BIOSYSTEMATIC STUDIES ON MITES (ACARI) INFESTING BAMBOO

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DOCTOR OF PHILOSOPHY IN ZOOLOGY

By

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CERTIFICATE

This is to certify that the thesis entitled "**BIOSYSTEMATIC STUDIES ON MITES (ACARI) INFESTING BAMBOO**" is an authentic record of the work carried out by **Ms. Vibija C.P**. under my supervision and guidance in partial fulfillment of the requirements of the Degree of Doctor of Philosophy in Zoology in the Division of Acarology of this Department and that no part thereof has been presented before for any other degree or diploma.

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DECLARATION

I, **Vibija, C.P**, hereby declare that this thesis entitled "**BIOSYSTEMATIC STUDIES ON MITES (ACARI) INFESTING BAMBOO**" 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 that no part of this has been submitted before for the award of any other Degree or Diploma.

C U Campus **Vibija C.P.**

Date:

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GENERAL INTRODUCTION

Earth is known to foster a highly complex, dynamic and bewildering biological diversity that has been estimated to reach 8.7 millions with remarkable predominance of microbes and invertebrates, constituting 95% of the total biota. Being very minute, microbes are quite invisible to the naked eye, but still the food and agriculture production of the world is largely dependent on this "hidden" biodiversity. Nearly 80% of the invertebrate diversity is contributed by members of the phylum Arthropoda, with the major share contributed by members of two classes viz. the Insecta and Arachnida. Both the above classes have established themselves as successful groups, colonizing all available niches of the terrestrial, aquatic and aerial ecosystems. While the insect diversity is largely determined by the beetle community, the arachnid diversity is dependent on the Acari, the group which comprises the mites and ticks.

The Acari (mites and ticks) has been designated as a distinct subclass under the class Arachnida, subphylum Chelicerata and phylum Arthropoda and the discipline of Acarology has been developed as a separate offshoot of Entomology. Acarines are easily distinguishable from insects by the possession of a combination of several features like the four pairs of legs (with the exclusion of Eriophyoidea which have two pairs of legs in all stages of life), chelicerate mouth parts and lack of wings, antennae, head and so on. The Acari represents a heterogenous assemblage of organisms which share varied habitats and habits with diverse life styles like the phytophagous, parasitic, predatory, commensalistic and scavenging modes of life. Accordingly, their mouthparts are variable, capable of piercing the plant tissues to suck out cell sap, or to predate on animals such as nematodes, springtails or other tiny micro-organisms or to devour solid particles like the litter components and other organic residues of terrestrial ecosystems. Several species of acari including ticks enjoy an exclusively haematophagous diet also.

The subclass Acari, is classified variously by different authors to accommodate the currently described ≈ 55,000 species (Krantz and Walter, 2009) under the two superorders viz. the Parasitiformes and Acariformes. The parasitiformes is further divided into orders Opilioacarida, Holothyrida, Ixodida and Mesostigmata. The order Mesostigmata comprises an extensive series of mite families, with diverse habits and habitats. The order Ixodida encompasses the ticks. The superorder Acariformes includes two orders namely Trombidiformes and Sarcoptiformes, of which the former group includes two suborders, Sphaerolichida and Prostigmata. Most of the plant dwelling pest mites come under the suborder Prostigmata. The order Sarcoptiformes is divided into two suborders, Endeostigmata and Oribatida. The latter includes the subcohort, Astigmatina/Astigmata which includes mites showing varying habits and habitats.

Of these, majority of the plant mites included in the present thesis, are grouped under the suborder Prostigmata and the latter group includes diverse families of mites, distributed over a wide range of habitats. This group includes the most important invasive species belonging to the families Tetranychidae, Tenuipalpidae, Tarsonemidae and Eriophyidae. Tetranychid mites, the popularly called 'spider mites' have the unique ability to spin webs of silken threads secreted by their salivary glands, to afford protection to life stages, to facilitate dispersal, to transfer pheromones and to shield from pesticide sprays too. These mites complete their life cycle within a very short time, passing through the egg, larva, protonymph and deutonymph to reach the adulthood. Each of the active instar commencing from the larval stage, is followed by an inactive/quiescent phase and thus the spider mites pass through three quiescent phases also during their course of development. The shorter life cycle, high reproductive potential and extremely polyphagous habit of spider mites facilitate rapid buildup of their population to attain peak levels, causing extensive damage to crop plants and inducing significant economic loss.

Another exclusively phytophagous and widely distributed group of mites is the Eriophyoidea which represents a unique group with very small, fusiform, worm like and annulated body with two pairs of legs in all stages of development. Eriophyids induce diverse types of plant abnormalities ranging from the simple folding and edge rolling of leaves to highly complex structures like the galls and erinea through brooming and blister formation, leaf rusting, bud deformation etc. Several species successfully vectorise phytopathogenic viruses also thereby leading to drastic decline in agricultural productivity. Most of the eriophyid species are highly host specific, but some are oligophagous, as in the case of *Aculops lycopersici* which is capable of thriving well on several species of solanaceous plants.

Mites of the family, Tenuipalpidae are known by the common name 'false spider mites' and which are generally reddish, slow moving and inhabit on the lower surface of the host leaves. Some species inhabit on the bark, floral heads or the underside of leaf sheaths also. The feeding symptoms of false spider mites greatly resemble those of spider mites and in several cases, leprotic spots and patches also develop successfully leading to the dryness and defoliation of plants. Species like *Larvacarus transittans* induces gall formation also. Several plant pathogenic viruses are vectored and transmitted by false spider mites and therefore the damage potential of these mites is greatly intensified.

Tarsonemidae represents another family of mites the members of which are generally very small and with a very hard and shiny integument. Some species are recognized as parasites of scale insects, and some are even suspected to have a parasitic relationship with higher animals including man. The relation between tarsonemids and agriculture has long been established and many species have been labeled as agricultural pests since 1877. Species of *Polyphagotarsonemus* are excellent examples. Feeding by tarsonemid mites causes curling, twisting *etc.* on respective host plants.

The feeding activity of mites not only reduces the photosynthetic efficiency of plants but also causes various biochemical changes in host plants. Reports show that feeding activity of mites leads to alterations in the concentration of minerals, sugars and several other inorganic and organic compounds in host plants, ultimately resulting in various physiological and morphological changes (Shree and Nataraj, 1993). Fluctuations in the amounts of carbohydrates, proteins, phenols, amino acids, nitrate, potassium etc. would drastically affect the physiological processes of host plants and thereby reduce the crop yield.

Despite the negative impact mentioned above, mites also have several beneficial roles as well-known ecofriendly agents, stimulating complex ecosystem processes like organic decomposition and nutrient cycling. Soil mites, particularly the oribatids actively participate in the biodegradation of organic residues in the soil ecosystem and promote the enrichment of soil fertility, apart from their significant roles in bioindication, biological control, bioremediation as well as forensic science as tools in detecting post mortem intervals.

A good number of mites lead a parasitic mode of life on/in animals of both the invertebrate and vertebrate categories. The entire species of ticks and a good number of mites belonging to the families Gamasidae, Trombididae, Sarcoptidae, Demodecidae etc. are the excellent examples of the above mentioned category. Several species of mites coming under the family Acaridae are known to transmit entomopathogenic fungi. A few species are parasites of cockroaches too. Many species belonging to Anystidae feed on thrips, springtails, hemipterans like bugs, leafhoppers, psyllids, aphids, armoured scales etc. Some species like *Hemicheyletia bakeri* immobilize their prey's body by injecting toxins (Laing, 1973). Members of Bdellidae are active hunters of small arthropods. Cunaxid mites trap their prey by making silken traps and these mites have been reported from a variety of habitats like plants, mosses, litter, bark, soil and stored products (Gerson *et al.*, 2003). Many species of Laelapidae are ectoparasitic on small mammals while members of the Stigmaeidae often feed on the eggs and sessile forms of Tetranychidae, Tenuipalpidae and the others. The superfamily Phytoseioidea includes mites displaying widely ranging habits, being parasitic, fungivorous, predatory and pollen feeding types. Some are ground dwelling forms while some species occupy aerial habitats (Krantz and Walter, 2009).

Plants harbor almost all groups of mites with widely different feeding modes and hardly there is any plant which is devoid of acarines. Bamboos, "the poor man's timber" which form the basis of the present research work, represent an important non- woody bioresource, coming under the family Poaceae. Bamboos have a multitude of economic utility and are susceptible to infestation by arthropods, mainly by the insects and mites (Paduvil, 2008). Nearly 1,200 species of bamboos coming under 87 genera have been identified globally, with predominant distribution in South East Asia, Africa and Latin America (Ram *et al.*, 2010; Hogarth and Belcher, 2013). Approximately 3.2% of the world's total forest area (37 million hectares) is constituted by the bamboo forests. India is ranked as the second richest country in bamboo genetic resources after China (with more than 590 species) and the two countries together contribute more than half of the total bamboo resources of the world. Bamboos are regarded as the most economically important plants, having different names in different countries. The Vietnamese call bamboos "My brother" while the Chinese call them as "Friends of the people". In India, it is commonly called as the "Green Gold".

Possession of a unique combination of features like the strength, flexibility, straightness and lightness coupled with amazing variations in size, extraordinary hardness, abundance, easy propagation and short maturation time etc. raise the economic status of bamboos and presently, man depends this plant to meet more than 1500 purposes (Goyal *et al.,* 2010). The size of the plant ranges from one foot to nearly 100 feet and it is adapted to grow in different climates, from the jungles to the mountains.

Some species are deciduous while the others are evergreen and some can even thrive in much different habitats.

Since the ancient time, bamboos have become an integral part of human life. Typically the plant is useful to man from the shoot to the root. Bamboo shoots are used in the preparation of bamboo candy, chutney, canned juice, beer etc. whereas the culms are used as toothpicks, skewers, woven articles, handicrafts, curtains, laminated furnitures, flooring and vinegar preparation. Being an excellent substitute for wood in paper industries, cottage industries and domestic commodities (Lobovikov *et al.*, 2007) bamboos have gained much popularity among the people of Asia, Africa and South America. The leaves are used as fodder, in medicine and beverage while rhizome is used in handicraft industry (Yue, 2012). Bamboos are also used in road reinforcements and in bridge construction.

Bamboos are monocarpic and die after flowering. Some species bloom only once in 40-60 years. The plants compensate this limitation through mass flowering. Bamboo rice collected from the seeds is rich in nutritive and medicinal values and forms the major source of income of tribals. Bamboos play significant roles in ecological restoration also. These plants are highly preferred to reduce the impacts of landslide, having strong regenerative capacity, and with well-developed crisscrossing root system, capable of conserving water and soil quality (Yang and Hui, 2010; Paudel and Kafle, 2012). Species like *Bambusa bambos, B. balcooa, B. vulgaris, B. tulda* and *Dendrocalamus strictus* are usually planted closely in areas prone to floods and riverbanks to promote soil and water conservation, sequestration of carbon, lowering of light intensity, and also to ensure protection from ultraviolet rays and maintenance of oxygen and carbon dioxide balance in the atmosphere. Considering the above aspects, bamboos have received great attention in recent decades (Song *et al.*, 2011) and the high amenity value of which can be easily observed in many of the Asia's beautiful landscapes.

Bamboos serve as natural habitat for various groups of animals and plants, which take food, shade, shelter, nutrients and water. Many endangered animals like the Giant Panda, Mountain Gorilla, Lesser and Greater Lemurs and Bamboo rats rely on bamboos as their habitats. As many as 34 species of birds are living on bamboos in the Amazon alone. Around 1000 species of fungi have been recorded growing on bamboos alone, and their presence has not been reported from elsewhere.

India occupies the second position next to China, in the richness and diversity of bamboo plants, being home to 136 species coming under 30 genera (Ramachandran, 2009). The state of Kerala has 22 species and two varieties of native bamboos belonging to 6 genera such as *Bambusa*, *Dendrocalamus*, *Pseudoxytenanthera*, *Sinarundinaria*, *Schizostachyum* and *Ochlandra,* which constitute 19% of the total bamboos of the country. Species like *B. vulgaris, B. polymorpha, B. balcooa, B. multiplex, D. brandsii, D. longispathus, D. giganteus, D. hamiltonii, Thyrsostachys oliveri, T. regia* and still more are cultivated in Kerala and the most common species among these are *B.bambos* and *D. strictus* which are grow in dry plains and hilly tracts. The total stock of thorny bamboos (*Bambusa bambos*) in the forests of Kerala is estimated to be around 2.63 million tonnes and these are well distributed in the forests of Chinnar, Nilambur, Attapady and Nelliampathy at an altitude of 150-750m above the sea level. Kerala has around 11 types of thin walled bamboos called as reeds, belonging to the genus *Ochlandra* and these are used mainly for weaving puposes by the artisans and are supplied mainly to the artisans through the State Bamboo Corporation.

Kerala is one of the largest bamboo producing states in India. Bamboos are locally called as Mula and the reed is locally called as Eetta or Oda. Bamboo industry is one of the age old traditional industries of Kerala. Wayanad is one of the major districts having large bamboo forests. In Kerala, 67.3% of the extracted bamboo comes from home gardens and not from the forests. About one lakh people in Kerala depend on bamboos for their livelihood. Kerala's handicraft industry is dependent on five species of bamboos viz. *B. bambos, D. strictus, D. stocksii, O.travancorica* and *Pseudoxytenanthera ritcheyii*. Due to the unique characters, from the tag of "poor man's timber", bamboo is being raised to the status of "the timber of the 21st century". Species like *B.vulgaris, B. tulda, D.asper, D. brandisii, D. giganteus, D. longispathus, D. membranaceous, Guadua angustifolia, T. oliveri* are some species of bamboos suitable for cultivation.

During the past two decades, several species of bamboos are under the threat of extinction (Biswas, 1997), owing to excessive use and over exploitation. Large scale reduction of bamboo habitats due to poor harvesting and over harvesting, illegal encroachments in forest areas, establishment of river associated projects, shifting cultivation, gregarious flowering and extensive forest fire resulted in the destruction of bamboos. Changes in rainfall patterns also contributed to the decline of bamboos. Another factor which affects the bamboo diversity is pest attack and a lot of pests are reported right from the seed to the finished products. Many borers, defoliators, shoot borers and sap- suckers hamper the growth of bamboos. Insects coming under orders Orthoptera, Hemiptera, Lepidoptera, Hymenoptera and Coleoptera attack seeds, foliage and culms of bamboos (Koshy *et al.,* 2001). Species of the genus *Bambusa* are susceptible to the attack of nearly 40 species of aphids (Blackman and Eastop, 1994).

Spider mites and mealy bugs are amongst the worst pests affecting the bamboos worldwide. Species of spider mite genera *Aponychus* and *Schizotetranychus* and also the eriophyid mites either alone or in mixed populations cause serious injuries to bamboo plantations. Orchards, plantations and nurseries are the perfect breeding grounds for these pests. Bamboo spider mites are cosmopolitan, distributed everywhere bamboos exist. They cause potential damage to the leaves and weaken the bamboo plants by sucking sap and reducing photosynthetic efficiency. These mites spin tough webs to protect their eggs and juveniles and cause irreparable damage to leaves and the aesthetic value of ornamental bamboo leaves is reduced greatly. Among the spider mites, species of *Schizotetranychus*, known as the nest weaving spider mites, are considered as the most serious pests of bamboos. Members of this genus prefer the leaves of newly growing bamboos. In bamboos which renew leaves in two years, the attack by these mites on the new leaves pose a serious threat to the vitality of plants. Spider mite infestation initiates along the midvein or edge of the leaf where a linear depression is typically found. A newly formed web is composed of a single translucent layer and mites live underneath the webbing. More and more layers are added as the colony ages, resulting in an opaque, shiny and protective nest. Social behaviour is also met with in these species, similar to ants, termites and bees. They exhibit parental care and protect the colony from predators through active defensive mechanisms. Adults defend their nests and offspring by driving away nest intruders or by killing them. Waste management behaviour also is displayed by the members to keep their nest space and food from becoming fouled by group living.

Aponychus corpuzae is another important spider mite pest, which is widely distributed on various bamboo species throughout Asia. It prefers mostly the older shoots and leaves of bamboos. *A. corpuzae* seldom produces silk threads and is not adapted for wind dispersal. Bamboos harbor predatory mites also and members of the phytoseiid genus *Typhlodromus* are the most dominant predators associated with bamboos. Many phytoseiid species display a dispersal behavior called "posturing" with the help of wind (Tixier *et al.*, 1998). Some other phytoseiid predators frequently seen in association with the bamboo spider mites are the members of *Phytoseius*, *Neoseiulus*, *Amblyseius*, *Paraseiulus* and *Typhlodromips*. Apart from Phytoseiidae, members of predatory families like Stigmaeidae, Tydeidae and Chelytidae also show association with bamboo mites. Several species of tarsonemid mites are also reported from bamboos.

Despite the rich diversity, abundance and injurious status, the bamboo mites still remain as a very poorly explored entity and the reports are mainly concentrated on the studies made in China and Japan and some scattered information available in Brazil, Hungary and United States (Saito, 1990a; Lin, *et al.,* 2000; Zhang, *et al.,* 2000f, Zhang, *et al.,* 2003; Gotoh and Shida, 2007 and Kontschan *et al.,* 2015). Though India is the second country with respect to bamboo wealth and diversity, and Indians especially the Keralites heavily depend on this plant to meet various requirements in almost all fields of their life such as, nutritional, medicinal, industrial, occupational, ecological, ceremonial and the like, no earnest attempts have been undertaken either by the public or the Government sectors to study the faunal composition of bamboos and to elucidate the economic status of the various faunal ingredients. In this context, the present work was undertaken as a basic step to explore the faunal diversity of bamboo mites, to study in detail the taxonomic diversity and species composition of bamboo mites, to study the nature and extent of damage induced by selected common, dominant species on their host species of bamboos, and to trace the developmental biology and life history parameters of selected species.

With these objectives, the present study was initiated to find out the important species of bamboos growing/cultivated in different localities of Kerala, to screen the faunal composition and population density of bamboo mites, to identify the dominant species and trace the injurious status of the dominant species through qualitative and quantitative studies of feeding habits and also to conduct biological observations on the life history and life stages of selected most injurious and locally important species. This study forms the first of its kind in India, especially in South India and it would help to enrich the existing knowledge on the biodiversity of mites in general and bamboo mites in particular.

One of the fundamental quests of science, especially the biological science is the discovery as well as description of the existing biodiversity of our mother earth. The need for an authoritative taxonomic information of the various taxa of the existing flora and fauna has become higher than ever, as mankind is facing several crucial issues related to habitat loss, global warming, climate change, invasive species, biodiversity loss and so on. Being the most abundant group of arthropods, insects have received comparatively greater attention by scientists, especially the entomologists, the Arachnida the second larger group next to insects, still represents a relatively less focused group and the Acari, the largest group of Arachnids forms a totally neglected group in India, especially in a South Indian states like Kerala. Being one of the biodiversity rich area with splendid natural resources like the forests, rivers, mountains, oceans etc. Kerala is blessed with an abundance of diverse faunal entities, particularly of the invertebrate groups. Dearth of knowledge on the importance of individual faunal component coupled with the lack of experts in the concerned groups together pause a great hindrance to the progress of invertebrate taxonomy in our country, especially in the state of Kerala. This is especially true with respect to Acari and at present, studies related to the survey, identification, description of species etc. of mites are facing a total neglect even among the scientific sector. As a result, information on the faunal diversity of mites is relatively very scarce and as far as the bamboo mites are concerned it is practically meager. Bamboos constitute an important crop with a multitude of uses to all sectors of people on a global level and India has an amazing diversity of bamboos, ranked with the second position after China. India together with China and Myanmar share 19,800,000 hectares of bamboo resources with an annual production of around 3.2 million tones (Ramachandran, 2009). Bamboos are considered to be one of the Nature's gift and known by different geographical names like 'the green gold of the forest', 'wood of the poor', 'friend of the people' and so on.

The bamboo diversity of India has been recognized to include 125 native and 11 exotic species belonging to 30 genera (Ramachandran, 2009). The most dominant genera of bamboos in India are *Bambusa*, *Dendrocalamus* and *Ochlandra*. Together, these three genera constitute 45% of the total bamboo species in India. More than 50% of the total species of bamboos in India are found in Eastern India, *viz.* Assam, Arunachal Pradesh, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim, Tripura and West Bengal. Other bamboo rich areas of India include the Andaman and Nicobar Islands, Bastar region of Chattisgarh and the Western Ghats.

Being highly adapted to grow in varied climatic conditions and with their innate potential to withstand extremes, bamboos play very vital roles, which are closely interwoven with various, ecological, environmental and health related aspects. The unique root system of bamboos very effectively hinders soil erosion, thereby ensuring protection and conservation of water. Bamboos grow in extremes of climates from the cold mountains to the hot jungles. Being one of the fastest growing plants on earth, bamboos support various industries which are now booming in Asia and are quickly widening across the continents.

A healthy stand of bamboo is surprisingly resistant to pests and diseases. But still several insects depend on bamboos for their food and shelter and hence are liable to be attacked by various kinds of pests (Singh and Bhandari, 1988; Tewari, 1988; Paduvil, 2008). The common pests associated with bamboos are the mites, aphids, mealy bugs, scale insects and ants. Mites, being very minute and less devastating when compared to the insects, generally get unnoticed, but are very significant as once they get established it is very difficult to eradicate them from bamboos.

Morphologically, mites show remarkable variation from insects in showing the complete absence of wings, body segmentation, antennae, maxillae and mandibles. Insects possess three pairs of legs while the mites have four pairs of legs except in the larval stage and in the group Eriophyioidea, the members possess only two pairs of legs in all stages of development. The body of mites is differentiated into gnathosoma and idiosoma, the former includes the mouth parts, comprising the paired chelicerae and pedipalps. The idiosoma is further demarcated into Propodosoma and Hysterosoma. Idiosomal striae have significant roles in determining the taxonomic identity of species. Further, the number, position, nature and relative lengths of idiosomal setae all supply taxonomic information for species identification. Generally, the legs of mites are five segmented, with the segments being the trochanter, femur, genu, tibia and tarsus. The number, nature and position of leg setae show variation from species to species and often features like the empodia, macrosetae, feather claws, solenidia etc. serve as important tools for species identification.

Bamboo mites are diverse having varied modes of feeding and breeding strategies and represent different feeding guilds. Some species are exclusively phytophagous, while others show predatory and saprophagous habits. Generally, members of Tetranychidae, Eriophyidae, Tarsonemidae, Cheyletidae, Cunaxidae, Eupalospellidae, Stigmaeidae, Phytoseiidae and Erythraeidae are the common and widely distributed species associated with bamboo plants. Of these, spider mites of the family Tetranychidae colonise the undersurface of bamboo leaves, and which initiate infestation along the midrib or leaf edge with specific preference to occupy linear depressions present on the foliar surface, where they readily spin webs. Bamboo leaves with prominent multiple veins would serve as ideal sites for the build up of mite colonies and hence such leaves are highly susceptible to mite attack.

Economic damage results only when sufficient plant materials are lost or removed as a result of prolonged feeding by high mite populations. The populations required to cause visible or measurable symptom are influenced by the vigour of the plant, food and moisture supplied to the leaves by the root and transpiration rate which in turn is affected by the weather conditions. The faunal diversity and population dynamics of bamboo mites, like all other faunal components, are greatly influenced by the prevailing climatic factors. Among the seasonal factors, temperature, rain fall and relative humidity (RH) have been shown to exert tremendous impact on the population density and developmental parameters of mites. Generally, bamboo mite populations attain peak levels, exerting the maximum degree of damage to the foliage during summer months, as the dry season accelerates the development of mites. On the other hand, rain fall exerts a negative impact, leading to a decline in the mite density as evident during field sampling. A decrease in the relative humidity also would impose a slight reduction in mite population. During unfavourable conditions, prevalence of adversely affecting climatic factors would induce a cessation of physiological activity, leading to a condition similar to diapause and such diapausing individuals resume their normal activity at the onset of optimum conditions.

The present chapter is focused on the exploration of faunal diversity of bamboo mites by undertaking extensive surveys on the various species of bamboos grown/cultivated in different localities distributed over five districts of Kerala. Though Kerala is rich in sylvan resources and bamboos form one of the dominant species, no earnest attempts have been undertaken so far neither to elucidate the faunal diversity of bamboo mites nor to study the nature and extent of damage induced by these mites. Hence the present work was taken up to generate knowledge on the species composition of bamboo mites, population fluctuations of dominant species with respect to climatic factors, feeding damage induced by dominant species and also to trace the breeding parameters of injurious species.

CHAPTER I

FAUNAL DIVERSITY AND POPULATION STUDIES ON BAMBOO MITES

Relatively very little information is available in India on the bamboo mites and much of the faunal diversity of mites associated with Indian bamboos remains as unexplored. The present study forms the first of its kind to provide information on the mite fauna, systematic position and salient features of the various species of bamboo mites, seasonal distribution and population dynamics of selected dominant species and the details of the feeding and breeding parameters of these species. Accordingly, the review of literature presented here is mainly concerned with the incorporation of research works done on the faunal composition and species description.

The earliest record on mites associated with bamboos was made by Chilson (1941) by discovering a species of the snout mite of the family Bdellidae viz. *Bdella distincta* Baker and Balock on Bamboo and it was Rainwater (1963) who made a record on this discovery. Paschoal (1971) described a new species of *Schizotetranychus* viz. *S. taquarae* from the leaves of *Bambusa vulgaris* from Brazil. Based on the mite specimens collected from the leaves of bamboos grown in India, Prasad (1975) erected a new subgenus, *Aponychus (Stylophoronychus*) to accommodate the species, *A. (S.) baghensis* and he divided the genus *Aponychus* in to two subgenera viz. *Aponychus s.s.* and *Stylophoronychus*. The new subgenus was characterized by the presence of a stylophore, bearing two anterior horn-like projections. From the bamboo leaves collected from Southern China, Ma and Yuan (1980) erected a monobasic genus, *Sinotetranychus* to include the species, *S. guangzhouensis*. The new genus was considered by the authors to be closely related to *Aponychus*. While studying the mites of Andaman and Nicobar islands, Gupta (1980) found a new species, *A. sarjui* infesting *Bambusa* sp. Tseng (1980) recorded the presence of the predatory cunaxid mite, *Neocunaxoides andrei* in association with the decaying bamboo.

The presence of Erythraeidae was recorded in China by collecting a species viz. *Abrolophus* sp. from the Huangtan county, Hunan province by Anonymous (1980) from the leaves of bamboo, wild chrysanthemum, broad bean, elm, day lily and cotton. The presence of spider mites belonging to the genus *Schizotetranychus* viz. *S. bambusae* and *S. celarius* was recorded on bamboos collected from different localities and provinces of China such as Beijing, Shaanxi, Jiangsu, Guangxi, Hainan, Fujian etc. by Wang (1981), Ma *et al.* (1984) and Wang *et al.* (1985).Wang (1983) described two new species of *Schizotetranychus* from the bamboos of Sichuan, China.

The sociobiology of spider mites received significant boost by the discovery of Saito (1986a, b) on the gregarious mode of life of the species, *S. celarius* in united nests constructed on the leaves of Sasa bamboos. The author observed that the adults of the species attacked or even killed the invading predatory phytoseiid mites, to protect the immature stages living underneath the nest, and which were not always their own offsprings. Gotoh (1987) observed that the preference shown by the European Red mite, *Panonychus ulmi* to the surface of dwarf bamboo leaves varied in relation to seasonal changes. The active stages of the species preferred to get distributed on the upper surface of the leaves whereas during night hours, they preferred to live on the lower surface. These movements were dependent up on various physical factors like the light intensity, air temperature and relative humidity.

Eight species of spider mites which caused damage to bamboo forests of China were reported by Cui (1989). The species included *A. corpuzae, T. bambusae, Eotetranychus mirabilis*, *S. celarius*, *S. elongatus*, *S. bambusae*, *S. minutus* and *S. emeiensis*. Saito (1990a) recorded the presence of *S. miscanthi* and *S.longus* for the first time on bamboos. The presence of two species of *Aponychus viz. A. corpuzae* and *A. vannus* on the foliage of the ornamental yellow bamboos of Java, Indonesia was recorded by Johnston and Flechtmann (1990). Wang and Cui (1991) described a new species under the genus *Schizotetranychus* viz. *S. elongatus* from the bamboos collected from Yunnan, China. Yu and Shi (1991) conducted studies on *S. nanjinensis*, a species specifically reported from the moso bamboo and other bamboo plants.

Wang *et al.* (1994) recorded the presence of *S. bambusae* on bamboos collected from Anhui, of China. The association of rust mites belonging to the superfamily Eriophyoidea with bamboos was reported by several authors. Kuang (1991, 1995) described several species viz. *Knorella gigantochloae*, *K. bambusae*, *Gigantochloa ligulata*, *Neoknorella bambusae*, *Dichopelmus bambusae*, *Aculus bambusae*, *Abacarus bambusae*, *A. panticis*, *A.wuyinensis* and *Acarhynchus dendrocalami* inhabiting on different species of bamboos growing in different regions of China. The presence of mite species like *S. papillatus, Pretydeus reticulatus, Agistemus tarsilobus* and *Euseius ho* on bamboo leaves was reported by Flechtmann (1995a) from Brazil. Four new species viz. *Monoceronychus bambusicola, Oligonychus santoantoniensis, S. longirostris* and *S. paraelymus,* were described from bamboos growing in the North western Sao Paulo

State of Brazil by Feres and Flechtmann (1995). The authors recorded a total of 12 species of mites belonging to 11 genera and 5 families in association with *Bambusa* species and they also recorded the genus *Cheletomimus* for the first time from South America.

The association of tarsonemid mites with bamboos was reported by several authors. Lin and Zhang (1995) described species viz. *Diadalotarsonemus biovatus*, *Steneotarsonemus acricorn*, *Tarsonemus randsi* and *T. scaurus* from the moso bamboos of Fujian. Infestation by several species of spider mites viz. *S. nanjingensis*, *S. bambusae*, *A. corpuzae* and *O. urama* in the moso bamboo forests of Fujian, China, was brought to light through the studies of Zhang *et al.,* (1997) and the authors observed that these species induced defoliation, leading to large scale destruction of bamboos. The presence of predatory mites of the family Phytoseiidae on bamboos growing in China was observed by Wu *et al.,*(1997). The authors recovered nine species of phytoseiids representing three genera viz. *Amblyseius, Phytoseius* and *Typhlodormus* and the species recorded were *A. pascalis*, *A. ezoensis*, *A. ainu*, *A.baraki*, *P.nipponicus*, *P. hawaiiensis*, *P. chinensis*, *P. brevicrinis* and *T. higoensis*. Predatory mites belonging to other families were also reported in association with bamboos. The association of predatory mites belonging to Raphignathoidea with bamboos was reported by Fan *et al.,*(1997).

Extensive surveys were carried out by Zhang *et al.,* (1998c) on the mites infesting bamboo forests in 63 countries/ cities/districts. The results of their studies showed that 5% of the bamboo forests were heavily damaged, 30% were moderately damaged and 40% were lightly damaged and 25% were free of mite infestation. Zhang *et al.,* (1999b) described species viz. *Tetra phyllostachyis* on *Phyllostachyis pubescens* from bamboos of Zhangping county of Fujian. Studies made by Lin and Zhang (1999) also revealed the presence of *T. cornus* on bamboos growing in Fujian.

A new species under the genus *Abalakeus* viz. *A. bambusae* belonging to the family Erythraeidae was collected and described by Zhang *et al.,*(2000f) from the leaves of moso bamboo growing in China. The same authors (2000e) described three new species of *Schizotetranychus* viz. *S. nanjingensis*, *S. bambusae* and *S. tenuinidus* from the bamboos of China. The authors also provided a key for separating the females of three species along with notes on their biology. Lin *et al.,* (2000) prepared a checklist of mites infesting the moso bamboos of Fujian, China providing information on 45 species of mites coming under 23 genera and 9 families. The authors reported that tetranychid species viz. *A. corpuzae* and *S. nanjingensis* and the eriophyid species, *Aculus bambusae* either alone or together caused serious damage to these bamboos. Extensive survey carried out by Fan *et al.,* (2000) enabled to collect four species of stigmaeid and three species of eupalopsellid mites from leaves of the bamboo species, *P. pubescens*. Of these, four species viz. *Eryngiopus dicrotrichus*, *Saniosulus molliculus*, *S. longidius* and *S. yonganensis* were new to science. The authors also provided a key to separate the species of the genus *Saniosulus*.

Lin and Zhang (2000) recorded the occurrence of a species of Bdellidae viz. *B. muscorum* on maple and bamboo. The spider mite genus, *Stylophoronychus* infesting moso bamboos was reviewed by Zhang *et al*., (2000g) and the authors made the first report of *S. baghensis* from China. The authors subsequently (2000c) studied the impact of physical and biological factors on the mite pests of moso bamboos by recording the effects of temperature, relative humidity, rainfall and predation by predatory mites. Studies on the population dynamics of *S. nanjingensis*, *A. corpuzae* and *A. bambusae* and their natural predator, *Typhlodromus bambusae* were made by Zhang *et al.,* (2001f) in moso bamboo forests of Nanping, Fujian, China. The authors recorded that out of the 68 countries of Fujian, the moso bamboo forests of 63 countries were damaged by spider mite species like *S. nanjingensis*, *A. corpuzae* and the eriophyid mite, *A. bambusae*.

Ho (2003) made a redescription of the species, *A. corpuzae* collected from the bamboos of Taiwan, based on the length of dorsal setae and leg chaetotaxy. Zhang *et al.,* (2003) studied the migratory behavior of spider mite pests such as *A. corpuzae*, *S. nanjingensis* and the predatory mite species, *T. bambusae*. The authors observed that a sticky barrier around the stem was effective in disrupting the ambulatory immigration of pest mites from the ground to new leaves but it had no effect on the migration of the phytoseiid predator. Based on the morphology of the distal segment of palpus, Saito *et al.,* (2004) reinstated the genus *Stigmaeopsis* and described two new species viz. *S. saharai* and *S. takahashii* infesting the bamboo forests of Hokkaido, Japan.

Infestation by three new species of vagrant type of eriophyid mites on the bamboos growing in the Qinling Mountains of China was reported by Xue *et al.,* (2006). The new species described were *Tegolophus bashaniae*, *T.fargesiae* and *Tetraspinus vulgaris*. Lin *et al.,* (2006) collected the bdellid species, *B. uchidai* from the bark of trees and falling leaves of bamboo in the Fujian Province. While studying the life cycles and interactions of mite species on dwarf bamboos in Japan, Gotoh and Shida (2007) observed the coexistence of different species on the same bamboo leaves. The authors further recorded that species viz. *A. corpuzae*, *Panonychus bambusicola* and *S. longus* preferred glabrous leaves while *S.recki*, *Yezonychus sapporensis* , *A. summersi* and *P. tenuiformis* preferred hirsute leaves .

Infestation by spider mite species like *S. bambusae* on the bamboos growing in France was reported by Auger and Migeon (2007) and the presence of *S. nanjingensis* was recorded by Pellizzari and Duso (2009) on the bamboos of Europe (Italy). The authors observed the preference of *S. nanjingensis* to the lower surface of bamboo leaves, where it constructed dense web nests to protect its colonies. The nests were easily recognized by the presence of whitish spots developed on the underside of bamboo leaves. Hernandes and Feres (2010) provided information on the infestation of *A. corpuzae* on the bamboos growing in the forests of West- Palaearctic region of Europe. Konvipasruang *et al.,* (2012) redescribed seven species of eriophyid mites collected from bamboos of Thailand. The authors replaced *Neocatarhinus bambusae* with *N. namtai*, *Abacarus bambusae* was replaced by *A. sklaengensis* and *Aculus asperi* was reassigned to *Abacarus*. The authors also redescribed the species, *Kolacarus bambusae* and *Knorella thailandica.*

The population density of bamboo mites was found influenced by climatic factors as evidenced through the studies of Vibija and Ramani (2015) and the authors recorded the effects of temperature, relative humidity and rainfall on the population of *Schizotetranychus* sp. infesting on *B. multiplex*. Studies made by Chae *et al.,* (2015) provided clear evidence of reproductive isolation between sympatric species inhabiting on bamboos viz. *S. celarius* and its sibling species. Seljak (2015) newly recorded the infestation of *A. corpuzae* on the bamboo species, *P. bambusoides* in the South- Western Slovenia, Europe. Kontschan *et al.,* (2015) surveyed the mite fauna inhabiting the litter of five different bamboo plantations and described 11 species of mesostigmatid mites and 10 species of oribatid mites in association with the bamboo litter.

