

# **STUDIES ON LOHMANNIID MITES (ACARI: ORIBATEI) OF MALABAR**

Thesis submitted to the  
University of Calicut in partial fulfilment of  
the requirement for the degree of

**DOCTOR OF PHILOSOPHY IN ZOOLOGY**

Submitted by

**ANJANA M.**



**DEPARTMENT OF ZOOLOGY  
UNIVERSITY OF CALICUT  
KERALA, INDIA**

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**DEPARTMENT OF ZOOLOGY  
UNIVERSITY OF CALICUT**



**Dr. N. RAMANI**  
Professor

Tel: Office : (0494) 2407419  
HOD : (0494) 2407420  
Fax : (0494) 2400269  
Mob : 9495174338  
E-mail : [dnramani@gmail.com](mailto:dnramani@gmail.com)

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**CERTIFICATE**

This is to certify that the thesis entitled “**STUDIES ON LOHMANNIID MITES (ACARI: ORIBATEI) OF MALABAR**” submitted to University of Calicut, in partial fulfillment of the requirements for the award of the degree of Doctor of Philosophy in Zoology is an authentic record of research work carried out by **Ms. Anjana. M.**, Division of Acarology, Department of Zoology, University of Calicut, under my guidance and supervision. The thesis has not formed the basis for the award of any other Degree/ Diploma of this or any other University.

C. U. Campus

**Dr. N. Ramani**

09.11.2015

**DEPARTMENT OF ZOOLOGY  
UNIVERSITY OF CALICUT**



**Dr. N. RAMANI**  
Professor

Tel: Office : (0494) 2407419  
HOD : (0494) 2407420  
Fax : (0494) 2400269  
Mob : 9495174338  
E-mail : dmramani@gmail.com

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I also hereby certify that the corrections/suggestions from the adjudicators have been incorporated in the revised thesis. Content of the CD submitted and the hardcopy of the thesis is one and the same.

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**Dr. N. Ramani**

## **DECLARATION**

I do hereby declare that this thesis entitled “**STUDIES ON LOHMANNIID MITES (ACARI: ORIBATEI) OF MALABAR**”, is an authentic record of the work carried out by me under the supervision and guidance of **Dr. N. Ramani**, Professor, Division of Acarology, Department of Zoology, University of Calicut and no part of the thesis has been presented by me for the award of any other Degree, Diploma on similar title.

C. U. Campus

**Anjana M.**

09.11.2015

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***Anjana.M***

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**DEDICATED TO**

**MY MOTHER**

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Biodiversity of acarina is best represented in soil ecosystem and which is often endowed with extremities of micro-climatic and floral variations. Mites, especially the oribatid mites represent a major fraction of soil microarthropods. Acarines, by virtue of their small size and cryptic behaviour, endeavour with insects in conquering every possible habitats accessible for life. Among the acari, the group Oribatida deserves special mention for the beneficial and harmful roles they perform. Oribatids possess great potential in the decomposition and humification processes in soil ecosystem as well as in the indication of alterations of environmental conditions.

The suborder Oribatida broadly embraces members of two supercohorts like the Macropylina or the Oribatei inferiores and the Brachypylna or the Oribatei Superiores, comprising the members of inferior and superior taxa respectively. Majority of the inferior taxa are sluggish and seldom conduct active spatial migration. This would result in their existence as groups in localized pockets of soil ecosystem. The members of families like the Phthiracaridae and Lohmanniidae often prefer to inhabit in places where their food substances are readily available. Once they succeed in locating such preferred habitats, they flourish to build up their population subsequently. Active and consistent feeding activity of the members of these groups of mites exert profound influence in the conversion of their feeding substrates like the litter and other complex organic residues into simple micropellet like faecal pellets, which are easily leachable in to the soil layers for subsequent absorption by plants. Thus these mites would greatly help in biodegradation and thereby hastening the humification process in soil ecosystem. This eventually dignifies their role as promoters of soil fertility.

Soil invertebrates in general, have been recommended as tools in assessing the impact of anthropogenic effect on the environment and among the various invertebrate groups, oribatid mites with their numerical

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abundance, ecological and taxonomic diversity and distribution in all types of bioclimatic zones and soil profiles have been ranked as the most efficient component in indicating environmental alterations. Their ability to react very rapidly to even the minute changes in the environmental conditions including conditions of heavy metal contamination , radioactive and industrial pollution etc. have been well explored. Several species indicate dry conditions and many others exert horizontal and vertical migrations with respect to alterations in temperature and humidity conditions of their environment. The population density of several species of oribatid mites is often found positively correlated with the organic content of soil ecosystem. Species diversity and population size of these mites are largely influenced by the abiotic and biotic components of soil ecosystem. The population size of these mites show a decrease with the operation of adverse environmental conditions. Since oribatid mites are ecologically quite dependent on their environment, they could be used as indicators.

The technique of bioassays gives rapid diagnosis of environmental quality. Recently, edaphic microarthropods have been largely used to detect residual concentration of pesticides. After establishing the tolerance of a sensitive species to a residual toxicant, experimental population is kept in contact with tested pedological samples. By calculating the mortality rate in the experimental population, the concentration of residual toxicant can be inferred. With their amazing species diversity, spectacular spatial and temporal distribution and narrow ecological sensitivity, oribatids have been credited to become the prime candidates for research programmes in toxicology. The extreme sensitivity of the members of the family Lohmanniidae is often exploited in the bioindication of soil conditions. These mites often prefer to concentrate in isolated pockets of marine, forest and grassland situations where conditions are static. Probably this would have been the reason for their common existence in island belts. Species like

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*Heptacarus hirsutus* is found closely associated with moist habitat of marine and fresh water situation and hence would serve as indicators of humid conditions. The population density of lohmanniid mites has always been found positively correlated with the organic content of the soil. Manipulation of soil conditions for the betterment of practices is of primary importance to crop production. The bioindicative efficiency of these mites can be better utilized as a tool for charting agronomic practices.

While scrutinizing their role in decomposition of organic matter, lohmanniid mites are included under the macrophytophagous category by virtue of their nutritional strategies. Materials of higher plant origin like dried leaves, twigs and decaying parts of wood and roots constitute the principal food items of these macrophytophages. They are armoured with strong and well developed mouth parts for trituration of plant litter. Microbial community available in their gut supplements production of cellulolytic enzymes necessary for bio-processing of these organic substances.

Lohmanniids are primarily concerned with consumption of plant residues accumulated on soil surface in the form of litter, thereby exposing them to further action of microbes in their gut. Their role in the removal of the continuously accumulating organic debris and restoring the fertility status of soil ecosystem through nutrient cycling has been recognized globally. Their role in energy transformation thus can be considered as one of the major functions involved in biological fertility.

As excellent biodegradators of organic residues, these mites promote soil fertility and hence enhance agricultural productivity. Suitable examples in physico-chemical conversion of organic polysaccharides can be envisaged in many genera of the family Lohmanniidae viz., *Heptacarus*, *Meristacarus*, *Haplacarus*, *Lepidacarus*, *Annectacarus*, *Cryptacarus*, *Torpacarus*, *Lohmannia*, *Javacarus* etc. in tropical habitats. The broad and blunt cutting

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edges of the rutella and chelicerae of these mites would help in skeletonization of leafy and woody components of litter. The possession of highly developed chelicerae and rutella of *M. degradatus*, *H. hirsutus* etc. would help in trituration of the leafy and woody fragments of litter and subsequent degradation in their gut and final egestion in the form of nutrient rich faecal pellets for getting leached and incorporated into the soil ecosystem.

The cylindrical body, golden-brown colouration, staggering setation and astonishing microsculpture of lohmanniid mites innovate an aesthetic sense to the observer. The possession of 'notogastral bands' presenting startling beauty hints evolutionary significance in metamerism with the other arthropodal cousins of these mites. It is hoped that attempts made for securing knowledge on this group will certainly fill up the gap on this group of mites to a certain extent. Therefore, a detailed study was intended in the present work which would enable a brief accounting of :

- (1) Distribution pattern of lohmanniid mites in various ecosystems of Malabar.
- (2) Taxonomic position and species diversity in the study area.
- (3) Population ecology in relation with various physical and chemical parameters.
- (4) Feeding strategies in terms of food preferences and gut content analysis.
- (5) Breeding biology of selected prominent lohmanniid species recovered from the study sites.

Studies on the taxonomy of oribatid mites though received an increasing attention globally during the past few decades, in India these mites still represent a very poorly explored group when compared to other groups of Acari. Duly recognizing the importance of oribatid mites in the soil ecosystem, various workers in different countries have undertaken studies on their feeding and breeding aspects, population dynamics and ecological roles. As a result, considerable information is now available on these mites, a consolidation of which has been presented here for future reference, giving more attention on members of the family Lohmanniidae.

The first known species of the family Lohmanniidae was described by Haller (1884) as *Michaelia paradoxa*. Berlese (1896) erected a new species, *Angelia murcioides* from Europe. Canestrini (1897) described a new species viz., *Hermannia rubescens* from the New Guinean collection. Michael (1898) redescribed Haller's species, *M. paradoxa* as *Lohmannia paradoxa* and simultaneously added another species, *A. murcioides* to the family.

Studies on oribatid fauna of India were initiated by Pearse (1906) by reporting twenty species and he established a new genus, *Chaunoproctus* from Sikkim, Himalaya. While amending the extraction technique for oribatid mites, Tullgren (1918) modified the funnel apparatus devised by Berlese (1905). Berlese (1923) added a new species of oribatid mite viz., *L. regalis* to the family Lohmanniidae. Sellnick (1928) pointed out the importance of oribatid mites in the maintenance of soil fertility and the same author (1931) described a new species, *L. reticulata* under the family Lohmanniidae.

Grandjean (1934) described a new genus, *Meristacarus* under the family Lohmanniidae with *M. porcula* as the type species from West Africa. Changes occurring in the body chaetotaxy of oribatid mites during postembryonic development were studied by Grandjean (1933, 1934 and 1938). The pattern of development of the genital and anal plates in oribatid

mites during ontogeny was also traced by the same author (1949). Further, he (1950) erected three new genera and species of lohmanniid mites, providing appropriate description and diagrammatic illustrations of *Annectacarus mucronatus*, *Cryptacarus promecus* and *Torpacarus omittens* from Venezuela and Panama. The same author (1954) provided an outline for the classification of oribatid mites, including the family Lohmanniidae.

Balogh (1958) erected *Mixacarus* as a new genus under Lohmanniidae with *M. integer* as the type species from Angola. Another new genus, *Papillacarus* was added to this family by Kunst (1959). Balogh (1960) erected three new genera viz., *Paulinacarus*, *Millotacarus* and *Dendracarus* from Madagascar to accommodate new three new species of *Paulinacarus* viz., *P. levis*, *P. rugosus*, *P. nodosus*, one species of *Millotacarus* viz., *M. granulatus* and one species of *Dendracarus* viz. *D. pulchellus*. Bulanova-Zachvatkina (1960) erected a new species under the genus *Papillacarus* viz., *P. pavlovskii* from the Soviet Union. Aoki (1961) described a new species under the genus *Cryptacarus*, viz. *C. hirsutus*. Balogh (1961) provided an outline for the classification of lohmanniid mites in which he included identification keys to twenty five genera and one hundred and forty species. From the soils of Indonesia, Csiszar (1961) erected two new genera viz., *Lepidacarus* and *Nesiacarus* with *L. ornatissimus* and *N. reticulatus* as type species respectively and also added one new species of *Cryptacarus* viz., *C. tuberculatus*.

Balogh (1962 a) identified some lohmanniid specimens from Eastern Peru, collected from the rain forest in the Amazon valley. Among these, species like *L. similis*, *M. neotropicus* and *J. inexpectatus* were described as new to science. The same author (1962 b) provided information on a new subspecies of the species, *M. madagascarensis* viz., *M. madagascarensis madagascarensis* from Madagascar. In his comprehensive paper on the

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lohmanniid mites of Ghana, Wallwork (1962) provided information on six genera, which included *Haplacarus*, *Mixacarus*, *Meristacarus*, *Papillacarus*, *Annectacarus* and *Torpacarus*. A new genus under Lohmanniidae viz., *Heptacarus* was erected by Piffel (1963) with *H. notoneotrichus* from Egypt. Wallwork (1964) added another species of *Heptacarus* viz. *H. hirsutus* from Tschad. The genus, *Vepracarus* was erected as a new taxon by Aoki (1965) based on the type species, *V.ogawai* along with descriptions of two new species viz., *H. pairathi* and *P. undirostratus*.

Woolley (1966) provided information on a new genus, *Euryacarus* from Guatemala with *E. petalus* as the type species. Seasonal fluctuations in the population density of oribatid mites were correlated with their reproductive cycle by Block (1966). Perez-Inigo (1967) supplemented data on the systematic position, distribution and habitats of four species of lohmanniid mites from Spain. A new species under the genus *Heptacarus* viz., *H. supertrichus* was described by Piffel (1967) from Iraq. Based on the oribatid materials collected from South America, Balogh and Mahunka (1969) created a new family, Xenolohmanniidae to accommodate a new genus, *Xenolohmannia*. The authors added descriptions of six other species also. The new family was distinct from Lohmanniidae in the features of the anogenital region.

Chakrabarthy and Bhaduri (1972) made contributions on Indian species of lohmanniid mites by collecting specimens of *C. tuberculatus* and *J. kuhnelti* from the districts of Nadia and 24-Parganas, West Bengal. Kardar (1972) erected a new species of *Papillacarus* from India viz., *P.indicus*. Hammer (1973) in her studies on oribatid mites of Tongatapu and Eua, The Tonga Islands and Upolu, Western Samoa, reported fifty seven species of oribatid mites. Her research work included the description of a new species of *Annectacarus* viz., *A. unilateralis*. Two new species viz., *M. vanhonggui*

and *V. koreanus* were erected by Mahunka (1973) from Korea. Bhattacharya *et al.* (1974), during their studies on the soil mites of Santinikethen in West Bengal, provided information on three new species *viz.*, *A. longisetosus*, *C.dendrisetosus* and *P. simplirostratus* and a new subspecies, *H. foliatus bengalensis*. This paper also included reports on other members like *C. hirsutus* and *J. kuhneli*. Prasad (1974) provided a key to the superfamilies of oribatid mites along with a list of known families of Indian oribatids. Shereef (1976) conducted biological studies on two species of lohmanniid mites *viz.*, *P. aciculatus* and *L. egypticus* in Egypt.

Haq (1978) described seven new species of oribatid mites belonging to seven genera collected from Kerala, which included the description of a new lohmanniid member also *viz.* *A. trivandricus*. Norton *et al.* (1978) described two new species under the genus *Lohmannia viz.*, *L. banksi* and *L. carolensis* along with a single species of *Mixacarus viz.*, *M. brevipes* from the Loblolly pine forest floor in North and South Carolina. The same authors proposed *Carolohmannia* as a subgenus under the genus *Lohmannia*. Bayoumi (1979) presented an annotated list of seventeen species of oribatid mites from Egypt, of which *L. hispaniola* and *J. kuhneli* were new to Egypt. While investigating the lohmanniid mites of Philippines, Corpus-Raros (1979a, b) described four new species *viz.*, *A.mahabaeus*, *M. tuloyus*, *V. ramirezae*, *P. hirsutus* and *P. ramosus*. Ghosh and Bhaduri (1979) erected a new subspecies of *H. foliatus viz.*, *H. foliatus bengalensis* from Nagaland, India. Mc Daniel *et al.* (1979) described a new genus, *Pseudocryptacarus* under the family from the Gulf costal region of South Texas.

While studying the oribatid specimens collected from Java, Hammer (1980) erected a new species *viz.*, *H. javensis*. Mahunka (1980) provided information on eighteen species of oribatid mites from Tunisia which included descriptions and illustrations of two new species, *L.hungarorum* and

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*P.pseudoaciculatus*. Balogh and Mahunka (1981) conducted taxonomic studies of oribatid specimens collected from Neogea and described one new species under *Nesiacarus* viz., *N.australis* and one new subspecies of *T. omittens* viz. *T. omittens paraguayensis*. Sanyal (1982) studied the oribatid fauna of Maharashtra, India and reported three species viz. *H. bhadurii*, *H. maharashtrensis* and *J. kuehnelti* as new for the state. Sengbusch (1982a) erected *H.pandanus* as a new species of lohmanniid mite, from the Islands of Yap in Micronesia. The same author (1982b) added another new species, *J. reticulatus* to the family Lohmanniidae from Panope.

Haq *et al.* (1984) described a new species and a new subspecies of lohmanniid mites, viz., *H. keralensis* and *L.ornatissimus rehmabia* respectively from the soils of Kerala. Sarkar and Subias (1984) erected two new species of lohmanniids viz., *V. cornutus* and *P. foliatus* from India. Further addition to the family was made by Sengbusch (1984 a, b) by describing two new species viz., *L. pinnigera* and *A. granditrichosus* from Truk and Saipan.

In their review on Lohmanniidae, Balogh and Balogh (1987) provided a new outline to the family by providing descriptions of twenty five genera and one hundred and forty species along with comprehensive keys and drawings. A review of the oribatid genera of Indian subcontinent was made by Sanyal and Bhaduri (1988) and the authors listed one hundred and thirty two genera under fifty seven families. Perez-Inigo (1989) described *V. gueyeae* from continental Africa and presented identification keys for the ten species included. The first African representative of the genus *Javacarus*, viz., *J. jocelynae* was described from South West Cameroon by Judson (1991). Clement and Haq (1991) erected two new species of lohmanniid mites, *A. wallworki* and *C. grandjeani* from Kerala.

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Studies on the taxonomy of oribatid mites though received an increasing attention globally during the past few decades, in India these mites still represent a very poorly explored group when compared to other groups of Acari. Duly recognizing the importance of oribatid mites in the soil ecosystem, various workers in different countries have undertaken studies on their feeding and breeding aspects, population dynamics and ecological roles. As a result, considerable information is now available on these mites, a consolidation of which has been presented here for future reference, giving more attention on members of the family Lohmanniidae.

The first known species of the family Lohmanniidae was described by Haller (1884) as *Michaelia paradoxa*. Berlese (1896) erected a new species, *Angelia murcioides* from Europe. Canestrini (1897) described a new species viz., *Hermannia rubescens* from the New Guinean collection. Michael (1898) redescribed Haller's species, *M. paradoxa* as *Lohmannia paradoxa* and simultaneously added another species, *A. murcioides* to the family.

Studies on oribatid fauna of India were initiated by Pearse (1906) by reporting twenty species and he established a new genus, *Chaunoproctus* from Sikkim, Himalaya. While amending the extraction technique for oribatid mites, Tullgren (1918) modified the funnel apparatus devised by Berlese (1905). Berlese (1923) added a new species of oribatid mite viz., *L. regalis* to the family Lohmanniidae. Sellnick (1928) pointed out the importance of oribatid mites in the maintenance of soil fertility and the same author (1931) described a new species, *L. reticulata* under the family Lohmanniidae.

Grandjean (1934) described a new genus, *Meristacarus* under the family Lohmanniidae with *M. porcula* as the type species from West Africa. Changes occurring in the body chaetotaxy of oribatid mites during postembryonic development were studied by Grandjean (1933, 1934 and 1938). The pattern of development of the genital and anal plates in oribatid

mites during ontogeny was also traced by the same author (1949). Further, he (1950) erected three new genera and species of lohmanniid mites, providing appropriate description and diagrammatic illustrations of *Annectacarus mucronatus*, *Cryptacarus promecus* and *Torpacarus omittens* from Venezuela and Panama. The same author (1954) provided an outline for the classification of oribatid mites, including the family Lohmanniidae.

Balogh (1958) erected *Mixacarus* as a new genus under Lohmanniidae with *M. integer* as the type species from Angola. Another new genus, *Papillacarus* was added to this family by Kunst (1959). Balogh (1960) erected three new genera viz., *Paulinacarus*, *Millotacarus* and *Dendracarus* from Madagascar to accommodate new three new species of *Paulinacarus* viz., *P. levis*, *P. rugosus*, *P. nodosus*, one species of *Millotacarus* viz., *M. granulatus* and one species of *Dendracarus* viz. *D. pulchellus*. Bulanova-Zachvatkina (1960) erected a new species under the genus *Papillacarus* viz., *P. pavlovskii* from the Soviet Union. Aoki (1961) described a new species under the genus *Cryptacarus*, viz. *C. hirsutus*. Balogh (1961) provided an outline for the classification of lohmanniid mites in which he included identification keys to twenty five genera and one hundred and forty species. From the soils of Indonesia, Csiszar (1961) erected two new genera viz., *Lepidacarus* and *Nesiacarus* with *L. ornatissimus* and *N. reticulatus* as type species respectively and also added one new species of *Cryptacarus* viz., *C. tuberculatus*.

Balogh (1962 a) identified some lohmanniid specimens from Eastern Peru, collected from the rain forest in the Amazon valley. Among these, species like *L. similis*, *M. neotropicus* and *J. inexpectatus* were described as new to science. The same author (1962 b) provided information on a new subspecies of the species, *M. madagascarensis* viz., *M. madagascarensis madagascarensis* from Madagascar. In his comprehensive paper on the

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lohmanniid mites of Ghana, Wallwork (1962) provided information on six genera, which included *Haplacarus*, *Mixacarus*, *Meristacarus*, *Papillacarus*, *Annectacarus* and *Torpacarus*. A new genus under Lohmanniidae viz., *Heptacarus* was erected by Piffel (1963) with *H. notoneotrichus* from Egypt. Wallwork (1964) added another species of *Heptacarus* viz. *H. hirsutus* from Tschad. The genus, *Vepracarus* was erected as a new taxon by Aoki (1965) based on the type species, *V.ogawai* along with descriptions of two new species viz., *H. pairathi* and *P. undirostratus*.

Woolley (1966) provided information on a new genus, *Euryacarus* from Guatemala with *E. petalus* as the type species. Seasonal fluctuations in the population density of oribatid mites were correlated with their reproductive cycle by Block (1966). Perez-Inigo (1967) supplemented data on the systematic position, distribution and habitats of four species of lohmanniid mites from Spain. A new species under the genus *Heptacarus* viz., *H. supertrichus* was described by Piffel (1967) from Iraq. Based on the oribatid materials collected from South America, Balogh and Mahunka (1969) created a new family, Xenolohmanniidae to accommodate a new genus, *Xenolohmannia*. The authors added descriptions of six other species also. The new family was distinct from Lohmanniidae in the features of the anogenital region.

Chakrabarthy and Bhaduri (1972) made contributions on Indian species of lohmanniid mites by collecting specimens of *C. tuberculatus* and *J. kuhnelti* from the districts of Nadia and 24-Parganas, West Bengal. Kardar (1972) erected a new species of *Papillacarus* from India viz., *P.indicus*. Hammer (1973) in her studies on oribatid mites of Tongatapu and Eua, The Tonga Islands and Upolu, Western Samoa, reported fifty seven species of oribatid mites. Her research work included the description of a new species of *Annectacarus* viz., *A. unilateralis*. Two new species viz., *M. vanhonggui*

and *V. koreanus* were erected by Mahunka (1973) from Korea. Bhattacharya *et al.* (1974), during their studies on the soil mites of Santinikethen in West Bengal, provided information on three new species *viz.*, *A. longisetosus*, *C.dendrisetosus* and *P. simplirostratus* and a new subspecies, *H. foliatus bengalensis*. This paper also included reports on other members like *C. hirsutus* and *J. kuhneli*. Prasad (1974) provided a key to the superfamilies of oribatid mites along with a list of known families of Indian oribatids. Shereef (1976) conducted biological studies on two species of lohmanniid mites *viz.*, *P. aciculatus* and *L. egypticus* in Egypt.

Haq (1978) described seven new species of oribatid mites belonging to seven genera collected from Kerala, which included the description of a new lohmanniid member also *viz.* *A. trivandricus*. Norton *et al.* (1978) described two new species under the genus *Lohmannia viz.*, *L. banksi* and *L. carolensis* along with a single species of *Mixacarus viz.*, *M. brevipes* from the Loblolly pine forest floor in North and South Carolina. The same authors proposed *Carolohmannia* as a subgenus under the genus *Lohmannia*. Bayoumi (1979) presented an annotated list of seventeen species of oribatid mites from Egypt, of which *L. hispaniola* and *J. kuhneli* were new to Egypt. While investigating the lohmanniid mites of Philippines, Corpus-Raros (1979a, b) described four new species *viz.*, *A.mahabaeus*, *M. tuloyus*, *V. ramirezae*, *P. hirsutus* and *P. ramosus*. Ghosh and Bhaduri (1979) erected a new subspecies of *H. foliatus viz.*, *H. foliatus bengalensis* from Nagaland, India. Mc Daniel *et al.* (1979) described a new genus, *Pseudocryptacarus* under the family from the Gulf costal region of South Texas.

While studying the oribatid specimens collected from Java, Hammer (1980) erected a new species *viz.*, *H. javensis*. Mahunka (1980) provided information on eighteen species of oribatid mites from Tunisia which included descriptions and illustrations of two new species, *L.hungarorum* and

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*P.pseudoaciculatus*. Balogh and Mahunka (1981) conducted taxonomic studies of oribatid specimens collected from Neogea and described one new species under *Nesiacarus* viz., *N.australis* and one new subspecies of *T. omittens* viz. *T. omittens paraguayensis*. Sanyal (1982) studied the oribatid fauna of Maharashtra, India and reported three species viz. *H. bhadurii*, *H. maharashtrensis* and *J. kuehnelti* as new for the state. Sengbusch (1982a) erected *H.pandanus* as a new species of lohmanniid mite, from the Islands of Yap in Micronesia. The same author (1982b) added another new species, *J. reticulatus* to the family Lohmanniidae from Panope.

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Oribatid mites or the so called “beetle mites” are characterized by heavily sclerotised body. The body of an adult oribatid mite is dorsally divided into two parts: the anterior *proterosoma* and the posterior *hysterosoma*. The proterosoma represents the anterior part of the prosoma and the hysterosoma consists of the posterior part of the prosoma and the hysterosoma consists of the posterior part of the prosoma bearing legs III and IV as well as the opisthosoma. The *propodosoma* is the region bearing legs I and II and the *metapodosoma* represents the region between III and IV. The propodosoma and metapodosoma together constitute the *podosoma*. The dorsal and dorsolateral region of the sclerotised proterosoma together constitutes the prodorsum. The gnathosoma or the mouth part bearing part is located at the antero-ventral region of the proterosoma.

## **A. DORSAL REGION**

### **a) Prodorsum**

The anterior tip of the prodorsum is the rostrum. Extending from the base of the bothridium (*bo*) towards the rostrum, there is an outgrowth. If these outgrowths are flat, lath or plate like they are called *lamellae*. If these outgrowths are rib-like, protruding like a bar from the plane of the prodorsum and never plate-like or with horizontal extension, they are called *costula*. Prodorsum bears five pairs of setae *viz.*,

1. Rostral setae (*ro*)
2. Lamellar setae (*le*)
3. Interlamellar setate (*in*)
4. Anterior exobothridial setae (*exa*)
5. Posterior exobothridial setae (*exp*)

Sensillus (*ss*) arises from the bothridium (*bo*), and which shows varied shape in various genera and species.

### **Notogaster**

The prodorsum is separated from the notogaster by a dorsosejugal suture (*dsj*). The notogaster is undivided or rarely separated into small regions by transverse bands. In primitive Oribatids, there are usually sixteen pairs of notogastral setae which will be reduced into ten or fourteen pairs in higher oribatids. Grandjean applied different 'hair terminology' to define various setal types. Thus, when the setal number is sixteenpairs, the notation is as follows:

First row :  $c_1, c_2, c_3$

Second row :  $d_1, d_2, d_3$

Third row :  $e_1, e_2$

Fourth row :  $f_1, f_2$

Fifth row :  $h_1, h_2, h_3$  and

Sixth row :  $ps_1, ps_2, ps_3$

When the setal number is fourteen or fifteen pairs, the notation changes as:

First row :  $c_1, c_2, c_3$

Second row :  $da, la$

Third row :  $dm, lm$

Fourth row :  $dp, lp$

Fifth row :  $h_1, h_2, h_3$  and

### *External Morphology of Lohmanniid Mites*

Sixth row :  $Ps_1, Ps_2, Ps_3$

Here 'd' indicates dorsal, 'l' lateral, 'a' anterior, 'm' median and 'p' posterior position. When the number of notogastral setae is 10 pairs, the notation changes to:

First row :  $ta, te, ti$

Second row :  $ms$

Third row :  $r_1, r_2, r_3$

Fourth row :  $p_1, p_2, p_3$

Here the letter 'a' stands for anterior, 'e' for exterior and 'i' for interior. Some primitive oribatids have more than sixteen pairs of notogastral setae. These setae are called neotricheal setae and the condition is known as *neotrichy*.

Certain groups of oribatids have wing-like anterolateral projections called *Pteromorphs* (*ptm*) which some times extend beyond the body and may curve ventrally over the legs. Pteromorphs may be movable or immovable.

Most of the oribatids are characterised by special respiratory areas of the notogaster *viz.*, *area porosae* or *sacculi* or *pori*. The *area porosae* are portions thinner than the cuticle of the notogaster and are supplied with fine pores. They vary in number and shape. Higher oribatids usually carry four pairs of area porosae *viz.*,  $Aa, A_1, A_2,$  and  $A_3$ . In addition to these, two more pairs of area porosae,  $Ad$  and  $Apa$  are also found in few forms. If the area porosae sink into the cuticle, with only a dot-like opening on the surface, they are called *sacculi*. They are denoted by  $Sa, S_1, S_2$  and  $S_3$ . If the area porosae disappear with only a point-like pore present in their place, these are called *pori* and as denoted by  $Pa, P_1, P_2,$  and  $P_3$ . They may also take the form of

‘slits’ on the notogaster called *fissures* and are denoted by *ia*, *im*, *ih*, *ips* and *ip*.

## **B. LATERAL REGION**

A chitinous, longitudinal ridge called *tutorium* (*tu*) may be present on the lateral side in higher oribatids. *Pedotecta* ( $P_1$ ,  $P_2$  and  $P_3$ ) are structures which partly cover or protect the bases of legs. The ventral plate is laterally produced into projections of various shapes called the *discidia* (*dis*), which protect the base of IV<sup>th</sup> leg. In some oribatids, a wedge shaped structure arises from leg IV, called the *custodium* (*cus*).

## **VENTRAL REGION**

### **a) Gnathosoma**

It is the region bearing the oral organs or the mouthparts and is situated in an anterior cavity or the *camerostome*. The basal part of the gnathosoma is called the *subcapitulum* or *infracapitulum*, which consists of an unpaired *mentum*, a dorsal neck or *cervix*, the paired *gena* and their continuation in the *rutellum* (*ru*). The articulation between the mentum and genae is called the labiogenal articulation and which is of 4 types:

- 1) Anarthric type - Without special articulation
- 2) Stenarthric type - Labiogenal articulation directed posteriorad so that the mentum appears triangular
- 3) Diarthric type - Labiogenal suture is transverse with a large quadrangular mentum. Genae and rutella are large.
- 4) Suctorial type - Mentum and genae are fused and no suture is present. Rutella are modified into tubes.

## *External Morphology of Lohmanniid Mites*

The infracapitular region bears setae, the number of which varies. Usually mentum and genae bear one pair of setae each (*h* and *a* respectively). In addition to this, genae also bear 1-2 pairs of minute setae (*m<sub>1</sub>* and *m<sub>2</sub>*). In higher oribatids, usually a single pair of minute seta (*m*) may be present. The chelicerae of oribatid mites are of two types: (1) a wide or chewing type and (2) an elongated picking or peloptoid type. Chewing type of chelicerae possess two setae (*cha* and *chb*) and a fixed digit (*digitus fixus*) and a movable digit (*digitus mobilis*). Both the digits bear teeth. Peloptoid chelicerae have only one seta. The pedipalps are formed by 2-5 segments, the setation of each segment is related to that of the ambulatory legs.

### ***b) Epimeral region***

The epimeral or coxisternal region is the area between the infracapitulum and genital plate. This region is covered over by four epimeral plates viz., *ep<sub>1</sub>*, *ep<sub>2</sub>*, *ep<sub>3</sub>* and *ep<sub>4</sub>*. The epimeral plates are bordered by continuous thickening called the *apodemata*. A total of five apodemata viz., *apo<sub>1</sub>*, *apo<sub>2</sub>*, *apo<sub>3</sub>*, *apo<sub>4</sub>* and *aposj* (*apodemata sejugalis*) are distinguished. The epimeres carry varying number of setae which are denoted by a formula of four figures, the epimeral setal formula. The number of setae is denoted by a letter of alphabet from middle to margin.

### ***c) Ano-Genital Region***

The ventral region of the body behind the area of epimeres is occupied by the genital and anal plates and is called the anogenital region. Genital plates carry ten pairs of setae. Lying laterally above the genital plates, a pair of small triangular plates are seen which are known as aggenital plates. In between the genital and anal plates, a preanal plate is present. Lateral to the anal plate, a pair of longitudinally placed adanal plates are seen which may be either fused with the anal plates or may stand separate. The genital and anal

areas may also have porous fields, viz., *area porosae postanal* (*Apa*) and slit organs or fissure (*iad*). The ventral plate bears different types of ornamentation viz., punctulate, punctate, foveolate, alveolate, granulate, reticulate, rugose etc.

## LEGS

Adult oribatid mites possess four pairs of legs. Each leg has five segments, viz., trochanter, femur, genu, tibia and tarsus. Legs are inserted into the acetabuli. The chaetotaxy of legs vary from species to species as well as from leg 1 to leg 4. The most common type of setal arrangement of leg segments in oribatids is that with five setae. The names and notations given to these setae are the dorsal (*d*), the laterals (*l'*, *l''*) and the ventrals (*v'*, *v''*). Occasionally, the latter two pairs have been called as the laterodorsals and lateroventrals, respectively. When there are seven setae, consist of a dorsal (*d*) and three pairs, the superior laterals (*ls'*, *ls''*), inferior laterals (*li'*, *li''*) and subtibials (*st'*, *st''*). The larval seta commonly found at the base of femur is considered as a remnant of a vertical, distinct from the distal setae. This seta is called the *basiventral*, with the notation *bv''* on legs I and II and *ev'* on legs III and IV.

For designating a seta of a given segment, one may follow the setal notation with a capital *Tr*, *F*, *G*, *Ti* and *Ta* referring to the trochanter, femur, genu, tibia and tarsus respectively. Also, the leg may be indicated by Roman numerals I-IV. The tarsi of oribatids present significant obstacles to the application of these vertical notations. A special system of notation was developed by Grandjean to overcome these problems. A maximum of 16 setae is found on the larval tarsus. The ambulacrum is encircled by two pairs of setae; immediately above it are the *prorals* (*p'*, *p''*) and below it are *unguinals* (*u'*, *u''*). two pairs are dorsally situated, the *tectals* (*tc'*, *tc''*) and the *fastigials* (*ft'*, *ft''*) respectively, from distal to proximal. Proximal to the unguinals are

an unpaired medial seta, the *subunguinal* (*s*) and the *primiventrals* (*pv'*, *pv''*). The *antilateral pair* (*a'*, *a''*) is more or less laterally situated, proximal to the proral-unguinal whorl, and the *primilaterals* (*pl'*, *pl''*) are proximal to the antilaterals. The *monotropic seta* (*m''*) is found in some oribatids, slightly proximal to the subunguinal on the anterior legs. Spatial relationships are somewhat dependent on the shape of the tarsus and therefore vary between species. In addition to the normal setae, eupathidia, famuli and solenidia are also seen on the tarsus. The leg setae are of 4 major types:

### **1. Normal Setae**

They are the most abundant setiform organs on the legs and are homogenous with a median cavity and contain actinochitin.

### **2. Solenidia**

Solenidia are hollow, thin-walled and can be easily distinguished from other setiform organs by the lack of actinochitin. They are of the following 4 types.

- a. Baculiform                    - When they have the same diameter throughout
- b. Ceratiform                    - When they taper towards the tip
- c. Tactile                         - When they are very long and flagellate.
- d. Piliform                        - When they are elongated and with fine tip.

The solenidial notation varies with segments and accordingly they are noted as '*sigma*' ( $\sigma$ ) when they are on genu, '*phi*' ( $\psi$ ) when they are on tibia and '*omega*' ( $\omega$ ) when they are on tarsus.

### **3. Eupathidic setae**

Eupathidic setae are usually present on the tarsus of leg-1 and they represent modified setae having a hollow canal, penetrating the small root and a large alveolus. They are formed as a result of regressive evolution. They are given same notations that a normal seta in the same location, followed by the Greek letter zeta ( $\zeta$ ).

### **4. Famuli**

They are seen only on the tarsal segments and can be distinguished by their unique shape. They are like solenidion or eupathidium but stand separate by the presence of actinochitin. Their internal surface is rugose and are also formed by regressive evolution. The notation given for famulus by Grandjean is the Greek letter *epsilon* ( $\epsilon$ ).

## **EXTERNAL CHARACTERS OF LOHMANNIID MITES**

Lohmanniid mites belong to the suborder Oribatida and include members of primitive (Macropylina) groups, known as the Oribatei inferiores. Like other oribatid mites, lohmanniids have heavily sclerotized body and with little or no sexual dimorphism. The body is slightly elongated and posteriorly oval or rounded in appearance.

### **DORSAL REGION (Plate-I, Fig: 1)**

#### ***a) Prodorsum***

The anterior tip of the prodorsum is known as the rostrum. Lamellae are flat or plate like. In some lohmanniids, the lamellae are produced into spine like contour below, the lamellar setae (*le*). Prodorsum bears one pair of rostral setae (*ro*), lamellar setae (*le*), interlamellar setae (*in*) and two pairs of exobothridial setae (anterior exobothridial setae (*exa*) and posterior

exbothridial setae (*exp*). Sensillus (*ss*) which arises from the cup shaped bothridium (*bo*) is pectinate whose braches varies with genus and species.

### **b) Notogaster**

Dorsosejugal suture separates the prodorsum from the notogaster. The notogaster may be undivided or divided into small regions, by transverse bands. The nature and number of bands varies with the individual species. In lohmanniid mites, there are usually 16 pairs of notogastral setae arranged in six rows. In some lohmanniid mites, more than 16 pairs of notogastral setae are present. These setae are called the neotrichial setae and the condition is known as *neotrichy*, as seen in *Heptacarus* spp. Notogaster carries special respiratory regions called the *area porosae*, which are transversally situated, irregularly or circularly shaped structures. They may also take the form of ‘slits’ on the notogaster called fissure and are denoted by *ia*, *im*, *ih* and *ip*.

## **VENTRAL REGION** (Plate- I, Fig: 2)

### **a) Gnathosoma**

The labio-genal articulation in lohmanniid mites is of stenarthric type. The pedipalps (Fig. 4) have 5 segments. Chelicerae (Fig. 3) are widely chewing type with a fixed digit or digitus fixus and a movable digit or digitus mobilis bearing varied number of teeth. Chelicerae possess two setae (*cha* and *chb*). Infracapitular setae vary in number, but usually carry 3 pairs of setae, *a*, *m* and *h*. In many lohmanniid members, the number of minute setae *m* varies *m*<sub>1</sub>, *m*<sub>2</sub>, *m*<sub>3</sub>, etc.

### **b) Epimeral Region**

Epimeral region is covered by the four epimeral plates viz., *ep*<sub>1</sub>, *ep*<sub>2</sub>, *ep*<sub>3</sub>, and *ep*<sub>4</sub>. The epimeral plates are distinguished by five apodemata *apo*<sub>1</sub>, *apo*<sub>2</sub>, *apo*<sub>3</sub>, *apo*<sub>4</sub> and *aposj* (*apodemata sejugails*). The epimeres carry varying

number of setae which are denoted by a formula of four figure, the epimeral setal formula. The epimeral setation varies with individual species.

***c) Ano-genital Region***

In the family Lohmanniidae, the genital and anal plates touch each other and occupy the entire length of genito-anal region (Macropyline type). Genital plates carry ten pairs of setae. In members of some lohmannid genera like *Papillacarus*, *Vepracarus*, *Heptacarus* etc., the genital plates are divided by a transverse suture. In between the genital and anal plates, a pre-anal plate is present. The anal plate bears 1 or 2 setae and the adanal plates bear 4 or 5 setae. The adanal plates may be fused with the anal plates or may be separated by the *ano-adanal suture*. The ano-adanal setal formula, nature of genital plates, shape of pre-anal plate etc. are variable and form the identifying characters of the genera of the family Lohmanniidae. The ventral plates may be ornamented variously.

**LEGS** (Plate – I, Fig: 5)

There are four pairs of legs. each bearing 5 segments *viz.*, the trochanter, femur, genu, tibia and tarsus. The chaetotaxy of legs vary from species to species and also from legs I to IV.

In the present study, the taxonomic characters proposed by Grandjean (1934) and Balogh and Balogh (1987) are mainly followed.

## **Study Area**

Malabar region lies along the south-west coast of Indian Peninsula and forms the northern part of the present day Kerala state. It represents the land area between the Western Ghats and the Arabian sea, which ecologists usually refer as the tropical moist broad leaved forests. Malabar proper extends about 240km lying between N. Lat  $10^{\circ}15'$  and  $12^{\circ}18'$  and E. long.  $75^{\circ}14'$  and  $76^{\circ}56'$ . It includes the Palakkad, Malappuram, Kozhikode, Wayanad, Kannur and some regions of Kasargod districts of Kerala State.

The present study was initiated in May, 2010 and continued upto May 2013. During the period of study, soil and litter samples were collected randomly from various localities of Palakkad, Malappuram, Kozhikode, Wayanad and Kanur districts.

### **Sampling sites in Palakkad District**

Nelliampathy forest, a less explored part of Western Ghats was the main sampling locality selected in the Palakkad district. The four sites surveyed during the present study included the undisturbed forest floor (FA) having soils with mixed vegetation, soil and litter samples adjacent to Pothundi Dam premises (DP) and the different agroecosystems like the coffee (CP) and Tea (TP) plantations.

### **Sampling sites in Malappuram District**

This site comprised of various localities of the Calicut University Campus and Kakkanchery. The Botanical garden (BG) of the Calicut University constituted the major site of collection in the Campus, along with other sites like the staff residential area (QR) and Stadium premises (SD). The sites at Kakkanchery (KY) included cultivated areas like the paddy fields, coconut plantations, arecanut plantations, vegetable gardens in the

backyard of residential areas etc. which are prone to continuous human interference. Regular monthly collections were taken from BG and KY for ecological studies as a part of the present study. Leafy and woody litter plants like *Artocarpus heterophyllus* Lam., *Mangifera indica* L., *Mesua ferrea* L., *Michelia alba* Dc., *Anacardium occidentale* L. were the predominant vegetation in the collection sites.

### **Sampling sites in Kozhikkode District**

Four localities viz., Chaliyam (CH), Kadalundi (KD), Narikuni (NK) and Janakikad (JK) were surveyed for collection of soil/litter samples in the Kozhikkode district. The site at Chaliyam was a water logged area with drift wood accumulation during monsoon period and the common vegetation of the site was dominated by *Calotropis gigantea* (L.) and *Cocos nucifera* L. A private property with *A. heterophyllus*, *Psidium guajava* L. and *M. indica* represented the site at Narikuni. Virgin forest ecosystem with mixed vegetation and heaps of litter accumulation characterized the site at Janakikad. A mangrove ecosystem situated near Kadalundi river was recognized as the site KD.

