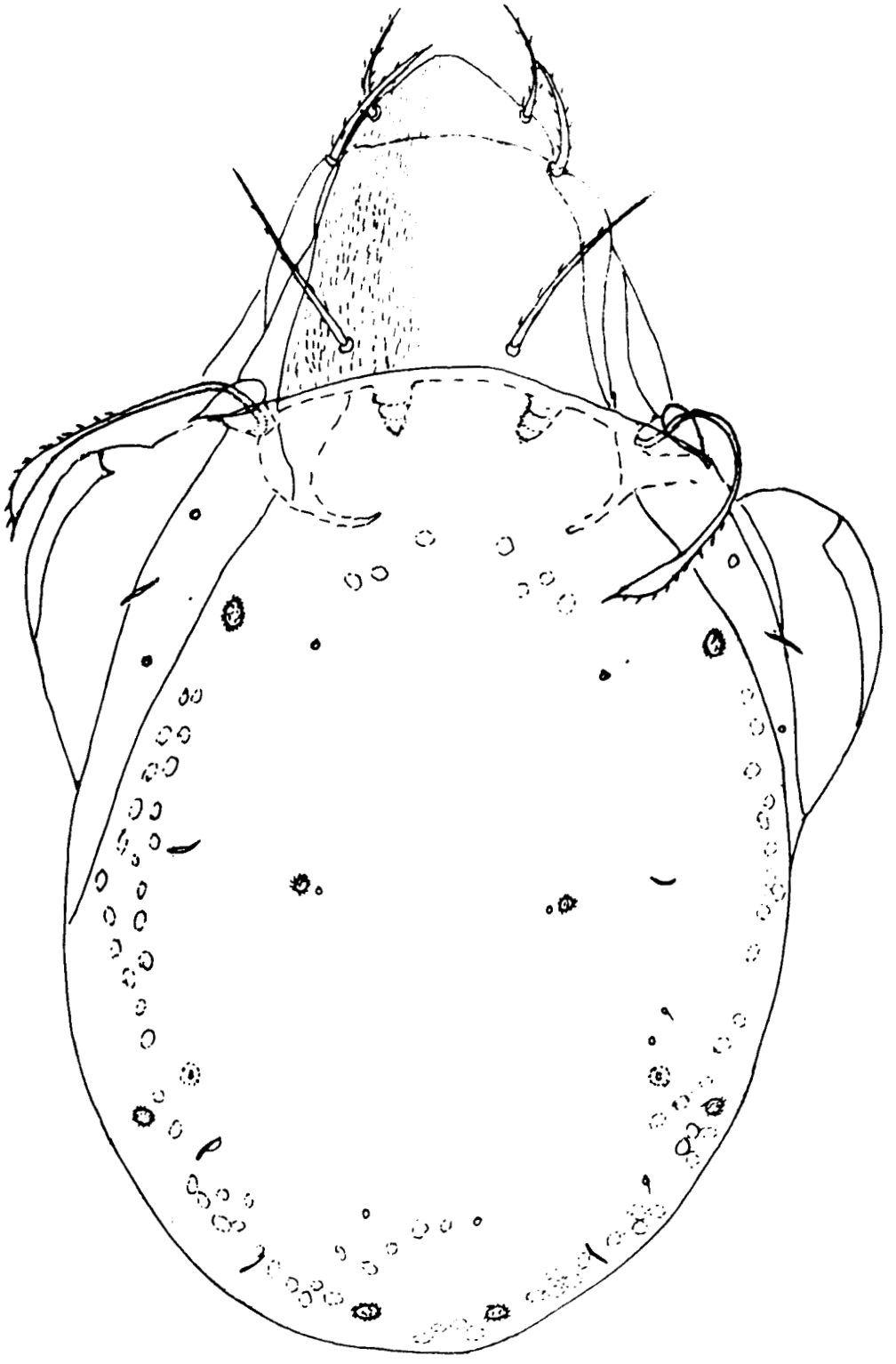
DORSAL VIEW

FIG XX **Pilobates pilosellus Balogh, 1960**



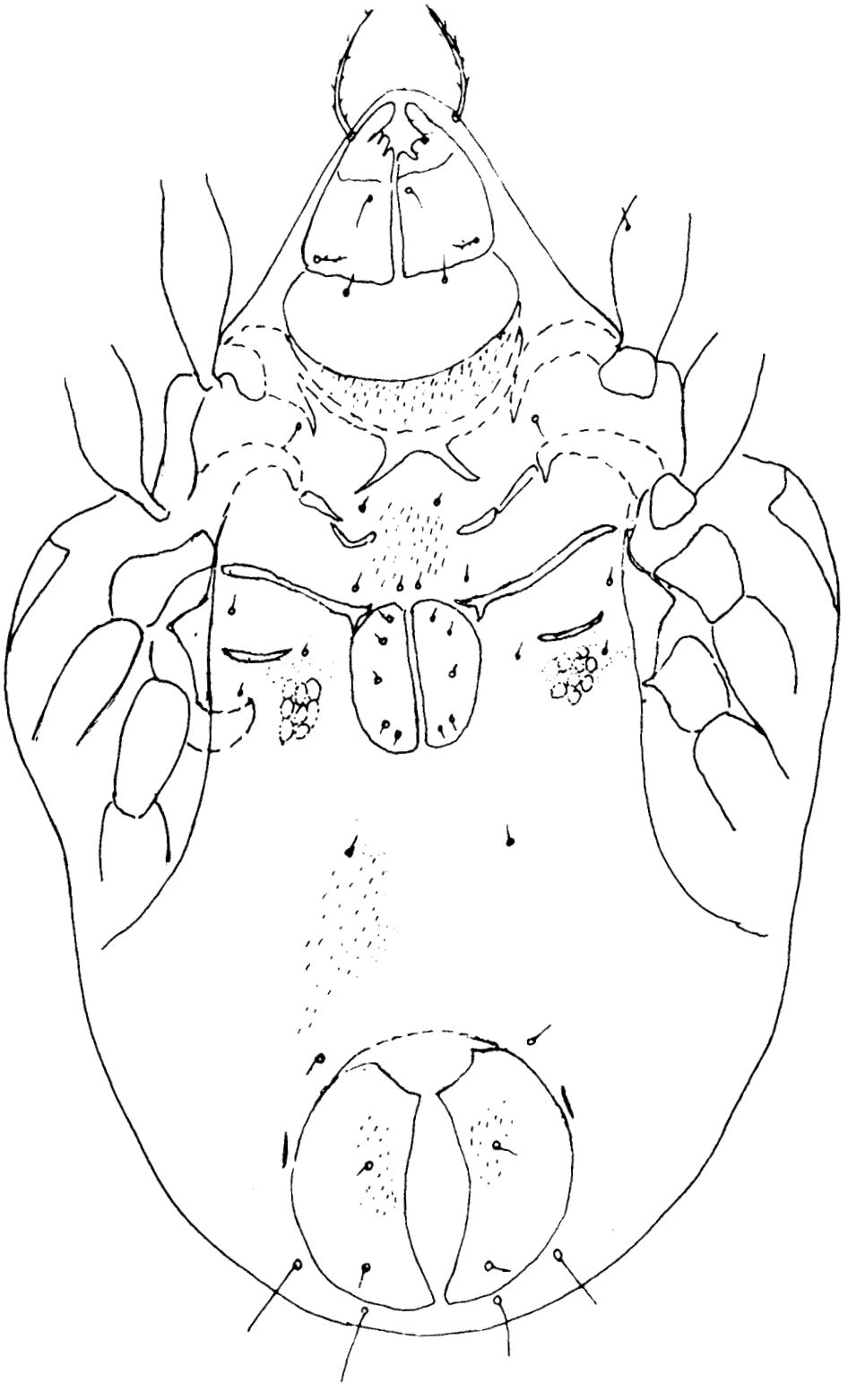
VENTRAL VIEW

FIG XXI **Xylobates seminudus Hammer, 1971**



DORSAL VIEW

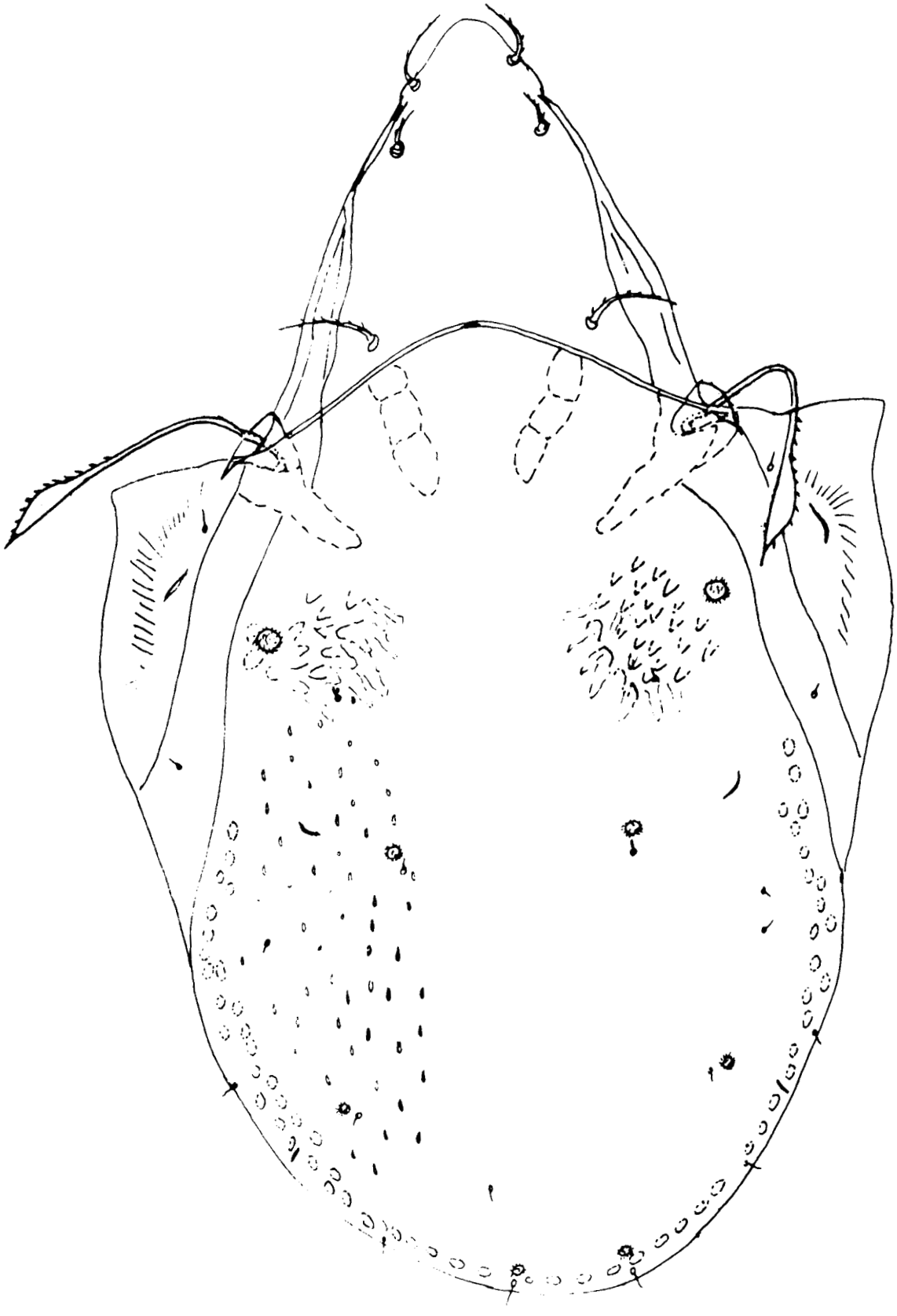
FIG XXII **Xylobates seminudus Hammer, 1971**



VENTRAL VIEW

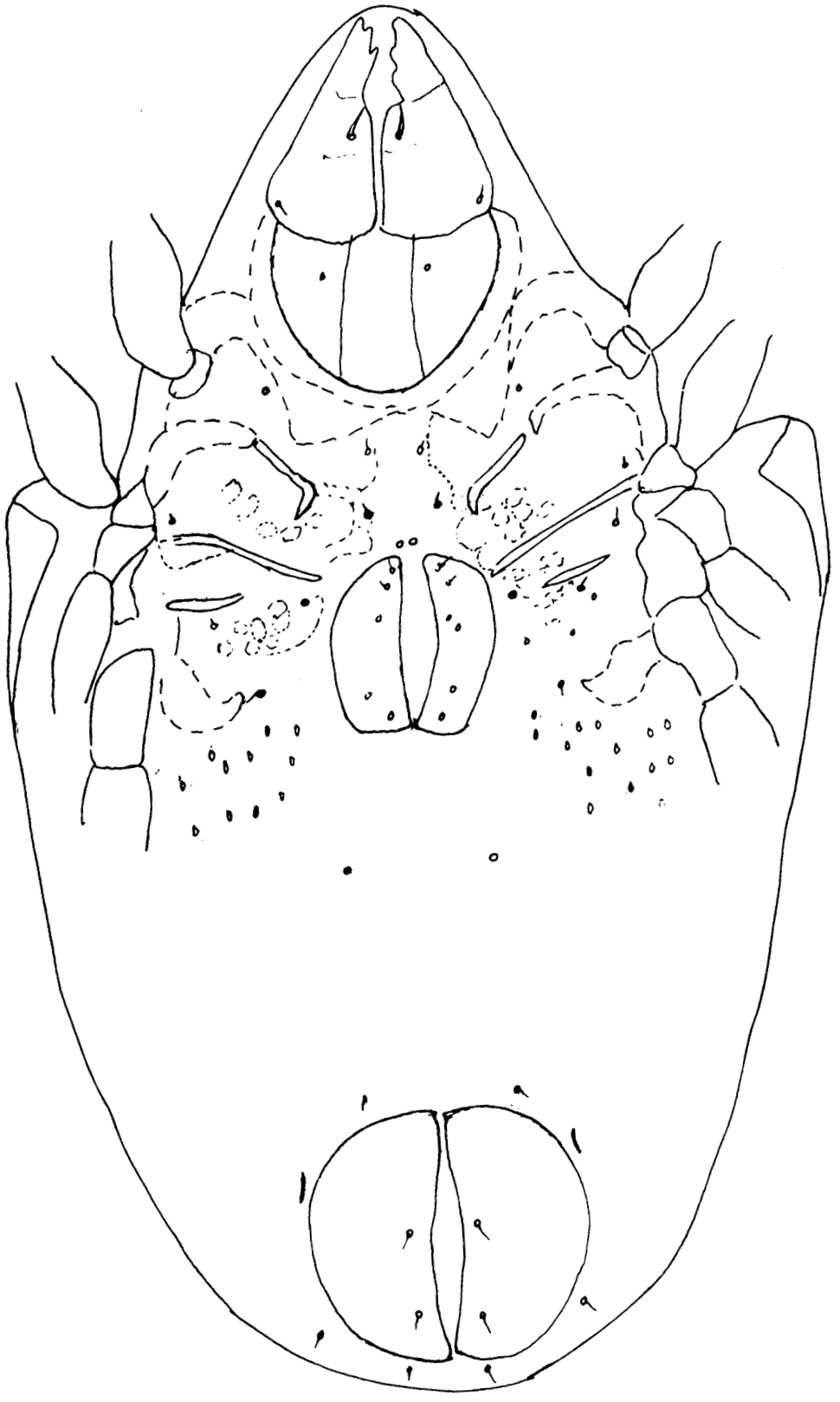
120 N

FIG XXIII **Xylobates triangularis Hammer, 1971**



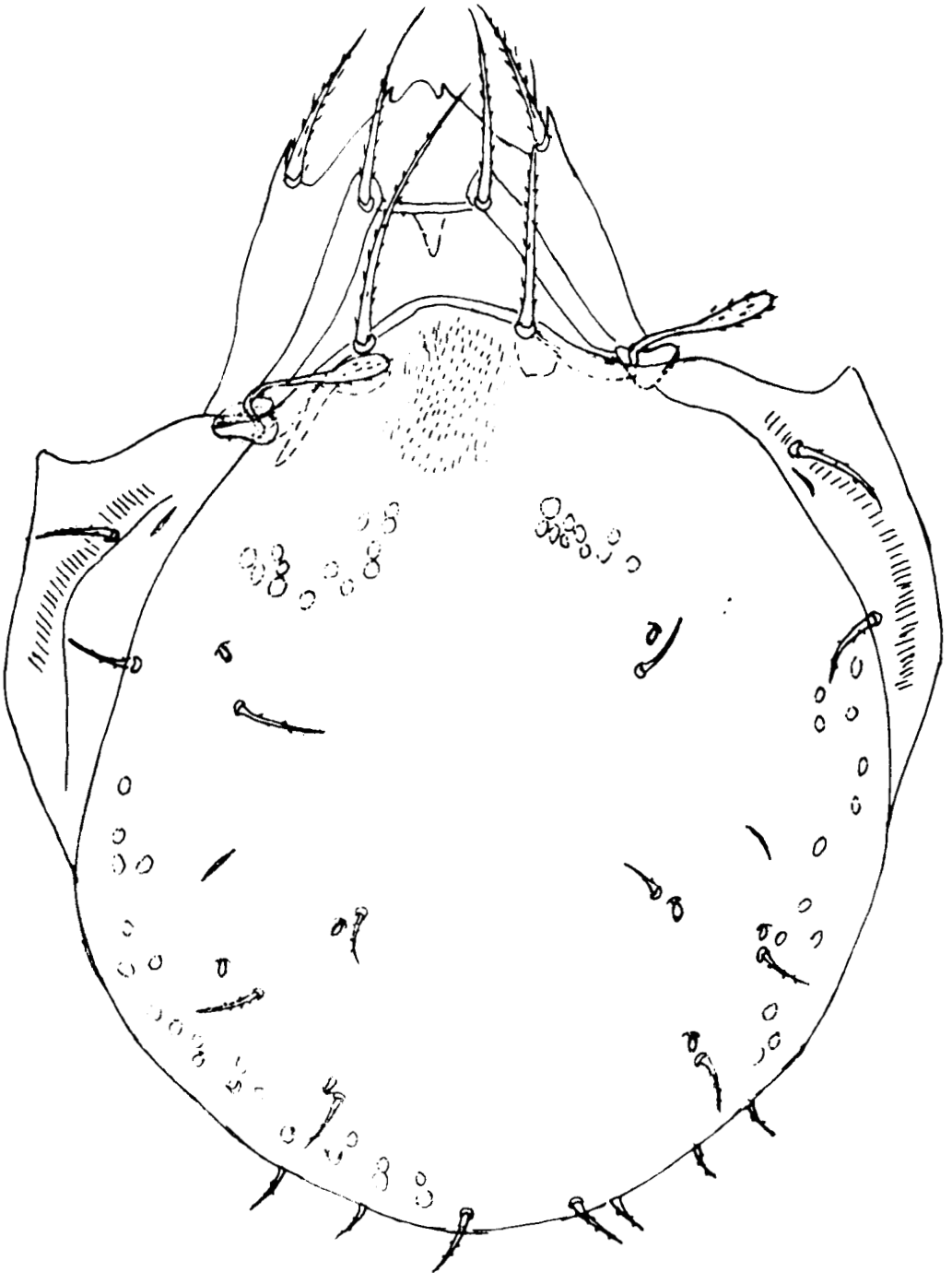
DORSAL VIEW

FIG XXIV **Xylobates triangularis Hammer, 1971**



VENTRAL VIEW

FIG XXV **Hypozetes imitator Balogh, 1959**

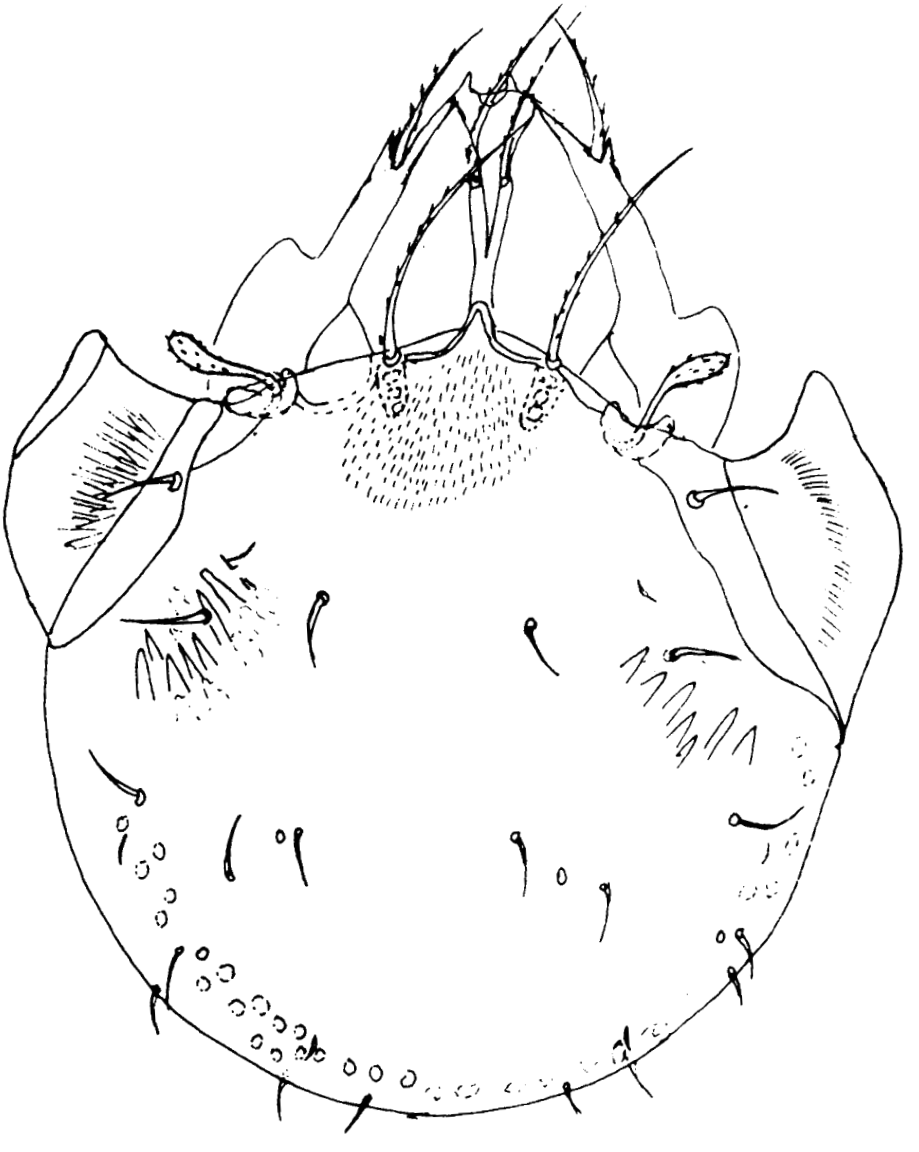


DORSAL VIEW

FIG XXVI **Hypozetes imitator Balogh, 1959**

VENTRAL VIEW

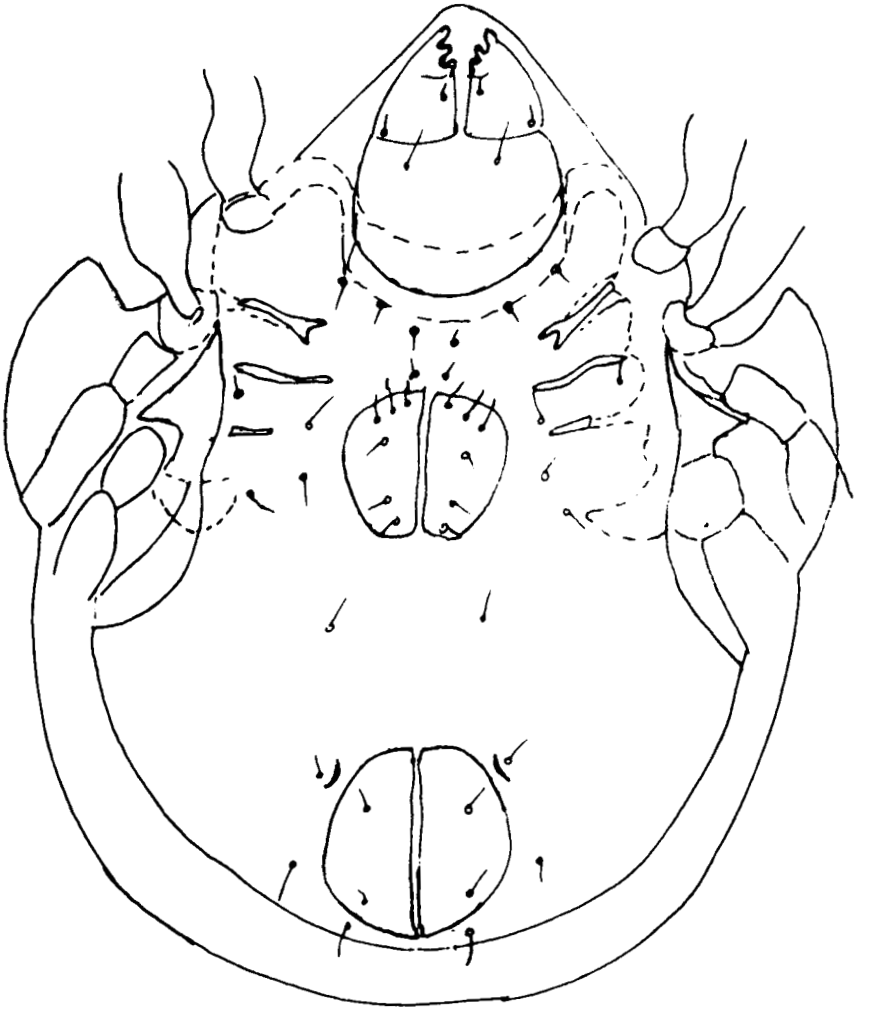
FIG XXVII **Anachipteria globatus sp.nov.**



DORSAL VIEW

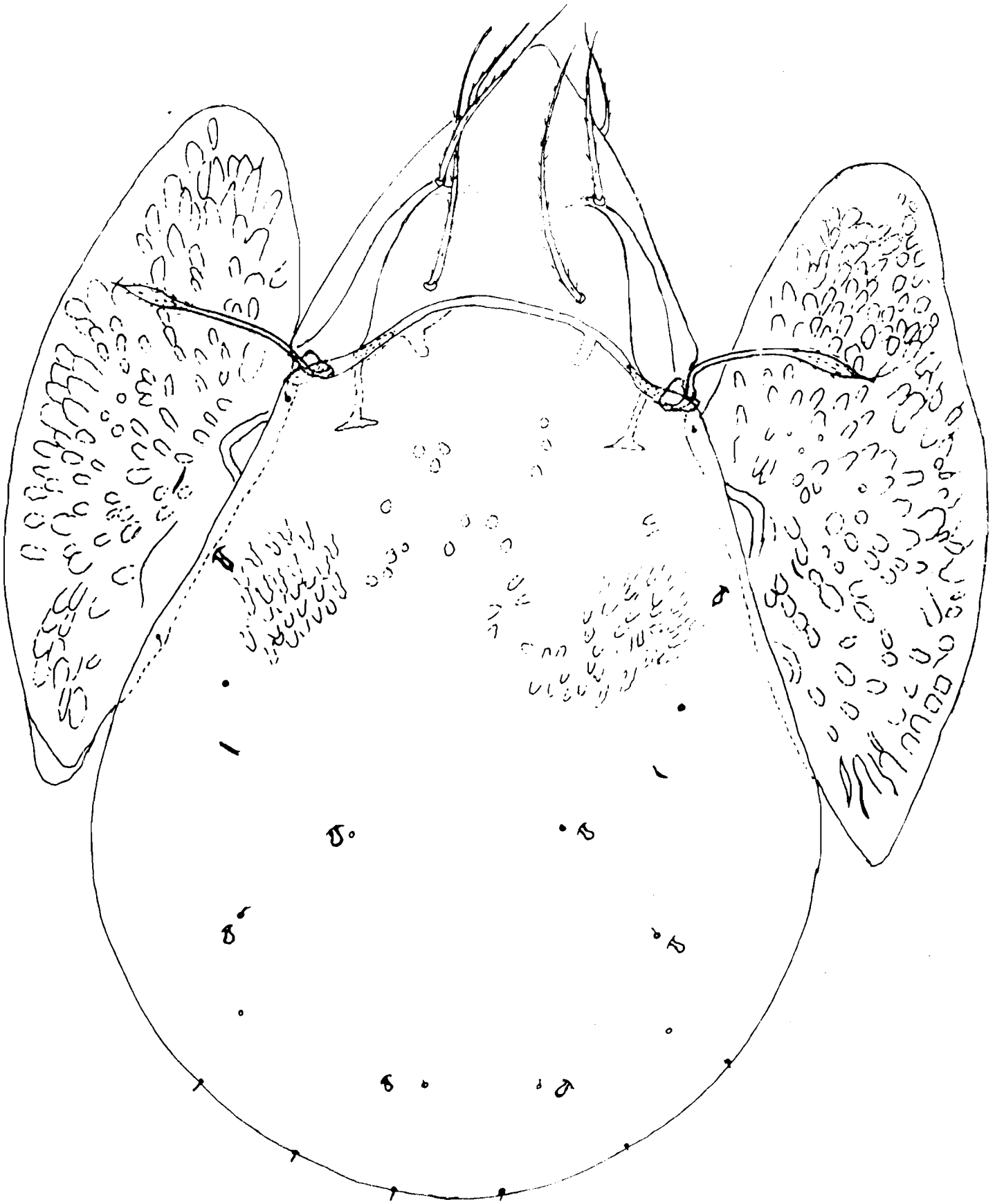
FIG XXVIII

Anachipteria globatus sp.nov.