Studies of Chandrapatya *et al.,* (2016) disclosed the oligophagous habit of two species of eriophyoid mites on closely related species of bamboos in Thailand. The authors recorded the infestation of *N. namtai* on two species of *Bambusa* viz. *B. ventricosa* and *B. vulgaris* while the other species, *K. bambusae* infested on five species of *Bambusa* viz. *B. bambos, B. blumeana*, *B. multiplex, B. ventricosa*, *B. vulgaris*, and one species of *Dendrocalamus viz. D. latiflorus.*

In par with the objectives of the study, detailed surveys were conducted for a period of four years, from November 2012-2016 to explore the faunal diversity of mites associated with bamboos. During the survey period, samples of bamboo leaves/leaf sheaths etc. harbouring the various mite specimens were collected from bamboo plants/groves growing/cultivated in different localities of Kerala. A total of 18 sampling sites distributed over 5 districts of Kerala viz. Kannur, Kozhikode, Malappuram, Wayanad and Thrissur were considered for the conduct of regular/intermittent sampling of bamboo leaves. The different collection localities considered for the study of bamboo mites are discussed below:

I. Collection sites (Plate 1)

A. Sampling localities in the Kannur Dt.: In the Kannur Dt., three sites were considered for sampling of bamboo plants included in the present study.

1. Iritty (11º59′20.5044″ N 75º40′37.4016″ E; Sea Level: 57m) – It is also known as Coorg valley of the God's own country. Unique rivers, streams, green valleys and hills add to the beauty of the locality. The major vegetation of Iritty is rubber. Bamboos are seen scattered in the homes or nearby areas. Two species of bamboos viz. *Bambusa bambos* and *Bambusa vulgaris* were recognized as the dominant species in this area.
2. Kottiyoor (11º52′32.0448″ N 75º51′52.6932″ E; Sea Level: 139m) – This site lies in the eastern area of Kannur, located in the hills of Western Ghats. This region is classified as Critical Biodiversity hot spot as it is a transition zone between the moist forests in the South to the dried forests of the North. The main vegetation types are the tropical evergreen and the tropical semi evergreen. The most common species of bamboos located at this area were *B. vulgaris*, *B. bambos* and *Ochlandra travancorica.*
3. Pappinisseri (11º56′34.2096″ N 75º20′59.8668″ E; Sea Level: 11m) – This region is known for small islands and hills and characterized by the possession of varied types of vegetation. Bamboo plants are also found growing in a scattered manner, with the dominance of a species of *Ochlandra*.

B. **Sampling localities in the Kozhikode Dt**.: In the Kozhikode Dt., five sampling sites were selected for collection of bamboo leaves.

4. Janakikadu (11º37′47.928″ N 75º47′9.0924″ E; Sea Level: 19m) – This site is situated in the Maronthongara panchayat of the Kuttiyadi range coming under the Kozhikode forest division. The site derives its name from V.K. Janaki Amma, sister of the renowned statesman, V.K. Krishna Menon to whom this 131 hectares of land once belonged. This ecological hotspot, Janakikadu homes over 680 species of rare plants. The bamboo vegetation of this area is dominated by the species, *B. vulgaris*.

5. Thusharagiri (11º28′23.0808″N 76º3′15.264″E; Sea Level: 465m) – This area includes beautiful waterfalls, located in the Kozhikode district. This place is so called due to the presence of three waterfalls which create a snowy spray. The place is well known for trekking, rock climbing and the presence of some rare and beautiful plant species. Bamboo groves were seen scattered throughout the region with a dominance of *O. travancorica.*

6. V M K Botanical Garden (11º20′35.0484″N 75º53′26.4768″ E; Sea Level: 42m) – This is a private botanical garden under the ownership of a person, Shri. V. Mohammed Koya, and it spreads over two acres of wooded land. The area is situated about 20 km east to the Kozhikode town on the Kozhikode-Wayanad State highway. This garden is home for 250 varieties of plants including the bamboos, palms, medicinal plants, ficus, olive, chestnut and cinchona. *Dendrocalamus longispathus*, *O. travancorica, B. strictus* and *B. arundinacea* were some of the common species of bamboos seen in this beautiful garden.

7. Vanaparvam Biodiversity Park (11º29′47.7204″N 75º58′3.8964″ E; Sea Level: 57m) – This park was started as a part of the Eco-tourism project in the Thamarassery forest range in Kakkavayal, of the Kozhikode district. The vegetation of this park includes around 150 species of herbal plants, 23 species of bamboo saplings and 20 orchid varieties.

8. Kakkadampoyil (11º20′10.2444″N 76º6′36.9″ E; Sea Level: 675m) – This is a small site, partly located in the Malappuram and Kozhikode districts of Kerala, and is located about 24 km from Nilambur. It occupies the top of the

Western Ghats, and is characterized by the presence of dense valleys and forests. Bamboos constitute one of the major vegetation along the roadsides with a wide distribution of *O. travancorica.*

C. Sampling localities in the Malappuram Dt.: In the Malappuram Dt., five sites were included in the survey, of which Calicut University Campus and the adjacent sites were the major localities considered for frequent sampling of bamboos.

9. Calicut University Campus ($11^{o}8'1.9212''$N $75^{o}53'26.3148''$ E; Sea Level: 77m) – The University Campus forms an excellent biodiversity centre for the *ex-situ* conservation of flora and fauna. The Calicut University Botanical Garden (CUBG) is the largest and most diverse botanical gardens among the varsities across the country, and is the unique site to shelter hundreds of rare, endangered and threatened (RET) trees from the ecologically fragile Western Ghats, and recently it has been included in the coveted UNESCO World Heritage list. The CUBG spreads over an area of 19.5ha and it formed the important collection site for making regular sampling of mites involved in the study. Some of the important species of bamboos in the Botanical Garden are *B. bambos*, *B. vulgaris*, *B. multiplex*, *O. travancorica* etc.

10. Nilambur Teak Museum ($11^{o}18'1.026''$N $75^{o}15'0.9288''$ E; Sea Level: 39m) – The teak museum is situated 4 km from the Nilambur town. Besides the best teak forests, the museum also harbours 23 varieties of bamboos, medicinal plants and other plantations.

11. Villunniyal ($11^{o}7'54.066''$N $75^{o}53'19.1472''$ E; Sea Level: 71m) - This site is situated hardly 1 km away from the Calicut University Campus and it is a homely area having a wide range of flora. The site is characterized by bamboo plants of the species, *B.vulgaris* and *B. bambos* grown in the homeyards and hence selected for sampling.

12. Conolly's Plot ($11^{o}16'6.1644''$N $76^{o}12'22.2156''$ E; Sea Level: 21m) – This site is commonly mis- spelled as Canoli plot/ Canoly's Plot, and it is known for its oldest teak plantation. The site is located in the Vadapuram region, near to the Government depot of Nilambur. This place is well maintained by the Forest department and hence the flora has been conserved as such in the

natural habitat. Among the vegetation, bamboo plants of the species, *B. bambos* were found growing in a scattered pattern and hence was selected as one of the sampling sites.

13. Kadavu Resort and nearby areas (11º12′17.0172″N 75º51′59.3676″ E; Sea Level: 20m) - The resort is located along the banks of the river Chaliyar. This site constitutes a charming location with groves of swaying coconut palms and bamboos facing the water. Clumps of *B. vulgaris* are present at the site and hence selected as one of the major sampling sites during the present study.

D. Sampling localities in the Wayanad Dt. : In the Wayanad Dt., four localities were considered for the survey of bamboo mites, of which two represented uninhabited forest cum sanctuary areas. The localities were:

14. Muthanga Forest (11º38′43.5264″N 76º22′32.6388″ E; Sea Level: 861m) – The sanctuary is a part of the Nilgiri Biosphere Reserve, and is well known for its rich biodiversity. This sanctuary consists of mostly moist deciduous forests with semi evergreen patches. Main vegetation is formed of rosewood, bamboos, Lagerstroemia, *Veteria indica* and *Terminalia paniculata*. The bamboos are predominated by *B. bambos*.

15. Pookode Lake (11º32′32.748″N 76º1′39.1296″ E; Sea Level: 769m) – It is located about 15km from Kalpetta town. It is a natural fresh water lake situated amidst the evergreen forests and mountain slopes, about 770 m above the sea level. Bamboos belonging to the species, *B. vulgaris* were found growing along the shore of the lake and hence the site was selected as one of the sampling localities.

16. Thirunelli Temple (11º54′42.1092″N 75º59′45.0744″ E; Sea Level: 865m) – It is an ancient temple situated in a valley and is built on the side of the Brahmagiri hill, at an altitude of about 900m in north Wayanad. The temple is surrounded by mountains and beautiful forests and the place is situated at 32 km away from the Manathavady town. Rich growth of bamboo bushes is present at this site and hence selected as one of the collection sites during the study.

17. Kuruvadweep (11º49′18.0012″N 76º5′31.9992″ E; Sea Level: 723m) – This forms one of the uninhabited, dense and evergreen forests of Wayanad and is the home to rare kinds of fauna and flora. This place embraces 950 acres of protected river delta on the Kabini river in the Wayanad district of Kerala. It is the only island surrounded with naturally purified water source. This place is well known for its bamboo canopy and hence selected for collection of bamboo mites.

E. **Sampling localities in the Thrissur Dt.:** A single site was selected from the Thrissur Dt. and which was the man made bamboo plantation raised by the Kerala Forest Research Institute (KFRI).

18. Velupadam- KFRI Field Research Centre (10º25′38.7876″N 76º20′36.4848″ E; Sea Level: 27m) – This bambusetum was established by the KFRI, as part of the IDRC Bamboo project. Sixty three species of bamboos formed the major attraction of this centre. This area spreads in 47.3 ha and provides valuable information on clump development, culm production and management practices like weeding, soil working and selective cutting. This bambusetum also serves as genetic resource for future crop improvement programmes.

II. Bamboo species Surveyed:

A total of 27 species of bamboos (Table-1) were surveyed from the different sampling localities listed above. Table-1 lists the economic utility of each species along with data on their distribution in different sites etc. As shown in the table, the 27 species of plants could be categorized under 9 genera of a single family Poaceae.

III. Collection of samples:

During sampling, the aerial parts of bamboo plants such as the leaves, leaflets and culms which displayed visible symptoms of mite infestation were collected at different heights from bottom to top of bamboo plants. The maximum height considered for collection of leaf/culm samples was 250 cm, from plants with erect posture while from bent plants the height was still higher, reaching up to 350cm. Small twigs bearing the leaves/leaf lets were cut with the help of a scissors and the collected samples were immediately transferred to zip lock bags, labeled and transported to the laboratory for subsequent studies. Proper care was taken while transporting the collected samples to ensure protection from becoming dried up through direct exposure to sunlight and also from water/moisture condensation inside the polythene bags. In the laboratory, the collected samples were subjected to thorough microscopic examination under a stereozoom microscope (Radical Scientific Equipment, Model No: RSM- 47). While examining the individual leaf sample under the microscope, care was taken to record data on the sites of mite infestation, nature of infestation, life stages of the mites, preferred sites on the foliar surface, feeding symptoms caused, mode of feeding etc. For determining the faunal diversity of mites associated with leaves of different species of bamboos, the live mites were segregated with the help of a moistened camel hair brush and preserved by transferring to 70% alcohol in a cavity block for further processing.

IV. Preparation of specimens for taxonomic studies:

a) Dehydration and clearing of specimens:

The mite specimens preserved in 70% alcohol were dehydrated in alcohol series by passing through 80%, 90% and absolute alcohol. The less sclerotized specimens, especially most of the prostigmatid and astimatid members were directly slide mounted in Hoyers' medium while the highly sclerotized forms like the members of the suborder Oribatida required further clearing. The dehydrated oribatid specimens were transferred to eppendorf tubes containing clearing medium prepared by mixing equal volumes (1:1) of absolute alcohol and lactic acid. Depending upon sclerotization, oribatid specimens required varied clearing time ranging from a few weeks to a few months and quite often around one year. The cleared specimens were slide mounted in Hoyer's medium for subsequent examination to determine the taxonomic identity.

i) Preparation of Hoyer's medium:

The mounting medium used for making the slide mounts of mite specimens was prepared with the following ingredients:

Gum Arabic	:	30 g
Chloral hydrate	:	200 g
Distilled water	:	50 ml
Glycerol	:	20 ml

The above chemicals were weighed in the prescribed quantities and added to a 500 ml beaker. The mixture was gently warmed on a heater with frequent stirring. When all the chemicals were dissolved, heating was stopped and the mixture was cooled to room temperature. After cooling, the mixture was filtered through cotton and the filtrate was stored in an amber coloured bottle and used for mounting of mite specimens.

b) Preparation of slide mounts of mite specimens:

A small drop of Hoyer's medium was placed at the centre of a microslide and the mite specimen was transferred to the medium using a fine hair brush. The specimen was oriented properly in the dorsal/ventral/lateral position with the legs stretched outwards so as to make the morphological features clearly visible for microscopic examination. Small glass bristles, approximately of the same size as that of the specimen were also placed adjacent to the specimen on the microslide to prevent the crushing or other damage of the specimen which might be possible while placing the coverslip. For preparing temporary mounts of the specimens, lactic acid was used. The slides were labeled by providing collection data such as date of collection, name of collection locality, name of host plant etc. The mounted slides were kept in an oven at 30ºC for around one week to facilitate adequate clearing of the specimens. Properly cleared and labeled specimens were transferred to slide boxes and stored.

c) Identification of Mite specimens:

Identification of slide mounted specimens was made following the general keys available in standard text books authored by Krantz and Walter (2009) and Zhang (2003) up to the order/family levels. Identification up to genera/species was made following books on plant mites like Baker and Pritchard (1960), Jeppson *et al.,* (1975); Hughes (1976), Gupta (2002, 2003), Mary Anithalatha and Ramani (2009) and relevant research publications and keys. For identification of oribatid specimens, identification keys of Balogh (1972), Balogh and Mahunka (1978), Balogh and Balogh (1992 and 2002), and relevant research publications on oribatid taxonomy were referred and confirmation of species was made with the help of experts. The morphological features of individual specimen were examined under a binocular phase contrast research microscope (Leitz-Diaplan) and the characters were compared with those of the described species following the keys/literature. Morphological features of individual species were drawn using a prism type Camera Lucida attached to a binocular research microscope (Unitron). Measurements of the specimens were made using an ocular micrometer.

V. Studies on the impact of climatic factors on population density of selected species:

Based on the results of field sampling, the most dominant species of bamboo spider mite viz. *S. schizopus* was selected for detailed population studies on three most common species of bamboo hosts (*B. bambos*, *B. vulgaris* and *B. multiplex*) with respect to the impact of variations in the climatic factors like temperature, rainfall and relative humidity (RH). For estimating the population density of the species, the number of adult specimens present on 20 leaves of each species of bamboos mentioned above were counted on a monthly basis for a period of one year from November, 2012 to October, 2013. For recording the seasonal impact on the population density of the mite species, the one year period was categorized under three seasons viz. pre- monsoon, monsoon and post- monsoon season, based on the availability of rain. Accordingly, the period of February – May was categorized as the pre-monsoon season, June – September was considered as the monsoon season and October – January period was presented as the post- monsoon season. The number of mites present in the respective months of each season was counted separately and pooled together with respect to season and the mean population density was calculated for each season. Data on the various climatic parameters such as the temperature, rainfall and RH were collected from the nearest meteorological station, at Karipur, Malappuram Dt. For recording the impact of the climatic factors mentioned above on the population density of *S. schizopus*, correlation studies were carried out following SPSS software version 16 and the correlation coefficients were calculated for each parameter. Data were tabulated and presented graphically.

During the study period, a total of 27 species of bamboos were surveyed across five districts of Kerala for the recovery of the diverse fauna of mites associated with these plants. Among the bamboos screened from the 18 sampling sites selected during the study, two species viz. *B. bambos* and *B. vulgaris* were recognized as the most dominant species showing distribution in all the five districts surveyed. Most of the mite species recovered during the study were also found to inhabit on the foliage of the above two species of bamboos, as evidenced through the results of sampling. The survey yielded a total of 43 species of mites representing the two superorders of the Subclass Acari. The systematic position of the various species of mites recovered during the study has also been presented in this chapter.

a) Faunal Diversity:

Detailed taxonomic analysis of the 43 species of bamboo mites collected during the study enabled to categorise them under 34 genera, 18 families, 14 superfamilies, 3 suborders and 3 orders coming under two superorders viz. Parasitiformes and Acariformes of the subclass Acari. The superorder Parasitiformes constituted 30% of the bamboo mites collected and which included members of a single order viz. Mesostigmata. The latter was found represented by members of a single suborder, Monogynaspida. Despite this, representatives of two orders viz. the Trombidiformes and Sarcoptiformes were recovered from the bamboos under the superorder Acariformes, which constituted 70% of the total mites obtained during this study (Table 2; Fig. 1). The diversity of the various taxa such as the order, suborder, superfamily and family were also relatively high in the superorder Acariformes (Fig.2, Plate 4,5).

As presented in Table 2, the suborder Monogynaspida was found to comprise members of two families viz. Phytoseiidae and Ascidae. Of these, phytoseiidae was the dominant one as it included 12 species, belonging to 6 genera under three subfamilies viz. Amblyseiinae, Phytoseiinae and Typhlodrominae and constituting 83% of the total mesostigmatid mites collected during the present study (Fig 3).

Of these, the subfamily Amblyseiinae exhibited the maximum species representation, with a total of 8 species under two genera, *Amblyseius* and *Typhlodromalus* respectively. Under the subfamily Phytoseiinae, three species were recovered representing three genera viz. *Phytoseius, Paraphytoseius* and *Neoseiulus*. The subfamily Typhlodrominae was represented by a single species, under the genus *Amblydromella.* The family Ascidae was found represented by a single species under the genus, *Asca,* constituting about 17% of the total mesostigmatid mites (Table -2 & Fig. 3 & 4).

Among the phytoseiid mites collected during the study, the species diversity of the genus *Amblyseius* was found far superior to the other genera as it included 7 species out of the total 12, thereby constituting 54% of the mesostigmatid mites (Fig 4) recovered. The seven species of *Amblyseius* collected were *A. aerialis, A. bhadrakshae, A. channabasavannai, A. kundurukkae, A. largoensis, A. malabarensis* and *A. orientalis*. The remaining six genera viz. *Amblydromella*, *Neoseiulus, Phytoseius, Paraphytoseius, Typhlodromalus* and *Asca* showed representation by a single species each, thereby constituting 8% of the total species composition in mesostigmata. The species recovered under the above five genera were *A. bambusicolus, N. longispinosus*, *P. punicae, P. orientalis, T. sativae* and *A. afroaphidiodes* (Fig. 5).

Mites belonging to the order Trombidiformes recovered during the present study were found to represent 9 families viz. Tetranychidae, Tarsonemidae, Eriophyidae, Cheyletidae, Cunaxidae, Tydeidae, Stigmaeidae, Eupodidae and Bdellidae (Table 2 & Fig 6). Of these, Tetranychidae was recognized as the most dominant group showing the maximum number of genera and species, constituting 28% of the total Trombidiformes mites. The species recovered under Tetranychidae were *Aponychus corpuzae, Oligonychus biharensis, Tetranychus urticae, Stigmaeopsis longus*, *Schizotetranychus recki, S. schizopus* and *Stylophoronychus vannus*.

One of the unique observations made during the study was the occurrence of *T. urticae* in the green form on bamboo foliage in all seasons and all sampling occasions. Based on the number of inclusive genera recovered, the various families of bamboo mites identified under the order Trombidiformes could be presented in the sequence: Tetranychidae (28%) >Tydeidae (17%) >Tarsonemidae = Eriophyidae = Cunaxidae (11% each) > Cheyletidae = Bdellidae = Eupodidae = Stigmaeidae (5% each) (Table 2& Fig 6). The family Tydeidae was represented by members of three genera viz. *Tydeus, Parapronematus* and *Lorryia* and the species recovered were *T. interruptus, T. caudatus, P. acacia* and *L. stricta*. The families Tarsonemidae, Eriophyidae and Cunaxidae were found represented by two species each. As shown in Table-2, the species recovered under Tarsonemidae were *Steneotarsonemus spinki* and *Diadalotarsonemus serratus*. Both the species recovered under the family Eriophyidae were of the vagrant type and were identified as *Aceria bambusae* and *Knorella blumeanae*. The cunaxid representatives recovered from the bamboos were *Cunaxa bambusae* and *Cunaxoides decastroae*. All the remaining families viz. Cheyletidae, Bdellidae, Eupodidae and Stigmaeidae included a single species each, and the species recovered were *Cheyletus rosensis, Octobdellodes guajavae, Eupodes parafusifer* and *Agistemus aimogastaensis* respectively (Table 2, Figs. 6& 7).

Bamboo plants screened during the study were also found to harbor mites under the order Sarcoptiformes of the Superorder Acariformes and these mites could be further categorized under a single suborder viz. the Oribatida. Members of four superfamilies viz. Oripodoidea, Ceratozetoidea, Galumnoidea and Acaroidea were recovered during the present study. Of these, the former three superfamilies represented the oribatid/beetle/cryptostigmatid mites which could be categorized under the cohort Brachypylina. The fourth superfamily was found to comprise the Astigmatid/Acarid mites and which could be included under the cohort Astigmatina. Both the above cohorts were categorized under the supercohort Desmonomatides. Under the superfamily Oripodoidea, members of four families viz. Hemileiidae, Mochlozetidae, Scheloribatidae and Caloppiidae were recovered from bamboos while the remaining three superfamilies included members of a single family each. Thus superfamily Ceratozetoidea was represented by members of Heterozetidae while Galumnoidea and Acaroidea comprised members of Galumnidae and Acaridae respectively (Table 2; Fig 8).

Astigmatid mites were poorly represented on bamboo foliage as evidenced during the present study and under the Cohort Astigmata, a single species was recovered belonging to the genus *Tyrophagus*, viz. *T. putrescentiae* of the superfamily Acaroidea and family Acaridae. The Oribatid mites exhibited relatively more diversity on bamboo foliage and included eight species belonging to seven genera and five families. The species collected from bamboos under the family Hemileiidae were *Siculobata malabarica* and *Hemileius (Tuberemaeus) singularis*. Species like *Lamellobates (Paralamellobates) misella, Zetorchella sejugata, Galumna (Galumna) flabellifera orientalis* and *Scheloribates decarinatus* were the representatives of the respective families Heterozetidae, Caloppidae, Galumnidae and Scheloribatidae. The oribatid family Mochlozetidae was represented by two species recognized under the genus *Uracrobates,* viz. *U. indicus* and another new subgenus and new species viz. *U.(Ovouracrobates) keralensis*. (Table 2; Fig 8 & 9).

Results of the survey conducted during the present study on 27 species of bamboos grown across 18 sites distributed over 5 districts of Kerala enabled to locate differences in the species composition, diversity and distribution with respect to geographical variations. Accordingly, bamboo species like *B. bambos, B. vulgaris, B. multiplex* and *O. travancorica* dominated in all the sampling localities and could be identified as the widely distributed species. In general, the mites showed preference to colonize the foliage of two species of bamboos viz. *B. bambos* and *B. vulgaris* when compared to the other species screened during the study period. Bamboo species like *G. atroviolacea, M. baccifera, D. longispathus, O. scriptoria, O. abyssinica, P. ritcheyi, T. oliveri* and *T. regia* were recognized as more tolerant to mite attack. Species like *B. bamboos* was found colonized by 37 species of mites coming under 29 genera and 12 families while the leaves of *B. vulgaris* harboured 28 species belonging to 19 genera and 9 families (Tables 3 & 4). Of the total mite population recovered from the bamboo plants, 25% could be collected from *B. bambos* while 21% showed preference to inhabit on *B. vulgaris*. Bamboo species like *O. travacorica* and *D. giganteus*, which were found in abundance in the forests of Kerala, harboured comparatively lesser proportions of mite populations accounting for 8 and 11% respectively (Fig. 10). The species diversity of bamboo mites with respect to individual species of bamboos is presented in Table 5.

As presented in Table 4 & Fig 10, the numerical density of the various taxa of mites showed variation with respect to the differences in the host plants. *B. bambos* was observed to host the maximum number of species, genera and families of bamboo mites and the respective numbers could be recorded as 37, 29 and 12. *B. vulgaris* was the second bamboo species with respect to richness of taxa as it harboured 28 species under 19 genera and 9 families. *B. tulda* harboured 24 species belonging to 15 genera and 6 families while the foliage of *B. balcooa* was found preferred by 23 species of mites belonging to 17 genera and 7 families. Diversity and abundance of mite fauna were relatively very low on the bamboo species, *S. griffithiana* as it revealed the presence of only three species of mites belonging to three genera and two families.

The mites collected during the study showed considerable variation in host range among the bamboo species screened. *A. corpuzae* was the species which enjoyed the maximum host range, extending distribution on 16 species of bamboos screened during the study. An equal host range was exhibited by the predatory species coming under the family Cunaxidae viz. *C. bambusae* which was also found in association with the foliage of 16 species of bamboos. The second position was occupied by *S. schizopus*, which showed distribution on 15 species of bamboos surveyed during the study. The third position in host range was shared by two species viz. the pest mite, *T. urticae* and the member of the Tydeidae, *P. acacia*, both enjoyed distribution on 14 species of bamboos each. Species like *S. vannus* and *T. interruptus* showed association with 13 species of bamboos. Two species viz. *D. serratus*, a member of Tarsonemidae and the Ascid species, *A. afroaphidoides* exhibited minimum host range by restricting distribution on a single species of bamboo each. (Fig: 11).

The faunal composition and diversity of mites showed variation with respect to the differences in the geographical localities where the bamboo plants were grown. Accordingly, the different species of bamboos collected and screened from the various localities of Kozhikode Dt. revealed the presence of 30 species coming under 20 genera, 9 families and 3 orders. The bamboo plants screened from the various localities of Kannur Dt. harbored 15 species coming under 9 genera, 4 families and 2 orders. The bamboo plants screened from the collection sites of Malappuram and Thrissur districts showed the presence of all the 43 species listed in the table. However, the species diversity in Wayanad district was comparatively low, represented by 32 species under 23 genera, 12 families and 3 orders (Table 6 & Fig. 12).

The various species of bamboo mites collected during the study showed differences in their distribution pattern with respect to variations in the host species as well as geographical places. Species of the spider mite family Tetranychidae were the predominant members on most species of bamboos and which induced considerable damage symptoms also. Among the spider mites recovered, the populations of *Schizotetranychus* were comparatively high and *S. schizopus,* the commonly called bamboo spider mite was recognized as the most dominant species which showed a wide distribution on the bamboos surveyed from various localities of Kannur, Kozhikode, Malappuram and Thrissur districts. In addition to *S. schizopus*, the bamboos collected from Kannur and Kozhikode districts also showed dominance of other species of spider mites viz. *S. recki* and *S. longus*. Bamboo plants collected from Thrissur district showed the presence of *S. recki*, *A. corpuzae*, *K. blumeanae* and *A. bambusae* apart from *S. schizopus.* The bamboo plants collected from Wayanad district showed domination of eriophyid mites. The species collected under the family Eriophyidae were *A. bambusae* and *K. blumeanae* which formed the most dominant species on the bamboos of this area. This was followed by the spider mite population belonging to the genus, *Schizotetranychus.*

Results of the present study apart from revealing the faunal diversity of mites associated with the bamboos grown in various localities of Kerala also enabled to identify two new taxa of mites, one in the species and another one in the subgeneric categories. The new species identified was an oribatid mite belonging to the family Mochlozetidae and genus *Uracrobates*. Based on the unique possession of the oval nature of the notogaster, a new subgenus viz. *Ovouracrobates* was erected to accommodate the new species and the species was named as *U. (Ovouracrobates) keralensis* sp.nov.

Results of the survey also helped to report nine species of mites for the first time from India. The newly reported species could be listed as *A. aimogastaensis, C. decastroae, S. schizopus, S. recki, S. longus, D. serratus, K. blumeanae, A. afroaphidiodes* and *H. (T.) singularis* (Table 7). Further, the present study also helped to report four species for the first time from Kerala. The new reported species from Kerala were *S. vannus, A. corpuzae, P. acacia* and *P. orientalis.* In addition, 18 species viz. *O. biharensis*, *S. spinki*, *T. interruptus*, *T. caudatus*, *L. stricta*, *C. rosensis*, *O. guajavae*, *E. parafusifer*, *A. aerialis*, *A. bhadrakshae*, *A. channabasavannai*, *A. kundurukkae, A. malabarensis, A. orientalis, A. sativae, N. longispinosus, P. punicae* and *T. putrescentiae* could be reported for the first time from bamboo plants (Table 8 & 9).

Table 10 illustrates the results of comparative evaluation of the species richness and diversity of bamboo mites in the five districts of Kerala viz. Kozhikode, Kannur, Wayanad, Malappuram and Thrissur by calculating the Shannon- Weiner diversity indices (H′). As depicted in the table, a higher diversity index (H′) was observed for the Kozhikode (H′- 2.829) district, followed by Malappuram (H′- 2.823) and Thrissur (H′-2.685) districts. Wayanad Dt. though was found to accommodate large number of bamboos, H′ was comparatively low (H′- 2.303). The lowest H′ value was calculated (H′- 2.204) for Kannur district.

b) Impact of abiotic factors on the population density of the bamboo spider mite, *S. schizopus*

Results of studies on the impact of rainfall on the population density of the most dominant bamboo mite species viz. *S. schizopus* on three common species of bamboos viz. *B. bambos, B. vulgaris* and *B. multiplex* carried out for the period of November 2012 to October, 2013 are presented in Figs. 13, 14 & 15. As shown in the figures, the mite population showed a decrease in population with an increase in the rainfall. During the period of June to August, 2013, when the rainfall was maximum due to the onset of monsoon, the mite population showed a considerable decrease and the per leaf count of mites got reduced from 80± 10 to 3±5. A similar pattern of decrease was observed in the population density of the species on the foliage of all the three species of bamboos studied.

Relative humidity also exerted a negative impact on the population density of *S. schizopus*. As evident in Figs.16, 17 and 18, when the relative humidity was nearly 72%, the population of *S. schizopus* on *B. bambos* was nearly 80± 10 mites per leaf. But when relative humidity increased to 90%, the population was decreased to reach 2± 3 mites/leaf. A similar pattern of population decline was observed on *B. vulgaris* and *B. multiplex* also.

Despite the negative impact of rain fall and relative humidity, temperature exerted a positive influence on the population of *S. schizopus*. As shown in Fig. 19, when the temperature got increased from 27.2^{o}C to 31.35^{o}C, the mite population on *B. bambos* showed an increase from nearly 2± 5 to 80 ± 10 mites/leaf. A similar positive impact was evident in the population of *S. schizopus* on other host plants like *B. vulgaris* and *B. multiplex* also (Figs. 20 & 21).

Results of correlation studies carried out to analyse the significance of the data gathered on the impact of climatic factors like rainfall, temperature and relative humidity on the population density of *S. schizopus*, revealed a negative correlation between rainfall and mite population with an r-value of -0.568 in the case of *B. mulitplex* whereas r- values of - 0.55 and -0.44 were obtained for *B. vulgaris* and *B. bambos* respectively (Fig 22). The correlation between population density of mites and relative humidity also showed slight negative r- values of -0.309,- 0.289 and -0.168 on *B. multiplex*, *B. vulgaris* and *B. bambos* respectively (Fig 23). As shown in Fig 24, an r -value of 0.838 was obtained while correlating the temperature with the population density of *S. schizopus* infesting *B. multiplex*. Similar results were also obtained while correlating the population density of *S. schizopus* infesting *B. vulgaris* and *B. bambos* with an r- value of 0.829 and 0.785 respectively.

c) Preferred sites of mite infestation

All the 43 species of mites collected from the bamboo plants surveyed during the study, were found to colonise the foliage irrespective of taxonomic differences. However, the relationship of the above species with respective host plants was not uniform and showed considerable difference with respect to feeding and breeding habits on their respective host plants. Accordingly, the bamboo mites collected during the present study could be assigned to feeding groups like phytophagous, predatory, parasitic and saprophagous/omnivorous. The members of Mesostigmata, especially species belonging to families, Phytoseiidae and Ascidae were mostly confined to the lower leaf lamina and were wandering in search of prey and exhibited fast running habit. Among the Trombidiformes group, species of Bdellidae, Tydeidae, Stigmaeidae, Eupodidae, Cheyletidae and Cunaxidae also showed preference to the lower leaf lamina and were found wandering in search of prey, but were not fast runners as the phytoseiid and ascid members.

The tarsonemid and eriophyid species were found to be more sluggish and confined to the lower surface of bamboo leaves of respective hosts and were phytophagous in habit. The most dominant phytophagous group identified during the study were the members of family Tetranychidae, under which seven species could be recovered from the bamboo plants surveyed. Of the seven species, five species viz. *T. urticae, O. biharensis, S. schizopus, S. recki* and *S. longus* showed specific preference to the lower leaf lamina of respective bamboo hosts. However, *T. urticae* and *O. biharensis* were found to extend their distribution to the upper surface of bamboo leaves also, when their population density got increased. Two species of Tetranychidae collected during the study viz. *A. bambusae* and *S. vannus* unlike the other members of the family showed an entirely different distribution trend, restricting their habitat on the upper surface of bamboo leaves. *A. bambusae* showed preference to the upper surface of bamboo leaves for feeding and oviposition whereas species like *A. corpuzae* showed distribution on both surfaces. These mites also preferred more hairy leaves of *B. bambos* than *B. vulgaris*.

The two species coming under the genus *Schizotetranychus* viz. *S. schizopus* and *S. recki* and a species from the genus *Stigmaeopsis* viz. *S. longus* were found constructing dense webs like spiders, and colonies were found protected under the webs. These species were found to complete their entire life history under these webs as their colonies comprised of all life stages. The presence of innumerable egg cases, faecal pellets, exuviae and webs, were of common occurrence under these webs. Dust particles also were found accumulated on these webs forming a thick coating over the leaf surface. Highly infested leaves harboured 8-10 nests, which often covered the midrib as well adjacent veins. Quite often, the nests extended to leaf edges also. Leaves of *B. bambos* and *B. vulgaris* very often displayed the co-existence of all the tetranychid and eriophyid species mentioned above.

Members of the suborder oribatida also showed preference to the lower surface of bamboo leaves. However, rarely they were recovered from the upper surface also. Certain species were found occupying the destroyed nests of *Schizotetranychus* spp. Phytophagous habit could not be observed among the oribatid and astigmatid species as their presence was mostly observed on the damaged areas of bamboo leaves.

d) Web/nest spinning habit observed among spider mites:

Mite infested leaf surface of bamboo plants were found to harbor fecal pellets, moulting skins and webbings. Species like *S. schizopus*, *S. recki*, *S. longus* and *T. urticae* constructed webs on the lower surface of bamboo leaves. These mites preferred foliar regions adjacent to the midrib or the depressions present near the leaf edges to construct their webs. Webbing was often seen to extend parallelly along the veins. Individuals could be seen moving frequently between these webs. The webs constructed by *T. urticae* and *O. biharensis* appeared thinner and are often represented by silken strands. The webs constructed by *Schizotetranychus* species differed from those of *T. urticae* or *O. biharensis*, in being more dense and thick, constructed in a zig- zag manner and these were quite often termed as 'nests' alternatively by different authors. Unlike the other spider mite species, *S. vannus* and *A. corpuzae* did not construct any webs on the leaves of their host plants.