### **Sampling sites in Wyanad District**

Soojipara (SP) and Thirunelli (TL) were the sampling sites selected in the Wyanad district. Bamboo grooves (BA), grasslands (GL) and undisturbed litter accumulated areas with mixed vegetation were the sites selected for the sampling purpose during the present study.

### **Sampling sites in Kannur district**

The collection localities in the Kannur district were Thalassery (TY), Darmadam (DM), Kottiyoor (KT) and a protected area called 'Santhivanam' (SV) in the Government Brennen College Campus. SV represented a

secondary forest ecosystem with leafy and woody vegetation. Water logged mangroove ecosystem in the Thalassery town area and undisturbed litter accumulated forest area of Kottiyoor were the main sampling localities.

### **Sampling of Soil**

Soil and litter samples were collected from the upper few centimeters of the soil, with the help of a shovel. An iron corer of 10 cm height and 5 cm diameter, was also used to collect samples. Samples collected in polythene bags were immediately taken to the laboratory for extraction of mites. Samples were handled carefully during the collection and transportation, to avoid disturbance of organisms present in the samples.

### **Extraction of Mites**

#### **Principle of Extraction**

Soil mesofauna show extreme sensitivity to variations in the intensity of light and heat of their microhabitats. Negatively phototrophic behaviour of the soil organisms is exploited for their extraction from the soil/litter samples. Desiccation of soil samples by heat drive the fauna from the top to bottom of the sample container and gradually drive out of the sample, through the sides of the funnel, into the collecting vial. The extraction technique was based on the principle of Berlese's (1905) original funnel apparatus.

#### **Extraction Apparatus**

The collected soil/litter samples were subjected to extraction in the Open brass funnel apparatus (Haq and Ramani, 2002). The apparatus is a rectangular unit, the frame of which measures 168 cm x 90 cm x 190 cm and made of steel. It consists of two rows of wooden planks, each with 12 holes for accommodating the funnels and sample containers. Each row consists of

12 units arranged in two parallel series of six each. Each unit was composed of three parts:

- 1) A heat source
- 2) A sample container set
- 3) A collecting vial

### ***1. Heating Source***

The heat source of each unit consists of an electric bulb, the intensity of which was decided by considering the moisture content of the soil sample to be extracted. Though the distance between the bulb above and the sample below was normally kept 12 cm, it could be increased or minimized by raising or lowering the wooden planks with the help of screws at the corners of the unit. When the soil samples were comparatively dry, 40 watt bulbs were used and 60 or 100 watt bulbs were used as the heat source for extraction of moistened samples, especially during the monsoon season.

### ***2. Sample container set***

The sample container was made of brass with a diameter of 15 cm and a height of 10 cm. This was attached to a fine wire mesh of 0.8 mm size and 15 cm in diameter which served as bottom for the sample container. There was a gap of one centimeter between the base and lower rim of the sample container. This arrangement was specially made for the escape of bigger animals. Below the sample container, a round resting shield with larger mesh size of 0.5 mm was kept. The sample with the resting shield could be removed and replaced by lifting the rod attached to either side of the shield, without disturbing the sample. The brass funnel was well flattened like a platform with raised edges, so as to hold well on the holes in the wooden plank. Below the tail end of the funnel was placed a collection vial.

### **3. Collecting Vial**

The collecting vial was a plastic tube of 6 cm in length. The collection vial was held tightly to the lower end of the funnel with the help of a spring fixed to an iron sheet. The combined effect of heat and light caused gradual desiccation of the soil sample, compelling the cryptic soil organisms, particularly the mites to come out from the soil. The soil arthropods which reached the fine mesh screen fell through the funnel into the collection vials, containing 70 percent alcohol.

### **Separation of Mites**

For taxonomic studies, the mites were collected in 70 percent ethyl alcohol. After extraction, the contents of the collecting tubes were transferred to a watch-glass. Under a stereomicroscope, the collected mites were segregated, and from which the lohmanniid mites were separated by means of a fine needle and brush.

### **Mounting**

Two types of slide mounting were practiced during the present study.

#### **1. Temporary mounting**

For routine examination, cleared specimens were mounted in glycerine. A drop of glycerine was placed in the centre of a clean microscopic slide. A single mite specimen was then carefully transferred into the glycerine drop. After orienting the specimen properly, a glass bristle which was larger than the size of the specimen was placed near the specimen, which helped to handle the mite in the desired position with out damage. The specimen was then mounted using a cover glass of 18 mm diameter.

## **2. Permanent mounting**

Permanent slides were prepared either by using polyvinyl alcohol or Hoyers' medium (Baker and Wharton, 1952). A drop of mounting medium was placed in the centre of a microscopic slide, and the specimen was placed in it using a fine camel hair brush. It was then oriented in the desired position, glass bristle was added and covered by cover glass. The prepared slides were kept at 50°C in an incubator until desired clarity was obtained.

### **Preparation of Mounting Medium**

#### **a) Hoyer's Medium**

- Weighed 30 gm of gum Arabic and 200gm of chloral hydrate and transferred in to a 1000ml beaker.
- Added 50ml of distilled water.
- Added 20ml of glycerin and thoroughly mixed at room temperature.
- Filtered the mixture and used for mounting.

#### **b) Polyvinyl Medium**

- Elvanol 71-24 (Du pont poly vinyl Alcohol) was dissolved in 4 volumes of distilled water at 90°C.
- Filtered the solution.
- Concentrated the clear filtrate in a water bath until the solution became syrupy.
- Added 22 parts of lactic acid to 56 parts of PVA and used for mounting.

### **Identification of Lohmanniid Mites**

The cleared specimens were temporarily mounted in glycerine and generic level identification was made temporarily with a Carl zeiss Research Microscope. After temporary assessment, the specimens were mounted in Hoyer's medium and warmed for 10-15 minutes in an oven at 50<sup>0</sup>C. The process helped to secure better clarity of specimens so that taxonomic characters could be located with certainty. Preliminary identification was made following standard dichotomous keys and the literature available in the Acarology Laboratory of the Calicut University. Further, discussion, consultation and confirmation of the species was made with the help of Dr. N. Ramani, at the Division of Acarology, Department of Zoology, University of Calicut.

Drawings were made using a mirror type camera lucida fitted to an Olympus Research microscope/Unitron research microscope and also Meopta research microscope. Measurements were taken using an ocular micrometer and expressed in  $\mu\text{m}$  in the description of the species throughout. After drawing, the specimens were transferred to specimen tubes containing clearing medium and labelled. The holotypes and paratypes were kept in plastic vials in the Department. After identification and drawing, the specimens were transferred into eppendorff tubes containing clearing medium.

## A. DISTRIBUTION PATTERN AND DIVERSITY OF LOHMANNIID MITES IN THE FIVE STUDY AREAS OF MALABAR .

Results of general surveys conducted during the present study at five districts of Malabar area disclosed a rich and varied population of lohmanniid mites. Lohmanniid mites are generally considered as the species rich and widely distributed group among the OribateiInferiores and represented 35-40 % of total oribatid population of the edaphic ecosystem. The survey yielded a total of fifteen species belonging to seven genera of lohmanniid mites from the soils collected from various localities of Malabar, Kerala of which nine were found to be new to science.

*Haplacarus* could be recorded as the most species rich genus, with four species and which showed even distribution in all the five study areas. Two genera viz., *Annectacarus* and *Papillacarus* achieved the second position, represented by three species each. *Javacarus* was ranked as the third genus with respect to species diversity and two species could be recovered under this genus. Three genera viz., *Cryptacarus*, *Meristacarus* and *Heptacarus* were represented by a single species each, thereby recording the minimum diversity. The generic diversity could be represented as:

$$\textit{Haplacarus} > \textit{Annectacarus} = \textit{Papillacarus} > \textit{Javacarus} > \textit{Cryptacarus} = \textit{Meristacarus} = \textit{Heptacarus}$$

The results of the survey (Table:1) revealed that the relative distribution pattern and abundance of these mites could be influenced by various geographical characters as well as floral composition. The genus *Haplacarus* was found to be predominant in all the sites studied. Of the four species recovered under this genus, two species viz., *H. foveolatus* and *H. granulatus* were found to be new to science. The genus was recorded in

### *Observation*

various virgin ecosystems like FA, BG, JK, SV & KT and SP & TL of Palakkad, Malappuram, Kozhikode, and Wayanad districts respectively. The sites QR, KY, NK, KD and TY though represented areas of periodical human interference, showed the presence of *Haplacarus* species. *H. keralensis* was found in abundance at sites FA and BG while *H. porosus* showed dominance at KY and NK. Sites QR and BG revealed numerical abundance of *H. foveolatus* whereas *H. granulatus* could be retrieved in large numbers from JK and SP sites. The genus *Annectacarus* was found distributed evenly in all the five districts under study. The site BG was noted to be an ideal site for all the three species of *Annectacarus* viz., *A. wallworki*, *A. areolatus* and *A. phyllotrichus*. Of these, *A. areolatus* and *A. phyllotrichus* were described as new species. The dominance of *A. areolatus* could be detected in two sites, FA & BG and its presence was also observed in other sites such as KT, NK, TL & SV. The other new species, *A. phyllotrichus* showed its dominance in sites DP, JK, SP & TY.

Among the three species of *Papillacarus*, *P. graminosus* = *Vepracarus* showed a restricted distribution trend by confining to Palakkad and Wayanad districts, in sites CP & TP, SP & TL respectively. Two new species of *Papillacarus* viz., *P. heterosetosus* and *P. reticulatus* could be collected from different localities surveyed in the five study areas. *P. heterosetosus* could be described as a new species and which was collected from the sites, BG and DP. Numerical abundance of *P. reticulatus* was recognized in sites JK and KT.

(TABLE : I) RELATIVE DISTRIBUTION OF LOHMANNIID MITES IN THE STUDY SITES

Sl.NO	SPECIES	STUDY AREA - 1				STUDY AREA - 2				STUDY AREA - 3				STUDY AREA - 4				STUDY AREA - 5			
		PALAKKAD DT.				MALAPPURAM DT.				KOZHIKODE DT.				WAYANAD DT.				KANNUR DT.			
		FA	CP	TP	DP	BG	SD	QR	KY	CH	KD	NK	JK	SP	BA	GL	TL	TY	DM	SV	KT
1	<i>A.wallworki</i>	-	-	-	-	+++	-	+	-	-	-	-	+	+	-	-	+	++	-	-	+
2	<i>A. areolatus</i> sp .nov	++++	-	-	-	+++	-	-	-	-	-	+++	++	-	-	-	++	-	-	-	++
3	<i>A.phyllotrichus</i> sp.nov	-	-	-	++++	+++	-	-	-	-	-	++	++++	+++	-	+	-	++	+	++	-
4	<i>C.grandjeani</i>	-	-	-	-	-	++	-	-	-	-	-	-	-	+++	++	-	-	-	-	-
5	<i>H.keralensis</i>	++++	-	-	-	++++	-	+	+	-	-	++	++	+	-	-	+	+	+	++	+
6	<i>H.porosus</i>	+	-	-	+	+	-	++++	++++	-	-	+	+	+	-	-	+	+	+	+	+
7	<i>H.foveolatus</i> sp.nov	++	-	-	+	++++	+	++++	+	-	+	+	++	+	-	-	+	++	+	+	++
8	<i>H.granulatus</i> sp.nov	+	-	-	+	++	+	++	++	-	+	+	++++	++++	-	-	+	++	+	++	+
9	<i>H.notobandus</i> sp.nov	-	-	-	-	-	-	-	-	++++	++++	-	-	-	-	-	-	-	-	-	-
10	<i>J.porosus</i>	+	-	-	+	++	+	+	-	-	++	+	+	++	-	-	-	-	-	-	-
11	<i>J.punctatus</i> sp.nov	+	-	-	++	++++	-	++	-	-	+	+	-	-	-	-	+	-	-	+	+
12	<i>M.degradatus</i>	+	-	-	-	-	-	-	++++	-	-	-	++	-	-	-	-	-	-	-	-
13	<i>P.heterosetosus</i> sp.nov	-	-	-	++++	++++	+	+	++	-	+	+	-	+	-	+	-	+	-	+	-
14	<i>P.reticulatus</i> sp.nov	++	-	-	+	+	-	++	+	-	+	+	++++	-	+	-	+	-	+	-	++++
15	<i>P.graminosus</i> sp. nov = <i>Vepracarus</i>	-	++++	++++	-	-	-	-	-	-	-	-	-	++	-	-	++	-	-	-	-

- : 0 individual + : 5-10 individuals ++ : 10-15 individuals +++ : 15-20 individuals ++++ : 20- 25 individuals

FA-Forest area CP- Coffee plantation TP-Tea plantation DP-Dam premises  
 BG-Botanical garden SD- Stadium premises QR-Staff quarters premises KY-Kakkancherry  
 CH- Chaliyam beach KD- Kadalundi NK-Narikuni JK-Janakikkad  
 SP-SoojiparaBA-Bamboo groove GL- Grass land TL-Thirunelli  
 TY-Thalassery DM-Darmadam SV- SanthivanamKT-Kottiyoor

### *Observation*

Members of the genus *Javacarus* were recovered from all the five study areas. *J.punctatus*, the new addition to the genus was collected from sites BG, QR, KD and NK of Malappuram and Kozhikkode districts. The species was also recovered from sites KT, TL and SV. *J.porosus* was detected in large numbers in sites KD, BG, FA, TY and SP. The genus *Cryptacarus* was found represented by *C.grandjeani* and its distribution was seen restricted to grasslands with little foliage as seen in sites SD, GL and BA. The population density of the species was found maximum in sites GL and SD.

Two genera viz., *Heptacarus* and *Meristacarus* were found represented by a single species each. The presence of *H.notobandus* was found restricted to the decomposing drift wood accumulations in the sites CH and KD. *M.degradatus* could be retrieved in abundance from the site KY and the species showed its occurrence in sites JK, KT and FA also.

Results of qualitative and quantitative analysis of the distribution pattern of lohmanniid mites recorded during the present study clearly indicated that the population density of these mites was greatly influenced by the vegetation, soil characteristics and human interference. Lohmanniid members showed numerical abundance and species diversity in undisturbed forest floors when compared to the areas with periodical human interference. *P. graminosus* = *Vepracarus* was recovered in large numbers in high altitude areas like Nelliampathy of Palakkad district and Soojipara, Wayanad district, which represented mainly agro-ecosystems dominated by *C.arabica* and *C.sinensis* plantations.

## **B. DESCRIPTION OF SPECIES**

**Superorder : Acariformes Zakhvatkin, 1952**

**Order : Sarcoptiformes Reuter, 1909**

**Suborder : Oribatida Duges, 1834**

**Supercohort : Enarthronota Grandjean, 1947**

**Superfamily : Hypochthonioidea Berlese, 2010.**

**Family: Lohmanniidae, Berlese 1916**

Members of this family are yellow to brown in colour. Sensillus is typically pectinate with a minimum of 9 branches. Anogenital plates meet and fill the entire length of the ventral side. All legs are monodactylous. Gnathosoma is not usually visible from above. A well developed notogaster is present. The propodosoma is movably connected with the hysterosoma. Body is more or less cylindrical and strongly convex.

**Genus : *Annectacarus* Grandjean, 1950**

### **Generic Characters**

Genital plates without transverse suture. Anal and adanal plates fused. Pre-anal plate narrow. Two pairs of anal and four pairs of adanal setae present. Notogastral and epimeral regions with neotrichy.

***Annectacarus areolatus* sp. nov.**

(Plate: 4)

(Figures:1-5 )

Colour : Light Brown

Measurements : Length – 528µm (Range: 492 - 528µm)

Width – 300µm (Range: 252-300µm)

**DORSAL REGION (Fig.2 )****Prodorsum**

Rostral tectum with two incisions anteriorly. Seta *ro* measures 60µm, finely barbed with a curved tip and inserted a little below the tip of rostrum. Seta *le* 79.5 µm long and finely barbed. An arched line extends between the lamellae, just below the base of seta *ro* . Seta *in* 76.5 µm long ,barbed and inserted near to bothridium. A line extends horizontally between setae *in* of both sides; setae *exa* and *exp* equally long (75µm) and barbed, lamellae on each side produced into condyles, near base of *exa*. Bothridium (*bo*) cup shaped. Sensillus (*ss*) long and pectinate with 11-12 long ,wavy branches on one side and 4-5 very short spines on the other side. Lateral margins of prodorsum bears fine punctations. The region between the lamellae carries polygonated ornamentation.

**Notogaster**

Notogaster broad and cylindrical with a rounded posterior region . Twenty pairs of setae of varying size and nature present on notogaster, median setae *c*<sub>1</sub>, *d*<sub>1</sub> and *e*<sub>1</sub> small and smooth while *f*<sub>1</sub> and *h*<sub>1</sub> longer and barbed, all others unilaterally barbed .Remnants of four notogastral bands formed of circular area porosae like structures present laterally on notogaster. Fissure ‘*im*’ located obliquely above the insertion point of seta *e*<sub>2</sub> .A weakly developed ridge present posteriorly on notogaster , between setae *h*<sub>1</sub> of either

side; notogastral integument bears polygonal structures, more prominent as rounded bodies at the pygidial region. Pygidial neotrichy present.

### **VENTRAL REGION (Fig.1 )**

Chelicerae (Fig.3 ) stout and bears sharp teeth; seta *chb* slightly longer than *cha*; pedipalp (Fig.4) five segmented, palp chaetotaxy 0-1-0-1-7(1). Infracapitulum carries 4 pairs of setae (*a*, *h*, *m*<sub>1</sub> and *m*<sub>2</sub>) of which *a* smooth, the others barbed. Epimeral setal formula 6-4-3-3. Epimere I carries 6 pairs of setae. Seta *1a* small and smooth, *1b* much longer than others with barbs and others intermediate in size and barbed. Epimere 2 bears 4 pairs of setae, of which seta *2a* smooth and others barbed. Epimeres 3 and 4 bear 3 pairs of setae each. Setae *3a* and *4a* smooth and others barbed. All epimeres carry area porosae. Fissure *ia* seen laterally; apodemata 2, 3 and 4 well developed ; apodeme 3 of the two sides united medially; fissure *ia* placed laterally. Epimeral surface punctated.

Genital plates entire. Each genital plate carries 10 setae, 4 longer setae in the paraxial row and 6 smaller setae; in the anti-axial row, first and third setae smooth while the second and fourth setae barbed, all setae in the paraxial row smooth. Aggenital plates not conspicuous . Pre-anal plate wide with a posteromedian projection. Anal and adanal plates fused. Ano-adanal setal formula (2+4). Adanal setae longer than the anal setae, both anal and adanal setae barbed; fissures *ih* and *ip* well developed, the former vertically placed and the latter located more anteriorly.

### **LEGS (Fig.5 )**

All legs monodactylous with a stout claw. Femur, Genu and Tibia of leg 1 bear reticulations and punctations. All setae on femur 1 barbed. Seta *d* of genu 1 closely associated with solenidion 'σ'. Tibia 1 bears a strongly set, very long solenidion φ. Tarsus 1 bears 2 solenidia ω<sub>1</sub> and ω<sub>2</sub>. Seta *ft*' barbed,

seen closely associated with  $\omega_2$ . Setae  $pv'$ ,  $ft'$  and  $a''$  barbed while  $m''$ ,  $s$ ,  $(p)$ ,  $(u)$ ,  $(tc)$  smooth. Chaetotaxy of leg 1: 0-4-4(1)-5(1)-14(2).

### **MATERIALS EXAMINED**

Holotype ♀, paratypes 7 specimens, 4 ♀♀ and 3 ♂♂ collected from cashew litter taken from the Botanical Garden, Calicut University Campus, Kerala, India on 21. VIII. 2010, coll. Anjana, M.

### **REMARKS**

The genus *Annectacarus* was erected by Grandjean (1950) with *A. mucronatus* as the type species from Venezuela. Balogh (1961) described *A. africanus* from East Africa. Wallwork (1962) added two more species viz., *A. insculptus* and *A. sejugatus* from Ghana. Hammer (1973) described *A. unilateralis* from Tongatapu island. Bhattacharya *et al.* (1974) provided information on *A. longisetosus* from W. Bengal, North India. Haq (1978) erected *A. trivandricus* from South India. A new species, *A. mahabeus* was erected by Corpuz-Raros (1979) from Philippines. Sengbusch (1984) described *A. granditrichosus* from Turk and Saipan, Indonesia. Hu and Wang (1990) erected two other species viz., *A. wallworki* and *A. hainanensis* from China and *A. aokii* was added to the genus by Clement and Haq (1991) and Jaikumar *et al.* (1994) respectively from Kerala, South India. Coetzee (2001) reported *A. eksteeni* from South Africa. A South Indian species viz., *A. hammerae* was described by Shiji *et al.* (2007) from Kerala and the authors also provided a key to the genus.

The specimens collected during the present study can be easily separated from the known species of *Annectacarus*, viz., *A. africanus*, *A. insculptus* and *A. longisetosus* based on the possession of only 4 pairs of infracapitular setae. *A. trivandricus* and *A. sejugatus* possess 2 notogastral bands where as remnants of 4 band like structures alone present in the present specimen. The line extending between  $h_1$  setae of the present specimen resembles that of *A. mucronatus* but differs in the epimeral setal

### *Observation*

formula 6-4-3-4. The epimeral setal formula 6-4-3-3 of the current specimen resembles with that of *A. wallworki* and differs from *A. aokii* where it is 7-4-3-4. The unilaterally barbed nature of notogastral setae of the present specimen shows close resemblance with that of *A. unilateralis* described by Hammer (1973), but shows difference from the latter by the absence of neotrichy.

A thorough examination of the morphological features of the present specimens revealed the following character deviations from the known species of the genus, which strongly support erection of a new species under the genus *Annectacarus*.

- 1) Prodorsal setae bilaterally barbed and notogastral setae unilaterally barbed.
- 2) First and third genital setae of the antiaxial row smooth and second and fourth setae barbed.
- 3) Presence of remnants of 4 irregular and incomplete notogastral bands, ( $S_2$ ,  $S_3$ ,  $S_4$  and  $S_5$ ) formed of area porosae like structures .
- 4) Possession of a line between  $h_1$  setae on the notogaster.

***Annectacarus phyllotrichus* sp. nov.**

( Plates: 5 & 6 )

( Figures:1&2,1-5 )

Colour : Dark Brown

Measurements : Length- 465  $\mu\text{m}$  (Range: 452 – 510  $\mu\text{m}$ )

Width – 375  $\mu\text{m}$  (Range: 321-390  $\mu\text{m}$ )

**Dorsal Region (Plate : 5, Fig:1&2)**

**Prodorsum**

Rostral tectum without incisions and convex anteriorly. Seta *ro* measures 52  $\mu\text{m}$ , inserted well below the rostral tip. Seta *le* 75.6  $\mu\text{m}$  long and barbed. Setae *in* 73.3  $\mu\text{m}$  long, placed just below the bothridium. Both anterior and posterior exobothridial setae (*exa* and *exp*) present, measuring 74.5  $\mu\text{m}$  and 74.1  $\mu\text{m}$  respectively. Lamellar ridges on either side narrow down posteriorly just above *exa*. Bothridium (*bo*) projects well above the body, with an oval opening. Sensillus (*ss*) long and pectinate with 12-13 branches(Fig:2). All prodorsal setae with a median rib and pointed tip and finely barbed along the margin. Prodorsum bears fine punctations and scattered polygonate structures, the latter prominent near the insertion of setae *le* and *ro*.

**Notogaster**

Notogaster cylindrical with a posterior border. It bears polygonate punctations, more prominent towards the lateral margins. Pygidial neotrichy absent. Median setae *c<sub>1</sub>*, *d<sub>1</sub>* and *e<sub>1</sub>* small and smooth while all other notogastral setae long, somewhat foliate and barbed. A ridge extends between

$h_1$  setae of both sides. Band  $s_1$  complete but  $s_2$  present only laterally on either side.

**Ventral Region: ( Plate :6 ,Fig:1-5)**

Chelicerae (Fig:3) stout and bears sharp teeth. Pedipalp (Fig:3) 5 segmented. Infracapitulum (Fig:3) carries 4 pairs of setae ( $a$ ,  $h$ ,  $m_1$ , and  $m_2$ ), of which  $a$  smooth,  $h$ ,  $m_1$  and  $m_2$  barbed. Epimere 1 carries 5 pairs of setae. Seta  $1a$  small and smooth and  $1b$ ,  $1c$ ,  $1d$  and  $1e$  long and barbed. Epimere 2 bears 3 pairs of setae, seta  $2a$  smooth and small,  $2b$  and  $2c$  barbed and long. Epimeres 3 and 4 carry 3 pairs of setae. Setae  $3a$  and  $4a$  smooth and others barbed. Epimeral setal formula 5-3-3-3. Sejugal apodeme continuous medially. All epimeres possess area porosae (Fig:2) .

Genital plates entire (Fig. 4&5). Each genital plate with 10 smooth setae inserted in an antiaxial row of 4 and paraxial row of 6. The first and third antiaxial setae longer than the second and fourth. All setae in the paraxial row equally long. Pre-anal plate with a median projection. Anal and adanal plates fused (Fig. 4&5). Ano-adanal setal formula 4+2. Adanal setae longer than the anal setae, both anal and adanal setae barbed and foliate.

**LEGS( Plate :6, Fig.1 )**

All legs monodactylous with a stout claw. Femur, Genu and Tibia of leg 1 (Fig. 1) bear reticulations and punctations. All setae on femur 1 barbed. Seta  $d$  of genu 1 closely associated with solenidion ' $\sigma$ '. Tibia 1 bears a strongly set, very long solenidion  $\phi$ . Tarsus 1 bears 2 solenidia  $\omega_1$  and  $\omega_2$ . Seta  $ft'$  barbed, seen closely associated with  $\omega_2$ . Chaetotaxy of leg 1: 0-4-5(1)-5(1)-13(2).

### **Material Examined**

Holotype: ♀, paratypes 6 ♂♂, collected from soils of Santhivanam, Government Brennen College Campus, Kerala, India on 18.11.2011 Coll. Anjana, M.

### **Remarks**

The specimens collected during the present study show resemblance to *A. granditrichosus* in characters like the possession of long and barbed lateral ciliate notogastral setae and the median setae being smaller than the others. But it differs from *A. granditrichosus* in the number of infracapitular and pygidial setae. The presence of a ridge between  $h_1$  setae of the present specimen resembles that of *A. mucronatus*, but it differs in its epimeral setal formula of 6-4-3-4. The complete nature of band  $s_1$  in the present specimen resembles with that of *A. insculptus* and differs in the absence of *neotrichy*. Polygonate punctation on the notogaster and prodorsum of the current specimen resembles with that of *A. hammerae* but can easily be separated by the roughened nature of  $c_1$ ,  $d_1$ , and  $e_1$  setae and possession of 14 barbs on the sensillus.

The possession of the following combination of characters strongly supports to assign the present species as a new taxon, under the genus *Annectacarus*.

- 1) Foliate and barbed nature of prodorsal and notogastral setae.
- 2) Epimeral setal formula of 5-3-3-3.
- 3) Absence of pygidial *neotrichy*.
- 4) The complete nature of the band  $s_1$  and presence of polygonate structure over the body.

***Annectacarus wallworki* Clement and Haq, 1991**

(Plate:7 )

(Figures : 1-5)

Colour : Brown  
Measurements : Length: 520-542  $\mu$ m  
Width: 272-284  $\mu$ m

**DORSAL REGION (Fig. 1)**

**Prodorsum:**

Rostrum with two incisions. Seta *ro* curved at the tip and finely barbed. Seta *le* projects anterolaterally. Seta *exa* longer than seta *exp*. Cup shaped bothridium (*bo*) carries pectinate sensillus (*ss*), the latter bears 10-12 branches on its upper side and with a few small branches on the lower side. Seta *in* little smaller than *le* and *exa*. Prodorsum punctate throughout. A few area porosae arranged in a reticulate fashion, seen scattered on the prodorsum, particularly near *bo* and seta *le*.

**Notogaster:**

Notogaster cylindrical with a rounded posterior margin. Median setae *c*<sub>1</sub>, *d*<sub>1</sub> and *e*<sub>1</sub> small, thin and smooth, other notogastral setae longer and barbed. Setae *e*<sub>1</sub> of both sides placed closely, while *f*<sub>1</sub> setae placed apart. Notogastral neotrichy present. Remnants of a band formed of area porosae like structures seen between setae *c*<sub>1</sub> and *c*<sub>2</sub> on both sides. A few area porosae seen on notogaster, towards posterior end. Fissure *im* present on each side of notogaster, above the insertions of setae *e*<sub>2</sub>.

**VENTRAL REGION (Fig.2 )**

Chelicerae (fig:3 )well developed with strong teeth. Setae *cha* smaller than *chb*. Pedipalp (Fig:4 )with five segments. Palpal chaetotaxy 0-1-0-1-7(1),

### *Observation*

setae ( $ul_3$ ) eupathidic. Infracapitulum bears 4 pairs of setae, of which  $a$  smooth,  $h$ ,  $m_1$  and  $m_2$  barbed.

Epimeral boundaries clear with neotrichy on epimeres 1 and 2, while 3 and 4 without any neotrichy. Epimeral setal formula 6-4-3-3. On epimeres 1 and 2, setae  $1a$  and  $2a$  smooth while others barbed, seta  $1f$  the longest, epimeres 3 and 4 bear 3 smooth setae and a pair of area porosae each.

Genital plates entire, each plate, bears 10 finely barbed setae, arranged in two longitudinal rows of 6 small setae and 4 long setae. Pre-anal plate narrow with a postero-median projection. Anal and adanal plates fused. Four pairs of long adanal and 2 pairs of small anal setae present, all finely barbed. Adano-anal setal formula (4+2). Ventral plate lying around ano-adanal plate bears remnants of bands; fissure  $ih$  obliquely placed above the insertion point of seta  $h_2$ .

### **LEGS (Fig.5).**

All legs monodactylous. Chaetotaxy of leg I: 0-5-4-4-17 (Fig.5 ). Reticulations present on femur, genu, tibia and tarsus.

### **MATERIALS EXAMINED**

13 specimens, 9 ♀♀ and 4 ♂♂. All collected from cashew litter, Botanical Garden, Calicut University Campus, Kerala, India on 17.01.2011, Coll. Anjana, M.

### **REMARKS**

Specimens collected during the study resembles *A. wallworki* described by Clement and Haq (1991) from the soils of Kerala, India in all characters

**Genus: *Cryptacarus* Grandjean, 1950**

**Generic Characters:**

Genital plates with transverse suture. Anal and adanal plates fused. Pre-anal plate narrow. Two pairs of anal and four pairs of adanal setae present. Notogaster and epimeral regions with neotrichy.

***Cryptacarus grandjeani* Clement and Haq, 1991**

(Plate:8 )

(Figs:1-5 )

Colour : Yellowish brown

Measurements : Length : 348-360 $\mu$ m

Width : 156-180 $\mu$ m

**DORSAL REGION (Fig.1 )**

**Prodorsum**

Rostral tectum round and without any incisions. Seta *ro* inserted well below the anterior tip and of the rostrum. Seta *le* inserted laterally, below the insertion of *ro*. Setae *exa* and setae *exp* almost of the same length. Seta *in* placed slightly below the level of bothridium. All prodorsal setae distinctly branched, seta *ro* being, the longest with more branches. Bothridium (*bo*) cup shaped. Sensillus pectinate, bearing 13-15 branches. Prodorsum carries tubercles throughout, except at lateral and the extreme anterior and posterior regions.

**Notogaster:**

Lateral and posterior margins of notogaster appear wavy owing to the possession of large number of tubercles. All setae distinctly branched.

Marginal setae longer than the median ones. Notogaster with pygidial neutrichial setae. Seta,  $ps_1$  longer and brush like than the other pygidial setae.

**VENTRAL REGION: (Fig.2 )**

Chelicerae (Fig.3 ) stout with strong teeth. Seta  $chb$  almost twice the length of  $cha$ . Pedipalp (Fig.4. ) five segmented, with a chaetotaxy of 0-1-0-1-6(1). Infracapitulum bears five pairs of setae ( $a$ ,  $h$ ,  $m_1$ ,  $m_2$  and  $m_3$ ). Seta  $a$  simple, others barbed. Epimeral setal formula 5-5-3-3. All the five setae of epimere 1 short and branched. Seta  $2b$  on epimere 2 simple and all others barbed. Epimeres 3 and 4 bear three pairs of barbed setae each. Fissure  $ia$  seen laterally as a small curved slit. Epimeres bear micropunctations.

Genital plates divided by a transverse suture into two unequal halves, an upper smaller plate and lower larger plate. On each genital plate, 3 pairs of setae placed in paraxial row and 2 pairs in the antiaxial row. The second pair of genital setae lying in the antiaxial row of upper half of possess long barbs while others with short barbs.

Aggenital plates triangular in appearance, pre-anal plate narrow, postero-median region projected downwards. Anal and adanal plates fused. Anal plates with 2 pairs of short and branched setae. Adanal plates with 4 pairs of long, branched setae. Ano-adanal setal formula (2+4). The ventral plate lying lateral to genital and ano-adanal plates heavily tuberculated.

**LEGS (Fig.5 )**

All legs monodactylous. Chaetotaxy of leg 1: 0-5-5-4-14(2) (Fig.5 ). Trochanter 1 small, triangular in shape and bears no setae. Reticulations and punctations seen on femur, genu, tibia and tarsus of leg 1. Femur 1 with a ventral tooth, just above seta  $bv$ . Setae  $d$ ,  $l'$ ,  $l''$ ,  $v''$  present on femur 1, all setae except  $l'$  barbed. On genu 1 solenidia  $\sigma_1$  and  $\sigma_2$  closely associated with

### *Observation*

a smooth seta  $d$ . Seta  $l'$  thick and barbed while  $v''$  thin and smooth. Tibia 1 bears a long solenidion  $\psi$ , 2 barbed setae  $xt_1$ ,  $xt_2$  and one smooth lateral seta  $l'$ . Tarsus 1 with 2 solenidia,  $\omega_1$  and  $\omega_2$  in addition to 14 other setae. Setae  $pv'$  and  $pv''$  barbed and others smooth. Seta  $ft'$  closely associated with  $\omega_2$ . A thin famulus,  $\varepsilon$  closely seen in association with  $\omega_1$ .

### **MATERIALS EXAMINED**

7 specimens, 5 ♀♀ and 2 ♂♂. collected from soil samples of Botanical Garden, Calicut University Campus, Kerala, India, on 13 x 2011. Coll. Anjana, M.

### **REMARKS**

The present specimens resemble *Cryptacarus grandjeani* Clement and Haq, 1991, in all characters like the nature of body setae and ornamentation.

**Genus *Haplacarus* Wallwork, 1962**

**Generic Characters**

Genital plates without transverse suture. Anal and adanal plates fused. Pre-anal plate wide. One pair of anal and 4 pairs of adanal setae present. Notogastral and epimeral regions without neotrichy.

***Haplacarus foveolatus* sp. nov.**

(Plates:9&10)

( Fig: 1-5,1-4)

Colour : Brown

Measurements: Length : 658 $\mu$ m (Range: 612-708 $\mu$ m)

Width : 305 $\mu$ m (Range: 305-354 $\mu$ m)

**DORSAL REGION (Plate : 9 Fig.1-5 )**

**Prodorsum:( Fig.2)**

Prodorsum triangular in outline with a narrow, blunt rostrum. Seta *ro* foliate with minute barbs, 88 $\mu$ m long, inserted far below the rostral tip. Seta *le* measures 77  $\mu$ m long and foliate with minute barbs and curved outwards. Seta *exa* the longest among prodorsal hairs, measuring 105 $\mu$ m and directed downwards. Seta *exp* measures 92  $\mu$ m, thick, foliate with minute barbs and directed backwards. Lamellar ridge with a median contour. Seta *in* thicker but shorter, measuring 71 $\mu$ m long, foliate with minute barbs and inserted adjacent to bothridium, *in* the stouter and smallest of prodorsal setae. Bothridium (*bo*) (Fig. 3) cup shaped with an oval opening from which sprouts the pectinate sensillus (*ss*) bearing 9-11 branches. A transverse band extends between the insertion point of *in*, and the dorsosejugal suture. Integument of prodorsum with dense, spherical tubercles except at the

extreme anterior part of the rostrum and the prodorsal band. Each tubercle with an inner concavity. Under higher magnification, adjacent tubercles often seen connected by tubular canals (Fig. 5)

### **Notogaster**

Notogaster cylindrical and elongate with a rounded posterior margin. Nine complete notogastral bands (Fig.5) present, the posterior 3 bands convex medially. Seta  $c_2$  smaller than  $c_1$  and  $c_3$ . Setae  $d_1$  and  $d_2$  of almost same size while  $d_3$  twice longer than  $d_1$  and  $d_2$ . Seta  $e_1$  long and extends up to  $s_8$  and tip of  $f_1$ . Setae  $f_1$  and  $h_1$  placed laterally than medially. Seta  $ps_1$  thicker and shorter than the other notogastral setae and curved downwards(Fig.4). Notogastral integument also heavily ornamented with circular tubercles, bearing inner concavities, except at regions of notogastral bands.

### **Ventral Region (Plate : 10, Fig.1-5 )**

Infracapitulum (Fig.1) bears tubercles. Chelicerae well developed and Pedipalp with five segments. Infracapitulum bears four smooth setae –  $a$ ,  $h$ ,  $m_1$  and  $m_2$ . Setae  $m_1$  and  $m_2$  longer than  $a$  and  $h$ .

Epimeral setal formula 3-2-2-3(Fig.1). On epimere 1 three setae of equal length,  $1a$ ,  $1b$  and  $1c$ . Seta  $2a$  smaller and medially placed where as  $2b$  longer and placed laterally. Epimere 3 also bears two setae,  $3a$  and  $3b$ . Epimere 4 possesses three setae, of which  $4a$  smaller than  $4b$  and  $4c$ . All epimeral setae smooth. Epimeral surface also heavily ornamented with tubercles.

Genital plates without transverse suture(Fig.2). Aggenital plates triangular and seen inserted on genital plates at the antero-lateral corners of genital plates. Ten pairs of genital setae, six pairs in the median line and four pairs towards the outer margin. First seta in the marginal row longer than the others. Pre- anal plate wide and without a postero-median projection. Anal

and adanal plates fused with a setal formula of (1+4). Anal setae smaller than the adanal setae. Genital and fused ano-adanal plates also bear small spherical tubercles bearing concavities(Figs.2&3). The extreme lateral region of the ventral plate, lying exterior of acetabula of legs 3 and 4 devoid of tubercles.

## LEGS

All legs monodactylous with a stout claw. Chaetotaxy of leg 1- 0-3-4-5-14(2) (Fig.4). Femur 1 with a ventral keel. Tubercles present on ventral surface of femur 1 and dorsally polygonal structures present. Setae of femur 1 thick and with minute barbs. Genu 1 bears 2 solenidia,  $\sigma_1$  and  $\sigma_2$ . Tibia 1 bears a whip like solenidion ( $\psi$ ) and setae  $xt_1$  thicker than  $xt_2$  and  $l'$ . Tarsus 1 bears 16 setae including solenidia  $\omega_1$  and  $\omega_2$ , all long, thick and with minute barbs.

## Materials Examined

Holotype ♀, 12 paratypes, 7 ♀♀ and 5 ♂♂ collected from the soil and litter samples of Nelliampathy forest, Palakkad, Kerala, India, on 05.XI.2012 coll. Anjana, M.

## Remarks:

The genus *Haplacarus* was erected by Wallwork (1962) with *H. foliatus* as type species from Ghana. The second species, *H. pairathi* was added by Aoki (1965) from Thailand. Bhattacharya *et al.* (1974) described a subspecies, *H. foliatus bengalensis* from India. *H. javensis* was reported from java by Hammer (1979). Sengbusch (1982) described another species, *H. pandanus* from Micronesia. Haq *et al.* (1984) reported *H. keralensis* from South India. Two new species, viz., *H. maharashtrensis* and *H. bhadurii* were erected from North India by Sanyal (1984). *H. rugosus* was reported by Mahunka (1987) from Malaysia and subsequently, *H. porosus* was erected by Haq and Clement (1995) from Kerala, India. Alphonsa *et al.* (2005)

### *Observation*

described two new species, *H. davisii* and *H. xavieri* from Kerala, India. Therefore, ten species have been reported under the genus *Haplacarus* so far.

The specimen collected during present study can be easily separated from the type species, *H. foliatus* by the complete nature of all notogastral bands in the current specimen where bands  $s_1$ ,  $s_3$  and  $s_6$  incomplete in the type species. The present specimen shows close resemblance to *H. javensis* described by Hammer (1979) in the barbed nature of prodorsal setae and smooth nature of notogastral setae and can be distinguished by the presence of 11 branches on sensillus when compared to the 8 branches in the latter. The current specimen shows resemblance to *H. keralensis* described by Haq *et.al.* (1984) in the nature of notogastral ornamentation, but differs in the possession of epimeral setal formula of 3-2-2-3 when compared to the 3-1-3-4 of the latter and smooth nature of anal and adanal setae.

The unique features of the species by which it can be easily distinguished from the other known species of the genus are the following:

- 1) Body ornamentation with dense tubercles of different size with inner concavity.
- 2) Possession of complete nature of all the 9 notogastral bands.
- 3) Epimeral setal formula of 3-2-2-3.
- 4) Small and stout nature of inter lamellar seta (*in*)

***Haplacarus granulatus* sp. nov.**

(Plate:11 )

(Figures:1-5 )

Colour : Golden brown

Measurements: Length – 880µm (Range 880-915µm)

Width – 465µm(Range 435-465µm)

**DORSAL REGION (Fig. 1)**

**Prodorsum:**

Prodorsum triangular and extends as a narrow blunt rostrum anteriorly. Seta *ro* 105 µm long, smooth, thick and placed close together. Seta *le* 92 long and inserted below, but lateral to *ro*, resembles the latter in nature but directed outwards. Seta *in* 75µm long, thick, smooth, inserted very close to the bothridium. Both setae *exa* and *exp* thick and smooth, *exa* longer, measuring 90µm and *exp* slightly shorter, with a length of 80µm. *bo* cup shaped and carries a pectinate sensillus (*ss*) with 11 branches. A transverse, thick band extends below the insertion point of seta *in* and the dorsosejugal suture. Prodorsum bears small, circular papillae medially. Region between prodorsal band and dorsosejugal suture bears fine punctations.

**Notogaster:**

Notogaster cylindrical and oval in appearance. Nine notogastral bands present. Bands  $S_2$  and  $S_3$  incomplete medially, the remaining bands, especially the posterior ones convex medially; 14 pairs of notogastral setae, all smooth and foliate. Marginal setae  $c_3$  and  $d_3$  longer than median setae,  $c_1$  and  $d_1$ . Setae  $f_1$  and  $h_1$  placed more towards lateral margins of notogaster than

medially. Seta *ps<sub>1</sub>* thicker and shorter than the other setae. Notogaster bears spherical papillae all over, except on notogastral bands.

### **VENTRAL REGION (Fig. 2)**

Infracapitulum bears papillae. Chelicerae (Fig.3 ) well developed with pronounced teeth. Seta *cha* smaller than *chb*. Pedipalp (Fig.4 ) five segmented. Palpal chaetotaxy represented by formula 0-1-0-1-7(1), palp solenidion  $\omega$  thick with a blunt tip. Setae *a*, *h*, *m<sub>1</sub>* and *m<sub>2</sub>* smooth, seta *a* longer than the others.