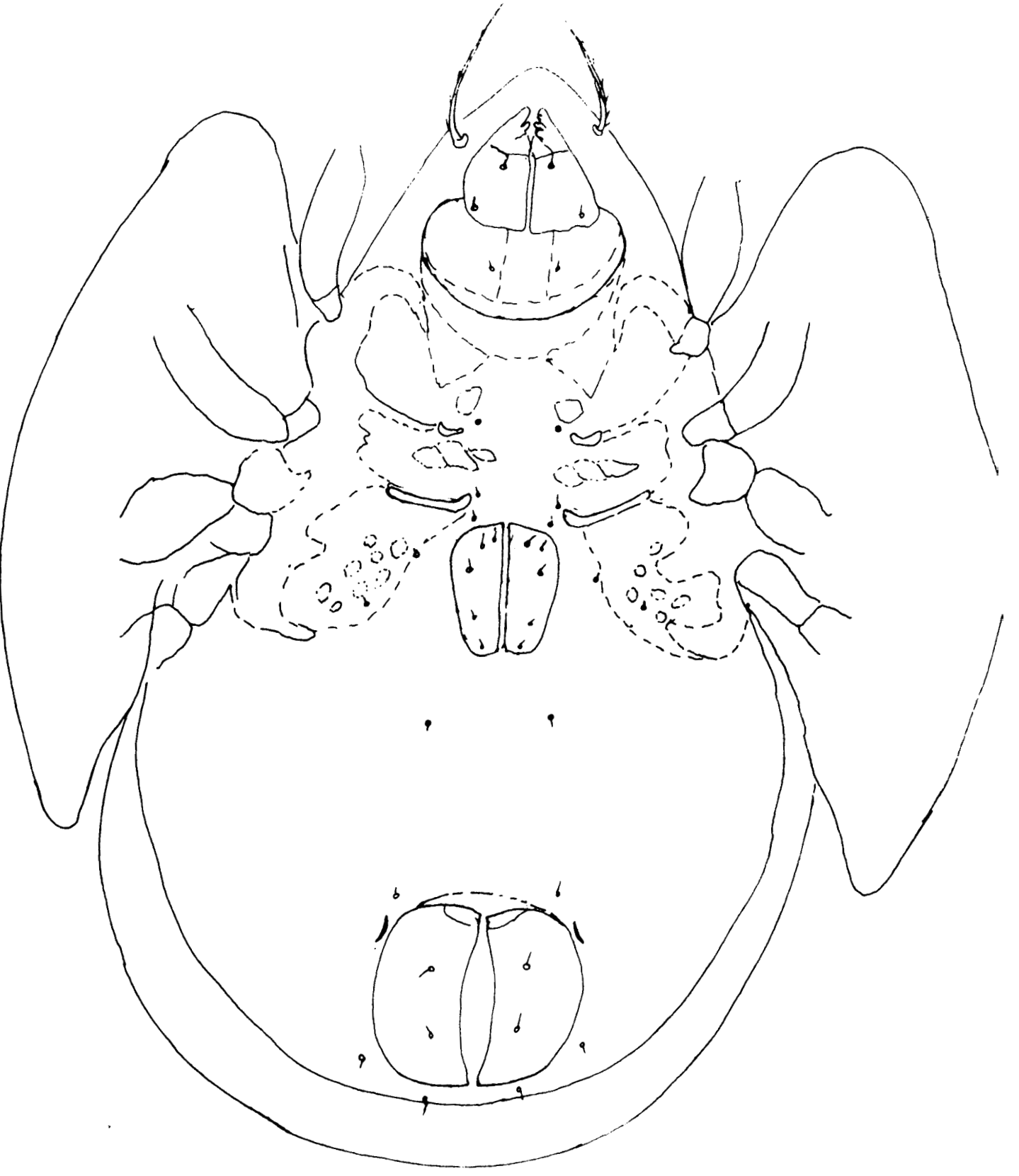
VENTRAL VIEW

FIG XXIX **Protokalumma erecta Balogh and Mahunka, 1969**



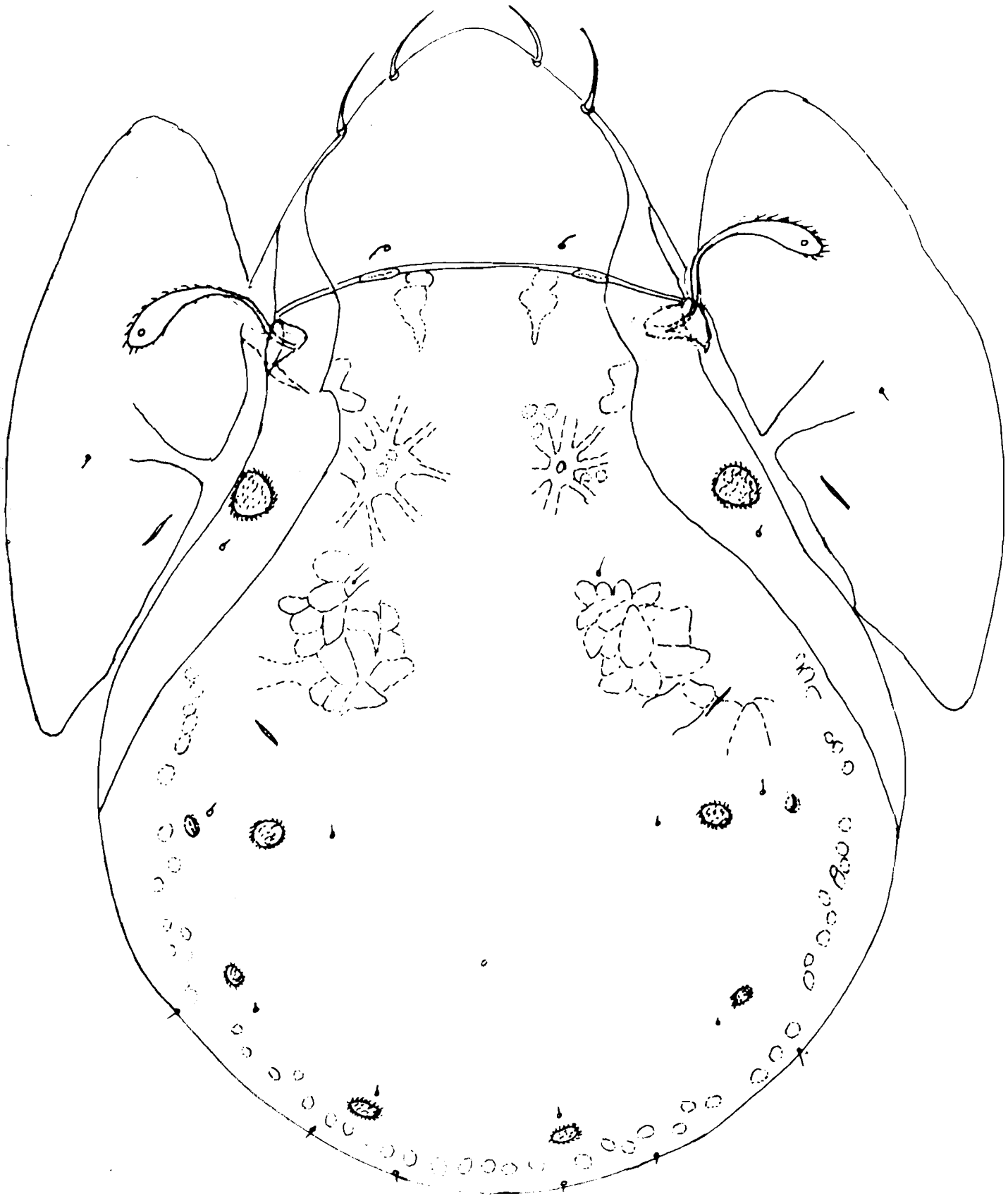
DORSAL VIEW

FIG XXX **Protokalumma erecta Balogh and Mahunka, 1969**



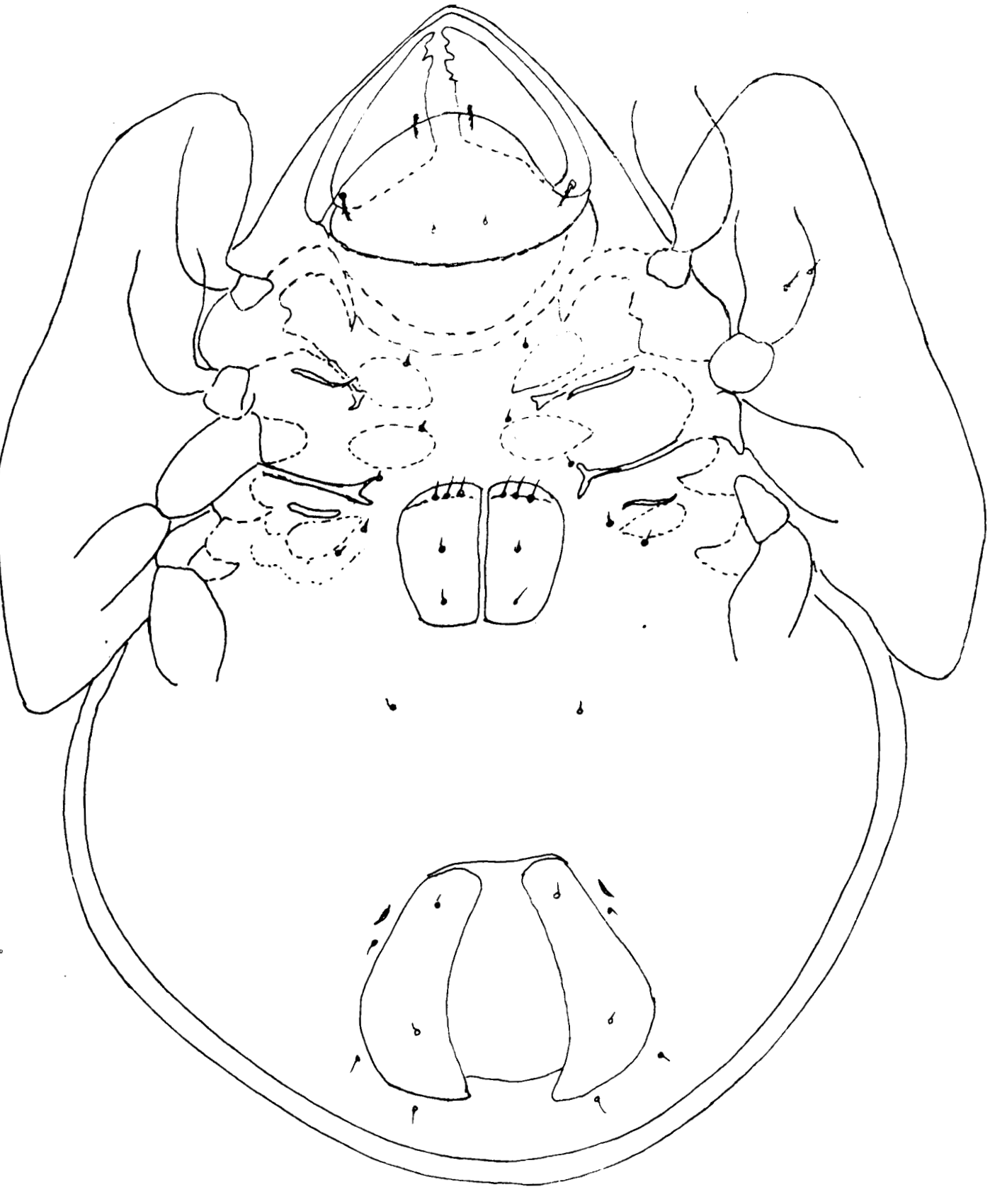
VENTRAL VIEW

FIG. XXXI **Galumna flabellifera orientalis Aoki, 1965**



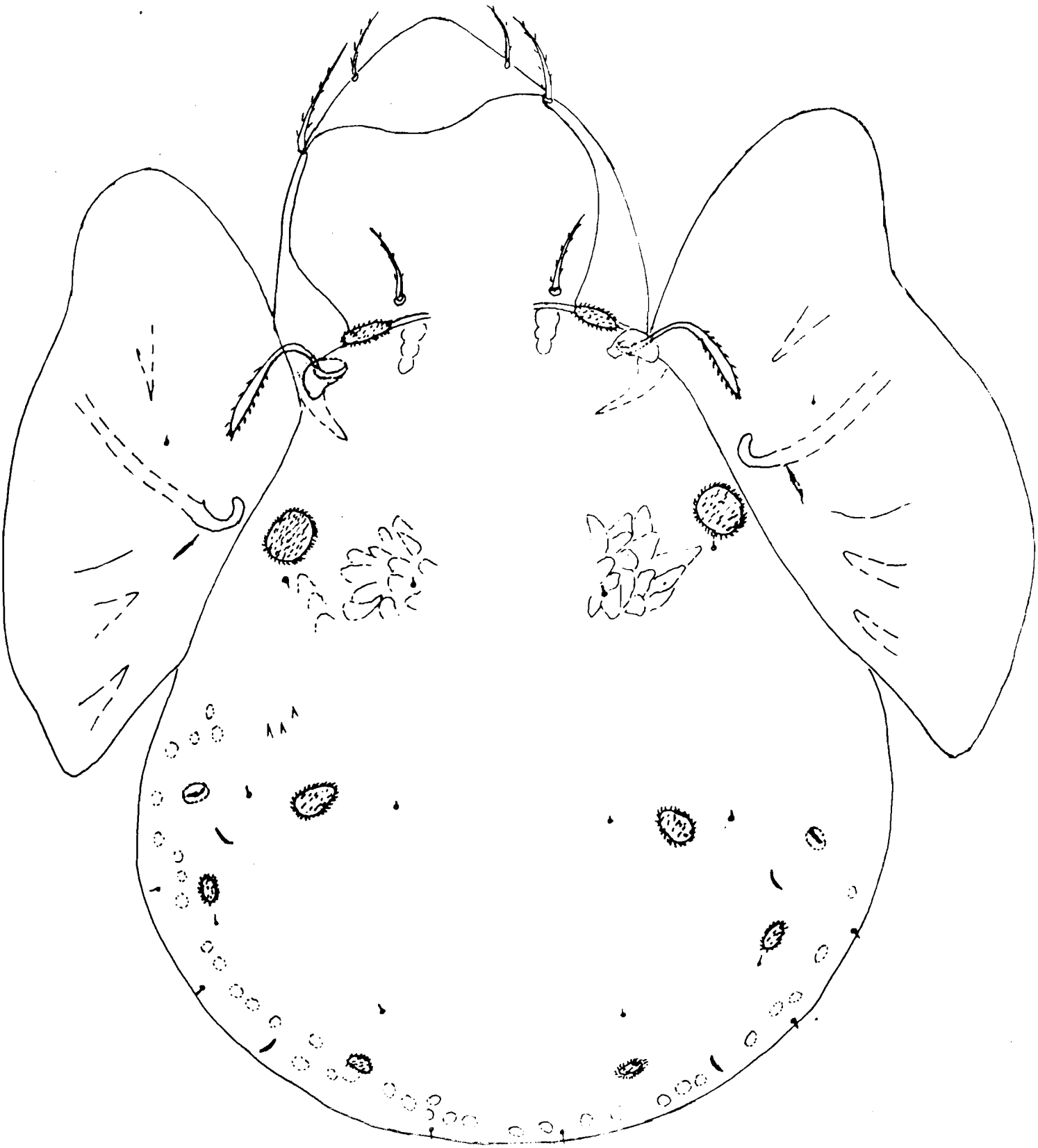
DORSAL VIEW

FIG. XXXII **Galumna flabellifera orientalis Aoki, 1965**



VENTRAL VIEW

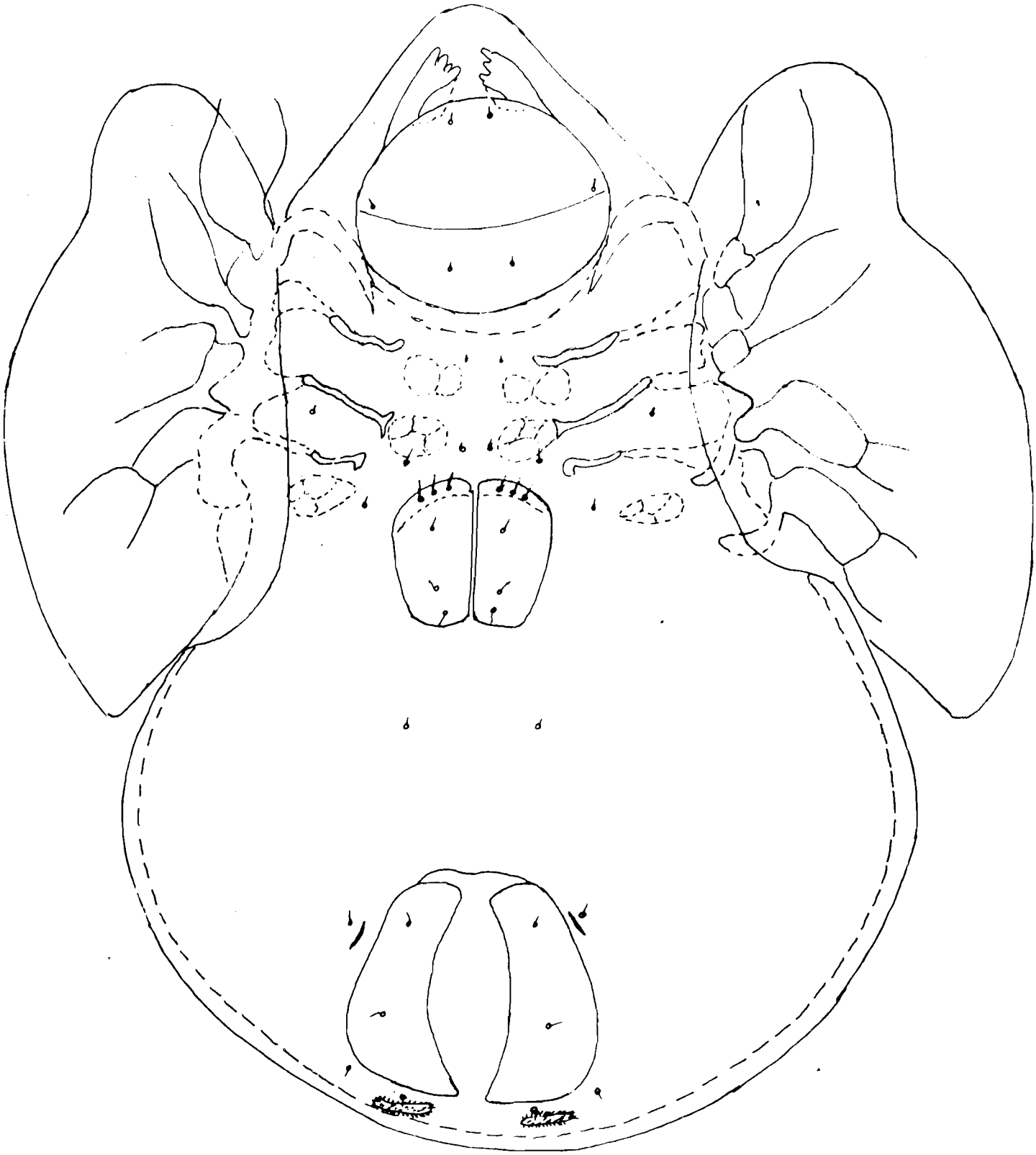
FIG. XXXIII Galumna triquetra Aoki, 1965



DORSAL VIEW

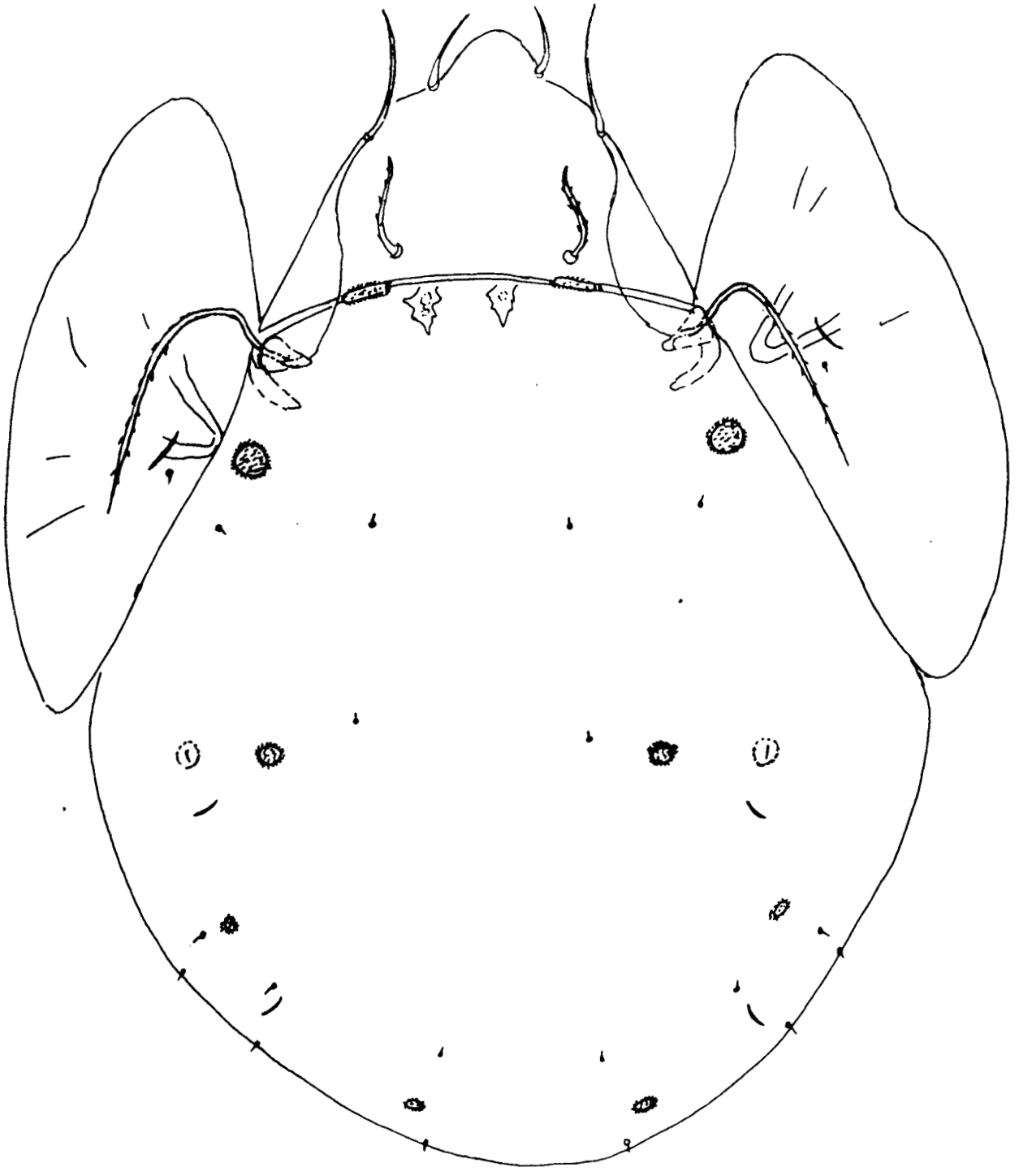
120 D6

FIG. XXXIV Galumna triquetra Aoki, 1965



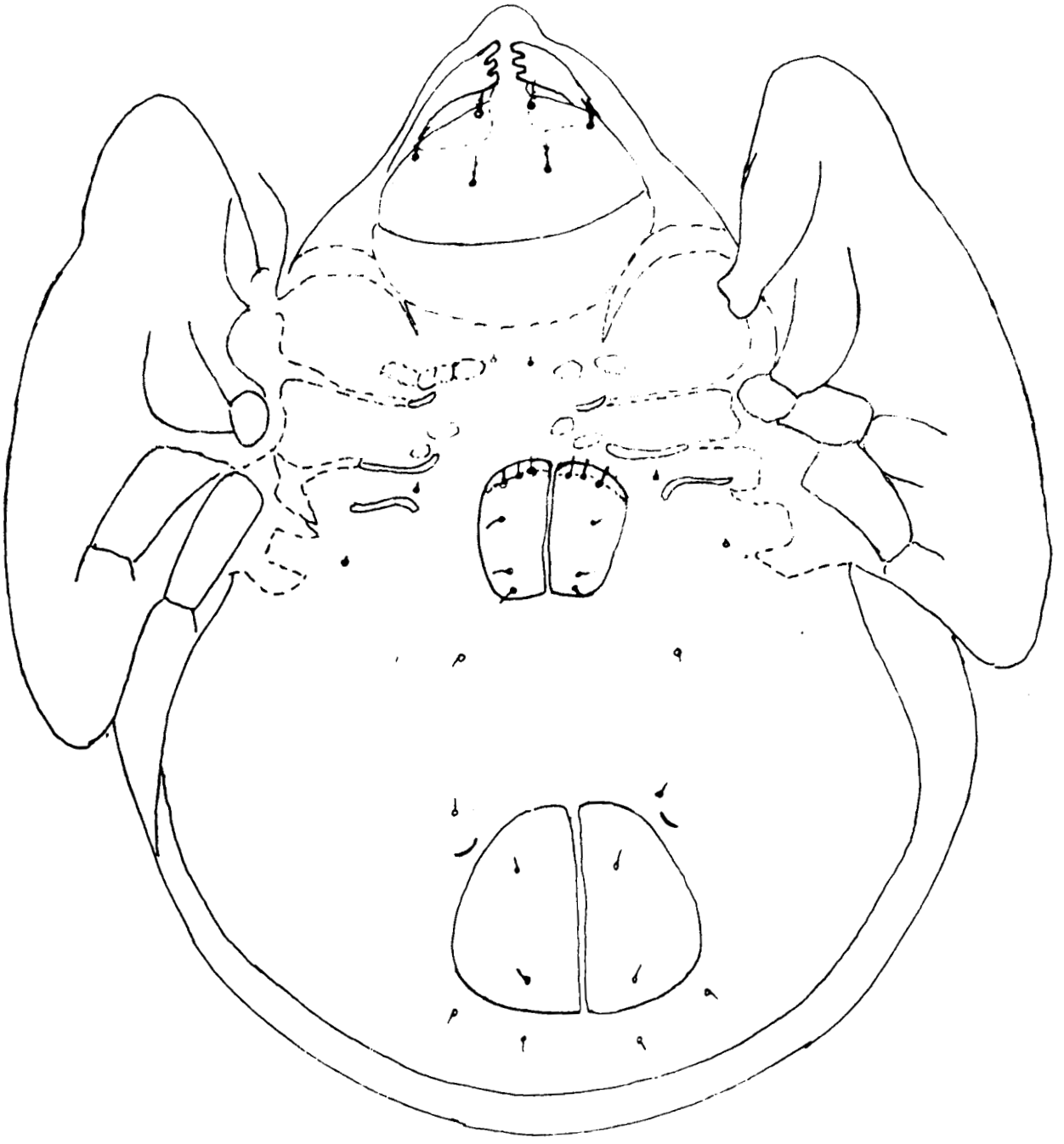
VENTRAL VIEW

FIG. XXXV Galumna longipluma (Berlese, 1904)



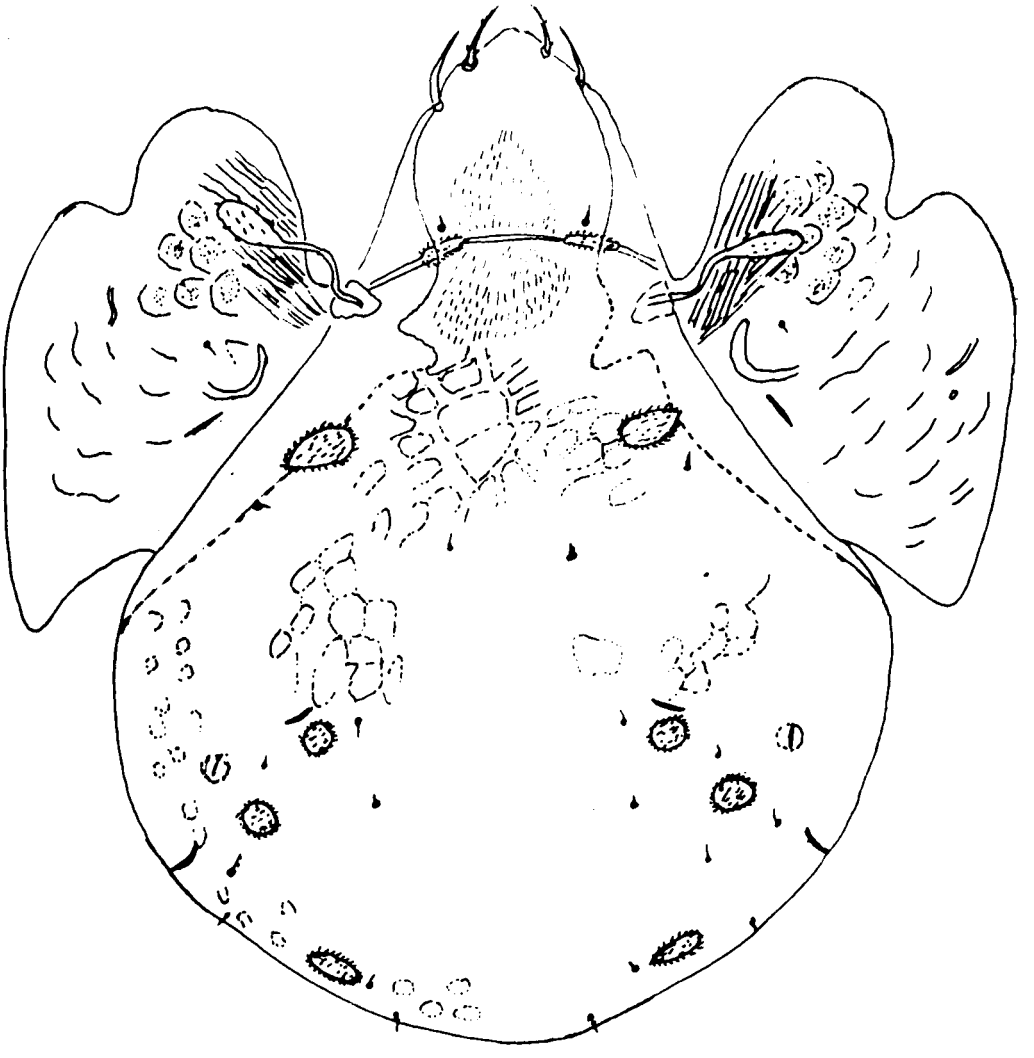
DORSAL VIEW

FIG. XXXVI Galumna longipluma (Berlese, 1904)



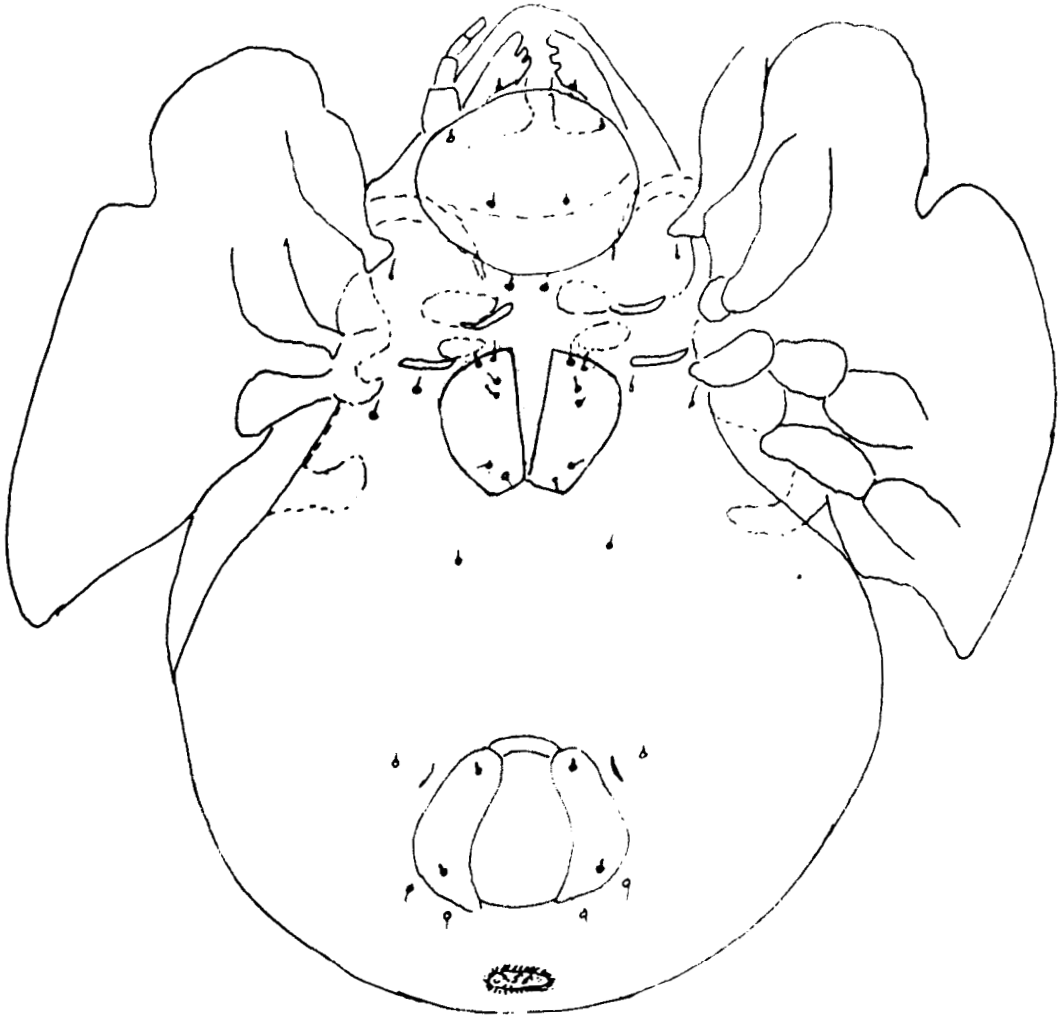
VENTRAL VIEW

FIG. XXXVII **Galumna discifera Balogh, 1958**



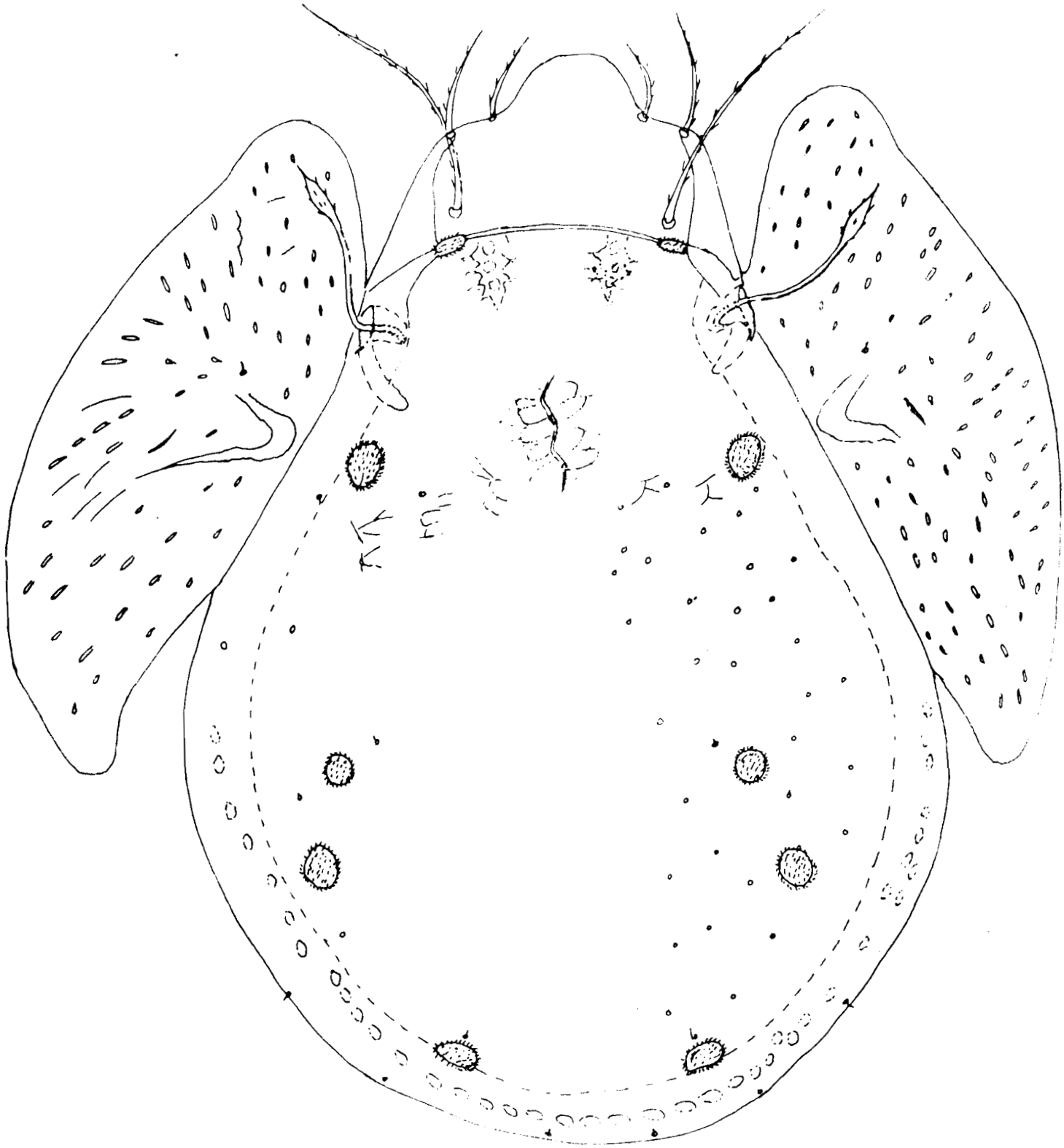
DORSAL VIEW

FIG. XXXVIII **Galumna discifera Balogh, 1958**



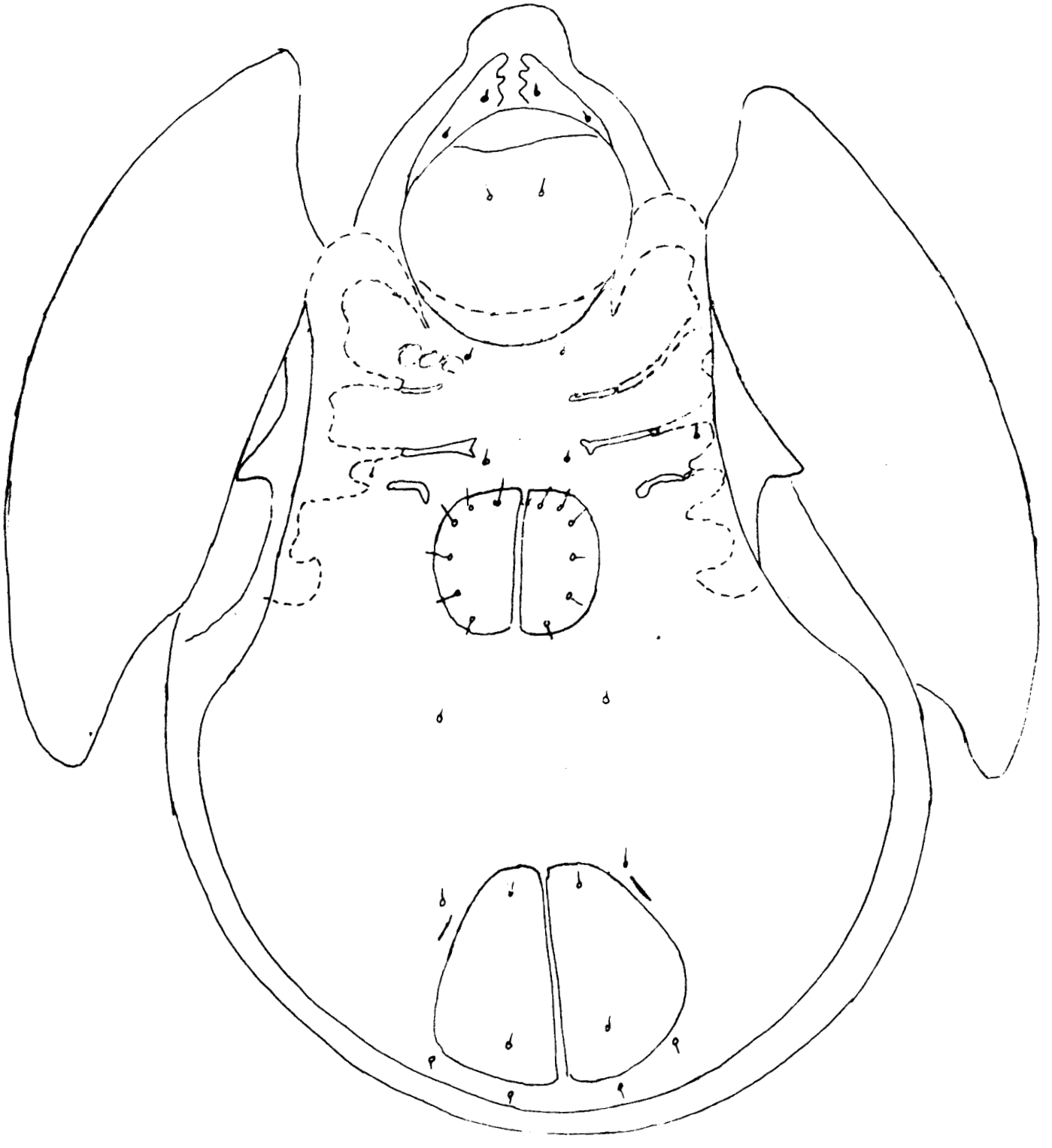
VENTRAL VIEW

FIG. XXXIX Galumna alata (Hermann, 1804)