Subsocial behavior among spider mites:

Detailed observations made on the behavior of *S. schizopus* clearly indicated the prevalence of a subsocial behavioral pattern. Practice of co-operative nest sanitation behavior was evident among the individuals of the species. Several females of the species were found very actively engaged in webbing the nests prior to oviposition. The females laid eggs underneath the newly woven webs. These nests were used by the females for a long period and subsequent to reproduction and development of immatures, the females enlarged their nest. These large and united nests were used to provide shelter to the mites for a long duration with their young ones, apart from helping substantially to avail nutritional resources also.

Co-ordinated nest cleaning activity was also observed among the females of the species. Cleanliness of the webbed area was ensured by the members of the colony by restricting defaecation to one or two specific sites. The members of the colony laid faecal pellets at the inner margin of the nest alone. Female and male individuals defended their colonies against predators, even at the risk of their own death. The females of *S.schizopus* were observed to take care of their young ones living underneath the nest alone. The immature stages which remained outside the nest were not at all attended by the females of the species.

Phylum **Arthropoda von Siebold, 1848**

Subphylum **Chelicerata Heymons, 1901**

Class **Arachnida Cuvier, 1812**

Subclass **Acari Leach, 1817**

I. Superorder : Parasitiformes Reuter, 1909

A. Order : Mesostigmata G. Canestrini, 1891

Suborder : Monogynaspida Camin and Gorirossi, 1955

Cohort : Gamasina Kramer, 1881

Subcohort : Dermanyssiae Evans and Till, 1979

i) Superfamily : Phytoseioidea Berlese, 1916

a) Family : Phytoseiidae Berlese, 1916

Subfamily : Amblyseiinae Muma, 1961

Tribe : Amblyseiini Muma, 1961

Subtribe : Amblyseiina Chant and McMurtry, 2004

1. Genus : *Amblyseius* Berlese, 1914

1 : *Amblyseius aerialis* (Muma, 1955)

2 : *Amblyseius bhadrakshae* Sadanandan and Ramani, 2006

3 : *Amblyseius channabasavannai* Gupta and Daniel, 1978

4 : *Amblyseius kundurukkae* Anithalatha and Ramani, 2004

5 : *Amblyseius largoensis* (Muma, 1955)

6 : *Amblyseius malabarensis* Anithalatha and Ramani, 2004

7 : *Amblyseius orientalis* Ehara,1959

2. Genus : *Typhlodromalus* Muma, 1961

8 : *Typhlodromalus sativae* (Anithalatha and Ramani, 2009)

Subfamily : Phytoseiinae Berlese, 1913

3. Genus : *Phytoseius* Ribaga, 1904

9 : *Phytoseius punicae* Chinniah and Mohansundaram, 2001

Tribe : Kampimodromini Kolodochka, 1998

Subtribe : Paraphytoseiina Chant and Mc Murtry, 2003

4. Genus : *Paraphytoseius* Swirski and Shechter, 1961

10 : *Paraphytoseius orientalis* Narayan, Kaur and Ghai, 1960

Tribe : Neoseiulini Chant and Mc Murtry, 2003

5. Genus : *Neoseiulus* Hughes, 1948

11 : *Neoseiulus longispinosus* (Evans, 1952)

Subfamily : Typhlodrominae Wainstein 1962

Tribe : Typhlodromini Wainstein, 1962

6. Genus : *Amblydromella* Muma, 1961

12 : *Amblydromella bambusicolus* (Gupta, 1977)

ii) Superfamily : Ascoidea Voigts and Fauzago, 1877

b) Family : Ascidae Oudemans, 1905

7. Genus : *Asca* Von Hayden,1826

13 : *Asca afroaphidiodes* Hurlbutt, 1971

II. Superorder : Acariformes Zakhvatkin, 1952

B. Order : Trombidiformes Reuter, 1909

Suborder : Prostigmata Kramer, 1877

iii) Superfamily : Bdelloidea Duges, 1834

c) Family : Bdellidae Duges, 1834

8. Genus : *Octobdellodes* Atyeo, 1960

14 : *Octobdellodes guajavae* Chatteerjee and Gupta, 2002

d) Family : Cunaxidae Thor, 1902

9. Genus : *Cunaxa* Von Heyden, 1826

15 : *Cunaxa bambusae* Gupta and Ghosh, 1980

10. Genus : *Cunaxoides* Baker and Hoffmann, 1948

16 : *Cunaxoides decastroae* Den Heyer, 2013

iv) Superfamily : Tydeoidea Kramer, 1877

e) Family : Tydeidae Kramer, 1877

11. Genus : *Tydeus* Koch, 1836

17 : *Tydeus interruptus* Thor, 1932

18 : *Tydeus caudatus* (Duges, 1834)

12. Genus : *Parapronematus* Baker, 1965

19 : *Parapronematus acacia* Baker, 1965

13. Genus : *Lorryia* Oudemans, 1925

20 : Lorryia stricta Gupta, 1991

v) Superfamily : Eriophyoidea Nalepa, 1898

f) Family : Eriophyidae Nalepa, 1898

14. Genus : *Aceria* Keifer, 1944

21: *Aceria bambusae* Channabasavanna, 1956

15. Genus : *Knorella* Keifer, 1975

22 : *Knorella blumeanae* Xue and Zhang, 2009

vi) Superfamily : Eupodoidea Koch, 1842

g) Family : Eupodidae Koch, 1842

16. Genus : *Eupodes* Koch, 1835

23 : *Eupodes parafusifer* Meyer and Ryke, 1960

vii) Superfamily : Tetranychoidea Donnadieu, 1876

h) Family : Tetranychidae Murray, 1877

17. Genus : *Aponychus* Rimando, 1966

24 : *Aponychus corpuzae* Rimando, 1966

18. Genus : *Oligonychus* Berlese, 1886

25 : *Oligonychus biharensis* (Hirst, 1924)

19. Genus : *Tetranychus* Dufour, 1832

26 : *Tetranychus urticae* Koch, 1836

20. Genus : *Schizotetranychus* Tragardh, 1915

27 : *Schizotetranychus schizopus* (Zacher, 1913)

28 : *Schizotetranychus recki* Ehara, 1957

21. Genus : *Stigmaeopsis Banks, 1917*

29 : *Stigmaeopsis longus* (Saito, 1990)

22. Genus : *Stylophoronychus* Prasad, 1975

30 : *Stylophoronychus vannus* (Rimando, 1968)

viii) Superfamily : Cheyletoidea Leach, 1815

i) Family : Cheyletidae Leach, 1815

23. Genus : *Cheyletus* Latereille, 1796

31 : *Cheyletus rosensis* MaryAnitha and Ramani, 2009

ix) Superfamily : Raphignathoidea Kramer, 1877

j) Family : Stigmaeidae Oudemans, 1931

24. Genus : *Agistemus* Summers, 1960

32 : *Agistemus aimogastaensis* Leiva, Fernandez, Theron and Rollard, 2013

x) Superfamily : Tarsonemoidea Canestrini and Fanzago, 1877

k) Family : Tarsonemidae Kramer, 1877

25. Genus : *Diadalotarsonemus* De Leon, 1956

33 : *Diadalotarsonemus serratus* Rezende, Ochoa and Lofego, 2015

26. Genus : *Steneotarsonemu*s Beer, 1954

34 : *Steneotarsonemus spinki* Smiley, 1967

C. Order : Sarcoptiformes Reuter, 1909

Suborder : Oribatida (Duges, 1833)

xi) Superfamily : Oripodoidea Jacot, 1925

l) Family : Hemileiidae J and P Balogh, 1984

27. Genus : *Hemileius* Berlese,1916

Subgenus : *Hemileius (Tuberemaeus)* Sellnick, 1930

35 : *Hemileius (T.) singularis* (Sellnick, 1930)

28. Genus : *Siculobata* Grandjean, 1953

36 : *Siculobata malabarica* (Ramani and Haq, 1998)

m) Family : Mochlozetidae Grandjean, 1960

29. Genus : *Uracrobates* Balogh and Mahunka, 1967

37 : *Uracrobates indicus* Ramani and Haq, 1990

38 : *Uracrobates* (*Ovouracrobates*) keralensis sp. Nov.

n) Family : Scheloribatidae Grandjean, 1933

30. Genus : *Scheloribates* Berlese, 1908

39 : *Scheloribates decarinatus* Aoki, 1984

o) Family : Caloppiidae Balogh, 1960

31. Genus : *Zetorchella* Berlese, 1916

40 : *Zetorchella sejugata* (Ramani andHaq, 1997)

xii) Superfamily : Ceratozetoidea Jacot, 1925

p) Family : Heterozetidae Kunst, 1971

32. Genus : *Lamellobates* Hammer, 1958

Subgenus : *Lamellobates (Paralamellobates)* Bhaduri and Raychaudhuri, 1968

41: *Lamellobates (P.) misella* Berlese, 1910

xiii) Superfamily : Galumnoidea Jacot, 1925

q) Family : Galumnidae Jacot, 1925

33. Genus : *Galumna* Heyden, 1826

Subgenus : *Galumna (Galumna)* Heyden, 1826

42 : *Galumna (G.) flabellifera orientalis* Aoki, 1965

xiv) Superfamily : Acaroidea Latreille, 1802

r) Family : Acaridae Latreille, 1802

34. Genus : *Tyrophagus* Oudemans, 1924

43 : *Tyrophagus putrescentiae* Shrank, 1781

In the present study, 43 species of bamboo mites were collected and subjected to detailed taxonomic studies. The important taxonomic characters of the mites were described and drawn using camera lucida and the measurements were expressed in µm.

Superfamily : Phytoseioidea Berlese, 1916

Family : Phytoseiidae Berlese, 1916

Subfamily : Amblyseiinae Muma, 1961

Tribe : Amblyseiini Muma, 1961

Subtribe : Amblyseiina Chant and McMurtry, 2004

Genus : *Amblyseius* Berlese, 1914

Generic Diagnosis: Dorsal shield with 17 pairs of setae; setae Z_5, s_4, Z_4 whip like, sometimes serrated; peritreme extending up to j_1; sternal shield with three pairs of setae; presence of macrosetae on genu, tibia and tarsus of Leg IV.

Amblyseius aerialis (Muma, 1955) **(Plate: 18; Fig. 25 a-e)**

Colour : Transparent white

Measurements : Length : 328-380

Width : 254-263

Female: Dorsal shield with 17 pairs of setae, setae j_1, j_3, s_4, Z_4 and Z_5 long, setae Z_5 longest and whip like, $z_2$longer than z_4. Measurements of setae: j_1-36, j_3-58, s_4-110, z_2-10, z_4-9, Z_4-130, Z_5-292. Measurements of other setae: j_4-6, j_5-6, j_6-6, J_2-8, J_5-8, z_5-6, Z_1-8, S_2-10, S_4-10, S_5-10. Setae $r_3$and R_1 sublateral and 10 and 13 long respectively. Sternal shield 102 long, 80 wide with 3 pairs of sternal setae, 22 long. Genital shield 84 wide, with a pair of setae, 22 long. Ventrianal shield 132 long and 78 wide, with 3 pairs of anal setae, 20 long, 4 pairs of smooth setae around ventrianal shield, 20 long, except JV_5, the latter 63 long. 2 pairs of metapodal plates present, primary one 20 long and accessory 11 long. Movable digit of chelicera with 4 teeth and fixed digit multidentate and with *pilus dentilis*. Peritreme extends anteriorly upto j_1. Spermatheca with narrow tubular cervix.

Leg: Macrosetae on Leg IV: Genu- 135, Tibia-85 and Tarsus-54. Macrosetae on Genu I-III:25. Macrosetae on Tibia III-20.

Leg chaetotaxy: Genu II: 2-2/0-2/0-1; Genu III: 1-2/1-2/0-1; Tibia II: 1-1/1-2/1-1; Tibia III: 1-2/1-1/1-1.

Male: Not found while sampling.

Materials Examined: 4♀♀, from *B. bambos*, collected on 27.05.2016, from Calicut Dt., 5♀♀, from *B. vulgaris*, collected on 03.03.2016, from Malappuram Dt., Kerala, India. Coll. Vibija, C.P.

Other bamboo hosts: *B. balcooa*, *B. longispiculata*, *B. tulda*, *B. membranacea*, *B.nutans*, *B.wamin*, *D. hamiltonii, D. longispathus*, *D. strictus*, *M.bacciferra*, *T.oliveri* and *T.regia*

Host Range: *Citrus limon*, *Citrus medica, Amorphophallus companulatus* Blume, *Theobroma grandiflorum*, *T. cacao*, *Psidium guajava*, *Carica papaya* and *Cocos nucifera.*

Remarks: The specimen agrees with *A. aerialis* (Muma, 1955) in all characters and hence fixed as *A. aerialis*. This is the first report from bamboos.

Amblyseius bhadrakshae Mary Anitha and Ramani, 2006 **(Plate: 19; Fig. 26 a-e)**

Colour : Transparent white

Measurements : Length : 380-398

Width : 290- 320

Female: Dorsal shield smooth with 17 pairs of setae. j_1, j_3, s_4, Z_4 and Z_5 longer than other dorsal setae, Z_5 the longest. Measurements: j_1 -22, j_3-45, j_4-7, j_6-8, j_2-7, j_5-7, z_2-8, z_4-10, z_5-7, s_4-99, Z_1-10,S_2-10, S_4 -12, S_5-11, Z_4-99, Z_5-243. Sublateral setae r_3 -11 and R_1 -10. Sternal shield 80 long and 94 wide with 3 pairs of setae, 22 long, 1 pair of setae (22) on metasternal shield, Genital shield 92 wide with 1 pair of setae, 24 long. Ventrianal shield 125 long and 80 wide with 3 pairs of preanal setae and a pair of preanal pores. 4 pairs of setae around ventrianal shield. Setae JV_5 64 long. Two pairs of metapodal plates, primary one 20 and accessory one 12 long. Peritreme extends up to j_1. Cervix of spermatheca short. Fixed digit of chelicera with 9 teeth, 4 anterior and 5 posterior to *pilus dentilis*. Movable digit with 3 teeth.

Leg: Macrosetae on Leg IV: Genu - 120, Tibia -96, and Tarsus- 82.

Leg chaetotaxy: Genu II: 2-2/0-2/0-1; Genu III: 1-2/0-2/1-1; Tibia II: 1-1/1-2/1-1; Tibia III: 1-1/1-2/1-1.

Male: Not recovered during sampling.

Materials Examined: 5♀♀ from *B. bambos*, collected on 27.05.2016, from Kozhikode Dt., 2♀♀ from *B. vulgaris* and *B. tulda*, collected on 3.03.2016, from Malappuram Dt., Kerala, India. Coll. Vibija,C.P.

Other bamboo hosts: *B. balcooa*, *B. longispiculata*, *B. wamin*, *D. giganteus*, *D. hamiltonii*, *D. longispathus*, *D.strictus*, *O. scriptoria*, *T. oliveri*, *T. regia*, *O. ebracteata*

Host range: *Scaevola taccada.*

Remarks: The specimens agree with *A. bhadrakshae* described by Mary Anitha and Ramani (2006) in all features and hence named as such. This is the first report from bamboos.

Amblyseius channabasavannai Gupta and Daniel, 1978(**Plate: 20; Fig. 27 a-e**)

Colour : Transparent white
Measurements : Length : 360-380
Width : 270-292

Female: Dorsal shield rugose posteriorly and with 17 pairs of setae. Setae j_1, j_3,s_4, Z_4 and Z_5longer than the rest, j_1(31), j_3(54), s_4 (90), Z_4(94.5) and Z_5(225) long. All other setae small; Z_5 long and whip- like. Sternal shield 130 long and 85 wide with 3 pairs of sternal setae, 20 long.A pair of setae on the metasternal shield. Ventrianal shield 140 long and 98 wide, with 3 pairs of smooth setae, 22 long and a pair of pores. Setae JV_5 smooth and 82 long. 4 pairs of setae (21 long) around the ventrianal shield. Metapodal plates 2 pairs, primary 22 long and accessory 9 long. Spermatheca as drawn in the figure. Peritreme extending upto j_1 anteriorly.Chelicera multidentate with a strong *pilus dentilis*, movable digit with 3 teeth.

Leg : Macrosetae on leg IV: Genu- 92, Tibia-64, Tarsus-60.

Leg chaetotaxy - Genu II: 2-2/0-2/0-1; Genu III: 1-2/1-2/0-1; Tibia II: 1-1/1-2/1-1; Tibia III: 1-1/1-2/1-1.

Male : Not found while sampling.

Materials examined: 3♀♀, from *B. bambos*, collected on 24.10.2016, from Thrissur Dt., 2♀♀, from *B. wamin* and from 2♀♀ from *B. tulda*, collected on 03.03.2017, from Malappuram Dt., Kerala, India, Coll. Vibija, C.P.

Other bamboo Hosts: *B.balcooa*, *B.longispiculata*, *B. vulgaris B.membranacea*, *D.asper*, *D. brandisii*, *O.ebracteata*, *T. oliveri*, *T. regia*, *G. atroviolacea.*

Host range: *C. nucifera*, Chrysanthemum, Dahlia, Palm, *Abelmoschus esculentus* L. and *C. medica.*

Remarks: The specimen agrees with the characters of *A. channabasavannai* Gupta and Daniel, 1978, hence fixed as so. This forms the first report from bamboo plants.

Amblyseius kundurukkae Mary Anitha and Ramani, 2004**(Plate: 21; Fig. 28 a-e)**

Colour : Transparent white
Measurements : Length : 380-410
Width : 280-310

Female: Dorsal shield with 17 pairs of setae. j_1(36), j_3(59), s_4(110), Z_4(94) and Z_5(252) are long than other setae. Z_5 is longest and whip like. j_4 (5), j_6(5), J_2 (7) and J_5 (7) are extremely small. Measurements of other setae: Z_1(6),S_2(7) and S_5(6). Sublateral setae r_3(9) and R_1(11) present on the lateral integument. Sternal shield 110 long and 95 wide with three pairs of setae (7) long. One pair of setae on metasternal plate. Genital shield 90 wide. Ventrianal shield 110 long and 72 wide, vase shaped with 3 pairs of preanal setae (6 long). Four pairs of setae present on the membrane around ventrianal shield. Metapodal plates 2 pairs, primary one 35 long and accessory one 14 long. JV_5 – 60 long and smooth. Multidentate chelicera with *pilus dentilis* and eight teeth, movable digit toothless. Peritreme extends upto j_1. Cervix of spermatheca short.

Leg: Macrosetae on leg IV: Genu- 110, tibia- 80, tarsus- 66.

Leg chaetotaxy- Genu II: 2-2/0-2/0-1; Genu III: 1-2/1-2/0-1; Tibia II: 1-1/1-2/1-1; Tibia III: 1-1/1-2/1-1

Male: Dorsal body 300-310 long and 230-245 wide. Dorsal chaetotaxy similar to that of female. Ventrianal shield and palp as drawn in the figure.

Materials Examined- 4♀♀ and 2 ♂♂ from *B. wamin*, collected on 11.05.2016, from Malappuram Dt., Kerala, India. Coll. Vibija, C.P.

Other bamboo hosts: *B.longispiculata*, *B.multiplex*, *B. nutans*, *B. polymorpha*, *B. tulda*, *D. asper*, *D. brandisii*, *D. giganteus*, *D.hamiltonii*, *D.longispathus*, *T.oliveri*, *O.scriptoria*, *O.travancorica*, *P. ritcheyi*, *T. regia*, *O. ebracteata*, *G. atroviolacea.*

Host range: *Vateria indica.*

Remarks: The specimen examined resembles *A. kundurukkae* Mary Anitha and Ramani, 2004 and hence fixed as so. This is newly reported from bamboos.

Amblyseius largoensis (Muma, 1955) **(Plate: 22; Fig. 29 a-e)**

Colour : Yellow to Orange

Measurements : Length : 380-401

Width : 290- 310

Female: Dorsal shield with 17 pairs of setae. Setae j_1(28), j_3(54), s_4(98), Z_4(120) and Z_5(238) long, and the latter whip like.Other setae small- j_4(6), j_5(7), j_6(6), J_2(6), z_2(7), z_4(7). Sublateral setae r_3(8) and R_1(8) present on lateral integument. Sternal shield 125 long and 93 wide with three pairs of setae (23 long). Metasternal shield with one pair of setae. Genital shield 78 wide with one pair of setae (23 long). Ventrianal shield 106 long and 78 wide, vase shaped with three pairs of preanal setae and a pair of semilunar pores, four pairs of setae present around the ventrianal shield. Seta JV_5 64 long and smooth. Two pairs of metapodal plates with primary one 26 and accessory one 15 long. Chelicera multidentate- fixed digit with seven teeth and *pilus dentilis*, movable digit with two sharp teeth. Peritreme extending upto j_1. Spermatheca with tubular cervix.

Leg : Macrosetae on leg IV: Genu- 109, Tibia- 78 , Tarsus-49.

Leg chaetotaxy : Genu II: 2- 2/0 -2/0- 1; Genu III: 1- 2/1- 2/1-1; Tibia II: 1- 1/1- 2/1-1; Tibia III: 1- 1/1 – 2/1-1.

Male: Not found while sampling.

Materials Examined: 5 ♀♀ from *B. bambos*, collected on 24. 10. 2016, from Thrissur Dt., 4 ♀♀ from *B. vulgaris*, collected on 11.05.2016, from Malappuram Dt., Kerala, India. Coll. Vibija, C.P.

Other bamboo hosts: *B. balcooa*, *B. longispiculata*, *B. multiplex, B. nutans*, *B. polymorpha*, *B. tulda*, *B. wamin*, *D. asper*, *D. brandisii*, *D. giganteus*, *D. hamiltonii*, *O. scriptoria, D. longispathus*, *O. travancorica*, *T. oliveri*, *O. ebracteata, G. atroviolacea, T.regia, P.ritcheyi.*

Host range: *Mangifera indica*, *Callophyllum inophyllum*, *Musanda corymbosa*, *Tabernaemontam coronria*, Castor, Banana, Citrus, *C.nucifera,* Pomegranate, Dalbergia, Eucalyptus, *Tectona grandis*, Black berry, Sugarcane, Rose, Cashewnut, Bamboo, Arecanut, Eugenia, Fig, Guava, Pepper, *Nerium oleander*, Litchi, Plum, *Manglietia insignis*, Chilli, Shorea, Papaya, *Bauhinia acuminate*, Poppy, Pine cone, Grass, Dahlia, *Cassia fistula, C.medica.*

Remarks: The specimen agrees with the characters of *A. largoensis* (Muma, 1955), and hence fixed as *A. largoensis*.

Amblysieus malabarensis Mary Anitha and Ramani, 2004**(Plate: 23; Fig. 30 a-e)**

Colour : Pale yellow
Measurements : Length : 410- 430
Width : 340- 352

Female: Dorsal shield smooth with 17 pairs of setae. Measurements of setae: j_1 (29), j_3 (58), s_4(99), Z_4(102), Z_5(270), j_4(12), j_6(12), J_2(10), J_5(10), z_4(8), z_5(8), Z_1(12), S_2(7) and S_5(10). Setae r_3(12) and R_1(12) on the lateral integument. Sternal shield 102 long, 94 wide with three pairs of sternal setae (20), one pair of setae on metasternal plate.Genital shield 93 wide with a pair of setae, (24) long. Ventrianal shield 158 long and 99 wide with three pairs of preanal setae (28). Four pairs of setae around the ventrianal shield, 28 long. Metapodal plates 2 pairs, primary one 28 and accessory one 5long. Seta JV_5 73 long and smooth. Chelicera multidentate with a strong *pilus dentilis,* movable digit toothless.

Spermatheca with long and tubular cervix. Capitulum of spermatheca bulged. Peritreme extends up to seta j_1.

Leg : Macrosetae on leg IV: Genu- 142, Tibia- 118 and Tarsus- 74.

Leg chaetotaxy: Genu II: 2- 3/0-1/0- 1; Genu III: 1-2/2-1/0-1; Tibia II: 1-2/1-1/1-1; Tibia III: 1-2/1-1/1-1.

Male: Not found while sampling.

Materials Examined: 2♀♀ from *B. bambos* collected on 13.02.2015, from Kannur; 4♀♀ from *B. tulda*, collected on 11.05.2016, from Malappuram Dt., Kerala, India. Coll.Vibija, C.P.

Other Bamboo Hosts: *B.balcooa*, *B. longispiculata*, *B. nutans*, *B. polymorpha*, *O.scriptoria, G. atroviolacea, B.wamin*, *D.asper*, *O.travancorica*, *P.ritcheyi*, *T.oliveri*, *T.regia*, *O. ebracteata*.

Host Range:*Areca catechu, Ficus racemosa* and *Saraca asoca*

Remarks: The material agrees with *A. malabarensis* Mary Anitha and Ramani, 2004, in all characters, hence fixed so. This is the first report from the host plant.

Amblyseius orientalis Ehara, 1959**(Plate: 24; Fig. 31 a-e)**

Colour : Pale Yellow

Measurement : Length : 380-410

Width : 300-315

Female: Dorsal shield with 17 pairs of setae. All setae small, except j_1(22), j_3(48), s_4(110), Z_4(114) and Z_5(263), the latter long and whip like. The other setae measure: j_4 (6), j_6(7), J_2(6), J_5(6), z_2(12), z_4(12) and z_5(10). Length of lateral setae, r_3 and R_1 16 and 18 respectively. Sternal shield 102 long and 110 wide with 3 pairs of sternal setae (24 long). Ventrianal shield 126 long and 98 wide with three pairs of preanal setae (26 long) and a pair of pores. Four pairs of setae around the ventrianal shield (24 long). Setae $JV_5$89 long and smooth. On chelicera, fixed digit multidentate with *pilus dentilis*, movable digit with three teeth. Peritreme extends upto j_1 anteriorly. Spermatheca as shown in the figure.

Leg : Macrosetae on Leg IV: Genu- 84, Tibia-53 and Tarsus-54.

Leg chaetotaxy: Genu II: 2-2/0-2/0-1; Genu III: 1-2/0-2/1-1; Tibia II- 1-2/0-2/1-1.

Male: Not found while sampling.

Materials Examined: 3♀♀ from *B. vulgaris* and 2♀♀ from *B. wamin*, collected on 24.10.2016 from Thrissur Dt., Kerala, India. Coll. Vibija, C.P.

Other bamboo hosts: *B. bambos*, *B. longispiculata*, *B. membranacea*, *B. tulda*, *D. brandisii*, *D. giganteus*, *D. hamiltonii*, *T. oliveri, D. longispathus*, *O. abyssinica, T.regia.*

Host range:*Capsicum annum* and *Murraya koenigii.*

Remarks: The specimen examined closely resembles *A. orientalis* Ehara, 1959, in all characters examined and hence fixed as *A. orientalis*. This forms the first report from the bamboo host.

Genus : *Typhlodromalus* Muma, 1961

Generic Diagnosis: Females have four pairs of dorsal setae, three pairs of median setae and eight pairs of lateral setae of which s_4, Z_4 and Z_5 are longer; Z_5 usually serrate.

Typhlodromalus sativae (Anithalatha and Ramani, 2009)(**Plate: 25; Fig. 32 a-e**)

Colour : Transparent

Measurements : Length : 320-340

Width : 240-254

Female: Oval shaped body. Dorsal shield with 17 pairs of setae. Measurements of setae: j_1(12), j_3(24), s_4(34), Z_4(32), Z_5(74), r_3(21) and R_1(25). Except j_1, j_3, s_4, Z_4 and Z_5all other setae small.Z_5weakly serrated. Sternal shield 82 long and 74 wide with three pairs of setae (24 long).One pair of setae on the metasternal plate (24 long).Genital shield 93 wide with a pair of setae, 24 long. Ventrianal shield 104 long and 76 wide, crescent shaped, with three pairs of preanal setae (18 long). Four pairs of setae around ventrianal shield (18 long). Setae JV_5 smooth and 36 long. Peritreme extends upto j_1 anteriorly. Two pairs of metapoodal plates- primary one 18 and accessory one 12 long. Spermatheca as shown in the figure. Chelicera with fixed digit multidentate with *pilus dentilis* and movable digit with three teeth.

Leg: Macrosetae on Leg IV: Genu- 50, Tibia- 34, Tarsus- 50.

Leg Chaetotaxy: Genu II: 2-2/0-2/0-1; Genu III: 1-2/0-2/1-1; Tibia II: 1-1/1-2/1-1; Tibia III: 1-1/1-2/1-1.

Male: Size smaller than female with 290- 310 long and 210-222 wide. Dorsal chaetotaxy similar to that of female. Spermatophoral process as shown in the figure. Ventral plate with 4 pairs of setae.

Materials Examined: 4♀♀ from *B.tulda*, collected on 15.03.2015, from Wayanad Dt. and 3♂♂ from *B.bambos* collected on 20.04.2015 from Thrissur Dt., Kerala, India.

Other bamboo hosts: *B. balcooa*, *B. vulgaris*, *D. giganteus*, *O. scriptoria*, *T. oliveri*, *T. regia*, *O.ebracteata.*

Host Range: *Pisum sativum*

Remarks: The specimen examined closely resembles in size, shape, measurements and number of setae, shape of spermatheca and leg chaetotaxy with *T. sativae* (Mary Anitha and Ramani, 2009), hence fixed as *T. sativae.* This is the first report from the host plant.

Subfamily : Phytoseiinae Berlese, 1913

Genus : *Phytoseius* Ribaga, 1904

Generic Diagnosis: Oval shape body with 14 long and serrated dorsal setae, of which s_4 and S_6 large and erect, macroseta on genu of leg IV.

Phytoseius punicae Chinniah and Mohansundaram, 2001**(Plate: 26; Fig. 33 a-e)**

Colour : Light yellow

Measurements : Length : 260- 285

Width : 120-130

Female: Dorsal shield smooth, narrow compared to body size with 16 pairs of setae. Peritreme extends up to j_1.Setae j_1, j_3, z_3, s_4, S_6, Z_5, Z_4, r_3 long, thick and serrated, other setae small and smooth. Measurements: j_1- 25, j_3- 68, z_3- 52, s_4- 109, S_6- 92, Z_5- 88, Z_4- 85, r_3- 47, R_1- 20. Length of other setae between 6-12. Fixed digit of chelicera with two strong teeth, movable digit with one teeth. Spermatheca as shown in the figure. Sternal shield 82 long with three pairs of setae (26).Metasternal plate not distinct, IV^{th} pair of sternal setae on the membrane. Genital shield 85 long with a pair of setae, 26 long.

Ventrianal shield 102 long with three pairs of preanal setae. *JV_5*64 long, thick and serrated.

Leg: Macroseta on leg IV: genu- 28, tibia- 32, basitarsus- 23, all with spatulate head.

Leg chaetotaxy: Genu II: 2-2/2-0/0-1; Tibia II: 1-2/1-1/1-1; Genu III: 1-1/2-0/1-1; Tibia III: 1-1/2-1/1-1.

Male: not found while sampling.

Materials Examined: 4♀♀ from *B. tulda*, collected on 8.03.2016, Malappuram Dt., Kerala, India. Coll. Vibija, C.P.

Other bamboo hosts: *B. balcooa*, *B. bambos*, *D. hamiltonii*, *P. ritcheyi*, and *T. regia*.

Host Range: *Solanum torvum* and *Punica granatum.*

Remarks: This specimen resembles in all characters with *P. punicae* Chinniah and Mohansundaram, 2001, and hence confirmed as so. This is the first report from India on Bamboos.

Tribe	**:**	**Kampimodromini Kolodochka, 1998**
Subtribe	**:**	**Paraphytoseiina Chant and Mc Murtry, 2003**
Genus	**:**	***Paraphytoseius* Swirski and Shechter, 1961**

Generic Diagnosis: Dorsal shield sclerotized with 5 pairs of dorsocentral setae, 2 pairs of median, 5-6 pairs of laterals and 2 pairs of sublateral setae. Setae j_1, j_3, s_4, Z_4, Z_5, r_3 and R_1 long, thick and serrated. Sternal shield with 3 pairs of setae. Macroseta on genu, tibia and tarsus of leg IV.

Paraphytoseius orientalis (Narayanan, Kaur and Ghai, 1960)
(Plate: 27; Fig. 34 a-e)

Colour : pale yellow

Measurements : Length : 376- 384

Width : 160- 168

Female: Dorsal shield smooth, longer than wide, rounded posteriorly. Dorsal shield with 13 pairs of setae j_1(42), j_3(81), j_4(4), j_5(4), j_6(9), J_5(6), z_2(11), z_4(14), z_5(6), Z_1(9), Z_4(86),

Z_5(109), and s_4(120). Two pairs of lateral setae, r_3(56) and R_1(36). Setae j_3, s_4, Z_4 and Z_5 long, thick and serrated. Peritreme extends upto j_1. Sternal shield smooth, wider than long with two pairs of sternal setae (75). Third pair of setae inserted on margin of the sternal shield (75). Genital shield 80 wide with one pair of setae (76). Ventrianal shield 101 long and 52 wide, with three pairs of preanal setae.

Leg: Four stout macrosetae on leg IV with swollen tips.

Male: Not found while sampling.

Materials Examined: 3♀♀ from *B. vulgaris*, collected on 20.04.2015, Thrissur Dt., Kerala, India. Coll. Vibija, C.P.

Other bamboo hosts: *B. longispiculata*, *B. membranacea*, *B. nutans*, *B. pallida*, *B. polymorpha*, *D.asper*, *D. hamiltonii*, *D. longispathus* and *P. ritcheyi*.

Host Range: *Psidium guajava*, *Chromolaena odorata* and *B. vulgaris*.

Remarks: This species closely resembles *P. orientalis* (Narayanan, Kaur and Ghai, 1960) in almost all aspects and hence fixed as so. This is reported for the first time from Kerala.

Tribe : Neoseiulini Chant and Mc Murtry, 2003

Genus : *Neoseiulus* Hughes, 1948

Generic Diagnosis: Dorsal shield sclerotized with 17 pairs of setae. 4-8 teeth on the fixed digit of chelicera. Sternal shield with 3 pairs of seta. Ventrianal shield pentagonal, elongate, nearly quadrate or shield shaped with 3 pairs of preanal seta. Macroseta on leg IV.

Neoseiulus longispinosus (Evans, 1952) **(Plate: 28; Fig. 35 a-e)**

Colour : Transparent

Measurements : Length : 320-342

Width : 220-231

Female: Dorsal shield smooth with 17 pairs of setae, all long except j_1, J_5 and S_5. Measurements of setae: j_1(18),j_3(58.5), j_4(53), j_5(67), j_6(67), J_2(68), J_5 (12),z_2(64), z_4(60), z_5(32), s_4(78), S_2(66), S_4(62), S_5(16), Z_5(74), Z_1(69) and Z_4(68). R_1(70) and r_3(63) present on the lateral integument. Sternal shield 112 long and 72 wide with three pairs of sternal setae (34), one pair of setae present on the metasternal plate (32).Genital shield 68 wide with a pair of setae (36). Ventrianal shield 102 long and 86 wide, reticulate with 3 pairs of preanal setae (36) and a pair of preanal pores. Four pairs of setae (36) long, present around the ventrianal shield. Setae JV_5 (60) long and smooth. Two pairs of metapodal plates present, 20 and 9 long. Spermatheca as shown in the figure. Chelicera multidentate, fixed digit with three teeth anterior to *pilus dentilis*, movable digit with two sharp teeth. Peritreme extends upto j_1.