Epimeral setal formula 3-1-3-4, all smooth and show size variation. On epimere 1, seta *1b* longer than *1a* and *1c*. Epimere 2 bears only a pair of seta, *2a*. On epimere 3, seta *3c* longer than *3a* and *3b*. Setae *4a* and *4d* of epimere 4 smaller than *4c* and *4d*. Fissure *ia* seen laterally to epimere 3. Epimeral region also bears circular papillae.

Genital plates without transverse suture. Triangular aggenital plate present at the antero-lateral corner of each plate. Ten pairs of genital setae present, six pairs arranged vertically on the inner border and four pairs towards outer border of genital plates. The inner row of setae arranged alternatively between the genital plates. The second pair of genital seta inserted on outer row smaller than the same seta of the opposite side, in the holotype. Pre-anal plate wide with a slight postero-median projection. Anal and adanal plates fused. Four pairs of adanal setae and one pair of anal setae present. Adanal and anal setal formula (4+1). Anal setae smaller than the adanal setae. Ano-adanal and genital plates ornamented with fine papillae medially. Lateral sides of ano-genital plates also ornamented with irregularly arranged papillae.

**LEGS**

All legs mondoactylous with a stout claw. Chaetotaxy of Leg I, 0-4-6-4-20 (Fig.5 ) Trochanter 1 small and bears no setae. Setae *d* and *v*'' on femur thicker than other setae and with barbs. Setae *l*' and *l*'' smooth and thin. Genu 1 bears two solenidia,  $\sigma_1$  and  $\sigma_2$ , the former longer and thicker than the latter. Seta *d* smooth and thin, seen closely associated with  $\sigma_1$ . Seta *v*' thick and barbed. Seta *l*' thin and barbed, while seta *l*'' thin and smooth and seen close to seta *v*'. Tibia 1 bears a long, whip like solenidion ( $\phi$ ). The other tibial setae, *xt*<sub>1</sub>, *xt*<sub>2</sub> and *l*' thin and smooth. Tarsus 1 bears 20 setae. The solenidion  $\omega_1$  thicker and longer than  $\omega_2$ . Famulus ( $\epsilon$ ) present near  $\omega_2$ . Setae *pv*' and *pv*'' with barbs. Seta *a*'' thick and longer than *a*'. Setae *ft*' and *ft*'' seen close together. Tarsus 1 bears setae *m*'', *s*, (*u*), (*p*), (*it*), (*tc*), all smooth. Leg segments finely punctated, femur 1 bears sparsely arranged tubercles also.

**MATERIALS EXAMINED:**

Holotype ♀, 6 paratypes, 4 ♀♀ and 2 ♂♂, collected from soil and litter samples of Botanical Garden, Calicut University campus, Kerala, India, on 23. IV. 2012, coll. Anjana, M.

**REMARKS:**

The genus *Haplacarus* was erected by Wallwork in 1962 with *H. foliatus* as type species. The present specimen differs from the types species by the incomplete nature of two notogastral bands (*S*<sub>2</sub> and *S*<sub>3</sub>) while in the types species, only one band, *S*<sub>7</sub> is incomplete. The new species bears smooth foliate notogastral setae as in *H. porosus* and can be distinguished from *H. javensis* and *H. pairathi* based on the barbed nature of notogastral setae. The specimen under study shows resemblance to *H. keralensis* in the

### *Observation*

epimeral setal formula of 3-1-3-4 and nature of notogastral ornamentation, but differs from it based on the smooth nature of anal and adanal setae.

Possession of unique characters like (1) second pair of genital setae in the antiaxial row smaller than other 3 pairs, (2) genital setae in the paraxial row arranged alternatively than opposite and (3) region between prodorsal band and dorsosejugal suture ornamented with fine granulations strongly supports for the erection of the present specimen as a new species under the genus *Haplacarus*.

***Haplacarus keralensis* Haq, Mubarak and Ramani, 1984**

(Plate: 13)

(Fig: 1-5)

Colour : Yellowish brown

Measurements : Length : 584-720 $\mu$ m

Width : Range 348-372 $\mu$ m

**DORSAL REGION (Fig.1 )**

**Prodorsum:**

Anterior margin of rostrum smooth. All prodorsal setae foliate and weak with barbs at the base only. Seta *ro* inserted far below rostral tip, and more than three times longer than their mutual distance. Seta *le* curved, inserted below level of *ro* and with barbs at the base alone. Seta *exa* longer than *exp*, and both *exa* and *exp* with barbs at the base. Lamellae of both sides produced into blunt projections, a little above insertion point of seta *exa*. Seta *in* inserted below the level of bothridium and resembles other prodorsal hairs in nature. A wavy median band extends transversely between the setae *in* of both sides. Bothridium (*bo*) cup shaped. Sensillus (*ss*) pectinate with 10-12 branches. Prodorsum bears papillae and fine punctuations, except at the extreme anterior, posterior and lateral regions.

**Notogaster:**

Notogaster cylindrical, bearing uniformly distributed papillae, except in places where notogastral bands present. Ten notogastral bands present, of which  $S_2$  and  $S_6$  incomplete. Band  $S_2$  very short and seen laterally as a small band, but  $S_6$  runs more than half the way. Sixteen pairs of smooth, foliate notogastral setae present, marginal setae  $c_3$ ,  $d_3$ ,  $e_2$ ,  $f_2$  and  $h_3$  longer than the

other setae. Seta  $ps_1$  incurved distally. Fissure *im* seen between setae  $d_2$  and  $e_2$ , as a slit.

### **VENTRAL REGION (Fig.2 )**

Chelicerae (Fig.3 ) stout with strong teeth. Setae *chb* longer than *cha*. Chaetotaxy of pedipalp 0-1-0-1-6(1) (Fig.4 ). Infracapitulum bears 4 pairs of smooth setae (*a*, *h*,  $m_1$  and  $m_2$ ). Setae  $m_1$  and  $m_2$  thicker than *a* and *h*. Infracapitulum ornamented with fine papillae .

Epimere 1 bears three pairs setae, of which *1a* weakly barbed and longer where as *1b* and *1c* smooth and short. Epimere 2 bears a single pair of seta, *2a*. Epimere 3 carries three pairs of setae, viz., *3a*, *3b* and *3c* of which *3a* smooth and others barbed. Epimere 4 with four pairs of setae, *4a* and *4b* smooth and *4c* and *4d* barbed. Epimeral setal formula 3-1-3-4. Epimeral boundaries very clear. Sejugal apodeme continuous medially. Epimeral region also ornamented with fine papillae.

A pair of aggenital plates present at the anterolateral margins of each genital plate. Genital plates without any transverse suture. Each plate bears ten smooth setae, an antiaxial row of four and a paraxial row of six setae. Pre-anal plate wide with a prominent postero-median projection. Ano-adanal plates fused with a single pair of anal and four pairs of adanal setae, all smooth. Ano-adanal setal formula (1+4)

### **LEGS**

All legs monodactylous. Chaetotaxy of leg 1: 1-4(2)-4(1)-5-14(2) (fig.5). Trochanter 1, without any setae. Femur 1 bears a ventral ridge and fine punctations. Setae *d*, *l'* and *V''* present on femur 1 barbed, *d* thicker and longer than the other setae. Genu 1 bears two solenidia,  $\sigma_1$  and  $\sigma_2$ ;  $\sigma_1$  seen in close association with smooth seta *d*. Seta *l''* thick and barbed. Tibia 1 bears

### *Observation*

5 setae, of which  $xt'$ ,  $xt''$  and  $l'$  barbed and  $d$  smooth. The solenidium  $\psi$  of femur 1, long and closely set with setae  $d$  and  $xt'$ . Tarsus 1 bears 17 setae including two solenidia  $\omega^1$  and  $\omega^2$ . Setae  $u$  and  $a'$  barbed, setae  $pv'$ ,  $m''$ ,  $s$ ,  $(it)$ ,  $(p)$ ,  $(tc)$ ,  $ft'$ ,  $ft''$  and  $a$  smooth.

### **MATERIALS EXAMINED**

13 specimens, 8 ♀♀ and 5 ♂♂, collected from the soil and litter samples of Botanical Garden, Calicut University Campus, Kerala, India, on 5.IV.2011.coll. Anjana,M.

### **REMARKS**

The specimens collected during the preset study resemble *H.keralensis* described by Haq *et. al.* (1984) in all characters like :

- (1) incomplete nature of band  $S_2$
- (2) wavy notogastral margin with distinct papillae
- (3) pre-anal plate with postero-median projection
- (4) epimeral setal formula of 3-1-3-4 and finely barbed nature of epimeral setae,  $1a$ ,  $3b$ ,  $3c$ ,  $4c$  and  $4d$ .

The variations from *H. keralensis* are weakly barbed nature of prodorsal setae, complete nature of  $s_4$  and incomplete nature of  $s_6$ .

***Haplacarus porosus* Haq and Clement, 1995**

(Plate:12 )

(Figures:1-5 )

Colour : Dark brown

Measurements : Length – 672 $\mu$ m (Range: 684-744 $\mu$ m)

Width – 336 $\mu$ m (Range – 324-360 $\mu$ m)

**DORSAL REGION (Fig.1)**

**Prodorsum:**

Anterior margin of rostrum without any incisions. Seta *ro* roughened, inserted far below the rostral tip, placed close together. A median ridge present between the insertions of seta *ro* of both sides . Seta *le* also roughened, inserted below and lateral to level of seta *ro*. Lamellar ridge with a median conical projection. Setae *exa* and *exp* present, *exa* inserted a little below the angular contour of lamellae. Bothridium (*bo*) cup shaped. Sensillus (*ss*) pectinate with 12-14 branches. Seta *in* seen below the level of bothridium. A wavy transverse band present in between setae *in*. All prodorsal setae foliate in appearance and without barbs. Integument of prodorsum finely punctate . Characteristic area porosae like structures present between setae *le* and *exa*.

**Notogaster:**

Notogaster elongate, bearing sixteen pairs of foliate, smooth setae . Seta *ps*<sub>1</sub> slightly incurved. Nine notogastral bands formed of area porosae present, of which the posterior ones broken. An incomplete line of area porosae present in between bands *S*<sub>1</sub> and *S*<sub>2</sub>. A few area porosae of varying size and numbers scattered between notogastral bands. Integument of

notogaster lying just below the dorsosejugal suture finely punctate, other areas smooth.

### **VENTRAL REGION (Fig.2 )**

Infracapitulum bears four pairs of setae. Setae 'a' and 'm<sub>2</sub>' smooth while *h* and *m<sub>1</sub>* barbed. A few area porosae and fine punctations present on infracapitulum. Chelicerae (Fig.3 ) stout and bears blunt teeth. Seta *chb* twice longer than *cha*. Pedipalp (Fig.4 ) with a chaetotaxy of 0-1-0-1-7. Epimeral setal formula 3-1-3-3. Epimere 1 bears three pairs of setae. Setae *1a* and *1c* small and smooth, *1b* long and barbed. Epimere 2 bears only a single pair of smooth seta, *2a*. Epimere 3 carries three pairs of setae, *3a* simple while *3b* and *3c* barbed. Epimere 4 carries three pairs of setae, *4a* and *4c* smooth, while *4b* barbed. Fissure *ia* present laterally. Epimeral surface finely punctate.

Aggenital plates triangular and seen at the anterolateral corners of each genital plate. Genital plates without transverse suture, each bearing ten smooth setae, an antiaxial row of four and a paraxial row of six setae present, on each genital plate. Pre-anal plate broad with a postero-median projection. Anal and adanal plates fused. Ano-adanal setal formula (1+4). Adanal setae long and smooth where as anal setae short, reaching half the length of adanal setae, anal setae also smooth. Fissure *ih* present between setae *ps<sub>3</sub>* and *h<sub>3</sub>*. A few area porosae and micropunctations seen on either sides of fissure *ih*.

### **LEGS**

All legs monodactylous. Chaetogaxy of leg 1 : 0-4-5-4-17 (Fig. 5) . Trochanter 1 bears no setae. Femur 1 bears four setae, of which seta 'd' thick and lanceolate, seta *v*' smooth. seta *l'* thin and *l''* with fine barbs at the tip. Genu 1 carries five setae, 'd' smooth and seen closely associated with solenidia  $\sigma_1$  and  $\sigma_2$ . Two lateral setae, *l'* and *l''* present, *l'* thick and slightly roughened, *l''* thin and smooth. Tibia 1 bears a long solenidion ( $\psi$ ) and setae

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$xt$ ,  $xt_2$  and  $l'$ . Tarsus 1 bears seventeen setae including 2 solenidia,  $\omega_1$  and  $\omega_2$ . Setae  $pv'$  and  $u$  barbed while  $ft'$ ,  $ft''$ ,  $(it)$ ,  $(tc)$ ,  $(p)$ ,  $s$ ,  $m''$  and  $(a)$  smooth. Femur, genu and tibia of leg I bear reticulations.

### **MATERIALS EXAMINED**

8 specimens, 5 ♀♀ and 3 ♂♂ collected from soil samples of Botanical Garden, Calicut University Campus, Kerala, India on 12. VIII. 2012, Coll. Anjana, M.

### **REMARKS**

The present specimen shows close resemblance with *H. porosus* described by Haq and Clement (1995) in characters like smooth and foliate nature of notogastral setae, epimeral setal formula of 3-1-3-3, the beaded nature of notogastral bands, slightly roughened nature of prodorsal setae, postero-median projection of pre-anal plate etc. The present specimen shows variation from *H. porosus* in the incomplete nature of bands  $s_6$ ,  $s_7$ ,  $s_8$  and  $s_9$ .

**Genus *Heptacarus* Piffel, 1963**

**Generic Characters**

Genital plates with transverse suture. Anal and adanal plates fused. Pre-anal plate broad. Five pairs of adanal and two pairs of anal setae present. Pygidium with weak or strong neutrichy. Epimeral region with weak neutrichy.

***Heptacarus notobandus* sp. nov.**

(Plate:14 )

(Fig.1-5 )

Colour : Yellowish brown

Measurements : Length 585 $\mu$ m (Range 570-600 $\mu$ m)

Width 270  $\mu$ m(Range 270-300 $\mu$ m)

**DORSAL REGION (Fig. 1)**

**Prodorsum**

Prodorsum broadly triangular. Rostral apex rounded. Seta *ro*, 60 $\mu$ m long, barbed, arising a little below the rostral apex. Seta *le*, 85 $\mu$ m long, barbed, inserted lateral and external to the insertion point of *ro*. Seta *in* 90 $\mu$ m, inserted at the level of bothridium. Both setae *exa* and *exp* barbed, both equally long, measuring 45 $\mu$ m and shorter than the other prodorsal setae. Bothridium (*bo*) cup shaped. Sensillus (*ss*) pectinate with 13 branches. All prodorsal setae barbed. Prodorsal integument with irregular polygonated microsculpture.

**Notogaster:**

Notogaster broader anteriorly and narrowing posteriorly. Strong neotrichy present, more pronounced posteriorly. The *c* row bears 4 pairs of setae *c*<sub>1</sub>, *c*<sub>2</sub>, *c*<sub>3</sub> and *c*<sub>4</sub>. Four pairs of setae present in the *d* row, *d*<sub>1</sub>, *d*<sub>2</sub>, *d*<sub>3</sub> and *d*<sub>4</sub>. Three pairs of setae present in the *e* row, *e*<sub>1</sub>, *e*<sub>2</sub> and *e*<sub>3</sub>. Beyond this region, strong neotrichy persists with setae bending downwards. Notogaster carries polygonated reticulations similar to those on prodorsum. Two irregular band like clear areas seen at the posterior half of the notogaster, as remnants of posterior notogastral bands.

**VENTRAL REGION: (Fig. 2)**

Infracapitulum carries four pairs of setae, *a*, *h*, *m*<sub>1</sub> and *m*<sub>2</sub>, all setae barbed.

Chelicerae (Fig.3 ) strong with stout, blunt teeth. Setae *cha* and *chb* present, both smooth, *chb* longer than *cha*. Pedipalp (Fig.4) five segmented. Palpal chaetotaxy 0-1-0-2-10. Integument of the infracapitulum smooth.

Epimeral surface also smooth. Epimeral setal formula 3-1-3-4, all setae barbed. Seta *1a* longer than *1b* and *1c*. Epimere 2 bears only a single pair of barbed seta, *2a*. Sejugal apodeme continuous medially. Seta *3b* longer than *3a* and a median slit like structure present on epimere 3. Fissure *ia* seen as an oblique slit laterally. Epimere 4 carries four pairs of barbed setae, *4a*, *4b*, *4c* and *4d*. Posterior border of epimere 4 produced into two lobe like structures on either side, above the genital plate.

Genital plates divided unequally into two halves by a transverse suture. Each half carries five barbed setae, arranged in 2 rows. Marginal setae long and thick than median setae. Pre-anal plate wide. Fused ano- adanal plates bear five pairs of long, barbed adanal setae and two pairs of small barbed anal setae. No ornamentation on genital and ano-adanal plates. Polygonal

reticulations present on the ventral plate, lying exterior to the genital and ano-anal plates.

## LEGS

All legs monodactylous. Chaetotaxy of leg I 0-4-5-5-16 (Fig.5 ). Trochanter 1 without setae. Femur 1 with a keel ventrally. Seta *d* thick and roughened . Genu 1 with two solenidia,  $\sigma_1$  and  $\sigma_2$ , both thick, seta *d* long and barbed while setae *l'* and *l''* small and smooth. Tibia 1 with a thick and long solenidion( $\varphi$ ), seta *xt* seen closely associated with  $\varphi$ , seta *l'* longer than *xt*<sub>1</sub>, *xt*<sub>2</sub> and *v''*. Tarsus 1 with 2 solenidia,  $\omega_1$  and  $\omega_2$ , the former thicker than the latter. Famulus ( $\varepsilon$ ) seen in between  $\omega_1$  and  $\omega_2$ . Setae *ft'*, *ft''*, *pv'* and *pv''* barbed and *m''*, *s*, (*u*), (*p*), (*it*) (*tc*), and (*a*) smooth. All leg segments ornamented with granulations.

## MATERIALS EXAMINED

Holotype ♂, 6 Paratypes, 4 ♀♀ and 2 ♂♂ collected from soil and litter samples at Chaliyam, Calicut, Kerala, India, on 24. V. 2012, coll. Anjana, M.

## REMARKS

The genus *Heptacarus* was erected by Piffli (1963) with *H. notoneotrichus* as the typespecies from Egypt. Wallwork (1964) added another species. *H. hirsutus* from Tchad. Piffli (1967) described *H. supertrichus* from Iraq. *H. plumosus* was added by Hammer (1973) from Western Samoa. Mahunka (1977) described *H. piffli* from Indonesia. McDaniel *et al.* (1979) described *H. graminosus* from South Texas. *H. neotropicus* and *H. reitculatus* were subsequently added to the genus by Mahunka (1985) from Antilles and Indonesia respectively. Bayoumi and Al-

### *Observation*

Khalifa (1985) erected *H. ornatus* from the oriental region. Later, *H. encantadae* was added to the genus by Schatz (1994).

The present species can be easily separated from *H. notoneotrichus* and *H. piffli* based on its strong notogastral neutrichy. The barbed nature of infracapitular setae clearly distinguishes the present species from *H. supertrichus* where it is smooth. The presence of notogastral bands keeps the new species distinct from *H. neotropicus* and *H. hirsutus*. The presence and continuous disposition of the notogastral bands in the present species support its erection as a new species under the genus *Heptacarus*.

**Genus *Javacarus* Balogh, 1961**

**Generic Characters**

Genital plates without transverse suture. Anal and adanal plates fused. Pre-anal plate wide. Anal setae absent. Four pairs of adanal setae present. Notogaster and epimeral regions without neotrichy.

***Javacarus porosus* Hammer, 1980**

(Plate:15 )

(Figures:1-5 )

Colour : Brown

Measurements: Length: 600-636 $\mu$ m

Width: 312-336 $\mu$ m

**DORSAL REGION (Fig.1 )**

**Prodorsum:**

Rostrum without any incisions. Seta *ro* foliate, smooth and placed close together. Seta *le* inserted laterally, below insertion point of seta *ro*. Seta *in* foliate, smooth and shorter than *ro*, placed below the level of bothridium. Lamellar ridge with a median contour. Setae *exa* and *exp* longer than *le*, foliate and smooth. A wavy band extends transversely between *in*. Bothridium (*bo*) cup shaped. Sensillus (*ss*) pectinate with 8-10 branches. Prodorsum bears large tubercles medially. The anterior, lateral and posterior margins of prodorsum devoid of any sculptures.

**Notogaster:**

Notogaster bears sixteen pairs of smooth, foliate setae. Nine notogastral bands formed of bead like structures present, all complete. A few area porosae like structures seen scattered, in between most of the notogastral bands. Fissure *im* seen between setae  $d_2$  and  $e_2$ . Marginal setae  $c_3$ ,  $d_3$ ,  $h_3$  longer than the other notogastral setae. Seta  $ps_1$  slightly incurved.

**VENTRAL REGION (Fig.2 )**

Infracapitulum bears four pairs of setae  $a$ ,  $h$ ,  $m_1$  and  $m_2$ . 2-3 area porosae clustered in the region between setae  $h$ . Chelicerae (Fig.3 ) well developed with stout pronounced teeth, seta  $chb$  more than four times longer than  $cha$ . Pedipalp (Fig. 4) five segmented. Palpal chaetotaxy represented by formula 0-1-0-1-9.

Epimeral boundaries very clear. Epimeral setal formula 3-1-3-4. All epimeral setae smooth. Epimeres 1 and 2 bear scattered area porosae. Seta  $1a$  longer than  $1b$  and  $1c$ . Epimere 2 bears only one pair of smooth setae,  $2a$ . Epimere 3 bears three pairs of setae,  $3a$  smaller than  $3b$  and  $3c$ . Lateral to the epimere 3, fissure  $ia$ , present. Epimere 4 bears four pairs of setae,  $4a$ ,  $4b$ ,  $4c$  and  $4d$ .

Genital plates without transverse suture. Aggenital plates absent. Each genital plate carries ten setae, antiaxial row of four setae and paraxial row of six setae. Pre-anal plate wide and slightly projects postero-medially. Fused ano-adanal plates carry four pairs of adanal setae. Anal setae absent. Adano-anal setal formula (4+0). Lateral to the ano-genital region, area porosae like structures present. Fissure  $ip$  seen between setae  $ps_3$  and  $h_3$ .

## LEGS

All legs monodactylous. Chaetotaxy of leg I (Fig. 5) 0-4-5-5-16. Fine punctations seen on all leg segments. Trochanter 1 without setae. Femur 1 bears four setae ( $d$ ,  $l'$ ,  $l''$  and  $v''$ ), of which seta  $d$  thick and barbed while others smooth. Genu 1 carries five setae, solenidia  $\sigma_1$  and  $\sigma_2$  seen in close association with seta  $d$ . Seta  $l''$  thick and smooth. Tibia 1 bears five setae. The solenidion  $\phi$  long and seen in close association with seta  $d$ . Seta  $xt_1$  thicker and longer than  $xt_2$ . Tarsus 1 carries sixteen setae. Solenidia  $\omega_1$  and  $\omega_2$  almost of same length and not seen associated with  $ft^l$ ,  $ft''$  thicker and longer than  $ft'$ . Other tarsal setae  $pv'$ ,  $m''$ ,  $s$ ,  $(u)$ ,  $(p)$ ,  $(it)$ ,  $(tc)$  and  $a$  smooth.

## MATERIAL EXAMINED

9 specimens, 6 ♀♀ and 3 ♂♂, collected from soil and litter samples at Botanical Garden, Calicut University Campus, Kerala, India, on 07.II.2011.coll.Anjana,M.

## REMARKS

The present specimens closely resemble *J. porosus* described by Hammer (1979) in the possession of characters like: (1) Presence of 9 complete, bead like notogastral bands (2) Large tubercles on the prodorsum (3) Prodorsal band between interlamellar setae (4) Interlamellar setae extending beyond the insertion point of  $c_1$ . (5) Epimeral setal formula 3-1-3-4. However, smooth nature of prodorsal setae forms a notable variation from *J. porosus*.

***Javacarus punctatus* sp. nov.**

(Plate:16&17 )

(Figures:1-2,1-3 )

Colour : Dark Brown

Measurements : Length: 578 $\mu$ m (Range: 578 - 625 $\mu$ m)

Width : 326 $\mu$ m (Range :318-342 $\mu$ m)

**Dorsal Region** (Plate:16 )

**Prodorsum** (Figures:1&2)

Anterior tip of the rostrum pointed. Seta *ro* 98 $\mu$ m long, lanceolate with mid rib and slightly dentate. Seta *le* almost equal to *ro*, measuring 97.5 $\mu$ m, curved outwards and resembles *ro* in nature . Seta *in* resembles *le* in appearance , measuring 62 $\mu$ m, curved downwards. Seta *exa* twice longer than seta *exp*, measure 128 $\mu$ m and 67 $\mu$ m respectively. A band formed of continuous bead like structures present transversely between setae *in*. Bothridium (*bo*) cup shaped. Sensillus, *ss* pectinate bears 10 branches. Prodorsum bears large tubercles medially.

**Notogaster**

Lateral margins of notogaster wavy. Notogaster bears slender, long, lanceolate setae with mid rib. Area just below the dorsosejugal suture with 2 rows of prominent tubercles. Nine complete notogastral bands formed of distinct bead like tubercles present. Regions between bands *s*<sub>1</sub> and *s*<sub>2</sub> and *s*<sub>2</sub> and *s*<sub>3</sub> and posterior region bear aggregates of area porosae. Marginal setae *c*<sub>3</sub> and *d*<sub>3</sub> twice longer than *c*<sub>1</sub>, *c*<sub>2</sub>, *d*<sub>1</sub> and *d*<sub>2</sub>. Seta *e*<sub>2</sub> smaller than *e*<sub>1</sub> and seta *ps*<sub>1</sub> curved inwards.

**Ventral Region** (Plate:17, Fig.1 )

Infracapitulum (Fig.3 ) bears four pairs of setae  $-a, h, m_1$  and  $m_2$ . Seta  $a$  longer and straight while  $h$  slightly curved inwards. Chelicerae (Fig.3 ) well developed with pronounced teeth and Pedipalp (Fig.3 ) five segmented. A group of 5-6 area porosae seen medially at the infracapitular region, between the insertion points of setae  $h$ . All infracapitular setae smooth.

Epimeral setal formula 3-1-3-3. Epimeres bear fine punctations . On epimere 1, seta  $a$  twice the length of setae  $1b$  and  $1c$ . A few area porosae seen epimere 1. Epimere 2 possesses only a single seta,  $2a$ . Three setae seen on epimere 3, of which  $3a$ , smaller than  $3b$  and  $3c$ . Fourth epimere also bears three setae  $4a, 4b, 4c$ ;  $4b$  longer than others..

Genital plates without transverse suture (Fig.2 ) . Aggenital plates absent. Ten pairs of genital setae present, six pairs arranged in paraxial row and four pairs in antiaxial rows. First and third genital setae in the antiaxial row longer than second and fourth. Pre- anal plate wide with a projection medially. Anal and adanal plates fused. Four pairs of adanal setae present. Anal setae absent. Adano-anal setal formula (4+0). Ventral plate lying exterior to genital and ano-adanal plate bears fine microsculpture and area porosae at the base of insertion point of setae  $h_3, ps_2$  and  $ps_3$ .

**LEGS**

All legs monodactylous. Chaetotaxy of leg I (Plate:16, Fig. 3) 0-4-5-5-14. Fine punctations seen on all leg segments. Trochanter 1 without setae and bears a prominent spine. Femur 1 bears four setae ( $d, l', l''$  and  $v''$ ), of which seta  $d$  thick and barbed while others smooth. Genu 1 carries five setae, solenidia  $\sigma_1$  and  $\sigma_2$  seen in close association with seta  $d$ . Seta  $l''$  thick and smooth. Tibia 1 bears five setae. The solenidion  $\phi$  long and seen in close association with seta  $d$ . Seta  $xt_1$  thicker and longer than  $xt_2$ . Tarsus 1 carries

fourteen setae. Solenidia  $\omega_1$  and  $\omega_2$  almost of same length and not seen associated with  $ft^l, ft''$  thicker and longer than  $ft'$ . Other tarsal setae  $pv', m'', s, (u), (p), (it), (tc)$  and  $a$  smooth.

### **Materials Examined**

Holotype ♀, 8 paratypes, 5 ♀♀ and 3 ♂♂, collected from soil and litter samples at Soojipara, Wyanad, Kerala, India, on 25.X.2012.coll.Anjana,M.

### **Remarks**

The genus *Javacarus* was erected by Balogh (1961) with *J. kuehnelti* as type species from Java. Csiszar (1961) added *J. granulatus* from Java. Balogh (1962) described *J. inexpectatus* from Peru, South America. *J. kuhneli* var. *foliatus* was described by Hammer (1972) from Tahiti. The same author (1980) provided descriptions of another new species, *J. porosus* from Java. Sengbusch (1982) described *J. reticulatus* from Micronesia. *J. jocelynae* was added to the genus by Judson(1991) from Cameroon, Africa.

The specimen collected during the present study shows resemblance to *J. reticulatus* described by Sengbusch(1982) in the complete nature of nine notogastral bands, large tubercles on the prodorsum and presence of a band between setae *in*, but can be distinguished by the nature of notogastral setae; bicilate in *J. reticulates* and smooth in present specimen and epimeral setal formula of 3-1-3-3. Complete nature of notogastral bands in the present specimen separates it from *J. granulatus* and *J. kuehnelti*. Long interlamellar setae of *J. inexpectatus* clearly demarcates the current specimen which possesses short, stout and slightly dentate seta *in*.

### *Observation*

Unique feature in the specimen which strongly support the erection of new species are.

- 1) Epimeral setal formula of 3-1-3-3
- 2) Presence of nine complete notogastral bands formed of distinct beaded tubercles.
- 3) Seta *exa* longer and seta *in* smaller than those of other described species.
- 4) Body with large tubercles dorsally and fine punctations ventrally.

**Genus *Meristacarus* Grandjean, 1934**

**Generic Characters:**

Genital plates without transverse suture. Anal and adanal plates separated. Pre-anal plate wide. Anal setae absent. Four pairs of adanal setae present. Anal plates narrow and band like. Notogaster and epimeral region without neotrichy.

***Meristacarus degradatus* Haq and Jaikumar, 1993**

(Plates:18 &19 )

(Figures:1-4&1-4 )

Colour : Yellowish brown

Measurements : Length –790-955µm

Width –512 - 675µm

**DORSAL REGION (Plate :18 , Fig. 1)**

**Prodorsum: ( Fig. 1)**

Prodorsum broadly triangular , ending in a narrow rostrum. A transverse ridge present at the rostral region which extends to the lateral borders of the prodorsum. Seta *ro* ,barbed inserted just below the transverse edge, directed outwards. Seta *le* placed slightly below and lateral to seta *ro*. Setae *exa* and *exp* of equal length. Seta *in*, located slightly above the bothridium (*bo*) ( Fig. 3 ). Bothridial cups small and oriented laterad. A more or less oblique ridge present at postero- lateral boarders of bothridium. Sensillus(*ss*) unilaterally barbed with 18-20 thin bristles. A band consisting of serially arranged polygonal cells in 2-4 rows seen between interlamellar setae. Entire surface of prodorsum, except the regions adjacent to

dorsosejugal suture ornamented sparsely with rounded area porosae and fine micropunctations. All prodorsal setae long and barbed.

**Notogaster:**

Notogaster cylindrical and posterior margin rounded. Sixteen pairs of notogastral setae present. Marginal setae ( $c_3, d_3, e_2, f_2$ ) and posterior setae ( $ps_1$  and  $ps_2$ ) very long when compared to median setae ( $c_1, d_1, e_1, f_1$  and  $h_1$ ). Seta  $d_1$  shortest and seta  $ps_1$  longest among the notogastral setae. Nine wavy, curved or looped notogastral bands present, each formed of round pore like structures. Band  $S_1$  incomplete in the middle while band  $s_4$  represented only medially in the form of incurved loop. Bands  $s_5$  and  $s_6$  connected medially, forming another loop. Bands  $s_2, s_3, s_7, s_8$  and  $s_9$  complete (Fig. 4). Notogaster densely porose and ornamented with scattered and pronounced area porosae.

**VENTRAL REGION (Plate : 19, Figs.1-4 )**

Four pairs of weakly barbed infracapitular setae ( $a, m_1, m_2$  and  $h$ ) present.

Chelicerae (Fig.2 ) with strong and well sclerotized digits and carries prominent, blunt teeth. Seta  $chb$  long and barbed while  $cha$  very small. Pedipalp (Fig.2 ) five segmented with a chaetotaxy of 0-1-0-2-11.

Epimeral setal formula 3-1-3-4. Epimeral boundaries clear and epimeral plates distinct. Apodeme 3 ( $ap_3$ ) of both sides continuous medially and produced into a posterior extension. Epimere 1 carries three pairs of setae, seta  $1a$  and  $1b$  and  $1c$ . . Epimere 2 bears only a single pair of seta,  $2a$ . Epimeres 3 and 4 carry three and four pairs of setae respectively. Seta  $3c$  longest,  $3a$  smallest and  $3b$  intermediate in size. Seta  $4a$  slightly smaller than  $4b, 4c$  and  $4d$ . All epimeral setae finely barbed. . Epimeres 1 and 2 bear area

### *Observation*

porosae. All epimeres densely punctate. Fissure *ia* placed laterally, as an oblique slit.

Genital plates without transverse suture (Fig.3 ). Each plate carries ten barbed setae arranged in two rows, six setae in the inner row and four setae in the outer row. Pre-anal plate broad. Anal plates devoid of setae. Adanal plates bear 4 barbed setae, which increase in length from anterior to posterior end. Fissures *ip* and *ih* seen above and below seta  $h_3$ . Region lying outer and lateral to genital and anal plates ornamented with porosae, chitinous tubercles and polygonal cells.

### **LEGS**

All legs monodactylous. Chaetotaxy of leg I ( Plate:19Fig. 1) represented by the formula 0-5-4-5-19. Trochanter 1 without setae. Femur 1 carries five barbed setae and with a well developed notch dorsally and a keel ventrally. Genu 1 bears two solenidia  $\sigma_1$  and  $\sigma_2$ , the latter thicker than the former. Seta *d* thin and smooth while seta *l'* thick and serrate. Tibia 1 carries a stout and long solenidion ( $\varphi$ ), seta *d* coupled with this solenidion. Setae *xt'* and *l'* thick and barbed and *xt<sub>2</sub>* smooth. Tarsus 1 bears twenty setae, including two solenidia  $\omega_1$  and  $\omega_2$ . Setae *tc* thick, curved apically and bears small barbs. Famulus ( $\epsilon$ ) placed in between  $\omega_1$  and  $\omega_2$ . Setae (*p*), *s*, *m* smooth, while *pv'*, *pv''*, *ft'*, *it'*, *it''*, *a'*, *a''* and (*u*) barbed in various degrees. All leg segments bear micropunctations.

### **MATERIALS EXAMINED**

10 specimens, 1 ♂ and 9 ♀♀ collected from litter and soil samples at Kakkancherry, Malappuram, Kerala, India on 13.06. 2001. Coll.Anjana,M

**REMARKS**

A comparison of the characters of the present specimen with the known species of the genus revealed that it belongs to the species *M. degradatus* described by Haq and Jaikumar (1993) in all respects like:

1. Body ornamentation and setal disposition.
2. Medially incurved nature of fourth notogastral band.
3. Epimeral setal formula of 3-1-3-4.
4. Presence of transverse ridge on the prodorsum.

**Genus *Papillacarus* Kunst, 1959**

**Generic Characters:**

Genital plates with transverse suture. Anal and adanal plates separated. Pre-anal plate narrow. Two pairs of anal, four pairs of adanal setae present. Pygidial and epimeral regions with weak neotrichy.

***Papillacarus heterosetosus* sp. nov.**

(Plates:20 &21)

(Figures: 1-3)

Colour : Brown

Measurements : Length – 568µm (Range: 552-600µm)

Width – 300µm (Range: 276-336µm)

**DORSAL REGION (Plate :20, Fig.1-3 )**

**Prodorsum:**

Rostral tectum with two incisions anteriorly. Seta *ro* barbed and finely pointed, measuring 45µm . Seta *le* 52µm long, barbed and inserted far below *ro*. Both setae *exa* and *exp* of equal size, measuring 75µm each, both bear small barbs. Seta *in* 60 µm in length, inserted just below the bothridial cup. A transverse band present between setae *in* of both sides. Bothridium (*bo*) cup shaped(Fig.3). Sensillus (*ss*) pectinate with 8-11 branches. Prodorsum bears polygonated structures laterally.

**Notogaster:**

The lateral margins of notogaster more or less parallel and posterior border almost oval in shape. Median notogastral setae *c*<sub>1</sub>, *c*<sub>2</sub>, *d*<sub>1</sub>, *e*<sub>1</sub>, and *f*<sub>1</sub> simple and smaller than the other notogastral hairs. Setae *h*<sub>1</sub> and *h*<sub>2</sub> small,

barbed and slightly incurved. Pygidial neotrichy shows heterotrichy. Setae  $ps_1$  and  $ps_2$  longer and well barbed than other notogastral setae. Fissure *im* present as a slit in between setae  $d_2$  and  $e_2$ . Notogaster bears  $S_1$ ,  $S_2$ ,  $S_3$  and  $S_5$  band in usual positions. Band  $S_1$  continuous but vague towards the lateral margins. Bands  $S_2$ ,  $S_3$  and  $S_5$  discontinuous and with wavy margins(Fig.2). Irregular polygonated structures present throughout notogaster.

### **VENTRAL REGION ( Plate :21, Fig.1-3 )**

Infracapitulum(Fig.3) bears five pairs of setae  $a$ ,  $h$ ,  $m_1$ ,  $m_2$  and  $m_3$ . Seta  $a$  simple and others barbed. Infracapitulum bears fine punctations. Chelicerae (Fig.3 ) broad with well developed teeth. Pedipalp (Fig.3 ) five segmented. Palpal chaetotaxy, 0-1-0-1-7.

Epimeral setal formula 9-5-3-3. Epimeral region bears fine punctations medially. Epimere 1 bears nine pairs of setae, of which setae  $1a$  and  $1e$  smooth. Seta  $1i$  longer than other setae, rest intermediate in size and barbed. Area porosae present on epimere 1, at the base of seta  $1h$ . Epimere 2 carries five pairs of setae, seta  $2a$  smooth and others barbed. Epimeres 3 and 4 bear three pairs of setae each. Setae  $3a$ ,  $4a$  and  $4b$  smooth, whereas,  $3b$ ,  $3c$  and  $4c$  barbed.

Aggenital plates absent. Genital plates with transverse suture, which divides it unequally into two halves. Ten pairs of genital setae present. Five pairs of genital setae inner in position, four pairs outer in position and one pair of setae placed in between these, on the upper half. Pre-anal plate narrow with 'w' shaped postero-median projection over the anal plates (Plate:21, Fig.2). Anal and adanal plates separated. Adanal plate bears four pairs of long, barbed setae and anal plate bears two pairs of barbed setae. Ano-adanal setal formula (2+4). Irregular circular punctations seen lateral to

the genital region ventrally. Fine porose areas seen lateral to ano-adanal region. Fissure *ia* and *ih* present on the ventral side.

## LEGS

All legs monodactylous with stout claws. Leg I (Plate:21, Fig.1) shows chaetotaxy of 1-4-5-7-16. Trochanter 1 bears one barbed seta *bv*. Femur, genu, tibia and tarsus bear reticulations. Femur 1 carries two spine like projections, one basally on the ventral side and the other little above it, on dorsal side and carries four setae *d*, *l'*, *l''*, *v*". Genu 1 bears two solenidia ' $\sigma_1$ ' and ' $\sigma_2$ ' associated with smooth seta '*d*'. Two lateral setae *l'* and *l''* also present on this segment. Tibia 1 bears seven setae. It bears a long solenidion ( $\phi$ ). Tarsus 1 with sixteen setae, solenidia  $\omega_1$  and  $\omega_2$  present. Setae *pv'*, *pv''*, *m''*, *a*, *ft'* and *ft''* barbed and others *s*, (*u*), (*p*), (*it*), (*tc*) smooth. Famulus ( $\epsilon$ ) present below *ft''*.

## MATERIALS EXAMINED:

Holotype ♀. 8 paratypes, 5 ♀♀ and 3 ♂♂, collected from soil and litter samples taken from the Botanical Garden, Calicut University Campus, Keala, India on 20.IX.11.coll.Anjana,M.

## REMARKS

The genus *Papillacarus* was erected by Kunst, 1959 with *P. aciculata* Berlese, 1905 as the type species. Specimen collected during the present study can be distinguished from known species like *P. aciculatus*, *P. chamartinensis*, *P. simplirostratus*, *P. pseudoaciculatus* and *P. pavlowskii* by the presence of notogastral bands. Notogastral bands of the present species resemble those of *P. ondriasi*. However it can be separated from *P. ondriasi* by the possession of simple median notogastral setae *c*<sub>1</sub>, *d*<sub>1</sub>, *e*<sub>1</sub>, and *f*<sub>1</sub> which are barbed in *P. ondriasi*. The epimeral setal formula of 9-5-3-3 of this

### *Observation*

species clearly demarcates it from all other species under this genus. Other peculiar characters noted in the specimen are the following:

- (1) Infracapitulum with 5 pairs of setae (*a*, *h*, *m*<sub>1</sub>, *m*<sub>2</sub> and *m*<sub>3</sub>)
- (2) Incomplete nature of 4 bands (*S*<sub>1</sub>, *S*<sub>2</sub>, *S*<sub>3</sub> and *S*<sub>5</sub>).
- (3) 23 pairs of notogastral setae.
- (4) Prodorsum and notogaster with indistinct polygonated structures.

All the above characters possessed by the present species support its elevation as a new species under the genus *Papillacarus* Kunst, 1959.

***Papillacarus reticulatus* sp. nov.**

(Plate:22 )

(Figure.1-5)

Colour : Brown

Measurements : Length – 576 $\mu$ m (Range :564-600 $\mu$ m)

Width – 276 $\mu$ m (Range 288-312 $\mu$ m)

**DORSAL REGION (Fig.1)**

**Prodorsum:**

Rostral tectum entire, seta *ro* 45 $\mu$ m long, barbed, inserted far below the rostral tip and finely pointed. A transverse ridge present in between the lamellae, just below the level of *ro*. A distinct flat lamella present which tapers towards its distal ends. Seta *le* measures 60 $\mu$ m in length, stout, barbed and inserted a little below seta *ro* on either side. Both setae *exa* and *exp* barbed which measure 75 $\mu$ m and 68 $\mu$ m respectively. Bothridium (*bo*) cup shaped. Sensillus (*ss*) pectinate with 8-10 branches. Seta *in* 76.5 $\mu$ m long inserted just below the bothridial cup, and extends upto the notogastral seta *c*<sub>1</sub>. A transverse band present in between setae *in* of either side. Prodorsum bears irregular and indistinct polygonated structures.

**Notogaster:**

The lateral margin of notogaster more or less parallel and posterior border rounded. Median notogastral setae *c*<sub>1</sub>, *d*<sub>1</sub> and *e*<sub>1</sub> simple and smaller than the other setae. Seta *h*<sub>1</sub> slightly incurved. Pygidial neotrichy present which shows marked heterotrichy. Twenty two pairs of notogastral setae present including those arising ventrally. Of these, seta *ps*<sub>1</sub> longer than the other notogastral setae. Notogastral region with indistinct polygonated structures, except at the region near the dorsosejugal suture.