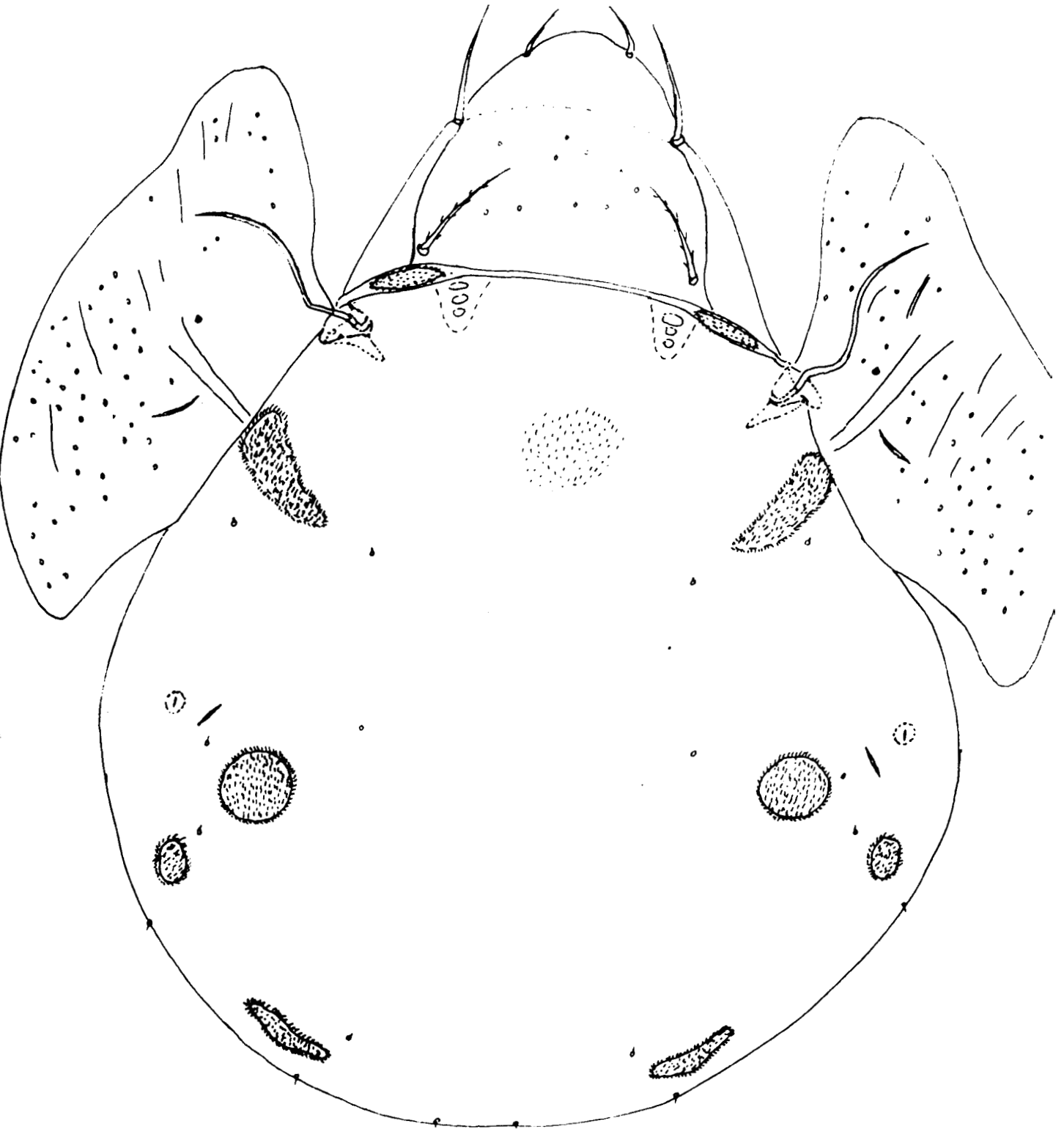
DORSAL VIEW

FIG. XXXX **Galumna alata (Hermann, 1804)**



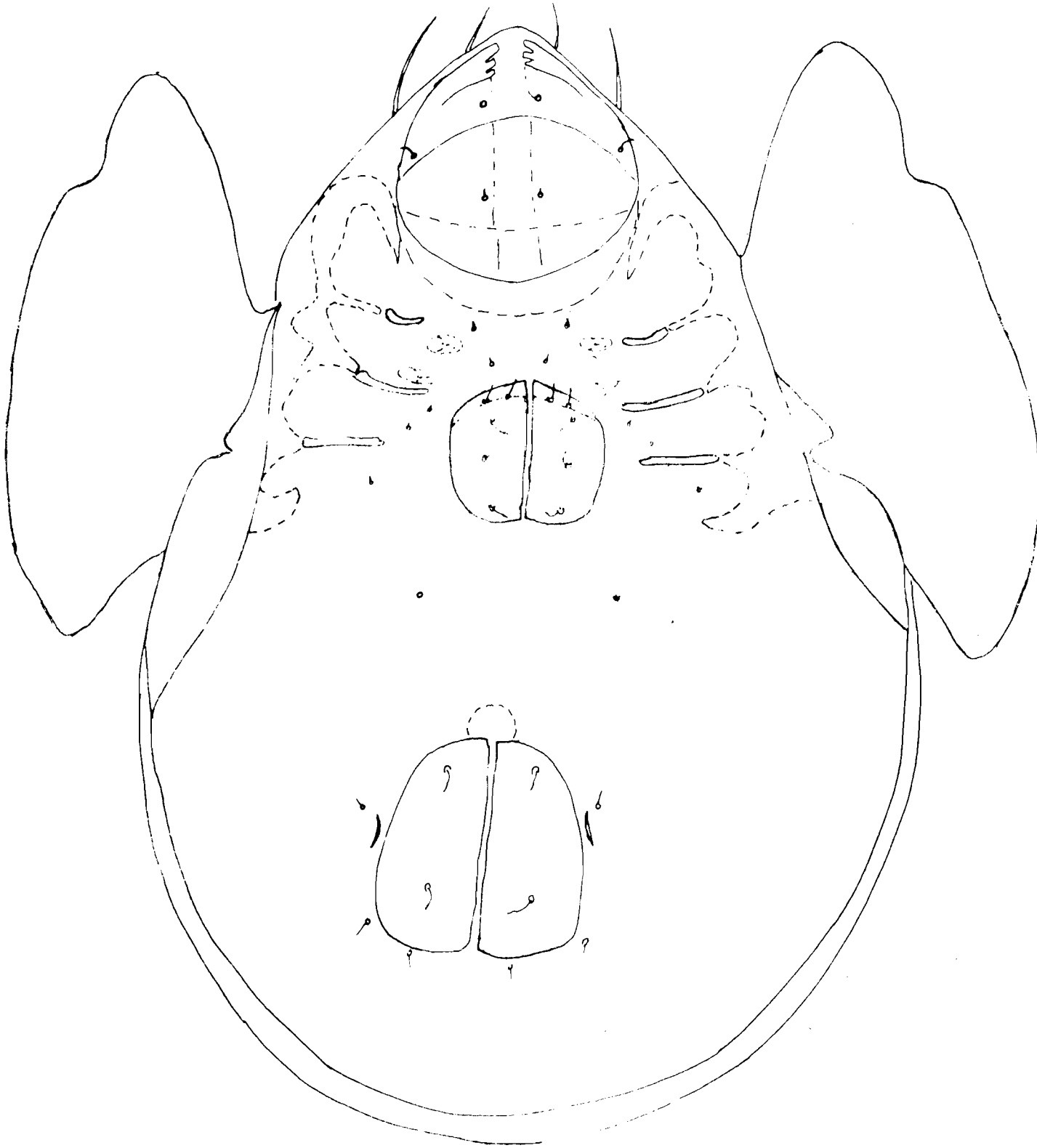
VENTRAL VIEW

FIG. XXXXI *Galumna obvia* (Berlese, 1915)



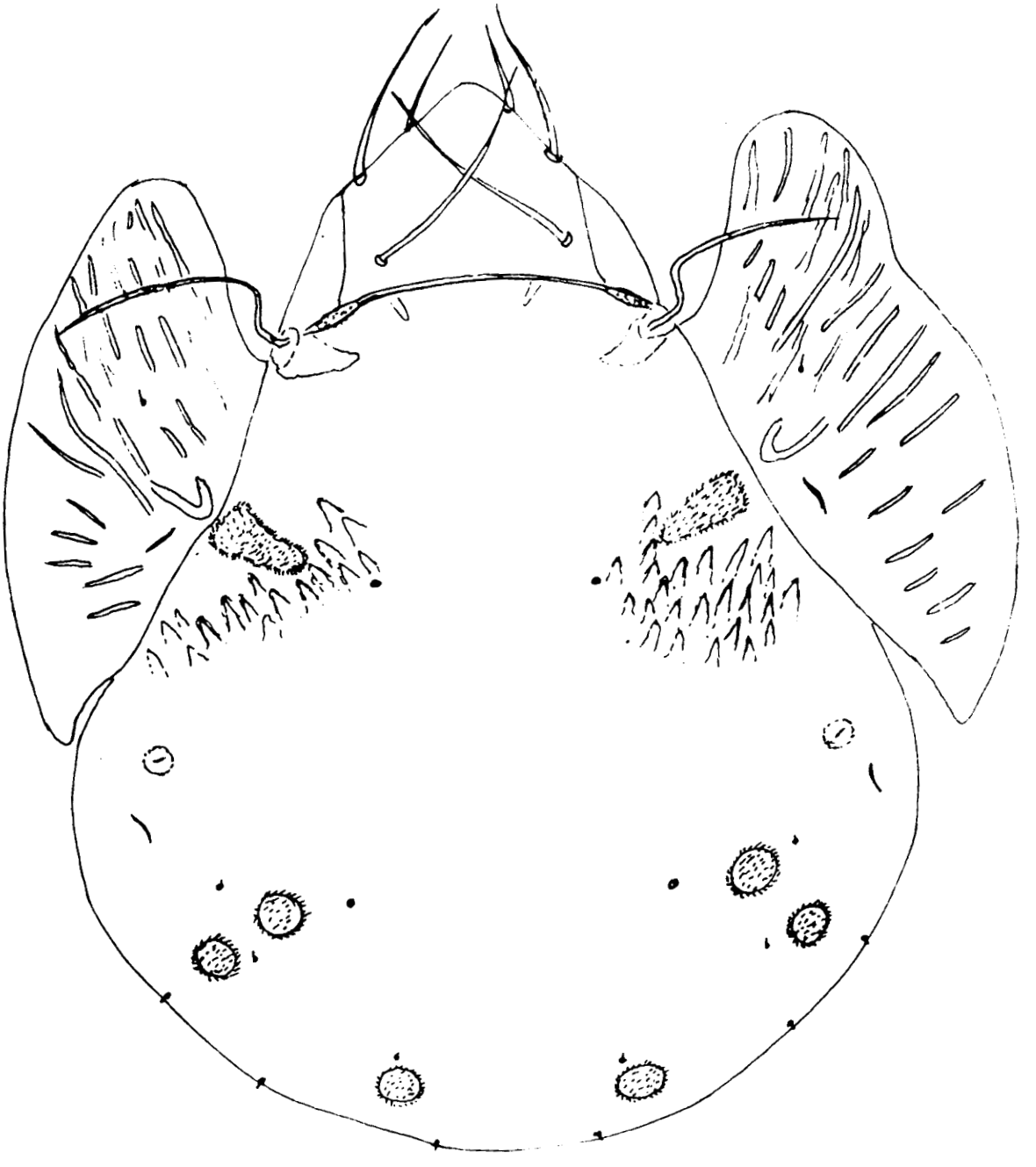
DORSAL VIEW

FIG. XXXXII Galumna obvia (Berlese, 1915)



VENTRAL VIEW

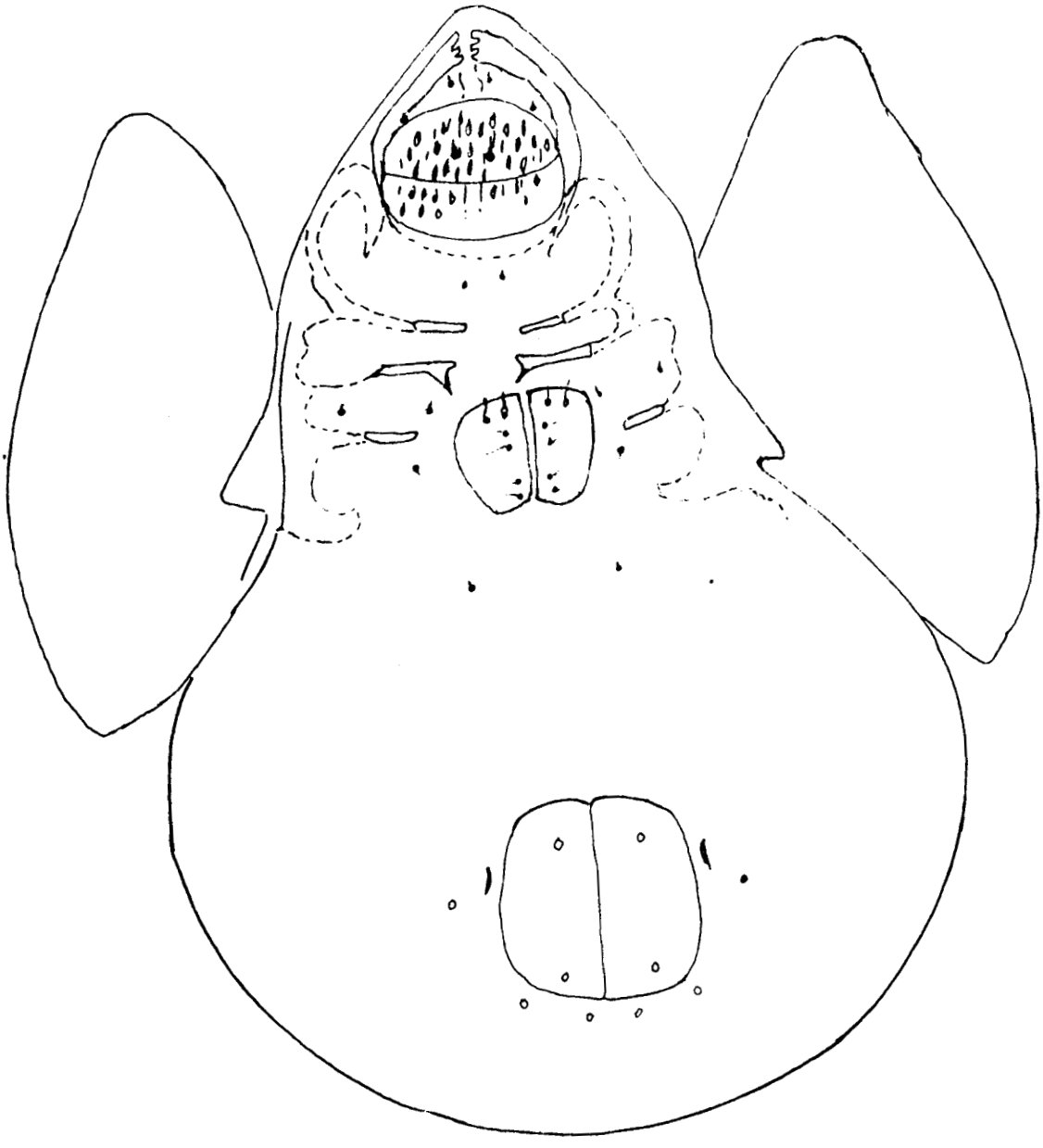
FIG. XXXXIII Pergalumna nervosa (Berlese, 1915)



DORSAL VIEW

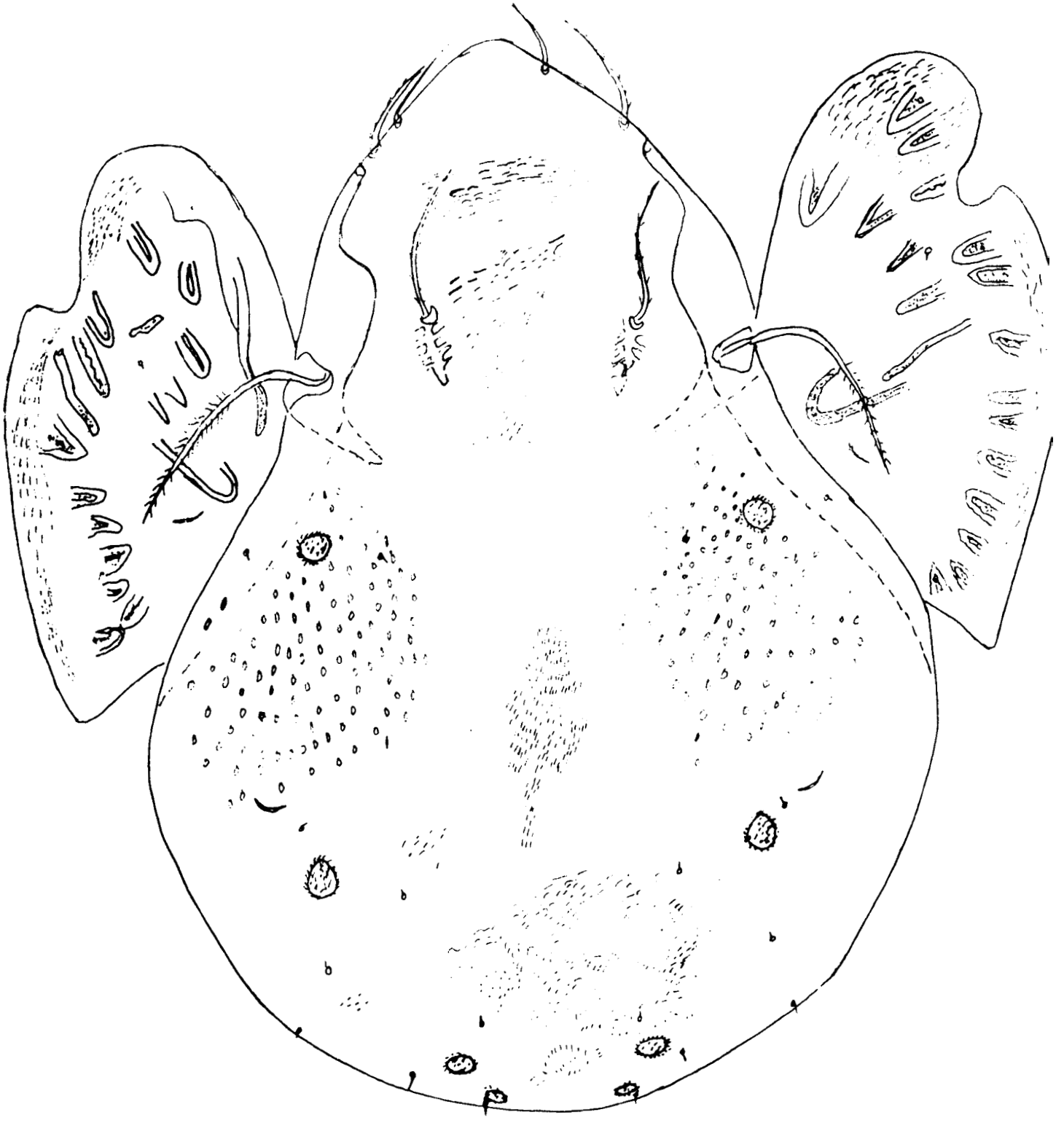
CH

FIG. XXXXIV Pergalumna nervosa (Berlese, 1915)



VENTRAL VIEW

FIG. XXXXV Pergalumna intermedia Aoki, 1963



DORSAL VIEW

FIG. XXXXVI Pergalumna intermedia Aoki, 1963

VENTRAL VIEW

OBSERVATION

R. Sobhana Amma “Studies on oribatid vectors” Thesis. Department of Zoology , University of Calicut, 1997

OBSERVATION

OBSERVATION

a) General Survey

The localities selected for the collection of oribatid mites during the present study can be broadly divided into 4 types of vegetationally contrasting ecosystems, such as open grassland (OG), shaded grassland (SG),* mixed cultivation (MC) and virgin forests (VF). Of these, the former 3 ecosystems represented true pasture lands where active grazing by ruminants occurs. The last type of ecosystem on the other hand represented areas of minimum accessibility to the grazing animals. Results of the survey from these areas provided a better picture on the incidence, distribution and prevalence of cestode infection among oribatid mites. This in turn helped much in identifying areas of critical importance with respect to cestode infection in ruminants.

Results of the survey enabled to recover 15 groups of micro-arthropods from the localities examined. They included Acari, Collembola, Protura, Diplura, Chilopoda, Deplopoda, Isopoda, Araneids, Chelonethi, Symphyla, Isoptera, Thysanoptera, Homoptera, Coleoptera and Diptera. Among these, Acari, Collembola and Isoptera represented the most common groups, as their presence

* Shaded grasslands here represent areas of forest region where species of fodder grasses were grown for grazing ruminants.

was recorded in all the 16 collection localities screened. Hymenoptera occupied the second place in terms of distribution, as members of this group were collected from 12 out of the above 16 localities. Isopods were recorded in the extracted samples from 11 different sites, while chelonethi (pseudoscorpionidae), Coloptera and Diptera were collected from 10 sites each. Symphyla and Araneids, on the other hand, showed their presence in 9 and 8 sites respectively. Minimum representation was noted in the case of Proturans, which were found restricted only in forest localities namely Silent Valley, Wynad and Attapadi.

The Acari collected from the soil samples included three suborders, namely, Prostigmata, Mesostigmata and Cryptostigmata. Interestingly members of the suborder Astigmata were totally lacking in all the samples collected. The prostigmatid mites collected during the sampling occasions included representatives of families such as Cheyletidae, Stigmaeidae, Tydeidae, Scutacaridae, Labiostomatidae and Rhaphignathidae. Of these, most of them were predatory forms preying upon eggs and young ones of insects and other arthropods. The suborder mesostigmata was represented by Macrochelidae, Rhodacaridae and Uropodidae. Among these, macrochelid members often out numbered the others, particularly in pasture lands. The prostigmatid mites on the other hand were more abundant in open grass lands, where the mineral composition of the soil was

comparatively high. The suborder Cryptostigmata exhibited more diverse representation with wide range of contrasting groups, many of which showing numerical abundance. This trend was evident in all the collection localities particularly with the virgin forest sites where appreciable quantity of litter and high organic content were found.

The cryptostigmatid mites represented the most abundant group of acari in terms of both speceis diversity and population density (Fig. 20) As the study had been oriented towards exploration of the oribatid mites in the transmission of anoplocephaline cestodes to ruminants, special emphasis has been given to the diversity and distribution of these mites. Accordingly, incidence of a total of 101 species of oribatid mites belonging to 57 genera and 35 families including one subgenus and 6 subspecies has been recorded from the 16 sites surveyed (Table 2). While considering the species composition of various families, dominance of Galumnidae (Fig. 21) and Scheloribatidae (Fig. 22) was quite evident. Of these, the former comprised 18 species under 4 genera namely, *Galumna, Pergalumna, Cryptogalumna* and *Notogalumna.* Representatives of Scheloribatidae comprised 17 species under 3 genera namely *Scheloribates, Ischeloribates* and *Perscheloribates.* The third position in terms of species composition was occupied by the family Lomanniidae which included 7 speceis under 4 genera

namely, *Annectacarus*, *Cryptacarus*, *Haplacaus* and *Javacarus*. Family Phthiracaridae was found represented by species under 2 genera and a subgenus. Family Oppiidae included 6 species distributed in 4 genera namely, *Oppia*, *Oppiella*, *Multioppia* and *Stachyoppia*. The species composition of the remaining families ranged from 1-3. Apoplophoridae, Oribotritiidae, Sphaerochthoniidae, Epilohmanniidae, Nanhermaniidae, Liodidae etc. were the families which contributed a single species each to the oribatid fauna collected during the study. While considering the oribatid population, the genus *Scheloribates* appeared to be interesting in terms of species diversity, as indicated by the recovery of 15 species in the faunal components during the study. The second genus qualitatively striking during the study was *Galumna* represented by 12 species including a subspecies. The other genera belonging to Galumnidae comprised *Pergalumna*, *Cryptogalumna* and *Notogalumna*. Of these, *Pergalumna* included 4 species while the other 2 genera represented by a single species each.

The distribution pattern and relative abundance of oribatid mites among the collection localities (Table 2) showed considerable variation with respect to site characteristics. While considering the faunal diversity of oribatid mites, virgin forest ecosystems were found to harbour higher number of species in comparison with the others. This was evident by the fact that Silent Valley and Wyanad

represented the first and second places in terms of species diversity recording the incidence of 85 and 80 species of mites respectively. The virgin forest site at Vadakottuthara, however, recorded only 50 species of mites, closely followed by mixed cultivation, which harboured 70 species of mites, as illustrated in the table. Number of oribatid species collected from the shaded grassland area ranged from 21 to 34 while of open grassland area ranged from 26 to 56. Therefore, the 4 types of ecosystems screened during the present study for the diversity of their oribatid fauna can be arranged in the following order with respect to their species diversity.

Virgin forest > Mixed cultivation > Open grassland > Shaded grassland

However, open and shaded grasslands exhibited much variation in the species diversity of oribatid fauna.

b) Natural infection of oribatid mites by *Moniezia* spp.

Microscopic examination of the cleared specimens of oribatid mites collected during the survey revealed the occurrence of developing stages of the cestode parasites belonging to the genus *Moniezia*, on several occasions. Such incidence of natural infection by *Moniezia* has been recorded in 23 out of the 101 species of mites encountered during the present study. Table 3 illustrates the general distribution and relative abundance of the oribatid species infected with *Moniezia* and incidence of their natural infection among various localities screened. As

presented in table 3, the collection localities included 8 open grassland sites, 4 shaded grassland sites, 3 localities of virgin forests and 1 mixed cultivation area. Species composition of the vector oribatid mites ranged from 5 to 17 among various sites. Maximum number of species was recorded in virgin forest sites, with the collection of 16 to 17 species of mites, except in Vadakottuthara where only 7 species could be encountered. The mixed cultivation area screened in the Calicut University Campus also harboured 17 species of mites. Open grassland sites occupied second position in terms of species diversity, showing the presence of 11 to 15 species of mites except Attapadi, where only 6 species could be encountered. The shaded grassland sites recorded comparatively lesser number of oribatid species which ranged from 5 to 10.

Incidence of cestode infection among the oribatid mites at different collection localities showed considerable variation. Mixed cultivation site at Calicut University Campus revealed infection in 9 species of mites namely, *Nesotocepheus hauseri, S. praeincisus* var. *interruptus, S. latipes, S. laevigatus, Xylobates triangularis, X. seminudus, I lanceolatus, P. laevipunctatus* and *P. intermedia*. Open grassland sites at Komeri and Mannarghat showed the incidence of cestode infection in 4 species of mites each. Developing stages of *Moniezia* sp. were recovered from individuals of *S. praeincisus* var. *interruptus, I. lanceolatus,*

H. imitator and *P. intermedia* collected from the open pasture field at Komeri. In the case of Mannarghat, *Fosseremus silensis, S. praeincisus* var. *interruptus, Z. lineata* and *G. alata* were found harbouring the parasite. West Hill, Calicut University, Thiruvazhankunnu and Mannuthy showed the occurrence of cestode infection among 3 species of mites each, while the open grasslands at Vadakottuthara and Attapadi recorded the cestode infection in 2 species of mites each. Incidence of cestode infection among the mite fauna of the shaded grassland site was similar in all the localities screened, each recording the infection in one of the species of mites. Interestingly, no infection was encountered among the oribatid mites of virgin forest area, as none of these sites revealed the cestode infected mites during the survey.

Incidence of natural infection among different species of mites varied at different sites.Thus, *S. praeincisus* var. *interruptus, S. laevigatus* and *I. lanceolatus* exhibited the infection at 4 sites each while *S. latipes, Peloribates laevipunctatus, X. seminudus, H. imitator* and *P. intermedia* were found to carry the cestode larvae at 2 localities each. The remaining 15 species showed infection at one locality each. Among the 23 species of mites which exhibited incidence of natural infection by cestodes, *S. praeincisus* var. *interruptus* and *S. laevigatus* were found carrying cestode larvae in 3 types of ecosystems screened namely, open pasture fields (open

grasslands), shaded grasslands and mixed cultivation, thereby indicating their potential status as transmitting agents of the parasite in all types of grazing areas. *S. latipes* and *P. intermedia* recorded infection in open grasslands and mixed cultivation areas, while the infection in the remaining species was found confined to a single ecosystem each.

In order to obtain a picture on the rate of natural infection prevailing among the vector oribatid species collected during the survey, percentage infection in individual species of mites was calculated from the samples collected (Table 4). As presented in the table, the rate of infection varied from 0.75% to 8.5%, under natural conditions. Minimum rate of infection was noted in *Fosseremus* sp. and maximum in *S. praeincisus* var. *interruptus*. *G. flabellifera orientalis* came next with 8.1% natural infection and *S. rectus* occupied the third position showing 7.5% infection. *P. intermedia* and *X. seminudus* represented the other 2 species which also recorded high rate of infection. Of these, the former showed 7.2% infection while the latter showed 5.4% infection. All the remaining species of mites recorded less than 5% infection among them.

Careful examination of the mites carrying the cestodes revealed different developmental stages of the parasite within them. Eggs (Fig. 23), onchosphere (Fig. 24), spherical larva (Figs. 25, 26), pyriform larva (Fig. 27), vermiform larva (Fig.

28) and cysticercoid (Fig. 29, 30, 31, 32) were the important stages of the parasite (Fig. 33) recovered from the mites during the current study. The eggs were very often found in groups, in the alimentary canal of the mites. They were found as square shaped or rhomboid bodies scattered in the gut contents of the mites. Some of them were often found partially crushed and damaged. The onchospheres and all the other stages of the parasite were found occurring in the body cavity of the mites. Onchospheres were found as more or less round bodies with transluscent matrix. They were characterized by the presence of 6 hooks. However, these hooks were not distinct, while the larva was observed *in situ*. The spherical larvae were similar to the onchospheres but larger in size. Pyriform larvae were longer than the spherical larvae and more or less pear shaped, with hooks at the tapering end. The vermiform stage of the cestode was observed only on a few occasions. At this stage the larva had a round head and a short flexible tail (Fig. 28). The last stage of development of the parasite within the oribatid mites was the cysticercoid, which was characterized by a round body and with thick double layered outer wall. Interior of the cyst was marked by a granular matrix embedded with 4 suckers. However, the suckers were distinct only in the mature cysticercoids.