Leg: Macrosetae present on the basitarsus of Leg IV- 66 long.
Leg chaetotaxy: Genu II: 2-2/0-2/0-1; Genu III: 1-2/1-2/0-1; Tibia II: 1-2/1-1/1-1; Tibia III: 1-1/1-2/1-1.
Male: Not found while sampling.

Materials Examined: 3♀♀ from *B. vulgaris*, collected on 20.04.2015, from Thrissur Dt., Kerala, India. Coll. Vibija, C.P.

Other bamboo hosts: *B. balcooa*, *B. bambos*, *B. multiplex*, *B. nutans*, *B. pallida*, *B. polymorpha*, *B. tulda*, *B. wamin*, *D. brandisii*, *D. giganteus*, *D. hamiltonii*, *M.bacciferra*, *O. scriptoria*, *T. oliveri*, *T. regia* and *O. ebracteata.*
Host range: *A. esculentus, C. nucifera*, *M. esculenta*, *S. melongena*, *Datura* sp., *Tabernaemontana coronaria, Bauhinia purpuria, Castor, Zinia* sp., Paddy, Guava, Rose, Datura metal.
Remarks: The specimen studied very closely resembles *N. longispinosus* (Evans, 1952), in all characters and hence fixed so. This is reported on bamboos for the first time from Kerala.

Subfamily : Typhlodrominae Wainstein 1962

Tribe : Typhlodromini Wainstein, 1962

Genus : *Amblydromella* Muma, 1961

Generic Diagnosis: Dorsal shield sclerotized with 18 pairs of setae, of which Z_4 and Z_5 are thick and serrate, the latter may be knobbed; 3 pairs of setae on sternal shield; Ventrianal shield with a pair of preanal setae; macrosetae on genu, tibia and tarsus of leg IV, which is simple or knobbed.

Amblydromella bambusicolus (Gupta, 1977)**(Plate: 29; Fig. 36 a-e)**

Colour : Transparent

Measurements : Length : 295- 300

Width : 175-182

Female: Body elongate, sclerotized dorsal shield with reticulate pattern. Dorsum with 18 pairs of setae. All setae short except S_2, S_4, Z_4, Z_5, r_3 and R_1. Z_4 and Z_5 serrate. Z_5 ends in a slightly knobbed tip. All other setae thin and pointed. Two pairs of setae arise from the lateral integument. Measurements of setae: j_1- 18, j_3-19, j_4- 10, j_5- 10, z_2- 14, z_3- 12, z_4- 15, s_4- 15, S_2- 23, S_4- 24, Z_4- 27, Z_5- 48, r_3- 19 and R_1- 22. Sternal shield 105 long and 75 wide with three pairs of sternal setae (20 long). One pair of setae lies on the integument. Genital shield 68 wide with one pair of setae (20 long). A thick integumental fold presents between genital and ventrianal shields. Ventrianal shield pentagonal, 82 long and 72 wide, 3 pairs of preanal setae (19 long) and a pair of preanal pores. 3 pairs of ventrolateral setae present around the shield. Setae JV_5- 25 long with knobbed tip. Metapodal plates two, small in size. Peritreme extends upto j_1. Chelicera: fixed digit- multidentate with *pilus dentilis*, movable digit with a single tooth. Spermatheca as shown in the figure.

Leg: Macroseta with knobbed tips on leg IV: Genu- 14, tibia- 18, basitarsus-24.
Leg chaetotaxy : Genu II: 2-2/0-2/0-1; Tibia II: 1-1/1-1/1-1.

Male: Not found in the samples collected.

Materials Examined: 3♀♀ from *B. bambos*, collected on 24.09. 2015, from Malappuram Dt., 4♀♀ from *B. vulgaris* and *B. multiplex*, on 26. 02. 2016, from Thrissur Dt., Kerala, India. Coll. Vibija, C.P.

Other bamboo hosts: *B. balcooa*, *B. longispiculata*, *B. membranacea*, *B.tulda*, *D. brandisii*, *D. giganteus*, *D.hamiltonii*, *D.longispathus*, *O. abyssinica*, *T. oliveri* and *T. regia.*

Host range: *T. cocoa*, *Coffea arabica*, Bamboo and Citrus.

Remarks: This specimen agrees with all characters of *A. bambusicolus* (Gupta, 1977), and hence fixed so.

Superfamily : Ascoidea

Family : Ascidae Oudemans, 1905

Genus : *Asca* Von Hayden,1826

Generic Diagnosis: Completely divided dorsal shield, Z_4 andS_5 usually inserted on a pair of prominent posterolateral tubercles, Podonotal shield with j_2 well behind level of j_1. Genu I with 12 setae.

Asca afroaphidiodes Hurlbutt, 1971**(Plate: 30; Fig. 37 a-e)**

Colour : Pale Yellow

Measurements : Length : 290- 310

Width : 160- 175

Female: Anterior dorsal shield with 17 pairs of pilose setae. Setae r_2 and r_3 on peritremal shield. Setae j_1- 15, z_6- 18, s_6- 22. Posterior dorsal shield with few grooves and few minute protuberances between J_4 and J_5. J_2- 25, J_3- 30, J_4- 38, J_4- 40 long. J_1 to J_4, Z_1, Z_2, S_1, S_2 and S_3 are pilose in nature. S_4 -36 and simple. S_5- 42 long and hair like coming from a solid protruded base. *R* setae simple. Sternal shield 58 long. Ventrianal shield 115 long and 185 wide with 15 setae. Chelicera- fixed digit with five teeth.

Leg: Tarsus IV with long whip like seta, basitarsus with longest seta- 28.

Male: Not found while sampling.

Materials Examined: 2♀♀ from *B. nutans*, collected on 20.04. 2015, Thrissur Dt., Kerala, India. Coll. Vibija, C.P.

Host range: litter sample

Remarks: This specimen agrees with all characters of *A. afroaphidiodes* Hurlbutt, 1971 and hence fixed so. This is the first report from India.

Superorder : Acariformes

Order : Trombidiformes

Suborder : Prostigmata

Superfamily : Bdelloidea Duges, 1834

Family : Bdellidae Duges, 1834

Genus : *Octobdellodes* Atyeo, 1960

Generic Diagnosis: this genus closely resembles Bdellodes, except the presence of 6-7 pairs of hypostomal setae and the presence of lateral propodosomal setae; chelicera each with two setae; posterior sensilla longer than median propodosomal setae.

Octobdellodes guajavae Chatterjee and Gupta, 2002**(Plate: 31; Fig. 38 a-e)**

Colour : Pale Yellow

Measurements : Length : 800-810

Width : 370-384

Female: Body elongated with dorsal striations as figured. Length of gnathosoma (184). Measurements of palpal segments: trochanter- 18, basifemur- 36, telofemur- 30, genu- 23 and tibiotarsus- 42. Chaetotaxy of palp: basifemur- 6, telofemur- 1, genu- 4, tibiotarsus- 4 small and 2 long setae, 140 and 108 long. Each chelicera sickle shaped and toothless, 179 long, longitudinally striated with two setae, 44 and 40 long. Anterior sensory seta, 85 long and posterior sensory seta 96 long. Lateral propodosomal seta 40 long, median propodosomal seta- 43 long. Anal setae one pair, 30 long. Striation pattern of the broader region transverse. Genital plate with 6 setae each, paragenital setae 2 pairs.

Leg: Legs transversely striated and with empodial claws and 4 lateral rays.
Leg Chaetotaxy- trochanter- 4-8-0-0, basifemur- 2-7-0-1(setae on basifemur of IV leg multiforked); telofemur- 6-8-0-2(setae on telofemur of IV leg multiforked); genu- 10+1(trichobothridia)-11-0-1(trichobothridia);tibiotarsus-20-15+2(trichobothridia)-1(trichobothridia) -1(trichobothridia).

Male: Not found while sampling.

Materials Examined: 2♀♀ from *B. bambos*, collected on 11.05.2016, Malappuram Dt., Kerala, India. Coll. Vibija, C.P.

Other bamboo hosts: *B. balcooa*, *B. nutans*, *B. vulgaris*, *B. wamin*, *T. regia*, *S. griffithiana* and *O. ebracteata.*

Host Range: *Psidium guajava.*

Remarks: The specimens examined resemble with *O. guajavae* described by Chatterjee and Gupts, 2009 in most of the features, but the dorsal setae are thick, distally pointed, and barbed at one fourth of the distal part. This is the first report from the bamboo plants.

Family : Cunaxidae Thor, 1902

Genus : *Cunaxa* Von Heyden, 1826

Generic Diagnosis: Body strongly sclerotized; propodosomal shield smooth, reticulate or striated; propodosoma and hysterosoma may be with or without shield; palpi 5 segmented and bears stout spine like seta; tarsi I- IV long and slender.

Cunaxa bambusae Gupta and Ghosh, 1980 (**Plate: 32; Fig. 39 a-e**)

Colour : Pale Yellow

Measurements : Length : 400- 410

Width : 275- 285

Female: Hypostome cone shaped distally. Propodosoma without any shield, with two pairs of finely branched sensillae (anterior 209 long and posterior 253 long) and two pairs of simple setae, of which P_1 (18) shorter than P_2 (28). Hysterosoma without any shield with setae L_1 (16), D_1- D_3 (18), D_4-D_5(31). Gnathosomal palp 144 long and 5 segmented. Chaetotaxy of palp: trochanter-0, basifemur- 1 dorsomedian simple seta, telofemur- one outer lateral and one anteromid-dorsal seta, Genu- two inner lateral, one outer lateral and one anteromid-dorsal seta, tibiotarsus- one, long simple seta medially, one dorsolateral and one dorsomedian simple seta on outer surface and one spine- like seta. Chelicera broad at base and gradually tapering anteriorly, movable digit sharp. Four pairs of setae on genital plate. Hypostomal venter with 5pairs of setae.

Leg: Each tarsus terminates in two claws and forked empodium.

Leg chaetotaxy: coxae: 3-1-3-2; trochanter: 1-1-2-1; basifemur: 5-5-4-2; telofemur: 4-4-4-4; genu : 5(4)- 5(2)- 5(1)-5(2); tibia : 5(2)- 5(1)- 5(1)- 4 (1 trichobothridia); tarsus: 20(5)- 20(1)- 14(1)- 17.

Male: Not found while sampling.

Materials Examined: 3♀♀ from *B. bambos*, collected on 13. 02. 2015, from Kannur Dt., 2♀♀ from *B. vulgaris*, collected on 11. 05. 2016, from Malappuram Dt., Kerala, India. Coll. Vibija, C.P.

Other bamboo hosts: *B. balcooa*, *B. membranacea*, *B. pallida*, *B. polymorpha*, *D. asper*, *D. hamiltonii*, *D. longispathus*, *T. regia, M. bacciferra*, *O. abyssinica*, *P. ritcheyi*, *O.ebracteata* and *G. atroviolacea*

Host range: *Anacardium occidentale, B. arundinaceae*

Remarks: This specimen agrees in dorsal & ventral chaetotaxy, number of setae and patterns in striations with *C. bambusae* Gupta and Ghosh, 1980, and hence fixed as so.

Genus : *Cunaxoides* Baker and Hoffmann, 1948

Generic Diagnosis: Propodosoma bearing ill-defined and weakly sclerotized shield, complemented by 2 pairs of seta and 2 pairs of setose sensilla; dorsal hysterosoma with or without shield; pedipalp 3 segmented; genital plates with 4 setae, anal plate with a pair of seta, trichobothrium present on leg IV.

Cunaxoides decastroae Den Heyer, 2013 (**Plate: 33; Fig. 40 a-e**)

Colour : Transparent white

Measurements : Length : 300-310

Width : 220-235

Female: Dorsum weakly sclerotized but with well demarcated shield- like area having two pairs of sensillae, *vi* (115) and *sce* (130) long. Hypognathum 135 in length and 80 wide. Four pairs of setae on hypognathum, hg_3 longer than others. Palp chaetotaxy: Trochanter -0, Femora -genu – 5, Tibiotarsus- 5(1)+1 tooth like process+1 claw. Setae present on dorsal shield: *ve* (26), *sci* (30), c_1(20), c_2(22), d_1(22) and e_1(28). Shield provided with lobes. Integumental striae also lobed. Setae f_1(30) and h_1(36) present on posterior to dorsal shield. Sternal, coxal and genital areas heavier lobed than integument. Genital valves surrounded by longitudinal striae and with four pairs of simple setae; setae g_4 longer than g_{1-3}.

Legs: Chaetotaxy: Trochanter: 1-1-2-1; basifemur: 4-3-3-0; Telofemur: 4-4-3-2; Genu: (4)-5+(2)-5(1)-5(2); tibia: (1)-5(1)-5(1)-5(4): tarsi: 12(7)-18(3)-19(1)-15.

Male: not found while sampling.

Materials Examined: 2♀♀ from *B. vulgaris*, collected on 11.05. 2016, Malappuram Dt., Kerala, India. Coll. Vibija, C.P.

Other bamboo hosts: *B. bambos*, *B. nutans* and *G. atroviolacea*

Host Range: clover

Remarks: This specimen agrees in all characters with *C. decastroae* Den Heyer, 2013, and hence confirmed as so. This forms the first report from India.

Superfamily : Tydeoidea Kramer, 1877

Family : Tydeidae Kramer, 1877

Genus : *Tydeus* Koch, 1836

Generic Diagnosis: Propodosoma with fine longitudinal striations, hysterosoma with 9 pairs of setae and transverse striations in dorsomedian region, 6 pairs of genital setae, 4 pairs of paragenital setae and 1 pair of anal setae. All tarsi with claws and empodium.

Tydeus caudatus (Duges, 1834) Sensu Baker, 1970 **(Plate: 34; Fig. 41 a-b)**

Colour : Pale Yellow

Measurements : Length : 265-275

Width : 155-170

Female: Dorsal body striae longitudinal on propodosoma and transverse on hysterosoma. The propodosomal trichobothriae stout, slightly serrated and not much longer than other dorsal body setae. Dorsal body setae thin, setaceous and slightly serrate except h_1, h_2 and ps_1, which spatulate distally. Palpi elongate. Genital setae 6 pairs. Palp setal formula- 5-2-2. Setae *d* and *l* on hysterosoma lie in transverse rows.

Legs: chaetotaxy: Trochanter: 1-0-1-0; Femur: 3-2-1-1; Genu: 3-2-1-1, Tibia: 4-2-2-2; Tarsus: 8-6-5-5.

Male: Not found while sampling.

Materials Examined: 2♀♀ from *B. tulda*, collected on 8.03.2016, Malappuram Dt., Kerala, India. Coll. Vibija, C.P.

Other bamboo hosts: *B. balcooa*, *B. bambos* and *T. oliveri.*

Host Range: Sour cherry leaf, walnut leaf, apple leaf, soil, plum leaf and cherry leaf.

Remarks: This specimen agrees in all characters with *T. caudatus* (Duges, 1834) Sensu Baker, 1970, and hence fixed as so. This is the first report from the host plant.

Tydeus interruptus Sig Thor, 1932**(Plate: 35; Fig. 42 a-b)**

Colour : Black

Measurements : Length : 270-300

Width : 160-170

Female: Idiosoma diamond shaped. Cuticle wrinkled, groves being accentuated by lines of evenly- spaced tubercles. Gnathosoma short and broad. Chelicera with movable digit forming finely curved spike, fitting into a shallow groove of fixed arm. Palp- tarsus bearing a terminal cluster of five setae and a small basal solenidion; tibia, femur and genu with two setae each. Propodosoma separated from hysterosoma by a transverse groove. Three pairs of propodosomal setae (P_1, P_2, P_3) and a pair of longer sensory setae present on propodosoma. From the dorsal and lateral sides of the hysterosoma, five pairs of dorsal and four pairs of lateral setae arise. The ventral genital opening bordered by six pairs of genital setae and four pairs of paragenital setae. One pair of setae present on the sides of the anus.

Legs: All legs long and slender, terminating in a pair of claws and pad shaped empodium. A dorsal solenidion and two setae arising from a hump present on the dorsal side of tarsus I. Two additional setae inserted more distally and three shorter setae encircling the tip of tarsus I. Three setae each on tibia I, femur I and genu I and one seta on trochanter I.

Male: Not found while sampling.

Materials Examined: 3♀♀ from *D. brandisii*, collected on 20.04. 2015, Thrissur Dt., 2♀♀ from *B. bambos*, collected on 24. 09. 2015 from Kozhikode Dt., Kerala, India. Coll. Vibija, C.P.

Other bamboo hosts: *B. balcooa*, *B. longispiculata*, *B.bambos*, *B. nutans*, *B. tulda*, *B. vulgaris*, *D. giganteus*, *D. hamiltonii*, *D. longispathus*, *D.strictus*, *M. bacciferra* and *O. scriptoria*.

Host range: Moss.

Remarks: The specimen resembles in all characters with *T. interruptus* Sig Thor, 1932, and hence confirmed as so. This is the first report from the bamboo plants.

Genus : *Parapronematus* Baker, 1965

Generic Diagnosis: Hysterosomal setae arranged in four and half rows; d_2 setae located in dorsal position; Tarsus I lacks empodium and claws, ending in 4 long and short terminal setae; genital setae 3 pairs, ventral setae 3 pairs and anal setae absent; Dorsal setae on femur III and IV distinctly forked.

Parapronematus acacia Baker, 1965 **(Plate: 36; Fig. 43 a-c)**

Colour : Pale yellow

Measurements : Length : 270-282

Width : 156-164

Female: Stylophore cleft anteriorly. Palp with chaetotaxy 5-1-2, distal segment long and slender.Longitudinal striations on propodosoma and hysterosoma. Seta *vi* shifted posteriorly between sensory setae. Body setae stout, serrate and lanceolate. Sensory setae longer than body setae.First and second rows of hysterosomal setae similar to that of propodosoma. Third and fourth rows of setae longer. Measurements of setae: *vi*- 20, *sci*-40, *sce*- 24, c_1- 23, c_2- 20, d_1- 18, d_2- 20, e_1- 42, e_2- 84, f_1-42, f_2- 60 and h_1-24.

Legs: Tibia and Tarsus I almost equal in size. Solenidion circular on tarsus and slender on tibia.Leg setae pilose. Femora III and IV with Y- like setae.

Male: Not found while sampling.

Materials Examined: 2♀♀ from *B. tulda*, 3♀♀ from *B. bambos*, collected on 20.04.2015, Thrissur Dt., Kerala, India. Coll. Vibija, C.P.

Other bamboo hosts: *B. balcooa*, *B. membranacea*, *B. nutans*, *B. vulgaris*, *B. wamin*, *D. asper*, *D. brandisii*, *D. giganteus*, *D. longispathus*, *O. travancorica* and *O. abyssinica.*

Host range: Bamboo and Acacia.

Remarks: This specimen agrees with *P.acacia* Baker, 1965 in all characters and hence confirmed as so. This is the first report from Kerala.

Genus : *Lorryia* Oudemans, 1925

Generic Diagnosis: Dorsal body surface with reticulate striations with spine like lobes, hysterosomal setae arranged in four rows, *vi* anterior to trichobothria (*sci*), genital setae 6 pairs, paragenital setae 4 pairs, anal setae 1 pair, ventral setae 3 pairs.

Lorryia stricta Gupta, 1991**(Plate: 37; Fig. 44a-b)**

Colour : Pale yellow

Measurements : Length : 258- 273

Width : 162- 172

Female: Gnathosoma distinct. Distal segment of palp longer than broad. Palp setal formula: 5-1-2. Palp terminal sensillum with broader tip. Body outline irregular, indented anteriorly and posteriorly. Body elongate with strong reticulation. Propodosomal sensory setae sc_1 long, whip like. Dorsal body setae long, lanceolate and subequal. Genital setae 5 pairs. Four pairs of paragenital setae present. One pair of anal setae present.

Legs: Legs with empodia having strong claws. Tarsus I with one rod like solenidion.

Leg chaetotaxy: Trochanter: 1-0-1-0; femur: 2-3-2-1; genu: 3-2-1-1; Tibia: 3-2-2-2; Tarsus: 7(1)-6-5-5.

Male: Not found while sampling.

Materials Examined: 3♀♀ from *B. bambos*, collected on 22.03. 2015, Kozhikode Dt., Kerala, India. Coll. Vibija, C.P.

Other bamboo hosts: *B. balcooa*, *B. vulgaris*, *D. longispathus*, *O. scriptoria* and *P. ritcheyi*.

Host range: *C. aurantium*

Remarks: The specimen resembles *L. stricta* Gupta, 1991 in all respects and hence confirmed as so. This is the first report from the bamboo plants.

Superfamily : EriophyoideaNalepa, 1898
Family : Eriophyidae Nalepa, 1898
Genus : *Aceria* Keifer, 1944

Generic Diagnosis: Body worm like, rostrum variable in size, shield usually subtriangular, dorsal setiferous paired tubercles in subdorsal positions; legs with all usual setae and simple featherclaw; female genitalia little behind hind coxae.

Aceria bambusae Channabasavanna, 1966 (**Plate: 38; Fig. 45 a-f**)

Colour : Transparent

Measurements : Length : 184- 215
Width : 40- 50

Female: Body elongate and vermiform. Length 184- 215 including gnathosoma. Gnathosoma 15- 20, curved, basal setae *ep* 4; antapical setae *d* 4; chelicera 15. Prodorsal shield 31 long, truncated anteriorly. Semicircular, incomplete median line broken and restricted to posterior 2/3rdof prodorsal shield. Complete admedian lines with dashes started from anterior, broken at ½, restricted to posterior third. Submedian lines of dashes ahead of scapular tubercles, laterally ornamented with short striae. Scapular seta (*sc*) 18, inserted on rear shield margin, directed backwards. Coxa I with short dashes, Coxa II with granules.Coxal seta I (*1b*) 3long, coxal seta II (*1a*) 11; coxal seta III (*2a*) 23.Coxigenital area with 5 annuli. Opisthosomal annuli sub- equal dorsoventrally, body with 58 annului, with oval microtubercles except the rear 10th annulus, the latter possesses linear microtubercles ventrally. Lateral seta (c_2) 3 long and inserted on annulus 9, ventral seta I (*d*) 34 on annulus 18; ventral seta II (*e*) 9 long and placed on annulus 32; ventral seta III (*f*) 19 long and inserted on annulus 54. Caudal seta (h_2) 34 long; accessory seta (h_1) 3.

Leg: On Leg I- femur 7 long and femoral seta (*bv*) 5 long; genu 4 long and genual seta (*l″*) 19; tibia 4 long and tibial seta (*l′*) 4; tarsus 4 long with empodium 7 rayed, two setae and one tarsal solenidion. On Leg II – femur 6 long and *bv’’* 5long; genu 3 and *l″* 6; tibia 3; tarsus 4 with empodium 7 rayed, two setae and one solenidion.

Male: Smaller than female.

Materials Examined: 5♀♀ and 4♂♂ from *B. vulgaris*, collected on 14. 04. 2016, Wayanad, Kerala, India. Coll. Vibija, C.P.

Other bamboo hosts: *B.balcooa, B.bambos, B.multiplex, B.polymorpha, B.tulda, D.asper, D. longispathus, D.strictus, O.scriptoria, O.abyssinica, P.ritcheyi, T.oliveri*

Host range: *Bambusa sp.*

Remarks: Vagrant on the lower surface of bamboo leaves. This is the first report from bamboo plants, with the exception of *B. vulgaris.*

Genus : *Knorella* Keifer, 1975

Generic Diagnosis: Opisthosoma with central longitudinal ridge; annuli projecting laterally and unevenly; genu II, femoral and opisthosomal setae *d* and *e* absent; scapular and tibial setae absent; femora one segmented.

Knorella blumeanae Xue & Zhang, 2009 **(Plate: 39; Fig. 46 a-e)**

Colour : Light Yellow

Measurements : Length : 130- 150

Width : 50- 60

Female: Ganthosoma 23 long, projecting downwards. Pedipalp coxal seta *(ep)* 2 long, genual seta *(d)* absent. Chelicerae 20 long. Prodorsal shield 45 long and semicircular.

Scapular setae and tubercles absent. Prodorsal shield consists of two admedian lines close to each other with several granules, and extends over gnathosoma 4 long. Coxisternal plate with short lines and granules. Setae on coxisternum: *1a*- 16 long; *1b*- 6 long, *2a*- 24, *3a*- 14 long. Opisthosoma with 23 smooth dorsal annuli.Ventral opisthosoma with 49 annuli, with elongate microtubercles situated on margin of annuli. Annuli 2,4,7,10,12 and 15 project as distinct lateral lobes. Opisthosomal seta c_2 on annulus 6 and 23 long. Opisthosomal setae *d* and *e* absent, *f* on 42[nd] annulus. Opisthosomal seta h_2 53 long and h_1 absent. Genital coverflap 17 long with longitudinal ridges.

Leg: Empodium with 6 rays. Leg I: Femur- 8 long, without seta and with numerous granules; Genu- 3 long with *l″* 21 long; Tibia 4 long with *l′* 18 long; Tarsus 6 long with three normal setae and one slightly curved solenidion. Leg II: Femur- 9 long with granules, no seta; Genu- 2 long with no seta; Tibia- 3 long, no seta; Tarsus- 5 long with three normal setae and one straight solenidion.

Male: Smaller in size when compared to females.

Materials Examined: 4♀♀ and 2♂♂ from *B. bambos*, collected on 14.04. 2016, Wayanad, Kerala, India. Coll. Vibija, C.P.

Other bamboo hosts: *B. balcooa, B. longispiculata, B. multiplex, B. tulda, B. vulgaris, B. wamin, D. longispathus, O. travancorica, O. abyssinica* and *P.ritcheyi.*

Host range: *Bambusa blumeana*

Remarks: Vagrant on the lower leaf surface. First report from India.

Superfamily : Eupodoidea Koch, 1842

Family : Eupodidae Koch, 1842

Genus : *Eupodes* Koch, 1835

Generic Diagnosis: Body soft and delicate; dorsal setae inflated basally and tapering towards distal end, setae f_1 not modified as trichobothria. Leg IV thicker than other legs with very thick femora.

Eupodes parafusifer Meyer and Ryke, 1960 (**Plate: 40; Fig. 47 a-e**)

Colour : yellowish black

Measurements: Length : 440- 460

Width : 250- 265

Female: Body oval in appearance. Propodosoma separated from hysterosoma by a distinct suture. A small plate bearing two short setae present at the anterior region of propodosoma. Propodosoma bears a pair of finely setose sensory setae (105). Anterior to the sensory setae, a pair of spindle shaped setae present, one on each side present. A pair of conspicuous, but simple setae present lateral to the sensory setae, one on either side. Hysterosoma with 10 pairs of setae, six pairs spindle shaped and four pairs of linear-lanceolate in nature, the latter arranged in two rows at the posterior margin of the body. Palp- femur forms the longest segment bearing a pair of setose setae. Genu and tibiotarsus with three and four setae respectively.

Leg: Femur IV- thickened. Tarsus with claws and empodium.

Male: Not found while sampling.

Materials Examined: 3♀♀ from *B. bambos*, collected on 8.03.2016, Malappuram Dt., Kerala, India. Coll. Vibija, C.P.

Other bamboo hosts: *B. balcooa, B. longispiculata, D. giganteus, M. bacciferra* and *O. ebracteata.*

Host range: *Ficus carica, Ficus religiosa, Millettia pinnata, Mangifera indica, Artocarpus heterophyllus, Terminalia catappa, Sapindus mukorossi, Amoora lawii, Mesua ferrea, Syzygium jambos, Tabebuia argentea.*

Remarks: The specimen agrees with *E. parafusifer* Meyer and Ryke, 1960 in all features and hence fixed as so. This is the first report on the infestation of the species on bamboo hosts.

Superfamily : Tetranychoidea Donnadieu, 1876
Family : Tetranychidae Murray, 1877
Genus : *Aponychus* Rimando, 1966

Generic Diagnosis: dorsoventrally compressed body; wrinkled dorsal integument; hysterosoma with 10 pairs of dorsal body setae; 1 pair of anal setae.

Aponychus corpuzae Rimando, 1966 (**Plate: 41; Fig. 48 a-e**)

Colour : Light green

Measurement : Length : 420-470

Width : 378-410

Female: Body dorsoventrally flattened, ovoid- trapezoid, with propodosomal enlargement in lateral sides, narrowing towards the body end. Body margin uneven, dorsum transversely striated. Legs very long with long setae. Striations anteriorly transverse and posteriorly longitudinal. Stylophore with deep cleft anteriorly forming two horn like projections. Propodosoma laterally enlarged between setae sc_2 and c_3. Dorsum with three pairs of propodosomal setae and ten pairs of hysterosomal setae.Setae v_2 (54), sc_2 (66), c_3 (71), e_2 (44), f_2 (62) and h_1 (60) thick, densely barbulate, arising from tubercles. Setae sc_1 (20), c_1(19), c_2 (19), d_1 (21), d_2 (29) and e_1 (24) much shorter, serrate with blunt tips, tubercles not well formed. Setae f_1 (24) thinner, set on set slightly lower to f_2. One pair of pseudoanal setae, two pairs of genital setae and two pairs of finely barbed paraanal setae present.

Leg: Leg chaetotaxy: Trochanter: 1-1-1-1; femur: 7-5-4-2; genu: 3-3-2-2; tibia: 5(1)-3-2-2; tarsus: 10(5)-8 (3)+1ds-8(1)-8(1).

Male: Smaller than female with 300-320 long and 240- 260 wide, paler, narrower, setae much weaker, set on weak tubercles, fine serrated. One pair of pseudo anal setae, two pairs of para anal setae and three pairs of genital setae present. Aedeagus bent distally.

Materials Examined: 3♀♀ from *B. bambos*, collected on 20.04. 2015, from Thrissur Dt., 2 ♀♀ from *B. tulda* and 3♀♀ from *B. vulgaris*, collected on 11.05.2016, from Malappuram Dt., Kerala, India. Coll. Vibija, C.P.

Other bamboo hosts: *B.balcooa, B.nutans, B.longispiculata, D.giganteus, B.polymorpha, M.bacciferra, B.membranacea, B.multiplex, B.pallida, B.wamin, D.asper, D.brandisii* and *T.regia.*

Host range: *Bambusa sp.*

Remarks: This specimen closely resembles *A. corpuzae* Rimando, 1966, in all dorsal and ventral characters and hence confirmed as so. This is the first report from Kerala.

Genus : *Oligonychus* Berlese, 1886

Generic Diagnosis: Opisthosoma with 10 pairs of dorsal setae; empodium claw like with proximoventral hairs; duplex setae of tarsus I are distal and adjacent; anal region with 2 pairs of pseudoanal setae and 1 pair of setae.

Oligonychus biharensis (Hirst, 1924) **(Plate: 42; Fig. 49 a-e)**

Colour: Reddish brown with dark spots

Measurement: Length : 420- 440

Width : 300-315

Female: Dorsal setae slender, pubescent, not set on tubercles, longer than intervals between their bases. Outer sacral setae approximately as long as inner sacral setae. Peritreme 'U' shaped distally. Medioventral opisthosomal setae thick as normal setae. Transverse striae on genital flap. Longitudinal striae on area ahead of genital flap. Palp-terminal sensillum twice as long as wide, dorsal sensillum small, tibial claw slightly concave.

Leg: Empodial claw of leg I with three pairs of proximoventral hairs. Tarsus I with four tactile and one sensory setae proximal to proximal set of duplex setae. Tibia I with nine tactile and one sensory setae. Tarsus II with three tactile and one sensory setae proximal to duplex setae. Tibia II with seven tactile setae. Tarsus III with ten tactile and one sensory setae, tibia III with six tactile setae. Tarsus IV with ten tactile setae, tibia IV with seven tactile setae.

Male: Smaller than female with body 380-400 long and 180-200 wide. Aedeagus bent dorsad, axis of knob parallel to axis of shaft. Terminal sensillum of palpus about four times as long as wide, dorsal sensillum very short. Tarsus I with four tactile and three sensory setae proximal to proximal set of duplex setae. Tibia I with nine tactile and four sensory setae. All other setae similar to that of female.

Materials Examined: 4♀♀ and 3♂♂ from *B. bambos*, collected on 20.04. 2015, Thrissur Dt., Kerala, India. Coll. Vibija, C.P.

Other bamboo hosts: *B. tulda*, *B. vulgaris* and *G. atroviolacea.*

Host range: *M. indica, C. esculenta, C. nucifera, Diospyros maritime, M. esculenta, T. indicus, Vigna unguiculata, P. guajavae, Cinnamomum camphora* etc.

Remarks: The observed specimen resembles *O. biharensis* (Hirst, 1924), in features such as dorsal chaetotaxy, leg chaetotaxy and all other characters of hence fixed as so. This is the first report on the occurrence of the species from *B. bambos.*

Genus : *Tetranychus* Dufour, 1832

Generic Diagnosis: Peritreme recurved distally; empodium split distally, commonly into three pairs of hairs; empodial spur commonly visible; duplex setae of tarsus I well separated; anal region with one pair of setae;

Tetranychus urticae C.L. Koch, 1836 **(Plate: 43; Fig. 50 a-e)**

Colour: Green form

Measurement : Length : 320 - 340

Width : 220 - 230

Female: The species seems to exist in both red and green forms. Peritreme hooked. Opisthosomal dorsal striae lobate. Lobes vary from triangular to semicircular, between setae e_1-e_1 and f_1-f_1 longitudinal and between setae e_1-f_1 they form diamond shape. Ventral striae lack lobes. Pregenital striae usually entire.

Leg: Tarsus I with four tactile setae proximal to the proximal duplex setae. Empodia having six proximoventral hairs and lacks spurs.

Male: Empodia I-II bears a dorsal spur. Empodia I claw like, Empodia II- IV with long and free proximoventral hairs. Aedeagus with small knob, axis of knob parallel to axis of shaft. Anterior and posterior angulations of the knob small and similar.

Materials Examined: 3♂♂ from *B. vulgaris* and 3♀♀ from *B. bambos*, collected on 8. 03. 2016, Malappuram Dt., Kerala, India. Coll. Vibija, C.P.

Other bamboo hosts: *B. balcooa*, *B. longispiculata*, *B. membranacea*, *B. nutans*, *B. polymorpha*, *B. tulda*, *B. wamin*, *D.asper*, *D. hamiltonii*, *P. ritcheyi*, *G.atroviolacea* and *S. griffithiana*.

Host range: *M. indica, Coriandrum sativum, Asparagus offcinalis, Oryza sativa, Saccharum officinarum, Zea mays, Avena sativa* etc.

Remarks: This specimen resembles all characters of *T. urticae* C.L.Koch, 1836 and hence confirmed as so. This is the first report from bamboo hosts.

Genus : *Schizotetranychus* Tragardh, 1915

Generic Diagnosis: Opisthosoma with 10 pairs of dorsal setae; empodium claw like; 2 pairs of para- anal setae; distal segment of palpus with 3 simple setae, 3 eupathidia and 1 solenidion.

Schizotetranychus schizopus (Zacher, 1913) **(Plate: 44; Fig. 51 a-e)**

Colour : Pale Yellow

Measurement : Length : 350 - 355
Width : 230 - 235

Female: Oval shaped body with slight constriction between propodosoma and hysterosoma laterally. Dorsal sensillum spindle shaped, terminal sensillum of palpus twice as long as broad. Mandibular plate slightly notched. Peritreme slightly bent in distal portion, ending into a swollen chamber. Dorsal setae slender, somewhat widened near the base, not arising from tubercles, barely surpassing base of next seta. Area adjacent to the genital flap with transverse striae, genital flap with transverse striae. Posterior portion longitudinally striated.