**VENTRAL REGION (Fig. 2)**

Infracapitulum bears six pairs of setae (*a, h, m<sub>1</sub>, m<sub>2</sub>, m<sub>3</sub>& m<sub>4</sub>*), seta *a* smooth, others barbed. Chelicerae (Fig.3) stout with sharp teeth, seta *chb* twice longer than seta *cha*. Pedipalp (Fig.4) five segmented, palpal chaetotaxy 0-1-0-1-5.

Epimeral setal formula 8-4-3-3. Epimere 1 bears eight pairs of setae, *1a* and *1d* smooth, all others barbed. Epimere 2 carries four pairs of setae. Seta *2a* smooth and others barbed. Above and between setae *2a* and *2b* small area porosae present. Epimere 3 possesses three pairs of setae, *3a* smooth and others barbed and laterally bears fissure *ia* as a small oblique slit. All the three pairs of setae on epimere 4 smooth. Epimeral region bears fine punctations medially.

Genital plates with transverse suture, which divides each plate unequally into a small upper and a large lower half. Ten pairs of genital setae present on the genital plates, of which five pairs on upper half and five pairs on the lower half. All the genital setae smooth. Pre-anal plate narrow with peculiar 'w' shaped projection on the postero-medial margin which extends into the ano-adanal region. Aggenital plates absent. Anal and adanal plates separated. Four pairs of long, barbed adanal setae and two pairs of small barbed anal setae present. Ano-adanal setal formula (2+4). Ano-adanal plates ornamented with fine granulations.

**LEGS**

All legs monodactylous with stout claw. The chaetotaxy of leg I (Fig.5) represented by the formula 1-4-5-5-20(1), leg segments bear reticulations. Seta *bv* present on trochanter 1. Femur 1 broader than the rest of the leg segments with a projection towards its distal end. Femur 1, bears four barbed setae *d, l', l'', v''*. Genu 1 bears five setae, of which seta *l'* barbed and setae *d*

### *Observation*

*and l'* are smooth, and seen closely associated with solenedia  $\sigma_2$ . Seta *l'* thicker than thin *l'* seta. Tibia bears five setae *xt<sub>1</sub>*, *xt<sub>2</sub>*, *v*, *l'* barbed. The solenidion ( $\phi$ ) on tibia 1 long and whip like. Tarsus 1 bears twenty-one setae.

### **MATERIALS EXAMINED**

Holotype ♀, Paratypes 4 ♀♀ and 2 ♂♂, collected from soil and litter samples at Nelliampathy, Palakkad, Kerala, India on 12-IX-2000. coll. Anjana, M.

### **REMARKS**

The genus *Papillacarus* was erected by Kunst (1959) with *P. aciculata* Berlese (1905) as type species. Bulanova-zachvatkina (1960) described *P. pavlowskii* from Soviet Union. Two new species *P. hirsutus* and *P. ramosus* were added by Aoki (1961) and Balogh (1961) from Japan and Java respectively. Wallwork (1962) erected *P. angulatus* from Ghana. Aoki (1965) added another species *P. undirostratus* from Thailand. Perez-Inigo (1967) described *P. chamartinensis* from Spain. Another species, *P. spinosus* was added by Alzuet (1972) from Argentina. Kardar (1972) described *P. indicus* from India. Bhattacharya *et al.* (1974) erected *P. simplirostratus* from North India. Mahunka (1974) described *P. ondriasi* from Greece. Corpuz Raros (1979) erected *P. cruzae* from Philippines. *P. pseudoaciculatus* was added to the genus by Mahunka (1980) from Tunisia. Jeleva and Vu (1987) described *P. arboriseta* from Bulgaria.

The known species, *P. spinosus* and *P. undirostratus* show some degree of resemblance to present species as they bear irregular polygonated structures on prodorsum and notogaster. However, it can be separated from *P. spinosus* by the absence of prodorsal line below rostral setae and with *P. undirostratus* for the epimeral setal formula of 8-4-3-3 instead of 9-4-3-4. The

### *Observation*

present species shows close resemblance to *P. aciculatus* in the following characters: (1) absence of notogastral bands (2) notogaster with polygonated structures but it differs from it in the possession of large number of neutrichial setae.

A thorough examination of the species collected during the present study supports the erection of a new species under the genus *Papillacarus* by the following characters:

- 1) Presence of a transverse ridge in between lamellae, below the rostral setae.
- 2) Epimeral setal formula of 8-4-3-3.
- 3) Presence of six pairs of setae (*a*, *h*, *m*<sub>1</sub>, *m*<sub>2</sub>, *m*<sub>3</sub> and *m*<sub>4</sub>) on the infracapitulum.
- 4) A transverse band in between the interlamellar setae.
- 5) Twenty-two pairs of notogastral setae.

***Papillacarus graminosus* sp. nov. = *Vepracarus***

(Plates:23&24 )

(Figures: 1-5,& 1-5)

Colour : Golden Yellow

Measurements : Length 396µm (Range – 396-420µm)

Width 168 µm(Range – 156-180µm)

**DORSAL REGION (Plates: 23,Figs.1-5 )**

**Prodorsum: ( Fig.1 )**

Rostral border entire, seta *ro* measures 45µm, situated half the way away from the rostral border, rests on a median ridge which connects lamellae of both sides. Seta *le* 30µm long and placed near lamellae on either side. Seta *in* 40.5µm long, inserted just below level of the bothridium. Both setae *exa* and setae *exp* measures 35.5µm and 37.5 µm respectively. Terminally, lamellae on both sides produced into spine like projections and which run parallel to each other. Bothridium (*bo*) cup shaped ( Fig.4 ). Sensillus (*ss*) pectinate with 12-14 branches. Prodorsum bears an arched band, below seta *in*. Prodorsum carries chitinous spherical tubercles which bears punctations. Region between prodorsal band and dorsosejugal suture devoid of tubercles, and with dense punctations . All prodorsal setae barbed marginally.

**Notogaster: ( Fig.3-5 )**

The lateral margins of notogaster more or less parallel and posterior end rounded. Median notogastral setae *c*<sub>1</sub>, *d*<sub>1</sub>, *e*<sub>1</sub>, *f*<sub>1</sub> and *h*<sub>1</sub> smaller than other notogastral setae , except neotrichial setae. Seta *e*<sub>1</sub> the smallest among the median setae, all notogastral setae barbed. Fissure *im* seen between setae *c*<sub>2</sub> and *d*<sub>2</sub>. Pygidial neotrichy present( Fig.5 ).

Most of the neotrichial setae star shaped or brush like. Entire notogastral area covered with rounded tubercles containing fine punctations.

**VENTRAL REGION (Plates: 24,Figs.1-5 )**

Infracapitulum (Fig.2 ) carries five pairs of setae, *a*, *h*, *m*<sub>1</sub>, *m*<sub>2</sub> and *m*<sub>3</sub>. Seta *a* simple and others barbed at various degrees. Chelicerae (Fig.2-4) stout with well developed teeth. Seta *cha* slightly smaller than *chb*. Chaetotaxy of pedipalp (Fig.2-4 ) 0-1-0-1-7. Setae *v'*, *l'* and *cm* barbed, *l'*, *l''* and *ul*<sub>3</sub> smooth.

Epimeral setal formula 7-4-3-3. Epimere 1 bears seven pairs of setae, all barbed. Seta *2a* of epimere 2 smooth while *2b* and *2c* barbed. Epimeres 3 and 4 bear three pairs of setae each, all barbed. Seta *3c* the longest. Lyrifissure *ia* seen lateral to the epimere 3, as an oblique slit.

Genital plates unequally divided by a transverse suture into small upper and large lower halves. Ten pairs of genital setae present, all smooth. Triangular aggenital plates present at the antero-lateral corners of the genital plate. Pre -anal plate with a postero- median projection .Ano-adanal plates separated by an incomplete suture (Fig.5 ) . Two pairs of bilaterally barbed setae present on the anal plate. Adanal setae four pairs, which resemble the anal setae in nature. Many wavy lines seen lateral to adanal plates on both sides. Adanal plate finely punctated.

**LEGS:**

All legs monodactylous, chaetotaxy of leg 1,0-5-5-6-17 (Fig.4) Trochanter 1 bears no setae. Femur 1 bears a spine like projection at the base and the unilaterally barbed seta *bv* inserted below the spine like projection, other setae, *d*, *l'*, *l''*, *v''* barbed. Solenidia ' $\sigma_1$ ' and ' $\sigma_2$ ' of genu 1 seen close to seta *d*. Tibia 1 bears long solenidion ( $\phi$ ), barbed setae *xt*<sub>1</sub> and *xt*<sub>2</sub> and smooth seta *l''*. Tarsus 1 bears, solenidia  $\omega_1$  and  $\omega_2$  and other 15 setae. Reticulations and punctations seen on all leg segments.

## **MATERIALS EXAMINED:**

Holotype ♀, 8 paratypes, 6 ♀♀ and 2 ♂♂, collected from soil and litter samples of Nelliampathy, Palakkad, Kerala, India, on 2.IX.12.coll. Anjana, M.

## **REMARKS**

The genus *Papillacarus* was erected by Kunst (1959) with *P. aciculata* Berlese (1905) as type species. The species collected during present study was compared with all other known species and showed close resemblance with *P. cornutus* described by Sarkar and Subias (1984) collected from Tripura, India. The pronounced characters with which the present species resemble with *P. cornutus* include

1. possession of two horn-like structures on either side of prodorsum in front of *exa*
2. bilaterally branched nature of *ss*
3. presence of prodorsal band.

However, the present species can be easily separated from *P. cornutus* by novel characters like:

1. Smooth genital setae.
2. Epimeral setal formula of 7-4-3-3, smooth nature of *2a*.
3. Absence of tubercles in the region between prodorsal band and dorsalsejugal suture.

The characters strongly support the erection of a new species under the genus *Papillacarus*.

## **POPULATION STUDIES ON LOHMANNIID MITES**

Soil is functionally a decomposition product with two main constituents- the mineral material derived as a result of weathering and organic material formed by biotic components. Both of these constituents undergo transformation and decomposition under the action of various physical, chemical and biological agents. Soil supports rich and diverse life by providing a variety of microhabitats with special characteristic features of food, shelter and concealment from predators. Oribatid mites represent one of the main groups of edaphic mesofauna, owing to their species diversity and richness as well. Among the oribatid mites, lohmanniid members represent an important group, which generally show preference to thrive in undisturbed moist organic layers by getting themselves very actively involved in the decomposition process of organic matter and subsequent nutrient cycling in soil ecosystem.

Soil as a unique habitat acts as a key discriminate for determining temporal population behavior and increased population sizes in layers with high rates of fermentation would explain food sources translocation. Duration of life cycle and spatial distribution pattern of these mites within their microhabitats are very closely related to various physical and chemical parameters. The extreme sensitivity of these mites towards the diverse environmental conditions would enhance their potential to detect even minor variations in physico-chemical parameters like the temperature, moisture content, pH, organic carbon content, presence of pollutants/toxicants/heavy metal and pesticide contaminants and so on, thereby ensuring their effective utilization as biological indicators of soil health.

The present study was initiated to find out the population dynamics of lohmanniid mites in different areas like undisturbed litter accumulated areas

and areas of human interferences. The relationship in mite population dynamics to different physico-chemical factors in their microhabitat was analysed to provide information on their roles as indicators of soil profile. The role of lohmanniids in biodegradation and bioindication of soil health was intended to be explored through this experimental study. A knowledge on their sensitivity to climatic factors and seasonal variations in population density in the natural ecosystem would be helpful in the large scale laboratory culturing of these mites for bioprocessing of organic matter.

## **Methods**

### **STUDY AREA**

The study was carried out at the Botanical garden of the Calicut University Campus (Site A) and an adjacent site at Kakkancherry (Site B), located in the Malappuram district of Kerala, from where regular monthly samples of soil/litter were collected. Site A represented a typical undisturbed area of high litter accumulation, supporting diverse flora. The Site B comprised of low leaf litter areas, agricultural fields, coconut plantations and vegetable gardens in residential areas which experienced frequent human interference. Sampling was completed in three years, starting from May 2010 and ending in April 2013.

### **SAMPLING AND EXTRACTION OF SOIL**

During the three year period of study, five plots were defined in each site, the area of each plot was 1 m<sup>2</sup>. Regular monthly sampling of soil/litter was carried out from each of the sampling site. Five -six replicates per each site were collected and samples consisted of 250g of soil from the upper 5 cm approximately. Collection was made covering the three seasons like pre-monsoon, monsoon and post-monsoon seasons. Each sample was put in plastic bag and transported to the laboratory for subsequent extraction in an

open brass funnel apparatus. Extraction was continued for at least 48 hours till the soil got completely dried. The mite specimens escaped out of the soil samples were collected in 70% alcohol and the number of lohmanniid species was counted. Data on the Temperature, Relative humidity and Rainfall of the collection sites were recorded at the time of collection. The number of collected individuals was analysed considering three different physical parameters like temperature, rainfall and RH during pre --monsoon (March-May), monsoon (June-November) and post monsoon (December-February) seasons of the year. The chemical analysis of soil samples was performed at the Division of Soil Science, Kerala Forest Research Institute, Peechi.

## **PROCESSING OF SOIL SAMPLES**

Dried each of the collected sample under shade. Crushed the soil clods, lightly with wooden pestle and mortar. Sieved using a stainless steel 2 mm sieve and discarded plant residues, gravel and other foreign matter retained on the sieve. For certain types of analysis (e.g. organic carbon) it was necessary to grind the soil further so as to pass it through a 0.5mm sieve.

## **PROCEDURES FOR SOIL ANALYSIS**

### **1. Soil pH**

**Principle:** The pH of 1:2.5 soil water suspension is was estimated using a pH meter. Being a measure of hydrogen ion activity of the soil water system it indicates whether the soil is acidic, neutral or alkaline in reaction.

### **Reagents:**

Standard buffer solutions: Prepared buffer solutions of pH 4.0, 7.0 and 9.2 using commercially available buffer tablets. Dissolved the respective tablets in freshly prepared distilled water and made up the volume to 100 ml. It

was necessary to prepare fresh buffer solutions after every few days as these solutions were not advisable for keeping long time.

### **Procedure**

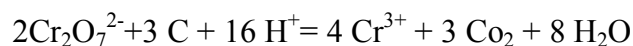
Calibrated the pH meter using buffer solutions. The pH of soil was determined in 1:2.5 soil water suspensions. Took 10 gm sample of soil sifted through 2mm sieve in a 50 or 100 ml beaker. Added 25 ml of distilled water, stirred well for about 5 minutes and kept for half an hour. Stirred well again and measured the reading using the pH meter.

## **2. ORGANIC CARBON IN SOIL**

Soil organic matter has been defined as the organic fraction of soil, including plant, animal and microbial residues, fresh and at all stages of decomposition and the relatively resistant soil humus. However, soil organic matter estimates include only those organic materials that accompany soil particles through a 2 mm sieve. Carbon is the chief element present in soil organic matter, and forms 48-58% of the total weight. Therefore organic carbon determinations are often used as a basis for estimation of organic matter. For many years the *Van Bemmelen factor* of 1.724 has been used based on the assumption that the organic matter contains 58% organic carbon.

### **Principle**

Schollenberger (1927) first proposed that the organic matter in soil may be oxidized by treatment with a hot mixture of  $K_2Cr_2O_7$  and  $H_2SO_4$  according to the equation.



After the reaction, the un-reacted  $\text{Cr}_2\text{O}_7^{2-}$  is titrated with standard  $\text{Fe}(\text{NH}_4)_2\text{SO}_4 \cdot 6\text{H}_2\text{O}$  and the  $\text{Cr}_2\text{O}_7^{2-}$  reduced during the reaction with soil is assumed to be equivalent to the organic carbon present in the sample. Jackson (1958) recommended that o-phenanthroline can be used as an indicator in the  $\text{Cr}_2\text{O}_7^{2-}$  titrations because the colour change (formation of the complex with  $\text{Fe}^{2+}$ ) occurs at higher oxidation-reduction potential.

Dichromate methods that use heat of dilution or minimal heating do not give complete oxidation of organic compounds in soil although the most active forms of organic carbon are converted to  $\text{CO}_2$ . Walkley and Black (1934) recorded that on an average about 76% of the organic carbon was recovered by the heat of dilution procedure and they proposed that a correction factor, 1.32, be used to account for unrecovered organic carbon.

### **Walkley-Black Wet Digestion Method (Walkley, 1947)**

#### **Reagents**

- 1) Potassium dichromate ( $\text{K}_2\text{Cr}_2\text{O}_7$ ) – 1N: Dissolved 49.04 g of reagent grade  $\text{K}_2\text{Cr}_2\text{O}_7$  (dried at  $105^\circ\text{C}$ ) in water and diluted the solution to a volume of 1000 ml.
- 2) Ferrous ammonium sulphate hexahydrate solution - 0.5 N : Dissolved 197 g of reagent grade  $\text{Fe}(\text{NH}_4)_2\text{SO}_4 \cdot 6\text{H}_2\text{O}$  in water, added 15 ml of concentrated sulphuric acid, cooled the solution and diluted it to a volume of 1000 ml. Standardized this reagent daily by titrating it against 10 ml of 1N potassium dichromate.
- 3) O-phenanthroline-ferrous complex (ferroin) - 0.025 N: Dissolved 14.85 g of o-phenanthroline monohydrate and 6.95 g of ferrous sulphate heptahydrate ( $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$ ) in water. Dilute the solution to a

volume of 1000 ml. The o-phenathroline-ferrous complex is available under the name of Ferroin.

- 4) Sulphuric acid ( $H_2SO_4$ ) concentrated: If Cl is present in soil, add  $Ag_2SO_4$  to the acid, 15 g/L.

### **Procedure**

Ground the soil to pass through a 0.5 mm sieve, avoiding iron or steel mortars. Transferred a weighed sample, containing 10-25 mg of organic carbon (approximately 0.5 to 1 g soil), but not in excess of 10 g soil, into a 500 ml wide mouthed conical flask. Added 10 ml of 1N  $K_2Cr_2O_7$  and swirled the flask gently to disperse the soil in the solution. Then rapidly added 20 ml of concentrated  $H_2SO_4$ . Immediately swirled the flask gently until the soil and the reagents were mixed, then more vigorously for a total of one minute. Allowed the flask to stand on an asbestos sheet for about 30 minutes. Then added 200 ml of water to the flask. Added 3-4 drops of O-phenathroline indicator and titrated the solution with 0.5N ferrous ammonium sulphate. As the endpoint approached, the solution changed to greenish cast and then got changed to a dark green colour. At this point, added the ferrous ammonium sulphate drop by drop until the colour changed sharply from blue to red. Made a blank determination in the same manner, but without soil, to standardise the  $Cr_2O_7^{2-}$ .

### **Calculation**

$$\text{Organic Carbon \%} = \frac{(\{ 10 \times 1 - \text{Titre value (ml)} \} \times \text{Normality of Fe(NH}_4\text{)}_2\text{SO}_4 \} \times 0.39)}{\text{weight of soil}}$$

### **3. AVAILABLE NITROGEN**

#### **Reagents**

1. 0.32%  $\text{KMnO}_4$
2. 2.5% NaOH
3. Liquid paraffin
4. 0.02N sulphuric acid (0.54ml  $\text{H}_2\text{SO}_4$  in 1L)
5. Mixed Indicator – 0.07 g Methyl red, 0.1g Bromocresol green in 100 ml of 75% ethanol
6. Boric acid indicator solution: Dissolved 20g of boric acid in 700ml of hot water. Cooled and transferred it in a 1L flask containing 200ml of ethanol and 20ml mixed indicator solution. After mixing the contents of the flask, added approximately 0.05N NaOH continuously until the colour became reddish purple. Then made up the solution to 1L.

#### **Procedure**

20gm soil + 20 ml water + 1 ml liquid paraffin + 100ml  $\text{KMnO}_4$  + 100ml NaOH were kept in a long necked conical flask at  $95^\circ\text{C}$  for 1hr. Some glass beads were also added to prevent bouncing.

Taken 20ml Boric acid mixed indicator in a beaker and kept at the end of the condenser.

60ml green solution in the beaker was titrated against 0.02N  $\text{H}_2\text{SO}_4$ .

### **4. AVAILABLE PHOSPHORUS**

Determination of available P in soil has two distinct phases- first, the extraction of plant available pool of phosphorous present in soil, and second the quantitative determination of the P in the extract. The choice of a colorimetric method for determining P depends on the P concentration in

the solution, the concentration of interfering substances in the solution to be analysed and the particular acid system involved in the analytical procedure. The molybdenum blue method is the most sensitive and widely used one for soil extracts containing small amounts of P.

### **Principle**

In an acid molybdate solution, the orthophosphate ions get precipitated as phosphomolybdate complex forms that can be reduced by ascorbic acid, stannous chloride and other reducing agents. The reduced phosphomolybdate has blue colour. The intensity of the blue colour varies with the P concentration but is affected also by other factors such as acidity, arsenates, silicates and substances that influence the oxidation - reduction conditions of the system. As the available pool of P varies depending up on the pH of the soil, reagents used for extraction of this pool also are different.

### **Available P in acidic soils**

Available P is commonly extracted using Bray No. 1 (Bray and Kurtz, 1945), which consists of 0.03N  $\text{NH}_4\text{F}$  and 0.025N HCl. The combination of HCl and  $\text{NH}_4\text{F}$  is designed to remove easily acid soluble P forms, largely calcium phosphates, and a portion of the aluminium and iron phosphates. The  $\text{NH}_4\text{F}$  dissolves aluminium and iron phosphates by its complex ion formation with these metal ions in acid solution.

### **Reagents**

- 1) Ammonium fluoride ( $\text{NH}_4\text{F}$ ), 1N; Dissolved 37 g of  $\text{NH}_4\text{F}$  in distilled water and diluted the solution to 1 litre. Stored the solution in polyethylene bottle.
- 2) Hydrochloric acid (HCl), 0.5 N: Diluted 20.2 ml of concentrated HCl to a volume of 500ml with distilled water.

- 3) Bray No.1: Added 15 ml of 1N ammonium fluoride ( $\text{NH}_4\text{F}$ ) and 25 ml of 0.5N Hydrochloric acid ( $\text{HCl}$ ) to 460 ml of distilled water. This solution could be kept in glass for more than one year.
- 4) Ammonium paramolybdate ( $\text{NH}_4)_6\text{Mo}_7\text{O}_{24}\cdot 4\text{H}_2\text{O}$ ): Dissolved 12 g of ammonium paramolybdate in 250 ml of distilled water. Dissolved 0.2908 g of potassium antimony tartarate ( $\text{KSbO}\cdot\text{C}_4\text{H}_4\text{O}_6$ ) in 100 ml of distilled water. Added these dissolved reagents to 1 litre of 5N Sulphuric acid ( $\text{H}_2\text{SO}_4$ ) (141 ml of concentrated  $\text{H}_2\text{SO}_4$  diluted to 1 litre), mixed thoroughly and diluted with distilled water to 2 litres. Stored in a pyrex glass bottle in a dark and cool compartment **(Reagent A)**.
- 5) Ascorbic acid: Dissolved 1.056 g of ascorbic acid in 200 ml of Reagent A and mixed. This ascorbic acid **(Reagent B)** was prepared as required because it was not possible to keep it for more than 24 hours.
- 6) Standard phosphate solution: Dissolved 0.4393 g of oven-dried AR grade potassium dihydrogen phosphate ( $\text{KH}_2\text{PO}_4$ ) in distilled water, and diluted the solution to 1 litre. One millilitre of this solution contained 100 $\mu\text{g}$  of P. From this solution, prepared a secondary standard of 2  $\mu\text{g}/\text{ml}$  by pipetting out 2 ml and diluting to 100 ml with distilled water.

## **Procedure**

### *Extraction*

Weighed out 5g of soil to a 100ml conical flask and added 50 ml of BrayNo. 1 reagent and shaken for exactly 5 minutes. Filter through Whatman No. 42 filter paper. To avoid interference of fluoride, 7.5ml of 0.8M boric acid (50g of  $\text{H}_3\text{BO}_3$  per litre) was added. Estimated the amount of

phosphorous present in the extract by ascorbic acid method (Watanabe and Olsen, 1965).

*Estimation by reduced molybdate blue colour method*

Pipetted out 5 ml of the extract into a 25 ml volumetric flask and diluted it to approximately 20 ml. Added 4 ml of Reagent B. Made up the volume with distilled water and shaken the contents well. Read the intensity of colour after 10 minutes at 660nm. The colour remained stable for 24 hours and the maximum intensity developed within 10 minutes. The concentration of P in the sample was computed from the standard curve.

*Preparation of Standard Curve*

Prepared different concentrations of P by taking 1,2,3,4,5 and 10 ml of 2µg/ml P solution in 25 ml volumetric flasks. Add 5 ml of the extracting reagent (Bray No. 1) and developed colour as described above by adding reagent B. Plotted the concentration vs. absorbance curve on a graph paper.

**Calculation**

$$\text{Available P (mg kg}^{-1}\text{ soil)} = \frac{\text{Absorbance for sample}}{\text{Slope of standard curve}} \times 50$$

**Available P in alkaline/calcareous soils**

The phosphorus was extracted from the soil with 0.5M sodium bicarbonate (NaHCO<sub>3</sub>) at a nearly constant pH of 8.5. In calcareous, alkaline or neutral soil containing calcium phosphates, this extractant decreased the concentration of calcium in solution by causing precipitation of calcium as CaCO<sub>3</sub>; as a result, the concentration of P in solution increased. In the presence of solid phase calcite, the concentration of calcium in the extracting solution at equilibrium was  $6 \times 10^{-7}$  M (Olsen *et al.*, 1954).

## **Reagents**

- 1) Sodium bicarbonate ( $\text{NaHCO}_3$ ) solution, 0.5 M: Dissolved 42g of  $\text{NaHCO}_3$  in distilled water to give 1 litre of the solution. Adjusted the pH of the solution to 8.5 with 1M sodium hydroxide ( $\text{NaOH}$ ). Added mineral oil to avoid exposure of the solution to the air. Stored the solution in a polyethylene container for periods more than one month, but checked the pH of the solution each month.
- 2) Sulphuric acid ( $\text{H}_2\text{SO}_4$ ) 5N: Added 141 ml of concentrated  $\text{H}_2\text{SO}_4$  to 800 ml of distilled water. Cooled the solution and diluted to 1000 ml distilled water.
- 3) Ammonium paramolybdate ( $(\text{NH}_4)_6 \text{Mo}_7\text{O}_{24} \cdot 4\text{H}_2\text{O}$ ): Dissolved 12g of ammonium paramolybdate in 250 ml of distilled water. Dissolved 0.2908g of Potassium antimony tartarate ( $\text{KSbO} \cdot \text{C}_4\text{H}_4\text{O}_6$ ) in 100 ml of distilled water. Added these dissolved reagents to 1 litre of 5N sulphuric acid ( $\text{H}_2\text{SO}_4$ ) (141 ml of concentrated  $\text{H}_2\text{SO}_4$  was diluted to 1 litre), mixed thoroughly, and diluted with distilled water to 2 litre. Stored in a pyrex glass bottle in a dark and cool compartment (Reagent A).
- 4) Ascorbic acid: Dissolved 1.056g of ascorbic acid in 200 ml of Reagent A and mix. This ascorbic acid, (Reagent B) was prepared as required because it could not keep for more than 24 hours.
- 5) Standard phosphate solution: Dissolved 0.4393 g of oven-dry AR grade potassium dihydrogen phosphate ( $\text{KH}_2\text{PO}_4$ ) in distilled water, and diluted the solution to 1 litre. One millilitre of this solution contained 100  $\mu\text{g}$  of P. From this solution, prepared a secondary standard of 2  $\mu\text{g}/\text{ml}$  by pipetting out 2 ml and diluting to 100 ml with distilled water.

## **Procedure**

### *Extraction*

Added 5 g of soil and 100 ml of extracting solution to a 250 ml conical flask. Shaken the flask for 30 minutes. Filtered the suspension through Whatman No. 42 filter paper. Added carbon black (activated charcoal) to obtain a clear filtrate if necessary.

### *Estimation by reduced molybdate blue colour method*

Placed a 5 ml aliquot of the extract in 25 ml volumetric flask and acidified with 5N H<sub>2</sub>SO<sub>4</sub> to pH 5. This was done by taking 5 ml of 0.5M extracting solution (NaHCO<sub>3</sub>) and determining the amount of acid required to bring the solution to pH 5 using *p*-nitrophenol indicator. Then added the required acid to all the unknown samples. Added distilled water to 20 ml, and then added 4 ml of reagent B. Made up the volume with distilled water and shaken the contents well. Read the intensity of colour after 10 minutes at 660nm. The concentration of P in the sample was computed from the standard curve.

### *Preparation of Standard Curve*

Prepared different concentrations of P by taking 1, 2, 3, 4, 5 and 10 ml of 2 µg/ml P solution in 25 ml volumetric flasks. Added 5 ml of the extracting reagent (Bray No. 1) and developed colour as described above by adding reagent B. Plotted the concentration vs. absorbance curve on a graph paper.

## **Calculation**

$$\text{Available P (mg kg}^{-1}\text{ soil)} = \frac{\text{Absorbance for sample}}{\text{Slope of standard curve}} \times 50$$

## **5. AVAILABLE POTASSIUM**

A relatively small portion of the total K in soils is exchangeable (approx. 1%). Exchangeable K generally ranges from <100 to 2000  $\mu\text{g/ml}$  or more when compared with total K values which is in the order of 1 to 20%. Water soluble K seldom exceeds a few parts per million except in the case of certain saline soils. Exchangeable plus water soluble K contributes to the plant available pool of potassium in the soil. Hence, most soil test procedures to estimate plant available K involve extractants that replace a significant portion of the exchangeable K. In highly weathered soils, or soils where parent materials contain little K-bearing minerals, the exchangeable K can be depleted by K removal and is replenished only by fertilizer application or return of K from plant residues.

### **Principle**

By definition, the exchangeable potassium is that which is free to exchange with cations of salt solution added to soils. But the quantity exchanged from the soil depends on the nature of the replacing solution. Hence with reference to fertility evaluation, exchangeable K is defined more specifically as that which is extracted with neutral 1 N ammonium acetate minus the water soluble K. In normal soils, as the water soluble K is so small, there is no appreciable error even if it is included and the water soluble plus exchangeable K represent the available pool. The removal of water soluble K before extraction with ammonium acetate is not recommended because as the salt content of soil solution is decreased, the adsorption of divalent cations in solution increases.

## **Reagents**

1. Neutral 1N ammonium acetate solution ( $\text{CH}_3\text{COONH}_4$ ): Dissolved 77.08 g of ammonium acetate in distilled water and made up to 1 L. Adjusted the pH to 1 with acetic acid or ammoniumhydroxide.
2. Standard K solution: Dissolved 1.908 g of dried potassium chloride (KCl) AR grade in distilled water and made up to 1 L so as to get 1000 $\mu\text{g/ml}$  K solution.

## **Procedure**

### *Extraction*

Shaken 5 g of soil with 25 ml of neutral normal ammonium acetate for 5 minutes and filtered immediately through a dry Whatman No. 42 filter paper. First few ml of the filtrate was discarded. Potassium concentration in the extract was determined using flame photometer after necessary setting and calibration of the instrument.

### *Standard Curve for Potassium*

Diluted the measured aliquots from the standard solution using ammonium acetate solution to give concentrations of 5 to 20 $\mu\text{g/ml}$  K. After attaching the appropriate filter and adjusting the gas and air pressure, set reading in the flame photometer as zero for the blank (ammonium acetate) and at 100 for 20 $\mu\text{g/ml}$  K. The curve was obtained by plotting the readings against the different concentrations (5, 10, 15 and 20  $\mu\text{g/ml}$ ) of K.

## **Calculation**

$$\text{Available K (mg/kg soil)} = \mu\text{g K/ml of the aliquot} \times 5$$

## **6. AVAILABLE CALCIUM AND MAGNESIUM**

As in the case of potassium, exchangeable and water soluble calcium and magnesium contribute to the plant available pool. The neutral normal ammonium acetate extracts the pools of calcium and magnesium also along with potassium and sodium.

### **Principle**

In the absence of excess of  $\text{CaCO}_3$ , the cations  $\text{Ca}^{2+}$ ,  $\text{Mg}^{2+}$ , and  $\text{Na}^+$  along with  $\text{K}^+$  appear to be completely exchangeable by neutral normal ammonium acetate.

### **Reagents**

Neutral normal ammonium acetate solution ( $\text{CH}_3\text{COONH}_4$ ): Dissolved 77.08g of ammonium acetate in distilled water and made up to 1 L. Adjust the pH if necessary to 7 with acetic acid or ammonium hydroxide.

### **Procedure**

#### *Extraction of available Calcium and Magnesium*

Shaken 5g of soil with 25 ml of neutral normal ammonium acetate for 5 minutes and filtered immediately, through a dry Whatman No. 1 filter paper. First few ml of the filtrate was discarded.

#### *Estimation of Calcium and Magnesium by Atomic Absorption Spectrophotometry*

From the soil extract, Ca and Mg were estimated by Atomic Absorption Spectrophotometry (AAS). The chemical interference, resulting from the formation of stable compounds between Ca and Mg ions

and the accompanying anions would reduce the absorption. This interference was overcome by using a releasing agent such as Lanthanum or Strontium.

### **Calculation**

Available Ca/Mg (mg/kg soil) =  $\mu\text{g Ca/Mg ml}^{-1}$  of the aliquot  $\times 5$

## **7. IRON, MANGANESE, ZINC AND COPPER**

### **Principle**

The major categories of micronutrient extractants presently in use are dilute acids, and solutions containing chelating agents, such as DTPA or EDTA.

Dilute acids (0.025-0.1M) have been used as micronutrient extractants for many years, primarily on acidic soils. Their applicability is confined to acidic soils because they generally are not sufficiently buffered to extract meaningful levels of micronutrients from calcareous soils. Acidic extractants do not have a particularly sound theoretical basis, but, due to their extensive use in field and laboratory studies, a well developed database exists relating acid extractable levels of micronutrients to crop response. The most commonly used dilute acids are: Mehlich-1 (dilute double acid, 0.0125 M  $\text{H}_2\text{SO}_4 + 0.05 \text{ M HCl}$ ) and 0.1M HCl (Sims and Johnson. 1991).

Among the chelating agents, DTPA is the most commonly used one. The DTPA soil test, developed for near neutral and calcareous soil by Lindsay and Norvell (1978) illustrates the evolution of a soil test extractant from theoretical principles. The extracting solution consists of 0.005M DTPA and 0.01 M  $\text{CaCl}_2 \cdot 2\text{H}_2\text{O}$ , buffered at pH 7.3 by 0.1 M triethanolamine (TEA). The DTPA extractant offers the most favourable combination of stability constants necessary to simultaneously extract four micronutrient cations (Fe, Mn, Cu and Zn). The buffered pH and presence of soluble  $\text{Ca}^{2+}$

prevent excessive dissolution of calcium carbonate, avoiding the release of unavailable micronutrients occluded by this solid phase. At pH 7.3, 70-80% of the buffering capacity provided by TEA has been consumed. Therefore use of DTPA extractant on acidic soils, will result in neutralization of remaining buffer capacity and unpredictable extraction pH.

### **Reagents**

1. Hydrochloric acid (HCl), 0.1N: Added 8.1 ml of concentrated HCl (reagent grade) to approximately 900 ml of distilled water, mixed and cool to room temperature and made up to 1 litre.
2. DTPA: Prepared the extractant by dissolving 1.967 g of DTPA, 14.92 g of TEA and 1.47 g of  $\text{CaCl}_2 \cdot 2\text{H}_2\text{O}$  in 200 ml of distilled water and diluted to approximately 900 ml. Adjusted the pH to  $7.3 \pm 0.05$  with 1:1 HCl and made up the volume to 1 litre.

### **Estimation of Fe, Mn, Zn and Cu in acid soils (pH < 6.5)**

#### *Extraction and Estimation*

Shaken 2g of soil with 20 ml of 0.1M HCl for 5 minutes. Filtered through Whatman No.42 filter paper. Collected the filtrate and estimated the contents of Fe, Mn, Zn and Cu, using an Atomic Absorption Spectrophotometer.

#### *Calculation*

$$\text{Amount of micronutrient} \left( \frac{\text{mg}}{\text{kg}} \text{ soil} \right) = \text{Concentration from the instrument} \times 10$$

**Estimation of Fe, Mn, Zn, and Cu in near neutral to alkaline soils (pH>6.5)**

*Extraction and estimation*

Shaken 10g of soil with 20 ml of DTPA for 2 hours. Filtered through Whatman No. 42 filter paper. Collected the filtrate and estimated the contents of Fe, Mn, Zn and Cu using an Atomic Absorption Spectrophotometer.

*Calculation*

$$\text{Amount of micronutrient (mg kg}^{-1}\text{ soil)} = \frac{\text{Concentration from the instrument}}{10} \times 20$$

**DATA ANALYSIS**

Statistical analysis of relationship between number of mites and physical (Temperature, RH and Rainfall) and chemical parameters (Macro and Micro nutrients in the soil) was done using SPSS version 16.

Correlation was calculated by the formula :

$$\rho = \frac{(\sum xi yi - \sum xi \sum yi)}{\sqrt{\frac{1}{n} \sum (xi - \bar{x})^2} \cdot \sqrt{\frac{1}{n} \sum (yi - \bar{y})^2}}$$

Where xi = Physical and Chemical parameters (Temperature, RH, Rainfall, Macro and Micro Nutrients)

Yi = Number of mites

**REGRESSION ANALYSIS**

Regression analysis was performed in order to find the relationship between the independent variables (Temperature ,RH and Rainfall) and the dependent variable ( Number of mites) from the data recorded during the study period in Site A and Site B separately.

**Regression Model :**  $Y = a + bx_1 + cx_2 + dx_3$

Y = Number of mites    a = Constant

b = Coefficient of temperature    c = Coefficient of RH    d = Coefficient of Rainfall

$x_1$  = Temperature variable     $x_2$  =RH variable     $x_3$  = Rainfall variable

The analysis was done for pre monsoon seasons, monsoon seasons and post monsoon seasons and respective coefficients were obtained with statistical software SPSS version 20.

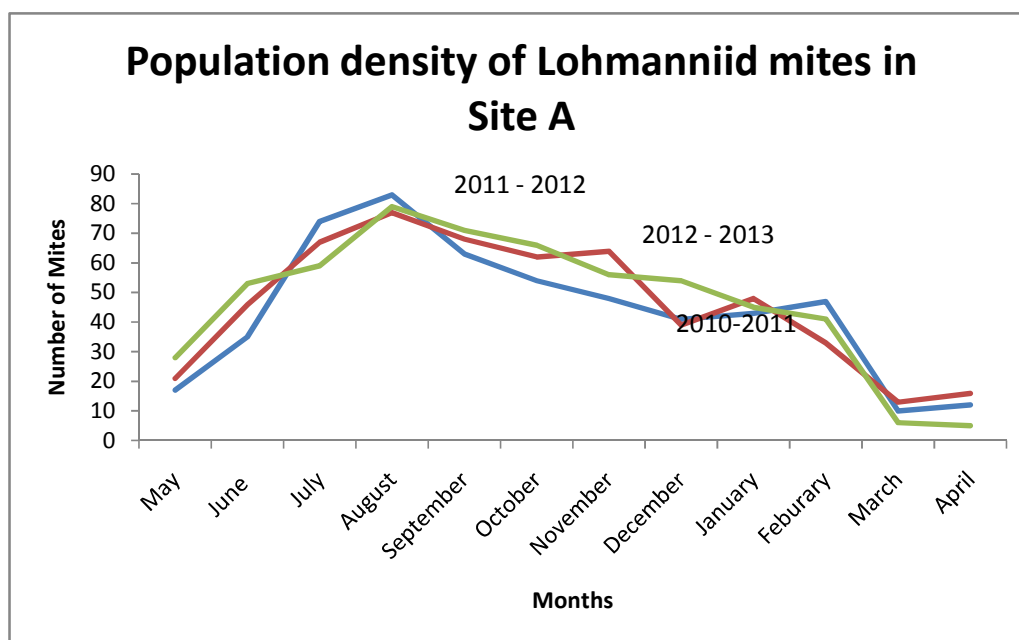
**Observations**

**TABLE : 2**

**Population density of Lohamniid mites – Site A**

Period	SITE A : BG				
	PRE -MONSOON SEASON				
MARCH	TEMP		RH %	RAINFALL	NO.OF MITES
	max	min			
2011	33	24	74	0	10
2012	32	24.2	71	0	13
2013	35.8	25.8	68	0	6
APRIL					
2011	31.9	24.4	74	6.570mm	12
2012	33.2	24.6	75	5.093mm	16
2013	33.7	25.2	73	0.020mm	5
MAY					
2010	35	26.8	69	086.1mm	17
2011	32.6	25.4	77	079.1mm	21
2012	31.6	25.4	80	063.3mm	28
	MONSOON SEASON				
JUNE					
2010	28.1	24.1	92	627.5mm	35
2011	27.6	24.8	95	725.7mm	46
2012	25.4	23.2	96	532.9mm	53
JULY					
2010	26.6	23.5	88	828.9mm	74
2011	28.7	22.4	93	554.6mm	67
2012	29.7	23.4	90	397mm	59
AUGUST					
2010	26.2	22.2	93	348.9mm	83
2011	28.8	21.8	95	531.3mm	77
2012	29.8	23.8	90	540.1mm	79

SEPT					
2010	28.9	23.8	96	287.3mm	63
2011	29.4	22.8	88	530.7mm	68
2012	27	23	90	183.1mm	71
OCT					
2010	28.6	23.5	88	403.4mm	54
2011	31.4	23.2	90	211.6mm	62
2012	32.6	24	92	112.4mm	66
NOV					
2010	29.8	24.3	91	296.8mm	48
2011	32	23.8	80	127.7mm	64
2012	31	22.5	79	021.3mm	56
POST- MONSOON SEASON					
DEC					
2010	30.6	23	88	054.3mm	41
2011	31	24.4	73	0	39
2012	32.4	23.6	76	019.4mm	54
JAN					
2011	32.4	21	79	0	43
2012	31.4	21.9	77	0	48
2013	33	21.8	88	0	45
FEB					
2011	31.6	21.6	81	011.4mm	47
2012	34.4	24	84	012.4mm	33
2013	31.8	24.8	84	017mm	41



**TABLE : 3**

**Relation between no. of mites and physical parameters for site A**

Year	Season	Variable (Site A)	Temperature	RH	Rain Fall	Mites
2010-2011	Pre-Monsoon	Temperature	1	-.324**	-.667**	-.669**
		RH	-.324**	1	-.445**	.536**
		Rain Fall	-.667**	-.445**	1	.494**
		Mites	-.669**	.536**	.494**	1
	Monsoon	Temperature	1	.795**	.879**	.992**
		RH	.795**	1	.912**	.956**
		Rain Fall	.879**	.912**	1	.964**
		Mites	.992**	.956**	.964**	1
	Post-Monsoon	Temperature	1	-.427**	-.615**	-.623**
		RH	-.427**	1	-.790**	.298**
		Rain Fall	-.615**	.790**	1	.389**
		Mites	-.623**	.298**	.389**	1
2011-2012	Pre-Monsoon	Temperature	1	-.335**	-.678**	-.690**
		RH	-.335**	1	-.490**	.576**
		Rain Fall	-.678**	-.490**	1	.505**
		Mites	-.690**	.576**	.505**	1
	Monsoon	Temperature	1	.801**	.891**	.994**
		RH	.801**	1	.912**	.961**
		Rain Fall	.891**	.912**	1	.977**
		Mites	.994**	.961**	.977**	1
	Post-Monsoon	Temperature	1	-.468**	-.624**	-.645**
		RH	-.468**	1	-.790**	.305**
		Rain Fall	-.624**	.790**	1	.391**
		Mites	-.645**	.305**	.391**	1
2012-2013	Pre-Monsoon	Temperature	1	-.389**	-.699**	-.712**
		RH	-.389**	1	-.490**	.589**
		Rain Fall	-.699**	-.490**	1	.545**
		Mites	-.712**	.589**	.545**	1
	Monsoon	Temperature	1	.876**	.899**	.995**
		RH	.876**	1	.912**	.971**
		Rain Fall	.899**	.912**	1	.989**
		Mites	.995**	.961**	.977**	1
	Post-Monsoon	Temperature	1	-.485**	-.597**	-.688**
		RH	-.485**	1	-.792**	.276**
		Rain Fall	-.597**	-.792**	1	.405**
		Mites	-.688**	.276**	.405**	1

\*Correlation is significant at 0.05 level(2-tailed)

\*\*Correlation is significant at 0.01 level (2-tailed)

The exploratory data on relationship of mite population to physical parameters like Temperature, RH and Rainfall during the study period recorded from Site A (Table:3 ) were analysed . The graphical representation clearly indicated that the population of lohmanniid mites increased stridently during monsoon season and maintained lower levels during pre- monsoon and post- monsoon seasons of 2010-2011, 2011-2012 and 2012-2013. Results of statistical analysis of the data revealed that the P values of number of mites to Rainfall 0.964 \*\*, 0.977\*\*, 0.989\*\* during monsoon seasons of the three consecutive years were significant at 0.01 levels. Pre- monsoon (0.494\*\*, 0.505\*\*, 0.545\*\*) and Post- monsoon (0.389\*\*, 0.391\*\*, 0.405\*\*) P values were also significant at 0.01 level; which indicated a positive influence of Rainfall on mite population rates. RH also was identified as a determinant of population dynamics of lohmanniid mites as evidenced in relation to the P values in pre- monsoon (0.536\*\*, 0.576\*\*, 0.589\*\*), monsoon (0.956\*\*, 0.961\*\*, 0.971\*\*) and post -monsoon (0.298\*\*, 0.305\*\*, 0.276\*\*) seasons of the year at 0.01 significant level. Temperature showed a negative correlation with the number of mites in the sites for pre- monsoon and post- monsoon seasons (-0.669\*\* & -0.623\*\*, -0.690\*\* & -0.645\*\*, -0.712\*\* & -0.688\*\*) of 2010-2011, 2011-2012, 2012-2013 annual cycles respectively.