The number of developmental stages of the cestode recovered from individual specimens varied considerably. In general, eggs were found in large

numbers when present. Number of eggs located in individual specimens ranged from 1 to 33 during the current study. The onchospheres and spherical larvae were comparatively rare and their number per individual specimens of mites ranged from 1 to 12. The number of pyriform larvae within individual species ranged from 2 to 15 and that of vermiform larvae ranged from 1 to 8. Cysticercoid stage was the most frequent form of the parasite encountered in the mites. The number of cysticercoids found in single individuals ranged from 1 to 6. Individuals of *Galumna* spp. and *Scheloribates* spp. often harboured more than one cysticercoids in their body cavity. During several occasions, more than one developing stages of the parasite could be located in a single specimen of the mites screened. The life stages of the cestodes recovered from each species of mites are presented in Table 4. Among the 23 species of mites, *S. praeincisus* var. *interruptus*, *S. laevigatus*, *I. lanceolatus*, *X. seminudus*, *X. triangularis*, *G. flabellifera orientalis* and *P. intermedia* were found carrying all the 5 stages of the parasite in them. The remaining species of mites recorded the occurrence of 1, 2, 3 or 4 stages of the cestodes in them.

c) Nutritional Biology

Oribatid mites constitute, perhaps the largest component of the soil mesofauna and are capable of inhabiting all types of soils. They are well known for

their diverse nutritional habits which enabled them to occupy even contrasting ecological realms. Accordingly, some of them are intimately associated with the process of organic decomposition in the soil, others thrive well as pests, parasites, vectors and intermediate hosts, a few as predators of other organisms, indicators of environmental conditions and still others as better tools in biological control programmes. Most of the above roles, on a closer scrutiny, would encounter a nutritional parameter, rather than assigned entity. Hence it would be reasonable to make an indepth search on the food and feeding modes of these mites. This would, to a greater extent, offer better backgrounds for gathering reliable estimates on their food choice. Interestingly, these food originate from multiple sources comprising even spores of various plants and eggs of cestode parasites. Assessment of the role of these mites in the transmission of tapeworms among ruminants being the ultimate aim of the present study, an overall search on the nutritional trends of these mites would supplement more to the objectives of the problem.

Knowledge on the ontogenic aspects of oribatid mites would help in evaluating their role as intermediate hosts for the cestode parasites. Therefore, attempts have been made to trace the ontogeny of a few selected members of oribatid mites acting as vectors of parasites and also the developmental pattern of the parasite within these secondary hosts.

Feeding trends of 22 species of higher oribatid mites belonging to 11 genera and 9 families were analysed in the laboratory through food choice test. Out of the 22 species of mites, 7 species were selected from Galumnidae and 6 species from Scheloribatidae. Maximum number of mites were selected from these 2 families because of their evidenced role in the transmission of parasitic tapeworms under natural conditions. Two species of mites each were selected from family Haplozetidae and Xylobatidae. The remaining 5 species of mites used in the experimental study belonged to 5 different families namely, Damaeolidae, Oribatulidae, Achipteriidae, Parakalummidae and Galumnellidae.

Food Choice Test

Results of the feeding experiment are presented in Table 5. A total of 23 items of food materials comprising bacteria, algae, fungi, lichen, moss, leaf litter, dead arthropods, nematodes and eggs of the tape worms, *M. expansa* and *M. benedini* were offered to the experimental mites under laboratory conditions. As illustrated in the table, the mites showed selective affinity towards different items of food provided. Besides this, the extent of feeding on different items of food was also found varied among the mites. The intensity of feeding activity of the mites was categorized into 4 types namely, rejection, consumption, preference and reproductive success. In the following observation, instances of both preference

and reproductive success are treated together since reproductive success involves prefereed feeding on the food material concerned.

F. silensis, the rare representative of Damaeolidae considered for the present study, though exhibited preference to *Flavobacterium* sp. I and the fungus, *Curvularia geniculata*, reproductive sucess could not be achieved in the laboratory. In addition to the above, this species rarely consumed *Bacillus subtilis*. However, total rejection of all the other food items could specifically be noted in the case of this species. Members of Scheloribatidae exhibited preferred feeding on 11 items of food including bacteria, fungi and leaf litter. However, all of them totally rejected 2 fungal species namely, *Phoma glomerata* and *Penicillium citrinum*. Interestingly, members of this group established successful reproduction on 7 out of the above 11 items of food by relishing them continuously. These food items included 2 species of bacteria, 4 species of microfungi and leaf remnants. Field collected fresh specimens of *I. lanceolatus* on introduction to the culture cells during two occasions were found congregating on a dying collembolan.

Zygoribatula lineata of the family Oribatulidae showed prefrence to leaf litter and 7 species of microfungi such as *Cladosporium oxysporum, Alternaria alternata, C. geniculata, P. glomerata, P. versicolor, Pestalotia* sp. and *B. theobromae*. Among these, successful breeding of the mite was attained on fungal

diet. In the developing stages the mites were found actively moving in and on the fungal cushions provided in culture cells. Maximum egg laying was noticed in cultures raised on *C. oxysporum* and *P. versicolor*. However, the species showed total rejection of all bacteria provided as food. Members of Haplozetidae namely, *Peloribates levipunctatus* and *Rostrozetes foveolatus* exhibited high affinity to a total of 9 food items offered, comprising fungi and litter components. But successful replenishment of colonies of these mites could not be attained in leaf litter. Meanwhile, oviposition and development of the young ones of these mites were observed on 6 species of fungi including *C. oxysporum*, *A. alternaria*, *C. geniculata*, *P. citrinum*, *P. glomerata* and *P. versicolor*. Positive consumption of lichen, moss, dead and living animals when shown by *R. foveolatus*, its relative *P. levipunctatus* showed no sign of ingestion of the above food materials. *R. foveolatus* fed normally on the litter particles whereas *P. levipunctatus* tasted this occasionally. Both the species were not seen consuming the cestode eggs.

Xylobates seminudus and *X. triangularis* were the 2 species of mites representing the family Xylobatidae, which thrived extremely well with *C. oxysporum*, *A. alternata*, *B. theobromae*, *P. glomerata* and *C. geniculata*. Both these species consumed cestode eggs on several occasions in the laboratory. Though these mites could survive well on litter items, they were rarely seen on moss

cushions. These two members deliciously fed on live nematodes provided to them. *Anachipteria globatus* of the family Achipteridae showed preference towards 2 species of microfungi and the leaf litter. The fungus *C. oxysporum* appeared to be the ideal food for this species, as the mite established successive generations on this diet. Most of the other food items except *C. geniculata* and the leaf particles were found avoided by this mite. However, both living nematodes and eggs of cestodes were found to be acceptable to this species.

Protokalumma erecta, the representative of Parakalummidae was found to perform preferential feeding on 6 items of food materials offered, including 4 species of microfungi, the moss *Funaria* sp. and leaf litter. Of these, successful reproduction of the mite was observed on the fungus *C. geniculata* only. In the case of *Galumnella angustifrons* of the family Galumnellidae, none of the food materials offered could elicit voracious feeding and reproductive success. However, the individuals subsisted on the fungus *A. alternata* and litter fragments. This species, as in the case of *P. erecta* was found avoiding the eggs of *Moniezia* spp. offered in the laboratory.

Seven species of the mites belonging to the family Galumnidae selected for the study included 5 species of *Galumna* and 2 species of *Pergalumna*. The 5 members of *Galumna* comprised 4 species and one subspecies namely, *G. lanceata*,

G. alata, G. comparabilis, G. emarginata, and *G. flabellifera orientalis.* Among the fungal species offered, *C. oxysporum* favoured reproductive success for the first 4 species for a prolonged time. Though this fungus was proved to be well acceptable to *G. emarginata,* egg laying was not achieved. Meanwhile, *G. comparabilis* and *G. emarginata* were often found exhibiting high acceptance of 3 species of fungi namely, *C. oxysporum, A. alternata* and *C. geniculata*, leading to their population build up in the culture cells. *C. comparabilis* was the only species of *Galumna* which accepted lower plants like moss and attained successful reproduction on this diet. *G. flabellifera orientalis* readily consumed both nematodes and *Moniezia* eggs as evidenced from the laboratory studies, whereas *G. emarginata* rejected both the items. *G. lanceata* and *G. comparabilis* showed similar trends in feeding on materials of animal origin by accepting nematodes and rejecting tapeworm eggs. The affinity towards these items was just contrary in the case of *G. alata.*

The 2 species of *Pergalumna, P. nervosa* and *P. intermedia* though rejected several of the food items offered, 3 fungal species namely, *C oxysporum, A. alternata* and *C. geniculata* were found voraciously consumed by these species. Apart from this, these species were found flourishing well on moss and litter components. Both the species readily accepted nematodes, and tapeworm eggs.

But in the case of cestode eggs, *P. nervosa* rejected the item while *P. intermedia* consumed the same.

Bacteria represent one of the essential inhabitants of the soil system and interact with other organisms through multiple ways. Bacteria constitute one of the dietary items for the oribatid mites. Therefore, 4 species of bacteria isolated from soil were offered as food for the mites during the current study. Interestingly, all these 4 species were found selected as preferred food by one or the other species of mites. A total of 5 species of mites belonging to families Damaeolidae and Scheloribatidae exhibited preference towards bacteria in the culture cells. In the case of *S. laevigatus* successful reproduction was also attained by feeding on *Seratia marcescens* and *Bacillus subtilis*. Apart from this, *P. erecta* and a few species of *Galumna* and *Pergalumna* were found consuming the bacteria occasionally. All the remaining mites were found to reject these food items completely.

Algae constitute another item of food selected and offered to the mites. *S. laevigatus* and *S. fimbriatus africanus* were found selective of algae as a source of food. However, successful breeding was not observed in any species of mites on this food. Fungi, particularly the species of microfungi appeard to be the most preferred food for these mites in general, as several species particularly *I.*

lanceolatus and *X. triangularis* showed profound liking to them. These fungi proved to be one of the delicious food items, helping the mites substantially in the replenishment of their colonies under laboratory as well as in the field situations (Figs 34-35). All the 22 species of mites exhibited intense feeding on one or the other species of the fungi tested. Evidently 20 species of the mites attained reproductive success on this diet. Preference of mites to these fungi varied considerably and the order of preference shown by the mites was found to be *C. oxysporum* = *C. geniculata* > *A. alternata* > *P. versicolor* > *B. theobromae* > *P. glomerata* > *Pestaloita* sp. > *P. citrinum*> *Fusarium solani*. The macrofungus *Agaricus* sp. was preferred by 2 species of mites namely, *S. fimbriatus africanus* and *S. decarinatus*. However, none of the mite species attained successful reproduction on this food.

Lichen was preferred over other items of food by *P. intermedia* alone among the 22 species of mites subjected for the test. However, the species could not attain reprodctive success on the lichen diet. The moss, *Funaria* sp. was more widely fed by the mites when compared to lichen in the laboratory. One species of mite belonging to Parakalummidae and 4 species belonging to Galumnidae established greater affinity towards this food item. Moreover, galumnoid members such as *G. comparabilis* and *P. intermedia* readily devoured the moss and produced large

number of eggs. Leaf litter, another important source of food available in the soil ecosystem was found preferred by a total of 13 species of the mites studied. They include members of Scheloribatidae, Oribatulidae, Haplozetide, Achipteriidae, Parakalummidae and Galumnidae. Of these, one species belonging to Scheloribatidae and 3 belonging to Galumnidae established successful reproduction by relishing on litter.

Consumption of live and dead animal matter has been considered as a common tendency among several soil mites (Figs. 36, 37). Though this trend could not be observed in general it was seen on several occasions during the current study. Live nematodes were consumed by a total of 12 species of mites, whereas tendency to devour dead arthropods was shown by 5 species of mites. The species of mites fed on nematodes included members of Scheloribatidae, Haplozetidae, Xylobatidae, Achipteriidae and Galumnidae. Dead arthropods on the other hand were devoured by members of Scheloribatidae, Haplozetidae and Parakalummidae. *S. praeincisus* var. *interruptus* and *R.foveolatus* were the two species of mites which consumed both the above materials as and when available.

A perusal of Table 5 would help to categorise 11 species of mites showing consumption of cestode eggs out of the 22 species of mites tested. The relative degree of consumption though showed little variation with respect to the number of

eggs consumed, they all could be included under normal feeding. These species comprised members of Scheloribatidae, Xylobatidae, Achipteriidae and Galummidae. However, none of these species showed preference towards the tapeworm eggs when offered with other food items.

Members of Scheloribatidae and Galumnidae have been established as potential agents among oribatid mites in the transmission of tapeworms. When we consider this in terms of the species of the above two families in the present study, it would become evident that they stand prominent in the consumption of tapeworm eggs. Members of Xylobatidae and Achipteriidae though consumed the cestode eggs, it would not be worthwhile to compare them, as the study included only one or two species of these mites. Among the members of Scheloribatidae, 66.6% of the species tested showed positive consumption of the cestode eggs, while in the case of Galumnidae 57.1% of the species devoured the item.

In order to analyse the rate of affinity of these mites to tapeworm eggs, specific studies were carried out with *G. flabellifera orientalis*, one of the galumnoid mites considered for the study. This mite was offered one of the fungal species namely, *C. geniculata* and tapeworm eggs simultaneously in the same culture cell, kept apart from each other. The second day onwards faecal production in sufficient numbers was noted near and over. *C. geniculata*. But they were

totally absent in the small cluster of cestode eggs. However, active adults were often found relishing and moving over the clustered eggs. When eggs of mites were found on the fungal cushion on the ninth day, they were totally absent anywhere on or around the cestode eggs. In order to confirm the preference of the mite to these food items, separate cultures were maintained with individual food item, where larval and nymphal stages could be observed in cultures provided with fungus. On the contrary, mites kept in cultures provided with cestode eggs could not sustain active oviposition. Though 2 eggs were noticed in cultures maintained with cestode eggs, further developmental stages of the mites could not be obtained.

d) Artificial Infection of Mites with *Moniezia expansa*

Laboratory studies involving artificial infection of a few oribatid representatives exhibiting the role as intermediate hosts in the transmission of monieziasis have been conducted to procure knowldge on their preference towards cestode eggs, rate of feeding, percentage of infection, influence of cestode infection on the mites and the ontogeny of the parasite within the mites. The preference of the mite towards cestode eggs, though has been traced through feeding tests, further trials on this would become necessary to confirm the vector status of the mites concerned. The intensity of feeding on a particular food item reflects, the rate of feeding which is all the more important, when we consider the chances of the

cestode eggs being ingested as a food item by oribatid mites. The question whether the cestode eggs constitute a nutritional food item for the mites or they are being accidentally or incidentally taken along with other food items needs to be thoroughly clarified. It would become mandatory to assess what quantum of the eggs being ingested by the mites escape from chewing and are carried accidentally into their digestive tract without any damage. The possibility of these eggs attaining the inefctive stage mainly depends on this fact. Information gained on this line would definitely help in calrifying whether ingestion of eggs by mites is intentional or accidental or both. Ingestion of cestode egg though a feature among several oribatid species, the prevalence of the tendency varies with species. Those species which are actively involved in this process have to be rated specifically when we think in terms of augmenting programmes for their control. The duration of the life span of the mites after infection by cestode eggs appears to be a point of crucial importance while considering the transmission of the parasite to its primary host. In this connection, knowledge on the longevity of the infected individuals would become an aspect of critical importance. Therefore tracing the ontongeny of the parasite within the mites seems to be absolutely essential for substantiating the knowledge on the life cycle, transmission and parasitic activity of

the cestodes on their primary and secondary hosts. The following account provides further information on the various aspects of the above points with supporting data.

i) Rate of Feeding of *M. expansa* and Percentage Infection in Oribatid Mites

During the food choice test in the laboratory, fresh eggs of *M. expansa* were offered to a total of 22 species of oribatid mites (Table 5) of which 10 species exhibited feeding activity of the eggs. The mites were found moving over the eggs, occasionally probing them with their mouthparts and finally ingesting them as a whole. A single individual was often found feeding on more than one egg at a time. The mode of feeding of the eggs was found to be similar in all the species of mites. However, frequency of consumption of the eggs varied considerably among them. Table 6 shows the rate of consumption of eggs by individual species of mites over a period of one week under laboratory conditions. Total number of eggs consumed by the mites ranged from 66 to 92 in 7 days and the average ranged from 3.3 to 4.5 eggs per mite *S. praeincisus* var. *interruptus* consumed maximum number of eggs while *Anachipteria* sp. consumed the lowest number. Percentage of infection of the experimental mites showed variation among different species, which ranged from 73 to 92. *Anachipteria* sp. recorded minimum infection with 73% while *I. lanceolatus* showed maximum infection of 92.

The average number of cysticercoids recovered from individual mites varied from 3.2 to 5.8 (Table 7). Maximum number of cysts were recovered from individuals of *G. alata*, while *X. triangularis* recorded the minimum. Size of the cysticercoids ranged from 130 µm to 200 µm. The size of the cyst was found reduced in individual mites harbouring more number of cysts and relatively larger cysts were recovered when their number was less.

ii) Influence of Cestode Infection on Oribatid Mites

In order to assess the influence of cestode infection on oribatid mites, longevity of the infected individuals of species of mites namely, *I. lanceolatus, X. triangularis, S. praeincisus* var. *interruptus* and *P. intermedia* were compared wih those of healthy mites of the same species. Table 10 illustrates the longevity and survival rate of the infected and healthy individuals of the above mites, under laboratory conditions. As presented in the table, notable reduction has been observed in the longevity of all the 4 species of mites infected with *M. expansa*. Longevity of uninfected individuals of *I. lanceolatus* ranged from 10-14 months under laboratory conditions while infected individuals of the same species could live only upto 8-10 months under the same conditions. Therefore, a reduction of 2-4 months has been recorded in the longevity of the species. Another interesting fact noted during the experiment was the reduction in the survival rate of the

individual of *I. lanceolatus* in the infected population, when compared to that of the healthy mites. In the populaton of healthy mites, 92% of the individuals attained the range of maximum age (i.e., survival rate), while in the infected population only 64% of the individuals survived up to the maximum range of age. Similar laboratory trials on the longevity of *X. triangularis, S. praeinscisus* var. *interruptus* and *P. intermedia* though attempted, confirmatory results could not be obtained due to mass death of the individuals in the experimental culture owing to some unknown reasons after ingesting the eggs of *M. expansa*.

iii) Ontogeny of *M. expansa* in Oribatid Mites

Sequence of development of the tapeworm egg within the body cavity of the mites was studied by periodic dissection of infected mites till the recovery of cysticercoid stage of the parasite. Five different stages in the development could be distinguished within the mites during the development of *M. expansa* (Table 8). However, duraton of the time required for attaining these stages varied among different species. During the first phase of development, the cestode egg hatched into a small, round larva with six hooks. This stage is called onchosphere. It appeared that the eggs of *M. expansa* hatched into the onchosphere stage within a few hours of their ingestion by the mites. Soon after hatching, the onchosphere entered the body cavity of the mite by penetrating the gut wall, where further

development was observed. During the second phase, the onchosphere enlarged into an irregular spherical body. The interior of the body was filled with a transluscent matrix with granular materials. This stage is known as spherical larva, (Fig. 26) the size of which ranged from 75 to 100 μm. The hooks which were present in the onchosphere larva were retained in the spherical larva, but the muscles were found atrophied. The third stage of development was accompanied by enlargement in size and its transformation to a pyriform larva. Internal organisation of the larva was similar to that of spherical larva, and was embedded with large granules. The hooks were found moved at the tapering region of the larva (Fig. 27). The size of the larva at this stage ranged from 80 to 90 μm.

The pyriform larval stage was followed by the fourth stage known as vermiform larva (Fig. 28). This stage was characterized by the development of a short tail. Head of the larva was more or less round and wide, filled with transluscent matrix embedded with granules of varying size. The head region was followed by a short tail with blunt end. The matrix at the region of the tail was more of less similar to that of the head, but the granules were of smaller size. The hooks present in the earlier stages of the larvae were almost indistinct at this stage. However, in some of them the hooks were found at the tail end of the vermiform larva. Length of the larva at this stage was found to be 100 to 115 μm. During the

last phase of development, the larva showed the degeneration of the tail region and enlargement of the head into a large spherical body. Gradually, the head region developed muscular layers and a double layered wall was formed around it. Simultaneously matrix of the larva condensed to form 2 pairs of round suckers and a scolex. This was followed by the invagination of the scolex and attainment of movement by the suckers. The outer double wall of the cyst transformed into a rigid round structure. This stage is called as cysticercoid (Fig. 29, 30, 31 and 32), which measured 130 to 200 μm in diameter. The cysticercoid is the infective form and remains without any further change until it reaches the intestine of the pimary host i.e., ruminants. Therefore the cysticercoid represented the final development stage of the parasite in the body cavity of the mite.

A comparative account on the development and transformation of *M. expansa* from the egg to the cysticercoid stage among the 10 species of oribatid mites is presented in table 8. The total duration required for the development of the first four stages of *M. expansa* ranged from 25.6 days to 41.2 days among the various species of mites studied (Table 8). Maximum duration of development was recorded in *I. lanceolatus* and minimum duration in *X. triangularis*. In general, members of scheloribatidae recorded relatively shorter developmental period of the cestode ranging from 25.6 to 31.4 days. *P. intermedia* also showed similar trend in

developmental time of *M. expansa*. However, *Galumna* spp. and *Anachipteria* sp. showed further increase in duration of development to cysticercoid by 2 to 3 days.

Apart from the variation in total duration of development of the parasite, the period required to individual developmental stages was also found highly variable among the 10 species of mites studied. Duration of onchosphere ranged from a minimum period of 5 days in *S. laevigatus* to a maximum of 11 days in *X. triangularis* (Table 8). The developmental range of spherical larva was found to be 3.1 to 10.1 days. Of these, the minimum period was noticed in *I. lanceolatus* and the maximum in *X. triangularis* (Table 8). The period of development of pyriform larva was found to be larger when compared to the earlier stages, which ranged from 5.1 to 12.1 days (Table 8). Minimum duration of 5.1 days was recorded in *I. lanceolatus*, while *Anachipteria* sp. showed maximum duration of 12.1 days. The vermiform larva consumed maximum period for transformation within the mites. This stage took a minimum period of 6.4 days in *G.alata* and a maximum period of 11.4 days in *X. seminudus* (Table 8). The vermiform larva after attaining cysticercoid stage, continued to be retained in the body cavity of the oribatid mites (secondary host), till the mites are ingested by the ruminants (primary host) along with grasses.

e) Reproductive Biology of Oribatid Mites

An analysis of the feeding habis of 22 species of oribatid mites in the earlier part of the thesis has proved beyond doubt the potential of several species of them in the transmission of cestode parasites under laboratory and field conditions. While considering their vector status in terms of pathogenic efficiency, it would become more reasonable to propound an indepth study on the duration of the life-span of the mites. This would help to provide reasonable apprehension to demographic parameters of the vector mites, which in turn will help to correlate the developmental sequence of the cestodes and their transmission to the primary host. Realizing this as a major concern here, reproductive behaviour and post-embryonic development of 3 species of oribatid mites were traced. These species included *S. praeincisus* var. *interruptus*, *P. intermedia* and *X. triangularis*, which were selected because of their common occurrence in the pasture soils of Kerala and of the incidence of tapeworm eggs/larvae in them.

i) *Scheloribates praeincisus* var. *interruptus*

During the food choice test, this species showed greater affinity to litter and fungal items and was found devouring *C. oxysporum* repeatedly in the laboratory. Hence rearing of the mite with this food item was carried out throughout its biological study.

a) Oviposition

Active feeding was followed by the deposition of spermatophores by the males and eggs by the females. Usually spermatophore deposition preceded oviposition and spermatophores were detected as erect bodies all over the culture cells. The females were found actively moving over these small erect bodies when genital plates picked them up between them. Wandering females were found carelessly ovipositing in or on the food materials, cracks and crevices in the culture cells, walls of the culture cells and even the plaster of paris substratum. Eggs were usually laid singly but clustered eggs were also noted in few instances. Eggs were small in size and smooth in appearance (Fig. 38).

b) Incubation and hatching

The eggs remained without any change for 6-7 days. On the 6th or 7th day they turned transluscent to transparent. Just before hatching, a longitudinal slit was developed along the median axis of the egg. Wriggling movements of the larva widened the slit separating the two halves from each other. At this stage, the larva moved forward slowly leaving behind the split up egg-case. The process was completed within 20 to 40 minutes. The larvae remained inactive for a few minutes and later started moving and feeding.

c) Duration of life stages

Newly emerged larvae were small, transparent, hexapod and appeared to be very much inactive. They were found nibbling on the fungal hyphae in the culture cells. Feeding activity of larvae lasted for 2-3 days. At the end of this period, they turned inactive and remained motionless, withdrawing their legs. The individuals looked turgid and swollen during this time. This period was called the I quiescent period which lasted for 1-2 days. At the end of the quiescent period the larvae moulted into the protonymphal stage.

The protonymph was larger in size and transluscent with 4 pairs of legs. Similar to the larvae they remained inactive for sometime immediately after emergence and later initiated feeding acvitity. The protonymphs were comparatively more active than larvae. Active period of the protonymphal stage lasted for 4-5 days. End of the active period was marked by II quiescent stage and moulting which were similar to those of the larval stage. The II quiescent period lasted for 1-2 days. At the end of the II quiescent period the protonymph moulted into the deutonymphal stage. Deutonymph was larger than protonymph and cream coloured. After, a few minutes of their emergence, deutonymhs started voracious feeding activity. The deutonymphs remained active for 4-5 days which was followed by III quiescent period, extending for 1-2 days.

Moulting of the quiescent deutonymph resulted in the emergence of the third nymphal instar known as the tritonymph. The tritonymphs were larger in size and pale yellow in colour. They were the most active forms among the developing stages, often found voraciously feeding on the fungal material provided. Active period of this instar extended for 6-7 days followed by the IV quiescent period. This quiescent phase lasted for 2-3 days. Moulting of the tritonymph led to the adult stage. Newly emerged adults were light yellowish in colour which later on transformed in to light brown.

d) Moulting

The process of moulting was identical in all stages of the mite. Onset of the moulting period was characterized by the formation of a pair of lateral longitudinal slits at the posterolateral region of the body, behind the hind pair of legs. These slits slowly extended backwards to meet at the posterior region. By this time the individual initiated slow backward movements. As a result of this, the slit got widened pushing the hind region of individual to the exterior. By repeated forward and backward movements of the body, the individual got detached itself from the moulting skin and slowly moved backwards leaving the cuticle in front. The process required about 3 hours for its completion.

As illustrated in Table 10, the total duration required for the completion of development of *S. praeinscisus* var *interruptus* was found ranging from 32 to 36 days under laboratory conditions. The newly emerged females initiated oviposition after 10-12 days of their final moult from the tritonymphal stage. Hence the period required for raising the F_1 generation of the mite was 40 to 50 days. Slight difference in durations may be anticipated in the field, due to altering physical environment factors prevailing there. Therefore, 5 to 6 annual generations of this mite can be expected in the field.

ii) *Xylobates triangularis*

X. triangularis was encountered in more than 80% of the collection localities surveyed during the present study. Natural and experimental infection by *Moniezia* spp. was recorded in this mite, which prompted to investigate the life cycle of the species. The mite was reared by offering *C. geniculata* for investigating the post-embryonic period.

a) Oviposition

In laboratory cultures, adults mites were found making irregular tunnels within the fungal cushion offered, during their feeding activity. The females laid eggs within these tunnels. The eggs were oval in shape and cream in colour with shining appearance. Large number of spermatophores were observed all over the

fungal matter and also at the base of the culture chamber. They were found as small glittering bodies with short stalk, standing erect on the substratum.

b) Incubation and hatching

The eggs remained without any change for 2 days. After 2-3.5 days, they turned transparent with the development of a longitudinal slit. The slit later got enlarged by the wriggling movements of the emerging larva. As the slit widened, the larva moved forward slowly leaving behind the egg case on its posterior side. The process was completed in 2-3 hours. Newly hatched larva was slugglish, transparent and remained motionless for 1-2 minutes. Later on it started to move within the tunnels in the fungal mass and initiated feeding activity.

c) Duration of life stages

Similar to the members of Scheloribatidae, development of *X. triangularis* involved a total of 4 active and 4 quiescent phases (Table 11), the end of which was marked by moulting. The larva remained active for 1 to 2 days and entered the first quiescent period at the end of the active period. During the quiescent period the individual remained stationary keeping all the legs folded beneath the body. Surface of the larval body exhibited a shining and turgid appearance. The first quiescent period lasted for 1 to 2 days. This phase was followed by moulting to the protonymphal stage.

The protonymphs were larger than the larvae, cream coloured and active. They were found moving all over the fungal mass and actively feeding for 1.5 to 2.5 days. At the end of this active period, they entered the II quiescent period which required 1 to 2 days for its completion. The II moult resulted in the emergence of deutonymphs. They were yellowish white in colour, larger than the protonymphs and more active. They continued feeding activity for 1.5 to 2.5 days and entered the III quiscent phase. This inactive period lasted for 1 to 2 days followed by moulting to the tritonymphal stage. The tritonymphs were long yellow and transluscent in appearance. They remained active for 2 to 3.5 days and entered the final quiescence. This IV quiescent period lasted for 2 to 3 days leading to the final moult into the adult stage. Thus the total duration required by the mite to complete its development from egg to adult stage was found to be 17.5 to 22.5 days under laboratory conditions (Table 11).

Moulting

The moulting sequence of the developing stages of *X.triangularis* was found to be similar to those of *S. praeinscisus* var *interruptus*. The process required 2 to 3 hours for its completion.

iii) *Pergalumna intermedia*

This is a common species of oribatid mite often encountered in pasture lands. The species showed positive consumption of tapeworm eggs during the laboratory feeding as well as in the natural condition. Among the fungal species offered in the laboratory *A. alternata* was found to be the most preferred food for *P. intermedia* supporting high reproduction rate. The above points favoured selection of this species for life history studies.

Oviposition

Adult mites of *P. intermedia* were more active than *S. praeinscisus* var. *interruptus*. After 6-7 days of intense feeding, spermatophores were found deposited in the culture cells; They were often found on the fungal matter and occasionally on the sides of the culture chamber. Within 2-3 days of spermatophore deposition, eggs were laid by the females with the help of ovipositor (Fig 39). Usually they were found deposited into the fungal cushions offered as food. Frequently eggs were found laid in batches (Fig. 40) of irregular number and nature. 15-30 eggs were found in a group generally but the number got reduced to 3 or 4 on the 3rd day of oviposition. The eggs were elliptical, creamy white and smooth in appearance with evenly distributed yolk (Fig. 41).

b) Incubation and hatching

The colour of the eggs remained unchanged for about 2 days. On the third day, they turned transluscent and gradually became transparent on the 4th day. This was followed by the development of a longitudinal slit along the median line of the egg. The slit appeared at the anterior end in the beginning and gradually continued backwards. The splitting of the egg case was accompanied by the wriggling movements of the larva. As a result of this the slit got further extended, facilitating the emergence of the larva. The larva moved forward slowly, leaving the egg case behind. The process required about one hour for its completion.

c) Duration of life stages

As illustrated in the Table 12 development of *P. intermedia* involved a larval and 3 nymphal instars interrupted by 4 successive quiescent periods. The newly hatched larva was sluggish for a few minutes and then started active movements. It was transparent, hexapod and smaller in size. The larvae fed on the fungal matter and often remained hidden underneath the food material. Feeding activity of the larvae continued for 2 to 3 days culminating in I quiescent period. This phase lasted for 1 to 1.5 days and followed by the first moult. The protonymph was eight-legged, cream coloured and larger than the larva. These nymphs actively fed upon the fungal matter for 3 to 4 days and entered the II quiescent period. The

quiescent phase lasted for 1.5 to 2 days giving rise to the succeeding instar namely the deutonymph. The deutonymph was similar to protonymph but larger in size. Active period of this instar ranged from 3 to 4 days. At the end of this period the deutonymphs entered the III quiescent phase followed by moulting into the tritonymphal stage. The quiescent phase of deutonymph lasted for 1.5 to 2 days. The tritonymph was light yellow in colour and very active. The tritonymphs exhibited voracious feeding activity for 3 to 4 days resulting in the final moult to the adult stage.

d) Moulting

The process of moulting in *P.intermedia* was similar to that of *S. praeinscisus* var. *interruptus* and *X. triangularis* and completed in about 2-3 hours. The total duration of the period required for the completion of development from egg to adult stage was found to be ranging from 25-28 days (Table 12). The newly emerged adults were somewhat golden yellow in colour and very active. They initiated oviposition after 7 to 8 days of attaining adulthood. Thus the period required by this species to complete F1 generation was found to be 32 to 36 days. Therefore, about 8 annual generations of the mite can be expected under field conditions.