Legs : Relative length of segments in leg I as follows: Trochanter- 9-11, Femur- 22-24, Genu- 10-13, tibia- 10-13, tarsus- 15-18 (excluding empodium). Tarsus I with two tactile and one sensory setae proximal to proximal duplex setae, tibia I with nine tactile setae and one sensory setae. Tarsus II with only one sensory setae proximal to duplex setae; tibia II and III with five tactile setae. Empodia split into two claws and with a pair of proximoventral hairs.

Male: Body about 230-233 long and about 158-160 wide at the widest part. Distal segment of palpus devoid of terminal sensillum, dorsal sensillum spindle shaped. Aedeagus as shown in the figure, shaft narrowing backward and curving upward to the barb, acutely angled anteriorly. The axis of the barb forming a definite angle with the axis of the shaft.

Legs: Tarsus I with two tactile and two sensory setae proximal to duplex setae. Tibia I with nine tactile and three sensory setae. Tarsus II with one sensory seta proximal to duplex setae. Tibia II and Tibia III with five tactile setae respectively. Empodia without claws and proximoventral hairs.

Materials examined: 3♀♀ and 2♂♂ from *B. bambos*, collected on 11.05.2016, from Malappuram Dt., Kerala, India. Coll. Vibija, C.P.

Other bamboo hosts: *B. balcooa*, *B. longispiculata*, *B. membranacea*, *B. multiplex*, *B. nutans*, *B. pallida*, *B. polymorpha*, *B. tulda*, *B. vulgaris*, *B. wamin*, *D.asper*, *D. giganteus*, *D. hamiltonii*, *O. scriptoria*, *P. ritcheyi*, *T. regia* and *G. atroviolacea*.

Host range: willow tree.

Remarks: This specimen closely resembles in all dorsal chaetotaxy with *S. schizopus* (Zacher, 1913), and hence fixed as so. This is the first report from India.

Schizotetranychus recki Ehara, 1957 **(Plate: 45; Fig. 52 a-e)**

Colour : Pale greenish yellow

Measurement : Length : 320 - 324

Width : 189 - 194

Female: Elliptical to oval in shape, Slender body. Terminal sensillum of palpus twice as long as wide; dorsal sensillum spindle shaped, shorter than terminal sensillum. Mandibular plate slightly incised in front. Peritreme slightly bent distally, ending in a swollen portion. Dorsal setae slender, tapering, pubescent, not set on tubercles, longer than intervals between their neighbouring bases. Area adjacent to genital flap transversely striated. Genital flap with transverse striae anteriorly and longitudinal striae posteriorly.

Leg: Trochanter I- 10-13 long , Femur I- 20-22 long , Genu I- 10-13 long , Tibia I- 12-14, Tarsus I - 16-19 (excluding empodium). Tarsus I with two adjacent sets of duplex setae, Tibia I with one sensory and seven tactile setae, Tarsus II with one sensory and one tactile setae proximal to duplex setae. Tibia II with six tactile setae, Tibia III with four tactile setae, Tibia IV with a long seta distally. Empodium splits into Y shaped claws without dorsal hairs and proximolateral hairs.

Male: Body 185-190 long, 115- 122 wide in widest part. Terminal sensillum three times as long as broad.

Leg: Tarsus I with three sensory and two tactile setae proximal to proximal set of duplex setae. Tibia I with one sensory and one tactile setae proximal to duplex setae. Tibia II and Tibia III with six and four tactile setae respectively. Empodia similar to that of female. Aedeagus tiny, bent upward to form a sigmoid distal portion as shown in figure.

Materials Examined: 4♀♀ and 2♂♂ from *B. bambos*, collected on 16. 04. 2016; 3♀♀ from *B. vulgaris*, collected on 8.03. 2012, Malappuram Dt., Kerala, India. Coll. Vibija, C.P.

Other Hosts: *B. balcooa*, *B. longispiculata*, *B. membranacea*, *B. nutans*, *B. pallida*, B. tulda, *B. wamin*, *D. brandisii*, *D. giganteus*, *P. ritcheyi*, *G. atroviolacea* and *S. griffithiana*.

Host range: Sasa bamboo.

Remarks: This species resembles in all characters with *S. recki* Ehara, 1957 and thus confirmed as so. This is the first report from India.

Genus: *Stigmaeopsis* Banks, 1917

Generic Diagnosis: palp tarsus bears 6 setiform structures (2 simple setae, 3 eupathidia and 1 solenidion), trapezoidal area present on dorsal integument, between pairs of setae, c_1- c_1; d_1- d_1 and e_1- e_1.

Stigmaeopsis longus (Saito, 1990) **(Plate: 46; Fig. 53 a-e)**

Colour: Greenish Yellow

Measurement : Length : 360 - 378
Width : 250 - 256

Female: Body flattened with small blackish green spots. Idiosoma with slender dorsal setae. Propodosoma well demarcated from the hysterosoma and second propodosomal setae as long as distance between their bases. All other dorsocentral hysterosomal setae placed almost on a straight line. c_2 and c_3 more than twice as long as distance between bases of them and of c_3 and c_4 respectively. Dorsal setae long, slender, not set on tubercles and tapering. Genital flap transversely striated, area anterior to flap also transversely striated. Spinneret on palpus conical in shape and about half to one third as long as wide.

Leg: Empodia with two claws. Leg chaetotaxy- Femur: 8-5-3-3; Genu: 5-4-3-2; Tibia: 7+1-5-5-5; Tarsus: 10(1)+2dp-9(1)+1dp-8(1)-8(1).

Male: Smaller than female with 265-272 and 320-329 long. Aedeagus broadly curved dorsad. Leg chaetotaxy of femur: 9-5-3-3; genu: 5-4-3-3; tibia- 7(2)-5-5-5; tarsi: 10(2)+2dp-9(1)+1dp-8(1)-8(1).

Materials Examined: 6 ♀♀ from *B. bambos*, collected on 11.05.2016, Malappuram Dt., Kerala, India. Coll. Vibija. C.P.

Other Hosts: *B. longispiculata*, *B. vulgaris*, *D. asper*, *D. brandisii* and *G. atroviolacea.*

Host range: *Sasa senanensis*

Remarks: Striations not much well developed, rest all characters in accordance with *S. longus* Saito, 1990. First report from India.

Genus : *Stylophoronychus* Prasad, 1975

Generic Diagnosis: Hysterosoma with 9 pairs of dorsal body setae.

Stylophoronychus vannus (Rimando, 1968) **(Plate: 47; Fig. 54 a-e)**

Colour : Reddish brown

Measurements : Length : 390- 410

Width : 160-175

Female: Body oblong. Peritreme hook like distally. Terminal sensillum of palpus slender.Idiosomal setae spatulate. Idiosoma with dorsal integument wrinkled. Propodosomal setae I-III, inner sacrals, clunals and third dorsocentral setae short and fan -like. Genital flap with transverse striae.

Leg Chaetotaxy: Tibia I with 1 sensory, 2 spatulate and 1 tactile setae; tarsus I with 10 tactile setae. Tibia II with 1 spatulate seta; tarsus II with 8 tactile setae.

Male: Not found while sampling.

Materials Examined: 4♀♀ from *B. vulgaris*, collected on 20. 04. 2015, Thrissur Dt., 6♀♀ from *B. tulda*, collected on 11.05. 2016, Malappuram Dt., Kerala, India. Coll. Vibija, C.P.

Other bamboo hosts: *B. bambos*, *B. balcooa*, *B. membranacea*, *B. multiplex*, *B. pallida*, *B. wamin*, *D. asper*, *D. brandisii* and *T. regia*.

Host range: *B. aurandinacea, Saccharum officinarum*

Remarks: This species resembles *S. vannus (Rimando,* 1968) and hence fixed as so.

Superfamily : Cheyletoidea Leach, 1815

Family : Cheyletidae Leach, 1815

Genus : *Cheyletus* Latereille, 1796

Generic Diagnosis: Palp tarsus with 2 sickle like and 2 comb like setae; peritreme M shaped, hysterosomal shield quadrangular, usually broadest on the front; 4 pairs of setae on propodosomal shield, 2-5 pairs on hysterosomal shield.

Cheyletus rosensis Mary Anitha and Ramani, 2009 **(Plate: 48; Fig. 55 a-e)**

Colour : Transparent –white

Measurements : Length : 343-356

Width : 300-315

Female: Gnathosoma 110 long with large palpi. Protegmen smooth, longitudinal striations on tegmen. Palp- claw curved with 7 basal processes, tarsus with 2 sickle shaped setae and two comb like setae, tibia with one thick, serrated seta on dorsal and one smooth seta on ventral side, Palp femora slightly convex on outer surface, striated and granular. Two spatulate setae placed dorsally, one simple seta on ventral, genu without any seta. Peritreme M shaped with 20 links. Dorsum without any shields and possesses fine striations as shown in figure. Prodorsum 180 long and 315 wide with three pairs of dorsal setae (20 long), three pairs of subdorsal setae (18 long) and a pair of lateral setae (18 long). Hysterosoma 218 long and 230 wide with six pairs of spatulate setae. Ventral region smooth, propodosomal region with two pairs of simple setae, hysterosomal region with four pairs of simple setae, two pairs of simple setae on genital region and three pairs of anal setae present.

Leg : Chaetotaxy: Coxae: 2-1-0-2; Trochanter : 0-1-2-1; Femora: 2-2-1-1; Genu: 2-2-2-1, Tibia: 3-4-4-4; Tarsi: 4(1)-5(1)-4(1)-4(1). Tarsus I ends in a pair of small claws and with one pair of adoral setae 'tc'. Tarsi II - IV end in well developed claws and rayed empodium.

Male: Not found in the sample.

Materials Examined: 5♀♀ from *B. vulgaris*, collected on 13.04.2016, from Malappuram Dt., Kerala, India. Coll. Vibija, C.P.

Other bamboo hosts: *B. bambos*, *B. tulda*, *O. travancorica*, *D. giganteus* and *O. ebracteata.*

Host range: *Rosa indica, C. nucifera*

Remarks: This specimen agrees with *C. rosensis* Mary Anitha and Ramani, 2009 in almost all characters and hence fixed so. This is the first report of the species from bamboos.

Superfamily : Raphignathoidea Kramer, 1877

Family : Stigmaeidae Oudemans, 1931

Genus : *Agistemus* Summers, 1960

Agistemus aimogastaensis Leiva, Fernandez, Theron and Rollard, 2013

(Plate: 49; Fig. 56 a-e)

Colour : Pale Yellow

Measurements: Length : 325-335

Width : 150-165

Female: Propodosomal plate more or less trapezoidal and ornamented with polyhedral reticulate pattern. Eyes visible. Post ocular body triangular. Rounded extremities with series of longitudinally aligned small round elevations, joined by thread like strands. Metapodosomal plate hexagonal, ornamented with transverse polyhedral reticulate pattern. Wide area with transverse integumental striae, separating metapodosomal and propodosomal plates. All dorsal setae minutely denticulate with following measurements: *vi* (12), *ve* (14), *sce* (18), c_2(22), c_1(20), d_1 (18), e_1(19.3), d_2(20), e_2(16), f_1(16), h_1(12), h_2(16). Ventral Setae *g*, ps_1, ps_2 finely barbed and sharply tipped. Seta ps_3

slightly dentate, setae *g*, ps_1 and ps_2 larger than ps_3. Two pairs of paragenital setae: ag_1, ag_2 and four pairs of genital setae and three pairs of anal setae, ps_1, ps_2, ps_3.

Legs: Ambulacrum with two claws having small tooth and an empodium with three pairs of fan shaped raylets. Leg chaetotaxy: trochanter: 1-1-1-1; femur: 4-4-2-2; Genu: 2(1)-0-0-0; tibia: 5(1)-5(1)-5(1)-4; tarsus: 11(1)-8(1)-7(1)-7.

Male: Not found while sampling.

Materials Examined: 3♀♀ from *B. nutans*, collected on 20.04.2015, Thrissur Dt., Kerala, India. Coll. Vibija, C.P.

Other bamboo hosts: *B. bambos* and *O. abyssinica.*

Host range: *Olea europaea*

Remarks: This specimen resembles *A. aimogastaensis* Leiva, Fernandez, Theron and Rollard, 2013 in all characters and hence confirmed as so. This is the first report from India.

Superfamily : Tarsonemoidea Canestrini and Fanzago, 1877

Family : Tarsonemidae Kramer, 1877

Genus : *Diadalotarsonemus* De Leon, 1956

Generic Diagnosis: ornamented tergite C and D, tegula rounded or truncated, posterior dorsal setae leaf like, rod like or serrated, dorsal apodeme distinct.

Diadalotarsonemus serratus Rezende, Ochoa and Lofego, 2015

(Plate: 50; Fig. 57 a-b)

Colour : Pale Yellow

Measurements : Length : 210- 225

Width : 110- 125

Female: Prodorsal shield with irregular ornamentation. Heavily arched tegula and position of c_1, near to the posterior margin of the tergite C. Tergite C ornamented, having long longitudinal ridges between setae c_1 and irregular ornamentation on the lateral sides. Tergite D with reticles and irregular ornamentation. All dorsal setae serrate. Bothridial setae sc_1 capitate, with tiny spines. Measurements of setae: v_1- 22, sc_1 -18, sc_2- 32, c_1- 24,

c_2- 19, *d*-23, *e* -18, *f*- 19 and *h*- 17. All setae inserted on tubercles except sc_1 and *h*. Seta sc_2 inserted posterior to sc_1.

Leg: Chaetotaxy: Femur: 3-3-1; Genu: 4-4-2; Tibia: 5(2)-4-4; Tarsus: 7(1)-4(1)-4

Male: Not found while sampling.

Materials Examined: 2 ♀♀ from *B. bambos*, collected on 8.03.2016, Malappuram Dt., Kerala, India. Coll. Vibija, C.P.

Host range: *Nephrolepis* sp.

Remarks: First report from India.

Genus : *Steneotarsonemus* Beer, 1954

Generic Diagnosis: Females with elongate body, legs I and II widely separated from legs III- IV, 2 pairs of propodosomal setae; males with 4 pairs of propodosomal setae, femur IV with a flanglike process.

Steneotarsonemus spinki Smiley, 1967**(Plate: 51; Fig. 58 c-d)**

Colour : Light Yellow

Measurements : Length: 210- 225

Width : 80- 90

Female: Idiosoma elongate and finely punctuated. The prodorsal shield not projected beyond the basal part of gnathosoma. Stigmata located on the margins of prodorsal shield. Seta v_1 stout and finely pilose, sc_2 filiform and inserted posterolateral to v_1. Bothridial seta sc_1 leaf like, finely pilose with rounded base, not covered by prodorsal shield. Seta c_1 barbed and shorter than setae the distance of c_1 -c_2, seta$c_2$transversely aligned. Setae *d*, *e* and *f* setiform, barbed and stout. Seta *e* as long as *f*. On the ventral side, seta *1a* twice longer than *2a*. Seta *3a* long and filiform.

Leg: The subunguinal setae on tarsus I spine like and bifid distally.

Male: Not found while sampling.

Materials Examined: 2♀♀ from *B. bambos*, collected on 22. 03. 2015, Kozhikode Dt., Kerala, India. Coll. Vibija, C.P.

Other bamboo hosts: *B. pallida* and *B. vulgaris*.

Host range: *Oryza sativa* and *Oryza latifolia*

Remarks: The specimen examined resembles in all characters with *S. spinki* Smiley, 1967 and hence confirmed as so. This forms the first report of the species from bamboos.

Order	:	**Sarcoptiformes Reuter, 1909**
Suborder	:	**Oribatida (Duges, 1833)**
Superfamily	:	**Oripodoidea Jacot, 1925**
Family	:	**Hemileiidae J & P Balogh, 1984**
Genus	:	***Hemileius*** **Berlese,1916**
Subgenus	:	***Hemileius (Tuberemaeus)*** **Sellnick, 1930**

Generic Diagnosis: Notogaster foveolate, punctuate or reticulate with 10 to 14 pairs of distinct setae; 4 pairs of genital setae, 1 pair of aggenital setae; 2 pairs of anal setae; Legs tridactylous.

Hemileius (Tuberemaeus) singularis (Sellnick, 1930) **(Plate- 52; Fig- 59a-b)**

Colour : Brown

Measurements : Length : 350

Width : 220

Dorsal region: Prodorsum areolate; seta *ro* thin, 20 long; seta *le* distinctly barbed ; seta *in* densely barbed and dilated, 14 long; lamella converging with distinct curvature at the level of seta *le*; sensillus short and capitate, densely barbed; translamella absent; pteromorphae absent.

Ventral region: Epimeral region with a setal formula of 2-1-2-1, all setae short and smooth; genital plates with four pairs of short, smooth setae; aggenital setae one pair; anal setae two pairs, an_1 located posteriorly and an_2 inserted anteriorly; three pairs of adanal setae present, ad_1 post-anal, ad_2 posterolateral and ad_3 anteriorly placed ; ventral plate with irregular areolae.

Legs: All legs tridactylous with thick central claw.

Materials Examined: 1♀ collected from leaves of *B. bambos*, on 11.05. 2016, Malappuram Dt., Kerala, India. Coll. Vibija, C.P.

Distribution: Soils of Oriental, East- Eastern Palearctic and Hawaiian.

Remarks: The specimen examined during the present study closely resembles the species, *H. (T.) singularis* (Sellnick, 1930) and hence fixed as so.

Superfamily : Oripodoidea Jacot, 1925

Family : Hemileiidae J and P Balogh, 1984

Genus : *Siculobata* Grandjean, 1953

Generic Diagnosis: Notogaster with 10 pairs of setae and 4 pairs of sacculi, sensilli short and capitate, aggenital seta if present will be 1 pair, 4 pairs of genital setae; 2 pairs of anal setae and 3 pairs of adanal setae present; solenidia of tibia III and IV ending in small vesicle.

Siculobata malabarica Ramani and Haq, 1998 **(Plate- 53; Fig- 60a-d)**

Colour : Dark Brown

Measurements : Length : 312

Width : 210

Dorsal region: Broader basally and narrowing towards the rostrum. Rostrum with two incisions, lamella sheath like and extending upto bothridium. Seta *ro* long, barbed and pointed, seta *le* - thicker than *ro*, bears spines and ends in blunt tip. Seta *in* the longest having spines and blunt tip. Measurements of setae as follows: *ro*- 50, *le*- 69 and *in*- 75. A pair of area porosae (A_1) present, one on either side of lamellae. Exobothridial setae absent; bothridium (*bo*) hidden by notogaster; sensillus (*ss*) with head globose and roughened, stalk short and smooth. Notogaster spherical and broadest medially; dorsosejugal suture demarcates anterior border from the prodorsum; 10 pairs of thin, simple setae mostly arranged laterally on notogaster, sacculus *sa* located near insertion of seta *te*, s_1 below the notogaster; fissure *im* present at middle of notogaster; integument of notogaster smooth and devoid of ornamentation.

Ventral region: Hypostome with seta *m* smaller than *h*; both *m* and *h* roughened; seta *a* thick, stout and barbed, chelicera well developed with porose area; Epimeral Region with apodemata II and III well developed; smooth epimeral area with setal formula 3-2-2-3, all setae smooth except *1c*; the latter barbed and stouter than others. Anterior border of the genital plates broader than the posterior border; three smooth setae present on each genital plate, g_1 anteriorly located while g_2 and g_3 posteriorly located. A pair of smooth aggenital setae (*ag*) inserted posterior to the genital plates. Anal plates with two pairs of smooth setae, an_1 posteriorly inserted and an_2 inserted anteriorly; three pairs of adanal setae present, all thin and smooth, ad_1 located posteriorly and ad_2 postero-laterally and ad_3 anterior to the anal plates; fissure *iad* vertical and placed outer to the anal plates, in between setae ad_2 and ad_3.

Legs: All legs tri and heterodactylous; on legs III and IV, solenidia of tibia end in small vesicles; femora III and IV slender and elongated; femur I thick, swollen, bears faint striations, porose area and barbed setae, *d, l'* and *l''*, *bv''* roughened; chaetotaxy of leg I: 0-5-3-6-19; solenidion (σ) of genu I setaceous; setae on distal half of tibia with two solenidia, φ_1 thicker and longer than φ_2; ω_1 thicker, shorter with blunt tip and ω_2 slender and tapering tip; famulus (*ε*) proximal to ω_2; tarsal setae mostly barbed and seta *p* eupathidic and thick.

Materials Examined: 2 ♀♀ collected from leaves of *B. bambos*, on 20. 04. 2015, Thrissur Dt., Kerala, India. Coll. Vibija, C.P.

Host range: *Mariscus javanicus,* Coconut palm.

Remarks: This species resembles *S. malabarica* Ramani and Haq, 1998 in all characters and hence fixed as so.

Superfamily : Oripodoidea Jacot, 1925

Family : Mochlozetidae Grandjean, 1960

Genus : *Uracrobates* Balogh & Mahunka, 1967

Generic Diagnosis: Presence of medially interrupted dorsosejugal suture, ten to eleven pairs of notogastral setae, posteriorly conical or truncated notogaster.

***Uracrobates (Uracrobates) indicus* Ramani & Haq, 1990 (Plate- 54; Fig- 61a-c)**

Colour : Light Brown

Measurements: Length : 575

Width : 410

Dorsal region: Rostrum with two incisions, one at extreme tip and other behind laterally; seta *ro* (90) long, barbed extending beyond rostral tip; lamellae with horizontal annulations, seta *le* barbed (120) long; sensillus (*ss*) with smooth stalk and clavate barbed head, seta *ex* barbed; notogaster with well developed pteromorph anterolaterally;10 pairs of small setae and four pairs of area porose located on notogaster; *im* located medially; anterior border of notogaster demarcated by a convex dorsosejugal suture while the posterior border conical in appearance.

Ventral region: Rutellum with five notches; setae of infracapitular region barbed; chelicera with sclerotized teeth and porose surface; sejugal apodeme longer; epimeral setae spined, setal formula of epimeral surface: 3-2-2-1; genital plates with six pairs of roughened setae; anal plates elongated with two pairs of smooth, small setae, an_1 posterior and an_2 anterior in location; adanal setae smooth, short and 3 pairs; ad_1 posterior to anal plate; ad_3 anterior and ad_2 lateral in position.

Legs: All legs tridactylous with three smooth unequal claws; leg I with setal formula: 0-6-4-6-22; femur I stout with a ridge, porose area and six barbed setae; tarsus I with 22 setae including two solenidia (ω_2 longer than ω_1) and a famulus (ε).

Materials Examined: 1 ♀ from *B. bambos*, collected on 22. 03. 2015, Kozhikode Dt., Kerala, India. Coll. Vibija, C.P.

Host range: *Cocos nucifera, Mangifera indica.*

Remarks: The specimen examined during the present study closely resembles the species, *U. indicus* Ramani & Haq, 1990 and hence fixed as so.

Uracrobates (Ovouracrobates) *subgenus nov.*

Subgeneric diagnosis:

The genus *Uracrobates* coming under the family Mochlozetidae, was erected by Balogh and Mahunka (1967), based on the type species, *U. magniporosus* Balogh and Mahunka (1967). Currently, the genus comprises five valid species erected under two subgenera Viz. *Uracrobates (Uracrobates)* and *Uracrobates (Parauracrobates)* which possess the common features like bidentate rostrum, well developed lamellae with strong outer and small inner teeth on cusps, translamella thinner than lamellae, short and clavate sensillus, 10 pairs of minute setae or alveoli and 4 pairs of area porosae on notogaster, immovable petromorphs, genital setae 6 pairs and legs tridactylous. The members of the two subgenera differ in the shape of the notogaster, which is conical in *U.(Uracrobates)* and truncated in *U. parauracrobates).* The new subgenus resembles the above two subgenera in all features mentioned above, but strongly differs in the distinctly oval nature of the notogaster.

Type species: *Uracrobates (Ovouracrobates) keralensis* sp. nov.

Etymology: The prefix 'Ovo' added to the subgeneric name represents the distinctly oval shape of the notogaster.

Uracrobates (Ovouracrobates) keralensis sp. nov. **(Plate- 55; Fig- 62a-h)**

Colour :	Light brown
Measurements :	Length : 630-684
	Width : 460- 510

Dorsal region: Prodorsum: Rostral apex marked by the presence of a pair of incisions; seta *ro* 75 long, inserted slightly behind the rostral tip and barbed; lamellar base narrow, thickening medially and narrowing towards cuspis; outer cuspis sharply pointed and longer; translamella wavy in outline and thick; seta *le* 120 long, barbed, sharply pointed with annulations at base, seta *in* the longest (190) and thickest among the prodorsal hairs, inserted above dorsosejugal suture; seta *ex* thin, barbed and deeply inserted, sensillus (*ss*) with clavate, barbed head, feeble punctuation on prodorsal integument, with aggregations on the surface of lamella, translamella and on the lateral margins of prodorsum, above and below the dorsosejugal suture.

Notogaster: Anterior border demarcated by the medially interrupted dorsosejugal suture; notogaster more or less oval in outline, with pteromorphae developed anteriorolaterally; pteromorphae with median striations; four pairs of area porosae on notogaster; *Aa* placed anteriorly far from others; A_1 well behind middle, A_2 posterolaterally; A_3 posteriorly; distance between *Aa* and A_1 more than twice the distance between A_2 and A_3 and more than thrice the distance between A_1 and A_2; setae *ta* and *te* on pteromorphae, *ms* slightly above the level of A_1 and below the middle; r_1 at extreme end of posterior side, r_2 between A_2 and A_3, r_3 at the middle of A_1 and A_2; p_1, p_2 and p_3 arranged posterolaterally in an ascending sequence; notogaster feebly foveolated along the lateral border; fissure *ia* present on pteromorphae, *im* located slightly below the middle of notogaster and *ip* located posteriorly.

Lateral region: Tutorium (*tu*) present; acetabulum entirely covered by well-developed pedotectum I; ¾ of its region possesses striae; acetabulum II also covered by well-developed pedotectum II; custodium (*cus*) and discidium (*dis*) visible clearly; circumpedal carina (*cir*) extending beyond acetabulum IV.

Ventral Region: Gnathosomal Region with diarthric labiogenal articulation; mentum broad and rectangular; well- developed genu; setae *h* and *m* barbed and equal, seta *a* short and barbed; rutellum (*ru*) with sclerotized notches; porose infracapitular surface; cheliceral setae barbed, cheliceral teeth strongly sclerotized; chelicerae except the fixed and movable digits porose; pedipalp setation: 0-2-1-3-10; palpal femur with striations and a ridge, tarsal eupathidia small, *acm* closely adhacent to solenidion (*ω*) but not fused with it.

Epimeral Region: Apodemes II, III and the sejugal one detected; epimeral setation: 3-2-2-1; setae roughened and of varying length, 1b the longest.

Genital and anal region: Genital plates with six pairs of roughened setae; aggenital setae (*ag*) roughened and inserted posterolateral to the genital plate; anal plates with two pairs of smooth, short setae; an_1 posteriorly and an_2 anteriorly located; three pairs of smooth adanal setae; ad_1 posterior, ad_2 posterolateral and ad_3 anterior in location; *iad* longitudinal and para- anal in position, between ad_2 and ad_3; small foveoles present on ventral plate, in between genital and anal plates, and epimeral surface.

Legs: All legs tridactylous, with central claw being thicker than the lateral ones. Leg I with a chaetotaxy of 0-6-4-6-21, femur I with porose area and a ridge, seta *d* densely barbed and thick, *l″* shorter than *l′*; genu I narrow, solenidion (σ) tapering apically; tibia I broader anteriorly and narrow posteriorly; φ_1 more than twice the length of φ_2; ω_1 and ω_2 of tarsus I equal , proximal to ω_2 lies the famulus (ε); all setae on tarsus I barbed, except *s* which is smooth and (*p*), which are roughened.

Materials examined: Holotype : ♀, paratypes : 2♀♀ collected from leaves of *B. bambos*, on 11.05. 2016, Malappuram Dt., Kerala, India. Coll. Vibija, C.P.

Remarks: The genus *Uracrobates* was erected by Balogh and Mahunka, 1967 based on the type species *U. magniporosus* from Tanzania. Presently, this genus has five species under two subgenera viz. *U. (Uracrobates)* and *U.(Parauracrobates).* The members of the two subgenera differe in the shape of their notogaster, in which the former possesses conical notogaster while the latter possesses truncated notogaster. The present new species could be easily differentiated from the above two subgenera based on the distinctly oval nature of the notogaster and hence a new subgenus viz. *Uracrobates (Ovouracrobates)* has been erected to accommodate the new species. The present new species resembles the known five species of the genus *Uracrobates* in having 10 pairs of notogastral setae, four pairs of well developed area porosae, short and clavate sensillus and thick lamella with well- developed teeth on cusps. However, it keeps its identity separate from all the described species in the distinctly oval nature of notogaster when compared to the truncated and conical notogaster of the species described under the two subgenera mentioned above.

Etymology: The specific name '*keralensis*' refers to the geographical region from where it was found.

Key to the subgenera and species of the genus *Uracrobates:*

1) Posterior part of notogaster conical or truncated ……………. …………………… 2

- Posterior part of notogaster distinctly oval in shape....................Subgenus *Uracrobates (Ovouracrobates)* **subgen. nov**.; one species……………………..*U. (O.) keralensis* **sp. nov.**

2) Posterior part of notogaster conical……………….. 3- Subgenus *Uracrobates (Uracrobates)* Balogh & Mahunka, 1967

- Posterior part of notogaster truncated in shape…...........................Subgenus *Uracrobates (Parauracrobates)* Ermilov and Martens, 2015; one species………..*U. (P). truncatus* Ermilov and Martens, 2015.

3) 11 pairs of notogastral setae; adanal setae ad_1 and ad_2 of medium size, longer than short ad_3; adanal lyrifissues in inverse apoanal position……………..*U. (U.) pygiseta* (Hammer, 1973).

- 10 pairs of notogastral setae or alveoli; all adanal setae short and of equal length, adanal lyrifissures in para anal position…………………………………………… 4

4) Notogastral intefument smooth, notogastral setae h_1 inserted antero- medially to A_3……………………………………………………*U. (U.) africanus* Mahunka, 1988.

- Notogastral integument foveolate, notogastral setae h_1 inserted postero- medially to A_3 or between them……………………………………………...……………….. 5

5) Conical part of notogaster with triangular ledge; distance between A_2-A_2 clearly greater than A_1-A_1……………………………………...*U. (U.) magniporosus* Balogh & Mahunka, 1967.

- Conical part of notogaster without triangular ledge; distance between A_2-A_2 slighly greater than A_1- A_1……………………………………………*U. (U.) indicus* Ramani & Haq, 1990.

Superfamily : Oripodoidea Jacot, 1925

Family : Scheloribatidae Grandjean, 1933

Genus : *Scheloribates* Berlese, 1908

Generic Diagnosis: Rostrum without apophyses; 10 pairs of notogastral setae, 4 pairs of genital setae and 4 pairs of sacculi.

***Scheloribates decarinatus* Aoki, 1984 (Plate- 56; Fig- 63a-d)**

Colour : Brown

Measurements : Length: 370

Width : 290

Dorsal Region: Prodorsum broader with setae *ro*, *le* and *in* barbed; prolamella transverse with interrupted translamellar line; sensillus (*ss*) clavate, with weakly barbed and round head; notogaster with four pairs of sacculi and ten pairs of small setae; fissure *ia* on pteromorph; *im* placed medially.

Ventral Region: Epimeral and infracapitular setae roughened; all other ventral setae smooth; setation of genito- anal area 4-1-2-3; position of ad_1- post anal, ad_2- posterolateral and ad_3- pre anal; *iad* aligned anterolaterally, below *ad3*.

Legs: All legs heterotridactylous; leg I with chaetotaxy : 0-5-4-7-21; femur I with porose trochanter IV with two sharp dorsal teeth and one ventral tooth .

Materials Examined: 1♀ from *D. strictus*, collected on 8.03.2016, Malappuram Dt., Kerala, India. Coll. Vibija, C.P.

Host range: *Chromolaena odorata*

Remarks: The specimen examined during the present study closely resembles *S.decarinatus* Aoki (1984), and hence fixed as so.

Superfamily : Oripodoidea Jacot, 1925

Family : Caloppiidae Balogh, 1960

Genus : *Zetorchella* Berlese, 1916

Generic Diagnosis: Heavily ornamented prodorsum, translamella present, notogaster foveate, notogastral setae strongly barbed, pteromorphs absent, two pairs of adanal setae.

Zetorchella sejugata (Ramani and Haq, 1997) (Plate- 57; Fig- 64a-e)

Colour : Dark brown

Measurements : Length : 380

Width : 320

Dorsal region: Broader and converging anteriorly. Seta *ro*- thin, pointed and barbed, measuring 93, seta *le* - barbed, shorter with blunt tip and 75 long, seta *in* shorter and thicker than *le,* densely barbed, measures 72; irregular reticulations at base of lamellar sheath. Lamellae connected medially by a rod shaped translamella. Seta '*ex*' barbed, thin and located at lateral border of prodorsum, bothridial cups (*bo*) wide, sensillus (*ss*) with densely barbed, clavate head and a smooth stalk. Prodorsal integument with imbricate reticulation anteriorly. Notogaster globular, anterior border with well-developed dorsal sejugal suture; notogastral setae 10 pairs, densely barbed and with thickened tip, seta p_2 shortest and p_3 longest, five pairs of minute pores present on notogaster in close association with setae *ta*, *te*, *ms*, r_3 and p_3 ; *im* laterally placed above seta r_3; notogaster sculptured with polygonal rounded foveolae of varying size; notogastral integument fuscous and punctuated densely.

Ventral Region: setae *h* and *a* roughened; *m* barbed, longer and thicker than *a* and *h*; four short notches on rutellum (*ru*); smooth chelicerae, seta *cha* longer than *chb*; pedipalp small and five segmented with setal formula: 0-2-1-3-9, palpal tarsus bears three eupathidia, one solenidion (ω) , the latter closely associated with *acm*. Apodeme II small, apodemes III –IV not developed, sejugal apodemata continuous medially; epimeral setal formula 3-2-3-2; setae *1c*, *3c* and *4c* barbed and thicker than others; all other setae roughened; epimeral surface with foveoles and punctations. Genital plates sclerotized, broader anteriorly, bearing six pairs of setae, as shown in figure, one pair of aggenital setae (*ag*) located posterior to the genital plates. Anal plates with surface foveolation, and two pairs of short, smooth setae; adanal setae two pairs, ad_1 posterolaterally inserted and ad_2 laterally located. *iad* anterolateral to anal plates. Ventral plate ornamented ornamented with reticulations and foveolations.

Legs: All legs heterotridactylous with central claw thicker than the lateral ones. Chaetotaxy of Leg I: 0-6-4-6-21; Femur I bears irregular porose areas and faint striations; seta *d* thicker and barbed than others, *bv″*smooth; one solenidion and three barbed setae on genu I, tibia I with two solenidia, φ_1 and φ_2 , the former twice longer than the latter, on tarsus I two solenidia (ω_1 & ω_2) and a famulus (ξ) present; all setae on tarsus I barbed, except *p* and *s*.

Materials Examined: 1 ♀ collected from leaves of *B. vulgaris*, on 11.05. 2016, Malappuram Dt., Kerala, India. Coll. Vibija, C.P.

Other hosts: Coconut palm.

Remarks: This species resembles *Z. sejugata* (Ramani &Haq, 1997) in all characters and hence fixed as so.

Superfamily	:	**Ceratozetoidea Jacot, 1925**
Family	:	**Heterozetidae Kunst, 1971**
Genus	:	***Lamellobates* Hammer, 1958**
Subgenus	:	***Lamellobates (Paralamellobates)* Bhaduri & Raychaudhuri, 1968**

Generic Diagnosis: Prodorsum with two large lamellae, ten pairs of notogastral setae, pteromorphae immovable, 6 pairs of genital setae, 1 pair of aggenital setae, 2 pairs of anal setae, monodactyle legs.