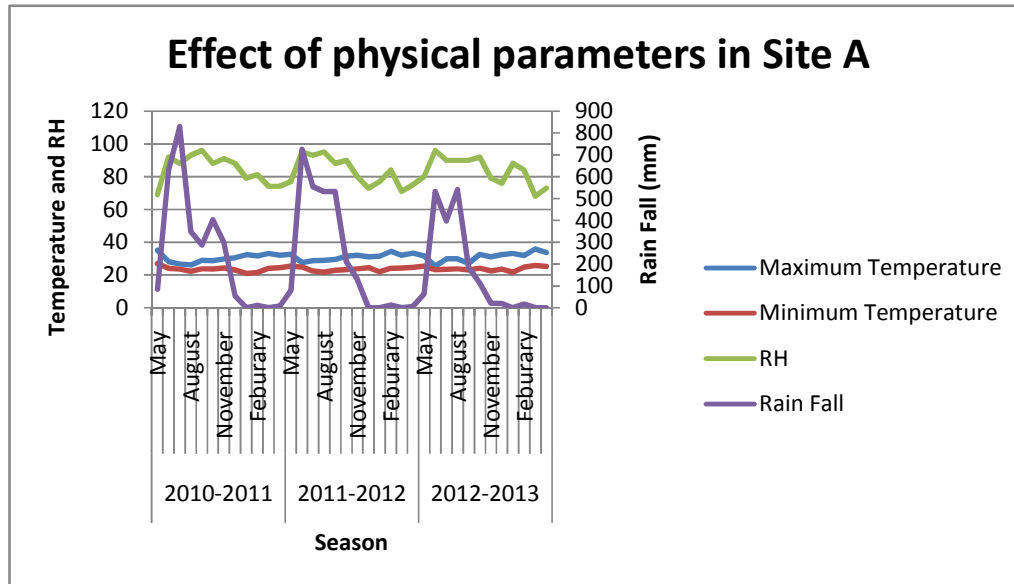


TABLE : 4

Model Summary - Site A

PRE-MONSOON SEASON							
R Square	F	Sig.	Variables	Coefficient	Std.error	t	Significant value
0.838	8.602	0.020	Constant	16.941	97.965	0.173	0.869
			Temperature	-1.783	2.102	-0.848	0.435
			RH%	0.619	0.587	1.055	0.340
			Rainfall	0.141	0.047	2.995	0.030
MONSOON SEASON							
R Square	F	Sig.	Variables	Coefficient	Std.error	t	Significant value
0.318	0.525	0.672	Constant	191.770	125,243	1.531	0.148
			Temperature	-4.105	3.327	-1.234	0.237
			RH%	-0.190	0.774	-0.246	0.810
			Rainfall	-0.012	0.017	-0.679	0.508
POST -MONSOON SEASON							
R Square	F	Sig.	Variables	Coefficient	Std.error	t	Significant value
0.306	0.735	0.575	Constant	154.361	75.441	2.048	0.096
			Temperature	-2.993	2.494	-1.200	0.284
			RH%	-0.357	0.484	-0.738	0.494
			Rainfall	0.028	0.147	0.178	0.866

**Site A**

The model fit indices gives the R square values 0.838,0.318 and 0.306 for pre- monsoon season, monsoon season and post -monsoon season and the significance of 0.02, 0.67 and 0.58respectively. Therefore, the model explains 84%, 32% and 31% of variability in the dependent variable (Number of mites) with respect to independent variables (Temperature, RH and Rainfall).

**TABLE: 5**

**Relationship between no. of mites & nutrients in soil samples – Site A**

SITE A									
Nutrients	OC	P	K	Cu	Zn	Mn	Fe	Mg	No. of mites
Year	PRE-MONSOON SEASON								
2011	7.211	5.9	395.2	0.71	27.14	81.9	6.5	0.8	274
2012	7.566	6.3	402	0.68	28.64	82.7	6.74	0.73	334
2013	7.361	6.1	431	0.7	28.8	82.5	6.66	0.71	307
	MONSOON SEASON								
2011	7.684	6.6	436.1	0.71	28.52	82.44	5.9	0.81	984
2012	7.722	6.62	453.7	0.75	27.95	82.75	6.21	0.76	1012
2013	7.71	6.6	455.3	0.72	28.18	82.13	5.71	0.82	1204
	POST MONSOON SEASON								
2011	7.432	6.01	402.2	0.7	28.04	81.8	5.88	0.8	421
2012	7.673	6.8	452.1	0.69	27.71	81.9	6.12	0.79	398
2013	7.703	6.3	444.8	0.71	27.22	80.28	6.37	0.81	411

**TABLE : 6**  
**Descriptive Statistics**

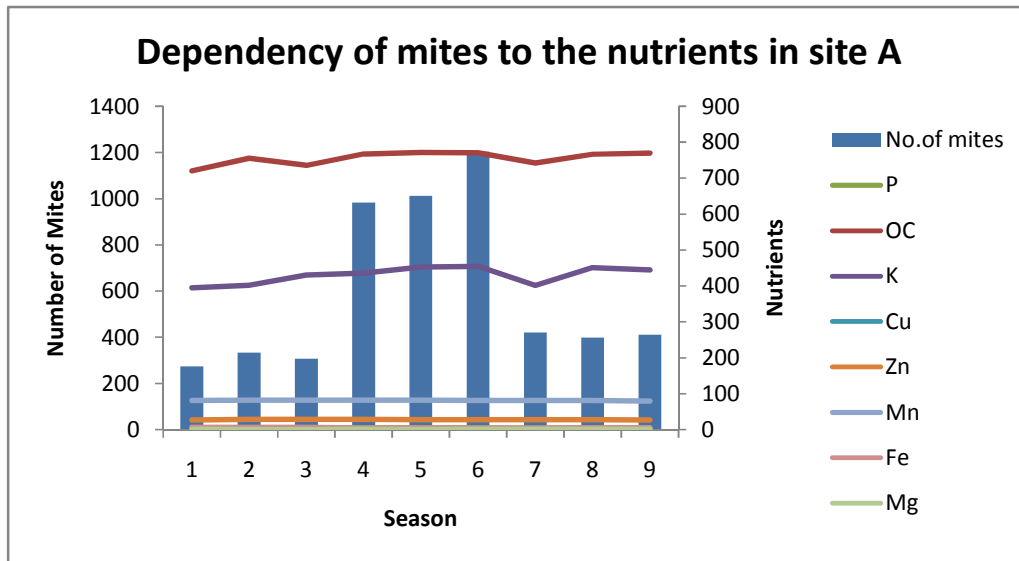
<b>Variables</b>	<b>N</b>	<b>Mean</b>	<b>Std. Deviation</b>
OC	9	7.5624	.18544
P	9	6.3589	.31331
K	9	4.3027E2	24.27622
CU	9	.7078	.01986
Zn	9	28.0222	.58993
Mn	9	82.0444	.75113
Fe	9	6.2322	.36259
Mg	9	.7811	.03887
No of mites	9	5.9389E2	362.82346

**TABLE : 7**  
**Dependency Test**

<b>Variables</b>	<b>Mean</b>	<b>Std. Deviation</b>	<b>Std. Error Mean</b>	<b>t</b>	<b>df</b>	<b>Sig. (2-tailed)</b>	<b>Correlation</b>
OC Vs No of Mites	-5.77657E2	362.07855	120.02618	-4.874	8	.005	.897
P Vs No of Mites	-5.87530E2	362.62668	120.87556	-4.861	8	.001	-.628
K Vs No of Mites	-1.63622E2	348.31865	116.10622	-1.409	8	.196	.859
CU Vs No of Mites	-5.93181E2	362.80997	120.93666	-4.905	8	.001	.679
Zn Vs No of Mites	-5.65867E2	362.69865	120.89955	-4.680	8	.002	.212
MnVs No of Mites	-5.11844E2	362.60371	120.86790	-4.235	8	.003	.294
Fe Vs No of Mites	-5.87657E2	363.07855	121.02618	-4.856	8	.001	.703
Mg Vs No of Mites	-5.93108E2	362.80847	120.93616	-4.904	8	.001	.386

Results of chemical analysis of soil samples collected from Site A( Table : 5) revealed high organic matter concentration, typical of tropical forests with high C/N proportions and acidic soils due to rich humus accumulations. Among the macronutrients analysed; (Tables : 6 & 7 ) Organic Carbon (OC) and Potassium(K)showed positive correlation with the number of mites with values 0.897 and 0.859 respectively. Phosphorous (P) showed

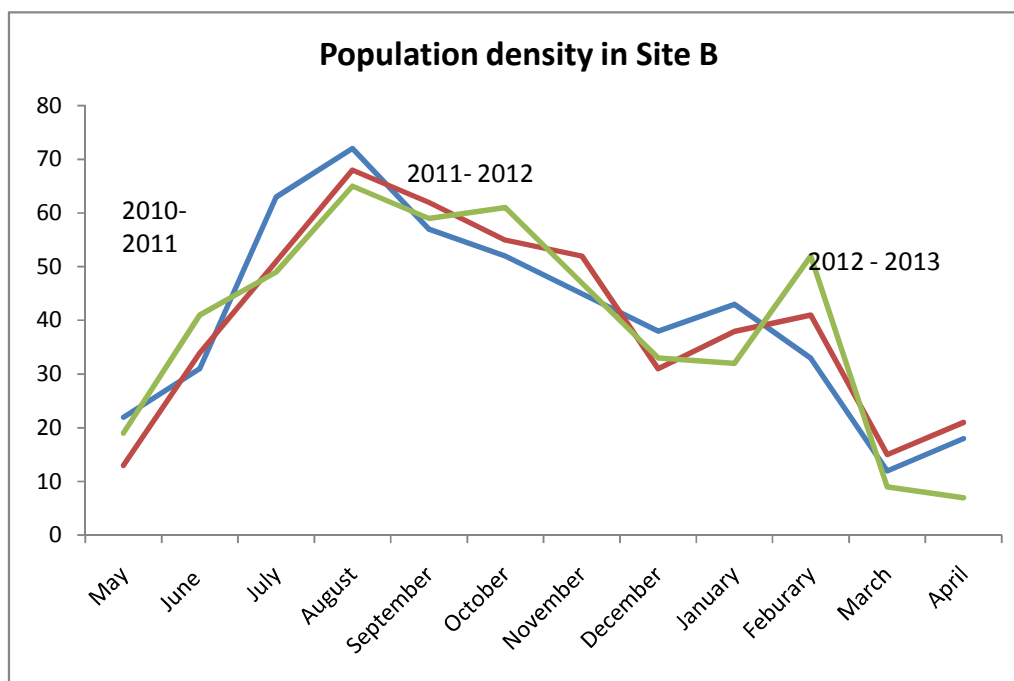
negative correlation (-0.6280, which implied low dependency towards the nutrient. Micronutrients like Zn, Mn and Mg were found in very low proportions (0.212, 0.294 & 0.386) and hence were less influencing than Cu and Fe (0.679 & 0.703).



**TABLE : 8**  
**Population density of Lohamniid mites –Site B**

Period	SITE B: KY				
	PRE- MONSOON SEASON				
MARCH	TEMP		RH%	RAINFALL	No.OF MITES
	max	min			
2011	33.8	25	75	0	12
2012	34	26	77	0	15
2013	34	25.6	69	0	9
APRIL					
2011	32.8	24.8	72	6.570mm	18
2012	33.3	25.2	77	5.093mm	21
2013	34.7	26.2	72	0.020mm	7
MAY					
2010	33.5	25.6	82	086.1mm	22
2011	34.4	26	65	079.1mm	13
2012	33.9	26.8	79	063.3mm	19
MONSOON SEASON					
JUNE					
2010	33.7	23.5	90	627.5mm	31
2011	27.6	24.8	92	725.7mm	34
2012	31.2	22.2	95	532.9mm	41
JULY					
2010	27.1	23.2	83	828.9mm	63
2011	28.8	23	87	554.6mm	51
2012	30.6	23.6	80	397mm	49
AUGUST					
2010	28.2	24	90	348.9mm	72
2011	29	22.7	91	531.3mm	68
2012	29.8	23.2	90	540.1mm	65
SEPT					
2010	33	24	89	287.3mm	57
2011	31.6	23.5	78	530.7mm	62
2012	32.1	24	77	183.1mm	59
OCT					
2010	29.8	23.3	82	403.4mm	52
2011	32.2	23.6	78	211.6mm	55
2012	32.6	24	92	112.4mm	61
NOV					
2010	28.6	22.8	90	296.8mm	45
2011	32.7	22.4	77	127.7mm	52
2012	32.7	22.4	78	021.3mm	47

POST -MONSOON SEASON					
DEC					
2010	31.6	20.8	72	054.3mm	38
2011	32.6	20.4	65	0	31
2012	32.4	22.4	74	0	33
JAN					
2011	30.6	23	73	0	43
2012	32.6	22.8	68		38
2013	32.4	23.7	79	0	32
FEB					
2011	33.1	22.2	70	011.4mm	33
2012	32.6	21.8	69	012.4mm	41
2013	33.3	22.4	72	017mm	52



**TABLE : 9**

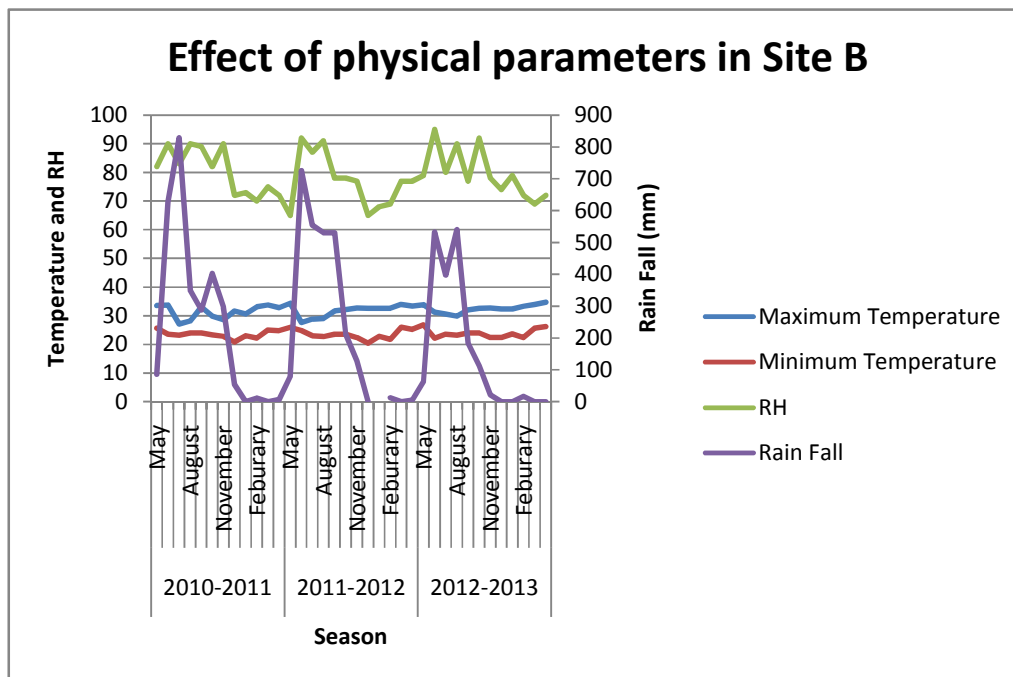
**Relation between no. of mites and physical parameters in site B**

Year	Season	Variable (Site B)	Temperature	RH	Rain Fall	Mites
2010-2011	Pre-Monsoon	Temperature	1	-.104**	-.565**	-.516**
		RH	.404**	1	-.312**	.206**
		Rain Fall	-.665**	-.812**	1	.474**
		Mites	-.516**	.206**	.474**	1
	Monsoon	Temperature	1	.704**	.765**	.816**
		RH	.704**	1	.812**	.806**
		Rain Fall	.765**	.812**	1	.874**
		Mites	.816**	.806**	.874**	1
	Post-Monsoon	Temperature	1	-.324**	-.565**	-.612**
		RH	-.324**	1	-.722**	.198**
		Rain Fall	-.565**	.722**	1	.364**
		Mites	-.612**	.198**	.364**	1
2011-2012	Pre-Monsoon	Temperature	1	-.131**	-.525**	-.503**
		RH	-.131**	1	-.398**	.316**
		Rain Fall	-.525**	-.398**	1	.414**
		Mites	-.503**	.316**	.414**	1
	Monsoon	Temperature	1	.789**	.778**	.819**
		RH	.789**	1	.856**	.845**
		Rain Fall	.778**	.856**	1	.891**
		Mites	.819**	.845**	.891**	1
	Post-Monsoon	Temperature	1	-.384**	-.512**	-.652**
		RH	-.384**	1	-.729**	.208**
		Rain Fall	-.512**	-.729**	1	.369**
		Mites	-.652**	.208**	.369**	1
2012-2013	Pre-Monsoon	Temperature	1	-.199**	-.567**	-.543**
		RH	-.199**	1	-.408**	.378**
		Rain Fall	-.567**	-.408**	1	.498**
		Mites	-.543**	.378**	.498**	1
	Monsoon	Temperature	1	.799**	.798**	.889**
		RH	.799**	1	.856**	.851**
		Rain Fall	.798**	.856**	1	.899**
		Mites	.889**	.851**	.899**	1
	Post-Monsoon	Temperature	1	-.405**	-.567**	-.678**
		RH	-.405**	1	-.781**	.256**
		Rain Fall	-.567**	-.781**	1	.399**
		Mites	-.678**	.256**	.399**	1

\*Correlation is significant at 0.05 level (2-tailed)

\*\*Correlation is significant at 0.01 level (2-tailed)

Mite population showed an increase in numerical abundance during monsoon seasons of the study period in Site B also (Table:8) which showed an accountable decrease in population during pre -monsoon and post-monsoon seasons over the three years of consecutive study. Correlation of 0.874, 0.891 & 0.899 at 99 % confidence level was noted between number of mites and Rainfall in monsoon seasons of 2010- 2011 , 2011-2012 & 2012-2013. Data analysis on impact of RH to number of mites indicated a positive relationship during pre-monsoon (0.206,0.316 ,0.378), monsoon (0.806,0.845,0.851) and post-monsoon (0.198,0.208,0.0.256) seasons of the study period respectively .Lohmanniid mite population was found to have an inverse relationship with the physical parameter; Temperature ,which showed negative correlation value.



**TABLE : 10**  
**Model Summary - Site B**

PRE-MONSOON SEASON							
R Square	F	Sig.	Variables	Coefficient	Std.error	t	Significant value
0.817	7.435	0.027	Constant	124.257	62.422	1.991	0.103
			Temperature	-5.011	1.948	-2.572	0.050
			RH%	0.512	0.198	2.582	0.049
			Rainfall	0.073	0.029	2.561	0.051
MONSOON SEASON							
R Square	F	Sig.	Variables	Coefficient	Std.error	t	Significant value
0.359	0.690	0.573	Constant	186.772	99.643	1.874	0.082
			Temperature	-4.006	3.157	-1.269	0.225
			RH%	-0.223	0.489	-0.456	0.655
			Rainfall	-0.015	0.016	-0.952	0.357
POST- MONSOON SEASON							
R Square	F	Sig.	Variables	Coefficient	Std.error	t	Significant value
0.372	0.267	0.847	Constant	-53.170	139.074	-0.382	0.718
			Temperature	3.906	5.696	0.686	0.523
			RH%	-0.240	0.794	-0.302	0.775
			Rainfall	0.159	0.187	0.852	0.443

**Site B**

The model fit indices for the R square and significance values were 0.817 & 0.027, 0.359 & 0.573 and 0.372 & 0.847 respectively for pre-monsoon, monsoon and post-monsoon seasons. The model explains 82%, 35% and 37% variability in the dependent variable (Number of mites) with respect to independent variables (Temperature, RH and Rainfall).

**TABLE : 11**

**Relationship between no. of mites & nutrients in soil samples - B**

		SITE B								
Nutrients		OC	P	K	Cu	Zn	Mn	Fe	Mg	No.of mites
Year	PRE-MONSOON SEASON									
2011		3.549	1.11	141.5	0.12	18.225	24.9	3.7	2.92	69
2012		4.287	1.13	144	0.11	18.31	25.11	3.9	3.31	113
2013		4.112	1.22	144.11	0.12	18.26	25.18	4.13	3.27	84
	MONSOON SEASON									
2011		3.99	1.25	144.3	0.15	18.43	25.2	4.2	3.16	389
2012		4.258	1.09	145.1	0.14	18.39	25.6	4.17	3.47	463
2013		4.267	1.12	143.89	0.13	18.44	25.52	4.3	3.45	427
	POST -MONSOON SEASON									
2011		3.412	1.21	143.39	0.11	18.23	25.14	3.9	3.11	79
2012		4.435	1.12	145.71	0.13	18.41	25.2	4.28	3.36	169
2013		4.322	1.31	144.8	0.12	18.37	25.3	4.19	3.24	136

**TABLE :12**

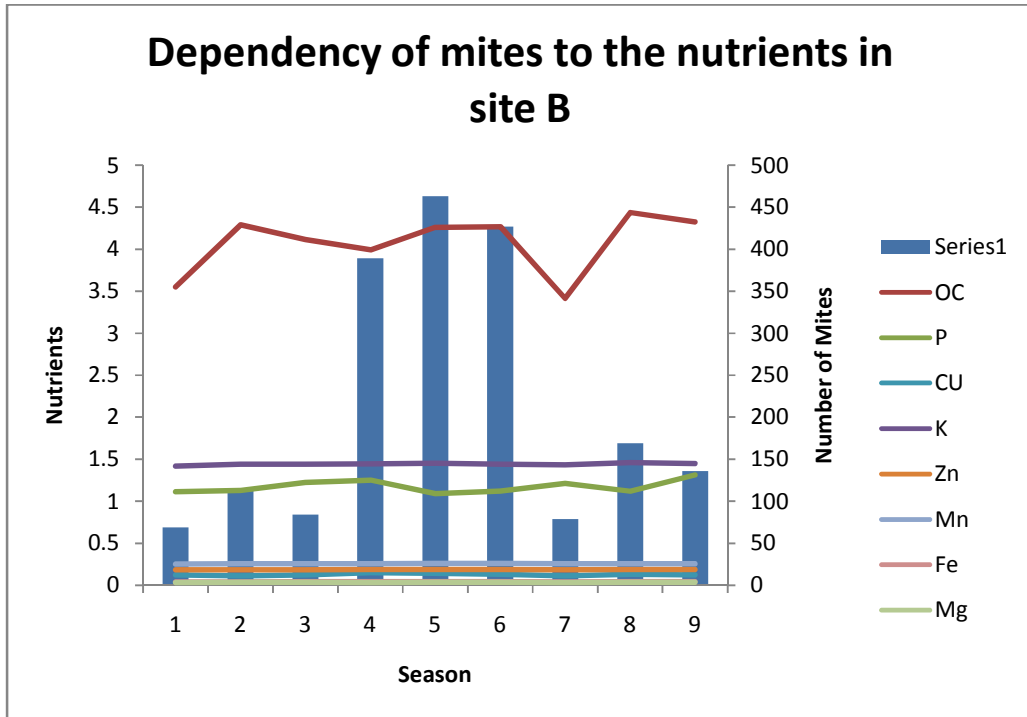
**Descriptive Statistics**

Variables	N	Mean	Std. Deviation
OC	9	4.0702	.35891
P	9	1.1733	.07632
K	9	1.4409E2	1.19579
CU	9	.1256	.01333
Zn	9	18.3406	.08589
Mn	9	25.2389	.21239
Fe	9	4.0856	.20446
Mg	9	3.2544	.17357
No of mites	9	2.1433E2	162.96242

**TABLE : 13**  
**Dependency Test**

Variables	Mean	Std. Deviation	Std. Error Mean	t	df	Sig. (2-tailed)	Correlation
OC Vs No of Mites	-2.10263E2	162.82800	54.27600	-3.874	8	.005	.875
P Vs No of Mites	-2.13160E2	162.98116	54.32705	-3.924	8	.004	-.245
K Vs No of Mites	-7.02444E1	162.51063	54.17021	-1.297	8	.031	.881
CU Vs No of Mites	-2.14208E2	162.95149	54.31716	-3.944	8	.004	.520
Zn Vs No of Mites	-1.95993E2	162.89419	54.29806	-3.610	8	.007	.794
MnVs No of Mites	-1.89094E2	162.79131	54.26377	-3.485	8	.008	.606
Fe Vs No of Mites	-2.10248E2	162.83689	54.27896	-3.873	8	.005	.614
Mg Vs No of Mites	-2.11079E2	162.85852	54.28617	-3.888	8	.005	.599

Dependency of lohmanniid mites towards nutrients in the soil samples of Site B ( Table:11 ) clearly pointed out that the presence of various nutrients contributed to the population density of mites. OC and K were highly correlated with the numerical abundance of mites as in Site A, with correlation values of 0.875 & 0.881 respectively. Phosphorous showed negative effect on mite population with -0.245 correlation value. Magnesium (0.599) and Copper(0.520) were detected to be the lowest influencing micronutrients while Manganese, Iron and Zinc showed a positive impact with respective correlation values of 0.606, 0.614 & 0.794 in ascending order of impact (Tables : 12 & 13).



Organisms tend to flourish in particular habitats which nurture their basic needs for survival. Availability of preferred food items and optimum physico-chemical parameters exert profound influence on the population dynamics of the species concerned. Several general and specific studies were carried out by many workers on the feeding and breeding parameters as well as the functional roles of oribatid mites in their natural habitats. The present chapter includes a consolidation of the various pieces of information available on the ecological and biological parameters of oribatid mites. Considering the scarcity of knowledge on the feeding and breeding biology of lohmanniid mites, the present review has been extended to include data on the biological parameters of oribatid mites in general, rather than limiting it to the lohmanniid mites alone.

It was Michael (1884, 1888) who pioneered in studies on biological parameters of oribatid mites by successfully rearing a few species like *Damaeus nitens*, *Notaspis bipilis* and *Cepheus palmicinctum* in specially designed culture cells made up of plastic rings mounted on microslides, on food items like lichen, decayed wood and cheese. The author reported that the above three species completed their development within 32, 60 and 345 days respectively. The feeding preference of oribatid mites to fungi and lower plant materials was established by Vitzthum (1923). Grandjean (1933, 1939) recorded the changes occurring in the leg chaetotaxy of oribatid mites during the process of development and provided data on the morphological details of the different life stages.

Krull (1939) conducted studies on the feeding preference of oribatids to various food items like fungal hyphae, spores, debris, eggs of anoplocephaline tapeworms and cellular materials of decomposing grass. Grandjean (1950) cultured five species of oribatids viz., *Nothrus palustris*, *N. silvestris*, *Nanhermannia nana*, *Camisia signis* and *Platynothrus peltifer* on

lichen. Riha (1951) observed that *Pelops* sp. cut out pieces of dry, undecomposed leaves with its mouth parts while feeding. Rhode (1955) designed culture vials using a mixture of plaster of Paris and charcoal for rearing oribatid mites and confirmed moss as the preferred food of *Euphthiracarus flavum*, *Pseudotritia* sp. and *Oribotritia* sp. Schuster (1956) categorized oribatid mites into macro-phytophages (feeding on higher plants), microphytophages (feeding on lower plant materials) and non-specialists (feeding on both higher and lower plant materials) based on their feeding preference. Grandjean (1957) correlated the structure of mouth parts of oribatid mites in relation to feeding activity and he suggested rutellum as a modified form of infracapitulum seta which would facilitate feeding.

Wallwork (1957) observed the burrowing habit of the adults and immatures of some oribatids on the bark and hardwood of fallen twigs. The same author (1958) studied the feeding behaviour of several species of soil inhabiting oribatids in relation to the selective decomposition of litter. According to him, the particle size, structure of mouth parts, nature of digestive system, stage of chemical decay of food and moisture content of the food would affect the feeding preference of oribatid mites. Further, he (1961) observed the association of mites with bacteria. Evans *et al.* (1961) identified the pest status of *Humerobates rostralamellatus* on split cherries and *Perlohmanna dissimilis* on tulips and potatoes respectively. Bhattacharya (1962) offered a variety of food materials to six species of oribatids and found that several species were omnivorous and concluded that the average longevity was an indication of nutritive value of food.

Hartenstein (1962) analyzed the feeding specificity of oribatid mites and recognized three feeding categories *viz.*, primarily wood and leaf feeders, primarily fungivores but would feed on wood and leaf tissue and strictly fungivores. Woodring (1963) observed that oribatid mites normally would

feed on partially or completely decomposed plant parts and he provided a consolidated list of oribatids which could be reared in the laboratory. Gasford and Goodnight (1963) reported a proportional increase in lignin and decrease in cellulose in the faeces of oribatid species like *Peloribates* sp. and *Hermannia* sp. Madge (1965) investigated leaf fall and litter disappearance in a tropical forest at Ihadam, Nigeria and inferred that feeding activity of mites and collembolans was responsible for litter disappearance. Seasonal fluctuations in the population density of oribatid mites were correlated with their reproductive cycle by Block (1966).

Wauthy *et al.* (1966) conducted studies on two subspecies of the oribatid mite, *Quadroppia quadricarinata* and provided information on enzymatic polymorphism due to nutritional and environmental adaptations. The direct and indirect effects of oribatids in soil formation, plant productivity and litter decomposition through their involvement in vertical translocation of organic matter to deeper layers of soil were studied by Wallwork (1967). Ultrastructural details of the alimentary canal of four species of oribatid mites *viz.*, *S. laevigatus*, *S. anomalus*, *Xenillus tigeoribates* and *Pthiracarus* sp. and the histology of different regions of the gut were studied using electron microscope by Bernini (1971). Zinkler (1971) analyzed the carbohydrases present in litter dwelling oribatids and he detected the presence of carboxy methyl cellulase, xylanase and pectinase in macrophytophagous and omnivorous oribatids which would help in decomposition of plant structural polysaccharides. The same author (1972) reported that microphytophagous mites could digest only intracellular compounds of algae, fungal mycelia and bacteria with the help of maltase and amylase.

Luxton (1972) made a review on the classification of oribatid mites based on their feeding habits and substituted the term 'panphytophages' for non specialized feeders. He added further terms like 'zoophages' (feeding on

living animal material), 'necrophages' (feeding on carrion) and 'coprophages' (feeding on faecal material). The same author (1975) conducted calorimetric studies of oribatid biomass and discussed it in terms of life histories and metabolic rates. Haq (1976) conducted feeding experiments on twenty species of oribatid mites and concluded that the wide range distribution of panphytophagous species could be correlated with their ability to digest various food items available in their habitat. Haq and Prabhoo (1976) analyzed the gut contents of ten species of oribatid mites through suitable staining procedures and categorized them as panphytophages.

Shereef (1976) reared two species of Lohmanniid mites viz., *P. aciculatus* and *Lohmannia egypticus* on varied food items like weathered wood, decaying roots and dry leaves and recorded the duration of life cycle as 71 and 101 days respectively. A detailed description of the morphological characters of all the developmental stages of the above two species along with figures were also provided by the same author. Stefaniak and Seniczak (1976) carried out microbiological studies on the adults and immatures of a polyphagous species, *Achipteria coleoptrata*. Their studies revealed that the gut microflora of the immature of these species were more abundant, active and varied when compared to the adults and the gut microflora were dependent up on the type of food eaten.

Behan and Hill (1978) studied the feeding habits of twenty five species of oribatid mites from North America through gut content analysis and reported that 50% of oribatids adopted 'eurytypic' feeding habit. The authors estimated the direct and indirect effects of oribatid mites in decomposition process. A detailed description on the activities of soil mites in various ecosystem processes, particularly in enhancement of soil fertility, biogeochemical cycles, humification, bio- indication and in the detection of residual concentration of pesticides, etc. was given by Lebrun (1978). Haq

(1978) studied the postembryonic development of *A. longisetosus* and *L. ornatissimus* which took 50 and 176 days respectively for completing their life cycle. Luxton (1979) estimated the rate of food processing by oribatid mites and also reviewed their nutritional biology. A study on the nutritional biology of fourteen species of oribatid mites harbouring the high alpine areas of Tyrol was studied by Schatz (1979).

A comparative study on the durations of life cycle of four species of oribatid mites viz., *L. ornatissimus*, *A. longisetosus*, *G. flabellifera orientalis* and *G. longipluma* from the soils of Kerala was made by Haq and Clement (1980). Vikram Reddy (1981) illustrated the various indispensable functions performed by different groups of acari. The author stressed the importance of mites in nutrient cycling, energy flow, bioindication, decomposition and soil aeration. Luxton (1981 a-c) conducted studies on the field population, developmental biology, vertical distribution and seasonal variations in population of oribatid mites in Danish beech wood soil.

Haq (1982a) classified ten species of oribatid mites, on the basis of food specificity into three major feeding categories viz., microphytophages, macrophytophages and panphytophages. He also reported that rate of reproduction was enhanced by preferred food. Life histories of three species of sub-antarctic oribatid mites were traced by West (1982). Behan and Hill (1983) analysed the feeding habits of sixteen species of oribatid mites from Glenamoy Ireland and reported that fifteen species were panphytophages, which acted as regulators in the process of mobilization of minerals, dissemination of fungal spores or as temporary store house of nutrients.

Hagan and Norton (1983) investigated the impact of habitat disturbance by man on the oribatid population density and observed that higher concentration of calcium had a positive influence on the species

richness of these mites. Purrini and Bukva (1984) screened the presence of microorganisms like bacteria, fungi and protozoans in the gut and body cavity of many species of oribatid mites. Haq (1984) established the role of a lohmanniid species, *H. hirsutus* in wood decomposition and also elucidated the involvement of gut microbes of the species in the process of wood digestion. Several species of bacteria were isolated from the alimentary tract of two species of oribatid mites, viz., *Rhysotritia* sp. and *Pergalumna* sp. by Wolf and Rockett (1984). The authors noted that, the micro-organisms in the oribatid gut varied with the species and their habitat. Ramani and Haq (1984) reported the association of several species of oribatid mites with different types of economically important plants.

Norton (1985) studied the role of oribatid mites in changing the soil structure by ingesting particulate food and producing discrete faecal pellets. He further noted the active gut microfauna in saprophagous and mycophagous oribatid mites tend to change with diet change. Cacela Da Fonesca (1985) correlated the effect of food characteristics on the spatial distribution of oribatid mites in particular microhabitats. Biodegradation of cellulose in the gut of *H. hirsutus* was studied by Haq (1987) and he isolated the bacterial colonies from the faecal pellets laid by the species. Ramani and Haq (1987 a & b) studied the influence of temperature on the duration of development of *S. decarinatus* inhabiting the terrestrial weed, *Chromolaena odorata* and further traced the postembryonic development of the species under laboratory conditions.

Haq and Konikkara (1988) elucidated the role of microbes in two xylophagous species of oribatid mites viz., *H. singularis* and *H. hirsutus*. Kaneko (1988) correlated cheliceral dimensions with the feeding habits of oribatid mites in cool temperate forest soils in Japan. The same author (1989) recorded the duration of life cycle as well as reproduction pattern of four

species of oribatid mites, viz., *Eohydroppia magnus*, *Ischeloribates lanceolatus*, *Qudroppia quadricarinata* and *Archoplophora villosa* collected from mull type soils.

Palmer and Norton (1990) experimentally proved the occurrence of thelytokous parthenogenesis in fifteen species of oribatid mites. Ramani and Haq (1991) reported a novel adaptive trend in oribatid mites to occupy newer habitats when their original habitat was destroyed. The potential of *M. degradatus* and *X. rhomboides* in the degradation of higher plant materials was revealed by the same authors (1991a). Neena and Haq (1991) studied the influence of a few species of fungi on the post-embryonic development of *Oppia kuehneli* at a temperature of  $30 \pm 2^{\circ}\text{C}$  and a relative humidity of 82-85%. The same authors (1991a) reported the occurrence of a large number of protozoans in the gut and body cavity of ten species of oribatid mites. Palmer and Norton (1992) noticed thelytokous parthenogenesis in the oribatid mite taxon Desmononata where males were found nonfunctional. Haq (1992) gave a detailed report on the beneficial aspects of oribatid mites, highlighting the potential of these mites in biodegradation, bioindication and natural predation.

Neena and Haq (1991, 1992a) observed mycophagy as a common feeding trend among oribatid mites and reported that members of Oribatei Superiores could thrive well on fungi when compared to the members of Oribatei Inferiores. Norton *et al.* (1993) described the occurrence of different modes of reproduction among oribatid mites. Behan (1993a) gave information on the diversity and distribution pattern of oribatid mites. Ramani and Haq (1993) observed that yeast could enhance the development of *Allonothrus giganticus*. A review on the role of oribatid mites in soil ecosystem was made by Haq (1994) and he highlighted the influence of these mites in the maintenance of soil fertility. Smrz (1994) conducted studies on the

behavioural and histological responses of oribatid mites under conditions of extreme humidity, and combined activity of microorganisms.

Siepel and Maaskamp (1994) gave information on the effect of five feeding guilds of oribatid mites on microbial respiration during decomposition of organic matter. Block and Convey (1995) gave a detailed report on the biology, life cycle and ecophysiology of the Antarctic mite, *Alaskozetes antarcticus*. Haq (1996) reported the involvement of microbes in the feeding habits of oribatid mites. Crossley (1997) evaluated the energetics of oribatid mite populations based on their contribution in mineral and nutrient cycling. Marie *et al.* (1997) observed the phenomenon of obligate thelytoky in oribatid mites and recommended an alternative hypothesis for the induction of thelytoky. The authors further studied its relevance to the observed diversification of thelytokous oribatid mites.

Mauran *et al.* (1998a) worked out the role of panphytophagous oribatid mites in the recovery of microbial community in F-layer material of soil, which was disturbed by human activities. Behan and Paoletti (1999) gave a detailed account on the general ecology, biology and life history of oribatid mites inhabiting the organic horizons of soil. The life cycle of *X. seminudus* was traced by Ramani (1999) and the duration of development ranged between 18.75-23.00 days. Heneghan *et al.* (1999) conducted litter bag experiments and showed that oribatid mites constituted a dominant component of soil fauna involved in the decomposition of a single substrate, *Quereus parinus*. Herbert *et al.* (2000) described the microanatomy of the digestive tract of oribatid mites and studied the feeding habits of a panphytophagous species, *S. laevigatus* on litter of the meadow grass, *Holeus lanatus*. Maraun and Behan and Walter (2000) studied the biodiversity of oribatid mites, feeding on tree canopies and litter.

Ramani and Haq (2001) examined the role of two species of oribatid mites, *Hoplothiracarus rimosus* and *Lohmanniasp.* to degrade higher plant materials. The results of enzyme assays clearly indicated the ability of these mites in degradation. Mauran (2001) analyzed sexual and parthenogenetic development in oribatid mites on molecular basis and derived evolutionary and phylogenetic conclusions.

Raspotnig *et al.* (2001) analyzed the chemistry of lemon-scented oil gland secretion of *Collohmanna gigantea* by gas chromatography- mass spectrometry. Their findings were consistent with the idea of astigmatid origin from a mixonomatan-desmonomatan group.

Smrz (2002) suggested nutritional biology as the basic step in the autecological studies. Further, microanatomical and biological aspects of bacterial associations in an Astigmatid mite, *Tryophagus putriscentiae* were also reported by same author (2003). Mauran *et al.* (2004) analyzed food preferences in oribatid mites. A review on the feeding biology of oribatid mites was provided by Schneider *et al.* (2004). The preferential feeding by oribatid mites on ectomycorrhizal fungi was established by Schneider *et al.* (2005) and the authors reported that saprotrophic fungi were comparatively less preferred by these mites. Alphonsa and Haq (2006) conducted studies on breeding biology and postembryonic development of a lohmanniid species, *H. davisii*. Microenvironmental preferences of oribatid mites inhabiting in a tropical rain forest floor were recorded by Badejo and Akinwale (2006). The potential of oribatid mites for degrading highly recalcitrant solid wastes accumulated on the retting grounds was assessed by Julie and Ramani (2007). The same authors (2008) conducted an inventory of oribatid fauna and studied the species richness of Muthanga Forest Reserve of the Western Ghats, India.

Bergmann *et al.* (2008) described the morphology of internal reproductive organs of *A. longisetosus* at various stages of development using microscope and noninvasive technique of synchrotron x-ray microtomography. They observed that genital duct was formed during the tritonymphal stage, close to the ventral body wall. Mauran *et al.* (2009) conducted phylogenetic studies of 51 oribatid mite species and four out group taxa using ribosomal 18S rDNA region and the results of which indicated that arboreal life evolved at least 15 times independently and ecological factors were most important for convergent evolution of arboreal life. Lee *et al.* (2009) studied the effect of trampling and litter removal on the relative abundance and composition of soil arthropods in a subtropical hardwood forest. Fischer *et al.* (2010) studied the community structure, trophic position and reproductive modes of soil and bark dwelling oribatid mites in an alpine grassland ecosystem.