Table 2. Distribution and diversity of oribatid mites in various collection sites

Sl. No.	Species of Oribatid Mites	COLLECTION LOCALITIES															
		KOM-I	KOM-II	WHILL	CUC-I	CUC-II	WYD	SVY	VTR-I	VTR-II	MNG	TVK-I	TVK-II	ATPD-I	ATPD-II	MNTY-I	MNTY-II
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
		OG	SG	OG	OG	MC	VF	VF	OG	VF	OG	OG	SG	OG	SG	OG	SG
1.	*Apoplophora pantotrema*	-	-	++	-	+++	++	++	-	+	-	-	-	-	-	-	-
2.	*Atropacarus (Hoplophorella) scapellata*	-	+	-	-	++	++	++	-	+	-	-	+	-	+	-	+
3.	*A. (H.) raychaudurii*	-	+	-	-	+	-	+	-	-	-	-	-	-	-	-	+
4.	*A. (H.) singularis*	+	-	+	-	-	-	++	+	-	+	+	-	+	-	+	++
5.	*Hoplophthiracarus rimosus*	-	+	+	-	-	+	++	-	+	-	-	++	-	-	-	-
6.	*Indotritia sellnicki*	-	-	-	-	-	+	+	-	-	-	-	-	-	-	-	-
7.	*Sphaerochthonius splendidus*	-	++	-	-	-	++	+++	+++	-	++	-	-	-	-	-	-
8.	*Annectacarus mucronatus*	-	-	-	-	++	+++	+++	-	++	-	-	-	-	-	-	-
9.	*A. wallworki*	-	-	-	-	-	++	-	-	+	-	-	-	-	-	-	-
10.	*Cryptacarus grandjeani*	-	-	-	-	++	+++	+++	-	++	-	-	-	-	-	-	+
11.	*C. polysetosus*	-	-	+	-	+	++	++	-	-	-	-	-	-	-	-	-
12.	*Haplacarus foliatus*	-	-	-	-	++	++	++	-	++	-	-	-	-	-	-	-
13.	*H. keralensis*	–	–	+	–	–	++	+	–	+	–	–	–	–	–	–	+
14.	*Javacarus kuhnelti foliatus*	–	–	–	–	–	+++	++	–	+	–	–	–	–	–	–	+
15.	*Epilohmannia pallida*	–	+	–	+	++	++	++	–	+	+	+	+	–	–	–	++
16.	*Allonothrus russeolus*	+	+	+	++	+++	+	+	–	+	–	–	–	–	–	–	–
17.	*A. giganticus*	+		+	+	+		+	+	+	+	+				+	
18.	*Archegozetes longisetosus*	–	++	–	+	+++	++	++	–	+	–	–	+	–	–	–	+
19.	*Bicyrthermannia duodentata*	–	–	–	–	–	+	+	–	+	–	–	–	–	–	–	–
20.	*Liodes terrestris*	–	–	–	–	+	+	+	–	+	–	–	–	–	+	–	+

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
21.	*Berlesezetes auxiliaris*	–	+	–	+	+++	+++	++	++	–	–	–	+	–	+	–	++
22.	*Eremulus wallworki*	–	–	–	++	+	++	+	–	+	–	–	–	–	–	–	–
23.	*E. flagellifer*	–	–	–	+++	+	+	++	–	+	–	–	–	–	+	–	–
24.*	*Fosseremus silensis* sp. nov.	–	–	–	–	–	–	+	–	–	+	–	–	–	–	–	+
25.	*Eremobelba nagaroorica*	–	–	–	–	–	++	+++	–	+	–	–	–	–	–	–	–
26.	*Basilobelba retiarius symmetrica*	+	+	+	+	++	+	+	+	+	+	+	+	+	+	+	+
27.	*B. africana*	+	–	+	+	–	+	–	–	+	+	–	–	–	+	–	+
28.	*Xiphobelba ismalia*	–	–	–	–	+	–	–	–	–	–	–	–	–	–	–	+
29.	*Zetorchestes schusteri*	+	+	–	–	+	+	++	–	+	–	–	–	–	–	–	++
30.	*Liacarus nigriscens*	–	–	+	–	+	+	+	–	+	–	–	–	–	–	–	–
31.	*Dolicheremaeus indicus*	–	+	–	–	+	+	++	–	+	–	–	–	–	–	–	+
32.	*D. papuensis*	–	+	–	+	–	+	+	–	+	–	–	–	–	–	–	–
33.	*Fissicepheus coronarius*	–	+	–	–	+	+	++	–	+	–	–	–	–	–	–	+
34.*	*Nesotocepheus hauseri*	–	–	–	–	+	+	++	–	–	–	–	–	–	–	–	+
35.	*Multioppia indica*	+	+	++	+	++	++	++	+	++	+	+	+	+	–	+	+
36.	*M. laniseta*	–	–	+	++	++	–	++	–	+++	++	+	–	–	+	++	++
37.	*Oppia kuhnelti*	–	+	–	+	++	+++	++	–	+	–	–	–	–	++	–	–
38.	*O. yodai*	–	–	–	+	++	+	+	–	–	+	–	–	–	+	–	–
39.	*Oppiella suramericana*	–	–	–	+	++	+	+	–	–	–	–	–	–	–	–	++
40.	*Stachyoppia muscicola*	+	–	+	+	–	–	–	+	–	+	–	–	–	–	+	–
41.	*Suctobelba* sp.	–	–	–	–	+	+	++	–	+	–	–	–	–	+	–	+
42.	*S. semiplumosa indica*	–	–	–	+	+	+	+	–	+	–	+	–	–	–	+	–
43.	*Eremella induta*	–	+	–	+	–	–	+	–	–	+	–	–	–	–	–	–
44.	*Keralotrichus plumosus*	–	–	–	–	–	–	+	–	–	+	–	–	+	+	–	–
45.	*Chaunoproctus deleoni*	+	–	–	+	++	++	++	–	+	–	–	–	–	+	–	–

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
46.*	*Scheloribates praeincisus* var. *interruptus*	++	++	++	++	+++	+++	+++	++	+++	+++	++	+++	++	+	++	+++
47.	*S. praeincisus* var. *rotundiclava*	+	+	–	+	+++	++	++	–	–	+	–	+	–	–	–	+
48.	*S. rugosus*	+	–	+++	++	+	+	+	–	+	+	–	+	–	+	–	–
49.*	*S. rectus*	–	–	++	+	+	+	++	+	–	+	+	–	+	–	++	–
50.	*S. thermophilus*	++	+	++	+	–	++	++	+	++	++	+	+	+	–	+	++
51.*	*S. latipes*	+	+	–	++	+++	++	++	++	+++	++	–	++	–	–	++	+
52.*	*S. laevigatus*	–	+	++	+	+++	++	+	+++	++	++	+	+	+	+	+++	+
53.	*S. minuta*	+	–	–	+	+	++	+	+	+	–	–	–	+	–	+	–
54.	*S. decarinatus*	+	+	+	+	+++	+++	++	–	+	+	+	+	–	–	+	+
55.	*S. elegantulus*	+	+	+	–	+	++	+	+	+	+	–	–	–	–	+	–
56.	*S. perforatus*	+	–	–	+	++	–	–	–	+	+	–	–	–	–	+	–
57.	*S. fimbriatus*	++	–	+	++	–	–	+	+	–	+	++	–	–	–	+	–
58.	*S. fimbriatus* var. *javensis*	–	–	++	+	+	+	++	–	++	+	–	–	+	–	–	–
59.	*S. yezoensis*	+	–	+	+	–	–	+	+	–	+	–	–	+	–	–	–
60.	*S. cuyi*	–	–	+	+	–	+	+	–	–	++	–	–	–	–	+	+
61.	*Ischeloribates lanceolatus*	++	–	+++	++	++	++	++	++	–	+	+	–	++	+	++	–
62.	*Perscheloribates lumotus*	–	–	+	–	+	+	–	–	–	–	–	–	–	+	–	–
63.	*Zygoribatula longiporosa*	+	–	++	+	+++	+	–	++	–	++	–	–	+	++	–	–
64.*	*Z. lineata*	–	–	+	–	+++	++	++	–	–	+++	–	–	–	–	++	–
65.	*Z. schauenbergi*	+	–	–	–	–	–	–	+	–	–	–	+	–	–	+	–
66.*	*Peloribates levipunctatus*	++	–	+	–	++	–	–	+	–	++	–	–	–	–	++	–
67.	*Phalacrozetes sinatus*	–	–	–	–	+	+	++	–	–	+	–	–	–	–	–	–
68.*	*Pilobates pilosellus*	–	–	–	–	–	–	+	–	–	–	–	–	+	–	–	–
69.	*Rostrozetes foveolatus*	++	+	+	++	+++	+++	++	+	–	++	–	–	+	+	++	–

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
94.*	*G. triquetra*	+	–	++	–	+	–	–	–	–	–	–	–	–	–	+	+
95.	*Pergalumna nervosa*	–	–	–	–	++	+	–	–	–	–	–	–	–	+	–	++
96.*	*P. intermedia*	++	++	+	++	+++	++	+++	–	+++	++	++	–	–	–	++	–
97.	*P. bimaculata*	+	–	–	+	–	++	+++	–	–	–	–	–	–	–	+	++
98.	*P. curva*	–	–	–	–	+	++	+	–	+	–	–	–	–	–	–	–
99.	*P. capillaris*	++	+	–	+	–	+	+	+	–	–	–	+	–	+	+	–
100.	*Cryptogalumna grandjeani*	++	–	–	–	–	–	–	–	+	–	–	–	–	+	+	+
101.	*Notogalumna nortoni*	+	+	–	++	+++.	+++	+++	–	+	++	–	+	–	–	+	–
	Total No. of species	43	34	46	56	70	80	85	29	50	46	26	21	27	27	35	37

+ - 1 to 10 individuals/500 sq. cm soil; ++ - 1 to 20 individuals/500 sq. cm soil; +++ - > 20 individuals/500 sq.cm. soil

Table 3. **Distribution, relative abundance and incidence of natural infection of oribatid vectors in various collection sites**

Sl. No.	Species of mites	COLLECTION LOCALITIES																No. of Inf. Sites
		Open Grassland (OG)								Shaded grass Land (SG)				Virgin Forest (VF)			Mixed cultivation	
		KOM-I	WHILL	CUC-I	VTR-I	MNG	TVK-I	ATPD-I	MNTY-I	KOM-II	TVK-II	ATPD-II	MNTY-II	WYD	SVY	VTR-II	CUC-II	
1	*Fosseremus silensis*	-	-	-	-	+*	-	-	-	-	-	-	+	-	+	-	-	1
2	*Nesotocepheus hauseri*	-	-	-	-	-	-	-	-	-	-	-	+	+	++	-	+*	1
3	*Scheloribates praeincisus* var. *interruptus*	++*	++	++	++	+++*	++	++	++	++	+++*	+	+++	+++	+++	+++	+++*	4
4	*S. rectus*	-	++	+	+	+	+	+	++*	-	-	-	-	+	++	-	+	1
5	*S. latipes*	+	-	++	++*	++	-	-	++	+	++	-	+	++	++	+++	+++*	2
6	*S. laevigatus*	-	++	+	+++*	++	+	+	+++*	+*	+	+	+	++	+	++	+++*	4
7	*Ischeloribates lanceolatus*	++*	+++	++	++	+	+*	++*	++	-	-	+	-	++	++	-	++*	4
8	*Zygoribatula lineata*	-	+	-	-	+++*	-	-	++	-	-	-	-	++	++	-	+++	1
9	*Peloribates levipunctatus*	++	+	-	+	++	-	-	++*	-	-	-	-	-	-	-	++*	2
10	*Pilobates pilosellus*	-	-	-	-	-	-	+*	-	-	-	-	-	-	+	-	-	1
11	*Xylobates seminudus*	++	+	++*	+	+	-	+	-	++	-	++	+	+++	+++	-	+++*	2
12	*X. triangularis*	-	+	+	-	-	+	-	+	-	-	-	-	+	+	-	++*	1
13	*Hypozetes imitator*	++*	+++	++	+	++	+*	-	-	-	-	+	-	+	+	-	-	2
14	*Anachipteria globatus*	-	-	-	-	-	+*	-	+	-	-	-	+	-	+	-	+	1
15	*Protokalumma erecta*	+	-	-	-	++	-	-	-	-	-	++*	-	-	++	-	-	1
16	*Galumna longipluma*	+	+++*	+	-	-	+	-	-	-	-	-	-	++	+	+	++	1

17	*G.flabellifera orientalis*	-	+++	++*	+	+	++	-	++	++	++	+	+++	+++	+++	-	+++	1
18	*G. obvia*	+	++	+*	+	-	-	-	-	-	-	-	-	-	+	++	-	1
19	*G. discifera*	-	++*	+	-	+	-	-	-	-	+	++	-	-	-	-	+	1
20	*G. alata*	+	+++	+	+	+*	+	-	-	+	-	-	-	++	-	++	-	1
21	*G. triquetra*	+	++*	-	-	-	-	-	+	-	-	-	+	-	-	-	+	1
22	*Pergalumna nervosa*	-	-	-	-	-	-	-	-	-	-	+	++*	+	-	-	++	1
23.	*P. intermedia*	++*	+	++	-	++	++	-	++	++	-	-	-	++	+++	+++	+++*	2

* - incidence of *Moniezia* infection recorded.

Table 4. **Percentage infection and life stages of cestodes recovered from oribatid mites**

	Species of oribatid mites	Total no. of specimens examined from all sites	No. of infected specimens	% Infection	Cestode life stages recovered
1	*Fosseremus silensis* sp. nov.	270	2	0.75	Early cysticercoid
2	*Nesotocepheus hauseri*	248	2	0.8	Spherical larva
3	*Scheloribates praeincisus* var. *interruptus*	1012	87	8.5	All stages
4	*S. rectus*	542	41	7.5	Eggs, onchosphere
5	*S. latipes*	414	5	1.2	Spherical larva
6	*S. laevigatus*	525	15	2.8	All stages
7	*Ischeloribates lanceolatus*	348	15	4.3	All stages
8	*Zygoribatula lineata*	210	6	2.8	Early cysticercoid
9	*Peloribates levipunctatus*	512	12	2.3	Eggs, spherical and pyriform larvae
10	*Pilobates pilosellus*	618	6	0.9	Eggs, onchosphere, spherical larva
11	*Xylobates seminudus*	221	12	5.4	All stages
12	*X. triangularis*	618	10	1.6	All stages
13	*Hypozites imitator*	328	9	2.7	Cysticercoid
14	*Anachipteria globatus* sp. nov.	319	6	1.8	Early cysticercoid
15	*Protokalumma erecta*	168	2	1.1	Vermiform larva
16	*Galumna longipluma*	466	18	3.8	Onchosphere, spherical, pyriform and vermiform larvae

17	*G. flabellifera orientalis*	296	24	8.1	All stages
18	*G. obvias*	248	7	2.8	Various stages
19	*G. discifera*	207	2	0.9	Spherical and pyriform larvae
20	*G. alata*	192	6	3.1	Eggs, onchosphere, spherical larva
21	*G. triquetra*	197	5	2.5	Mature cysticercoid
22	*Pergalumna nervosa*	186	6	3.2	Mature cysticercoid
23	*Pergalumna intermedia*	316	23	7.2	All stages

Table 5. **Feeding habits and food preference of oribatid mites in the laboratory**

	Species of mites	BACTERIA				ALGAE		MICROFUNGI										MACRO-FUNGI	LICHEN	MOSS				
		Serratia marcescens	*Bacillus subtilis*	*Flavobacterium* sp. I	*Flavobacterium* sp. II	*Protococcus* sp.	*Spheroplea* sp.	*Cladosporium oxysporum*	*Alternaria alternata*	*Curvularia geniculata*	*Trichoderma viride*	*Fusarium solani*	*Penicillium citrinum*	*Phoma glomerata*	*Pestalotiopsis versicolor*	*Pestalotia* sp.	*Botryodiplodia theobromae*	*Agaricus* sp.	Lichen	*Funaria* sp.	Leaf litter	Dead arthropods	Nematodes	Eggs of *Moniezia* spp.
1	*Fosseremus silensis* (Damaeolidae)	R	C	P	R	R	R	R	P	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
2	*Scheloribates laevigatus** (Scheloribatidae)	RS	RS	C	C	P	C	RS	P	RS	R	R	R	R	C	R	C	C	R	R	P	R	R	C
3	*S. praencisus interruptus**	C	C	P	C	R	C	RS	RS	RS	R	R	R	R	P	R	C	C	C	C	C	C	C	C
4	*S. rectus**	C	C	C	P	R	R	RS	RS	RS	R	R	R	R	P	R	C	C	C	C	C	R	C	C
5	*S. fimbriatus africanus*	P	P	P	C	P	P	RS	RS	P	R	R	R	R	R	C	C	P	R	R	C	R	C	R
6	*S. decarinatus*	R	R	R	R	R	R	RS	RS	RS	R	R	R	R	P	C	RS	P	R	C	RS	C	R	R
7	*Ischeloribates lanceolatus**	R	R	R	C	R	C	RS	RS	RS	C	C	R	R	P	R	C	C	R	R	P	C	R	C
8	*Zygoribatula lineata* (Oribatulidae)	R	R	R	R	C	R	RS	RS	RS	R	R	R	RS	RS	RS	RS	R	R	C	P	R	R	R
9	*Peloribates levipunctatus* (Haplozetidae)	R	R	R	R	R	C	P	P	P	R	R	RS	RS	RS	C	C	C	R	R	C	R	R	R
10	*Rostrozetes foveolatis* (Haplozetidae)	R	R	R	R	R	R	RS	RS	RS	P	R	R	C	C	P	C	C	C	C	P	C	C	R

11	*Xylobates seminudus** (Xylobatidae)	R	R	R	R	R	R	RS	RS	RS	C	C	R	P	C	C	RS	C	C	C	P	R	C	C
12	*X. triangularis** (Xylobatidae)	R	R	R	R	R	R	P	RS	RS	R	C	R	RS	C	C	RS	C	C	C	P	R	C	C
13	*Anachipteria globatus** (Achipteriidae)	R	R	R	R	R	R	RS	P	C	R	R	R	R	R	R	R	R	R	C	P	R	C	C
14	*Protokalumma erecta* (Parakalumnidae)	R	C	C	C	C	R	P	P	RS	R	R	R	C	P	R	R	R	C	P	P	C	R	R
15	*Galumnella angustifrons* (Galunellidae)	R	R	R	R	R	R	R	C	R	R	R	R	R	R	R	R	R	R	R	C	R	R	R
16	*Galumna flabellifera orientalis** (Galumnidae)	R	R	R	R	R	C	RS	C	RS	RS	R	R	R	R	R	RS	R	R	C	P	R	C	C
17	*G. lanceata*	R	R	R	R	R	R	RS	P	RS	C	R	C	R	P	C	R	C	C	C	C	R	C	R
18	*G. alata**	R	R	C	C	C	C	RS	P	P	R	R	R	R	RS	R	C	C	C	P	RS	R	R	C
19	*G. comparabilis*	R	R	R	R	R	R	RS	RS	RS	R	R	R	R	R	R	R	R	C	RS	R	R	C	R
20	*G. emarginata*	R	C	C	C	C	R	P	RS	RS	C	C	R	R	C	R	C	C	R	P	C	R	R	R
21	*Pergalumna nervosa**	R	C	R	R	C	C	RS	RS	RS	C	R	R	R	C	R	C	R	C	P	RS	R	C	C
22	*P. intermedia**	R	C	R	R	C	C	RS	RS	RS	R	R	R	R	R	R	C	R	P	RS	RS	R	C	C

R - Rejection; C - Consumtpion; P - Preference; RS - Reproductive success.
* Consumption of cestode eggs

Table 6. **Rate of consumption of *Moniezia expansa* eggs and percentage infection in oribatid mites**

Sl. No.	Species of mites	No. of eggs consumed / day							Total	Average	% Infection
		1	2	3	4	5	6	7			
1	*Scheloribates laevigatus*	13	15	12	14	11	13	12	90	4.5	90
2	*S. praeincisus* var. *interruptus*	14	12	16	8	15	13	14	92	4.6	82
3	*S. rectus*	4	11	13	15	17	5	13	78	3.9	84
4	*Ischeloribates lanceolatus*	12	8	16	13	15	14	11	89	4.45	92
5	*Xylobates seminudus*	13	5	7	9	16	14	12	76	3.8	78
6	*X. triangularis*	11	9	8	14	13	12	15	82	4.1	86
7	*Anachipteria globatus*	2	12	8	14	12	10	8	66	3.3	73
8	*Galumna flabellifera orientalis*	15	7	16	9	10	8	16	81	4.05	90
9	*G. alata*	16	15	8	9	14	7	15	84	4.2	88
10	*Pergalumna intermedia*	14	8	9	11	15	13	8	88	4.4	89

Table 7. **Number and size of cysticercoids recovered from Oribatid mites**

Sl. No.	Species of mites	Average number of cysticercoids recovered/mite	Size of cysticercoid (diameter in μm)
1	*S. laevigatus*	3.8	198
2	*S. praeincisus* var. *interruptus*	5.2	131
3	*S. rectus*	4.6	142
4	*I. lanceolatus*	4.8	139
5	*X. seminudus*	5.4	132
6	*X. triangularis*	3.2	200
7	*A. globatus*	4.3	145
8	*G. flabellifera orientalis*	4.7	138
9	*G. alata*	5.8	130
10	*P. intermedia*	4.9	143

Table 8. **Sequence and duration of development of *Moniezia expansa* in oribatid vectors**

Sl. No.	Developmental stage	Size	Morphological characters of the larva	Duration of development in days									
				Scheloribates laevigatus	*Scheloribates praeincisus* var. *interruptus*	*Scheloribates rectus*	*Ischeloribates lanceolatus*	*Xylobates seminudus*	*Xylobates triangularis*	*Anachipteria globatus*	*Galumna flabellifera orientalis*	*Galumna alata*	*Pergalumna intermedia*
1	Onchosphere	20-25µm	Small, round, movable larva with 6 hooks	5.0	5.2	5.1	6.4	8.4	11.0	5.0	7.3	9.4	6.0
2	Spherical larva	75-100µm	Spherical and transluscent larva with granular structures; hooks retained but muscles atrophied	5.2	4.9	5.6	3.1	6.2	10.1	7.8	5.5	8.5	5.5
3	Pyriform larva	80-90µm	Pyriform shape with granular structures, movement of hooks to the posterior region of the larva	10.1	9.5	10.1	5.1	7.6	10.5	12.1	12.0	9.5	8.5
4	Vermiform larva	100-115µm	Round and wide head, short tail with blunt end; indistinct hooks may or may not be present at the tail end	10.2	10.2	10.6	11.0	11.4	9.6	7.2	8.0	6.4	11.0
5	Cysticercoid	130-200µm	Degeneration of the tail; formation of double layered wall; development of suckers, formation and invagination of scolex	Upto infection to the primary host									
			Total	30.5	29.8	31.4	25.6	33.6	41.2	32.1	32.8	33.8	31.0

Table 9. **Longevity and survival rate of oribatid mites infected with *Moniezia expansa***

Sl. No.	Species of mites	Control				Infected			
		No. of individuals	Longevity	No. of individuals attained maximum age	Survival rate	No. of individuals	Longevity	No. of individuals attained maximum age	Survival rate
1	*Ischeloribates lanceolatus*	25	10-14 months	23	92%	25	8-10 months	16	64%
2	*Scheloribates praeincisus* var. *interruptus*	25	9-13 months	24	96%	25	--	--	--
3	*Xylobates triangularis*	25	8-12 months	22	88%	25	--	--	--
4	*Pergalumna intermedia*	25	9-15 months	23	92%	25	--	--	--

Table 10. **Duration of development of *Scheloribates praeincisus* var. *interruptus* at 30 ± 1°C (in days)**

Sl. No.	Egg	Larva	IQ	PN	IIQ	DN	IIIQ	TN	IVQ	Total
1	6	3	2	4	2	5	1	7	2	32
2	7	3	1	5	1	4	2	7	2	32
3	7	2	1	5	1	5	2	6	3	32
4	7	3	2	5	2	5	2	7	3	36
5	7	3	2	4	2	5	1	6	3	33
6	6	3	1	5	1	4	2	7	3	32
7	7	3	2	4	2	4	2	6	3	33
8	6	3	2	5	2	4	2	7	2	33
9	7	3	1	5	2	5	1	7	3	34
10	6	3	2	4	2	4	2	7	2	32
11	7	3	2	5	2	4	2	7	3	35
12	7	3	2	5	2	5	2	7	3	36
Range	6 - 7	2 - 3	1 - 2	4 - 5	1 - 2	4 - 5	1 - 2	6 - 7	2 - 3	32 - 36

PN - Protonymph; DN - Deutonymph; TN - Tritonymph; Q - Quiescence

Table 11. **Duration of development of *Xylobates triangularis* at 30 ± 1°C (in days)**

Sl. No.	Egg	Larva	IQ	PN	IIQ	DN	IIIQ	TN	IVQ	Total
1	2.5	1.5	1.5	2.0	1.5	2.5	1.5	3.0	2.0	18.0
2	3.0	2.0	2.0	2.5	1.0	2.5	2.0	3.5	2.5	21.0
3	3.0	1.5	1.0	2.0	1.5	2.0	1.5	3.0	2.0	17.5
4	3.5	2.0	2.0	2.5	1.5	2.5	2.0	3.5	3.0	22.5
5	2.5	1.0	2.0	2.5	2.0	2.5	1.5	3.0	2.5	19.5
6	3.0	1.5	2.0	1.5	2.0	2.0	1.5	3.0	2.0	18.5
7	2.5	2.0	1.5	2.0	1.5	2.5	2.0	3.5	2.5	20.0
8	3.5	2.0	1.0	1.5	1.5	2.0	1.5	3.0	2.0	18.0
9	3.0	1.5	1.5	2.5	1.0	2.5	2.0	3.5	2.5	20.0
10	2.5	2.0	2.0	2.0	2.0	2.5	2.0	3.5	3.0	21.5
11	3.0	1.5	2.0	1.5	2.0	1.5	3.0	2.0	2.0	18.5
12	3.0	2.0	2.0	2.5	1.5	2.5	2.0	3.5	3.0	22.0
Range	2.5 - 3.5	1 - 2	1 - 2	1.5 - 2.5	1 - 2	1.5 - 2.5	1 - 2	2 - 3.5	2 - 3	17.5 - 22.5

PN - Protonymph; DN - Deutonymph; TN - Tritonymph; Q - Quiescence

Table 12. **Duration of development of *Pergalumna intermedia* at 30 ± 1°C (in days)**

Sl. No.	Egg	Larva	IQ	PN	IIQ	DN	IIIQ	TN	IVQ	Total
1	5	2	1.5	4	1.5	3	2	4	2	25
2	4	3	1	4	2	4	1.5	3	2.5	25
3	5	3	1.5	4	2	4	2	4	2.5	28
4	5	2	1.5	4	1.5	3	2	4	2	25
5	5	3	1	3	1.5	4	2	4	2.5	26
6	4	2	1.5	4	2	4	2	3	2.5	25
7	5	3	1	4	1.5	4	2	4	2.5	27
8	4	3	1.5	3	1.5	4	1.5	4	2.5	25
9	5	2	1.5	4	1.5	4	2	4	2	26
10	4	3	1	4	2	3	1.5	4	2.5	25
11	5	3	1.5	4	2	4	2	4	2.5	28
12	4	3	1.5	3	2	3	2	4	2.5	25
Range	4 - 5	2 - 3	1 - 1.5	3 - 4	1.5 - 2	3 - 4	1.5 - 2	3 - 4	2 - 2.5	25 - 28

PN - Protonymph; DN - Deutonymph; TN - Tritonymph; Q - Quiescence

PLATE IV

Fig. 25. *S. rectus* showing spherical larva of the cestode parasites.

Fig. 26. *Pergalumna intermedia* showing spherical larva.

Fig. 27. Pyriform larva detected from *Galumna longipluma*.

Fig. 28. Vermiform larva located from *Protokalumna erecta*.

Fig. 29. Cysticercoid from *S. praeincisus* var. *interruptus*.

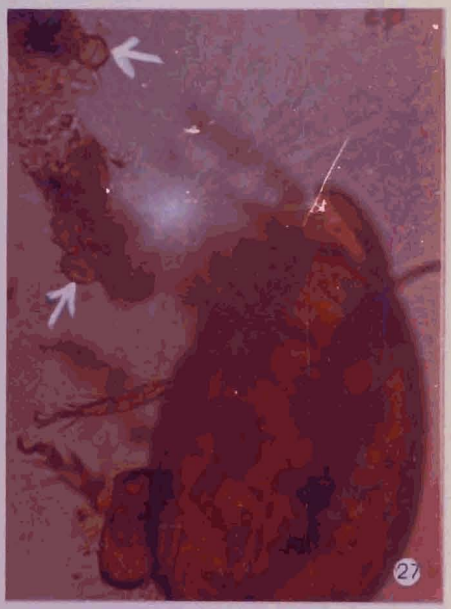
Fig. 30. *Ischeloribates lanceolatus* showing two cystercercoids.

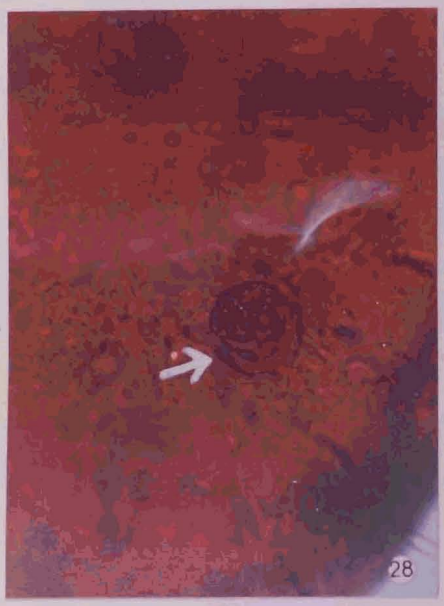
Fig. 31. *Pilobates pilosellus* showing cysticercoid.

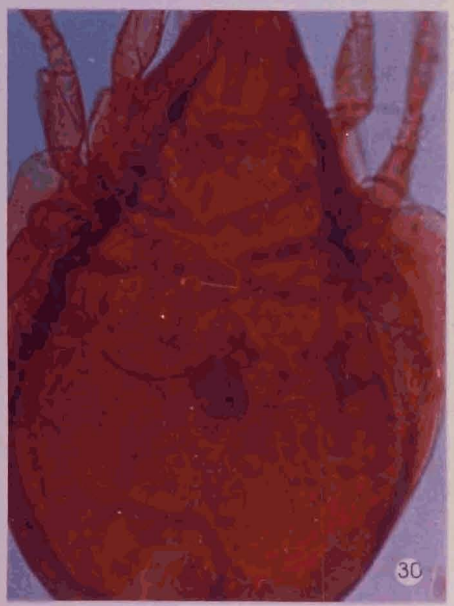
Fig. 32. Mature cysticercoid from *Xylobates seminudus* showing slightly evaginated head.

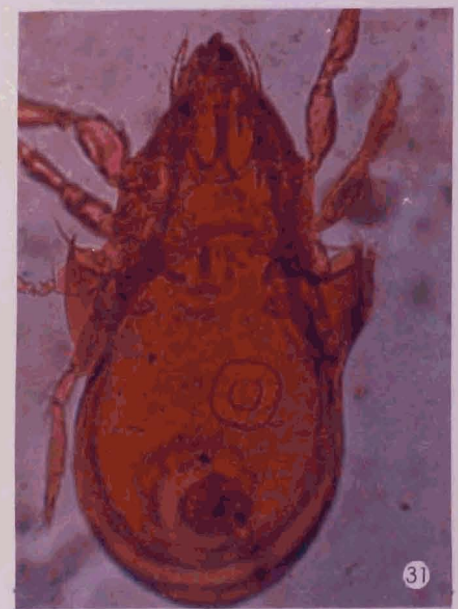
Fig. 33. Newly emerged adult of *Moniezia* sp. recovered from the intestine of sheep.

PLATE IV









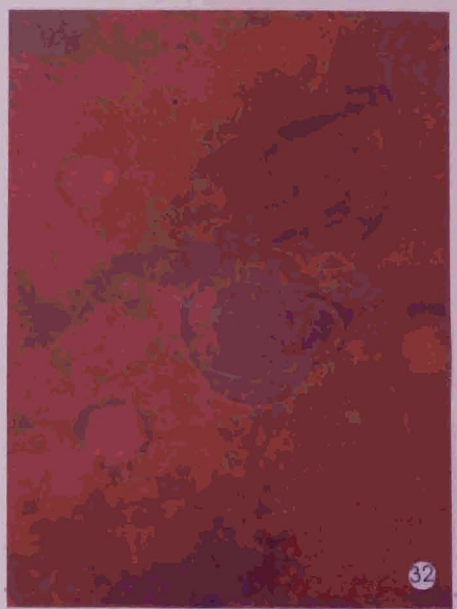


PLATE V

Fig. 34. *Ischeloribates lanceolatus* actively feeding on the fungus, *Curvularia geniculata* in laboratory culture.

Fig. 35. Scattered food bolus showing fungal matter in the gut of *Xylobates triangularis*, collected from the field.

Fig. 36. Dead collembolan along with galumnoid mites prepared from laboratory cultures.

Fig. 37. *Galumna flabellifera orientalis* showing remnants of nematode after feeding in the laboratory.

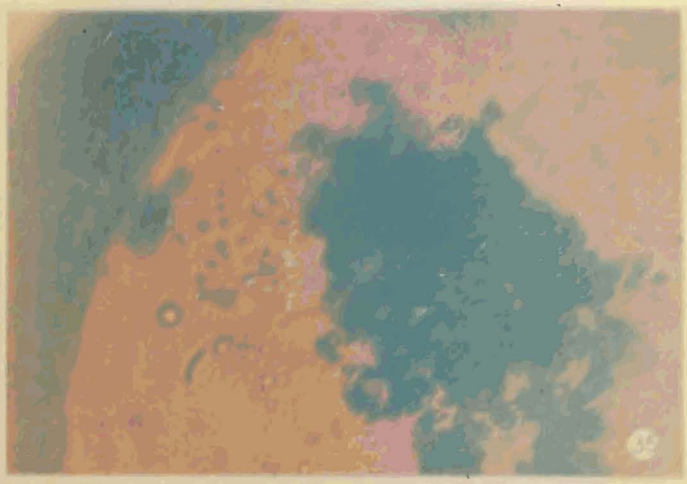
Fig.38. Gravid female of *Scheloribates praeincisus* var. *interruptus* showing eggs in the body.

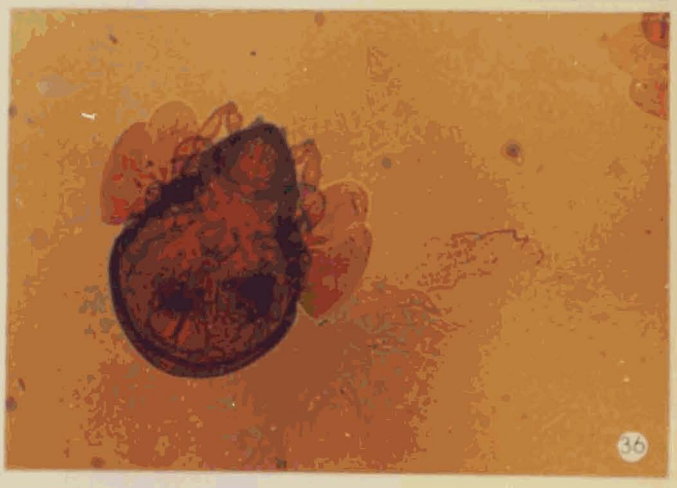
Fig.39. A view of *Pergalumna intermedia* showing the protruded ovipositor.