***Lamellobates (Paralamellobates) misella* (Berlese, 1910) (Plate- 58; Fig- 65a-c)**

Colour : Light brown

Measurements : Length : 310

Width : 280

Dorsal: Rostrum flattened to rounded medially and with a pair of strongly developed teeth; seta *ro* barbed, acuminate and 60 long; lamellae broad, converging with cusps 21 long and 20 wide; seta *le* thick with a few barbs, 58 long, arising more or less medially from lamellar cusps; seta *in* thick, barbed, and extends beyond tutorium; bothridium with medial and lateral scales; sensillus with short stalk and clavate, barbed head; seta ex_3 long; Notogaster slightly longer than wide with nine pairs of smooth, acuminate setae.

Ventral region: Epimeral setal formula : 3-1-2-1, seta *1c* barbed, thickest and longest (31), others thin, smooth and 15-20 long; genital setae 6 pairs; a pair of small, smooth setae on anal plates; adanal setae two pairs, ad_3 absent, a pair of smooth aggenital posterolateral to genital plates.

Legs: All legs monodactylous, tarsus I with solenidion and famulus inserted proximally; famulus distal to solenidia; Genu I, II and IV with ventral spur. Spinous and thicker seta *l″* on genu I and II.

Materials Examined: 1 ♀ from *B. vulgaris*, collected on 22. 03. 2015, Kozhikode Dt., Kerala, India. Coll. Vibija, C.P.

Host range: Banana

Remarks: the specimen examined during the present study closely resembles *L.* (*P.).* *misella* (Berlese, 1910) and hence fixed as so.

Superfamily	**:**	**Galumnoidea Jacot, 1925**
Family	**:**	**Galumnidae Jacot, 1925**
Genus	**:**	***Galumna* Heyden, 1826**

Generic Diagnosis: Rostrum pointed, medium sized rostral setae, lamellar and interlamellar setae long and barbed, bothridial setae spindle form.

Galumna (Galumna) flabellifera orientalis Aoki, 1965 **(Plate: 59; Fig. 66 a-c)**

Colour	:	Light brown
Measurements	:	Length : 335
		Width : 238

Dorsal region: Prodorsum with Rostrum conical and blunt; seta *ro* 29 long, simple, small and inserted slightly below the rostral apex; seta *le* short, 17 long; seta *in* minute; sensillus (*ss*) 56 long, thickened from base to apex with the head gradually thickened and barbed. Anterior border of notogaster more or less straight and posterior border rounded; pteromorphae well developed, possessing incomplete ridge medially; five pairs of area porosae present, *Aa* larger in size; 10 pairs of notogastral setae present; fissure *ia* on pteromorph, *im* located more or less medially on notogaster.

Ventral region: Epimeral boundaries short and clearly visible; genital plates broader anteriorly and narrow posteriorly; six pairs of genital setae, g_{1-3} placed anteriorly and g_{4-6} vertically behind one another; a pair of aggenital setae inserted posterior to genital plates. Anal plates narrow anteriorly and broad posteriorly bearing two pairs of setae, an_1 posteriorly and an_2 anteriorly located; three pairs of adanal setae; ad1 posterior, ad2 posterolateral and ad_3 anterior in location; *iad* slit like, closely apposed to ad_3.

Legs : All legs tridactylous.

Materials examined: 1♀ collected from leaves of *B. bambos*, on 11.05. 2016, Malappuram Dt., Kerala, India. Coll. Vibija, C.P.

Host range: decomposed wood.

Remarks: The specimen examined during the present study closely resembles *G.(G.) flabellifera orientalis* Aoki, 1965 and hence fixed as so.

Superfamily	**:**	**Acaroidea Latreille, 1802**
Family	**:**	**Acaridae Latreille, 1802**
Genus	**:**	***Tyrophagus* Oudemans, 1924**

Generic Diagnosis: Setae *sci* are longer than *sce*, Setae *ve* are longer than the length of the genu and pectinate, arising at the level of *vi,* five ventral tarsal setae, setae d_1 and *la* are almost equal in length and shorter than d_3 and d_4.

Tyrophagus putrescentiae (Shrank, 1781) **(Plate: 60; Fig. 67 a-d)**

Colour: White

Measurements: Length : 340- 360

Width : 230- 240

Female: Smooth shining cuticle. Propododsomal shield often indistinct, extending back upto scapular setae, with an almost straight posterior edge. Setae *vi* project beyond the tip of chelicera. All setae sparsely pectinate; *ve* arise posterior to *vi* and longer than the length of the genu. *sce* and *sci* longer than the propodosoma. Seta *sci* longer than *sce*. The supracoxal seta flattened. From the base of supracoxal setae, a stiff lateral projection arises. Grandjean's organ with two main branches- one rod shaped and one with an irregular outline. Apodemes feebly tanned. Epimeral plates colourless. Anterior edge of apodeme I with irregular outline. Seta d_2 two to three times longer than d_1.Setae c_2 and c_p at right angles to the sides of the body. Remaining setae long.On the ventral surface, anal opening almost reaching the posterior end of the body, encircled by five pairs of anal setae.$pa_1$and pa_2 also long and form part of the 'train' of setae. Each chelicera toothed and bears a spur like outgrowth and mandibular spine.

Leg: All legs terminate in stalked claw and well developed pretarsus. The length of tarsus I does not exceed the combined length of genu and tibia. On tarsus I, ω_1 slightly expanded distally and arises close to famulus. Seta *aa* distal to ω_1. ω_3 and seta *d* extend beyond the end of claw and longer than setae *e*. On genu I, $\sigma 1$ slightly longer than $\sigma 2$.

Male: Shape, length and arrangement of setae resemble that of the female. Anal suckers dome shaped extending beyond the posterior extremity of anus. pa_1 shorter and more slender than pa_2 and *pa*3.

Materials Examined: 3♀♀ and 2♂♂ from *B. bambos*, collected on 22. 03. 2015, Kozhikode Dt., Kerala, India. Coll. Vibija, C.P.

Other bamboo hosts: *B. membranacea*, *B. nutans*, *D. hamiltonii*, *D.strictus, B. vulgaris* and *G. atroviolacea.*

Host range: Banana, Water hyacinth, orchids, mushroom, orange, palm seed.

Remarks: This specimen resembles *T. putrescentiae* (Schrank, 1781) in all characters and hence confirmed as so. This forms the first report of the species on bamboos.

Bamboo, an ancient woody grass, distributed widely throughout the tropical, subtropical and temperate zones of the globe, is a major non-wood forest product. Though bamboo is an integral part of forestry, it is also widely spread in homesteads, farmlands, riverbanks, roadsides and urban areas. It is gaining popularity from the "poor man's tree" to the high-tech, industrial raw material and a prominent substitute for wood. Bamboos have the potential to even convert solar radiation into useful goods and services more efficiently than other tree species (Embaye *et.al.,* 2005). With global climate change, aspects like carbon sequestration and biomass production potential of bamboos have been receiving increasing attention (Kumar *et.al.,* 2005; Das and Chaturvedi, 2006; Nath and Das, 2008). As bamboo's significance got increased, the commerce and cultivation expanded, so too intensified the insects and mites taking residence on bamboos. Despite of their tensile strength, bamboos are prone to the attack of many pests and some of the most bothersome pests are the bamboo mites, which feed on bamboos and decline their aesthetic and economic values.

A total of 27 species of bamboos had been surveyed during the present study across five districts of Kerala viz. Kannur, Kozhikode, Wayanad, Malappuram and Thrissur. Of these, *B. bambos* and *B. vulgaris* showed maximum mite infestation and a total of 37 species under 31 genera and 17 families could be collected from *B. bambos* and 28 species under 19 genera and 9 families from *B. vulgaris*. This is in support of the results of earlier studies of Zhang *et al.,* (1999b) from China which revealed the presence of 34 species of mites representing the phytophagous and predatory groups in association with bamboos. Lin *et al.,* (2000) identified 45 species of mites collected from moso bamboos in Fujian province of China. Results of the present study revealed that bamboo species such as *G. atroviolacea, M. baccifera, D. longispathus, O. scriptoria, O. abyssinica, P. ritcheyi, T. oliveri* and *T. regia* were tolerant to mite attack. Earlier studies also showed the resistance of some species of bamboos against spider mite infestation and it was speculated that leaf pubescence played a great role in imparting resistance by interfering with the web construction by these mites (Meredith, 2001).

Comparatively, high species diversity of bamboo mites was observed in areas like Velupadam (Thrissur Dt.) and Nilambur (Malappuram Dt.) and during the present study, a total of 43 species had been recovered from these sites. Both these sites were bambusetums, practising monoculture of bamboos, whereas the other sites screened during the study were areas of polyculture containing diverse vegetation along with bamboos. These results were in concordance with the earlier findings of Zhang *et al.,* (2000a), who reported that the population of *S. nanjingensis* in monoculture bamboo forests in China showed a seven times increase than that of the polyculture forests. Similarly, higher populations of *A. corpuzae* and *A. bambusae* could be recorded in monoculture forests those of polyculture forests. Probably, monoculture forests would facilitate easy dispersal of phytophagous mites, unlike the polyculture forests, the latter would retard the dispersal of mites due to the presence of non- host plants surrounding the bamboos (Zhang *et al.,* 1999b; 2000a). Monoculture forests also would reduce the profusion of natural enemies of plant mites by diminishing the availability of alternate hosts, and thereby resulting in mite outbreaks (Risch *et al.,* 1983; Zhang *et al.,* 1999c, 2000b).

Another interesting finding of the present study was the great diversity of predatory mites in areas like VMK Botanical Garden (Kozhikode) and Muthanga (Wayanad) when compared to Velupadam (Thrissur) and Nilambur (Malappuram). The population of predatory mites might be influenced by the abiotic- biotic factors operating in the natural habitat (Sathe and Bhosale, 2001) and their density is dependent on varied factors like abundance of prey and their hosts, season, climate and ethology of the predator and prey (David, 1993). The abundance of predatory mites in polyculture forests than that of the monoculture forests could also be attributed to the availability of several other host plants in addition to bamboos (Risch *et al.,* 1983). This was confirmed through the findings of Zhang *et al.,* (2000a) who recorded that the number of predatory mites per 10 leaves in polyculture forests was three times higher than that of the monoculture forests. Hence, it could be assumed that monoculture practice would not only facilitate the movement of pest mites and influence the abundance of predatory mites but also would deplete the forest nutrients faster than that of the natural polyculture forests. Monoculture practice coupled with over- harvesting, would generally weaken the forest health and increase the susceptibility of forest plants to the attack of various pests and which in turn would reduce their ability for compensatory growth (Zhang *et al.,* 2000b).

The results of the present study disclosed that high altitude areas could support low populations of bamboo mites when compared to that of low altitude regions. This was evidenced through the recovery of 32 species of mites, under 23 genera, 12 families and 3 orders, from the bamboos collected from Wayanad when compared to the bamboos screened from Thrissur and Malappuram which supported 43 species under 34 genera, 18 families and 3 orders. Wayanad though seems to be rich in the biodiversity and number of bamboos, species diversity of mites was comparatively low and this observation is in support of the earlier findings (Zhang *et al.,* 2000b) that the sites at higher altitudes had lower mite population than sites at lower altitudes.

The phytophagous mites collected during the present study from the bamboo plants were found to belong to the order Trombidiformes and under this taxon, a total of 21 species belonging to 19 genera and 9 families could be identified. In accordance with the earlier reports, the dominant pest mites collected during the study were representatives of families Tetranychidae, Eriophyidae and Tarsonemidae (Lin *et al.,* 2000). *Schizotetranychus* was the most dominant genus supporting the maximum number of pest species as observed during the present study. The study also revealed the presence of species under the genera *Aponychus*, *Stylophoronychus*, *Tetranychus, Stigmaeopsis* and *Oligonychus* on bamboos of Kerala, thereby confirming their close association with bamboos as established in other countries (Wang, 1981; Ma *et al.,* 1984; Cui, 1989; Yu and Shi, 1991, Zheng, 1992; Sun *et al.,* 1997; Zhang *et al.,* 1997, Zhang *et al.,* 1998c and Zhang *et al.,* 2000e).

The species, *A. corpuzae* collected during the present study, had already been reported from several localities of Asia in association with various host plants (Rimando, 1966; Ehara, 1969; Gupta, 1976; Johnston and Flechtmann, 1990; Zhang *et al.,* 2000b). *A. corpuzae* was known to be a polyphagous species, and its distribution was reported (Seljak, 2015) mainly in the Oriental zoogeographical region with abundance in the East-Palaearctic region, especially in countries like China, Korea, Peninsula and Japan. However, the preferred host plants of the species are known to be the bamboo plants and its association with various species of bamboos like *Bambusa* sp., *Indocalamus longiuritus*, *D. basihirsuta*, *Pleioblastus incannatus*, *S. borealis*, *S. senanensis*, *Phyllostachys* sp., *Schizostachyum lima*, *T. siamensis*, *Vietnamosasa ciliata* has been recorded by many (Rimando, 1966; Ehara, 1969; Saito and Ueno, 1979; Ehara and Tho, 1988; Johnston and Flechtmann, 1990; Quinjing *et.al.,* 1999; Zhang *et al.,* 2000b; Ho, 2003; Hernandes and Feres, 2010).

Bamboo spider mites, coming under the genus *Schizotetranychus* were implicated as the most damaging species on bamboos, as revealed during the present study. This observation is in concordance with the findings on the bamboos of Japan (Saito,1979, 1981) reporting the attack of *Schizotetranychus*. Members of *Schizotetranychus* were reported to infest bamboos globally, including Europe, Asia and America (Banks and Tuttle, 1994; Flechtmann, 1995a, b; Ostoja- Starzewski, 2000, Saito, 1995a,b, Pratt and Croft, 1999). The bamboo forests of China were also reported to be under the check of *Schizotetranychus* species (Yu and Shi, 1991; Sun *et al.,* 1997; Lin *et al.,* 2000). The species under the genus reported from the bamboos across the world included *S. bambusae*, *S. emaiensis*, *S. elongates*, *S. nanjinensis*, *S. celarius*, *S. tenuinidus*, *S. minutus*, *S. taquarae*, *S. longus*, *S. approximatus*, *S. saitoi* and *S. recki* (Paschoal, 1971; Ma and Yuan, 1980; Wang 1981; Wang, 1983; Ma *et al.,* 1984; Wang *et al.,* 1985; Cui, 1989; Wang and Cui, 1991; Yu and Shi, 1991; Wang *et al.,* 1994, Zhang *et al.,* 2000e). Infestation by *S. longus* on bamboos of north western USA was also recorded (Pratt and Croft, 1999). The present discovery on the infestation of bamboos by *S. schizopus* forms the first report of the species on bamboo hosts and the earlier hosts recorded for the species were *Salix* sp. and willow tree (Ehara, 1956; Gotoh, 1989). Thus the present finding on its recovery from bamboos seems to stand out from the earlier observations and helps to extend the host range of the species.

T. urticae Koch, commonly called as the two spotted spider mite, represents a notorious pest on a variety of economic crops like vegetables, ornamentals, fruit crops, medicinal plants and so on in both field and greenhouse conditions. The species was reported for the first time from USA (Tuttle and Baker, 1968) and it has been recognized as a most polyphagous species of spider mite with worldwide distribution on > 1200 species of host plants (Dermauw *et.al.,* 2013). Bamboo plants (*Bambusa* sp.) also form one of the host plants of the species (Bolland *et.al.,* 1998). In addition to *T. urticae*, other species of *Tetranychus* viz. *T. bambusae* was also reported earlier from bamboos (Ma *et.al.,* 1984). The present recovery of *T.urticae* from the bamboos of Kerala supports the above findings and helps to confirm the host status of bamboos to spider mites.

Another interesting observation made during the study was the recovery of *O. biharensis* from the bamboos of Kerala. Though the species was reported to have a wide range of distribution in different countries like America, Australia, China, Bangladesh, India, West- Indies, Malaysia, S. Africa, Thailand, Brazil and Mexico on varied hosts like *Acacia* sp., *Artocarpus* sp., *Citrus* sp., *Colocasia* sp., *Litchi* sp., *Psidium* sp., *Tamarindus indica*, *Hibiscus tiliaceus*, *Hevea* sp., *Ficus* sp., etc. (Bolland *et al.,* 1998) bamboos have not been recorded as host plants of the species so far. However, another species of the genus viz. *O. urama* was recorded to infest bamboos of Thaiwan (Zheng, 1992) and China (Zhang *et al.,* 1997; Lin *et al.,* 2000). The present observation on the infestation of *O. biharensis* on bamboos forms the first report and it adds new host to the species.

Of the 3700 species of eriophyid mites reported worldwide, 110 species under 22 genera have been reported from plants of the bamboo family Poacea, among which 37 species are known to inhabit on bamboos (Amrine & Stasny, 1994, 1996). The genus *Aceria* erected by Keifer (1944) accommodates worm like mites and this genus consists of a large number of species which infest several host plants. In India also, the presence of *Aceria* spp. has been reported by many (Channabasavanna, 1966; Mohanasundaram, 1979, 1980, 1982, 1983; Chakrabarthi and Ghosh, 1980; Rishi and Rather, 1981; Mohanasundaram *et al.,*1984; Mohanasundaram and Sharma, 1984a, 1984b). In the present study, one species of *Aceria* viz. *A. bambusae* and another species of rust mites belonging to the genus *Knorella* viz. *K. blumeanae* were collected from the bamboo plants examined. Members of *Knorella* viz. *K. gigantochloae* and *K. bambusae* were reported earlier on bamboos like *B. vulfalis* and *G. ligulata* (Kuang, 1991). The association of eriophyid mites with bamboo plants in Thailand was also in report (Chandrapatya and Boczek,1993, 2000, 2002; Konvipasruang *et al.,* 2012). The results of the present study provided further confirmation of the earlier findings by revealing infestation by species of *Aceria* and *Knorella* on bamboos of India also.

Tarsonemid mites, though not injurious as the rust mites and spider mites were also found infesting bamboos. Earlier studies also disclosed the association of several species of tarsonemids like *Daidalotarsonemus biovatus*, *Steneotarsonemus acricorn*, *S. vasiljevae*, *Tarsonemus cornus*, *T. kaibeni*, *T. randsi*, *T. scaurus*, *T. zonghuii*, *Xenetarsonemus belemnitoides*, *X. ulignosus* and *X. xiufui* (Lin *et al.,* 1999; Lin *et al.,* 2000) in association with bamboos of China. However, the association of *D. serratus* and *S. spinki* observed during the present study with bamboo plants constitutes the first report of the species and thus helps to add new hosts to the species.

Phytoseiid mites constitute an important and most dominant group of predators detected on bamboos in association with phytophagous mites. Earlier studies in China (Lin *et al.,* 2000) also revealed the presence of phytoseiid species like *A. anuwati*, *A.*

herbicolus, *A. longisaccatus*, *A. longispinosus*, *A. makuwa*, *A. obtuserellus*, *A. okinawanus*, *E. nicholsi*, *P. vaginatus*, *T.bambusae*, *T. cervix* and *T. serrulatus*. The present study revealed the presence of species belonging to the genera *Amblyseius*, *Neoseiulus*, *Phytoseius*, *Typhlodromalus, Amblydromella* and *Paraphytoseius,* thereby supporting the observations made by earlier authors (Wu, 1983; Wu and Li, 1983; Zhu and Chen, 1983; Chen *et al.,* 1984; Wu and Li, 1984; Wu and Lan, 1989; Yin and Yu, 1996; Wu *et al.,* 1997), and confirming these mites as natural agents with biocontrol potential against bamboo mites

The phytoseiid predator, *N. longispinosus* (Evans) was found in association with 17 species of bamboos surveyed. This species was already reported as a successful biocontrol agent of several species of spider mites like *A. corpuzae* and *S. nanjingensis* (Zhang *et al.,* 1998c, 1999c) and *T.urticae* (Waite, 1988; Kongcheunsin, 2001; Singh and Singh, 2005). The presence of the species, after its first description as *A. longispinosus* from Indonesia (Evans, 1952) had been reported in many countries including Taiwan, Thailand, Philippines, India, New Zealand, Australia, Malaysia, China, Pakistan, New Guinea and Hawaii and was designated as the most abundant predatory species (Ho *et al.,* 1995; Ehara, 2002 a,b; Kongcheunsin *et al.,* 2005). The distribution of this species on 17 species of bamboo hosts seems to be encouraging, implicating its possible role as potential biocontrol agent of the injurious species of bamboo mites so as to suppress their population always under check in the field, in tolerable levels.

Apart from Phytoseiid predators, representatives of other families viz. Cheyletidae, Bdellidae, Eupodidae, Stigmaeidae, Tydeidae and Ascidae were also recovered from bamboos during the present study, thereby supporting earlier findings (Lin and Liu, 1995; Lin *et al.,* 1994). Of these, Cunaxid mites are known to be equally distributed in soil and arboreal ecosystems and are recognized as dominant predators in agricultural and natural ecosystems, feeding on different types of pests (Muma, 1960). Members of Tydeidae constitute another dominant group of predatory mites, generally seen in arid, semiarid and temperate ecosystems (Andre *et al.,* 1997; Noble *et al.,* 1996). Earlier works (Feres and Flechtmann, 1995) disclosed 12 species of mites including species of *Tydeus* and *Lorryia* as associates of *Bambusa* sp. The detection of four species viz. *T. interruptus*, *T. caudatus, P. acacia* and *L. stricta* made during the present survey would further establish bamboo plants as hosts for these predators. The recovery of another predator of the family Ascidae viz. *A. afroaphidoides* forms the first report of this species from bamboos of India and thus helps to extend the host range of this species, apart from the previously reported habitat of litter samples in South Africa (Hurlbutt, 1971).

The recovery of nine species of mites under the order Sarcoptiformes from bamboo foliage helped to add the faunal diversity of bamboo mites and elaborate the existing checklist. The sole representative of the family Acaridae was *T. putrescentiae* and eight species of oribatid mites belonging to seven genera and six families were also recovered from bamboo leaves. All the oribatid species collected were members of brachypylina (superior oribatids) and were found to belong to families Caloppiidae, Mochlozetidae, Hemileiidae, Heterozetidae, Galumnidae and Scheloribatidae. Members of genera like *Scheloribates, Galumna, Uracrobates, Lamellobates, Siculobata* etc. are very fastidious in habit, and enjoy extremely diverse types of food items (Wallwork, 1976).

Oribatid mites, despite their great diversity in the traditional soil and litter habitats, have long been known to occupy microniches available in arboreal, semi aquatic, corticolous, epithelic, bryophytic, epithilic habitats and can withstand challenging situations of mangrove, marine and antarctic situations even (Trave, 1963; Krantz, 1978; Andre, 1984; Walter and Proctor, 2013). Further, studies on the arthropod inhabitants of forest canopies also revealed a surprisingly rich diversity of oribatid mites (Walter *et al.,* 1994, Winchester, 1997; Behan- Pelletier and Walter, 2000) often designated as the most abundant arthropods collected through fumigation of canopies (Aoki, 1973, 1974; Watanabe, 1997). Around 102 species of oribatid mites were found to inhabit the rain forest of Australia (Walter and Behan-Pelletier, 1993; Walter, 1995).Though oribatid mites constitute an important component of arboreal arthropod diversity; it is still not clear whether arboreal oribatids represent an assemblage of tree dwelling mites or just a subset of soil fauna (Erwin, 1982). In contrast, the bark and canopy fauna from eucalyptus in Western Australia, did not reveal any overlap in oribatid families across different habitats (Heterick *et al.,* 2001).

As early as 1884, oribatid mites were considered as injurious agents to plants (Michael, 1884) and in the succeeding years, harmful effect of these mites on plants was reported by several workers (Jacot, 1930; Aoki, 1960). Several studies from Kerala, also revealed the adaptation of oribatid mites to live on a wide range of crop plants (Ramani and Haq, 1984) and weeds like *Chromolaena odorata* and *Eichhornia crassipes* (Ramani and Haq, 1983, 1987; Haq and Ramani, 1987; Sumangala and Haq, 1995). Species like *Orthogalumna terebrantis* was established for its biocontrol efficacy of noxious weeds like *E. crasspipes* all over the world (Wallwork, 1965; Del Fosse *et al.,* 1975; Cordo & DeLoach, 1975, 1976; Sankaran, 1976; Haq and Sumangala, 2003). Despite such isolated examples for clear designation of the role of these mites on arboreal habitats, much remains as unexplored, necessitating detailed studies to be undertaken for unraveling their role in arboreal habitats, especially in the foliage of bamboos.

Majority of the bamboo mites collected during the present study showed a preference to inhabit on the abaxial surface of bamboo leaves. However, species like *S. vannus* were exceptions, which preferred to colonise the adaxial surface. Generally, the distribution of mites on the abaxial and adaxial surfaces, to a large extent is regulated by various physical factors of the environment (Sudo and Osakabe, 2011). Also, the structural features of leaves such as presence of leaf domatia, density and shape of hairs, thickness of wax and cuticle and density of stomata etc. influence the microclimates and induce variations in temperature and humidity on the adaxial and abaxial surfaces of leaves (O'Dowd and Willson, 1989; Nishida, 2004; Chien and Sussex, 1996; Price, 1980; Gutschick, 1999; Grostal and O'Dowd, 1994; Weintraub *et al.,* 2007). As a result, adaxial and abaxial surfaces offer heterogenous conditions for plant dwelling arthropods and these along with differences in environment, would affect the behavior of inhabitants and their interspecific interactions (Krips *et al.,*1999).

Abaxial preference shown by mites could also be explained as an adaptation to escape from climatic factors like rainfall, wind and solar UVB radiation (Jeppson *et al.,* 1975; Ohtsuka and Osakabe, 2009; Sakai and Osakabe, 2010; Onzo *et al.,* 2010). Species like *A. corpuzae* was found distributed on both the adaxial and abaxial surfaces of bamboo leaves. The oribatid mites also were present on both surfaces of bamboo leaves. Oribatids, being heavily sclerotized and ornamented, avail protection from the harsh environment experienced on adaxial surface (Watanabe, 1997; Walter and Behan-Pelletier, 1999; Walter and Proctor, 1999). Mites were also reported to prefer leaf surface which faces downwards, regardless of their morphological categorization as abaxial or adaxial surface (Li and Margolies, 1991). Probably, the adaxial or the upper surface could serve a better location to initiate the take off behavior to facilitate aerial dispersal because of the eminence exposure to air currents (Fournier *et al.,* 2004).

Results of the present study also shed light on the preference pattern of tetranychid mites in relation to differences in the age of bamboo leaves and shoots. It was observed that *Schizotetranychus* species preferred to infest young and newly sprout leaves. Other species of spider mites belonging to the genera, *Aponychus, Oligonychus, Tetranychus* and *Stylophoronychus* showed more preference to the leaves of older shoots of bamboos. This observation was in support of earlier findings (Zhang *et al.,* 2003), on species such as *S. nanjingensis* and *A. corpuzae* infesting the leaves of moso bamboos. *A. corpuzae* was reported to restrict its distribution to the older shoots of bamboos alone while *S. nanjingensis* was recognized as the most damaging pest, destroying the newly grown leaves too. Any damage to the new leaves could cause serious decline in plant vitality.

Eriophyid species like *A. bambusae* and *K. blumeanae* showed more preference to the leaves of *B. bambos* than that of *B. vulgaris*. The leaves of *B. bambos* were more hairy when compared to that of *B. vulgaris*. The dense hair and domatia of the leaves might ensure protection to eriophyid mites from low humidity as well as inter or intraguild predators (Grostal and O'Dowd, 1994; Krips *et al.,* 1999; Norton *et al.,* 2001; Kasai *et al.,* 2005 and Oku *et al.,* 2006). Phytoseiid species also showed preference to the sheltered places available on the underside of the bamboo leaves, mostly along the midrib and among the leaf hairs or in domatia (McMurtry and Croft, 1997).

Species of *Schizotetranychus* was found to construct webs on the lower surface of bamboo leaves. These webs were thick, dense, and tightly woven unlike the loose chaotic webs built by *Tetranychus*. The newly formed web was composed of a single translucent layer, and the whole colony could be seen beneath the webs. They extended their web unit by unit in accordance with the increase in mite population and these cells later were linked together (Saito and Takahashi, 1982; Saito, 1986). As the colony became aged, successive sheets of webbing were added to the canopy, which resulted in shiny, opaque and protective nest (Gerdeman and Tanigoshi, 1992).

Tetranychid species like *A. corpuzae* and *S. vannus* were never found to produce silken threads. *Schizotetranychus* species on the other hand were found to form characteristic aggregations under dense woven nests (Saito, 1985; Sabelis and Dicke, 1985). Hence, it could be concluded that members of these two genera could not be designated to have any wind dispersal behavior or 'posturing'. Spider mites construct webs to provide protection against their eggs and immatures and which are also proved to maintain viability of eggs, as their removal often resulted in non – hatching of these eggs (Hazan *et al.,* 1974). These webs also could act as a place for excretion, means of transport for the mite species and also as a carrier of sex pheromone, which in turn would increase the potential of the species to compete with other phytophagous mites (Saito, 1983; Oku, 2008). Plants with web covered with dust and debris were pale coloured, thereby supporting the earlier observation of others (Griffiths and Fischer, 1950; Sadana, 1985) that spider mites are capable of affecting the metabolism of host plants even by reducing the photosynthetic activity of the plants by efficiently blocking the light reaching surface of leaves.

Bamboo spider mites showed initial infestation along the midvein of the leaf or leaf edges, where generally depressions were present. These depressions were found to serve as the proper nest building sites for these mites. Multiple prominent veins present on bamboo leaves imparted an abundance of building sites for these mites (Gerdeman and Tanigoshi, 1992). Confining oviposition to adjacent areas of the midrib on the lower surface of leaves, ensures better protection to these mites from the washing effects of rain as well as from desiccation when compared to the upper leaf surface, and which in turn would increase the survival rate of mites considerably (Sridhara *et al.,* 2009). The veins and veinlets also provide a firm grip to mites during oviposition (Dhooria, 1982).

One of the interesting observations made during the present study was the presence of different species of mites on the same leaves of bamboo plants. Species like *S. schizopus*, *S. longus*, *S. recki*, *A. corpuzae*, *S. vannus*, *T. urticae*, *D. serratus*, *S. spinki* and the eriophyids (*A. bambusae* and *K. blumeanea)* were found to share the same leaf. This is in agreement with the earlier studies indicating that atleast seven species of spider mites could inhabit syntopically on bamboo leaves (Hirota *et al.,* 2004). Coexistence of several species with different oviposition habit and webbing pattern might reduce the predation pressure from some of the common predators like *A. bambusicolus* and *C. bambusae*. Coexistence, might be one of the probable ways developed by mites as an adaptation to overcome the predatory pressures induced by the generalist predators. Leaf heterogeneity based on difference in leaf pubescence, also might play a significant role in the co-existence of mite species (Saito, 1990b; Gotoh and Shida, 2007). The availability of nutritional resources and secondary chemicals might also be contributing to the diversity of mite fauna on that leaf (Gotoh and Shida, 2007).

Results of field observations revealed that spider mite infestation on bamboos could be easily distinguished by the light coloration of infested areas than the surrounding leaf tissues, which is permanent and aesthetically displeasing. The feeding damage first appeared as light speckling or blotches on the upper leaf surface. As the leaf became more infested, the damage acquired a checkered pattern, resembling leaf variegation (Meredith, 2001). The mites pierced the individual plant cells on the underside of the leaf and sucked out the cell contents, causing discolouration on the upper leaf surface (Evans, 1992). Heavy mite infestations would cause green bamboos to appear yellow green in colour. Bamboos are known to renew their leaves in alternate years, but the abnormal physiology and metabolism induced by mite infestation, compel renewal of leaves in every year/ season (Zhang *et al.,* 2001f). This behavioural alteration would result in the availability of both old and new leaves at the same time, which is an added advantage to the mite fauna as it facilitates their dispersal from the infested to the renewed, uninfested bamboo leaves.

Seasonal variations in the abiotic factors also would affect the distribution and population density of arthropods, especially of the mites under field conditions (Yaninek *et al.,* 1989a; Colfer *et al.,* 2004; Hanna *et al.,* 2005; Sarmento *et al.,* 2011; Onzo *et al.,* 2005; Teodoro *et al.,* 2008; Zundel *et al.,* 2009). A significant increase in spider mite population was observed in the present study, with an increase in temperature, thereby supporting the earlier findings (Singh and Singh, 1993; Lingeri *et al.,* 1998; Khan *et al.,* 2008 and Stavrinides *et al.,* 2010). This is a clear indication of the significant impact of climatic factors like the temperature and humidity on mite population, of which temperature plays a very prominent role, thereby supporting the results of earlier workers (English and Turnipseed, 1941; Das and Sengupta ,1958; Mori, 1961; Easterbrook, 1979; Dhooria and Butani,1983; Perez- Moreno and Moraza- Zorrilla, 1998). The mite population was found to attain peak levels during April and May, when the temperature was higher, thereby agreeing with the peak formation in May by mite populations on guava plants when the temperature increased to nearly 31ºC (Ghoshal *et al.,* 2011). Seasonal changes on the population of *S. schizopus* observed during the present study were almost in agreement with those recorded earlier (Gotoh, 1989) inspite of the differences between the random sampling methods adopted during the present study, versus direct observation method adopted during earlier studies. The hot and dry conditions not only provided favourable conditions for the colossal increase in mite population but also reduced the growth of entomopathogenic fungi, which normally would check the spread of these mites (Dean, 1959; Ratcliffe *et al.,* 1960; Lal and Mukherji, 1979; Puttaswamy and Channabasavanna, 1981b; Klubertanz *et al.,* 1991 and Sugeetha and Shrinivasa, 1999).

Realtive humidity was also was reported as an important climatic factor that would affect the population of arthropods in the fields (Zundel *et al.,* 2009). An increase in relative humidity though was not found to affect the hatching process tremendously, the survival of nymphs was found adversely affected by the moisture levels. Thus, an increase in relative humidity would ensure a check in the population build- up of these mites (Boudreaux, 1958). Continuous exposure to high humidity conditions was reported to suppress spider mite populations (Jeppson *et al.,* 1962). Present study disclosed a negative impact of relative humidity on the population density of *S. schizopus* and thus confirmed the earlier studies which recorded the adverse effects of relative humidity on the development, survival and fecundity of the cassava green mite, *M. progresivus* and the cotton red mite, *O. gossypii*, in cassava fields (Bonato *et al.,* 1995).

Tetranychid populations are generally not much affected by the drizzling rain, as they might be moving to underside of leaves or other sheltered places. The natural pubescence of leaves also would help these mites to recover from these small drizzles. However, prevalence of prolonged periods of rains or heavy rains caused major reductions in the population densities of these mites (Das, 1959; Osakabe, 1965; Danthanarayana and Ranaweera, 1974; Jeppson *et al.,* 1975; Meena *et al.,* 2013). This is true for other phytophagous mites also, the populations of which also showed a drastic decline with high rainfall and low temperature (Oatman and McMurtry, 1966; Dhooria and Butani, 1983). A decrease was recorded in the predatory mite population also during rainfall on citrus trees (Reis *et al.,* 2000). This ill effect of rain on mite population could be due to the washing out of adults and nymphs by the force of rainstorm (Dharmendra *et al.,* 2015). Not all phytophagous mites were found to leave the bamboos when the leaves were fallen off or washing effect caused by rainfall, but some were found to hide in cracks and crevices of the stems. After refoliation or favourable conditions resumed, these mites were found to move back to the leaves within days, unhampered by the weather conditions (Zhang *et al.,* 2003). The mites could be seen to resume multiplication after an initial decrease in numbers during the monsoon and post-monsoon seasons. Similar findings were recorded in scarlet mites earlier (Oomen, 1982), where the mortality rate of mites decreased when the rain became less frequent. A decrease in the population was recorded in *M. tanajoa* also during periods of high rainfall (Hanna *et al.,* 2005 and Onzo *et al.,* 2005). This may be an adaptation to escape from the less favorable weather conditions.