Posada and Schuur (2011) suggested that soil nutrient availability would play a central role in the dynamics of carbon cycling in tropical rain forests. Fischer *et al.* (2011) analyzed feeding biology of oribatid mites in high alpine regions with dual stable isotopes. Heethoff *et al.* (2011) conducted integrative taxonomic studies combining morphological, molecular and chemical data for species delineation in the parthenogenetic species complex of *Tryhochthonius tectorum*. Information on the fine structure of the gnathosoma of *A. longisetosus* was provided by Alberti *et al.* (2011).

Fanin *et al.* (2012) evaluated the combined change in carbon, nitrogen and phosphorous availability affects soil and litter microbial respiration ; in relation to litter decomposition in an undisturbed Amazonian rainforest in French Guiana. They suggested that any change in relative C and nutrient fluxes between the litter layer and soil could have important consequences for biogeochemical cycles in tropical forest ecosystems. Erban and Hubert (2012)

studied the digestive physiology of a synanthropic mite and suggested the association of symbiotic bacteria in their gut. Ermilov *et al* (2012) described the morphology of juvenile instars of three species of *Meristacarus* viz., *M. porcula*, *M. africanus annobonensis* and *M. longisetosus* and one species of *Cryptacarus* viz., *C. promecus*. A description of the female and male reproductive systems in *Hermannia gibba* was made in detail by Liana and Witalinski (2012).

Skubala (2013) observed the radical negative change of environmental conditions for soil oribatid mites as a result of the invasive giant knotweed (*Fallopia schalinensis*). Zaitsev *et al.* (2013) suggested that spatial patterns of soil animal community diversity and composition could be significantly determined by geologic age at regional level.

## **EXTRACTION AND REARING OF LOHMANNIID MITES**

The live mites recovered through Berlese funnel extraction were reared in plastic vials of length 4cm and width 3.5cm based with plaster of paris-charcoalmixture (4:1) ratio. Moistened leaf litter collected from different habitats were offered as food during rearing under laboratory conditions. A few drops of 1% thymol solution were added to each of the rearing cells as a fungicide.

Developmental studies were initiated in fresh culture cells. Live mites isolated species wise under a stereozoom microscope were transferred into fresh culture cells with the aid of a moistened camel hair brush. The culture cells were regularly observed at fixed intervals to locate the eggs or spermatophores of individual species. When the eggs were noticed, they were transferred to special culture rings, prepared by fixing acrylic rings of 2.5cm diameter in a mixture of plaster of paris – charcoal (4:1) ratio contained in a petridish. The culture ring was covered with a cover glass and observed under a stereozoom microscope to record the changes occurred during days of incubation. Frequent observation was made to collect data on hatching, duration of active and quiescent stages, moulting etc. For studying the morphological details, few eggs and life stages were treated in alcohol series ( 70%, 90% and 100% ) and slide mounted. Drawings were made by using prism type camera Lucida attached to a Unitron Research Microscope. The culture cells were maintained at the temperature –humidity conditions of  $30 \pm 1^{\circ}\text{C}$  and 75 – 80% respectively in the laboratory.

## **A. QUALITATIVE ANALYSIS OF FEEDING HABITS**

An analysis of feeding habits of a few dominant species of lohmanniid members was carried out in the present study by laboratory food choice test and microbiological characterisation of the gut contents. Field collected mites as well as F<sub>1</sub> and F<sub>2</sub> generation individuals separated from the stock cultures maintained in the laboratory were subjected to laboratory food choice test. Optimum conditions of temperature, humidity and hygiene was maintained in the culture cells. Regular observations were made thrice daily.

### **I. LABORATORY FOOD CHOICE TEST**

Among the soil oribatid fauna, lohmanniid mites are designated as macrophytophagous, feeding on leafy and woody components of litter. Aggregation of many species of these mites in particular vegetative areas points an arbitrary nature in feeding habits. In the current study, the most preferred food item was identified and its effect in their population index was analysed. Adult mites and all immature stages were reared singly in the culture cells and the food items procured from the collection sites were offered individually. Leafy and woody components in various degrees of decomposition from different vegetation sites (Table : 14) were cut into pieces of 1 sq. cm (cm<sup>2</sup>) and provided at the centre of the cultural cell. Each food item was tested for a minimum of 5 times before drawing conclusions on the preferential order of feeding attributes. Periodical observation in the general feeding pattern was evaluated on the basis of various ascriptions like :

- Time taken for the initiation and completion of feeding entire food item.
- Feeding marks produced on the food items like formation of tunnels in wooden pieces, burrows or feeding holes on leaves leading to skeletonisation of leaves and eventual complete degradation.

- Presence and abundance of faecal pellets laid on and around the food materials and the substratum.
- Fecundity and longevity of the mites after feeding.
- Feeding potential of all immature stages (Larva, Protonymph, Deutonymph and Tritonymph) and successful completion of its life cycle .

## **II. GUT CONTENT ANALYSIS**

Lohmanniid mites play an amicable role in biodegradation of litter, subsequent nutrient cycling an enhancement of soil fertility. In order to elucidate the involvement of any symbiotic bacterial association in the gut of these mites, microbiological studies of the gut contents were carried out. Twenty five live specimens of *H. foveolatus* were isolated from stock culture and reared in sterilized culture vials. Newly emerged individuals prior to initiation of feeding activity were taken as the control set. Sterilized leaf litter of *Artocarpus heterophyllus* Linn. was provided as food item.

Mites from the culture vials were washed thoroughly with sterile water and transferred to 95% ethanol. These mites were dissected on a microscope slide under a stereozoom microscope by making a gentle cut on the notogaster. The gut was removed with the fine tip of the dissection needle. The gut of 5-10 mite specimens were pooled in a test tube containing peptone water (pH-7.4) and incubated for 2 hours. Then the turbid inoculum was taken with a sterile wire loop and streaked on Blood Agar and Mac Conkey Agar medium.

### **1. Preparation of Media**

- Mac Conkey Agar : This was prepared as per Manufacturers' protocol, Himedia Pvt. Ltd.
- Blood Agar : Medium was prepared by adding sterile

sheep blood to sterile nutrient agar that had been melted and cooled to 50°C.

The approximate amount of blood was poured from a screw – capped bottle.

The concentration of blood used was 7%.

## **2. Seeding of Culture Media**

The plates were inoculated using a sterile wire loop. Lift the bottom of the petridish containing medium from its lid with the left hand and hold it around the side with thumb and middle finger, using a sterile loop, one loop full of inoculum was taken and smeared thoroughly over an area 'A' to give a 'well inoculum' or 'well'. The loop was resterilised and drawn from the well in 3 or more parallel lines.

After the plates were seeded, the petridish was closed with its lid and incubated in the inverted position with the lid underneath. After incubation, the plates were examined for growth and identification was done based on colony morphology, colour change of the media, staining characteristics and other specific tests. The colony characteristics were defined according to their size, transparency, emulsifiability, consistency, elevation, swarming and haemolytic properties.

## **3. GRAM STAINING**

Reagents:

- Gram Crystal Violet solution:- 20g of Crystal Violet (95% dye content) was dissolved in 100ml of ethanol to make Crystal Violet stock solution. Similarly, 1g of ammonium oxalate stock solution was also prepared. Working solution was prepared by mixing 1ml of Crystal Violet solution with 10 ml of water and 40ml ammonium oxalate stock solution and stored in dark bottle.

## *Materials and Methods*

- Methylene Blue Solution:- Solution A: 1g of methylene blue (90% dye content) was dissolved in 100ml ethanol. Solution B: 0.03g of KOH in 300ml of H<sub>2</sub>O. Solution A+B mixed to form the working solution.
- Gram Iodine Solution:- 1g of Iodine, 2g of KI and 3g of Sodium Bicarbonate were dissolved in 300ml of H<sub>2</sub>O.
- Gram decolourizer Solution:- Equal volumes of 95% ethanol and acetone were mixed.
- Gram Safranin Solution:- 2.5g of safranin was dissolved in 100ml of 95% ethanol to make a stock solution. Working solution was obtained by diluting one part of the stock solution with 5 parts of water.

A drop of suspended bacterial culture was transferred to a slide with inoculation loop. It was spread with inoculation loop to form an even thin film over a circle of 1.5 cm in diameter. The slide with the bacterial spread was briefly air dried and fixed on it using a gentle flame, while moving the slide in a circular fashion to avoid localized overheating.

About 5 drops of crystal violet stain were added to the fixed culture and allowed to stand for 60 seconds. The stain was gently poured off and excess stain was rinsed with a stream of water from a plastic water bottle. About 5 drops of Iodine solution were added on the smear and allowed to stand for 30 seconds. Iodine solution was poured off and the slide was rinsed. A few drops of decolourized was added to the smear and it was removed by rinsing with water after 5 seconds. The smear was counterstained with 5 drops of safranin solution for 20 seconds. The red safranin solution was washed off with water, excess water blotted off with a blotting paper and air dried.

- Motility Test:- The test was performed by hanging drop preparation.
- Oxidase Test:- A small piece of filter paper (placed on to a glass slide or inside an inverted petridish lid) is moistened with 2 or 3 drops of

oxidase test reagent (1% tetra methyl diamine di hydrochloride solution) using a wooden applicator stick / stick or glass pipette tip. Select the suspect colony and smear it into the surface of the moistened filter paper. A positive reaction is shown by the development of a purple colour within 5 seconds.

#### **4. BIOCHEMICAL TESTS**

1. Triple Sugar Iron Agar Medium :- It contains 3 sugars-glucose-1g/L, sucrose-10g/L, Lactose-10g/L and phenol red 0.4% as indicator. Ferrous sulphate and sodium thiosulphate present in the medium detects H<sub>2</sub>S production.

The medium was inoculated from broth culture using a straight wire loop. Loop was first stabbed and then streaked on the surface of the slant. The reactions were read as follows.

- Red slant and yellow butt - Glucose fermented, peptone deaminated.
  - Yellow slant and yellow butt - All sugars fermented.
  - Red slant and Red butt - No fermentation.
  - Blackening of medium - H<sub>2</sub>S production.
2. IndoleTest :- This test detects the ability of bacteria to break down amino acid tryptophan using tryptophanase enzyme with the release of indole. The peptone water medium containing tryptophan was inoculated and incubated overnight. Indole is detected by the addition of Kovac's reagent (Paradimethyle amino benzaldehyde, 180-amylalcohol, concentrated HCL) along the sides of the test tube.

## *Materials and Methods*

3. Methyl Red Test :- This test detects the fermentation of glucose, production of sufficient acid and maintenance of the low P<sup>H</sup> during long incubation period.

Test organism was cultured in glucose phosphate peptone water for 48 hours. Methyl red indicator is added at the end of incubation period detected the acidic end product which is shown by bright red medium.

4. Voges-Proskauer Test :- This test detects the production of acetoin, non-acidic end product of glucose fermentation. In the presents of atmospheric O<sub>2</sub> under alkaline condition the action is oxidised to diacetyl.

The test organism was cultured in phosphate peptone water for 48 hours. After the incubation period, Buritts reagent (3ml of 5% solution of  $\alpha$ -naphthol in absolute alcohle followed by 1ml of 40% potassium hydroxide).

5. Simmons Citrate Medium :- This medium can be used to test the ability of an organism to utilise citrate as the sole source of carbon and energy for growth and an ammonium salt as the sole source of nitrogen. Bromothymol blue was used as the indicator. A wire loop from broth culture was streaked over the slant.

6. Urease Medium :- The Christensen's urease which degrades urea and forms ammonia and CO<sub>2</sub>. Alkalinity produced by ammonia can be detected using phenol red indicator.

Inoculation was done by pouring a drop of broth culture on to the surface of the medium. A wire loop from broth culture was streaked over the slant. A positive reaction indicated by change of colour of the indicator to purple pink.

## *Materials and Methods*

7. Phenyl Pyruvic Acid Medium :- This medium can be used for detecting the present of enzyme phenyl alanine forming Phenyl Pyruvic Acid which in turn , will react with ferric salts to give a green colour .

Inoculation of the medium was done by streaking over the surface of the slant from a broth culture. After overnight incubation, a few drops of 10% ferric chloride solution is allowed to run down over the growth on the slope

8. Mannitol Motility Medium :- The Medium was inoculated from the broth culture using straight wire loop. After overnight incubatin a colour change from red to yellow indicated Mannitol fermentation and spreading along the stab line induced motility.

**TABLE- 14 - RESULTS OF FOOD CHOICE TEST LABORATORY REARED LOHMANNIID SPECIES**

LOHMANNIID SPECIES	<i>Artocarpus heterophyllus</i>	<i>Anacardium occidentale</i>	<i>Bambusa arundanace</i>	<i>Bauhinia purpurea</i>	<i>Cocos nucifera</i>	<i>Chlerodendrum infolunatum</i>	<i>Coffea arabica</i>	<i>Psidium gujava</i>	<i>Mangifera indica</i>	<i>Myristica fragrans</i>	<i>Tectona grandis</i>	<i>Xytiloxylocarpa</i>
<i>A.phyllotrichoussp.nov</i>	L+++ W+	L++W+	L -W-	L+ W-	L -W+	L + W-	L + W-	L+++W+	L++ W-	L++ W-	L++W-	L++W-
<i>A.aereolatussp .nov</i>	L+++W+	L++ W+	L - W-	L ++ W-	L - W+	L+ W-	L - W-	L++ W+	L ++ W-	L++ W-	L++ W-	L ++ W+
<i>C.grandjeani</i>	L+W-	L- W-	L+++ W+	L - W-	L- W-	L- W-	L++ W-	L- W-	L++W-	L-W-	L-W-	L-W-
<i>H.granulatussp.nov</i>	L+++ W++	L++W++	L - W-	L+W-	L-W-	L+W-	L+W-	L ++ W-	L+W-	L ++ W-	L+ W-	L+W-
<i>H.foveolatussp.nov</i>	L+++W++	L++ W+	L- W-	L++W+	L-W+	L+W-	L+W-	L++W-	L ++W+	L++ W-	L+W-	L++W-
<i>H.notobandussp.nov</i>	L+W++	L - W+	L -W-	L- W-	L- W+	L+W-	L- W-	L- W+	L+W+	L+W++	L+W++	L+W++
<i>J.punctatussp.nov</i>	L+++W+	L+++W+	L - W-	L +W	L -W-	L +W-	L-W-	L+++W+	L+W-	L+W-	L -W-	L -W+
<i>P.heterosetosussp.nov</i>	L+++W+	L+ +W+	L -W-	L ++W-	L -W-	L +W-	L+W-	L+++W-	L ++W+	L ++W+	L+++W+	L+++W+
<i>M.degradatus</i>	L+W+	L+W+	L -W-	L+W+	L - W+	L -W+	L -W-	L+W+	L+W+	L ++W+	L+++W+	L+++W++
<i>P.graminosus=V.graminosus</i>	L -W-	L -W-	L+++ W-	L -W-	L -W-	L -W-	L++W+	L -W-	L -W-	L -W-	L -W-	L -W-

L - Leaf litter

W-Woody components

+++ indicate High feeding

+ indicate Low feeding

++ indicate Moderate feeding

- indicate No feeding

## A. Qualitative Analysis of Feeding

Results of food choice test carried out under laboratory conditions are displayed in the (Table-14). The feeding response of 10 species of lohmanniid mites to 12 different leaf litter and woody components varied considerably. Almost all species showed preference to leaf litter than woody parts, except *H. notobandus* sp.nov and *M. degradatus*. Larvae, protonymphs and deutonymphs initiated feeding activity on leaf litter which were in advanced stages of decomposition, while tritonymphs and adults preferred fresh leaf litter.

High degree of feeding specificity was exhibited by *C. grandjeani* to *B.arundanaceae* and *M.degradatus* to *X. xylocarpa*. *P. heterosetosus*, *A.phyllotrichous* and *A.aereolatus* devoured large quantities of *T.grandis* and *M.fragrans* leaf litter when provided in the culture cell in highly decomposed state. *C. arabica* was found to be preferred by *P. graminosus* sp.nov = *Vepracarus*. *A. heterophyllus* leaf litter was identified as the most preferred food item by all the 10 species studied. *A. occidentale*, *P. gujava* and *M. indica* were consumed by almost all lohmanniid members. The preferential order of food items could be recorded as *A. heterophyllus* > *A. occidentale* > *P. gujava* > *M. indica* > *T. grandis* > *M. fragrans* > *X. xylocarpa*.

The high, moderate and low rates of feeding could be identified by definite feeding marks produced through excessive grazing activity of these mites on food items provided. Progressive feeding by the juveniles and adults led to the formation of tunnels in the woody components, rapid skeletonization of leaf litter and complete degradation of the food materials. The high rates of feeding resulted in the deposition of heaps of faecal pellets at the base of the culture cells. The highly palatable food items supported oviposition and development of life stages under laboratory conditions.

## GUT CONTENT ANALYSIS

Petridishes containing Mac Conkey agar and blood agar medium containing turbid inoculum carrying the gut contents of mites after overnight incubation at 37°C were found developing two types of bacterial colonies in both experimental and control sets. The colony morphology and staining characteristics were examined and recorded (Table:15). The colony A developed on Mac Conkey agar was large to medium sized, thick and pink coloured due to lactose fermentation. Colony B were colourless, swarming with characteristic fishy odour.

**TABLE- 15**

### **Morphological and culture characteristics of bacterial colonies**

PLATE	COLONY	CULTURE CHARACTERISTICS		GRAM STAINING
		MAC CONKEY AGAR	BLOOD AGAR	
Experimental	A	Large, thick and moist colonies with dark pink colour due to lactose fermentation	Could not be detected	Gram negative rods
	B	Colourless colonies, Non-Lactose fermenting	Fishy odour swarming colonies	Gram negative rods
Control	A	Medium sized, thick colonies with dark pink colour due to lactose fermentation	Could not be detected	Gram negative rods
	B	Colourless colonies, Non-Lactose fermenting	Fishy odour swarming colonies	Gram negative rods

*Observation*

Colony A and B gram smear revealed the presence of gram negative bacilli. Motility tested by hanging drop preparation revealed that both gram negative rods were motile. Oxidase test was performed for non lactose fermenting colonies grown on Mac Conkey agar and Blood agar. A positive reaction was shown by the development of a purple colour within 5 seconds. Further identification was done on the basis of biochemical tests performed on the media listed (Table:16).

**TABLE : 16**

**Biochemical test results for *E.coli* and *P.vulgaris***

SL.NO.	BIOCHEMICAL TEST	A	B
1	Triple Sugar Iron Agar	A/A with gas production	K/A with gas & H <sub>2</sub> S production
2	Indole	+	-
3	Methyl Red	+	+
4	Voges- Proskauer	-	-
5	Simmon's Citrate	-	+
6	Nitrate	+	+
7	Urease	-	+
8	Phenyl Pyruvic Acid	-	+
9	Mannitol Motility	+	+
10	Sugars	+	+
	a) Glucose	+	+
	b) Sucrose	+	-
	c) Lactose	+	-

+ indicate positive reaction

- indicate negative reaction

### *Observation*

Triple Sugar Iron agar medium contains 3 sugars- Glucose, Sucrose and Lactose. Yellow slant and yellow butt developed for colony A indicated that all sugars fermented. Red slant and yellow butt for colony B revealed that only glucose was fermented, the blackening of this media revealed H<sub>2</sub>S production. Indole test was found to be positive in colony A which was shown by the development of pink ring on the top of the medium and negative reaction indicated in colony B could be inferred as the inability of the test organism to break down amino acid tryptophan. The acidic end product formed by glucose fermentation was detected by Methyl Red test, both colonies developed bright red colouration of the medium.

A streak of growth and blue coloration of Simmons Citrate medium by colony B clearly indicated the ability of the organism to utilize citrate as the sole source of carbon and ammonium salt as sole source of nitrogen. Colony A showed negative results for Urease and Phenyl Pyruvic Acid medium whereas colony B developed purple-pink and green colour respectively indicating positive results. Both the gram negative bacilli were negative to Voges-Proskauer test. Biochemical test results confirmed that the isolated bacterial colonies were as follows:

**Colony A** → Gram Negative, Motile, Lactose fermenting, IMViC (+ + - -)  
as *Escherichia coli*

**Colony B** → Gram Negative, Motile, Non-Lactose fermenting, IMViC (- + - +)  
as *Proteus vulgaris*

## **B - STUDIES ON THE POST EMBRYONIC DEVELOPMENT OF LOHMANNIID MITES**

Lohmanniid mites constitute a major proportion of oribatid fauna of soil ecosystem. Macrophytophagy exhibited by the Lohmanniid mites accounts for their crucial role in biodegradation. Variable feeding potential among immature and adults of different species of Lohmanniid mites was evident during breeding biological studies. Leaf litters of *Artocarpus heterophyllus*, *Mangifera indica*, *Psidium guajava*, *Tectona grandis* etc were provided as food items in the laboratory for biological studies. Skeletonization of leaf litter and subsequent accumulation of heaps of faecal pellets in the culture cells indicated their amicable role in litter decomposition, nutrient cycling and enhancement of soil fertility and productivity. The prolonged life cycle of Lohmanniid mites necessitates its representatives to adopt parthenogenetic mode of reproduction for the maintenance of population density.

### **1) Postembryonic Development of *Annectacarus phyllotrichous* sp.nov.**

**(Plate:28 , Fig: 1-8 )**

#### **Oviposition**

Adult females initiated egg laying after a short period of emergence which ranged between 18-20 days. Eggs were oval shaped, white in colour and laid solitarily on the substratum. Oviposition was initiated on 18<sup>th</sup> day, eggs were laid for a time interval of 7-10 days. A single female was found to lay 15-20 eggs during its life time of about 145-180 days.

### **Incubation and Hatching**

The period of incubation was found to range from 10-14 days. On progressive days of incubation, the eggs were found to lose their elasticity and the outer surface became more or less hardened. Towards the end of incubation, the egg shell showed areas of weakness, especially along the medio-lateral margins which later got developed into a slit. The slit got widened subsequently and got extended in both anterior and posterior directions. The emerging larva protruded its anterior pair of legs through the slit, followed by the subsequent extrusion of its prodorsum and notogaster. On completion of hatching process, the egg case was left behind as a fragile and transparent structure. The process of hatching was found completed within 35-45 minutes.

### **Duration of Life Stages**

The newly hatched hexapod larva was white, translucent and sluggish. After a hardening period of 1-2 hours, the larva showed regular movements in the culture cell and started feeding. After a voracious feeding period of 10-12 days, the larva became sluggish, assumed a swollen appearance and it ceased feeding activity and entered in to an inactive phase by getting attached to the substratum. This inactive period was recorded as the 1<sup>st</sup> quiescent phase and it lasted for 6-7 days.

At the end of the 1<sup>st</sup> quiescent phase, the postero-lateral regions of notogaster developed weakened areas which subsequently transformed in to slits, through which the last pair of legs of the moulting nymph protruded out. Simultaneous with the wriggling movements of the moulting nymph, the slits got widened along the lateral margins up to the dorsosejugal suture and the nymph slowly moved out of the exuviae by the gradual backward movement of the body. The entire process of moulting required 1-2 hours for completion,

### *Post Embryonic Development*

irrespective of instar variations and the process was similar in all the subsequent nymphal stages.

The newly emerged protonymph was easily distinguishable from the larva by the possession of 4 pairs of legs and slightly larger size of the body. The body of protonymph was light golden yellow in colour and after a hardening period of 30 minutes, it showed active feeding on the leaf litter offered in the culture cell. The protonymphal period lasted for 12-15 days and then it entered in to an inactive period (2<sup>nd</sup> quiescent phase) for 6-7 days. On subsequent moulting, the deutonymph got emerged and which was characterized by a light brownish tinge of the body. Deutonymph actively fed on the leaf litter for about 14-16 days, and then passed through the 3<sup>rd</sup> quiescent phase, which lasted for 7 days. The 3<sup>rd</sup> quiescent stage moulted in to the tritonymph, which was almost similar to the adult but smaller in size and paler in colouration. The tritonymph showed active feeding on leaf litter for 11-13 days and entered the 4<sup>th</sup> quiescent phase, which lasted for 7 days. After the fourth and final moulting, the adult mite got emerged. The newly emerged adult was light brown in colour and its colour gradually got deepened within 2-4 days. The newly emerged adults initiated oviposition after 18-20 days of emergence. Thus the total duration of development of F1 generation of *A. phyllotrichou* sp. nov. was found to complete within 89-95 days under specific temperature-humidity conditions of  $30 \pm 1^{\circ}\text{C}$  and 70-75% .

**TABLE :17**

**Duration of Development (In days) of**

**Life stages of *Annectacarus phyllotrichous* sp. nov at 30 ±1°C & 75% RH**

Sl. No.	Egg	Larva	I Quiescence	Proto-nymph	II Quiescence	Deuto-nymph	III Quiescence	Trito-nymph	IV Quiescence	Total
1	13	10	7	13	7	16	7	11	7	91
2	11	10	7	15	7	14	7	13	7	91
3	11	12	7	14	7	14	7	13	7	92
4	11	12	6	14	7	16	7	15	7	95
5	14	10	6	12	6	16	7	12	7	90
6	13	10	7	13	7	14	7	13	7	91
7	13	10	7	12	7	14	7	12	7	89
8	14	11	7	13	7	16	7	12	7	94
9	10	12	6	14	7	14	7	13	7	90
10	14	10	7	12	7	14	7	13	7	91
Range	10-14	10-12	6-7	12-15	6-7	14-16	7	11-15	7	89-95

**MORPHOLOGICAL DESCRIPTION OF LIFE STAGES OF**

*Annectacarus phyllotrichous* sp.nov.

**(PLATES: 29,30)**

**Egg (Fig : 1)**

Measurements: Length : 143-145  $\mu\text{m}$

Width : 102-104  $\mu\text{m}$

Freshly laid eggs were oval, white coloured, smooth and shiny in appearance.

**Larva (Fig : 1-2 )**

Measurements: Length : 208-220  $\mu\text{m}$

Width : 113-122  $\mu\text{m}$

The newly emerged larva was distinguished by its hexapod nature. The body was white coloured and transparent and the larval body gradually became cream coloured towards the end of the active period.

**Dorsal Region:**

**Prodorsum**

Prodorsum broad at base and produced anteriorly into a rounded rostrum. Lamella represented by a weak ridge, which possesses a median convex projection, just above the seta *exa*. All prodorsal setae weakly barbed and with pointed tip. Seta *ro* inserted far below the rostral apex. Bothridium (*bo*) bell shaped. Sensillus (*ss*) well developed with 9-10 branches of varying length on one side. Prodorsal integument finely punctate.

## **Notogaster**

Notogaster oval with a broad anterior border. Ten pairs of notogastral setae present, Setae  $c_1$ ,  $d_1$ ,  $e_1$ , and  $f_1$  thin and shorter than other notogastral setae. Seta  $h_1$  thick and slightly longer than  $c_1$ ,  $d_1$ ,  $e_1$ , and  $f_1$ .

## **Ventral region**

Infracapitulum bears 2 pairs of setae,  $a$  and  $h$ , both smooth. Epimeralsetal formula 2-1-2, all setae thin and smooth, except  $1b$  which is barbed, seta  $3b$  longer than  $2a$  and  $3a$ . Genital area not developed. Ano-adanal plate with 2 pairs of smooth adanal setae. Lyrifissures  $ia$  and  $ip$  located ventrally. Seta  $ps_2$  inserted on the mediolateral margins of the ano-adanal plate.

## **Legs**

3 pairs of legs present, all monodactylous

## **Protonymph (Fig : 3-4 )**

Measurements: Length : 239-273  $\mu\text{m}$

Width : 132-136  $\mu\text{m}$

The protonymph emerged after moulting of the I<sup>st</sup> quiescent stage appeared creamy white in colour which gradually got transformed into golden yellow. Protonymph could be easily distinguished from the larva by the possession of 4 pairs of legs and bigger size.

## **Dorsal Region**

### **Prodorsum**

Prodorsum almost semicircular anteriorly and broader posteriorly. Lamellae well developed with a characteristic conical projection, below seta

*le*. Rostral seta, *ro* extends beyond the rostral apex. All prodorsal setae barbed. Sensillus bears 10-12 barbs on one side. A poorly developed ridge present at interlamellar region, between the setae *in*.

### **Notogaster**

Notogaster broader anteriorly and its posterior end almost oval. Twelve pairs of notogastral setae present, of which setae *c*<sub>1</sub>, *d*<sub>1</sub>, *e*<sub>1</sub> and *f*<sub>1</sub> short and thin. Marginal setae *c*<sub>3</sub>, *d*<sub>3</sub>, *e*<sub>3</sub>, *f*<sub>2</sub> longer than *c*<sub>2</sub>, *d*<sub>2</sub> and *e*<sub>2</sub>. Seta *h*<sub>1</sub> stouter than *c*<sub>1</sub>, *d*<sub>1</sub>, *e*<sub>1</sub> and *f*<sub>1</sub>. On the ventral side, notogaster bears fine punctations, near ano-adanal plates.

### **Ventral region**

Infracapitulum bears 3 pairs of setae, *a*, *h*, and *m*, all smooth. Epimeral setal formula 3-2-2-1. Setae *lb* barbed and *lc* smooth. Genital plates developed with one pair of smooth setae. Ano-adanal plate bears one pair of anal and 3 pairs of adanal setae.

### **Legs**

Four pairs of legs, all monodactylous.

### **Deutonymph (Fig : 1-2 )**

Measurements: Length : 450 – 465 μm

Width : 218 - 242 μm

The deutonymph which emerged after the moulting of the 2<sup>nd</sup> quiescent instar was yellowish in colour initially and later assumed a brown tinge. The size of its body was comparatively larger than that of the protonymph.

## **Dorsal Region**

### **Prodorsum**

Prodorsum extended anteriorly into a slightly rounded rostrum. Lamellae more prominent. All prodorsal setae longer than those of the previous instar. Sensillus bears 10-12 barbs. The prodorsal band appeared more prominent.

### **Notogaster**

Notogaster broader anteriorly and oval posteriorly, bearing 14 pairs of setae. Notogaster without any neotrichial setae. Setae  $c_1$ ,  $d_1$ ,  $e_1$  comparatively smaller than the other setae. Notogastral integument finely punctate posteriorly.

## **Ventral region**

Infracapitulum bears 4 pairs of setae,  $a$ ,  $h$ ,  $m_1$  and  $m_2$ , all setae smooth. Epimeral setal formula 5-3-2-2. Seta  $1b$  barbed while all others smooth. Genital plates bear 6 pairs of setae. Ano-adanal plate bears 4 pairs of adanal and 2 pairs of anal setae, all smooth. Anal setae smaller than the adanal setae.

## **Legs**

Legs 4 pairs, all monodactylous.

## **Tritonymph (Fig : 3-4 )**

Measurements: Length : 560 – 568  $\mu\text{m}$

Width : 319 - 328  $\mu\text{m}$

## **Dorsal Region**

### **Prodorsum**

Prodorsum with wavy margin and with a broad base and conical tip. Lamellar ridge prominent with a median projection above seta *exa*. Rostral seta (*ro*) inserted well below the rostral tip. Bothridium and sensillus as in previous stages. Prodorsal integument finely punctate. All prodorsal setae broader at base and pointed towards the tip. Prodorsal band prominent.

### **Notogaster**

Notogaster elongated and with a more or less rounded posterior margin. Dorsosejugal suture well demarcated. All notogastral setae smooth, broad at base and pointed towards the tip. Setae *c*<sub>1</sub>, *d*<sub>1</sub>, *e*<sub>1</sub> comparatively smaller than the other setae. Marginal setae *c*<sub>3</sub>, *d*<sub>3</sub>, *e*<sub>3</sub>, *f*<sub>2</sub> longer than the submarginal setae *c*<sub>2</sub> and *d*<sub>2</sub>. Pygidial neotrichy absent. Notogaster bears fine punctations.

## **Ventral region**

Infracapitulum bears 4 pairs of setae, as in the previous stages. Epimeral setal formula 5-3-3-3. Setae *1b* barbed and *1d* smaller than the others. Setae *3c* and *4c* added newly. Eight pairs of genital setae present, 4 pairs along the outer margin and 4 pairs along the inner margin of the genital plates. Pre-anal plate narrow. Anal and adanal plates separated by a distinct ano- adanal suture. Two pairs of anal and 4 pairs of adanal setae present. Lyrifissures *ia* and *ip* seen at the posterior region of the ventral plate.

## **Legs**

Four pairs of monodactylous legs present.

**TABLE : 18****DIAGNOSTIC FEATURES OF LIFE STAGES OF*****Annectacarus phyllotrichus* sp.nov**

Sl. No	Stages	Notogastral setae	Infracapitular setae	Epimeral setae	Genital setae	Adanal setae	Anal setae	Length	Width
1	Larva	10 pairs	a,h	2-1-2	-	2 pairs	-	216µm	118µm
2	Protonymph	12 pairs	a ,h ,m	3-2-2-1	1 pair	3 pairs	1 pair	239µm	132µm
3	Deutonymph	14 pairs	a , h, m <sub>1</sub> ,m <sub>2</sub>	5-3-2-2	6 pairs	4 pairs	2 pairs	462µm	238µm
4	Tritonymph	14 pairs	a , h, m <sub>1</sub> ,m <sub>2</sub>	5-3-3-3	8 pairs	4 pairs	2 pairs	563µm	322µm
5	Adult	14 pairs	a , h, m <sub>1</sub> ,m <sub>2</sub>	5-3-3-3	10 pairs	4 pairs	2 pairs	665µm	375µm

**2) Postembryonic Development of *Haplacarus foveolatus* sp. nov.****( Plate:31, Fig : 1-8 )****Oviposition**

Newly emerged adult females initiated egg laying from the 15<sup>th</sup>-17<sup>th</sup> day onwards after their emergence. Eggs appeared as oval, transparent, shiny and white in colour. Around 20-25 eggs were laid by females within a time interval of 2-3 days. Eggs were laid singly, in a scattered manner over the food materials, at the culture base or among the faecal pellets. Females after a period of feeding for 18-20 days again initiated egg laying and continuously deposited 10-15 eggs with 2-3 days of interval in between. Next set of 5-10 eggs were laid with the same time interval of 2-3 days after 15-20 days of active feeding. Last period of egg laying was found to be between 145-170 days of the adult female. 1-5 eggs were deposited on alternative days during this period. Adults remained active up to 278-310 days. The number of eggs laid by a single female extended up to 65-70 on an average. During the egg laying period, the no. of eggs deposited was found to be decreasing from 20-25 > 10-15 > 5-10 > 1-5.

**Incubation and Hatching**

Incubation period in *H. foveolatus* was found to range from 27-30 days when the developmental studies were performed under the controlled temperature-humidity conditions. Eggs after a week of oviposition appeared opaque and dark white in colour. On 15-20 days of incubation, anterior narrow end of the egg became transparent and which developed weakened area. Splitting of the egg shell occurred along the weakened area, resulting in the hatching of the larva. During hatching, the emergence of the larva was observed through the split developed at the anterior narrow pole of the egg, through which the first pair of its legs were found protruding. Frequent movements of the legs of the emerging larva assisted in the widening of slit in mediolateral directions on either side, leading to the escape of the larval body from the egg case, and the latter was found left behind as an empty structure. Hatching was found to complete within 15-20 minutes.

**TABLE : 19**

**Duration of Development (In days) of  
Life stages of *Haplacarus foveolatus* sp. nov at 30 ±1°C & 75% RH**

Sl.no	Egg	Larva	I Quiescence	Proto-nymph	II Quiescence	Deuto-nymph	III Quiescence	Trito-nymph	IV Quiescence	Total
1	27	17	8	18	10	23	10	32	12	157
2	28	18	8	19	10	24	10	30	12	159
3	27	18	8	18	10	24	10	31	12	158
4	28	20	8	18	10	26	10	34	12	166
5	28	17	8	19	10	24	10	32	12	160
6	27	18	8	18	10	23	10	32	12	158
7	30	18	8	18	10	24	10	31	12	161
8	27	17	8	19	10	23	10	32	12	158
9	28	17	8	18	10	24	10	35	12	162
10	27	18	8	18	10	25	10	32	12	160
Range	27-30	17-20	8	18-19	10	23-26	10	30-35	12	157-166

### **Duration of Life Stages**

The hexapod larva was creamy white in colour and remained inactive for 5-10 minutes, which was noted as the hardening period. After this, the larva started slow movements which progressed gradually. The larva initiated feeding only after 1-2 hours of hatching. After an active feeding period of 17-20 days, the larva became sluggish, with retarded feeding activity and moved away from the food items offered in the culture cell. Its body became swollen and it ceased feeding completely and remained motionless at a suitable spot in the culture cell. This inactive period was recorded as the 1<sup>st</sup> quiescent phase and it lasted for 8 days. The culmination of this quiescent phase was marked by the moulting process, which was found initiated by the development of areas of weakness and subsequent slit formation on the larval cuticle, along the postero-lateral margins of the notogaster. The slits got widened along the lateral margins in both directions, as a result of the pressure exerted by the moulting nymph coupled with its vigorous leg movements. The protonymph slowly came out of the egg case, through the gradual backward movement of the body. The moulting skin was found discarded and it was intact anteriorly. Moulting was completed within 1-2 hours.

The protonymph could be readily distinguished from the larva by its bigger size and possession of 4 pairs of legs. It initiated feeding on the leaf litter offered in the culture cell and this feeding period prolonged for 18-19 days. This was followed by the 2<sup>nd</sup> quiescent phase, which lasted for 10 days and through subsequent moulting, the light yellow coloured deutonymph emerged. The voracious feeding period of the deutonymph continued for 23-26 days and then it passed through the 3<sup>rd</sup> quiescent phase of 10 days duration.

At the end of this quiescence, moulting occurred leading to the emergence of the tritonymph, which was characterized by a golden yellow

colouration coupled with a brownish tinge. Tritonymph was relatively larger in size than the earlier instars and its active period was of the longest duration, extending up to 30-35 days. After the active feeding period, the tritonymph entered into the 4<sup>th</sup> quiescent phase for 12 days, and moulted subsequently into the adult stage. The newly moulted adult was light brown in colour initially and its colour got deepened progressively, within 2-5 days. The total duration of life cycle of *H.foveolatus* sp.nov. was found completed within 157-162 days at a temperature-humidity combination of 30 ±1°C and 70-75%. The duration of F1 generation was found to be about 278-310 days.

**Morphological Description of Life stages of *Haplacarus foveolatus* sp.nov.**

**( Plates:32&33)**

**Egg**

Measurements: Length : 181-184 µm

Width : 112-115 µm

Eggs were oval, shiny and white in colour. The surface of egg appeared smooth and without any ornamentation or sculptures.

**Larva (fig: 1-2)**

Measurements: Length : 240-252 µm

Width : 128-136 µm

The body of newly emerged larva appeared creamy white in colour. It was characterized by the possession of 3 pairs of legs, a unique feature of all oribatid larvae.

**Dorsal Region :**

**Prodorsum**

Prodorsum almost triangular in outline with a broad base and rounded anterior rostrum. Lamella well demarcated with a median projection just above the seta *exa*. All prodorsal setae serrated and swollen at the base and pointed at the tip. Seta *ro* inserted just below the rostral apex. Bothridia(*bo*) cup shaped, sensillus possesses 8-12 barbs of varying length on one side. Prodorsum ornamented with fine punctations.

**Notogaster**

Notogaster oval in appearance with a broad anterior and a narrow posterior border. Three notogastral bands present, *s*<sub>1</sub>, *s*<sub>2</sub>, and *s*<sub>3</sub> complete and *s*<sub>4</sub> and *s*<sub>5</sub> wavy and incomplete medially. Ten pairs of notogastral setae present, all sparsely serrated at the base. Marginal setae *c*<sub>3</sub> and *d*<sub>3</sub> longer than the median setae (*c*<sub>1</sub>, *d*<sub>1</sub> and *e*<sub>1</sub>).

**Ventral region**

Infracapitulum bears 3 pairs of setae, *a*, *h* and *m*. Epimeral setal formula 3-2-1, all thin and smooth. Seta *2b* longer than seta *2a*. Genital area not developed. Adanal plate bears 2 pairs of adanal setae. Lyrifissures *ia* and *ip* located ventrally.

**Legs**

Legs 3 pairs, all monodactylous.

**Protonymph (fig :3-4)**

Measurements: Length : 290 – 298 μm

Width : 145 - 149 μm

The body size of protonymph slightly larger than that of the larva and it possesses 4 pairs of legs. Freshly moulted protonymph appeared cream coloured and gradually it developed light yellow colouration.

### **Dorsal Region:**

#### **Prodorsum**

Prodorsum elongated with a blunt rostral apex. Lamellae well developed than that of the larva, with a median convex projection. Setae *ro* and *exa* longer than the respective length of seta *le* and *exp*. Seta *in* inserted just below the bothridialcup. Sensillus with 10-12 barbs on one side. Fine punctuation present near the dorsosejugal suture.

#### **Notogaster**

Notogaster longer than wider, with 12 pairs of setae arranged sequentially. Setae *ps<sub>1</sub>* and *ps<sub>2</sub>* appeared anew and *ps<sub>2</sub>* inserted ventrally. Five notogastral bands present, all complete, wavy incomplete posterior bands seen developing at the lateral region. Notogaster ornamented with punctations and spicules.

### **Ventral region**

Infracapitular setae *a, h* and *m* as in the larval stage. Epimeral plates distinct, possessing a setal formula of 3-2-2-1. Genital plates developed and carry one pair of smooth setae. Ano-adanal plates not separated, bearing one pair of small anal setae and 3 pairs of long adanal setae .

### **Legs**

Legs 4 pairs, all monodactylous.

**Deutonymph (fig: 1-2)**

Measurements: Length : 402 – 410  $\mu\text{m}$

Width : 265 - 271  $\mu\text{m}$

Deutonymph comparatively larger in size than the previous stage and light brown in colour.

**Dorsal region**

**Prodorsum**

Prodorsum more or less triangular in shape with a rounded rostral apex and broad posterior region. Lamellar ridge prominent. All prodorsal setae slightly longer than those of the earlier stage. Sensillus same as that of the earlier stage.

**Notogaster**

Notogaster enlarged considerably with 16 pairs of setae. Notogaster possesses 6 complete bands, prominent at the posterior end. Lyrifissureia clearly visible.

**Ventral region**

A single pair of infracapitular setae added anew, thereby accounting to a total of 4 pairs of setae ( $a_1$ ,  $h_1$ ,  $m_1$  and  $m_2$ ), all smooth and foliate.. Epimeral setal formula 3-2-3-3. Setae  $1a$  and  $3c$  smaller than the others. Genital region well developed with 6 pairs of smooth setae. Ano-adanal plates well developed, carrying 5 setae arranged in the 1+4 pattern. Ventral integument ornamented with fine punctations and foveoles.

## **Legs**

4 pairs of legs, all monodactylous.

## **Tritonymph (fig : 3-4)**

Measurements: Length : 602 – 608  $\mu\text{m}$

Width : 379 - 384  $\mu\text{m}$

Tritonymph represented the largest instar among the immature stages and characterized by light brown colour.

## **Dorsal region**

### **Prodorsum**

Prodorsum roughly triangular with a broad base and a conical apex. All prodorsal setae broad at base and pointed towards the tip. Bothridium and sensillus as in the preceding stages. Integument of prodorsum bears fine punctuation.

### **Notogaster**

Length and width of notogaster increased than the previous instar. Eight pairs of complete notogastral bands developed. Notogastral setae same as those of the previous stages. Pygidial neotrichy absent. Notogastral integument finely punctate.