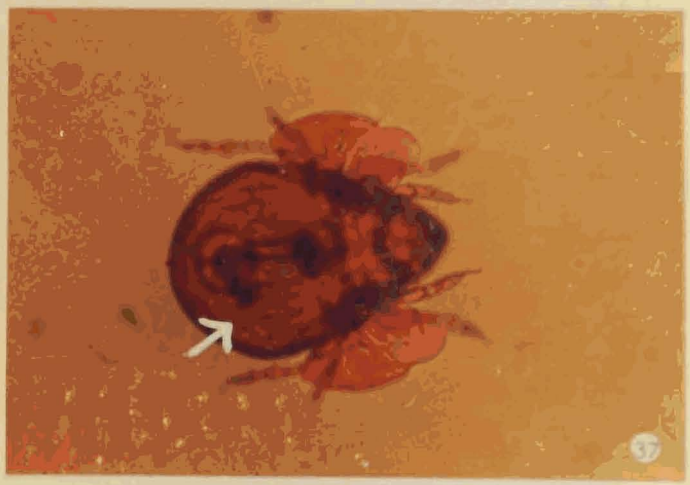
Fig. 40. Egg of *P. intermedia* under higher magnification showing evenly distributed yolk.

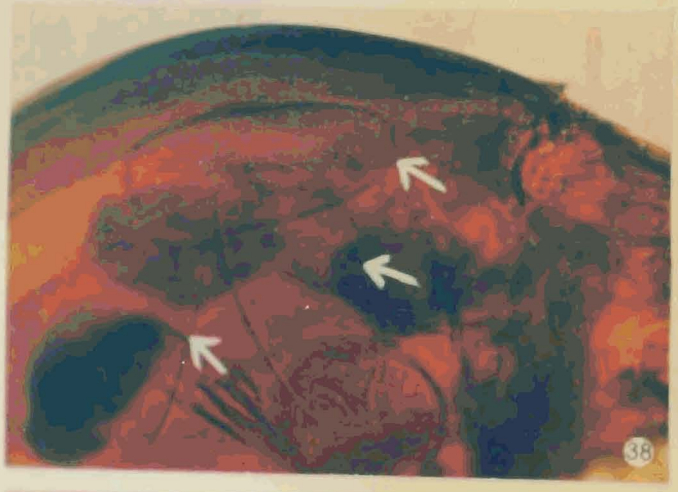
Fig. 41. Clustered eggs laid in the laboratory by *Pergalumna intermedia*.

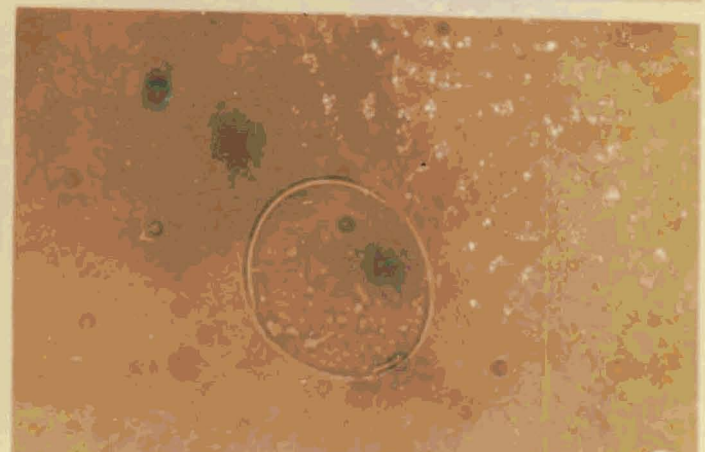
PLATE V











DISCUSSION

R. Sobhana Amma “Studies on oribatid vectors” Thesis. Department of Zoology , University of Calicut, 1997

158

DISCUSSION

DISCUSSION

Helminth parasites have proved to be a group of serious enemies of ruminants since the beginning this century. Anoplocephaline cestodes represent one of the persistent parasites of both domesticated and wild ruminants throughout the world (Kates and Goldberg, 1951). Digenetic habit of these parasites, particularly *Moniezia* spp. was confirmed by Stunkard (1934, 1937), with oribatid mites as the intermediate hosts. This has raised the status of oribatid mites from mere soil dwellers to organisms of much economic importance. Consequently much studies were oriented towards these mites to prove their relationship with the cestodes. Most of these studies were concentrated on the ecology and behaviour of these mites. Therefore, attempt has been made in this study to analyse the biological aspects of oribatid-cestode relationship in field and laboratory conditions.

The general survey carried out on the soil microarthropods at four vegetationally contrasting ecosystems, has revealed the abundance of oribatid and mesostigmatid mites in the upper layers of the soil. Astigmatid mites, though considered to be common members of soil acari (Sheals, 1956; Wallwork, 1970), the total absence of this group in the collection samples of the pesent study evoked interest to search the reason for the event. Recovery of 101 species of oribatid

mies made during the present study appears to be an important highlight of the general survey. This has indicated the extent of biodiversity of oribatid fauna in the soil ecosystems selected for the study. Eventhough, the oribatid mites obtained included 35 families, following discussion on eco-biological aspects of the mites are centered more around members of two families, namely Galumnidae and Scheloribatidae considering their established role in the transmission of cestode parasites in ruminants (Stunkard, 1937, 1938; Potemkina, 1941; Kates and Runkell, 1948; Anantaraman, 1951; Balakrishnan and Haq, 1984, 1989; Haq, 1988, 1990, 1991).

Taxonomic analysis of oribatid mites procured from 16 sites distributed in 6 districts of Northern Kerala revealed the presence of a total of 101 species belonging to 35 families under 57 genera. Among these 14 species belonging to 8 genera were identified as new records from South India. A closer scrutiny of the above 101 speceis further disclosed the presence of various life stages of cestode parasites in 23 species of mites thereby proving their role as natural vectors for the transmission of these parasites. These 23 species were found to belong to 12 genera and 10 families, which included 2 new species also. This observation warrants further studies on species diversity and the potentials of oribatid mites as natural vectors for the transmission of cestode parasites.

Among the 35 families of oribatid mites collected, Galumnidae and Scheloribatidae constituted the most diverse families, with a species composition of 18 and 16 respectively. Scrutiny of the distribution pattern of these mites further revealed their supremacy over members of the other families of mites in colonising various ecosystems. A comparison of the relative abundance of scheloribatid mites among the ecosystems revealed that out of the 16 species of mites, 12 species were more abundant in the grasslands than in forest lands. Similarly, 16 out of 18 species of galumnid mites were found to be abundant in the grasslands. While considering the proportion of the oribatid faunal components among the 4 ecosystems, it is quite certain that members of Scheloribatidae and Galumnidae together constituted about half of the fauna in the grasslands irrespective of the difference in their floral components. Meanwhile, proportion of these mites in the forest lands and mixed cultivation was found to be only one third of the total oribatid fauna. Therefore, it is evident that members of these two families represent the dominant groups of oribatid mites in the grassland ecosystems both in terms of species composition as well as population density.

In addition to the collection of 101 species of oribatid mites, the survey has helped to encounter incidence of natural cestode infection of 23 species of these mites. Owing to shortage of time, attempts were not made to infect the primary host

(i.e. ruminants) with the field collected cysticercoids. Hence the identity of the larval stages of cestodes found in the mites could not be confirmed during the present study. However, evidence gathered from the butcher shops and the veterinary hospitals near the collection localities, have indicated the occurrence *M. expansa* and *M. benedini* as the common intestinal parasites of goats and cattle in all the localities surveyed. Therefore, it is assumed that the larval stages of the cestodes found within the mites were of *M. expansa* and *M. benedini*. Out of the 23 species of mites 9 species namely *F. silensis, S. praencisus* var. *interruptus, Z. lineata, X. triangularis, A. globatus, G. longipluma, P. erecta, G. alata, G. discifera* were found to be new hosts for the tapeworms, as this forms the first report of natural infection of these species by the tapeworm larvae.

Incidence of natural infection in 23 out of 101 species of oribatid mites noted during the present study has indicated the fact that about 23% of the oribatid fauna inhabiting the pasture lands of this region is capable of acting as intermediate hosts of the tapeworm *Moniezia*. Of the 23 species of vector mites, *S. paraeincisus* var. *interruptus*, *S. laevigatus* and *I. lanceolatus* recorded infection, as evidenced by the presence of cestode larvae in them at 4 localities surveyed. Interestingly, these 4 localities included sites at 3 pasture ecosystems such as open grasslands, shaded grasslands and mixed cultivation. As mentioned during the discussion on the

results of the general survey, members of Scheloribatidae enjoyed wide distribution in all types of ecoystems screened and also showed higher population density. While considering in terms of percentage of natural infecton also, *S. praeincisus* var. *interruptus* ranked first by recording 8.5% infection. While analysing the role of oribatid mites in the transmission of cestode parasites, Sengbusch (1976) had pointed out that depending on their distribution, density and rate of infection different species of these mites act as agents of transmission in various ecosystems. This observation gained credence with the result of the present study, where incidence of cestode infection in various species of oribatid mites among the 16 sites considered could be established. It is intersting to realize in this context the magnitude of the potential of *S. praeincisus* var. *interruptus* as the principal agent of cestode transmission in Malabar area as infected specimens of the species could be recovered from 3out of 4 ecocystems screened. Apart from above, other mites like *X. seminudus* and *P. intermedia* can also be assigned to a similar status based on their distribution among the localities and percentage infection which reached to more than 5% under natural conditions. Apart from these, *S. latipes*, *S. rectus*, *H. imitator* and *G. flabellifera orientalis* may be considered as species of secondary importance in vector role owing to their low distribution pattern and pathogenicity as revealed by their occurrence in one or two sites only.

Among the four types of ecosystems included for the general survey during the current investigation, virgin forest sites were found to be free of natural infection in oribatid mites. Several causes though can be attributed for this, low accessibility of the grazing animals to these forest areas can be considered as the prime factor. Similar trends of low incidence of natural infection among oribatid mites have been reported earlier (Haq, 1990) in forest areas.

A total of eight sites of open grassland ecosystems were considered during the present study. Of these, 4 sites included goat farms, 3 sites included grazing fields of cattle and one site represented a common pasture land for goat and cattle. Among the goat farms, Komeri recorded infection in 4 species of mites, Mannuthy 3 and Vadakottuthara and Attapadi 2 each. This difference in the incidence of natural infection can be correlated with period allowed for grazing and population density of farm goats. Komeri represented the site when strength of the goat herds and period of grazing were found to be maximum. The low incidence of infection in oribatid mites at Vadakottuthara and Attapadi can be substantiated on the basis of the reduced population of goats and low frequency of grazing on these sites. Therefore, influence of grazing period allowed and population density of the ruminants are the two factors controlling incidence of infection among various species of mites.

Of the 3 cattle grazing open grasslands, Mannarghat recorded infection in 4 species of mites while West Hill and Thiruvazhamkunnu showed infection in 3 species of mites each. Meantime, common grazing field at Calicut University campus also revealed infection in 3 species of mites. The 4 sites of shaded grasslands screened during the present survey revealed infection in one species of mite each, irrespective of the type of grazing animals. Therefore, it would become evident that natural infection of oribatid mites by cestode parasites is a common phenomenon and it occurs very markedly in pasture lands where grazing by goat and cattle is of regular occurrence. Further, it may also be noted that infection to oribatid mites is not influenced by the type of grazing animals, as infection to these mites has been recorded from goat and cattle grazing fields.

The single mixed cultivation site, namely, Calicut University Campus included in the study recorded natural infection in 9 species of oribatid mites, whereas the 8 open grassland sites together yielded infection in 19 species. A comparison of the infection rate at individual open grassland site with that of the mixed cultivation would reveal the fact that the infection rate at the latter was more than double that of the open grassland site. This is all the while true with the open grassland site at stadium ground in the same locality where only 3 species of mites alone got infection. Restriction of grazing imposed to ruminants at this site would

have been a prominent reason for such a difference. This would further indicate that frequency of grazing acts as a major factor in cestode infection among oribatid mites.

An analysis of the gut contents and body cavity of the infected individuals of oribatid mites clearly disclosed the occurrence of various developmental stages of the cestode parasites in them. Eggs, onchosphere, spherical larva, pyriform larva, vermiform larva and cysticercoid were the frequent stages observed and identified within the body of these mites. The number of the life stages of the parasite recovered from individual specimens of mites showed considerable variation in all the vector species encountered. Generally, eggs were found in large numbers within the digestive tract whereas later stages of development showed a gradual discrease in their number. No instances of more than 6 cysticercoids could be recovered from any of the mite species examined. This observation helped to disclose the fact that all the eggs being ingested do not attain development up to the cysticercoid stage. This indicates positive sign of damage of eggs by one way or other after consumption. Whether the chewing activity of the eggs by mites induce chances of crushing/damage on consumption or the viability of the eggs got considerably reduced due to enzyme activity of the host gut or by both are yet to be determined, and debatable. This can further be supported from the detection of

crushed cestode eggs in the gut of a few species of mites during microscopic examination. However our knowledge on the chewing mechanism of food, particularly of the cestode eggs and their fate in the gut of the host mites appears to be very meagre. Therefore future investigations along the line are warranted to disclose the feeding mechanism, the fate and actual pathway of the cestode eggs. The impact of cestode invasion often elicit serious set back to their hosts. Though the injurious effect caused by cestode parasites to the host mites is not worked out conceivably, considerable amount of information is available on this aspect with respect to damage to ruminants (Kates and Goldberg, 1951). Therefore, it would become necessary to formulate programmes for the control of these parasites. Since the life-history of the cestode involves digenetic pattern, attempts to evolve measures of control around the intermediate host would be a feasible method. Oribatid mites being the largest arthropods enabling transmission of cestode parasites to domesticated animals, it is worthwhile to augment programmes for control of these oribatid vectors.

Results of the studies on oribatid-cestode interaction have shown that ingestion of cestode eggs by the mites is merely accidental or incidental. (Stunkard, 1937; Kates and Runkell, 1948). A critical analysis of the process of ingestion would suggest that an incident or accident can never be rated to a percentage upto

8.5 as evidenced through the present study. Further it would become more realistic to consider the process of cestode egg ingestion as an intentional act, since on several occasions experimental mites in cultures have been found congregating on egg mass and feeding them.

Information on the nutritional aspect of oribatid mites as in the case of any other animal groups, would substantially help in solving problems concerning issues on strategic points in replenishment of population. This would, all the more apropriate with respect to stable population, which would discretely decide the frontiers of survival policies. A stable population, no doubt is the requirement of the day as against the unstable population. Therefore, any attempt to bring forth healthy and stable population would become a welcome demand. The final goal of the present project is aimed at with this object in mind to protect our livestock wealth from the huddles of cestode parasites being mediated by oribatid vectors.

When we think nutritional procurement in terms of survival policies it would become a mandatory aspect of life sustenance. Oribatid mites, being universally distributed in all types of soils, their growing demands in terms of food resources are favourably met by the environment itself to a greater extent. Therefore, the pros and cons in relation to demands and supply would become a two way policy between the mite and its environment. How best the mites utilize the food sources

available to them depend on their consumption ability and wider choice of food selection (Haq, 1997) definitely would enhance survival regime. It is in this context, we are trying to evaluate feeding efficacy of oribatid mites. Better performance in food consumption, though elicit advantages, may mask the hidden tendency of a functional role one may be enthusiastic enough to vouch for such scene for it would otherwise become a very rare tendency to establish. Consumption of cestode eggs being an accidental or incidental affair in nature among oribatid mites, knowledge gathered on natural infection of oribatid mites and its documentation through laboratory feeding experiments would vouch better frontiers of future research programmes in oribatid -cestode relationship.

Oribatid mites, through their feeding activity display an important effect on organic decomposition in the soil ecosystem. Detailed analysis of the feeding habits of these mites (Wallwork, 1958; Hartenstein, 1962; Haq and Prabhoo, 1976; Haq, 1982, 1984, 1987; Neena and Haq, 1988) enabled formulation of classical feeding categorizations of these mites by many (Schuster, 1956; Luxton, 1972). In the present study also, an attempt has been made to trace out the nutritional habits of 22 species of mites belonging to 11 genera and 9 families, based on food choice test performed in the laboratory. The study was oriented in such a direction as to gather information primarily on the feeding habits of oribatid mites considering

their role to serve as intermediate host for various cestode parasites, which forms the subject matter of the present project. Accordingly, members of the known vector families, such as Oribatulidae, Achipteriidae, Galumnidae, Scheloribatidae, Parakalummidae, Haplozetidae and Xylobatidae were selected for the feeding experiments. Apart from the above families, representatives of Damaeolidae and Galumnellidae, so far unknown for their vector role, were also considered for food choice test in order to evaluate their feeding attributes.

Results of the food choice test disclosed the selective affinity of individual species to different items of food offered in the laboratory comprising bacteria, algae, fungi, lichen, moss, leaf litter, dead arthropods, nematodes and eggs of *Moniezia* spp. Evidences of bacterial feeding could be witnessed in 10 out of the 22 species studied with variation in their feeding intensity on the 4 types of bacteria offered. However, reproductive success on this type of food could be evidenced only in a single species of mite namely *S. laevigatus.* Such a prediliction for bacterial diet in oribatid mites like *Hypochthonius rufulus* and *Gustavia microcephala* could be noted by Schuster (1956) and Luxton (1972). The results of the present study add further proof to bacteriophagy among oribatid mites, establishing reproductive success also on this diet.

Mycophagy is considered to be one of the major feeding habits of oribatid mites as evidenced from earlier reports (Schuster, 1956; Hartenstein, 1962; Luxton, 1972; Haq and Prabhoo, 1976; Haq, 1982; Neena and Haq, 1992). It is well known that fungivorous mites and collembola form dominant mycophages in most terrestrial ecosystems (Seastedt, 1984). Evidences show that fungivorous oribatids are capable of producing considerable amount of faecal pellets which in turn contribute to soil structure (Norton, 1985). Results of the present study serve to establish mycophagy in all the species considered for the study, with the exception of one new species namely, *F. silensis* which exhibited preference to one species of fungus alone. The total rejection shown by this species to the other fungal diet can be correlated with the difference in components of the fungal diet offered. Detailed studies involving more species of fungal food are necessary to substantiate the negative mycophagous trend in the above species.

The mycophagous habit of oribatid mites, though could be witnessed in all the 22 species studied currently, specific variation was shown by individual species depending on the fungal species. Accordingly, certain species of fungi proved highly palatable to some species resulting in their reproductive success also while the same fungi proved less preferred or unpalatable to certain other species. Among the 10 species of microfungi offered, *Alternaria alternata* constituted the

first one in terms of consumption by mites. All the 22 species consumed this fungal food on which 13 species showed reproductive success also. The second position in the order of preference was occupied by two species of microfungi, *C. oxysporum* and *C. geniculata*, on which 16 species of mites reproduced successfully. *P. citrinum* occupied the lowest position in the order of preference, on which positive signs of feeding were exhibited by only 2 species. The high preference shown by oribatid mites to *A. alternaria* followed by *C. oxysporum* and *C. geniculata* was already discussed by Neena and Haq (1992) in the case of several other species of oribatids. The very low feeding preference observed on *P. citrinum* may be correlated to the presence of secondary metabolites produced by the fungal species, inhibiting feeding process as suggested by Kukor and Martin (1987). However, feeding preference alone cannot be taken as a criterion for reproductive success as indicated by Mitchell and Parkinson (1976).

The various species considered for food choice test though exhibited high preference to microfungi, the intensity of feeding was found varying not only with respect to species variation of fungi, but also with the stage of growth of the fungus. This was well evidenced as all the species showed preference to fresh cultures of fungi rather than sporulating ones. This showed the fact that age of the fungal tissue had a great influence on the palatability of the mites. The feeding variations

shown by mites on the same species of fungus in different stages of development may be considered as a reflection of the qulitative changes undergone by the fungal species owing to senescence resulting from resource depletion, microbial aging or accumulation of inhibitory by products (Lockwood 1977; Hanlon 1981). The chitin content of the fungal tissue was reported (Werner and Dindal 1987) to increase with age and this may be considered as the reason for the total rejection of sporulated fungal species by the various oribatid mites considered for the study.

Phycophagy (algal feeding) constitutes one of the many feeding categorizations of oribatid mites, though it is not a wide spread phenomenon in these mites. Members of *Scheloribates* and *Pergalumna* often devoured these items of food. In the present study, 11 species showed consumption of lichen, though reproductive success could not be obtained. Instances of algal feeding in oribatids were already reported by Woodring (1963), Luxton (1966) and Littlewood (1969). The ability of these mites to break open algal cells with their chelicerae was reported by Tarman (1968) who carried out studies on *Pleurococcus* sp. of alga. Phycophagy under natural conditions was evidenced by Schuster (1956) in 14 species of oribatid mites. The recovery of 50% of oribatid mites considered during the study as phycophages point out the increasing trend of oribatid consumption to these food items.

Lower plant materials like lichen and moss serve as food for oribatid mites quite often. Though these food items do not form a major food source for these mites, they serve as palatable items to several species as reported by Grandjean (1936), Trave (1963, 1969) and Lawrey (1987) . The association of oribatid mites with fruticose lichen was correlated by Andre (1979) who detected them in algae growing on trees. He further suggested that habitat alone (and not the nutritional factors) determines the preference of mites. In the present study, 10 species disclosed mere consumption of lichen while the remaining species totally rejected the food. Moss, on the other hand was found preferable to 16 species of oribatids, of which, 2 species attained reproductive success also, thereby supporting it as a better food item rather than lichen. This obeservation is similar to the findings of Gerson (1969) who reported that several arthropods depend on moss as a suitable item for food and shelter. However Strong (1967) is of the opinion that moss serves as a better source for adjustments of microclimatic condition rather than food items.

Leaf litter constitutes a major share of food for oribatids especially to the macrophytophagous species. Affinity to leafy components enabled Luxton (1972) to categorize these mites as phyllophages. In the present study leaf litter was found consumed by all the species, with the exception of two viz., *F. silensis* and *G. comparabilis*. Of these, preferential feeding on this diet was exhibited by 9 species

and reproductive success was recorded in 4 species. The remaining 7 species showed mere consumption of leaf litter. However, none of the species was found consuming dry-leaf litter. Possibly, palatability of the food item would have been one of the reasons for its rejection. Positive sign of feeding was located only on moistened leaf litter thereby supporting the earlier findings of Hartenstein (1962) and Harding and Stuttard (1974) that these mites feed only on moistened and microbially conditioned litter. However, contradictory reports were also made by Riha (1951), Kuhnelt (1961) and Wallwork (1960) revealing the affinity of microarthropods to dry litter.

Zoophagy, quite often constitutes a rare feeding category in oribatid mites. In the present study, dead arthropods, live nematodes and cestode eggs were offered as test food items for assessing the zoophagous trend in these mites. Of these, dead arthropods were found consumed by 5 species coming under Scheloribatidae, Haplozetidae and Parakalummidae. Affinity to live nematodes could be located in 12 species of mites coming under Scheloribatidae, Haplozetidae, Achipteriidae and Galumnidae. A clear case of nematophagy was presented by Rockett and Woodring (1966) and Rockett (1980) who recorded this habit in all stages of *P. omniphagous* except in the larvae. This helped them to pinpoint the innate habit of nematophagy in *P. omniphagous*. This nematophagous habit of galumnoid mite

would provide further support of their utilization in biological control programmes of plant parasitic nematodes (Rockett and Woodring, 1966; Rockett, 1980). These species can flourish well on other food items during the nonavailability of prey population also. Isolated reports also exist of the consumption of live body of fly larva by *Galumna* sp. (Graves, 1960) and on the pupae of a parasitic hymenopteran (Vitzthum, 1943) by *S. laevigatus*. However, consumption of parasitic hymenoptera as explained by Woodring (1963) by these mites appears to be doubtful in the context of their possession of ill-equipped mouth parts.

Ingestion of anoplocephaline cestode eggs by oribatid mites and their subsequent development up to cysticercoid stage in the body cavity of these mites present a splendid area of oribatid activity in terms of pathogenicity. This remarkable spectrum of activity has been well scrutinized by various authorities (Freeman, 1952; Krull, 1939; Stunkard, 1937; Wallwork and Rodriguez, 1961; Sengbusch, 1976; Haq, 1988, 1990, 1991) from different parts of the world. Accordingly, 73 species of oribatid mites belonging to 34 genera have been listed (Haq, 1988) for their vector role in the transmission of cestode parasites. In the present study, eggs of two species of *Moniezia* viz. *M. expansa* and *M. benedini* were offered as food items to the 22 species of mites. Of these, 11 species disclosed positive signs of feeding. Thus 50% of oribatid population exhibited clear

evidence of cestode egg consumption establishing their active role as intermediate hosts for these parasites. Affinity to cestode eggs was more prevalent among members of Galumnidae, followed by Scheloribatidae, Haplozetidae and Achipteriidae. This was proved under natural conditions also where the representatives of these families revealed various stages of cestodes in their body cavity, as observed during the present study. However, certian disparity also could be observed between the results of feeding experiments and that of natural infection. This was evidenced in *F. silensis*, *Z. lineata*, *P. levipunctatus* and *P. erecta* by revealing positive sign of natural infection and rejection of cestode eggs during food choice test. Such a feeding disparity can be correlated with the availability of their preferential food items offered in the laboratory. It may also be possible that, the above species while feeding on various food items available under natural conditions might have ingested cestode eggs accidentally or incidentally thereby supporting earlier suggestions made by Stunkard (1937) and Kates and Runkell (1948).

Experimental infection of oribatid mites by feeding with eggs of *M. expansa* had helped to trace the sequence and duration of development of the parasite within the mites. Onchosphere, spherical larva, pyriform larva, vermiform larva and cysticercoid were the 5 stages of the cestode recovered during dissection of the

infected mites. This observation has confirmed the life stages of *M. expansa* encountered in field collected mites. Similar sequence of development of the parasite was reported by Stunkard (1939) during his artificial infection experiments on oribatid mites. However Potemkina (1941) had reported 7 developmental stages of the parasite within the mites such as onchosphere, megalosphere, metamere scholexogeny invagination, cysticercoid before invasion and cysticercoid after invasion. Therefore, more studies involving frequent dissection of infected mites are warranted to confirm the exact developmental stages of *M. expansa* within the mites.

The duration of development of the tapeworm showed considerable variation among different species of mites. Thus the time required for attaining the cysticercoid stage ranged from 25.6 to 41.2 days among 10 species of mites included in the study . The duration was found to be lowest in *I. lanceolatus* and the highest in *X. triangularis.* Difference in the physiological interaction between the mites and the parasite may be considered as the cause for such variation in the duration of the development of the cestodes. Similar trends in duration of the development of the cysticercoid within the mites has been reported from various parts of the world. In the U.S.S.R extensive studies carried out by Potemkina (1941) revealed the duration of individual stages to be 23 to 113 days at 26^0C.

Further the studies disclosed the slower rate of development of the parasite at 16^0C. Therefore, it can be concluded that the time required for the parasite to attain cysticercoid stage within the mite depends on the species of host mite as well as temperature.

The percentage of infection of the mites in the laboratory cultures ranged from 73 to 92% which was found to be much higher than under natural conditions. This may be attributed to the prolonged exposure of the mite to the cestode eggs and the availability of limited varieties of other food items for the mites in laboratory cultures. Such high rate of infection among experimental mites of *S. laevigatus* and *S. latipes* has been observed by Schuster (1995) during artificial infection experiments. The average number of cysticercoids recovered from individual mites of different species during the present study ranged from 3.8 to 5.8, which is found almost similar to that recorded under natural condition. This observation further confirmed the cysticercoid carrying capacity of the mites as established through earlier studies (Stunkard, 1941; Kates and Runkell, 1948). However Schuster (1995) reported the presence of upto 23 cysticercoids in *Scheloribates* spp. under experimental conditions.

In the present study, spermatophore deposition was evidenced in all the three species. The spermatophores were found deposited all over the culture cells

without any site specificity. This observation seems contradictory to the earlier observation of Haq and Clement (1981) in *Pelokylla malabarica*, where spermatophores were found deposited on clean, bare substratum. Arlian and Woolley (1970) also recorded site specificity in *Liacarus cidarus*, which confined spermatophores on food materials. None of the species studied currently exhibited signs of feeding on spermatophores as reported by Rockett and Wooding (1966) in *P. omniphagous* and Shereef (1972) in *Epidamaeus plumosus*. This essentially points out the behavioural alterations, even among members of the same taxon.

Oviposition in hidden and protected habitats is a general trend in many animal groups including oribatid mites. This appeared true in all the 3 species studied currently. All the 3 species were found depositing eggs in the fungal cushions or in the crackes and crevices present on the culture substratum. Such an ovipositional habit was already reported in certain other species like *Oppia nitens* by Sengbusch and Sengbusch (1970), *Liacarus cidarus* by Arlian and Woolley (1970), *Orthogulumna terebrantis* by Cordo and De Loach (1976) and *Uracrobates indicus* by Ramani and Haq (1988). It is quite appropriate to expect that oviposition in sequestered habitats will ensure protection to the eggs from desiccation and to the immatures from natural predators. Moreover, laying of eggs in or on the feeding substrate enables the emerging larvae to locate their food easily.

Arthropods in general and oribatid mites in particular exhibit a vast variation with respect to the pattern of oviposition. In the present study, deposition of both clustered eggs and single eggs was met within 2 species viz. *S. praeincisus* var. *interruptus* and *P. intermedia*. On the other hand, *X. triangularis* always laid single eggs. Laying of solitary eggs was reported as a general rule in certain species like *O. terebrantis* (Cordo and De Loach, 1976), *Paralamellobates bengalensis* (Haq and Ramani, 1984) and *S. decarinatus* (Ramani and Haq, 1987). Contrary to this, species like *G. longipluma*, *G. elimatus* and *G. nervosus* (Sengbusch, 1954), *S. laevigatus* (Woodring and Cook, 1962), and *P. malabarica* (Clement and Haq, 1984) have been reported to lay aggregate eggs. Resembling *S. praeincisus* var. *interruptus* and *P. intermedia* considered in the present study, *L. cidarus* was also reported to lay both solitary and clustered eggs (Arlian and Woolley, 1970; Rockett and Woodring, 1966) correlated such a variation in the pattern of oviposition with seasonal alterations. Further studies along this line are warranted to trace out the determining factor for the ovipositional variation exhibited by *S. praeincisus* var. *interruptus* and *P. intermedia* involved in the current investigation.

A frequent phenomenon associated with hatching in several species of oribatid mites relates to colour change of eggs preceding the process of hatching. This was well evidenced in *G. elimatus, O. nitens, L. cidarus* and *U. indicus* as

reported by Sengbusch (1954), Sengbusch and Sengbusch (1970), Arlian and Woolley (1970) and Ramani and Haq (1988) respectively. However, none of the species involved in the present study exhibited such a phenomenon, even after repeated observation. The lack of change in colouration may be due to the inefficiency of the species to develop amber pigmentation. This may probably be resulted from the lack of possession of the necessary enzyme complement controlling the distribution of chromatophores on the egg case.

The duration of development of all animal groups is subject to alteration depending on the quality and quantity of food. In the present study, among the 3 species, maximum duration of development was recorded for *S. praeincisus* var. *interruptus* completing its F_1 progeny with in 40-50 days. The minimum duration was observed in the case of *X. triangularis,* which completed its development with 17.5 - 22 days. *P. intermedia* on the other hand, occupied an intermediate position requiring 25-28 days for completion of F1 generation. Microfungi like *C. oxysporum, A. alternata* and *C. geniculata* respectively were offered as food item during developmental studies, which were proved as ideal food items to these species during food choice test. The variation in the nutritional composition available in the food items might have resulted in the differences in the duration of individual instars and that of the F_1 generation observed in the present study.

A genreal trend reported in oribatid mites is the shorter duration of development for smaller species and longer duration for larger species (Butcher *et al.*, 1971; Haq and Ramani, 1984). This appeared true in the present study also where *S. praeincisus* var. *interruptus* was comparatively larger than the other two species and hence required the maximum days (40-50 days) for the completion of its F_1 generation. *X. triangularis* was the smallest species among the three and *P. intermedia* was of intermediate size. Accordingly, the minimum duration (17.5 - 22 days) was recorded for the completion of life cycle of *X. seminudus* whereas the duration of life cycle of *P. intermedia* occupied a intermediate position taking 25-28 days. However despite this developmental variation, all the species appeared to enjoy a wide distribution in most of the habitats surveyed. All the species exhibited positive signs of zoophagy particularly to cestode eggs offered in the laboratory thereby proving their potential to lead a vector life. This was confirmed through the results of field studies also where all the species disclosed natural infection, harbouring different stages of cestodes in their body cavity.

SUMMARY

SUMMARY

The present project work was undertaken with the sole objective of gathering information on the role of oribatid mites in the transmission of cestode diseases in domesticated animals, particularly goat and cattle in Kerala. For the purpose, extensive surveys were carried out from six districts of central and Northern Kerala namely Thrissur, Malappuram, Kozhikkode, Kannur, Palakkad and Wynad. Regular random samples from conrasting vegetational sites such as open and shaded pasture fields, undisturbed virgin forests and areas of mixed cultivation were subjected for detailed study.

For conducting general survey of the mites, random samples of soil along with grass and litter were collected from all the sites, preferably during the early hours of the day. The collected samples were transferred to clean polythene bags, labelled and immediately transported to the laboratory for extraction. Extraction was carried out in modified Berlese-Tullgren funnels. The oribatid mites separated were collected in 70% alcohol, upgraded in alcohol series and mounted in Hoyer's medium for locating the cestode life stages to document natural infection and identification of the species of mites.

Analysis of the extracted animals disclosed the presence of a dozen groups of microarthropods such as Acari, Collembola, Protura, Diplura, Isopoda, Symphyla, Diplopoda, Chilopoda, Pseudoscorpionida, Coleoptera, Hymenoptera and larval stages of Diptera. Generally, Acari constituted the dominant group of microarthropods in all the forest lands surveyed whereas the collembolans dominated in the grasslands. The acarine members recovered during the study were found to represent three suborders viz., Prostigmata, Mesostigmata and Oribatida. In all the sites surveyed, Oribatida formed the most abundant group among acari and a total of 101 species could be collected and identified during the study period. The above 101 species were found belonging to 57 genera and 35 families. Out of these, 23 species were proved natural vectors of cestodes and 9 of these were recorded for the first time as natural vectors of cestodes. These vector species were considered for detailed taxonomic studies. 2 genera namely *Fosseremus* and *Anachipteria* had been represented anew with respect to their vector status. Of these, *S. praeincisus* var. *interruptus* was the only representative which exhibited evidences of natural infection in all the sites surveyed. This was followed by *G. flabellifera orientalis, I. lanceolatus* and *P. intermedia* respectively. The species and subspecies which remained unknown for their vector status so far comprised *S. praeincisus* var. *interruptus, Z. lineata, X. triangularis, P. erecta, G. longipluma, G. alata, G. discifera, A. globatus* and *F. silensis*. Results of the study revealed

natural infection in species mainly harbouring the open grasslands and the number of infected specimens recovered from virgin forests and shaded grasslands was comparatively low. This clearly disclosed the prevalence of vector species in open grazing fields, which points out increasing chances of infestation in cattle which commonly graze in open grasslands when compared to goats which usually prefer shaded grasslands as evidenced during the study.