Results of the correlation studies performed between the weather parameters and the population density of *S.schizopus* could establish a significant positive correlation between temperature and mite population, whereas relative humidity and rainfall showed a negative correlation with the mite population. Similar trends of relationship could be recorded in other phytophagous mites like *Raoiella indica* Hirst on coconut (Nageschandra and ChannaBasavanna, 1984) and *T. telarius* on castor (Gupta *et al.,* 1976). However, a positive correlation with temperature and relative humidity and a negative correlation with rainfall was established by populations of *Tenuipalpus pernicis* on guava (Ghoshal *et al.,* 2011). The negative correlation with the rainfall might be due to the washing effect exerted by heavy rain on mite colonies present on the leaves (Yaninek *et al.,* 1989b).

Thus the results of the present study clearly indicated the rich and varied faunal diversity of bamboo mites and the potential of these mites to enjoy a wide host range. These mites were also proved to have the ability to withstand harsh environmental conditions. Despite their taxonomic and biological significance, bamboo mites have received little attention in India, though bamboos constitute an important crop with a multitude of economic utility. This warrants the need for detailed studies to be undertaken on bamboo mites to explore the rich diversity of these mites in our country.

CHAPTER II

BIOLOGICAL STUDIES

Bamboos are susceptible to the attack of a number of pests, mainly comprised of insects and to a certain extent by mites. The insect pests include the grass hoppers, bugs, scale insects, mealy bugs, aphids, beetles, moths etc. while the mites include the spider mites and eriophyoid mites, apart from several taxa of predatory mites and oribatid mites. Of these, mealy bugs and spider mites have been reported to inflict the maximum degree of damage to bamboos and hence are treated as the worst pests.

Bamboo mites represent a relatively unstudied group in India and most of the studies are concentrated in China which is ranked as No. 1 in terms of species richness of bamboo plants. Mite problems in China have been reported to become acute during the late 1980s owing to transformation of forest areas to monoculture bamboo forests to intensify bamboo resources for meeting the increasing demand of the people. Having exposed to unlimited supply of favourable nutritional resources, bamboo mites would experience rapid growth and dispersal. This would not be the situation in natural forests with diverse vegetation in which the bamboos are surrounded by unpreferred hosts also. The monoculture practices would serve to reduce the abundance natural enemy population of phytophagous mites (Zhang *et al.* 2000a) in turn leading to outbreak of the latter.

Despite the situation in China, in India bamboos are not planted as monocultures, though our country occupies the second position with respect to the richness in bamboo resources. Instead, bamboos are mostly found growing in the natural habitats along with other vegetation, especially in the forests and other wild situations. Rarely, bamboos are also found grown/cultivated in isolated conditions like the home yards. Hence, the severity of mite infestation on Indian bamboos is comparatively lower than that of the bamboos of China. However, mite infestation has become a common phenomenon now-a-days on bamboos growing in the various sites, as evidenced during the present study. The most injurious species of bamboo mites recognized during the present study are the spider mites, especially the members of genera like *Schizotetranychus, Aponychus,* and *Tetranychus* and also the eriophyid mites. Of these, *Schizotetranychus* formed the major genus which showed a cosmopolitan distribution on the bamboo plants surveyed. The genus *Schizotetranychus* is commonly called as the bamboo spider mites and includes around 140 species, distributed on grasses, especially the bamboos and other monocot plants. Colonies of spider mites feed on the underside of bamboo leaves and cause direct damage symptoms like appearance of striplings and thus retards the local tissue growth on the undersurface of leaves. On progressive feeding, symptoms like chlorosis, yellow-white colouration, bronzing and drying up of leaves occur, thereby drastically affecting the photosynthetic efficiency and vigor of the plant.

The second group of injurious mites which successfully infest the bamboos is the eriophyid mites, the so called blister mites, bud mites etc. Eriophyids feed on the growing plant tissues or buds and rarely cause complete destruction of the fruit primordia, leaves or stem. New primordia may develop but as each newly developed primordial gets injured, the growth pattern of the plant become irregular and the symptoms resemble those of viral diseases or those induced by other pests. It may eventually lead to varied damage symptoms such as rosette type growth, irregular fruit or leaf growth or even the total destruction of growing tips.

In recent years, due to the random use of chlorinated hydrocarbons for pest control and improved cultivation practices, many species have assumed the status of pests as these hydrocarbons cause the instability in natural control by predatory mites. Drastic changes in environmental conditions also contributed to the increase in mite populations to exceed the threshold levels thereby raising them to the 'pest' status. Mite pests are known to induce potential biotic stress to the host plants, and interfere with their biochemical and physiological processes. Feeding activity of mites has been proved to reduce the rates of net CO_2 assimilation, transpiration, stomatal and mesophyll conductance and photosynthetic activity of infested host plants. The levels of various biochemical constituents like proline and total phenol also get increased due to mite feeding. The vigour and biomass of affected plants show a considerable reduction and which in turn lead to reduced yield. Considering the relative abundance and injurious status of mites on the bamboo plants as evidenced through the results of field cum laboratory studies, two species of spider mites viz. *S. schizopus* and *T. urticae* were selected for undertaking detailed observation on the feeding and breeding parameters.

The fecundity and the developmental cycle of pest mites, to a large extent depend up on the nutritional components available on the host plants and the prevailing climatic/biotic parameters. However, the developmental pattern and the mode of reproduction are more or less similar for a particular group, though differences exist in the durations of individual instars and total duration of development. Generally, the life cycle of plant mites commences with the mating process followed by the deposition of eggs by the females and the subsequent development passing through a single larval and 2-3 nymphal instars. In several cases, a pre-larval stage is also reported. In between the active instars, there is an inactive instar called the ‘quiescent stage/phase’ the end of which is marked by the moulting process. The life cycle of eriophyid mites on the other hand is unique in lacking the larval instar and instead includes only two nymphal instars and two quiescent stages. Facultative parthenogenesis is also known to occur in some groups while arrhenotoky *i.e*. the production of male from unfertilized egg, is reported in Mesostigmata and Prostigmata. Thelytoky (the production of female from unfertilized eggs) is common among some Prostigmata, Mesostigmata, Metastigmata, Astigmata and Oribatida.

In the present study, the above two species of pest mites were subjected to detailed biological observation to trace their developmental pattern and duration of individual instars on their respective host bamboo plants under two selected combinations of temperature-humidity parameters. Data were recorded separately on the various developmental aspects such as mating, oviposition, fecundity and durations of pre-oviposition, oviposition and post-oviposition periods, and durations of larval, nymphal and quiescent instars.

The review of literature presented here is divided in to two sections viz. feeding biology and breeding biology. In the feeding biology section, the earlier research works carried out on diverse feeding parameters of mites like the nature of feeding, feeding activity, damage symptoms caused, morphological, anatomical, physiological and biological alterations resulted through the feeding activity of mites etc. have been included. In the breeding biology section, reports/research contributions made by earlier workers on the developmental aspects of mites like mating, oviposition, hatching, duration of the various life stages, parthenogenetic vs. sexual cycles, impact of variations in temperature-humidity conditions on developmental duration etc. have been incorporated.

1. Feeding Biology

Feeding activity of the spider mite, *Tetranychus telarius* was reported to cause a reduction in the sugar and nitrogen contents of host plants and an increase in the phosphorus, potassium and dry weight of foliage as evidenced through the studies of Rodriguez *et al*., (1960). Wang (1981) observed that *S. bambusae* could induce defoliation in moso bamboos, particularly during the dry seasons. Wermelinger *et al*., (1985) pointed out that nitrogen deficiency in plants increased the pre- imaginal developmental time and pre-oviposition period of the two spotted spider mite pest, *T. urticae* Koch, and decreased the female weight, fecundity and oviposition rate.

Studies of Mothes and Seitz (1982) indicated that spider mite feeding could lead to the development of small, light coloured punctures which up on prolonged feeding gave rise to the formation of irregular, white to greyish spots and both the spongy and palisade parenchymal layers were injured. Tomczyk and Kropczy´nska (1985) observed that spider mites while feeding penetrated the leaf surface with their cheliceral stylets to a depth of 70–120 µm and sucked out the cell contents and the leaf area remained intact.

Yu and Shi (1991) reported that the bamboo forests seriously infested with *S. nanjiensis* in China were easily identifiable even at far distances based on the “burnt appearance” and the affected plants suffered defoliation and severe reduction in photosynthetic activity. Pena and Bullock (1994) observed that the feeding activity of the Broad mite, *Tarsonemus latus* (Banks) on hosts such as potato, bean, lime and sour orange caused a reduction in the leaf area and water content of leaves.

The serious damage induced by *S. bambusae* to bamboos in Shandong in China were reported by Sun *et al.,* (1997) and the authors described the biology of the species, and presented data on the impact of temperature on the development and reproduction of the species. The effect of feeding by *T. urticae* on *Gossypium hirsutum* L. was studied by Sadras *et al.,* (1998) and the authors listed *T. urticae* as a mesophyll feeder with the adult female showing specific preference to well watered plants for feeding and oviposition.

Studies carried out by Zhang *et al.,*(1998b) in China revealed that feeding activity of the bamboo spider mite, *S. nanjiensis* resulted in the reduction in chlorophyll content by 11% up on light infestation (1-3 nests/leaf), 24% up on moderate infestation (4-10 nests/leaf) and 57% up on heavy infestation (11-20 or more nests/leaf). The sugar content was found reduced by 12% with light damage,19% with moderate damage, and 57 % with heavy damage, due to the feeding activity of the species. The same authors (1998a) observed that *A. corpuzae* also induced a reduction in the chlorophyll content of bamboo leaves, and the loss in quantity could be accounted to 11%, 58% and 63% up on light infestation (5-10 mites per leaf), moderate infestation (33.4-48.5 mites per leaf) and heavy infestation (65.8-80.0 mites per leaf) respectively.

According to Zhang *et al.,* (1998d) *A. longispinosus* was an efficient biocontrol agent of *A. corpuzae* in which the rate of prey consumption increased with an increase in temperature. The number of eggs laid by the predator increased linearly with the number of preys consumed and the adults of the prey mite, *A. corpuzae* adults in turn were found to defend their colonies against these predators. Zhang and Zhang (2000) reported that the web nests of *S. tenuinidus* were slender (length 7-15 mm and width 1-4 mm) and much narrower than those of *S. nanjingensis.* Comparative studies made by the authors showed that mite damage index in monoculture forests was twice as high than that of polyculture forests and the mean damage index was 17.5%, in polyculture forests. The authors also estimated the economic injury levels in monoculture bamboo forests.

Zhang *et al.,* (2001a) conducted studies on the ecology of the eriophyid species, *Aculus bambusae* Kuang, the results of which helped to establish a mutualistic association between the mite and acarodomatia (tufts of small hairs or invaginations in the leaf surface). Arimura *et al.,* (2001) reported that lima bean upon infestation by the two spotted spider mite, *T. urticae*, activated the transcription of genes, encoding parthenogenesis related proteins and phenyl alanine ammonia lyase in the leaves of neighbouring plants also. This in turn induced the expression of defense genes in uninfested plants. Landeros *et al.,* (2004) studied the effect of population density of *T. urticae* on CO_2 assimilation, transpiration and stomatal behavior in rose leaves. The net photosynthetic rate, transpiration and chlorophyll contents showed a decrease with an increase in mite densities and the authors suggested that spider mite densities caused the stomata to remain open for longer periods and also reduced the flower stem length.

Reddall *et al.,* (2004) proved that spider mite colonies initially established and developed near the midrib region of leaves and they suggested that the mite colonies caused a depletion in the rates of photosynthesis, stomatal conductance, transpiration, transpirational efficiency and chlorophyll content in their host plants. Further, the infested plants were reported to exhibit growth inhibition and a decrease in the area and number of leaves. Mite infestation was also found to induce a complete loss of epidermis in leaves as reported by Grinberg *et al.,*(2005). A decrease in the concentration of Ca^{2+}, Mg^{2+}, pigments, carbohydrates, amino acids, lignin and total soluble protein was reported due to mite infestation by Mithofer *et al.,* (2005) and Khattab and Khattab (2005). Mite infested leaf tissues were found disrupted and the xylem tissues in the midribs and petioles developed cavities. An increase in K^{+}, proline, Indole acetic acid and abscisic acid and enzymatic antioxidants such as superoxide dismutase, catalase, phenol oxidase, peroxidase and volatile organic compounds was also observed in mite infested plants.

Khattab (2007) observed that herbivory elicited certain effects on plants which included an increase in the uptake of Ca and K and a decrease in elements like P, Mg and Fe. Some alterations were observed in the activities of oxidative enzymes and on the antioxidant compounds. Comparative studies made by Schmidt *et al.,* (2009) on the feeding mechanism of spider mites and caterpillars revealed that the former sucked the cell contents via the stylets while the latter chewed out large amounts of photosynthetically active tissues. Mild spider mite infestation did not affect the growth or amino acid composition of the plant but increased the total nitrogen and sucrose concentrations in the leaves. Mite feeding also caused changes in leaf fluorescence, photosynthetic rate and variable carbon dioxide levels as observed by Bueno *et. al.* (2009). Vijaykumar *et al.,* (2009) also got similar results while conducting studies on plant resistance against herbivory and they recorded high levels of total phenol and total free amino acids in infested plants. Sivritepe *et al.,* (2009) also suggested that mite feeding could induce lipid peroxidation and protein degradation and recorded an increase in the concentration of Cu, Zn, K and Na and a tremendous decrease in the levels of soluble sugars and proline. Heavy infestation by spider mites would lead to formation of dark brown patches, crinkling and defoliation of affected leaves in host plants like *Manihot esculenta* L. as evidenced through the studies of Sangeetha and Ramani (2011).

Mites not only caused damage to host plants through direct feeding but also acted as vectors of many viruses as revealed through the studies of Murugan *et al.,*(2011). The authors reported that effective pest control was possible by controlling both virus and its vector. Studies made by Farouk and Osman (2012) disclosed that spider mite infestation could induce oxidative stress on plants by increasing the concentrations of soluble sugars, phenol, proline and peroxidase activity and decreasing catalase activity, ascorbic acid and carotenoid concentrations. Yano (2012) observed that the webs constructed by spider mites offered protection from predators, even to the intruded mites which took residence in the already established webs. It was also observed that the mites which lived together did not distinguish between species and hence heterospecific mites could live together and co-operate.

The effect of mite feeding on the concentrations of chlorophyll a and b, Mg, Zn, Cu, nitrate and nitrite on host plants was also reported by various authors like Ghosal and Barman (2012) and Prabheena and Ramani (2013). Nyoike and Liburd (2013) found that mite feeding could lead to disruption of shape and size of fruits and thereby lowering the marketable yield. Marriotta *et al.,* (2013) reported the use of *T. telarius* in the successful control of serious weeds like *Ulex europaeus*. The authors observed that feeding activity of the mite caused a reduction in the photosynthetic tissues by inducing water stress and thereby affecting the vigour and competitiveness of the host. Similar studies on mite infestation were also made by Prabheena and Ramani (2014) by studying the impact of *Brevipalpus phoenicis* on *Ocimum gratissimum.*

Developmental biology

Saito and Ueno (1979) conducted studies on the developmental biology of two species of spider mites infesting bamboos viz. *S. celarius* and *A. corpuzae* under laboratory conditions of 25±1ºC, 50-60% RH and 15L- 9D. Results of their studies revealed that *S. celarius* had a net reproduction rate of 67.60 and that of *A. corpuzae* was

53.84 and the mean generation time of the two species were 26.01 days and 22.02 days respectively. Life history of *P. akitanus* was studied by Gotoh (1986) on bamboo leaves and they revealed that adult females of this species stopped laying eggs at a temperature of 5ºC or lower in late November and December.

Observations made by Gotoh (1989) on the annual life cycles and diapause regulation of three species of *Schizoteranychus* viz. *S. schizopus, S. leguminosus* and *S. cercidiphylli* under laboratory conditions of 25± 1ºC, 50-60%RH and 15L- 9D revealed that short photoperiod, low temperature and infested leaves favoured the production of diapause eggs. The study also revealed that as the temperature got increased, the proportion of egg hatching also increased by terminating the diapause state.

Life history traits and feeding habit of *T. bambusae* on bamboo leaves were studied under laboratory conditions of 25 ± 1ºC, 60-80% RH and 15: 9 L: D by Saito (1990b). He observed that the egg to egg period of *T. bambusae* which fed on *S. celarius* was longer than that of *A. longispinosus* which fed on *T. urticae*. He also concluded that the intrinsic rate of natural increase (r_m) of *T. bambusae* was in concordance with the r_m of its prey, *S. celarius*. A preliminary account on the life history and biology of *S. bambusae* was provided by Yu and Shi (1991) on bamboos in the Zhejiang province of China. Saito (1995a) further reported parasocial behavior in species of *Schizotetranychus* and *Eotetranychus* in which individuals behaved co-operatively.

More biological data on *S. bambusae* were provided by Zhang *et. al.*, (2001c) based on the studies carried out in bamboo plantations at Fujian, China and the authors also provided data on the ecology and control of the species. The same authors further (1999a), conducted biological studies on the predatory species, *T. bambusae* which was a dominant predator of *S.nanjingensis*. Joutei *et al.,* (2000) reported that the elevation in CO_2 could affect the fecundity and development of mites and when the level of CO_2 was raised, the number of progeny was reduced up to 49%. Based on the results of their study, the authors suggested that the attack of the two spotted spider mite, *T. urticae* might be reduced in future when the concentration of CO_2 become elevated through global warming. The efficacy of the phytoseiid predator, *A. cucumeris* (Oudemans) as a potential biocontrol agent against the pest mite, *S. nanjingensis* Ma and Yuan was revealed through the studies carried out by Zhang *et al.,* (2000d) and the authors recorded an increase in the rate of consumption of the predator in relation to an increase in prey density, and the fecundity was found directly related to the rate of prey consumption. *A. cucumeris* though was found incapable of breaking the intact web nests of *S. nanjingensis,* it could easily invade the broken nests with existing openings. Zhang *et al.,* (2001e) also observed an unusual behavior in *S. nanjingensis* which was found attacking its predator, *T. bambusae*. The male spider mites either killed or pushed them out of the nest as a part of defending their colony. Female spider mites never attacked and killed the predators. The authors (2001b) further made observations on the behavior and life history of *S. tenuinidus* and studied the effect of temperature on the life history of *S. tenuinidus* on the leaves of moso bamboos and found that the development from the egg to the adult took just two weeks at 28-30ºC whereas it took nearly three weeks at 24-26ºC.

The same authors (2001d) studied the effect of age of moso bamboo leaves on the survival and reproductive rate of females of *S. bambusae*. The survival rate of females of the species was found decreased when it fed on old leaves when compared to that on young leaves. The authors (2001c) reported that the females of *S. bambusae* had three active immature stages namely larva, protonymph and deutonymph whereas the males had only the larval and protonymphal stages.

Results of studies made by James and Price (2002) under laboratory conditions revealed an increase in the fecundity of the two spotted spider mite when it was directly exposed to systemic insecticides like Imidacloprid. Gotoh *et al.,* (2003) conducted studies on the life history parameters of six species of spider mites belonging to the genus *Panonychus* on different host plants at a temperature of 25 °C and 16L: 8D, including *P. bambusicola* on dwarf bamboo (*Sasamorpha borealis*). They recorded the pre-oviposition, oviposition and post- oviposition durations for *P. bambusicola* as 1.9± 0.8 days, 14.5 ±0.36days and 1.3± 0.18 days respectively and found that the proportion of females during the whole study was 87.2± 1.12.

Mori and Saito (2005) conducted studies on the nest areas of *Stigmaeopsis longus, S.celarius, S.takahashii* and *S. saharai* and found that these mites would construct extremely dense web nests on the lower surface of host leaves and exhibited sociality. Chittenden and Saito (2001) reported that nest construction in *A. corpuzae* didn't serve as a defense mechanism for saving eggs from predators and they suggested that the morphology, posture, immobility and silken egg covers of the species played a cryptic function against its predators. Gotoh and Shida (2007) studied the effect of six constant temperatures under a 16L: 8D photoperiod on the duration of life stages of five spider mite species on dwarf bamboo leaves. The five species studied were viz. *A. corpuzae, P. bambusicola, S.longus, S.recki* and *Yezonychus sapporensis*. From the above study, they concluded that for all the five species, the development time decreased as the temperature increased from 15 to 28ºC. They also reported that the lowest temperature threshold was shown by *P. bambusicola* (10ºC) whereas *A. corpuzae* had highest temperature threshold (12.3ºC).

Studies on the biological parameters of *S. baltazari* Rimando on *Citrus aurantifolia* were made by Kottalagi *et al.,* (2014) and they reported that the total duration of development of the species from egg to reach the adulthood was an average of 13.31 days and the mean longevity of males and females was 8.58 and 15.25 days respectively. Chae *et al*., (2015) observed reproductive isolation in *S. celarius* Banks and its sibling species, both of which were found to live and feed up on the leaves of various bamboos, and build nests on the same leaves and exhibited a tendency to come in contact frequently.

In the present study, one of the most dominant and injurious species viz. *S. schizopus* as evidenced through the results of field sampling was selected for the conduct of detailed studies on biological parameters viz. the mode of infestation, visible symptoms of damage induced on bamboo hosts as well as alterations in the various biochemical, physiological and anatomical parameters of bamboo leaves etc. To ensure uninterrupted and repeated observations on these parameters, regular availability of the host plants was found most essential and hence the Calicut University Botanical garden was selected as the study site for collection of pest mites.

1. **Pest mite selected for study of feeding parameters :**

Being the most common and dominant species inducing visible symptoms of damage on bamboo hosts, *S. schizopus* was selected for detailed studies on the feeding parameters by adopting qualitative and quantitative methods. The species showed infestation mainly on the abaxial surface of bamboo leaves, constructing dense webs, commonly designated as the web nests by many authors. The species is considered as the social spider mite based on subsocial habit of colony defense, parental care, nest cleaning activity etc. During the present study, the species showed distribution on 15 species of bamboos with dominance on two species viz. *B. bambos* and *B. vulgaris.*

Host Plants selected for assessment of feeding response:

a) *Bambusa bambos* (L.) Voss (Plate 2): It is commonly called as the Indian Thorny bamboo, a species of clumping bamboo which is native to Southern Asia, covering about 28% of total bamboo area of India, reaching a height of 10- 35m with bright green and heavily branched culms. It grows naturally in the forests and is used extensively for the construction of bridges and ladders. The leaves are also widely used for thatching. Since this plant contains high levels of silica, it is also used in many ways in Ayurvedic medicine.

b) *B. vulgaris* var. striata (Lodd. ex Lindl.) Gamble (Plate 2): Commonly called as yellow bamboo which is native to Indo-china, most easily recognized by bright yellow culms with green stripes and dark green leaves. This bamboo constitutes the most preferred species for erosion control and is also commonly used in fences, border hedges, furniture, raw material for paper pulps, particle boards and flexible packaging material. This species of bamboo also stands out as a conventional species for ornamentation.

2. Assessment of Feeding Damage:

Visible signs of mite infestation and the consequent damage symptoms produced on the host plants in response to the feeding activity of the bamboo spider mite, *S. schizopus* were assessed on the above two species of host plants by adopting both qualitative and quantitative procedures. The qualitative measures included the assessment of morphological symptoms developed on the infested leaves as well as the cellular and tissue level damages evidenced through leaf sectioning.

a) Qualitative Assessment of Leaf Damage:

i) **Assessment of Morphological symptoms:**

Qualitative aspects of mite infestation such as the number of mites present on individual leaf, number of webs/nests constructed by the pest mite on bamboo leaves, preferred sites for nest/web construction on the foliar surface, nature and pattern of webs, surface area covered by the individual nest/web, number of mites under the individual nest/web, pattern of oviposition, etc. were examined and data were recorded carefully on individual species of bamboos. Symptoms of mite infestation such as the development of chlorotic spots, linear patches, bronzing, yellowing and drying up of leaves etc. were also examined and data on the various parameters were recorded. Photographs of the infested leaves, webs/nests constructed by the mite and damage symptoms produced were taken using a Google Nexus camera.

ii) **Anatomical Studies of Mite infested Bamboo Leaves**:

Studies on the anatomical features of uninfested and *S. schizopus* infested leaf tissues of selected bamboo plants viz. *B. bambos* and *B. vulgaris* were made by making leaf sections and comparing the cellular characteristics of both leaves. For making leaf sections, uninfested and mite infested leaves, from different sites of University of Calicut, were collected using a scissors, kept in zip lock bags and brought to the laboratory for further processing. The leaves were thoroughly cleaned to remove the mites/webs/nests prior to sectioning. Thin hand sections were made using a sharp blade and stained with saffranin. Stained sections were destained by washing in distilled water and mounted in DPX. Microphotographs of the stained sections of both the mite infested and uninfested leaves were taken using a Leica digital camera (DFC 295) and presented.

b) Quantitative Assessment of Leaf Damage:

The uninfested and mite infested leaves of the above two species of bamboos were considered for comparing the changes in the biochemical parameters resulted through the feeding activity of S. *schizopus*. Various parameters like the changes in the photosynthetic pigments (Chlorophyll a, b, total chlorophyll, carotenoids), photosynthetic efficiency through measurement of chlorophyll fluorescence, total phenol, proline, total protein, total nitrogen, total carbohydrate, leaf moisture and the concentration of macro and micronutrients etc. were assessed quantitatively in the mite infested and uninfested bamboo leaves following appropriate biochemical methods. Leaf samples for the above studies were collected from the bamboos grown in the Calicut University Campus and thoroughly cleaned in the laboratory to remove the mite specimens. Removal of mites/webs/nests in the leaf samples was confirmed through microscopic examination and such mite excluded leaves were considered for further biochemical analysis. The two categories of leaf samples viz. the uninfested and mite infested were subjected to the following estimations:

i) Estimation of Photosynthetic pigments:

Concentrations of photosynthetic pigments like chlorophyll a, chlorophyll b, total chlorophyll and total carotenoids present in the uninfested and infested leaf tissues of both species of bamboos mentioned above were estimated following the method of Arnon (1949).

Procedure:

One gram each of the uninfested and infested leaf tissue sample was weighed and ground in a mortar in 20ml of 80% acetone. It was then subjected to centrifugation at 5000 rpm for 5 minutes. The supernatant was transferred to volumetric flasks and made up to 100ml with 80% acetone. The experiment was carried out repeatedly till the residue became colourless. The absorbance of the solution was measured at 450, 645, 663 and 670 nm in a UV- VIS Spectrophotometer (UV 1800 SHIMADZU). The concentrations of photosynthetic pigments were calculated and expressed in µg/g. The experiment was repeated 5 times for confirmation of results.

ii) Measurement of Photosynthetic efficiency:

Chlorophyll fluorescence of uninfested and mite infested leaf samples was measured with the help of a Plant efficiency analyzer (Handy PEA, Hansatech Instrument pt. Ltd., UK) as described below:

Procedure:

The leaf samples of the above two categories of the two species of bamboos were attached to light exclusion clips and were dark adapted for 20 minutes and then subjected to continuous light at 650nm wavelength and 3000µ mol photon m^{-2} s-1, by providing light emitting diodes focussed on a circle of 5mm diameter of sample surface. The fluorescence signal received by the sensor, was recorded and digitalized by the control unit. These signals were digitalized at different rates. Maximal fluroscence was induced by a 1-s pulse of white light (3000µmol m^{-2} s^{-1}) with the gain adjusted to 0.7 to avoid errors.

iii) Estimation of Total Carbohydrate:

The amount of Total Carbohydrate was estimated following Anthrone method (Hedge and Hofreiter, 1962). The uninfested and mite infested leaf samples were weighed into 500 mg each and were homogenized separately with 5ml of 2.5N HCl. Each sample was then kept in hot water bath for 3 hours and then was made up to 25ml and centrifuged at 2000 rpm for 20 min. 0.1ml of the each supernatant was taken in respective test tubes and made up to 1ml with distilled water. To these, 4ml of cold anthrone reagent was added and heated for 8 min. and cooled to room temperature. The dark green colour developed was read spectrophotometrically at 630 nm against glucose as standard. The amount of Total Carbohydrate present in the leaf samples was calculated based on the following equation:

$$\text{Amount of Total Carbohydrate present in 100mg of the sample} = \frac{\text{mg of Glucose}}{\text{Volume of sample}} \times 100$$

iv) Estimation of Total Nitrogen:

The total nitrogen in the mite infested and uninfested bamboo leaf samples was determined following Kjeldahl method (1883). For estimating Nitrogen, each leaf sample was digested with 10 ml of NaOH for one hour. After digestion, 20 ml of Sodium

Thiosulphate was added. The digested sample was then subjected to distillation with boric acid indicator and titrated with 0.02% H_2SO_4, till the indicator turned to pale lavender in colour (APHA, 1992). The amount of total nitrogen was calculated following the equation:

$$\text{Mg NH3- Nitrogen/ Kg} = \frac{\text{A - B}}{\text{g of dry weight of the sample}} \text{ x280}$$

A - Volume of H_2SO_4 titrated with sample

B - Volume of H_2SO_4 titrated with blank

ii) Estimation of Total Protein:

The data recorded on the total nitrogen content in the leaf samples of both species of bamboos through Kjeldahl method (1883) were used for calculation of total protein content. The values obtained for total nitrogen content of the leaf samples were multiplied by 6.25, for the calculation of the concentration of total protein content (AOAC, 1990).

iii) Estimation of Total Phenol:

Total phenol content of mite infested and uninfested bamboo leaf samples was estimated following the method of Malick and Singh (1980). For this, 1g of each leaf sample was ground in 10 ml of 80% ethanol and then centrifuged at 10,000 rpm. To the residue, 5 ml of 80% ethanol was added, ground and centrifuged. The supernatant was evaporated to dryness and to the dried residue, 5ml of distilled water was added and mixed well. From the above solution, 1ml was pipetted out and to that 2ml of distilled water and 0.5ml of Folin- Ciocalteu reagent was added. 20% of sodium carbonate was added to the above solution, kept in a water bath for 1 min. cooled to room temperature and read at 650nm in a spectrophotometer. Tannic acid was used as the standard for this reaction. The total phenol content in the leaves was estimated following the equation given below and expressed in mg phenol/g sample.

$$\text{Concentration of Sample} = \frac{\text{Concentration of Standard} \times \text{OD of sample}}{\text{OD of Standard}} \text{ x } \frac{5}{1\text{g}} \text{ x } 1$$

iv) Estimation of Proline:

Comparative estimation of the proline concentration in the mite infested and uninfested leaf samples of both species of bamboos was made following the method of Bates *et al.,* (1973). 0.5 g of each leaf tissue was homogenized in 10 ml of 3% aqueous sulphosalicylic acid. The homogenate was filtered through a glass fibre filter and to the 2 ml of the filtrate, 2 ml of glacial acetic acid and 2 ml of acid ninhydrin reagent solution were added. The solution was then subjected to heating in a hot water bath for 1hour and for terminating the reaction the test tubes were kept immediately in ice bath for 5 minutes. To this ice cold test tubes, 4 ml of toluene was added and stirred well for 20 seconds. The separated toluene layer was taken out and read at 520nm. The concentration of proline in each sample was determined from the standard curve and calculated following the equation given below and expressed on a fresh weight basis. The 115.5 in the equation denotes the molecular weight of the Proline.

$$\mu g \text{ moles/ g tissue} = \frac{\mu g \text{ Proline/ ml} \times \text{ml Toluene}}{115.5} \times \frac{5}{\text{g sample}}$$

v) Analysis of Moisture content:

For assessing the percent of moisture content in the uninfested and mite infested leaf samples of the two species of bamboos, fresh weight and oven dried dry weight of nine samples were taken and recorded separately. The percentage of moisture content of each sample was measured based on following method:

% of moisture content = Fresh weight- Dry weight/ Fresh weight x100

vi) Estimation of Micro and Macro nutrients:

The impact of feeding by *S. schizopus* on the macro and micro nutrient contents such as Phosphorus, Potassium, Calcium, Magnesium, Sulphur, Iron, Manganese, Copper, Zinc and Boron in the bamboo leaves was also analyzed during the present study. For estimation, the leaves representing the uninfested and mite infested categories of both species of bamboos were subjected to wet oxidation before carrying out the estimations.

Wet oxidation of leaf tissues:

For wet oxidation of bamboo leaves, the collected leaves were washed thoroughly and dried in an oven for 8- 10 days at 60ºC. The dried leaves were ground to powder and then sieved to get the fine powder. 1 g each of finely powdered samples was taken separately in a 100 ml volumetric flask, to which 10 ml of acidic mixture (HNO_3: $HClO_4$, 2:1) was added and the flask was subjected to cold digestion for two hours. Then each sample was heated at 50ºC on a block digester for one hour and then heated at 80ºC till a white clear solution was obtained. The flask was cooled and the solution was made up to 100 ml with distilled water and filtered through a Whatman filter paper No. 42. This digested sample was used for further analysis of minerals like Phosphorus, Calcium, Potassium, Magnesium, Sulphur, Iron, Manganese, Zinc, Copper and Boron.

a) Estimation of Phosphorus:

The Phosphorus content in each of the bamboo leaf sample was analysed based on the method described by Piper (1966). For this, 5 ml of di- acid extract of bamboo leaves was taken and mixed with 5 ml of HNO_3 – Vando molybdate reagent in a 25 ml volumetric flask. Then the volume of the sample was made upto 25 ml with distilled water and the sample was read spectrophotometrically at 470nm. The value of Phosphorus was determined from the standard graph plotted.

b) Estimation of Manganese, Iron, Zinc, Copper, Calcium and Magnesium:

For estimation of changes in the concentration of Manganese, Zinc, Iron, Calcium, Copper and Magnesium owing to the feeding activity of *S. schizopus* , the di-acid digest extract obtained both from uninfested and mite infested bamboo leaf samples were read directly using Atomic Absorption Spectrophotometer, along with appropriate standards.

c) Estimation of Sulphur:

Alterations in the Sulphur content of the mite infested and uninfested bamboo leaves were analysed following the Barium chloride extractable sulphur method described by Williams and Steinbergs (1959). To 10 ml of the di- acid digest extract, 1 ml of 6 N HCl and 1 ml of 0.5 % gum acacia were added. The solution was mixed well and to that 0.5 g Barium chloride crystal was added. The test tube was swirled well so as to make the crystals dissolved and read this turbidity on a spectrophotometer at 420 nm. The concentration of Sulphur was measured from the standard graph.

d) Estimation of Boron:

Concentration of Boron in the uninfested and infested leaf samples of bamboos was estimated following hot water soluble boron estimation method of Gupta (1967). For this, 1 ml of di- acid digested sample was taken in a boiling tube and to which 2ml of buffer solution and 2 ml of Azomethine –H reagent were added and mixed well. After a period of 30 minutes, the solution was read spectrophotometrically at 420nm. The amount of Boron was measured from the standard curve.

e) Estimation of Potassium:

The concentration of Potassium was estimated directly from the di-acid digest using Flame photometer by adopting the method of Piper (1966). The flame photometer was calibrated using the standards prepared by diluting the stock solution containing 1000 ppm of K solution.

Data procured on all the biochemical estimations described above were statistically analysed to verify their level of significance based on Mann Whitney test, done with the help of SPSS software version 16.