## **Ventral region**

Infracapitular setae same as those of earlier stage. Epimeral setal formula 3-2-3-4, seta *4c* appeared anew. Genital plates with 10 pairs of setae. Pre-anal plate narrow. Anal and adanal plates fused, bearing 2 pairs of anal and 4 pairs of adanal setae. Lyrifissures (*ia, ip*) present ventrally. Ventral

integument lightly punctate with possesses characteristic wavy pattern, along postero-lateral margins.

**Legs**

Legs 4 pairs, all monodactylous.

**TABLE : 20**

**DIAGNOSTIC FEATURES OF LIFE STAGES OF  
*Haplacarus foveolatus* sp.nov**

Sl. No	Stages	Notogastral setae	Infracapitular setae	Epimeral setae	Genital setae	Adanal setae	Anal setae	Length	Width
1	Larva	10 pairs	a,h,m	3-2-1	-	2 pairs	-	240µm	130µm
2	Protonymph	12 pairs	a ,h ,m	3-2-2-1	1 pair	3 pairs	1 pair	292µm	146µm
3	Deutonymph	16 pairs	a , h, m <sub>1</sub> ,m <sub>2</sub>	3-2-3-3	6 pairs	4 pairs	1 pair	406µm	268µm
4	Tritonymph	16 pairs	a , h, m <sub>1</sub> ,m <sub>2</sub>	3-2-3-4	8 pairs	4 pairs	1 pair	605µm	380µm
5	Adult	16 pairs	a , h, m <sub>1</sub> ,m <sub>2</sub>	3-2-3-4	10 pairs	4 pairs	1 pair	725µm	430µm

**3) Postembryonic Development of *Papillacarus heterosetosus* sp. nov.**

**( Plate: 34, Fig : 1-8 )**

**Oviposition**

Newly emerged adults actively devoured the food materials offered in the laboratory and initiated oviposition within 21-23 days. The eggs laid were oval, white coloured and were laid singly at the base of the culture cells or among the food item. Oviposition was initiated from 23<sup>rd</sup> -25<sup>th</sup> day after emergence. Eggs were laid at an interval of 5-8 days. Total duration of life cycle ranged between 164-215 days. A single females was found to lay 36-45 eggs.

**Incubation and Hatching**

The duration of incubation in *P. heterosetosus* could be recorded as 21-24 days, during the current study. With the advancement of incubation, areas of weakness were developed on the egg surface, at the anterior and medio-lateral regions leading to the formation of slits, as described earlier, to facilitate the hatching of larva. The process of hatching was noted as 1-1½ hours. The larva emerged through the posterior part of the notogaster by the subsequent movement of legs.

**TABLE : 21****Duration of Development (In days) of  
Life stages of *Papillacarus heterosetosus* sp. nov. at 30±1°C & 75% RH**

Sl.No	Egg	Larva	I Quie- scence	Proto- nymph	II Quie- scence	Deuto- nymph	III Quie- scence	Trito- nymph	IV Quie- scence	Total
1	24	10	7	12	7	18	7	11	7	103
2	23	10	7	13	7	18	7	11	7	104
3	24	10	7	12	7	19	7	11	7	104
4	24	10	7	12	7	23	7	12	7	109
5	24	11	7	13	7	19	7	12	8	108
6	23	13	7	14	7	24	7	13	8	116
7	24	11	7	12	7	24	7	11	7	110
8	23	11	7	12	7	19	7	12	7	105
9	24	10	7	13	7	23	7	13	7	111
10	21	11	7	14	7	18	7	11	7	103
Range	21- 24	10-13	7	12-14	7	18-24	7	11-13	7-8	103- 116

**Duration of Life Stages**

The newly emerged larva was sluggish and transparent. It became active after a hardening period of 10-15 minutes. Larva slowly started feeding after 1-2 hours of hatching. Larval period extended up to 10-13 days, followed by an inactive period (1<sup>st</sup> quiescent phase) of 7 days duration. Protonymph emerged was a voracious feeder for about 12-14 days. The duration of 2<sup>nd</sup> quiescent phase was found to extend for one week. The deutonymph was golden yellow in colour and found wandering on and around the food materials and feeding on the leaf litter, for a period of 18-24 days. After the 3<sup>rd</sup> quiescent phase of 7 days, the tritonymph emerged and its active feeding period lasted for 11-13 days. After an inactive period of 7-8 days (4<sup>th</sup> quiescent phase), emergence of the adult was noted. The newly emerged adult was light brown in colour, and which gradually changed to dark brown, within 4-5 days. The adult females initiated oviposition within 21-24 days after their emergence and thus the total duration of F<sub>1</sub> and F<sub>2</sub> generations in *P.heterosetosus* sp. nov. could be recorded to range from 123-164 days, at 30±1°C and 70-75% RH.

**MORPHOLOGICAL DESCRIPTION OF LIFE STAGES OF**

***Papillacarus heterosetosus* sp.nov**

**(Plates: 35 & 36)**

**Egg**

Measurements: Length : 182-186  $\mu\text{m}$

Width : 106-110  $\mu\text{m}$

Freshly deposited eggs appeared oval, white and transparent with a smooth texture and became turgid with the advancement of incubation.

**Larva (Fig : 1-2 )**

Measurements: Length : 196 - 200  $\mu\text{m}$

Width : 110 - 114  $\mu\text{m}$

The newly emerged larva appeared creamy white in colour and lethargic in habit. It gradually resumed active movements and feeding, and became light yellow in colour.

**Dorsal region**

**Prodorsum**

Prodorsum roughly conical. All prodorsal setae barbed at base and smooth towards the tip. Lamella represented by a weak ridge with a median convex projection. Seta *ro* inserted far below the rostral tip. Sensillus with 14-16 branches on one side and 3-4 small barbs on the other side. Prodorsal band present in between setae *in*.

### **Notogaster**

Notogaster elongated with wavy margins. Thirteen pairs of setae present on notogaster. Setae  $c_1, d_1$  and  $e_1$  thin, short and smooth while all other setae barbed and arranged marginally. Wavy rudiments of notogastral bands noticed in freshly mounted specimens.

### **Ventral region**

Infracapitulum bears 2 pairs of smooth setae,  $a$  and  $h$ . Epimeral setal formula 3-2-2, all thin and smooth. Seta  $1b$  longer than all other epimeral setae. Genital area lacking. Anal plates not developed, adanal plates with 2 pairs of smooth, setae. Lyrifissures  $ia$  and  $ip$  located ventrally.

### **Legs**

Legs 3 pairs, all monodactylous.

### **Protonymph (fig : 3-4)**

Mesurments: Length : 234  $\mu\text{m}$ -239  $\mu\text{m}$

Width : 118  $\mu\text{m}$ -122  $\mu\text{m}$

Protonymph golden yellow in colour and possesses 4 pairs of legs.

### **Dorsal region**

#### **Prodorsum**

Prodorsum elongate, converging anteriorly into a blunt rostrum. Prodorsal setae longer than those of previous stage. Prodorsal band more distinct. Lamellae clearly demarcated.

### **Notogaster**

Notogaster enlarged and bears 16 pairs of setae. Setae  $c_1, d_1$  and  $e_1$  short and thicker than the other setae. Posterior end of notogaster bears short, barbed neotrichial setae. Rudiments of notogastral bands present, which merge with notogastral punctation.

### **Ventral region**

Infracapitulum bears 4 pairs of setae,  $a, h, m_1$  and  $m_2$ . Addition of setae observed on the epimeral plates, resulting in a setal formula of 4-3-3-1. Genital plates developed, carrying one pair of smooth setae. Anal plates not separated, adanal plates with 4 pairs of adanal setae.

### **Legs**

Legs 4 pairs, all monodactylous.

### **Deutonymph (fig :1-2)**

Measurements : Length : 262 $\mu$ m-267 $\mu$ m

Width : 137 $\mu$ m- 141 $\mu$ m

Body size of deutonymph larger than that of the protonymph and its colour was golden yellow.

### **Dorsal region**

#### **Prodorsum**

Prodorsum elongate and ends anteriorly into a round and blunt rostrum. All prodorsal setae longer than those of the previous stage. Sensillus more elongated and bears 16-17 barbs on one side and 5-7 barbs on the other side. Prodorsal band prominent, and lies between setae *in*.

### **Notogaster**

Notogaster increased in size, but the number of setae same as that of the previous stage. Pygidial neotrichy prominent with short and barbed setae. Three notogastral bands present, one complete and 2 incomplete in nature. Fine punctations seen at posterior end of notogaster.

### **Ventral region**

Infracapitulum possesses 4 barbed setae (*a*, *h*, *m*<sub>1</sub> and *m*<sub>2</sub>). Epimeral setation increased to 6-3-3-2. Seta *1b* longer than all other setae and barbed. Genital plates carry 6 pairs of setae. Pre-anal plate narrow. Anodanal plates separated. One pair of adanal and 2 pairs of anal setae appeared anew. Ventral integument ornamented with fine punctations.

### **Legs**

Legs 4 pairs, all monodactylous.

### **Tritonymph (fig :3-4)**

Mesurements : Length : 314µm-320µm

Width : 192 µm-198µm

Tritonymph was the largest among the immature stages and was easily distinguished by its light brown colour.

### **Dorsal region**

#### **Prodorsum**

Prodorsum broader than that of the deutonymph and ends in a blunt rostrum, apex of which wavy in outline. All prodorsal setae increased in

length. Seta *ro* inserted just below the rostral tip. Prodorsal band well developed. Bothridium and sensillus as in the preceding stage.

### **Notogaster**

Notogaster showed an increase in size. Dorsosejugal suture more distinct. Eighteen pairs of notogastral setae located, of which 2 pairs added anew. Four bands present on notogaster, 2 complete and 2 incomplete, which seem to merge with the notogastral ornamentation. Pygidial neotrichy present.

### **Ventral region**

The number of infracapitular setae increased with the addition of seta *m*<sub>3</sub>. Seta *a* the smallest and *h* the longest. Epimeral setal formula 7-3-3-4. Setae *1b, 1e, 1f, 2b, 2c, 3b* and *3c* barbed, and others smooth. Genital plates divided by a transverse suture. Ten pairs of genital setae located, 2 pairs added anew. Anal and adanal plates separated, bearing 2 pairs of anal and 4 pairs of adanal setae. Ventral integument punctate.

### **Legs**

Legs 4 pairs, all monodactylous.

**TABLE : 22**

### **-DIAGNOSTIC FEATURES OF LIFE STAGES OF**

#### ***Papillacarus heterosetosus* sp.nov**

Sl. No	Stages	Notogastral setae	Infracapitular Setae	Epimeral setae	Genital setae	Adanal setae	Anal setae	Length	Width
1	Larva	13 pairs	a, h	3-2-2	-	2 pairs	-	198µm	112µm
2	Protonymph	16 pairs	a, h, m <sub>1</sub> , m <sub>2</sub>	4-3-3-1	1 pair	3 pairs	-	236µm	121µm
3	Deutonymph	16 pairs	a, h, m <sub>1</sub> , m <sub>2</sub>	6-3-3-2	6 pairs	4 pairs	2 pairs	264µm	138µm
4	Tritonymph	18 pairs	a, h, m <sub>1</sub> , m <sub>2</sub> , m <sub>3</sub>	7-3-3-4	8 pairs	4 pairs	2 pairs	316µm	192µm
5	Adult	18 pairs	a, h, m <sub>1</sub> , m <sub>2</sub> , m <sub>3</sub>	7-3-3-4	10 pairs	4 pairs	2 pairs	396µm	267µm

Soil is an unique ecosystem that supports extremely rich and highly diverse biological communities by providing innumerable types of microhabitats, food resources and protection from predators. Oribatids are recognised as species rich group of soil mesofauna which play vital roles in the biodegradation process and subsequent cycling of nutrients, leading to the enrichment of soil health and productivity status. The family Lohmanniidae has been included under the category of Macropyline oribatids, based on the possession of a combination of specialised primitive features along with highly versatile pattern of dorsal setation and fused nature of ano-genital plates at the ventral region (Grandjean, 1950, 1954). Norton (2010) on examination of the morphological traits suggested that Lohmanniidae would form a clade within Hypochthoniidae of Enarthonota. Lohmanniidae has been recently listed under Enarthonota, one of the six major groups of oribatids, comprising twenty one genera, four subgenera, two hundred species and nine subspecies with tropical and subtropical distribution (Balogh and Balogh, 1992, Subias, 2004, 2012, 2015).

Lohmanniid mites have been proved to play pivotal roles in soil humification process, promoting soil fertility and agricultural productivity (Haq, 1992, 1994, 2007). Considering the beneficial role extended by these mites to mankind as promoters of soil fertility, the present work was undertaken to summon up the details on their distribution pattern, species diversity and richness, feeding and breeding strategies and population dynamics in relation to physio-chemical parameters in different ecosystems of Malabar. The study was carried out during the period of May 2010-April, 2013 at various vegetational sites distributed over 5 districts of Kerala, viz., Palakkad, Malappuram, Kozhikode, Kannur and Wayanad. Four different sites were recognised in each district with varied floristic pattern and soil profile,

which included undisturbed forest floors, secondary forests, grasslands, bamboo grooves, mangrove ecosystems, beach soils and agroecosystems.

Results of qualitative and quantitative assessment of lohmanniid mites in the soils of the selected study areas revealed the variation in distribution pattern, species diversity and richness depending upon soil topography, floral constituents and organic litter accumulation in the areas surveyed. The general survey results of the present study were in par with the reports of earlier investigators (Hartenstein, 1962, Ramani and Haq, 1991, Hansen *et al.*, 1998, Julie and Ramani, 2008), that species diversity and richness predominated in undisturbed forest floors. Detailed sampling conducted in the study areas enabled to record 15 species belonging to 7 genera of the family Lohmanniidae, of which 9 species were detected as new to science. The recovery of 9 new species out of the 15 species of lohmanniid mites recovered, is in fact quite encouraging, as it indicates the scope of further detailed studies on this group in future, by undertaking more elaborate surveys covering more geographical localities of Kerala, which would definitely enable recovery of several new taxa under the family.

Nelliampathy, a less explored part of Western Ghats was the major study area in the Palakkad district. The species rich areas identified were FA and DP, virgin forest floor and litter accumulated area, which showed the presence of 9 and 8 species respectively. Sites like CP and TP were agro ecosystems of coffee and tea plantations, notable with respect to the numerical abundance of *P. graminosus* sp. nov. The abundance of mites in the plantation area can be attributed to the availability of highly palatable food resource and micro climatic oddity prevailing in the area. The species diversity within the different sites in the study area showed a decrease in the order: FA > DP > TP = CP.

The BG site in the Malappuram district possessed all qualities of forest floor with plenty of organic litter and diverse flora and supported 11 species. The vegetation in the QR site was predominated by *A. heterophyllus*, *M.indica*, *A. occidentale* and *Acacia* sp., which revealed higher proportions of lohmanniid members. Agroecosystems like paddy fields, coconut plantations, vegetable gardens and isolated patches of woody vegetation supported low numerical strength of lohmanniid mites in the sites, which implies the impact of constant periodic human interference as suggested earlier (Wallwork, 1976; Badejo *et.al* 1999). The site SD was subjected to periodical removal of grass and was devoid of plant litter, remained rather dry during hot periods of the year. The site was of the lowest species rich area recognized in the study area, as it revealed the presence of a single species alone, under the genus *Cryptacarus*.

The study sites in the Kozhikkode district were notable for diverse topography of the soil. The CH site was characterised by beach soils with sparse vegetation, represented by shrubs like *Calotropis gigantea* apart from the accumulated drift wood in various stages of decay. The drift wood accumulated area was identified as an ideal site for the replenishment of populations of *H. notobandus* sp.nov., and it was found restricted to this site alone. The mangrove ecosystem with tenacious earth in the site KD was found inhabited by members of the genus *Javacarus*. Various challenging ecological situations like high salinity, fluctuating tidal currents, high water holding capacity and low aeration and porosity of the soil were the characteristic features of the site which would exert highly adverse impact on the population density of these mites in the mangrove soils (Julie and Ramani, 2007, Julie *et. al.*, 2009). A thick layer of organic litter in JK and NK sites harboured large proportions of lohmanniids.

In the Wyanad district, SP and TL were recognized during the present study as species rich virgin ecosystems which enabled to recover 9 species each. The remaining 2 sites of the study area, BA was a bamboo grove and GL was a grassland area, both showed low populations of lohmanniid mites represented by members of 2 genera viz., *Cryptacarus* and *Annectacarus*. The 4 different sites in the Kannur district disclosed equal distribution of lohmanniid species belonging to 4 genera, viz., *Annectacarus*, *Haplacarus*, *Javacarus* and *Papillacarus*. The site KT revealed 5 new species and from site TY, 4 new species were recorded. Oribatid fauna tend to flourish in forest floors and other litter accumulated areas (Hartenstein, 1962a, Ramani and Haq, 1991) was found true in site KT.

Among the 15 species collected, the genus *Haplacarus* showed wide distribution trend and *H.foveolatus* sp.nov. was ubiquitous species by recording its presence in 14 out of the 20 sites surveyed. The other members of the genus, *H. granulatus* and *H. porosus* were recovered from 13 different sites where as *H. keralensis* was collected from 12 sites. The genus *Papillacarus* achieved the second position and *P. reticulatus* sp.nov. showed distribution in 12 sites and *P. heterosetosus* sp.nov. in 10 sites. *P. graminosus* sp.nov. = *Vepracarus* showed numerical dominance in high altitude areas alone of the Palakkad and Wyanad districts ( Sites CP and TP in the former and SP and TL in the latter). The genus *Annectacarus* with 3 species ranked third in the distribution pattern with *A. phyllotrichous* sp. nov. in 9 sites, *A. wallworki* in 7 sites and *A. areolatus* sp. nov. in 6 sites. *M. degradatus* was found to occur in the litter and soil samples, in association with vegetation comprised of *X. xylocarpa* in sites like KY, FA and JK. The genus, *Heptacarus* was found restricted to CH and KD sites and *Cryptacarus* to BA and GL sites.

Oribatid mites among the soil mesofaunal elements are assigned as the most abundant and important decomposers in the soil ecosystem (Visser,1985,Norton and Behan Pelletier, 2009).While considering the phenomenal roles played by individual species of lohmanniid mites in the natural ecosystem, the feeding and breeding strategies and population dynamics of these mites were examined in detail during the study period.Lohmanniid mites, based on their feeding characteristics are categorised under the macrophytophagous feeding group (Luxton,1972; Haq, 1994; 1996,2005). Being the members of the same family, the species considered for studies on feeding biology possessed more or less similar food preferences, as observed during the present study, there by supporting the earlier findings (Denegri, 1993)The results of the laboratory food choice test performed in the present study ascertained the feeding preference of these mites to the leaf litter and woody components provided as food item.Cheliceral dimensions and possession of thumb like distal projection of the rutella (Kaneko,1988) of the various lohmanniid species recovered during the present study would further support the macrophytophagous feeding habit of these mites under field conditions also.

Feeding responses of 10 species of lohmanniid mites were found varied considerably. Leaf litter was found preferred by almost all the species, except *H.notobandus* sp.nov.High degree of feeding specificity was exhibited by *C.grandjeani* to *B.arundanaceae*, *M. degradatus* to *X.xylocarpa* and *P.graminosus* sp.nov. to *C.sinensis* and *C.arabica*.The degree of leaf litter decomposition and nutritional quality of the foliage exert influence on the feeding preference of oribatid mites and their role in leaf litter decomposition process and subsequent nutrient cycling in the soil profiles (Coleman *et.al* 2004; Badejo and Akinwole, 2006).Continuous feeding by juveniles and adults resulted in the formation of feeding holes on the fallen leaves, which

on progressive feeding would lead to complete devouring of the laminar area, leaving behind the veins, imparting a skeletonized appearance to decomposing leaf, which would further undergo complete decomposition in due course, leaving behind accumulations of faecal matter at the base of the culture cells.

The ability of lohmanniid mites to devour highly lignified and cellulose rich organic litter and its break down inside their digestive tract raise their status to be identified as potential biodegradators in the soil ecosystem. The presence of digestive enzymes like cellulase and cellobiase in mite extracts was already established apart from the the association of various bacterial symbionts in their gut (Bowman and Childs, 1982; Haq and Konikkara, 1988; Ramani and Haq, 2001; Erban and Hubert, 2012). In the present study, results of microbial screening and isolation of gut contents of *H.foveolatus* sp.nov. disclosed the presence of gram negative bacterial colonies on MacConkey and Blood agar plates. Biochemical characterisation of these colonies confirmed the close association of 2 bacterial strains viz., *Escherichia coli* and *Proteus vulgaris* within the gut of the species. *E.coli* and *P.vulgaris* are considered as the normal bowel flora of mammals and birds (Zinnah *et al.*, 2007), assisting in the digestion of food ingested by them. The recovery of these bacteria in the present study represents a novel and reliable finding on the bacterial community harbouring the gut of lohmanniid mites, and would further confirm their functional role in the decomposition process in the soil ecosystem.

The life cycle and breeding biology of oribatid mites in general are considered to be extraordinary among other arthropods (Gergőcs – Hufnagel, 2009). Some species follow sexual reproductive mode while some other species reproduce parthenogenetically. Parthenogenesis as the common mode of reproduction among primitive taxa of oribatid mites was stressed by earlier workers (Palmer and Norton, 1990. Norton, 1993) and around 10% of

oribatid species were reported to adopt obligate thelytokous parthenogenesis as their mode of reproduction (Lebrun and Van Straalen, 1995). Adoption of thelytoky as the sole mode of reproduction would be advantageous to these mites to compensate the comparatively low rate of fecundity (Norton, 1994). During the present work, 3 dominant species viz., *H.foveolatus* sp.nov., *P.heterosetosus* sp.nov. and *A.phyllotrichus* sp.nov, were considered for detailed postembryonic developmental studies. All the 3 species were found producing parthenogenetic lineages alone, and no instance of spermatophore deposition was noticed in any of the above species. The life cycles of all the 3 species were found quite prolonged and the duration of development of the above 3 species were in the range of 157-162, 123-165 and 89-95 days respectively. The prolonged developmental period significantly reduced the number of annual generations. Features like slow development, low reproductive output and prolonged period of life stages etc. possessed by these mites have been considered as advantageous for their effective utilization in indicating long-term disturbances (Gergócs – Hufnagel, 2009). Further, their low dispersion strategy (Lebrun and Van Straalen, 1995) represents another feature which enhances their utility in indication of environmental changes.

In lohmanniid mites, deposition of solitary eggs was generally observed, and incubation period ranged from 11-30 days. Eggs were laid at a time interval of about 7-10 days in *A.phyllotrichus* sp.nov., 5-8 days in *P.heterosetosus* sp.nov. and between 2-3 days in *H.foveolatus* sp.nov. Despite the several earlier incidence on the occurrence of prelarva in oribatid mites (Grandjean, 1956., Clement and Haq, 1984; Schuster, 1988), in the current study, none of the species studied showed the prelarval stage in their life cycle. Duration of life stages was found much prolonged in *H.foveolatus* sp.nov. when compared to that of *P.heterosetosus* sp.nov. and *A.phyllotrichous*

sp.nov. The larva was always a hexapod, and resembling other oribatid larvae were devoid of genital plates and suckers (Ramani and Haq, 1998., Alphonsa and Haq, 2006). Possession of a hexapod larval stage in the life history of mites is a clear indication of their intimate phylogenetic relationship with other arthropod cousins like insects (Wallwork, 1963).

The duration of quiescent phase was found remarkably same in all the 3 species studied and during moulting slit formation was observed at posterolateral regions. This seems to differ from the earlier findings on *L. ornatissimus* in which hatching was preceded by the formation of a small break at the anterolateral regions (Haq, 1978). The feeding efficacy of immatures in all the species was comparatively higher than that the adults as recorded earlier in other species of oribatids (Wallwork, 1967., Haq and Ramani, 1984). Voracious feeding by the nymphal stages suggests that the role of immatures in the turnover of nutrients would be relatively higher than that of the adults. During the course of development, a general increase in size and number of setae was observed in all the species studied. A progressive trend in setation was observed in the case of notogastral setae from larva to tritonymph and no evidences of setal regression were noticed in any of the species, during the present study, which is different from observations of earlier workers (Arlan and Wolley, 1970; Haq,1978)who noted regressive trend during the transformation from tritonymph to adult. Adults usually were more externally ornamented and heavily sclerotized than the tritonymph.

Soil biota exerts a great influence in nutrient cycling, either directly (comminution, litter decomposition) or indirectly (burrowing, casting and faecal deposition, changes in soil porosity and aeration) or both. Litter decomposition is determined by interaction between resource quality as well as consumers and decomposers, which are controlled by environmental conditions like climate and soil nutrients (Sheu, 2002, Sheu *et.al*, 2005, Hess,

2008). Anthropogenic activities have been considered increasingly important in establishing the organisation of biotic communities (Leburn,1978, Badejo *et.al*,1999, Sampson and Groves,1989), the impact of which was clearly identified in site KY with low proportion of mites than that of BG.

Results of statistical analysis of the data on mite population in Site A revealed the P values of number of mites in response to Rainfall as 0.964, 0.977, 0.989 during monsoon seasons of the three consecutive years and which were significant at 0.01 level. P values for Pre-monsoon (0.494, 0.505, 0.545) and Post-monsoon (0.389, 0.391, 0.405) seasons were also found significant at 0.01 level, which indicated a positive influence of Rainfall on mite population rates. RH also was identified as a determining factor of population density of lohmanniid mites by revealing P values in pre-monsoon (0.536, 0.576, 0.589), monsoon (0.956, 0.961, 0.971) and post-monsoon (0.298, 0.305, 0.276) seasons of the year at 0.01 significant level. Temperature exhibited a negative correlation with the number of mites in the site for pre-monsoon and post-monsoon seasons (-0.669 & -0.623, -0.690 & -0.645, -0.712 & -0.688) of 2010-2011, 2011-2012, 2012-2013 annual cycles respectively. In Site B, correlation values of 0.874, 0.891 & 0.899 at 99 % confidence level could be noted between number of mites and Rainfall in monsoon seasons of 2010- 2011, 2011-2012 & 2012-2013. Analysis of data obtained for RH to number of mites indicated a positive relationship, during pre-monsoon (0.206, 0.316, 0.378), monsoon (0.806, 0.845, 0.851) and post-monsoon (0.198, 0.208, 0.0.256) seasons of the study period respectively .

The results of regression analysis using the exponential form showed a significant relationship between dependent variable (mite population) and independent variables (physical factors). The data recorded from both Site A and Site B were strikingly similar in their predictive feature. The predictability of number of mites with respect to physical parameters was

84% and 82% during the pre-monsoon season in Site A and Site B . The monsoon season and post monsoon predictability observed was about 32% & 36% and 31% & 38% in both sites and which could be attributed to the considerable variations in climatic factors during the study period.

As reported by earlier workers (Curvey, 1978, Behan and Pelletier, 1999) concentration of organic carbon exerts great influence in oribatid mite density. In the present study also, macronutrients like carbon and potassium showed positive correlation with the population of mites in both the study areas, whereas phosphorus was found to be negatively correlated. In Site A, Organic Carbon (OC) and Potassium (K) showed positive correlation with the number of mites, with the correlation values being 0.897 and 0.859 respectively. Phosphorous (P) showed a negative correlation of -0.628, which implied low dependency towards the nutrient. Micronutrients like Zn, Mn and Mg could be detected in very low proportions (0.212, 0.294 & 0.386) and hence their impact would be less influencing than that of Cu and Fe (0.679 & 0.703). In site B, the values recorded for OC and K reflected high correlation with the numerical abundance of mites as in Site A, with the correlation values being 0.875 & 0.881 respectively. Phosphorous showed negative effect on mite population with -0.245 correlation value. Magnesium (0.599) and Copper (0.520) could be recorded as the lowest influencing micronutrients while Manganese, Iron and Zinc showed a positive impact with respective correlation values of 0.606, 0.614 & 0.794 in ascending order of impact. Mites showed low dependency on micro nutrients like Zinc, Magnesium and Manganese in site BG and on Copper and Magnesium in site KY. Results of comparative statistical analysis of nutrients in the soil samples of the 2 sites revealed site BG to be rich in organic matter, thereby supporting faunal diversity than that of site KY.

Resembling all other oribatids, lohmanniid mites also require optimum conditions of temperature, humidity and litter accumulation to establish a good population density. Variations in all these factors exert their own impact on the density of mite population, either positively or negatively, leading to fluctuations on a monthly, seasonal or annual basis. Availability of preferred food in the appropriate stage of decomposition in sufficient quantities would enhance the rate of reproduction leading to an increase in population density. These mites promote litter decomposition through direct litter consumption, litter fragmentation and dispersal of microbial population, thereby improving the palatability of the preferred food. Higher density of soil fauna and high taxonomic diversity in wet forest soils than in dry conditions were reported earlier (Gonzalez and Seastedt, 2000). Diversity of oribatids was found low in paddy fields when compared to that of the typical forest ecosystem (Li *et.al*, 2000), and it was found true in the present study also. The results of the study thus disclosed the extreme dependence of lohmanniid mites to physical parameters like RH and rainfall and thus enabled to establish their dynamic role in litter decomposition and bioindication.

Soil is a composite and diverse ecosystem supporting multifarious interactions among the diverse biotic and abiotic factors. It supports huge populations of micro and mesofauna above and below the ground layers. Oribatid mites represent the major elements of the soil mesofauna, owing to their numerical density and species diversity. These mites prefer moist and highly organic rich upper layers of undisturbed woodland and forest soils. Among the oribatid mites, members of the family Lohmanniidae play pivotal roles through their fastidious feeding activity by shredding and fragmenting the accumulated litter and other organic materials of the soil and enhancing the mineralisation of plant nutrients and promoting the fertility and productivity status of soil ecosystem. These mites render ecosystem services in biodegradation, nutrient cycling and energy flow, as active ingredients of the decomposer food chain. Extreme sensitivity of these mites to various physic-chemical factors in the environment designate them as efficient bioindicators of soil health. The present study was envisaged to carry out an in-depth study on the distribution pattern, species diversity, taxonomic description, population ecology and biological aspects of members of the family Lohmanniidae in the Malabar region of Kerala.

The first part of the thesis provides information on the distribution pattern, systematic aspects and impact of various physical and chemical parameters on the population density of lohmanniid mites. It includes the results of general surveys conducted on lohmanniid mites harbouring varied ecosystems like the forest soils, litter accumulated areas, areas of mixed vegetation and isolated pockets of organically rich soils of Malabar region. During the survey, soil and litter samples were collected from 20 different sites with diverse floral composition, distributed over 5 districts *viz.*, Palakkad, Malappuram, Kozhikkode, Wayanad and Kannur. The collected

samples were subjected to extraction through the open brass funnel apparatus to separate these mites. The extracted mites were preserved in 70% alcohol for taxonomic studies and as live in moistened, powdered litter for biological studies. Preserved specimens were dehydrated in alcohol series and cleared in a clearing medium of 1:1 mixture of lactic acid and ethanol, mounted in Hoyer's / PVA media and identified following appropriate keys and relevant literature, and confirmed with the help of concerned experts. Drawings were made with the help of a Camera Lucida attached to a Meopta/Unitron Research Microscope. SEM images were also taken for some new species identified, from the National Institute of Technology, Calicut.

Results of soil/litter sampling from the various selected study sites of the Malabar region enabled to recover 15 species belonging to 7 genera under the family Lohmanniidae, of which 9 were described as new to science. Of the 15 species collected, the genus *Haplacarus* showed wide distribution and *H.foveolatus* sp.nov. was identified as the most widely distributed species, recovered from 14 out of 20 sites surveyed. The other members of the genus, *H.granulatus* and *H.porosus* were recovered from 13 different sites while *H.keralensis* was collected from 12 study sites. The genus *Papillacarus* achieved the second position with *P.reticulatus* sp.nov. showing distribution in 12 sites and *P.heterosetosus* sp.nov. in 10 sites. The numerical density of *P.graminosus* sp.nov. was particularly high in high altitude areas of Palakkad and Wyanad districts. The genus *Annectacarus* with the recovery of 3 species was ranked as third in the distribution pattern. *A.phyllotrichous* sp.nov. was found distributed in 9 sites, *A.wallworki* in 7 sites and *A.areolatus* sp.nov. in 6 sites. The representative of the genus *Meristacarus* viz., *M.degradatus* was seen in high density in the litter and soil samples in association with *X.xylocarpa* vegetation. The distribution of the genus *Heptacarus* was found restricted to beach soils while *Cryptacarus* was seen in association with

bamboo grooves and grasslands. In the systematic part of the thesis, detailed morphological descriptions of 15 species collected during the study were included with appropriate figures. Camera Lucida drawings of morphological details and SEM images were also given for detailed analysis of characters of taxonomic importance.

In the present study, attention was also focussed to assess the population fluctuations of lohmanniid mites in accordance with the variations in environmental factors like Rainfall, RH, Temperature and soil nutrient composition. Regular monthly samples of soil were collected from 2 study sites in the Malappuram district *viz.*, The Botanical Garden of the Calicut University Campus and Kakkancherry for 3 consecutive years from May 2010 to April 2013 and the results were analysed statistically. The population density of these mites was found to fluctuate seasonally in their natural habitat. The population size attained its maximum level during the monsoon seasons and got declined with hot and dry summer months. The results of statistical analysis showed a positive correlation between number of mites and RH as well as Rainfall and a negative correlation between mite population and Temperature. Regression analysis done in the exponential form recorded 82-84 % predictability for pre -monsoon season, 32-36% for monsoon season and 31-37% for post -monsoon season. Results of nutrient analysis of the soil samples indicated a profound increase in mite population with high concentrations of organic carbon, nitrogen and potassium in the soil. The level of phosphorous did not influence the population size of these mites. The amounts of micronutrients like Cu, Zn, Mg, Mn and Fe also exerted an appreciable alteration in the mite population. These results could be attributed to the dependency of mites to these nutrients in the soil, and thereby indicating nutrient status of the soils which support high densities of these mites.

In the second part of the thesis, results of detailed studies on the feeding and breeding biology are included. The occurrence of these mites in different microhabitats was mainly dependent upon their feeding strategies, which showed a wide range of feeding preference to different types of leaf litter. Food choice test and Gut content analysis were performed in the laboratory for estimating the feeding strategies of selected species of lohmanniid mites. The live mites recovered through extraction were reared in special culture cells by providing different food items. Feeding response of 10 species of lohmanniid mites to 12 different leaf litter and woody components was recorded as a result of laboratory food choice test. Leaf litter was found preferred by almost all the species studied except *H. notobandus* sp.nov. High degree of feeding specificity was found exhibited by *C. grandjeani* to the litter of *B. arundaneaceae*, *M. degradatus* to *X. xylocarpa* and *P. graminosus* sp.nov. to *C. sinensis* and *C. arabica*. The leaf litter of *A. heterophyllus* was identified as the most preferred food item and the order of preference was recorded as: *A. heterophyllus* > *A. occidentale* > *P. gujava* > *M. indica* > *T. grandis* > *M. fragrans* > *X. xylocarpa*.

The microbiological screening and isolation of gut contents of *H. foveolatus* sp.nov. was carried out to identify the gut flora, which assisted in digestion of higher plant materials and to establish its role in the turnover of litter and subsequent nutrient cycling. Twenty five live specimens of *H. foveolatus* were isolated from stock cultures and reared in sterilized culture vials. Newly emerged individuals prior to initiation of feeding activity were taken as the control set. Sterilized leaf litter of *A. heterophyllus* was provided as food item. These mites were dissected on a microscope slide under a stereo zoom microscope by making a gentle cut on the notogaster. The gut was removed with the fine tip of a dissection needle. The gut of 5-10 mite specimens were pooled in a test tube containing peptone water (pH-7.4) and

incubated for 2 hours. Then the turbid inoculum was taken with a sterile wire loop and streaked on Blood Agar and Mac Conkey Agar medium. Petridishes containing Mac Conkey Agar and Blood Agar medium containing turbid inocula carrying the gut contents of mite after overnight incubation at 37°C were found developing two types of bacterial colonies in both experimental and control sets. The colony A developed on Mac Conkey agar appeared large to medium sized, thick and pink coloured due to lactose fermentation. Colony B appeared colourless, swarming with characteristic fishy odour. The results of biochemical analysis revealed that the gram negative colonies developed were of *Eschericia coli* and *Proteus vulgaris*.

In the present study, observations were made on the breeding biology of 3 dominant species of the family Lohmanniidae. The species selected for biological studies were *H.foveolatus* sp.nov., *P.heterosetosus* sp.nov. and *A.phyllotrichous* sp.nov. Developmental studies of these mites were carried out in the laboratory under temperature-humidity conditions of  $30 \pm 1^\circ\text{C}$  and 70-75%. Live adults were reared in special culture cells containing plaster of Paris- charcoal base by offering their most preferred food items. Observations were made on oviposition, hatching, active and quiescent stages, moulting, duration of individual instars, duration of F<sub>1</sub> generation etc. Morphological details of each stage were studied and presented through illustrations and drawings. In general, all the species were found to pass through five different active phases. The egg after incubation hatched out into a hexapod larva, followed by the protonymph, deutonymph, tritonymph and adult. Each active stage was followed by an inactive quiescent phase which subsequently moulted into the next phase. The duration of development varied with respect to variations in individual species. *A.phyllotrichous* sp.nov., *H.foveolatus* sp.nov. and *P.heterosetosus* sp.nov. completed their life cycles with 89-95, 157-166 and 103-116 days respectively. *H.foveolatus* sp.nov. required

comparatively longer time to complete its life cycle than *P.heterosetosus* sp.nov. and *A.phyllotrichous* sp.nov. The study also revealed that the different species followed the same pattern of development with species specific variations.

Thus the results of the present study helped to identify and contribute fifteen species belonging to seven genera, under the family Lohmanniidae, of which nine species represented new species and hence new additions to science, from the soils of Malabar. The data gathered on distribution pattern and influence of climatic factors and soil nutrient composition on the population density disclosed the extreme sensitivity of these mites to changes in the natural habitat, which would signify their role in bioindication. Macrophytophagy among these mites would denote its efficiency in breaking down of organic litter and stimulation of microbial activity. The activity of gut microflora would supplement their functional role in the turnover of litter which in turn would lead to complete degradation of plant litter and other organic residues. Studies on the feeding strategies of lohmanniid mites confirmed their potential as efficient biodegradators of the soil ecosystem. Further, the results of developmental studies revealed the prevalence of thelytokous mode of reproduction among these mites, morphological details of immature stages and duration of various life stages, total duration of development etc. thereby providing valuable information on the number of possible generations in the natural habitat.