The rate of infestation in individual vector species varied considerably. Maximum degree of infection recorded during the study was 8.5% and the lowest rate was 0.75%, which could be attributed respectively to *S. praeincisus* var. *interruptus* and *F. silensis*. The number of life stages of the cestode parasites present in the body cavity of the vector mites also showed variation. Accordingly, the maximum number of cysticercoids harboured by a single individual was 6 and the minimum was 1. The number of earlier stages of cestodes was comparatively higher in the body of infected individuals as upto 33 eggs could be recovered from the body of a single specimen of *S. praeincisus* var. *interruptus*. 8-15 oncospheres were observed within the body cavity of several species while the number of succeeding stages was still lower. The number of spherical larvae recovered from various species ranged from 6-8. Pyriform larvae were commonly observed in more number of species. Vermiform larvae and the spherical cysticercoids were also

observed in some species, of which the latter could be easily recognized by the characteristic double wall and the possession of 4 suckers. The maximum number of cysticercoids noted in a single mite did not exceed 6 in any instance.

In order to trace the food and feeding habits of oribatid mites and specifically to assess their affinity towards cestode eggs, 23 items of food available in their natural habitat including cestode eggs were offered to 22 species of commonly available mites in the laboratory. They included 4 species of bacteria, 2 species of algae, 10 species of microfungi, one species of macrofungus, one species of moss and lichen each, dead arthropods, live nematodes and eggs of tapeworms. The microfungi were proved to be the most preferred food for majority of the species studied. The order of preference exhibited by the mites to the various species of microfungi tested was *C. oxysporum* = *C. geniculata* > *A. alternata* > *P. versicolor* > *B. theobromae* > *P. glomerata* > *Pestalotia* sp. > *P. citrinum* > *F. solani*. The second item of food in terms of preference by the mites was leaf litter, to which 13 species exhibited high preference. Successful breeding was also evidenced in 4 species, on this food item. Moss was recognized as the third item of preferred food, which supported flourishing populations of 6 species of mites. 10 species belonging to Scheloribatidae, Xylobatidae, Achipteriidae and Galumnidae ingested tapeworm eggs in the laboratory. Members of the above families consumed live nematodes

also. Apart from these, affinity to live nematodes was recorded in another species, viz. *Rostrozetes foveolatus*, belonging to Haplozetidae.

The species of mites which consumed cestode eggs during food choice test were considered for studies involving artificial infection with eggs of *M. expansa*. Maximum number of cestode eggs was consumed by *S. praeincisus* var. *interruptus* and the minimum number was devoured by *A. globatus*. The percentage of infection among the various species ranged from 73-92%. The highest percentage of infection was recorded in *I. lanceolatus* whereas the lowest one was in *A. globatus*. Dissection of the infected mites was performed periodically, to trace the developmental pattern of the cestode eggs within the mites, till the recovery of cysticercoid stage. The above study revealed the occurrence of five different stages of cestodes within the body of oribatid mites such as the onchosphere, spherical larva, pyriform larva, vermiform stage and the cysticercoid stage.

The duration of development of the parasite from the egg to the cysticercoid stage showed variation in different species of the mites studied. The minimum duration was recorded in *I. lanceolatus* in which cysticercoids were recovered after 25.4 days of infection. Maximum duration of development was observed in *X. seminudus*, in which cysticercoids could be obtained within 54 days after infection. The average number of cysticercoids recovered from individual species also

showed variation with respect to species. Maximum number of cysticercoids were recovered from *G. alata* whereas *X. seminudus* exhibited the minimum number. Longevity of infected individuals of *S. praencisus* var. *interruptus*, *X. triangularis*, *I. lanceolatus* and *P. intermedia* was compared with that of the uninfected individuals of the same species in order to assess the influence of the parasite on the mites. The results of the study revealed a reduction in the longovity of the infected individuals in all the 4 species studied.

To get a general idea of the annual number of generations of the vector mites and to assess their population density in the field, life history studies of most common species were carried out under laboratory conditions at 30 $\pm$ 1°C and 80% RH. Three species of mites namely *S. praeincisus* var. *interruptus*, *X. triangularis* and *P. intermedia* were cultured in the laboratory on *C. oxysporum*, *C. geniculata* and *A. alternata* respectively. Ontogeny of the mites involved a larval and three nymphal instars in between the egg and the adult stages. Each instar included an active period followed by a quiescent period, the end of which was marked by moulting. The pattern of development was similar in all the 3 species, though the duration of individual instar of each species varied. Thus the development of *S. praeincisus* var. *interruptus* was completed with 32-36 days while *X. triangularis* and *P. intermedia* required 17.5-21.5 days and 25-28 days respectively.

REFERENCES

REFERENCES

AKBAEV (M.S.), 1986. Monieziozy ovec - potogenez, veprosy biologii, epizozortologii razrabotka leccbno-profilaktioeskich meroprijatij. Avtoreferat dissertacii na soiskanie ueenmoj stepeni doktora veterinarmych nauk, Moskava.

ANANTARAMAN (M.), 1943. 4th Rept. Madras. Helm. Scheme. - (ICAR).

ANANTARAMAN (M.), 1944. - 5th Rept. Madras. Helm. Scheme. (ICAR).

ANANTARAMAN (M.), 1951. - The development of *Moniezia*, the large tapeworm of domestic ruminants. - Sci & Cult.,174: 155-157.

ANDRE (M.), 1979. - Notes on the ecology of corticolous epiphyte dwellers. 1. The mite fauna of fruiticose lichens. In : J.G. Rodriguez (Ed.), Rec. adv. Acarol., 1, Academic Press, New York : 551-557.

AOKI (J.I.), 1961. On six new oribatids from Japan - Jap. J. Sanit. Zool., 12 (4) : 233-238.

AOKI (J.I.), 1963. - Einiege Neue Oribatiden aus dem kaiser Pichen palastgarten Japans. Annot. Zool. Japan, 36 (4): 218-224.

AOKI (J.I.), 1965a. New oribatiden von den insel sado (Acarina : Oribatei). Jap. J. Zool., 14 (3) : 1-12.

AOKI (J.I.), 1965b. A preliminary revision of the family Otocepheidae (Acari : Cryptostigmata), 1. Subfamily Otocepheinae. - Bull. Nat. Sci. Mus., 8 (3): 259-341.

AOKI (J.I.), 1965c. Oribatiden (Acarina) of Thailands. 1 - Nature and Life in S.E. Asia. 4 : 129-193.

AOKI (J.I.), 1967. A preliminary revision of the family Otocepheidae (Acari : Cryptostigmata) II. Subfamily Tetracondylinae. - Bull.Nat. Sci. Mus., Tokyo. 10 (3): 297-359.

AOKI (J.I.), 1968. Taxonomic investigation on free living mites in the subalpine forest on shiga Heights IBP Area, III Cryptostigmata. - Bull.Nat. Sci. Mus., Tokyo. 12 (1) :117-141.

AOKI(J.I), 1973. Oribatid mites from Iromote Jima, the southern most island of Japan, (I), Mem. Nat. Sci. Mus. Tokyo, 6 : 585-602.

AOKI (J.I.), 1975. Taxonomic notes on some little known oribatid mites of Japan. - Bull. Nat. Sci. Mus. Ser. A. (Zool)., 2(1) : 57-65.

AOKI (J.I.), 1977a. These species of the genus *Eohypochthonius* from Japan (Acari: Oribatei). - Acarologia, 19 (1) : 117-122.

AOKI (J.I.), 1977 b. Two new *Peloribates* sp. (Acari: Oribatidae) collected from lichens growing on tombstones in Ichi-harashi, Central Japan. - Annot. Zool. Jap., 50 (3) : 187-190.

AOKI (J.I.), 1984. - New and unrecorded oribatid mites from Amami - Ohshima Island, South West Japan. - Zool. Sci., 1 : 132-147.

AOKI (J.I.) 1987. Three new species of oribatid mites from Yoron island. South Japan. (Acari. Oribatida). - Int. J. Acarol., 13 (3) : 213-216.

AOKI (J.I.), and OKHUBO (N.), 1974. A proposal of new classification of the family Oripodidae (Slat) with description of new species - Bull. Nat. Sci. Mus., Tokyo, 17: 117-147.

AOKI (J.I.), and WANG (H.F), 1986. Two oribatid mites injurious to economic plants (Acariformes : Oribatidae). - Acta. Zool. Sinica, 11 (4) : 375-378.

AOKI (J.I.) and HAO (H.S.), 1993. Oribatid mites from tropical forests of yunnan province in China. II. Families Galuminidae and Galumnellidae. Zool. Sec., 10 (5): 835 - 848.

ARILLO (A), and SUBIAS (L.S.), 1993. New Galumnoidea of Spain (Acari: Oribatida: Galumnoidea). Nouveaux Galumnoidea de l'Espagne (Acari: Oribatida: Galumnoidea). - Acarologia, 34(4) : 377-386.

ARLIAN (L.G.) and WOOLLEY (T.A.), 1970. Observations on the biology of *Liacarus cidarus* (Acari : Cryptostigmata: Liacaridae) - J. Kansas. Entomol. Soc., 43 (3) : 297-301.

BAKER (E.W.), 1945 - *Scheloribates chauhani*, a new species of oribatid mite from India (Acarina : Ceratozetidae) - J. Wash. Acad. Sci., 35 : 386-388.

BAKER (E.W.) and WHARTON (G.W.), 1952. An introduction to Acarology, Mac Millan Co., New York, 465 pp.

BALAKRISHNAN (M.M.), 1985. A new genus of Galumnidae (Acari Oribatei) from India. Orient. Insects, 19 : 155-161.

BALAKRISHNAN (M.M). and HAQ (M.A.), 1982 - A new species of *Porogalumnella* (Acari : Oribatei : Galumnellidae) from Kerala, India. - Indian J. Acarol., 7: 20-25.

BALAKRISHNAN (M.M), and HAQ (M.A.), 1984. New oribatid vectors of cestodes from India. - In: D.A. Griffiths and C.E. Bowman (Eds.) Acarology VI(2), Ellis Horwood Ltd., England : 1161-1164.

BALAKRISHNAN (M.M.), and HAQ (M.A.), 1985 - A new species and subspecies of Galumnidae (Oribatei) from Kerala, India - Acarologia., 26 (2): 201-204.

BALAKRISHNAN (M.M.), and HAQ (M.A), 1989. Three new oribatid vectors of Anoplocephaline cestodes from Kerala. *Indian. J. Acarol.*, 10 (1 & 2) : 9-13.

BALOGH (J.), 1958. - Oribatides nouvelles de l'Afrique tropical. - Rev. Zool. Bot. Afr., 58 (1-2) : 1-34.

BALOGH (J.), 1959. Some oribatid mites from Eastern Africa (Acari : Oribatidae). - Acta. Zool. Acad. Sci. Hung ., 5 (1-2) : 1-132.

BALOGH (J.), 1972. - The oribatid genera of the world. - Akademiai Kiado, Budapest, 188 pp + 71 pls.

BALOGH (J.), 1985. - Some interesting Oribatuloidea from the Hawaiian islands (USA) (Acari : Oribatei). Opusc. Zool., 29-20 (0) : 57-62.

BALOGH (P.), 1988. - Oribatid mites (Acari) from Sri Lanka - Acta Zool. Hung., 34 (2-3) : 171-189.

BALOGH (P.)., 1995. Some oribatid mites (Acari) from the serra do Ma and Serra do Matigucra (Brazil Sao poulo) Acta. Zool. Acad. Sci. Hung., 41 (1) : 1-9.

BALOGH (J.) and BALOGH (P.), 1985. Fifteen new species of the genus *Xenillus* Robineau - Desvoidy, 1839 (Acari : Oribatei) from South America. - Acta Zool. Hung., 31 (1-3) : 53-79.

BALOGH (J) and BALOGH (P.). 1986. New oribatids (Acari) from New guinea III. Acta. Zool. Hung., 32 (1-2) : 35-60.

BALOGH (J.) and BALOGH (P.) 1988. The family Ceratokalummidae Balogh, 1970 (Acari : Oribatei) . Acta.Zool. Hung., 34 (2-3); 191-201.

BALOGH (J) and BALOGH (P), 1990a. Identification key to the genera of the Galumnidae Jacot 1925 (Acari: Oribatei). Acta. Zool., Hung., 36 (1-2): 1-23.

BALOGH (J.) and BALOGH (P.), 1990b. Oribatid mites of the Neotropical region II. Elsevier, Amsterdam, 333 pp.

BALOGH (J.) and MAHUNKA (S.), 1967 - New oribatids (Acari) from Vietnam. Acata. Zool. Hung., 13 (1-2) : 39-74.

BALOGH (J.), and MAHUNKA (S.), 1968a. The Scientific results of the Hungarian Soil Zoological expeditions to South America - 5. Acari : Data to the Oribatid fauna of the environment of Cordoba, Argentina. - Opuscula Zool. Budapest, 8 (2) : 317-340.

BALOGH, (J.) and MAHUNKA (S.), 1969. The zoological results of the Hungarian soil Zoological Expeditions to South America. II. Acari. Oribatids from the material of the second expedition, II. Opusc. Zool., Budapest, 9 (1) : 31-68.

BALOGH (J.) and MAHUNKA (S.) 1974. Oribatid species (Acari) from Malaysian soils. - Acata Zool. Acad. Sci. Hung., 20 : 243-264.

BALOGH (J) and MAHUNKA (S). 1981. New data on the oribatid fauna of the Neogea : VI (Acari) - Acta. Zool.Acad. Sci. Hung., 27 (1-2) : 49-102.

BALOGH (J.) and MAHUNKA (S). 1983. Primitive oribatids of the Palaearctic region. Elsevier Science Publishers. B.V., Amsterdam. The Netherlands, 226pp. + 133 pls.

BANKS (N.), 1895. On the oribatidae of the United States. - Trans. Amer. Ent. Soc., 22 : 1-66.

BAYOUMI (B.M). 1979. Some new oribatid mites from Hungary (Acari : Oribatida) - Folia Entomol. Hung., 32 (1) : 11-14.

BAYOUMI (B.M.), 1980 a. Oribatid species from some Egyptian habitats (Acari : Oribatida). Folia Entomol. Hung., 33 (1) : 33-36.

BAYOUMI (B.M.), 1980b. Oribatid species from some Egyptian habitats (Acari. Oribatida). - Folia Entomol Hung., 33 (1) : 33-36.

BAYOUMI (B.M) and ALKHAUFA (M.S.), 1986. Three new oribatid mites (Acari : Oribatei) from Saudi Arabia - Bull. Soc. Amis. Sci. Lett. Poznam Ser. D. Sci. Biol., 25 (0) : 119-126.

BEHAN (V.M.), 1985. - Ceratozetidae of the Western North American arctic. Can. Entomol., 117 (11) : 1287-1366.

BEHAN (V.M.), 1986a. Ceratozetidae of the Western North American arctic. - Can. Ent., 117 (11) : 1287-1366.

BEHAN (V.M.), 1986b. Ceratozetidae (Acari : Oribatei) of the western North American subarctic. - The can. Ent., 118 : 991-1057.

BERLESE (A.), 1905. Acari Nuovi 4. - Redia, Bd. 2: 10-32.

BERLESE (A.), 1908. Elenco di geri. e specie move. di Acari. Redia, 5 : 1-15.

BERLESE, (A.), 1915. Acari. Nouri. Redia X.

BERLESE (A.), 1916. Centuria seconda di Acari Nuiovi. Redia, 12 : 19-67.

BHADURI (A.K.), CHAKRABARTI (D.K.) and RAYCHAUDHURI, (D.N.). 1974. - A new species of *Basilobelba* (Acari : Oribatei) from Calcutta, India - Acta Entomol., 25 (2) 86-89.

BHADURI (A.K). and RAYCHAUDHURI (D.N.), 1981. Taxonomy and distribution of oribatid mites (Acari) in India . - Insecta Matsumurana, 0 (23): 21-40.

BHATTACHARYA, (T.), BHADURI (A.K.) and RAYCHAUDHURI, (D.N)., 1974. - Soil oribatid mites of Santiniketan, Birbhum, West Bengal, (Acarina : Lohmanniidae) - Oriental insects 8 : 281-289.

BISWAS (P.K.) and BHADURI (A.K.) 1976. Studies on the oribatid mites (Acari) of the genus *Scheloribates* Berlese 1908 from West Bengal - Proc. 63rd Int. Sci. Cong. part III. 1-120.

BOOTH (C.). 1971. Fungal culture media. In: C. Booth (Ed.) Methods in Microbiology, Academic Press, London. pp. 49-94.

BULANOVA - ZACHVATKINA (E.M) 1967. Pancirhye Kelsciribatidy Izdatelstor. - Vyssaja skola, Moskwa, 1-254.

BUTCHER (J.W.), SNIDER (R.), and SNIDER (J.R.), 1971. Bioecology of Edaphic collembola and Acarina *Ann. Rev. Entomol.*, 16 : 249 - 288.

CALEY, (J.). 1976. Ultrastructural studies of the cysticercoids of *Moniezia expansa,* with special reference to the development of the cyst. *Ztschv. Parasitenk.*, 48 (3-4) : 251-262.

CANCELA DA FONSECA and STAMOU (J.P.), 1987. About a new species of oribatid mite from the Holomon forest. Greece : *Achipteria holomonensis*. n. sp. (Acarina, Oribatida). - Acarologia, 38 (1) : 91-96.

CHAKRABARTI, (D.K.), BHADURI (A.K.), and RAYCHAUDHURI (D.N.), 1973. A new subspecies and a few new records of soil oribatid mites (Acari : Oribatei) from West Bengal. - Sci. & Cult., 39 (8) : 365-366.

CHAKRABARTI, (D.K.) MONDAL (B.K.) and KUNDU (B.G.) 1978. Two new speceis of *Pseudotocepheus* (Acari : Otocepheidae) fromWest Bengal India. Indian. J. Acarol.,3 (1) : 43-50.

CHAKRABARTI, (D.K.) CHABRA (B.K.) and JAMES (M.M.), 1979. On a collection of oribatid mites (Acari) from Darjeeling, West Bengal. - Acarol. Newsl., 8 : 4.

CLEMENT (A.) and HAQ (M.A.) 1982. A new genus of oribatid mite (Acari : Oribatei) from Malabar. Entomon., 7 (4) : 451-456.

CLEMENT (A.) and HAQ (M.A.), 1984. - Biology of *Pelokylla malabarica* Clement and Haq 1982 (Acari : Oribatei). In: D.A. Griffiths and C.E. Bowman (Eds.) Acarology VI(2), Ellis Horwood Ltd., Chichester, England : 847-854.

CLEMENT (A.) and HAQ (M.A.), 1991. Two new species of oribatid mites (Acari : Oribatei) from Kerala. - In: G.K. Veeresh, D. Rajagopal and C.A. Virakkamath (Eds.) Advances in management and conservation of soil fauna, Oxford & IBH Publishing Co. (PVT) Ltd., New Delhi, 733-739.

COETZEE (L.), 1995. A new species of the genus *Saltatrichus* Coetzee, 1993. (Acari : Oribatida: Zetomotrichidae) from South Africa. - Navorsinge Van die Nasionale Museum, Bleoemfontein, 11 (1) : 1-12.

COLLOFF (M.J.) and SEYD (E.Z.), 1987. A new species of *Parachipteria* (Van der Hammen, 1952) (Acari : Cryptostigmata : Achipteriidae) from Montane sites of North wales. Acarologia, 28 (3): 277-284.

CORDO (H.A.) and DE LOACH (C.J.), 1976. - Biology of the waterhyacinth mite in Argentina . Weed Science, 224 (3) : 245-249.

CORPUZ-RAROS (L.A.), 1979. Philippine Oribatei (Acarina) 1. Preliminary list of species and descriptions of 40 new species. Philipp. Agric., 62 (1) : 82 pp.

CORPUZ - RAROS (L.A.), 1981. Philippine Oribatei (Acarina) IV. The genus *Peloribates* Berlese (Oribatuloidea: Haplozetidae). - Philipp. Ent., 4 (5) : 435-456.

CORPUZ-RAROS (L.A.) 1991. New species and new records of Philippine oribatid mites (Acari : Oribatida) mainly from the Visayas - Philippine J. Science, 120 (2): 133-154.

DENEGRI (G.M.), 1993. Review of oribatid mites as intermediate hosts of tapeworms of the Anoplocephalidae. - Experimental and Applied Acarology, 17: 567-580.

DENEGRI (G.M.), and ALZUET (A.B.), 1992. Seasonal variation of oribatid mite (Acarina) populations and their relationship to sheep cestodiasis in Argentina. - Veterinary parasitology, 42 : 157-161.

DHALLI (S.G.), BHADURI (A.K.) and RAYCHAUDHURI (D.N.), 1980. Taxonomic investagions of soil oribatid mites (Acari) of Sikkim Himalaya. - Indian. J. Acar., 5 : 50-55.

DURRANI (M.Z.) and HAMEED (C.A.), 1967a. *Scheloribates* spp. (Oribatei : Acarina), the vectors of *Moniezia benedini* (Moniez) (Anoplocephalidae : Cestoda) in W. Pakistan. - *Proc.* 18-19 Pak. sci. conf. (Jamshoro), Part III, Abstracts. : 13: 18-19, G. 16-17.

DURRANI (M.Z.) and HAMMED (C.A.), 1967b. On the development of *Moniezia expansa* in *Scheloribates* spp. - Proc. 18-19 Pak. Sci. Conf. (Jamshoro), Part III Abstracts : B20, G.18.

EBERMANN (E.), 1976 a. Oribatiden als Zwischenwirte des Ban dwirmes *Hymnolepis asymetrica* Jaintski, 1904. (Hymenolepidae). - Zool. Jb. Syst. Bol., 103 : 105-116.

EBERMANN (E.), 1976 b. Oribatiden (Oiribatei, Acari) als Zwischemnirte des Murmeltier Band wurnes *Ctenotaenia marmotae* (Frolich, 1802). - *Ztschr. purasitenk*, 303-312.

EBERMANN (E.), 1979. Experimentelle nut ersuchungen iiber die zwischennirtsspezifitat des Bandnurmes *Hymenolepis fraterna* stiles 1906. *Scheriftenreihe des Forschungzentrums, Graz* A. 8010. 14 pp.

EDNEY (J.M.) and KELLEY (G.W.) 1953. Some studies on *Galumna virginiensis* and *Moniezia expansa (Acarina : Oribatoidea :* Cestoda : Anoplocephalidae). - J. Tenn. Acad. Sci., 28(4) : 287-296.

ENGELBRECHT (C.M.) 1969. Some South African species of the genus *Galumna*. Von Heyden, 1826 (Acari : Galumnidae). - J. Entomol, Soc. S. Afr, 32 (1) : 99-122.

EWING (H.E.), 1910 - New Acarina from India, Trans . Acad. Sci. St. Louis., 19 : 113-121.

EWING (H.E.), 1913. New Acarina. I. Descriptions of new species and varieties from Iowa, Misoiri, Illinois, Indiana, and Ohio. Bull. Amer. Mus. Nat. Hist., XXXII : 93-121.

EWING (H.E.), 1917. - A synopsis of the genera of beetle mites with special reference to the North American fauna. Ann. Ent. Soc. Amer., 10 (2) : 117-132.

EWING (H.E.), 1918. - The beetle mite fauna of Mary's park, cost Range, Oregon (Acarina) - Ent. News., 29 : 31-90.

FRANK, (F). 1965. A contribution to the knowledge of oribatid mite vectors of *Moniezia expansa* in Bosna and Herzegovina. (Eng. Summary) Godisujak. Biol. Inst. Univ. Surajevo., 18 : 129-158.

FREEMAN (R.S.), 1952. The biology and lifehistory of *Monoecocestus* Beddard 1914, (Cestoda: Anoplocephalidae) from the Porcupine . J. Parasitol., 38 : 111-129.

FREEMAN (R.S.) and WOOLLEY (T.A.), 1987. *Xenillus itascensis* sp. n. (Acari: Oribatei), an intermediate host of *Monecocestus* spp. (Eucestoda : Anoplocephalidae). - INT. J. Acarol., 13 (2) 153-156.

FRITZ (G.) 1982. *Zygoribatula floridana* n. sp. (Acari. Oribatulidae) with a list of species in the genus. - Flo. Entomol., 65 (4) : 483-491.

FUJIKAWA (T). 1972. A contribution to the knowlege of the oribatid fauna of Hokkaido (Acari : Oribatei). - Insecta Matsumuna., 35 (3): 127-183.

FUJIKAWA (T.) 1986. Oribatid fauna from nare farm in Nayora (9). - Edaphologia., 35 : 27-38.

FUJIKAWA (T.) and AOKI (J.I.), 1969. Noteson two species of the genus *Perlohmannia* Berlese (Acari : Perlohmanidae). - Taxonomic notes on oribatid mites of Hokkaido 11 - Annot. Zoc., Jap., 42 (4) : 220-225.

FUJIKAWA (T.) and AOKI (J.I.), 1969A. Five species of the genus *Liacarus michael* (Acari : Liacaridae). - Taxoomic notes on oribatid mites of Hokkaido III. Ann. Zool. Jap., 43 : 158-165.

GERSON (U.), 1969. Moss-arthropod associations. - Bryologist, 72 : 495-500.

GLEASON (L.N.) and BUCKER (R.L.), 1979. Oribatid mites as intermediate hosts of certain anoplocephalid cestodes. - Trans. Ky. Acad. Sci., 40 (1-2) : 27-32.

GRABER (M.) and GRUEL (J.) 1969. Oribates vectures de *Moniezia expansa* (Rudolphi; 1810) du mounton dans la region de Fort Lamy (Eng. and Span. Summaries). *Rev. Elevage, et. vet. pays. trop. n.s.*, 22(4) : 521-527.

GRANDJEAN (F), 1935. Observations sur les Oribates. Bull. Mus. Hist. Nat., Paris. (2) 7, No. 4.

GRANDJEAN (F.), 1936. Les Oribates de Jean Frederic Hermann et de son pere - Ann. Soc. France, 105 : 27-110.

GRANDJEAN (F.), 1949. Formules anales gastronotiques, genitales et aggenitals de development numerique des pols chez les oribates. Bull. Soc. Zool. France 74 : 201-225.

FUJIKAWA (T). 1972. A contribution to the knowlege of the oribatid fauna of Hokkaido (Acari : Oribatei). - Insecta Matsumuna., 35 (3): 127-183.

FUJIKAWA (T.) 1986. Oribatid fauna from nare farm in Nayora (9). - Edaphologia., 35 : 27-38.

FUJIKAWA (T.) and AOKI (J.I.), 1969. Noteson two species of the genus *Perlohmannia* Berlese (Acari : Perlohmanidae). - Taxonomic notes on oribatid mites of Hokkaido 11 - Annot. Zoc., Jap., 42 (4) : 220-225.

FUJIKAWA (T.) and AOKI (J.I.), 1969A. Five species of the genus *Liacarus michael* (Acari : Liacaridae). - Taxaomic notes on oribatid mites of Hokkaido III. Ann. Zool. Jap., 43 : 158-165.

GERSON (U.), 1969. Moss-arthropod associations. - Bryologist, 72 : 495-500.

GLEASON (L.N.) and BUCKER (R.L.), 1979. Oribatid mites as intermediate hosts of certain anoplocephalid cestodes. - Trans. Ky. Acad. Sci., 40 (1-2) : 27-32.

GRABER (M.) and GRUEL (J.) 1969. Oribates vectures de *Moniezia expansa* (Rudolphi; 1810) du mounton dans la region de Fort Lamy (Eng. and Span. Summaries). *Rev. Elevage, et. vet. pays. trop. n.s.*, 22(4) : 521-527.

GRANDJEAN (F), 1935. Observations sur les Oribates. Bull. Mus. Hist. Nat., Paris. (2) 7, No. 4.

GRANDJEAN (F.), 1936. Les Oribates de Jean Frederic Hermann et de son pere - Ann. Soc. France, 105 : 27-110.

GRANDJEAN (F.), 1949. Formules anales gastronotiques, genitales et aggenitals de development numerique des pols chez les oribates. Bull. Soc. Zool. France 74 : 201-225.

GRANDJEAN (F.), 1954. Essai de classification des oribates. - Bull. Soc. Zool. France., 78 : 421-446.

GRANDJEAN (F.), 1965. Nouvelles observations sur les oribates (4 serie) (New observations on oribatids 4th series). - Acarologia, 7 (1) : 91-112.

GRAVES (R.C.), 1960. Ecological observations on the insects and other inhabitants of woody shelf fungi in the chicago area - Ann. Entomol. Soc. Amer., 53 : 61-78.

GROBLER (L.), 1993. Species of the genus *Zygoribatula* Berlese, 1916 (Acari, Oribatida, Oribatulidae) from South Africa L. New species. - Navors, Nas. Mus. Blocmfontein, 9 (3) : 49-76.

GROBLER (L.), 1994. Species of the genus *Zygoribatula* Berlese,1916 (Acari, Oribatida, Oribatulidae) from the South Africa. III *Zygoribatula contracta* spec. nov. and *Zygoribatula setosa* Evans, 1953. Navors. Nas. Mus. Bloemfontein, 10 (6) : 261-279.

GROBLER (L.) and KOK (D.J.), 1993. Species of the genus Zygoribatula Berlese 1916. (Acari : Oribatida: Oribatulidae) from South Africa II. New and existing speices. Navors. Nas. Mus. Bloemfontein, 9 (6) : 181-212.

HAMMER (M.), 1953. A new species of oribatid mite from Queensland. - Australian J. Zool., 1 (2) : 236-238.

HAMMER (M), 1958. Investigations on the oribatid fauna of the Andes mountains. 1. The Argentine and Bolivia. - Biol. Skr. Dan. Vid. Selsk., 10(1) : 1-129.

HAMMER (M.), 1967. Investigations on the oribatid fauna of New Zealand II. Biol. Skr. Dan. Vid. Selsk., 15(2) : 1-108.

HAMMER (M.), 1971. On some oribatids from Vitilevu, the Fiji Islands. Biol. - Skr. Dam. Vid. Selsk., 16: 1-60.

HAMMER (M.), 1972. Investigations of the oribatid fauna of Tahiti and on some oribatids fauna on the atoll Rangiroa. - Biol. Skr. Dan. Vid. Selsk., 19 (3) : 1-65.

HAMMER (M.), 1973. Oribatids from Tongatapu and Eva, the Tonga Islands from Upolu, Western Samoa. - Biol. Skr., Dan.Vid.Selsk., 20 (3) : 1-70.

HAMMER (M.), 1975. On some oribatids from Central Sahara (Acari : Oribatidae) . Skeenstrupia, 3 (18): 187-196.

HAMMER (M.), 1979. Investigations on the oribatid fauna of Java - Biol. Skr. Dan. Vid. Selsk., 22 : 1-79.

HAMMER (M.), 1982. On a collection of oribatid mites from Bali, Indonesia (Acari : Cryptostimata). - Ent. Scand., 13 (4): 445-464.

HANLON (R.D.G.), 1981. Some factors influencing microbial growth on soil animal faeces. II. Bacterial and fungal growth on small animal faeces. *Pedobiologia,* 21 : 264 -270.

HAQ (M.A.), 1978a. Some aspects on the taxonomy of oribatid mites from the soils of Kerala. - In C.A. Edwards and G.K. Veeresh (Eds.) Soil Biology and Ecology in India, UAS Tech. Series, No. 22 : 117-134.

HAQ (M.A.), 1978b. Breeding biology of oribatid mites. - In: C.A. Edwards and G.K. Veeresh (Eds.) Soil Biology and Ecology in India, UAS Tech. Ser., No. 22: 145-151.

HAQ (M.A.), 1979a. A new species of *Xiphohelba* (Acari : Basilobelbidae) from Kerala. - Indian. J. Acarol., 4 (1) : 14-18.

HAQ (M.A.), 1979b. On the postembryonic development of *Galumna flabellifera orientalis* (Acari : Oribatei), an intermediate host of the cestode parasite, *Moniezia* sp. - Progress in Soil Biology and Ecology in India, - UAS. Tech. Ser., No. 22: 37-39.

HAQ (M.A.), 1980. A new species of Xiphobelba (Acari : Basilobelbidae) from Kerala . - Indian J. Acarol., 4 (1): 14-18.

HAQ (M.A), 1982. Feeding habits of ten species of oribatid mites (Acari : Oribatei) from the soils of Malabar, South India. - J . Acarology, 6 : 39-50.

HAQ (M.A.), 1984. The role of microbes in the nutrition of a lohmanniid mite (Acari : Oribatei). In : D.A. Griffiths and C.E. Bowman (Eds.), Acarology VI, (2), Ellis Horwood Ltd., Chichester, pp. 838-846.

HAQ (M.A.), 1988. An appraisal on oribatid vectors - In : K.S. Anantha Subramanian, P. Venketesan and S. Sivaraman (Eds.) Bicovas Proceedings, 1, New Metro Printers, India : 93-108.

HAQ (M.A.), 1990. Mites in disease transmission. - In: N. Balakrishnan Nair (Ed.) Proc. II Kerala Sci. Congr., Thiruvananthapuram, pp. 239-240.

HAQ (M.A.), 1991. New natural oribatid vectors from Kerala. In : G.K. Veeresh, D. Rajagopal and C.A. Viraktamath (Eds.) Advances in Management and conservation of soil fauna. Oxford & IBH Publ. Co. Pvt. Ltd., New Delhi, pp. 259-264.

HAQ (M.A.), 1997. Nutritional diversity of oribatid mites in relation to soil fertility. Karnataka Science Journal, Dharward, pp. 37-52.

HAQ (M.A.) and CLEMENT (A.), 1981. Spermatophore deposition and transfer in *Pelokylla malabarica* (Acari : Oribatei). - *Entomon*, 6 (2) : 135-141.

HAQ (M.A.) and CLEMENT (A.), 1995. Two new species of Lohmaniid mites (Acari : Oribatei) from Malabar, India. - J. Acarol., 13 (1 & 2) : 23-28.

HAQ (M.A.) and PRABHOO (N.R.), 1976. Observations on the feeding habits of oribatid mites from the soils of Kerala (Acarina: Cryptostigmata) Panphytophages. - Entomon, 1 (2) : 133-137.

HAQ (M.A.) and RAMANI (N.), 1984. Postembryonic development of *Paralamellobates bengalensis* (Acari : Oribatei) parasitic on *Dioscorea alata*. D.A.Griffiths and C.E. Bowman (Eds.) Acarology VI(2), Ellis Horwood Ltd., Chichester, England , pp.819 - 825.

HARDING (D.J.L.) and STUTTARD (R.A.), 1974. - Microarthropods. - G.H. Dickinson and C.F.J. Pough (Eds.) In : Biology of Plant litter composition, Academic Press, London, pp.484-532.

HARLON (R.D.G.), 1981. Some factors influencing microbial growth on soil animal faeces II. Bacterial and fungal growth on small animals faeces - Pedobiologia, 21 : 264 - 270.

HARRIGAN (W.F.) and MARGARET (E.M.), 1966. Laboratory methods in Microbiology, Academic Press, London, 362 pp.

HARTENSTEIN (R.), 1962. Soil Oribatei 1. Feeding specificity among forest soil Oribatei (Acarina). - Ann. Entomol. Soc. Amer., 55 (2) : 202-206.

HARTENSTEIN (R.), 1962a. Soil Oribatei II. *Belba Kingi* new species. (Acarina : Belbidae) and a study of its life history. Ann. Entomol. Soc. Amer., 55 (4) : 357-361.

HARTENSTEIN (R.), 1962b. Soil Oribatei III. Studies on the development, biology and ecology of *Metabelba montana* (Kulez) (Acarina : Belbidae) - Ann. Entomol . Soc. Amer., 55 (4) : 36-67.

HERMANN, (J.F.), 1804. Memorie Apterologique - Strasbourg : 87-95.

ITURRONDOBEITIA (J.C.) and ARILLLO (A.), 1997. A new oppiid mite (Acarina, Oribatida, Oppiidae) from the Basque country (Northern Spain). *Medioppia producta*, a new species of oppiid mite resembling *Medioppia melisi* (Valle, 1949) is described from a cave in Biscay (North Spain). Acarologia, XXXVIII. Fase. 2.

JACOT (A.P.), 1933. Two winged moss mites of the Nilgiri Hills. - Rec. Ind. Mus. Calcutta, 35 : 371-374.

JAIKUMAR (M.), HAQ (M.A.) and RAMANI (N.), 1994. Lohmanniid mites from Kerala, India - IV. A new species of *Annectacarus* Grandjean, 1950. - Acarologia, 35 (1) : 75-82.

KARDAR (M.A.H.), 1975. Two new species of *Oribatella* Banks, 1985 (Oribatei: Oribatellidae) from India. - Annot. Zool. Jap., 48 (1) : 60-64.

KARDAR (M.A.H), 1976. Four new species of *Scheloribates* (Oribatei : Oribatulidae) from India. - Indian J. Acarol., 1 : 38 - 42.

KARDAR (M.A.H.), 1988. Three new species of Oribatei (Acari : Cryptostigmata) from South Arabia. - In : G.P. Channa Basavanna and C.A. Viraktamath (Eds.) Progress in Acarology, 1: Oxford & IBH Publ. Co. Pvt. Ltd., New Delhi, pp. 291-294.

KATES (K.C.) and RUNKELL (C.E.), 1948. Observations on the oribatid mite vectors of *Moniezia expansa* on the pastures, with a report of several new vectors from U.S. - Proc. Helm. Soc. Wash., 15 (1) : 18-33.

KOCH (C.L.), 1836. Deutschlands Crustacean, Myriapoden and Arachniden. 3 (11, 19, 20).

KOCH (C.L.), 1841. - Deutschlands Crustacean, Myriapoden and Arachniden. - Acarina : Heft., Regenburg, 31-35.

KRIVOLUTSKIJ (D.A.), 1971a. Some new oribatid mites (Acariformes) from Central Asia. - Vestucesk Spoleenosti Zool., 35 (1) : 35-39.

KRIVOLUTSKIJ (D.A.), 1971b. Novye Vioy Oribateiiz Vostochnoi krigizii (Some new oribatei from eastern Kirgisia). - Zool. Zn., 50 (6) : 939 - 942.

KRIVOLUTSKIJ (D.A) DRUK(A.) and LASKOVA (L.M.), 1980. A new subfossil genus of oribatid mites from the mammoth burial on the kirgilyakh Creek. DOK I Akad Nank USSR, 252 (5) : 1246 - 1247.

KRULL (W.H.), 1939. - Observations on the distribution and ecology of the oribatid mites - J. Wash. Acad. Sci., 29: (12) 519-528.

KRULL (W.H.), 1939 a. On the life-history of *Moniezia expansa* and *Cittotaenia* sp. (Cestoda : Anoplocephalidae) - Proc. Helminthol. Soc. Wash., 6 (1) : 10-11.

KUHNELT (W.), 1961. Soil biology with special reference to the animal Kingdom, Faber and Faber Ltd., London, 397 pp.

KUKOR (J.J.) and MARTIN (M.M.), 1987. Nutritional ecology of fungus feeding arthropods - In : F. Slansky, Jr. and J.G. Rodriguez (Eds.) Nutritional ecology

of insects, mites, spiders and related invertebrates. - A. Wiley interscience Publications, New York, Chichester, pp. 791-814.

KUZNETSOV (M I.), 1970. The time needed for the development of 2 species of *Moniezia* cysticercoids in the oribatid mite, *Scheloribates laevigatus* under natural conditions (Eng. Summary). In : E.M. Bulanova - Zakhvatkina *et. al.,* (Eds.) Oribatei and their role in the process of the soil formation. Villinus Acad. Sci. Lth. Ssr. Inst. Zool. Parasitol., : 227.

LAWREY (J.D.), 1987. Nutritional ecology of Lichen/moss arthropods - In: F. Slansky and J.G. Rodriguez (Eds.) Nutritional ecology of insects, mites spiders and related invertebrates. - A Wiley interscience publications, NewYork, pp. 209-233.

LITTLEWOOD (C.E.), 1969. A surface sterilisation technique used in feeding algae to oribatei. - In: G.O. Evans (Ed.) Proc. 2nd Int. Cong. Acarology, Hungarian Academy of Sciences, Budapest, pp. 53-56.

LOCKWOOD (C.E.), 1977. - Fungistasis in Soil. - Biol. Rev., 52; 1-43.

LUXTON (M.), 1966. Laboratory studies on the feeding habits of saltmarsh Acarina with notes on their behaviour. - *Acarologia*, 8(1) : 163-175.

LUXTON (M.), 1972. Studies on the oribatid mites of Danish beech Wood soil. - Pedobiologea, 12 (5) : 434 - 463.

LUXTON (M.), 1985. Cryptostigmata: Arachnida : Acari A concise review . Fauna NZ., 0 (7) : 3 - 99.

MAHUNKA (S.), 1973. Neu und interessante milben aus dem Genfer Museum. XI. Mere und wening bekannte oribatiden aus Rhodesian (Acari). - Arch. Sci. Geneva, 26 (3): 205-225.

MAHUNKA (S.), 1976. New and interesting mites from the museum of Genf. XVIII. Oribatei from Hong Kong (Acari). - Aarologia, 18 (2) : 360 - 372.

MAHUNKA (S.), 1978. New and intersting mites from the Geneva museum XVII. A first survey of the oribatid (Acari) fauna of Mauritius, Reunion and the Seychelles. 1. Rev. Suisse. Zool., 85 : 177-236.

MAHUNKA (S.), 1979. Neue und interessante milben aus dem genfer museum XXXVI. A compendium of the oribatid (Acari) fauna of Mauritius Re union and the Seychelles. IS. II. - Rev.. Suisse. Zool., 85 (2) : 307- 340.

MAHUNKA (S.), 1980a. Oribatids from Tunisian soils (Acari : Oribatida) : 1. - Folia Ent. Hung., 33 (1) : 123-134.

MAHUNKA (S.), 1980b. Neue und intiressante milben aus Genfer strinati in Guatemala (Acari : Oribatida) - Acarologia., 21 (1) : 133-142.

MAHUNKA (S.), 1980c. Neue und interresante Milben aus dem Genfer Museum. XXXVIII. Oribatids (Acari) from Monte Susana (Tierra del fuego, Argentina). - Rev. Suisse. Zool., 87 : 155-181.

MAHUNKA (S.), 1982. New and interesting mites from the Geneva Museum (Switzerland) - Oribatida : Americana : 5 Costa Rica (Acari). - Arch. Sci., (Geneva), 35 (2) : 179-194.

MAHUNKA (S.), 1983. Oribatids from the eastern part of the Ethiopian Region (Acari). - Acta. Zool. Acad. Sci. Hung., 29 (4): 397-440.

MAHUNKA (S.), 1984. New and interesting mites from Geneva museum (Switzerland) 48. American Oribatida : 8 Paraguay. 1. (Acari). - Rev. Suisse. Zool., 91 (1) : 109 - 148.

MAHUNKA (S.), 1985. Oribatids from Africa (Acari : Oribatida) 1. Acta Zool. Hung., 31 (4) : 295-340.

MAHUNKA (S.), 1985b. Neue and intressante milben aus dem Genfer museum. LIV. Oribatids from South India I. (Acari - Oribatida) . - Rev. Suisse. Zool., 92 (2) : 367-383.

MAHUNKA (S.), 1986. Oribatids from Africa (Acari : Oribatidae) III. Folia Entomol. Hung., 47 : 41 - 74.

MAHUNKA (S.), 1988a. The oribatid fauna of Tanzania (Acari) II. - Ann. Hist. Nat. Mus. Hung., 80 : 189-213.

MAHUNKA (S.), 1988 b. New and interesting mites from the geneva museum LXI. Oribatids from Sabah (East Malaysia) III. (Acari: Oribatida). - Rev. Suisse. Zool., 95 (3) : 817-888.

MAHUNKA (S), 1988c. New and interesting mites from the geneva museum. Oribatids from Mauritius Reunion and Seychelles III (Acari : Oribatidae). - Rev. Suisse. Zool., 95 (4) : 1079-1115.

MAHUNKA (S.), 1988d. A survey of the oribatid fauna (Acari) of Vietnam II. Acta. Zool. Hung., 34 (2-3) : 215 - 246.

MAHUNKA (S.), 1989a. Oribatids from the Southern Hemisphere (Acari : Oribatida). - Acta. Zool. Hung., 35 (1-2) : 41-79.

MAHUNKA (S.). 1989b. Oribatids from Southern Hemisphere (Acari-oribatida). - Acta. Zool. Hung, 35(1-2) : 41-79.

MAHUNKA (S), 1989c. A survey of the oribatid fauna (Acari) of Vietnam, III. - Folia Entomol. Hung., 50 (15): 47-59.

MAHUNKA (S.),1990. New and interesting mites from the Geneva museum LXXI. New Oribatids (Acari) from the Philippines and Indonesia. - Arch. Sci., Geneva, 43 (3) : 453-460.

MAHUNKA (S.), 1991a. New and interesting mites from the Geneva museum LXVIII. Oribatids from Sabah (East Malaysia) IV (Acari : Oribatida). - Rev. Suisse Zool., 98 (1): 185-206.

MAHUNKA (S), 1991b. New and interesting mites from the Geneva museum LXX. Oribatids from the Cape Verde islands II (Acari : Oribatida). Rev. Suisse. Zool., 98 (3) : 567-580.

MAHUNKA (S.), 1994 a. Further oribatid species from the Comoro island (Acari : Oribatida). - Acta. Zool. Acad. Sci. Hung., 40 (3) : 273-288.

MAHUNKA (S.), 1994b. Two new galumnid species (Acari Oribatida) from Thailand. - Acta. Zool. Acad. Sci. Hung., 40 : 351-357.

MAHUNKA (S.), 1995. Oribatids from Sabah, East Malaysia (Acari, Oribatida), Parakalummoidea n. stat. and Galumnoidea. - Trop. Zool. 8(2) : 269-308.

MELVIN, (D.M.), 1952. Studies on the life cycle and biology of *Monoecocestus sigmodontis* (Cestoda : Anoplocephalidae) from the cotton rat, *Sigmodon hispidus*. - J. Parasitol., 38 : 346-355.

MIKO (L.) and TRAVE (J.), 1996. Hungarobelbidae N. Fam., with a description of *Hungarobelba pyrenaica* n.sp. (Acarina : Oribatida). - Acarologia, XXXVIII, fase. 2.

MITCHELL (M.J) and PARKINSON (D.), 1976. Fungal feeding of oribatid mites (Acari : Cryptostigmata) in an aspen woodland soil. - Ecology, 57 (2) : 302-312.

MURAI (E.), 1989. *Ceratozetes gracilis* (Michael, 1884) (Acari : Oribatida), an intermediate host of *Vampirolepis asymmetrica* (Janicki, 1904) (Cestoda : Hymenolepididae). - Miscellanea Zoologica Hungarica, 5: 13-19.

NADAKAL, (A.M.), 1960a. *Protoschelobates* sp., an oribatid mite from India, as a potential vector of the sheep tapeworms, *Moniezia benedini* and *Moniezia expansa*. - J. Parasitol., 46 (1): 817.

NADAKAL, (A.M.), 1960b. Observations on the life cycle of *Avitellina centripunctata* (Rivolta, 1874), an anoplocephaline cestode from sheep and goats. - J. Parasitol., 46 (2) : 12.

NARASAPUR (V.S.), 1974a. A note on the vectors of *Avitellina lahorea* (Woodland, 1927) in India. - Indian Vet. J., 51 : 54-56.

NARASAPUR (V.S.) 1974 b. Ecological and biological studies on the oribatid fauna of India (Bombay region) together with observations on the life cycle of common anoplocephalid tapeworms. - Ind. Vet. J., 51 (2) : 165-166.

NARASAPUR (V.S.), 1976. Intermediate hosts and larval development of *Moniezia benedini* (Moniez., *1879)* in Indian. - Indian J. Parasitol., 62 (5) : 720.

NARASAPUR, (V.S.), 1977. Observations on the biology of the sheep tapeworm *Moniezia expansa* in India. - Ind. J. Anim. Sci., 46 (11) : 603-609.

NARASAPUR, (V.S.) and PROKOPIC (J.), 1979. The influence of temperature on the development of *Moniezia expansa* in oribatid mites. Folia parasitol., (paragues), 26 (3) : 239-243.

NAWAR (M.S.) and BOROLOSSY (E.), 1993. *Zygoribatula grandjeani*, a new species of oribatid mite from Egypt. - Acarologia, 34 (3) : 273-276.

NAZAROA (S.A.), 1970. Oribatid mites of the pasture desert zone of Uzbekistan, the intermediate hosts of 2 speceis of *Moniezia* (Eng. summary). - In : E.M. Bulanova Zakhava kina *et. al.* (Eds.) Oribatei and their role in the process of the soil formation. - Villinus Acad. Sci. Litter. SR. Just. Zool. Parasitol., 223.

NEENA (P.) and HAQ (M.A.), 1988. - Feeding specificity of six species of soil oribatids (Acari : Oribatei) from Kerala, India. - In: G.P. Channabasavanna and C.A. Virakthamath (Eds.) Progress in Acarology, 1: Oxford & IBH Publishing Co. Pvt. Ltd., New Delhi, pp.503-508.

NEENA (P.) and HAQ (M.A.), 1992. Mycophagy in oribatid mites. - In : M.A. Haq and N. Ramani (Eds.) Man, mites and Environment, Anjengo Publications, Calicut University, p.62-71.

NEVIN (F.R.), 1976. Three new achipteriids from the Catskills of New York state, U.S.A. (Acari : Cryptostigmata : Oribatei: Oribatelloidea: Achipteriidae). - J. N. Y Entomol. Soc., 84 (4): 246-253.

NORTON (R.A.), 1982. *Arborichthonius,* new genus, an unusual enarthronote soil mite (Acarina : Oribatei) from Ontario, Canada. - Proc. Entomol, Soc. Wash., 84 (1) : 85-86.

NORTON (R.A), 1985. Aspects of the biology and biosystematics of soil arachnids particularly saprophagous and mycophagous mites. - *Questiones entomologicae*, 21: 523-541.

NORTON (R.A.), BONAMO (P.M.), GRIERSON (J.D.) and SHEAR (W.A.), 1988a. Oribatid mite fossils from a terrestrial devonian deposit near Gilboa, New York. - J. Palentol., 62 (12) : 259-269.

NORTON (R.A.), BONAMO (P.M.), GRIERSON (J.D.) and SHEAR (W.A.), 1988b. Fossil mites from the devonian of New York state. - In : G.P. Channabasavanna and C. A. Vivakammath (Eds.) Progress in Acarology, 1, Oxford and IBH Publ.Co., Pvt. Ltd., India , pp.271-277.

OKHUBO (N.), 1984. Several species of *Trichogalumna* (Acarina , Oribatida) from Japan. - Acarologia, 25 (3): 293-306.

OKHUBO (N.), 1996. Some oppiid species (Acari : Oribatida) from Chichijima island in the Bonin islands with Notes on morphological terms of Oppiidae. - Acarologia, XXXVII (3).

PEARCE (N.D.R.), 1906. On some oribatidae from the Sikkim Himalaya. - J. Roy. Micr. Soc., 269-273.

PEREZ-INIGO (C.), 1976a. Three new species of oribatids from Central Spain. EOS. (Madrid), 52 (1-4) : 175 - 184.

PEREZ-INIGO (C.), 1976. Acari (Oribatei) from the island of Teresite. II. A caros oribatidos de la isla de Tenerife 11. - Contribucion, 51 (1-4) : 85-141.

PEREZ-INIGO (C.) and PENA (M.A.) 1994. Soil oribatid mites (Acari: oribatei) from Gran Canaria (I) Oribatidos edificos (Acari : Oribatei) degran Canaria. - Bol. Asoc. Esp. Entomol., 18 (1-2) : 65-77.

PEREZ-INIGO (C.) and SARASOLA (M.), 1995. Soil oribatid mites from Uruguay (Acari Oribatei), three new species from the department of Cerro Largo. Acarologia, 36 (1) : 65-74.

PEREZ-INIGO (C.) and BAGGIO (D.), 1996. Oribatid edaphiques due Bresil (IX) Oribates de L'etat de Minas gerais premicre partie. - Acarologia, XXXVII (1).

POTEMKINA (V.A.), 1941. Contribution on the biology of *Moniezia expansa* (Rudolphi, 1810), a tapeworm parasite in sheep and goats. Acad. Sci. USSR., 30 (5) : 474-476.

POTEMKINA (V.A.), 1944a. On the decipherment of the biological cycle of *Moniezia benedini* (Moniez, 1979), a tapeworm parasitic in cattle and other domestic animals. - Acad. Sci. USSR., 42 (3) : 146-148.

POTEMKINA (V.A.) 1944b. contribution to the study of the development of *Thysaniezia ovilla* (Rivolta, 1878), a tapeworm parasitic in ruminants. Acad. Sci. USSR., 43 (1) 43-44.

POTEMKINA (V.A.), 1951. Moniezia teljat. Truday. gelm. Lab., 5: 299-302.

PRASAD (V.), 1974. Important families of Indian Cryptostigmata. - All India Summer Institute in Acarology, June 17 - July 13. Dept of Entomology U.A.S. Bangalore, 48-52.

PROKOPIC (J.), 1967. Bionomische studien uber band wurmer des Gattung *Moniezia* (Russian and Eng. Summaries) *Ang. Parasitol.*, 8(4): 200-209.

RAJSKI (A.), 1959. Mechowce (Acari : Oribatei) jako zywiciele posre dni tasiemcow (Cestodes: Anoplocephalata) in Swietle literatury. - Zes. nauk. UAM. Biologia, Poznam, 2 : 163-192.

RAJSKI (A.), 1960. Quantitative occurrence of the chief intermediate hosts of *Moniezia expansa* (Rend) in the vicinity of Poznan (in polish). - Wiad Parazyt., 7 : 39-42.

RAMANI (N.) and HAQ (M.A.), 1987. Biology of *Scheloribates decarinatus* (Acari : Oribatis) inhabiting *Chromolaena odorata.* - J. Soil. Biol. Ecol., 7 (1) : 27-35.

RAMANI (N.) and HAQ (M.A.), 1988. Developmental studies of *Uracrobates indicus* (Acari : Oribatei) inhabiting *Mangifera indica.* In : G.P. ChannaBasavanna and C.A. Viraktamath (Eds.) Progress in Acarology, I., Oxford & IBH Publishing Co., Pvt. Ltd., New Delhi, pp.483-489.

RAMANI (N.) and HAQ (M.A.), 1990a. Oribatid mites from coconut palm. I.A. new species of *Uracrobates* (Acari : Oribatei) from Kerala. India. - Acrologia, 31 (3) : 297-302.

RAMANI (N.) and HAQ (M.A.), 1990b. Oribatid mites from coconut palm 2. A new species of *Notogalumna* (Acari : Oribatei) from Kerala, India - Acarologia, 31 (4) : 401-404.

RAMANI (N.) and HAQ (M.A.), 1992. Oribatid mites from coconut palm 3. A new species of *Afronothrus* (Acari : Oribatei : Trypochthoniidae) from Kerala (India). - Acarologia, 33 (2) : 207 to 212.

RAYSKI (C), 1947. Sheep tapeworms and their intermediate hosts. *Scottish Farmer,* No. 2823 (55) ; 284.

RIHA (G), 1951. Zur Okologie der Oribatiden in Kalkstein boden. Zool. System, 80 : 497-500.

ROCKETT (C.L.), 1980. Nematode predation by oribatid mites (Acari : Oribatida). - *Int. J. Acarol.*, 6 (3) : 219-224.

ROCKETT (C.L.) and WOODRING (J.P.), 1966. Oribatid mites as predators of soil nematodes. - Ann. Entomol. Soc. Amer., 59 (4) : 669-671.

ROCKETT (C.L.) and WOODRING (J.P.), 1966a. Biological investigations on a new species of *Ceratozetes* and of *Pergalumna* (Acarina : Cryptostigmata). - Acarologia, 8 : 511-520.

ROBERTS (F.H.S.), 1953. *Zygoribatula longiporosa* Hammer (Oribatei: Acarina) an intermediate host of *Moniezia benedini* (Moniez) (Anoplocephalidae : Cestoda) in Australia. Austral. J. Zool., 1(2) : 239-241.

ROMERO (J.), DENEGRI (G.), NUIN (C.), VAENA (A.),and ESPINOSA (G.), 1989. Experimental reproduction of cysticercoids from *Anoplocephala perfoliata* Blanchard, 1848 in *Scheloribates.* sp. Berlese 1908 (Acarina : Oribatidae). - *Zentralbl. Veterinar. med. Reihie, B* 36 : 442-446.

RUNKELL (C.E.) and KATES (K.C.), 1947. A new intermediate host (*Protoscheloribates seghetii,* n. sp. Acarina : Scheloribatidae) of the sheep tapeworm *Moniezia expansa.* - *Proc. Helm. Soc. Wash.*, 14 (2) : 64-67.

SALDYBINA (E.S.), 1953. Zarazajemost razlicnych vidow oribatid I. rol. ich w. epizootologii moniezioza na past wiscach gorkowskoj oblasti. - *Rab. of elm.* (75-1 . a*cad. K. I.* Skrjabina), 740-746.

SANYAL (A.K.) and BHADURI (A.K.), 1983. A new species of the genus *Trichthonius*, new record (Acarina : Oribatei) from India. - Acarologia, 24 (2) : 219-221.

SCHUSTER (R.), 1956. Der Anteil der oribatiden an den Zergeit. - Z ungs forgangen in Borden Z, Morph. Aekol. Tiere., 45 : 1-33.

SCHUSTER (R.), 1986. Boden bewohnede Milben (Acari) ans Niederschsen und andersen region Deutschlands (BRD). - Branschw. Naturk. Schr., 2 : 519 - 525.

SCHUSTER (R.), 1988. Untersuchugen zur Epizootiologic der. Monieziose des schafes in der DDR Unter besounderer Beriicksichtigurg dez zwischenwirte Monatshefte fiir veterinamectizin, 43: 223-235.

SCHUSTER (R.), 1995. Experimental studies of the influence of *Moniezia expansa* infection in oribatid mites. - Journal of Helminthology 69: 177-179.

SCHWEIZER (J.), 1922. Beitrag zur Kenntnis der Terrestrischen Milben fauna der Schweig. - Verh. Naturf. Ges. Basel., 33 : 23-112.

SEASTEDT (T.R.), 1984. The role of microarthropods in decomposition and mineralization processes. - Ann. Rev. Entomol., 29 : 25-46.

SELLNICK (M.), 1925. Fauna sumatrensis (Beitrag No.6) Oribatidae (Acari). - Suppl. Ent. Berlin., 11 : 79-89.

SELLNICK (M.), 1928. Formenkneis. Hornmithen, Oribatei. 1-42. In : P. Brohmer, P. Ehrmann and G. Ulmer (Eds.) Tierwelt Mitteleuropas, 3. Quella and Meyer, Laipzig.

SENGBUSCH (H.G.), 1954. Studies on life history of three oribatid mites with observation on other species (Acarina : Oribatei) - Ann. Entomol. Soc. Amer., 47 (4) : 646-667.

SENGBUSCH (H.G.), 1976. Review of oribatid mite-anoplocephalan relationship (Acari : Oribatei : Cestoda : Anoplocephalidae). - In: D.L. Dindal (Ed.), The Biology of Oribatid mites. - State University of New York, pp.87-102.

SENGBUSCH (H.G.), 1977. Review of oribatid mite anoplocephaline - tapeworm relationship (Acari : Oribatei: cestoda: Anoplacephalidae). - In : D. Dindal (Ed.) Biology of Oribatid mites, SUNY, New York : 65: 70.

SENGBUSCH (H.G.) and SENBUSCH (C.H), 1970. Postembryonic development of *Oppia nitens* (Acarina : Oribatei). - J.N. York. Entomol. Soc., 78 (4) : 207-214.

SENIAZAK (S.), 1977. The systematic position of moss mites of the genus *Anachipteria* Grandjean, 1935 (Acarina: Oribatei) in the light of ontogenetic studies. - Acarologia, 18 (4): 740-747.

SHEALS (J.G.), 1956. Notes on a collection of soil acari. - *Ent. Mon. mag.*, 92 : 99-103.

SHEREEF (G.M.), 1972. Observations on oribatid mites in laboratory cultures - Acarologia, 14 (2) : 281-291.

SOLDATOVA (L.G.), 1945. A contribution to the study of the biology of oribatid mites, intermediate hosts of cestodes of the family anoplocephalidae. - Comples Rendus (Doklady) del'Academic des sciences de 1' USSR, 44 (8) : 343-344.

SPASKII, (A.A.), 1951. Anoplocephalate tapeworm of domestic and wild animals. - In : K.I. Skrajabin (Eds.) Essentials of Cestodology (Eng. trans.) Birron and Cole, 1961. *Nat. Sci. Found.*, Washington.

STARY (J.) and BLOCK (W.) 1995. Oribatid mites (Acari-Oirbatida) of South Georgia. - South Atlantic. J. Nat. Hist., 29 (6) : 1469 - 1481.

STOLL (N.R.), 1938. Tapeworm studies. VII. Variation in pasture infestation with *Moniezia expansa*. - *J. parasitol.*, 24 (6) : 527-545.

STRONG (J.), 1967. Ecology of terrestrial arthropods at palmer station, Antarctic peninsula. - In: J.L. Gressitt (Ed.) Entomology of Antartica, American Geophysical Union, Washington, 357-371.

STUNKARD (H.W.), 1934. Studies on the life history of anoplocephaline cestodes. - *Ztschr parasitenk.*, 6: 481-501.

STUNKARD (H.W.), 1937. The life cycle of *Moniezia expansa*. - *Biol. Bull.*, 73: 370.

STUNKARD (H.W.), 1939. The role of oribatid mites as transmitting agents and intermediate hosts of ovine cestodes. *Verhandi, VII. Intern. Kong. Entomol.*, Berlin, 1938, 3 : 1669-1674.

STUNKARD (H.W.), 1940a. The morphology and life history of the cestode, *Bertiella studeri*. - *Am. J. Trop. Med.*, 20: 305-333.

STUNKARD (H.W), 1940b. Observations on the development of the cestode, *Bertiella studeri*. - *Proc. III Intern. Con. Microbiol.*, New York, 461-462.

STUNKARD (H.W), 1941. Studies on the life history of the anoplocephaline cestodes of hares and rabbits. - *J. Parasitol.*, 27 : 299-325.

STUNKARD (H.W), 1944. Studies on the life-history of the oribatid mite *Galumna* sp., intermediate host of *Moniezia expansa*. - Anat. Rec. 89 : 550.

SUBIAS (L.S.) and ARILLO (H.), 1996. *Serratoppia guanicola* sp. nov. from a cave in central spain. Iberian speceis of genus serratopia (Acariformes: Oribatida, Oppiidae). - Acarologia, XXXVIII (I).

TARMAN (K.), 1968. Biol. Vest., 16 : 67-76.

TOLSTIKOV (A.V.), 1997. *Epidamaeus joshnstoni*, a new Damaeid mite (Acariformes : Oribatei) from Kazakhstan. - Acarologia, XXXVIII (2).

TRAVE (J.), 1963. Ecologie et biologie des oribates (Acariens) Saxicoles et arboricoles, Vie Miliev (Suppl)., 14 : 1-267.

TRAVE (J.), 1969. Sur le pueblement des lichens crustaces des lles sarvages par les oribates (Acariens). - Rev. Ecol. Biol. Sol., 6 : 239 - 248.

TRAVE (J.), 1981. *Vaghia blascoi* sp. nov. (Galumnidae), an oribatid mite from Palani mountain in Southern India. - Acarologia, 22 (3) : 325-332.

VITZTHUM (H.G.), 1943. Acarina, In H.G. Bronn's Klassen und ordungngen des Tierrcichus, leipzig, 5 : 1-1011.

WALLWORK (J.A.), 1958. - Notes on the feeding behaviour of some forest soil Acarina. - Oikos, 9 (2) : 260-271.

WALLWORK (J.A.) , 1960. Observation on the behaviour of some oribatid mites in experimentally controlled temperature gradients. - *Proc. Zool. Soc. Lon.*, 619-627.

WALLWORK (J.A.), 1967. - Acari. - In: A. Burges and F. Raw (Eds.) Soil Biology, Academic Press, London and New York, pp.363-395.

WALLWORK (J.A.), 1969a. The zoogeography of Antarctic Cryptostigmata. Proc. II. Int. Congress of Acarology, 17-26.

WALLWORK (J.A.), 1969b. Some basic principles underlying the classification and identification of cryptostimatid mites. In : J.G. Sheals (Ed.) The soil ecosystems, Sysematic Association, Publication No. 8, pp.155-168.

WALLWORK, (J.A.), 1970. Ecology of soil animals. Mc Graw Hill Publ. Co., Ltd., England 283 pp.

WALLWORK (J.A.), 1981 - A new aquatic oribatid mite from Western Australia (Acari : Cryptostigmata : Ameronothridae). - Acarologia, 22 (3): 333-339.

WALLWORK (J.A.) and RODRIGUEZ (J.G.), 1961. Ecological studies on oribatid mites with particular reference to their role as intermediate hosts of Anoplocephalid cestodes. J. Econ. Entomol., 54 (4): 701-705.

WARDLE (R.A.) and MILEOD (J.A.), 1952. The zoology of tapeworms. Univ. Minnesota Press, Minneapolis, 780 pp.

WEIGMANN (G.), 1975. Vorkommen von *Ameronothrus* (Acari : Oribatei) in littoral sudafrikas veroff Inst. - Meeresforch Bremerh, 15 : 65-67.

WEIGMANN (G.), 1976. Results of the 1969 Acores expedition of the International Research project of the Makaronese region VIII. Oribatidae of the Acores (Acari Oribatei). - Bol. Mus. Munnic. Funchal., 30 (130): 5-25.

WERNER (N.R.) and DINDAL (D.L.), 1987. Nutritional ecology of soil arthropods. - In: F. Slansky Jr. and J.G. Rodriguez (Eds.), Nutritional ecology of insects, mites, spider, and related invertebrates, Wiley interscience publications, New York,Chichester, pp.815-836.

WOODRING (J.P.), 1963. The nutrition and biology of saprophytic sarcoptiformes. - In : Advances in Acarology, 1, Carnell Univ. Press. Ithaca, pp. 89-111.

WOODRING (J.P.) and COOK (E.P.) 1962. The biology of *Ceratozetes cisalpinus* Berlese. *Scheloribates leavigatus* Koch and *Oppia neerlandica* Oudemans (Oribatei) with a description of all stages. - Acarologia, 4 (1) 101-137.

WOOLLEY (T.A.), 1988. Acarology, Mites and human welfare. - John Wiley & Sons, Inc., 484 pp.

WORLEY (D.E.), JACOBSON (R.H.) and BARETT (R.E.), 1974. The chronology of tapeworm (*Moniezia expansa*) acquisition by sheep on summer ranges in Montaha and Ihado. - *Proc. Helm. Soc. Wash.*, 41 (1) : 19-22.

WUNDERLE (I.), BECK (L.) and WOAS (S.), 1990. Ein Beitrag zur taxonomic and Okdogieder oribatulidae and Scheloribatidae (Acari : Oribatei) in sudwest denstsca - land . - Andrias, 7: 15-60.

ZIVKOVIC (V.) and FRANK (F.). 1964. Oribatiden (Oribatei, Acarine) einiger Weiden in serbien, Bosnien and Herzegowina. (Serbian text, German Summary). - *Glas Srpski, Akad. nauk.*, 257 (17) : 141-147.