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**PLATE 29**  
**Morphological description of life stages of**  
***Annectacus phyllotrichus* sp. nov**

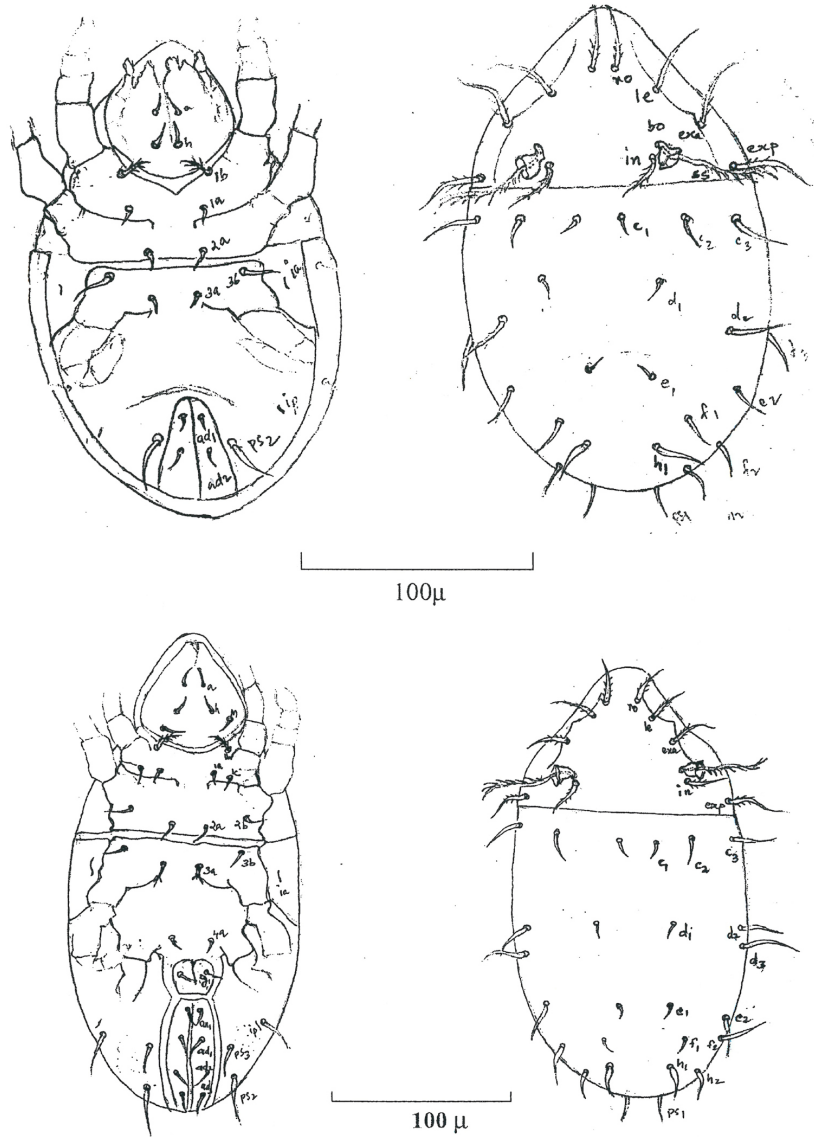


Figure 1. Larva Dorsal view; 2: Larva Ventral view; 3: Protonymph- Dorsal view; 4: Protonymph- Ventral view



**PLATE 35**  
**Morphological description of life stages of**  
*Papillacarus heterosetosus* sp. nov

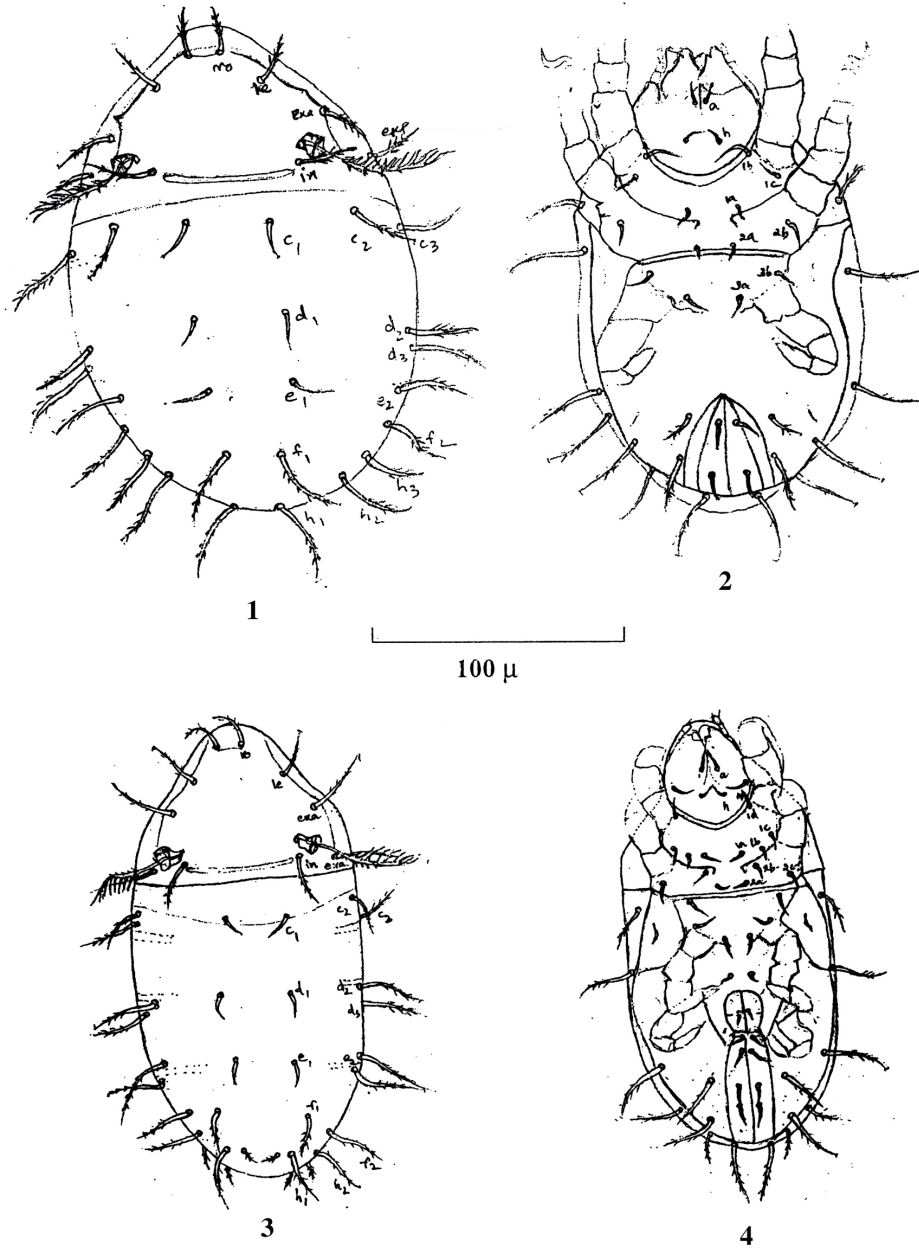


Figure 1. Larva Dorsal view; 2: Larva Ventral view; 3: Protonymph- Dorsal view; 4: Protonymph- Ventral view

**PLATE 4**  
*Annectacarus areolatus* sp. nov

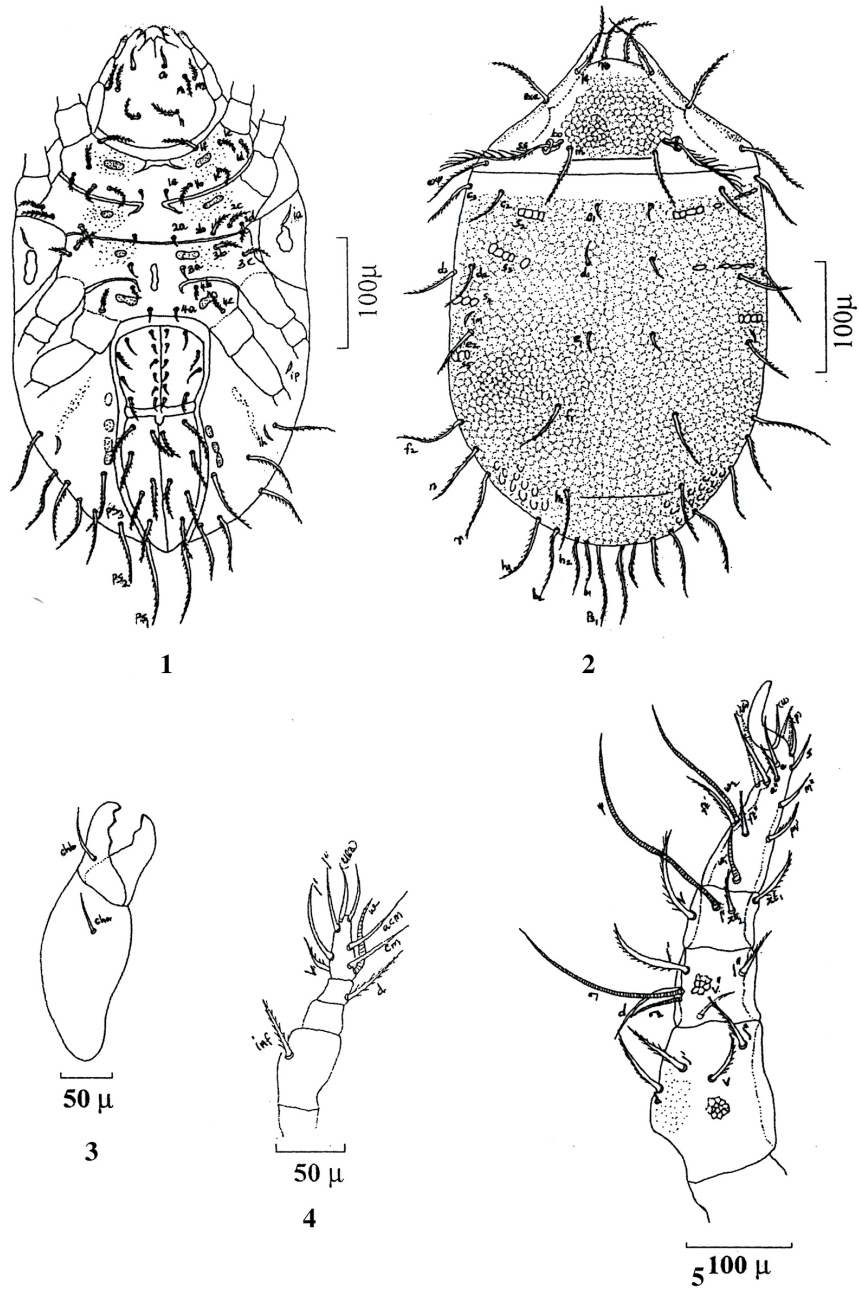


Figure 1. Ventral region; 2. Dorsal region; 3. Chelicera; 4. Pedipalp; 5. Leg



**PLATE 8**

*Cryptacarus grandjeani* Clement and Haq, 1991

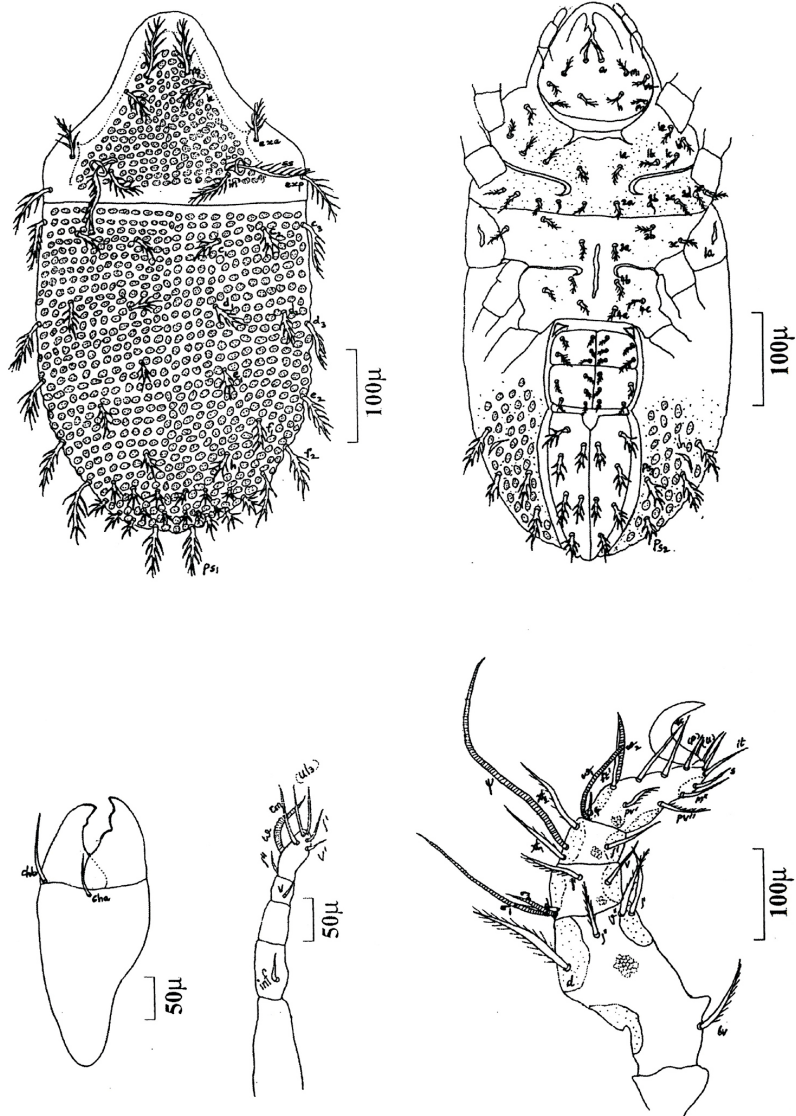


Figure 1. Dorsal region; 2. Ventral region; 3. Chelicera; 4. Pedipalp; 5. Leg

**PLATE 11**  
*Haplacarus granulatus* sp. nov

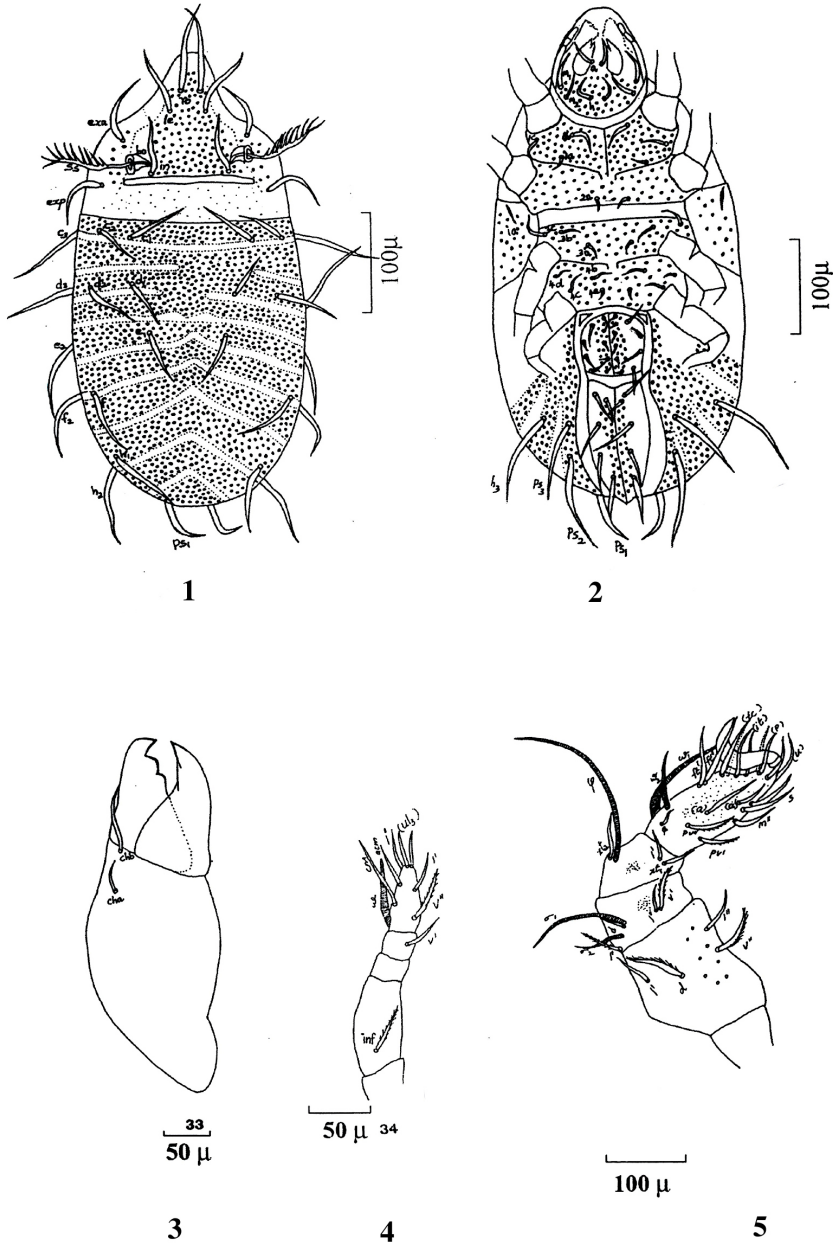


Figure 1. Dorsal region; 2. Ventral region; 3. Chelicera; 4. Pedipalp; 5. Leg

**PLATE 12**  
*Haplacarus porosus* Haq and Clement, 1995

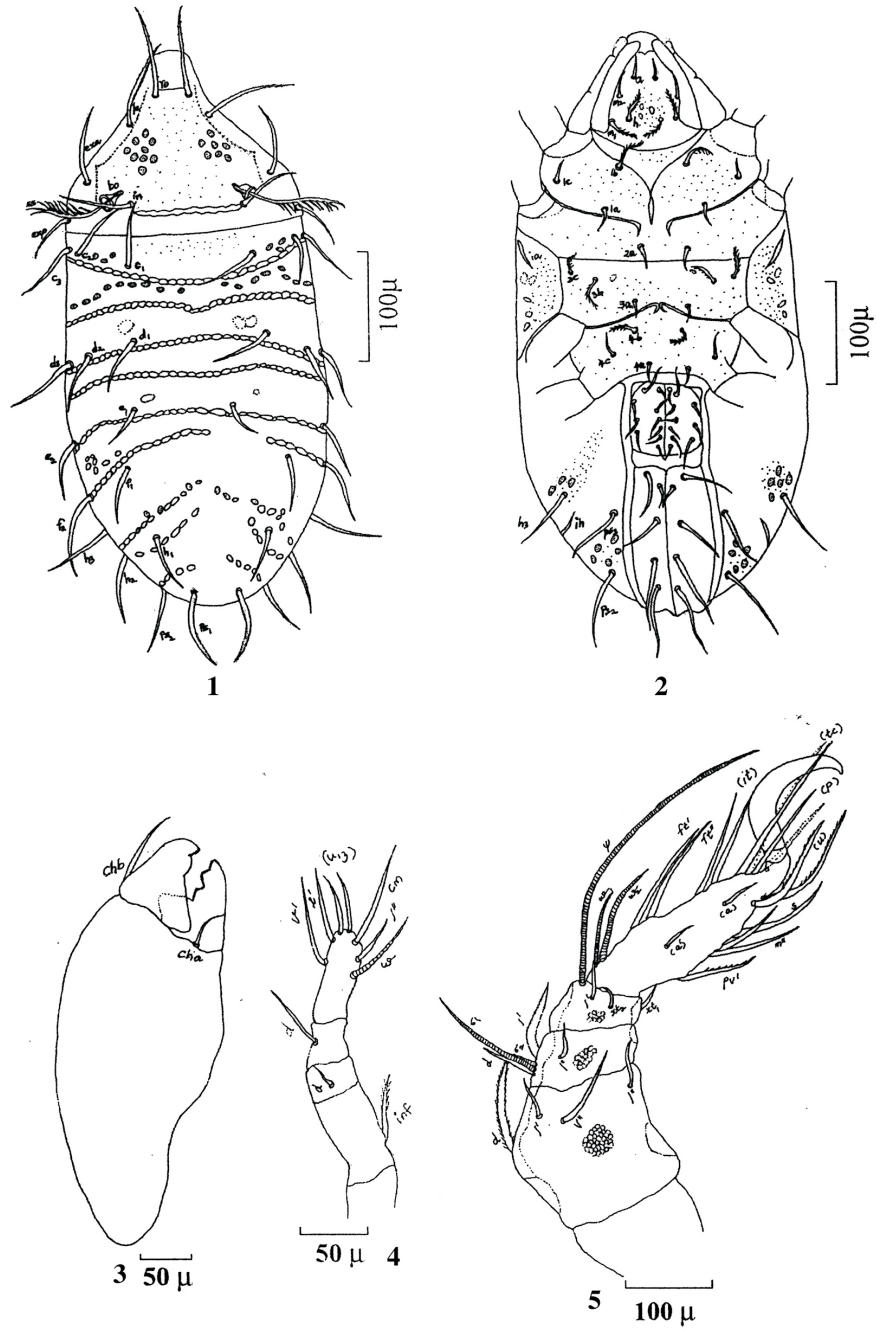


Figure 1. Dorsal region; 2. Ventral region; 3. Chelicera; 4. Pedipalp; 5. Leg

**PLATE 13**  
*Haplacarus keralensis* Haq, Mubarak  
and Ramani, 1984

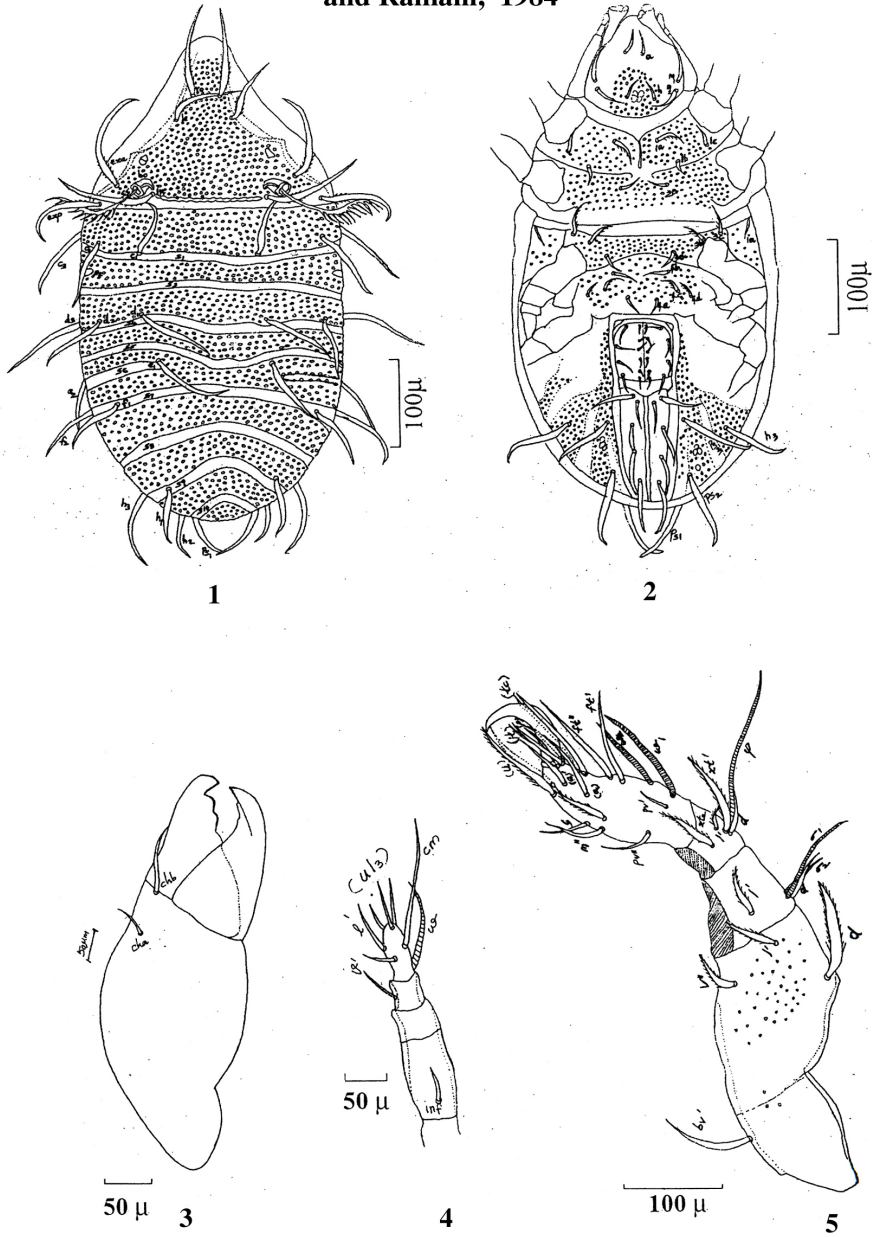


Figure 1. Dorsal region; 2. Ventral region; 3. Chelicera; 4. Pedipalp; 5. Leg

**PLATE 14**  
*Heptacarus notobandus* sp. nov

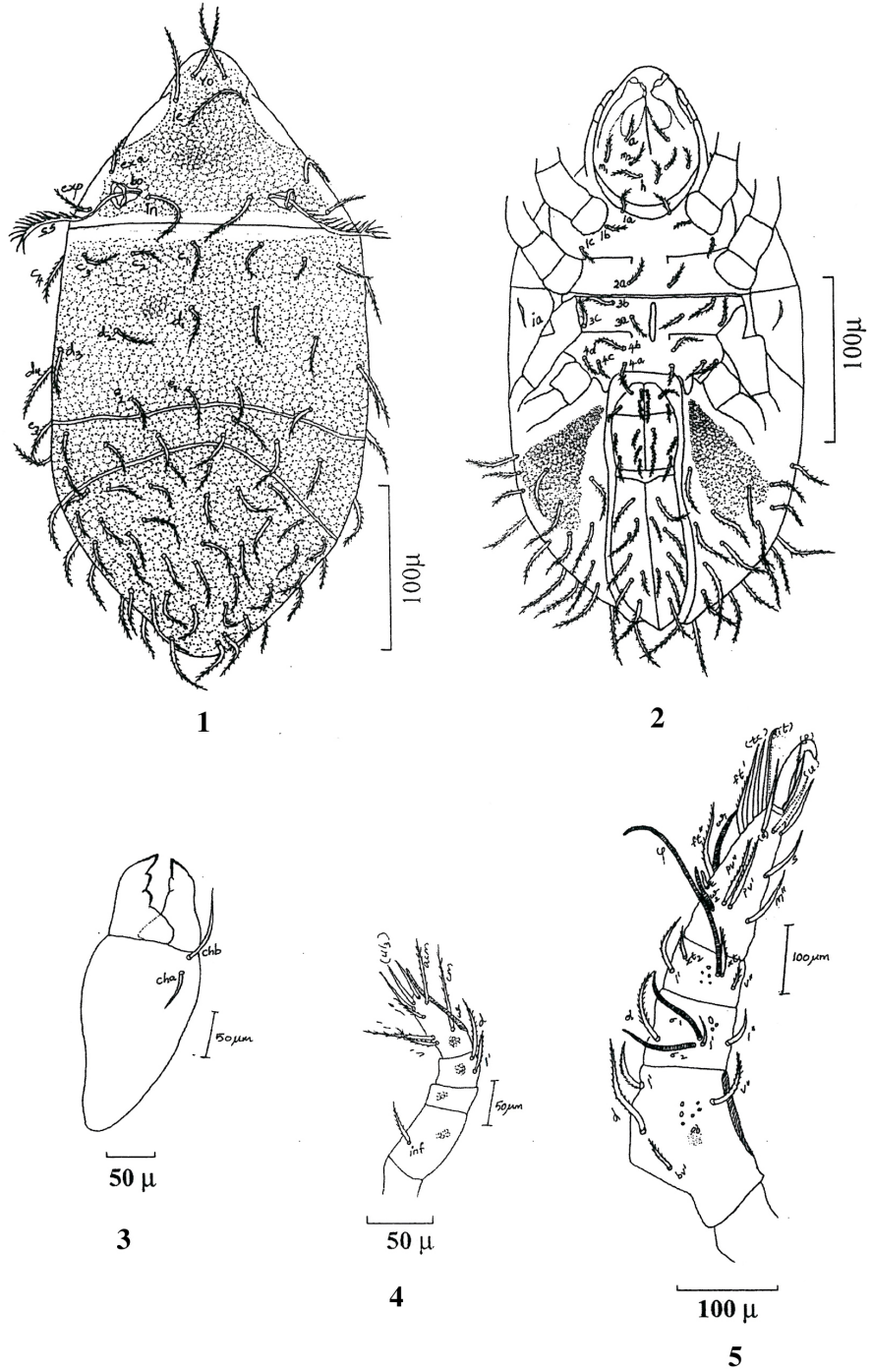


Figure 1. Dorsal region; 2. Ventral region; 3. Chelicera; 4. Pedipalp; 5. Leg

**PLATE 15**  
*Javacarus porosus* Hammaer, 1980

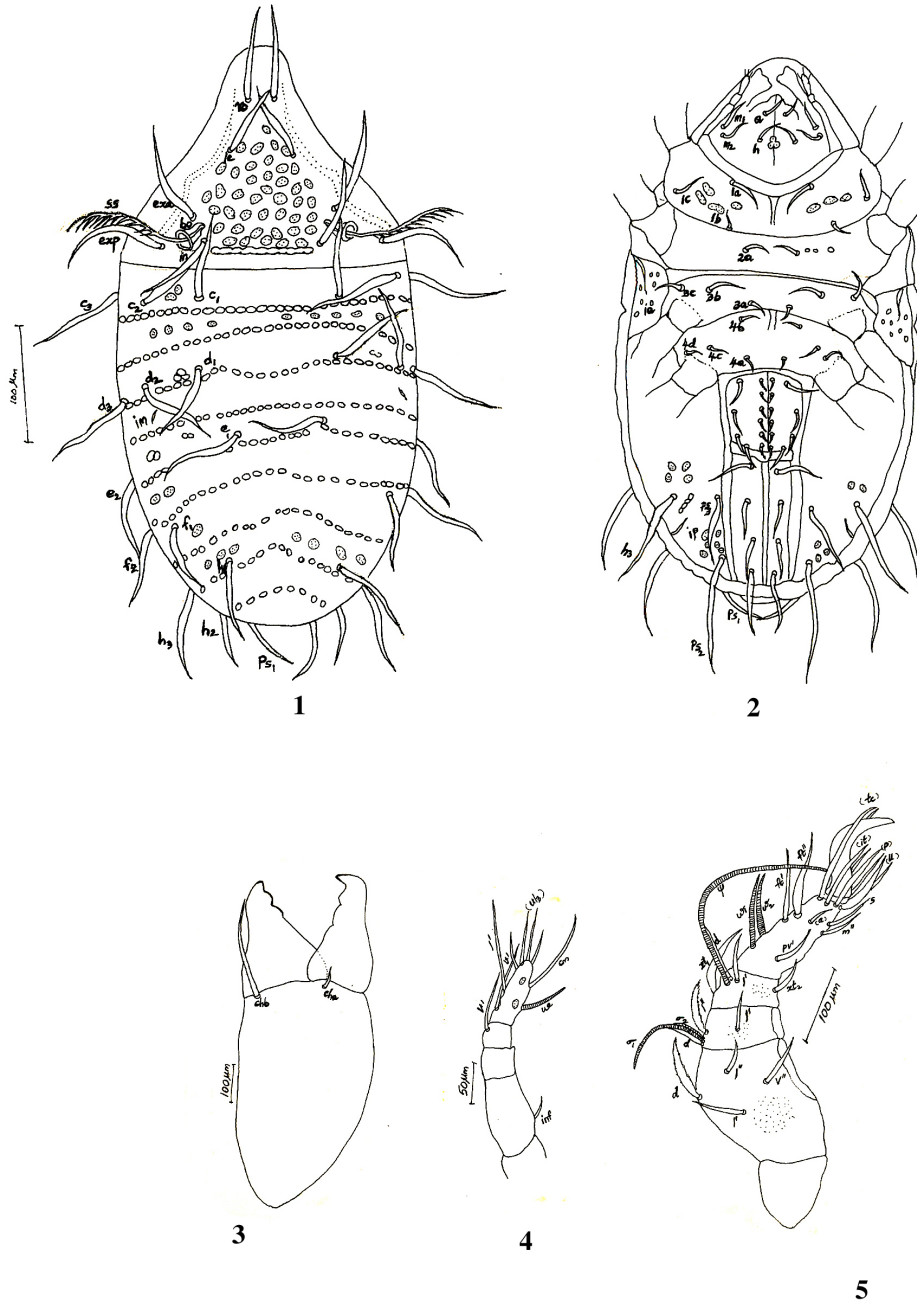
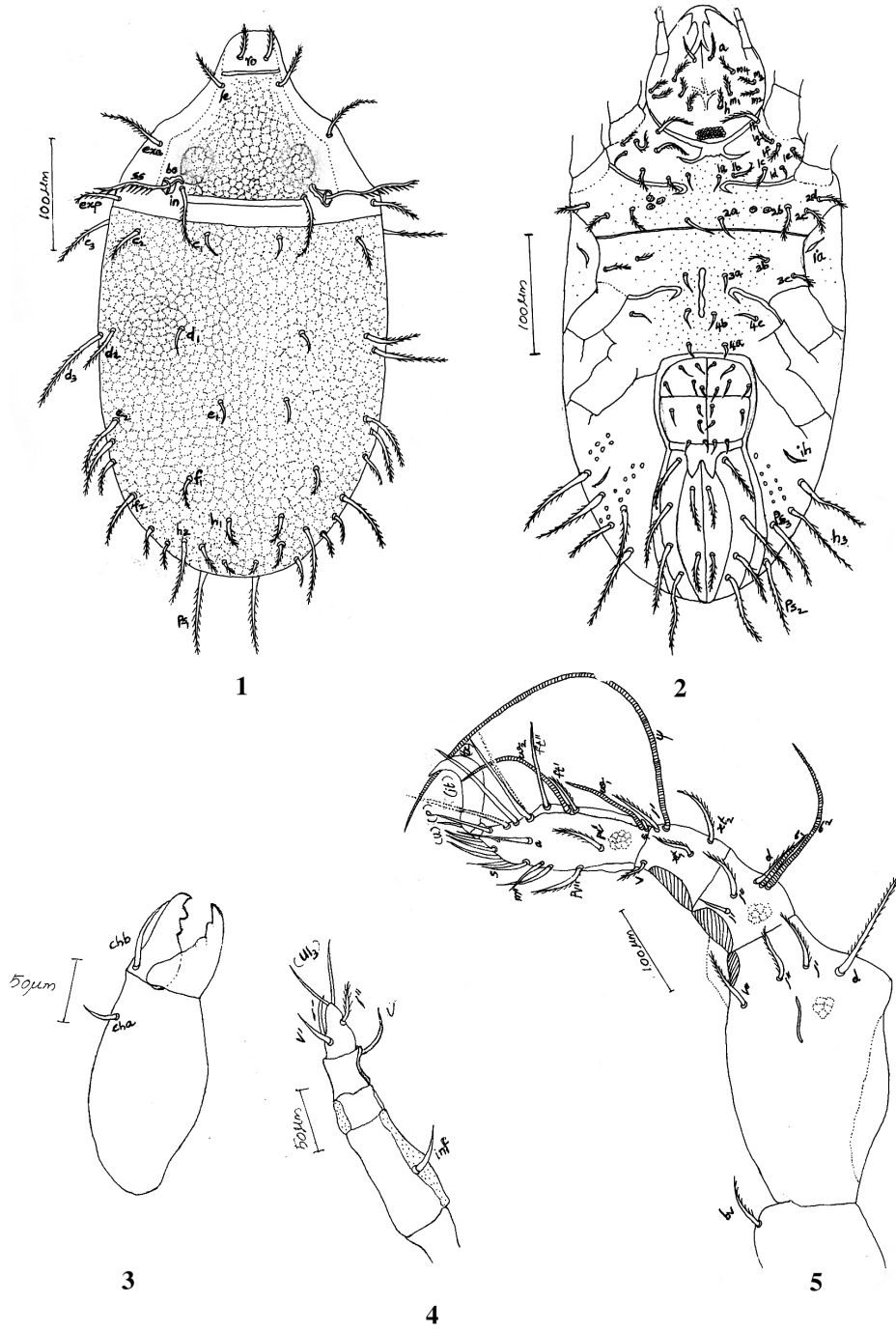


Figure 1. Dorsal region; 2. Ventral region; 3. Chelicera; 4. Pedipalp; 5. Leg

**PLATE 22**  
*Papillacarus reticulatus* sp. nov





**PLATE 30**  
**Morphological description of life stages of**  
*Annectacus phyllotrichous* sp. nov

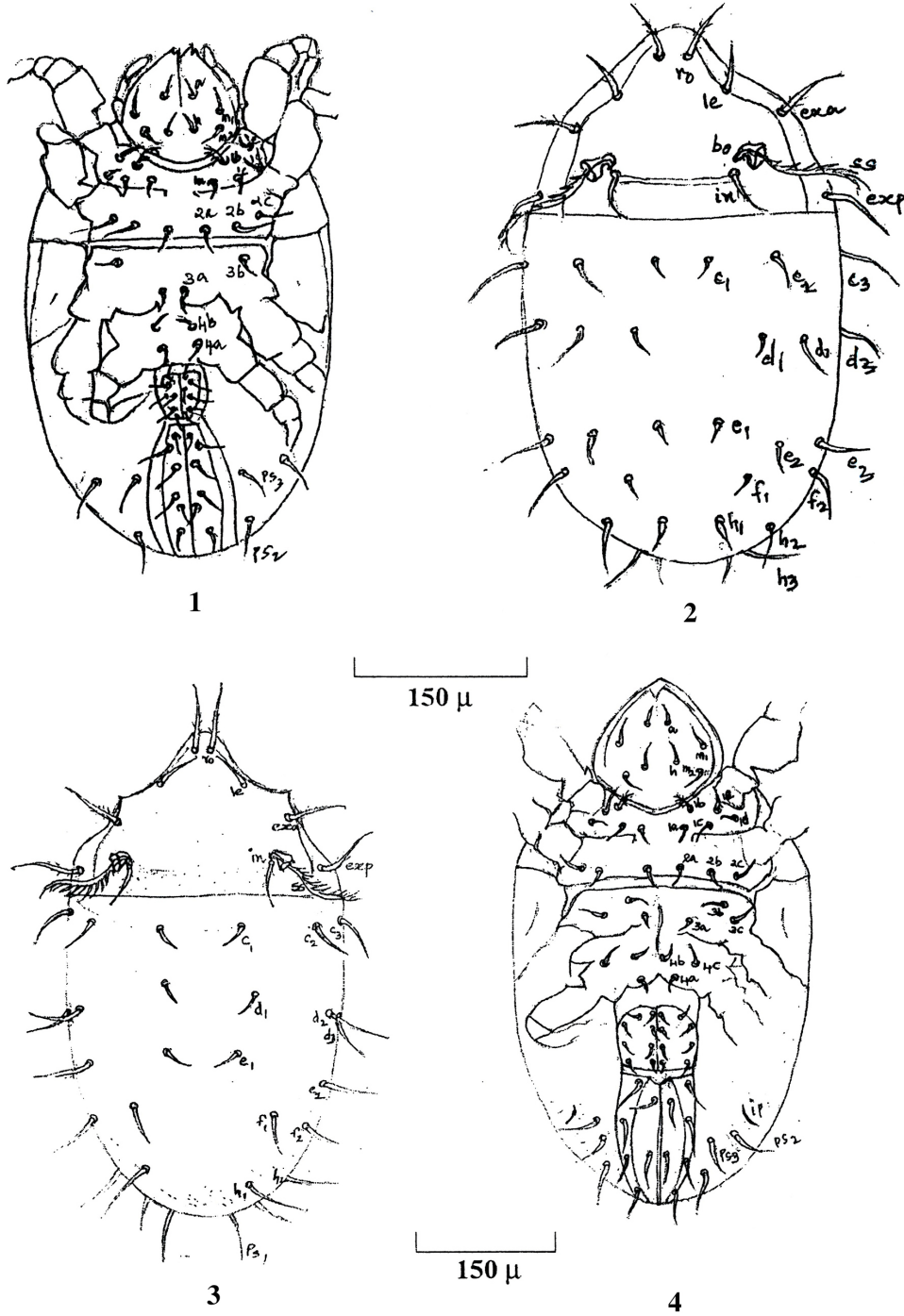


Figure 1. Deutonymph Ventral view; 2: Deutonymph Dorsal view; 3: Tritonymph-Dorsal view; 4: Tritonymph- Ventral view

**PLATE 32**

Morphological description of life stages of *Haplacarus foveolatus* sp. nov

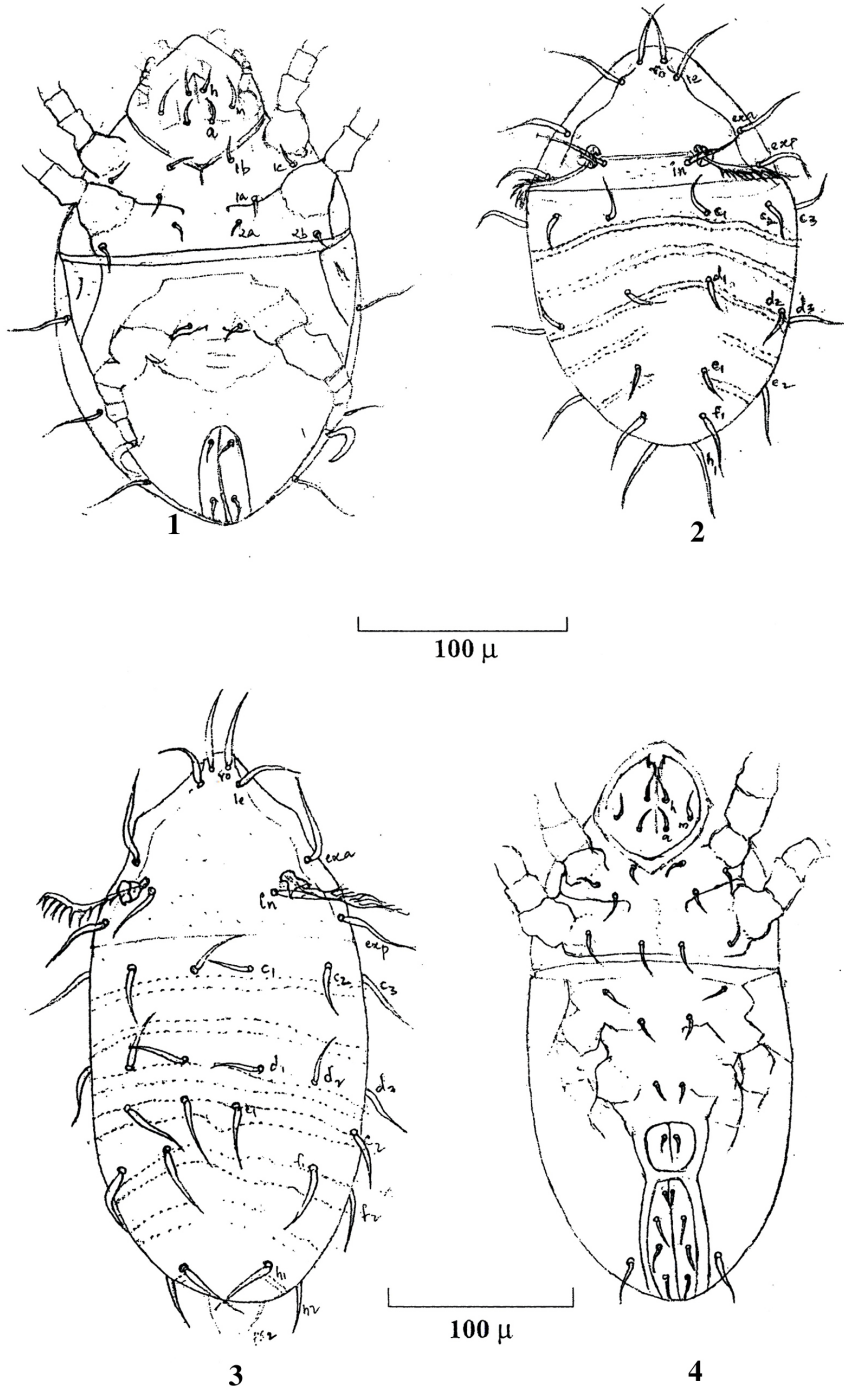


Figure 1. Larva - Ventral view; 2: Larva -Dorsal view; 3: Protonymph- Dorsal view;  
4: Protonymph- Ventral view

**PLATE 33**

**Morphological description of life stages of *Haplacarus foveolatus* sp. nov**

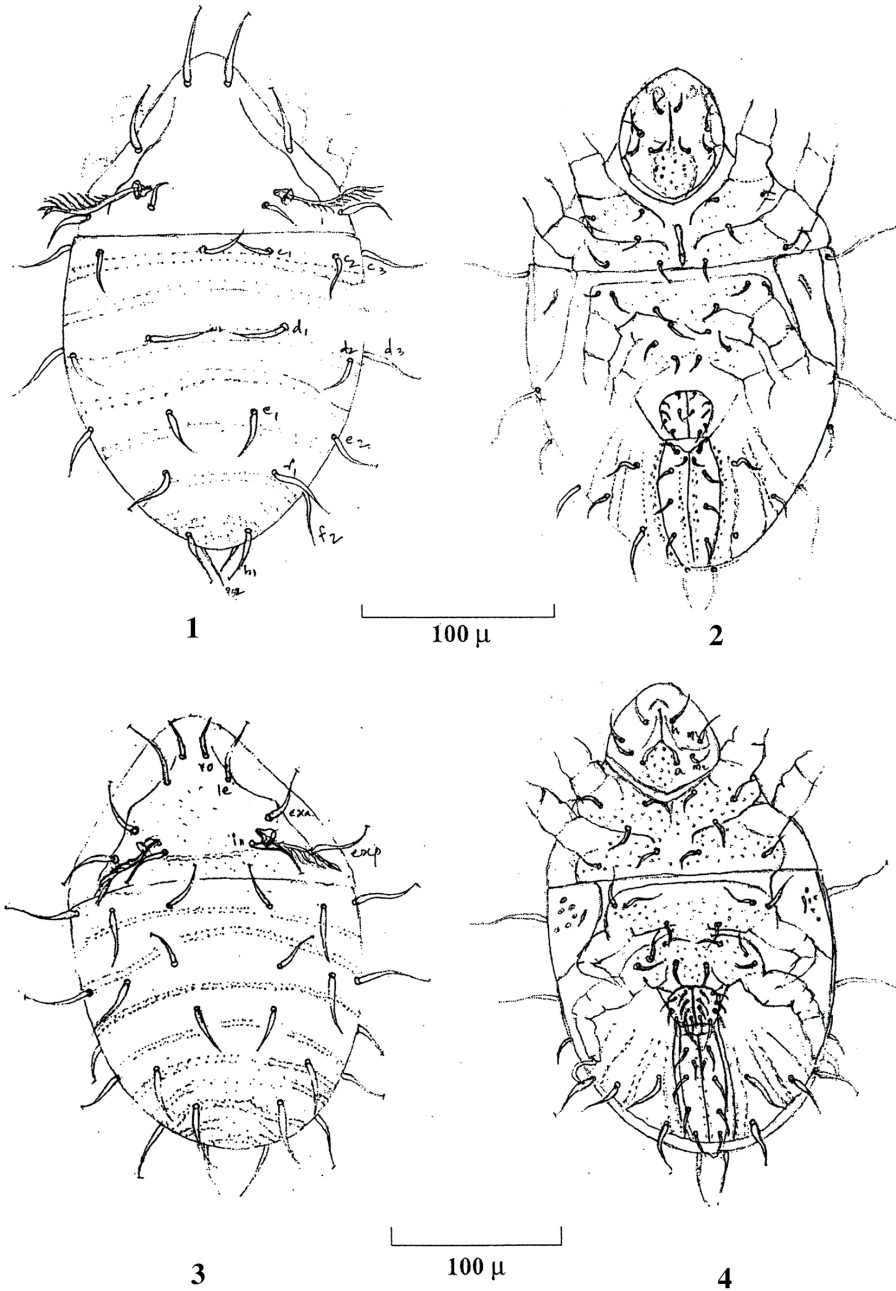


Figure 1. Deutonymph- Dorsal view; 2: Deutonymph- Ventral view; 3: Tritonymph- Dorsal view; 4: Tritonymph- Ventral view