3. Studies on the Developmental biology of pest mites

During the present study, two most dominant species of spider mite pests viz. *S. schizopus* and *T. urticae* were selected to make detailed observation on their breeding parameters. The study was initiated with the collection of the adult specimens from the bamboo host, *Bambusa bambos* grown in the Botanical Garden of the Calicut University.

a) Laboratory Rearing and culturing of the pest mites:

Rearing of the species was carried out in laboratory conditions following leaf disc method. Live cultures of the pest mite species were maintained on fresh leaves excised from the bamboo plant, *B. bambos* and kept in petridishes (90mm diameter and 10mm height) lined with cotton pads (88 mm dia. x 5 mm H). The bamboo leaves were placed with their abaxial surface facing up on the moistened cotton pads in the petridishes. The cotton pads were subjected to daily wetting to keep the freshness of the leaves and as and when the leaves showed the initial symptoms of decay the mites were very carefully moved to the newly constructed webs on fresh leaves (Plate 61, Fig 68).

Each culture set consisted of 2-5 leaves, depending up on the size of the leaves. Stock cultures of the mites were also maintained in the laboratory simultaneously by following leaf disc method mentioned above, to ensure constant and uninterrupted supply of mites for making repeated observations on various biological parameters like mating, oviposition, incubation, hatching, quiescence, moulting, durations of individual instars etc.

b) Studies on developmental parameters

In order to study the pre- oviposition periods of pest mites mentioned above, 5-10 colonies of newly moulted females were introduced onto the fresh leaf samples kept on moistened cotton pads in the petridishes along with 2-4 males. Regular observation was made under a stereomicroscope to collect data on mating and to record the initiation of oviposition by females. As and when the females started laying eggs, the males were removed from the leaves. For the study of parthenogenetic development, 5-10 quiescent female deutonymphs were reared in isolation and observation was made till the emergence of adults. The newly emerged adult females were kept isolated from males and the eggs laid by these females were considered for making further observation on parthenogenetic mode of life cycle. Data on the number of eggs laid by the mated and the virgin females were recorded periodically. The females were then transferred to fresh leaves and the eggs were kept on the same leaf discs till adult emergence. Regular observation was made on the leaves/leaf discs containing the different life stages of the spider mites to record data on the durations of individual instars as well as total duration of life cycle. The duration of development was recorded separately for males and females of the spider mite species. Observations were continued to record the durations of oviposition and post - oviposition periods as well as the longevity of the adult mites.

c) Studies on the impact of variations in temperature-humidity conditions on the development of pest mites:

To assess the impact of changes in the temperature- humidity parameters on the duration of life cycles of the selected species of spider mites, *S. schizopus* and *T. urticae*, biological studies were carried out under two different temperature - humidity combinations. The selected temperature –humidity combinations were 20 ± 2ºC and 70 ± 5% RH, 30 ± 2ºC and 80 ± 5% RH under which cultures of both species were maintained in an incubator. The specified temperature-humidity conditions of 20 ± 2ºC and 70 ± 5% RH were maintained by keeping saturated solution of ammonium sulphate in the incubator while 30 ± 2ºC and 80 ± 5% RH was maintained by keeping saturated solutions of equal amount of Sodium chloride and Potassium chloride respectively (Winston and Bates, 1960). The whole process was repeated 30 times for confirmation of the results. Regular observation was made to gather information on the duration of different life stages of the above species. Data collected were recorded and tabulated and expressed as Mean ± Standard error. Photographs of the various life stages and other biological parameters were also taken with the help of Leica DFC 295 attached to a Leica S8APO microscope. The significance of the data gathered on the impact of temperature-humidity variations on the developmental durations of the species was verified using Mann Whitney test done with the help of SPSS software version 16.

i) **Preparation of saturated salt solutions for maintaining constant RH**

Saturated salt solutions of $(NH_4)_2SO_4$ and NaCl- KCl used for maintaining constant humidity conditions required for biological studies of pest mites were prepared by dissolving the respective salts in boiling water. The salts were added until saturation was attained and then partially cooled. To the partially cooled solution, more salt was added and allowed to cool to the room temperature. More salt was added to each solution and kept undisturbed for a few days to ensure complete saturation. In order to ensure constant relative humidity in the incubator, temperature was adjusted appropriately, for each saturated salt solution (Winston and Bates, 1960).

d) Morphological studies on the developmental stages of pest mites

Morphological features of the various life stages of the pest mites such as the egg, larva, protonymph, deutonymph and adult (male & female) were studied through microscopic observation of slide mounted specimens. The various life stages of the pest mites were slide mounted in a drop of Hoyer's medium and kept in an oven at 45°C to get the desired clarity of the mounted specimens. Morphological features of the various life stages were drawn with the help of a Camera Lucida attached to a Unitron microscope. Measurements of the specimens (Larva, Protonymph, Deutonymph, male and female adult mites) were made using stage and ocular micrometers. Photographs were taken with the help of Leica DFC 295 attached to a Leica S8APO microscope.

The progressive damage induced by the most dominant and injurious species of bamboo spider mite, *S. schizopus* was studied by adopting both qualitative and quantitative methods. During the study, comparative evaluation of the various parameters associated with the feeding biology of the species was carried out by rearing the species on the leaves of two species of bamboo hosts, viz. *B. bambos* and *B.vulgaris* grown in the Calicut University Campus.

I. Qualitative assessment of feeding damage induced by *Schizotetranychus schizopus:*

A. Visible Symptoms of mite infestation :

Mite infested bamboo leaves were readily identifiable under field conditions based on the presence of white spots, linear patches and yellowing and browning of leaves. Detailed observations disclosed that feeding damages induced by the bamboo mites were resulted through the sucking activity of the mites, leading to the development of white spots. These white spots were initiated near the midrib region or along the leaf edges simultaneously with the slow establishment of mite colonies. Once the mite population successfully got established on the leaves and started to spread their colonies along the midrib and adjacent veins, the white coloured chlorotic spots also got widened and slowly developed into white parallel lines/patches on the upper surface of bamboo leaves. As the mite population showed a progressive increase on the leaves, chlorosis and bronzing of the leaves occurred which ultimately lead to the drying up of leaves (Plate 62; Fig. 69 a,b).

Results of microscopic observation on the feeding mechanisms of pest mites revealed that the feeding activity was initiated by the adult mites, which colonized generally on the lower abaxial surface of leaves. While feeding, the adult mites with the help of their cheliceral stylets, penetrated the epidermal layer of the bamboo leaves and sucked out the cell contents. After feeding for a period of one or two minutes, the mites retracted their cheliceral stylets and started to move in search of new feeding sites. When the mite population density attained peak level, some individuals were found migrating towards the adaxial surface of the leaves in search of new feeding sites.

B. Cellular levels of damage induced by *S. schizopus*

Results of qualitative assessment of damage induced by *S. schizopus* at the cellular level through comparative histological studies of stained sections of mite infested and uninfested leaves revealed significant differences in their anatomical features. Uninfested (healthy) leaves were found to consist of two epidermal layers viz. upper epidermis and lower epidermis. Upper epidermis possessed a number of bulliform cells whereas the lower epidermis consisted of stomata and was covered with strong cuticle. Mesophyll tissue was found to comprise compactly arranged cells, without any differentiation between palisade and spongy cells. The mesophyll tissue also had distinct cavities. The vascular bundles were collateral and closed, arranged in parallel series, comprised of xylem on the adaxial surface and phloem on the abaxial surface. Larger bundles had more distinct xylem and phloem surrounded by bundle sheath and patches of sclerenchyma cells on two sides (Plate 62; Fig. 69b).

Anatomical studies of infested leaf showed that the feeding activity of *S. schizopus* could lead to disruption of cuticle as observed in the stained sections. The mesophyll tissues were found reduced when compared to those of uninfested leaf tissues. Palisade tissues showed damaged chloroplasts when compared to that of the uninfested leaf section (Plate 62; Fig. 69d).

II. Quantitative Assessment of feeding damage induced by *S. schizopus*:

Results of Quantitative assessment of the feeding damage induced by *S. schizopus* on the two species of bamboos viz. *B. bambos* and *B. vulgaris* through biochemical estimations of varied parameters like photosynthetic pigments, total carbohydrates, phenols, nitrogen, moisture content, proline and the micro and macronutrients of mite infested and uninfested leaves have been presented here.

A. Estimation of Photosynthetic pigments:

Results of quantitative studies revealed considerable reduction in the chlorophyll contents of mite infested leaves of both the host plants. As presented in table 11 and Fig. 70, the mean concentrations of chlorophyll a, chlorophyll b and total chlorophyll in the uninfested leaves of *B. bambos* were 3592.89± 3.25µg/g , 3015.36± 11.03µg/g and 6574.66± 41.11µg/g respectively. The respective concentrations of the above pigments in the mite infested leaves of the same plant were found reduced to 877.38± 3.87 µg/g of chlorophyll 'a', 439.86± 8.34 µg/g of chlorophyll 'b' and 1429.04± 27.87 µg/g. Thus, the percent loss in photosynthetic pigments could be accounted to 75% loss in chlorophyll a, 78% loss in chlorophyll b and 78% loss in Total chlorophyll as observed in *B. bambos*. The mean concentrations of chlorophyll a, b and total chlorophyll in the uninfested leaves of *B. vulgaris* were estimated to be 3835.16±14.77 µg/g, 2704.53± 20.85 µg/g and 6542.14± 17.89 µg/g respectively. However, feeding activity of *S. schizopus* induced a significant reduction in the chlorophyll pigments and this was evident in the mite infested leaves which presented the mean concentrations of the above pigments as 1428.43± 17.58 µg/g, 810.86± 6.61µg/g and 2429.74± 41.64 µg/g respectively. The percent loss in chlorophyll when calculated based on the above results, could be recorded as 62%, 70% and 62% respectively for chlorophyll a, chlorophyll b and total chlorophyll in the mite infested leaves of *B. vulgaris*. The results on chlorophyll loss when analysed statistically were found highly significant ($p< 0.05$).

Carotenoid pigments in both the host plants also showed a significant reduction owing to the feeding activity of *S. schizopus*. The mean concentration of carotenoids in the uninfested leaves of *B.bambos* was observed to be 4096.27± 80.53 µg/g whereas that of mite infested leaves got reduced to 2125.28± 54.53 µg/g (Table 11 & Fig. 70). A similar reduction was observed in *B. vulgaris* also in which the mean carotenoid concentration was 4694.59± 4.95 µg/g in uninfested leaves and 2515.88± 17.32 µg/g in infested leaves (Table 11 & Fig. 70). The per cent loss in carotenoids on the host plants could be recorded as 48% in *B. bambos* and 46% in *B. vulgaris* respectively. The results were found highly significant upon statistical analysis ($p< 0.05$).

B. Analysis of Photosynthetic efficiency:

The photosynthetic efficiency of the mite infested and uninfested leaves of *B. bambos* and *B. vulgaris* when analysed using the Handy Photosynthetic Efficiency Analyser revealed that mite feeding could result in significant reduction in the photosynthetic efficiency. The mean value of Fv/Fm was found higher for the uninfested leaves of *B. bambos* and *B. vulgaris* whereas the leaves infested by *S. schizpous* disclosed lower Fv/Fm values. The mean value of Fv/Fm for uninfested leaves of *B. bambos* was 0.763±0.005 whereas it got reduced to 0.534±0.005 in the infested leaves of *B. bambos*. Similar results were obtained when the leaves of *B. vulgaris* were subjected to photosynthetic efficiency analysis. The uninfested leaves of *B. vulgaris* presented the value of Fv/Fm as 0.77 ± 0.01 whereas that of mite infested leaves was 0.63 ± 0.01 (Table 12 & Fig.71). Thus the feeding activity of *S. schizopus* was found to result in

30.10% loss in the value of Fv/Fm in *B. bambos* and a loss of 18.18% in Fv/Fm in *B. vulgaris*. Results of statistical analysis of the differences in the Fv/Fm values recorded for uninfested and mite infested leaves of both species of bamboos showed that these were significant ($p<0.05$).

C. Estimation of Leaf moisture content:

Infestation by *S. schizopus* was found to reduce the moisture content of the leaves in both species of bamboos studied. The mean moisture contents recorded for uninfested leaf samples of *B. bambos* and *B. vulgaris* were 89.25± 0.36% and 88.03 ± 1.01 % respectively. Mite infested leaves of *B. bambos* presented the mean moisture content as 78.67± 3.2 % while that of *B. vulgaris* was 74.13± 1.73% (Table 12 & Fig. 72).When these results were subjected to Mann- Whitney 't' test, the mean differences in the leaf moisture content in the uninfested and mite infested leaves of both species of bamboos were found highly significant ($p<0.05$).

D. Estimation of Total Carbohydrates:

The extent of biochemical alterations induced by the feeding activity of *S. schizopus* on *B. bambos* and *B. vulgaris* was analysed through estimation of total carbohydrate concentration following Anthrone's method (Hedge and Hofreiter, 1962). The uninfested leaves of *B. bambos* and *B. vulgaris* were found to possess a mean concentration of total carbohydrates as 76.82± 1.29 and 77.74± 1.73 mg/g respectively. Due to the feeding activity of *S. schizopus,* the total carbohydrate was found reduced to 31.59± 2.32 and 35.73± 3.45 mg/g in the leaves of *B. bambos* and *B. vulgaris* respectively (Table 13 & Fig. 73). When analysed statistically, the differences in total carbohydrate concentration were found highly significant ($p<0.05$).

E. **Estimation of Total Phenol:**

Unlike the photosynthetic pigments and total carbohydrates, mite infested leaves of *B. bambos* and *B. vulgaris* showed increased levels of phenolic contents when compared to the healthy leaves. The uninfested leaves of *B. bambos* had 47.78± 2.33 mg/g of total phenol. Due to the feeding of *S. schizopus,* the total phenol content of the leaf was found increased to 61.94± 1.49 mg/g. Similar results were obtained when the leaves of *B. vulgaris* were analysed for phenol content. The uninfested leaves of *B. vulgaris* showed 47.23± 0.87 mg/g of total phenol and the mite infested leaves presented an increased value of 70.69±2.41 mg/g of total phenol (Table 13 & Fig. 73). The differences in the total phenol in uninfested and mite infested leaves when subjected to Mann- Whitney ‘t’ test, were found highly significant ($p<0.05$).

F. Estimation of Total Nitrogen:

In order to quantify the amount of total nitrogen, the leaf samples of *B. bambos* and *B. vulgaris* were subjected to Kjeldal method (1883). The results of the studies revealed the total Nitrogen in uninfested leaves of *B. bambos* as 2.33 ± 0.12 % where as that of mite infested leaves was recorded as 1.84± 0.03% .The leaves of *B. vulgaris* also showed a decrease in total Nitrogen due to mite feeding. The respective values recorded for the total Nitrogen in the uninfested leaves and the mite infested leaves were 2.61± 0.01 and 2.04± 0.01% (Table 13 & Fig. 74). When these results were analysed statistically, significant difference was observed in the total nitrogen in the uninfested and mite infested leaves of both species of bamboos ($p<0.05$).

G. Estimation of Total Protein:

When the amounts of total Protein present in uninfested and *S. schizopus* infested leaf tissues were estimated using AOAC (1990), significant reduction was observed due to the feeding activity. The total protein content of uninfested leaves of *B. bambos* was recorded to be 14.56 ± 0.26 % where as it was found reduced to 11.5 ±0.19 % in mite infested leaf tissues.

The uninfested leaves of *B. vulgaris* showed 16.312 ± 0.02% of total protein and which got reduced to 12.75 ± 0.19% as seen in mite infested leaves (Table 13 & Fig. 74). When these results were subjected to Mann – Whitney ‘t’ test, the mean difference of Total protein between uninfested and mite infested leaves of both bamboos, was found to be highly significant ($p<0.05$).

H. Estimation of Proline:

Mite infestation was found to lead to an increase in proline production in the leaves of both species of bamboos studied. The uninfested leaves of *B. bambos* showed 11.26 ± 0.01µmol/g of proline, but mite infested leaves showed an increased value, reaching 23.84± 0.26 µmol/g of proline (Table 13). A similar increasing trend was observed in the leaves of *B. vulgaris* also. The uninfested and mite infested leaves of *B. vulgaris* showed 12.84 ± 0.49 and 30.11± 3.33 µmol/g of proline respectively (Table 13

& Fig. 75). The difference in mean proline concentration between uninfested and mite infested leaf tissues, was found highly significant (p<0.05).

I. Estimation of Macronutrients:

The alterations in the concentrations of macronutrients induced by the feeding activity of *S. schizopus* on the leaves of *B. bambos* and *B. vulgaris* were also analysed by estimating the amounts of Potassium, Phosphorus, Calcium, Magnesium and Sulphur. As presented in Table 14, 1.16±0.009 mg/g of Phosphorus was found in the uninfested leaves of *B. bambos* whereas mite infested leaves showed a lower value of 1.066 ± 0.003 mg/g. Similarly the concentration of Potassium was estimated to be 6.93± 0.05 mg/g in uninfested leaves and that of infested leaves was higher, reaching 8.541± 0.08 mg/g, When these results were analysed statistically, the mean differences observed in the concentrations of Phosphorus and Potassium in uninfested and mite infested leaves of *B. bambos*, were found significant (p<0.5) (Fig. 76).

The uninfested leaves of *B. bambos* showed 4.023 ± 0.09 mg/g of Calcium and 2.427± 0.02 mg/g of Magnesium respectively whereas mite infested leaves had 6.35± 0.07 mg/g of Calcium and 2.341± 0.06 mg/g of Magnesium respectively. Similarly, *B. bambos* also showed 5.246 ± 0.53mg/g and 5.165± 0.29 mg/g of Sulphur in the uninfested and mite infested leaves respectively (Table 14 & Fig. 76). When analysed statistically, the differences in the mean concentrations of Calcium, Magensium and Sulphur in the uninfested and mite infested leaves of *B. bambos* were found highly significant.

Results of biochemical analysis showed the concentration of Phosphorus as 1.254 ± 0.005 mg/g and 1.021± 0.008 mg/g in the uninfested and mite infested leaves respectively. The uninfested leaves of *B. vulgaris* also showed 6.523± 0.08 mg/g of potassium and 4.38 ± 0.03 mg/g of calcium respectively whereas the mite infested leaves showed 9.243 ±0.09 mg/g of potassium and 5.777 ± 0.01 mg/g of calcium respectively (Table 14 & Fig. 77). When these results were analysed by Mann- Whitney't' test, the difference in concentration of phosphorus, potassium and calcium, were found to be highly significant with p< 0.05.

The uninfested leaf samples of *B. vulgaris* had 2.407± 0.05 mg/g of magnesium and 6.683± 0.05 mg/g of Sulphur while the mite infested leaves showed a decreased value of 2.331± 0.06 mg/g and 5.694± 0.33 mg/g respectively (Fig. 77). The differences in the values obtained for the uninfested and mite infested leaves were found to be highly significant when analysed statistically with $p<0.05$.

J) **Estimation of Micronutrients:**

Table 15 depicts the concentration of micronutrients present in the leaves of *B. bambos* and *B. vulgaris*. The uninfested leaves of *B. bambos* when subjected to biochemical estimations, showed 0.595 ± 0.61 mg/g of Iron, 0.0132± 0.005 mg/g of Copper and 0.041± 0.004 mg/g of Zinc. Slight alterations were observed in the mite infested leaves of *B. bambos*, by revealing 0.526 ± 0.79 mg/g of Iron, 0.025 ± 0.004 mg/g of Copper and 0.051± 0.005 mg/g of Zinc. The uninfested leaves of *B. bambos* also showed 0.593 ± 0.003 mg/g of Manganese and 0.0438± 0.001 mg/g of Boron whereas the mite infested leaves had 0.512± 0.002 mg/g of Manganese and 0.031±0.07 mg/g of Boron respectively (Fig. 78 & 79). The differences observed in the concentrations of the above nutrients were found to be highly significant when analysed statistically using Mann- Whitney‘t’ test with $p< 0.05$.

Similar alterations were recorded in the leaves of *B. vulgaris* also due to mite feeding. The uninfested leaves of *B. vulgaris* showed 0.656± 0.65 mg/g of Iron, 0.0245± 0.001 mg/g of Copper and 0.0554± 0.004 mg/g of Zinc. The concentrations of Manganese and Boron were 0.6067 ± 0.004 mg/g and 0.0343± 0.002 mg/g respectively in the uninfested leaves. The mite infested leaves showed 0.5134 ± 0.29 mg/g of Iron, 0.0329 ± 0.006 mg/g of Copper and 0.0595± 0.003 mg/g of Zinc. These leaves also showed 0.543± 0.03 mg/g of Manganese and 0.025± 0.001 mg/g of Boron (Fig. 78 & 79). The differences in the mean concentrations of the above micronutrients in the leaves of *B. vulgaris* when analysed through Mann- Whitney‘t’ test, were found to be highly significant.

Developmental biology of the pest mites.

In the present study, developmental studies of two species of injurious spider mites viz. viz. *S. schizopus* and *T. urticae* were carried out under controlled conditions of temperature and relative humidity to gather information on the nature and pattern of web formation, development, mating, oviposition, hatching, durations of various developmental instars, quiescence, moulting, total duration of development, sex ratio etc. Data on the developmental features of the two species have been recorded, tabulated and presented.

A. Postembryonic development of *Schizotetranychus schizopus*: (Plate 70)

Results of microscopic observation clearly revealed that adult females were engaged very actively in the construction of webs. Adult females constructed thick silken webs near the midrib and edges of bamboo leaves. At the time of web construction itself, the females initiated oviposition underneath the newly constructed web. The eggs were found laid in a neat straight line, parallel to the mid ribs mostly. Concomittant with the development of immatures, the females of the species expanded their webs also. Two or more females were found to share a common nest, during the present study. The adult males and females were found to counter attack when the predators intruded into the nests to prey upon the offsprings of the pest mite. When the development of *S. schizopus* was studied in the laboratory under two sets of temperature-humidity combinations, the following results were obtained:

1) Durations of pre-oviposition and oviposition periods:

Prior to the initiation of oviposition, the females underwent a short pre-oviposition period, the mean duration of which was recorded as 1.9± 0.02 days at 30± 2°C & 70± 5% RH and 2.1± 0.03 days at 20±2°C & 80± 5% RH. The females initiated oviposition on the second or third day after their emergence as adults.

The variations in the temperature-humidity conditions were found to induce changes in the durations of oviposition period also. The duration of oviposition period at 30± 2°C & 70± 5% RH was 9 ±0.47 days whereas it was extended to 10.25± 0.5 days at a lower temperature-humidity condition of at 20±2°C & 80± 5%RH.

The post- oviposition period which followed the oviposition period was just 1± 0.3 days at 30± 2°C & 70± 5%RH and 1.1± 0.4 days at 20±2°C & 80± 5%RH conditions. During the post- oviposition period the adult showed a retardation of feeding activity and became more inactive and lethargic (Table 16 & Fig. 80).

2) Oviposition, fecundity and longevity

Adult females laid eggs near the midrib or the edges, underneath the web in a straight line parallel to the midrib. The females initiated oviposition by slightly lowering the hysterosoma and laying the eggs in close proximity to one another. The freshly laid eggs appeared smooth, round and white in colour and as the incubation period progressed, the colour of the eggs got changed from white to light yellow. Towards the end of incubation period, the eye spots of the developing larva became prominent and the eggs became turgid.

Fecundity *i.e.* the number of eggs laid by the female, during its lifetime, was 40± 2.5 at 30± 2ºC & 70± 5% RH and 34± 2.5 at 20±2ºC & 80± 5%RH. The fecundity was less during the initial days of oviposition (1or 2 eggs/day) and showed a gradual increase towards the 4^{th} or 5^{th} day (upto 10- 12 eggs/day) and then declined towards the last day of oviposition (Table 16).

When reared under the temperature and humidity conditions of 30± 2ºC & 70± 5%RH, the longevity of the adult male was found to be 8.5± 1.5days whereas at 20±2ºC & 80± 5% RH, the longevity of male was increased to 10.2± 0.5 days. Females showed greater longevity than the males and it was recorded as 12.5± 1.6 days at 30± 2ºC & 70± 5%RH and slightly increased to 13.5± 2.3 days at 20±2ºC & 80± 5%RH (Table 16 & Fig. 81).

3) Hatching :

The eggs laid by the gravid female, towards the onset of hatching, became turgid and ovoid in nature. After 4-5 days of incubation, a small slit appeared, which gradually extended through the thrusting action of the propodosoma and legs of the emerging larva. The hatching process took 15- 20 minutes for completion. Finally the larva emerged out of the egg case. The leftovers of the egg shell could be seen under the webs.

4) Durations of life stages:

a) Incubation Period: The duration of incubation period of *S. schizopus* was found varied depending up on the changes in the temperature and humidity conditions. At 30± 2ºC & 70± 5%RH, eggs hatched in 4.3± 0.04 days while the hatching duration was found extended to 6 ± 0.03 days at 20±2ºC & 80± 5% RH (Table 17 & Fig. 82).

b) Larval Period: The newly hatched larva appeared small, white coloured and with three pairs of legs. The body was with feeble segmentation. It remained motionless for a short duration and then slowly initiated feeding activity by inserting its feeding stylet into the leaf tissues. The duration of larval period also showed variation depending upon the changes in the temperature and humidity conditions. The larval duration lasted for 1.6 ±0.02 days under of 30± 2ºC & 70± 5%RH and 1.8± 0.05 days under 20±2ºC & 80± 5%RH (Table 17 & Fig. 82).

c) Protonymphal Period: Upon cessation of feeding activity, larva entered in to a physiological inactive stage called the first quiescent stage and subsequent moulting resulted in the emergence of the eight legged nymph known as the protonymph. The protonymph was larger than the larva and the colour of which got changed from white to pale green. As depicted in Table 17 & Fig. 82, the feeding period of the protonymph was observed as 1.5± 0.07 days at 30± 2ºC & 70± 5%RH and 1.6± 0.03 days at 20±2ºC & 80± 5%RH.

d) Deutonymphal Period: At the end of the active feeding period, the protonymph also became lethargic, immotile and entered in to the second quiescent stage. Subsequent moulting released the deutonymph, which was larger than the protonymph. The deutonymph showed much resemblance to the adult and the sexual difference was clearly visible at this stage. The male and female deutonymphs could be easily distinguished based on the shape of the hysterosoma, which appeared broadly oval in female and narrow and wedge shaped in the male. Table 17 & Fig. 82, presents the durations of these stages under the selected temperature and humidity conditions. The deutonymphal period lasted for 1.5± 0.03 days at 30± 2ºC & 70± 5%RH and 1.6± 0.04 days at 20±2ºC & 80± 5%RH.

e) Quiescent Stages: the life cycle of *S. schizopus*, comprised three quiescent stages following each of the active stage. Prior to quiescence, the instar became inactive, stopped feeding activity and retained a common posture by keeping its first two pairs of legs stretched anteriorly and the last two pairs of legs stretched posteriorly. The quiescent phase following the active larval stage was called protochrysalis and it lasted for 0.3± 0.06 days at 30± 2ºC & 70± 5%RH and 0.8± 0.03 days at 20±2ºC & 80± 5%RH. The inactive stage after protonymphal stage was called deutochrysalis and it took 0.4± 0.02 days to complete under 30± 2ºC & 70± 5%RH condition and 0.8± 0.02 days under 20±2ºC & 80± 5%RH condition. The inactive period between the deutonymph and adult stage was termed as teleiochrysalis and its duration lasted for 1 ±0.2 days and 1.1 ±0.06 days at 30± 2ºC & 70± 5%RH and 20±2ºC & 80± 5%RH conditions respectively (Table 17 & Fig. 82).

f) Moulting :

Moulting could be denoted as the shedding of old exoskeleton or cuticle and emergence of the new instar and it was found to occur towards the end of each quiescent stage viz. protochrysalis, deutochrysalis and teleiochrysalis. During moulting, a small slit appeared on the cuticle, one on each of the lateral side of the body, and which slowly extended in either direction. Followed by the shove of the emerging instar, the cuticle was found pushed apart and the instar came out. The whole process took 8-10 min. for completion. The broken moulting skin could be visible under the webs constructed by the adult mites.

g) Adults :

The adults were sexually dimorphic with the females larger in size with broadly oval hysterosoma and well-developed legs, capable of spinning the webs efficiently. The males were smaller in size, and with narrow, wedge shaped hysterosoma. Both males and females appeared greenish in colour and had prominent dark red spots. Some dark spots could be seen on the body of females and these spots were not so prominent in males. Both the males and females were found highly active.

h) Mating:

The process of sperm transfer was found achieved through mating. As soon as the female deutonymph became ready for moulting, the male crawled beneath the female hysterosoma and bent its posterior tip of hysterosoma in a characteristic position. Mating lasted for 2 to 3 minutes. After completion of mating, the male moved backwards.

5) Parthenogenetic Development:

Sexual as well as parthenogenetic mode of reproduction could be seen in *S. schizopus.* Under laboratory conditions, the female developed through sexual mode of reproduction produced both male and female progeny in 1: 9 ratio whereas the females which developed through parthenogenetic mode produced only male progeny.

The developmental pattern was found similar under both sexual and parthenogenetic modes of reproduction with egg, larva, protonymph, deutonymph and adult stages. However, the durations of the various life stages varied according to the temperature and humidity conditions (Table 18 & Fig. 83).

B. Morphological description of the life stages of *Schizotetranychus schizopus* (Zacher, 1913): (Plate 70 &71, Fig 84 & 85)

The genus *Schizotetranychus* closely resembles *Eotetranychus*, differing only in the nature of empodium. Presence of a bifid- claw like empodium is the key character of this genus. The members of the genus also possess two pairs of anal and two pairs of para anal setae. The life history of the species includes the egg, larva, protonymph, deutonymh and adult (male and female), the morphological features of which are described below:

Egg:

Colour: Pale Yellow

Diameter: 128-132

When freshly laid, the eggs appeared spherical, translucent and smooth. With the advancement of incubation period, the colour of the egg changed to pale yellow.

Larva:

Colour: Creamy white

Measurements: Length: 190- 205

Width : 110- 120

Dorsal region: Body of larva almost spherical in outline and possesses a translucent, finely striated integument. Rostrum conical and projecting anteriorly; three pairs of propodosomal setae and ten pairs of hysterosomal setae present; seta '*ve*' inserted at the anterior margin of the propodosoma; seta '*si*' longer than others; dorsal setae slender and somewhat widened at base; peritreme feebly visible.

Ventral region: Ventral integument also striated; genital area indistinct; two pairs of anal and two pairs of para anal setae present; two pairs of medioventral setae (MV_1 and MV_2) present; larva characterized by three pairs of legs, all legs six segmented and each terminating in a claw like empodium.

Protonymph:

Colour: Light yellow

Measurements: Length: 210- 215

Width: 125- 136

Dorsal region: Body broadest medially and more or less oval posteriorly; integument finely striated; peritreme with a slight bent at the dorsal portion; all setae showed an increase in length than that of the larva; seta '*si*' inserted more medially; hysterosomal setae more spaciously arranged; tubercles not present.

Ventral region: Ventral integument also striated finely; two pairs of medioventral setae (*MV1 & MV2)* present; genital area not distinct; anal area well separated with two pairs of anal and two pairs of para anal setae, the latter longer than the anal setae; all setae smooth and pointed; four pairs of legs present.

Deutonymph:

Colour: pale yellowish

Measurements: Length: 220- 225

Width : 140- 150

Dorsal region: Body enlarged than that of the protonymph with clearly visible peritreme; slight constriction between propodosoma and hysterosoma; all setae spaciously arranged. Setae c_1, c_2 and c_3 arranged almost in a straight line. Striations more striking at the posterior region.

Ventral region: Genital area distinct, bearing one pair of short, smooth setae; genital flap striated; two pairs of anal and two pairs of para anal setae located. All ventral setae smooth.

Adult Female:

Colour : Pale Yellow

Measurements: Length : 350-355

Width : 230-235

Dorsal region: Body oval with a slight constriction between propodosoma and hysterosoma; peritreme slightly bent at distal portion ending in swollen chamber; dorsal setae slender, somewhat widened near the base; setae not arising from tubercles; posterior portion longitudinally striated; dorsal sensillum of palpus spindle shaped; terminal sensillum of palpus twice as long as broad.

Ventral region: Transverse striae on area adjacent to genital flap; genital flap also with transverse striae; two pairs of anal setae and two pairs of para anal setae; all setae simple.

Leg : Relative length of segments of leg I as follows: Trochanter- 9-11, Femur- 22-24, Genu- 10-13, tibia- 10-13, tarsus- 15-18 (excluding empodium). Tarsus I with two tactile and one sensory setae proximal to proximal duplex setae, tibia I with nine tactile setae and one sensory setae. Tarsus II with only one sensory setae proximal to duplex setae; tibia II and III with five tactile setae; proximal pair of empodial hairs strongly developed resembling a bifid claw; dorsal hairs are minute.

Adult Male:

Colour : Pale Yellow

Measurements: Length : 230-233

Width : 158-160

Body smaller and slender; distal segment of palpus devoid of terminal sensillum, dorsal sensillum spindle shaped. Aedeagus as shown in the figure, shaft narrowing backward and curving upward to the barb acutely angled anteriorly. The axis of the barb forming a definite angle with the axis of the shaft; Striations clearly visible,

Leg: Tarsus I with two tactile and two sensory setae proximal to duplex setae. Tibia I with nine tactile and three sensory setae. Tarsus II with one sensory seta proximal to duplex setae. Tibia II and Tibia III with five tactile setae respectively. Empodia without claws and proximoventral hairs.

C. Post embryonic development of *Tetranychus urticae*: (Plate 74)

While conducting the biological studies of *T. urticae* on bamboo leaves, it was observed that unlike the normal red coloured females of the species, the females of *T. urticae* collected from bamboo plants existed as green forms throughout the course of development. The webs constructed by the females were in the form of thin silken threads unlike the dense webs of *S. schizopus*. Beneath the web, all life stages of the species were observed. The species preferred to colonise the abaxial surface of the leaves and the eggs were laid in clusters. The webs were found scattered without any preference towards the midrib region or edges.

1) Oviposition:

Adult females constructed thin webs on the entire abaxial surface of bamboo leaves and beneath this web they laid eggs in clusters, closer to each other. Freshly laid eggs were white, round and smooth in texture. Towards the end of incubation, eggs appeared more turgid and the colour changed from white to light yellow. The eye spots of the emerging larva could be perceived through the egg case.

As depicted in table 16, the pre-oviposition period was found to change in accordance with the alterations in the temperature and humidity conditions and at 30± 2ºC & 70± 5% RH, it was recorded as 0.5± 0.01 days. It was increased to 1.2 ± 0.19 when the temperature and humidity conditions were changed to 20±2ºC & 80± 5%RH.

Adult females started egg laying on the second day after emergence. The oviposition periods observed during the present study were 8.3 ± 0.48 days under 30± 2ºC & 70± 5%RH whereas it was 10.25± 0.42 days under 20±2ºC & 80± 5%RH. Oviposition period was followed by the post- oviposition period, in which the mite became more lethargic and inactive with reduced feeding activity. The duration of post-oviposition period was 0.53±0.17 days at 30± 2ºC & 70± 5%RH and 1.1 ±0.32 days at 20±2ºC & 80± 5%RH (Table 16 & Fig. 86).

The fecundity was low initially (1-2 eggs/day), and showed a gradual increase (10-15eggs/day) on successive days and towards the end of oviposition period, the rate of oviposition showed a decrease. The mean number of eggs laid by the female during its lifetime was 44± 2 at 30± 2ºC & 70± 5%RH and was found decreased to 30±2.5 at 20±2ºC & 80± 5%RH.

Table 16 shows the longevity of male and female individuals of *T. urticae*. At 30± 2ºC & 70± 5%RH, the female longevity was found to be 12.5± 2.5 days whereas at 20±2ºC & 80± 5%RH, longevity showed an increase, recording 14.9± 3.5 days. The male showed a decrease in longevity, and it could be recorded as 8± 2.1 days under 30± 2ºC & 70± 5% RH whereas under 20±2ºC & 80± 5%RH, it was 9.5± 2.3 days (Fig. 86).

2) Hatching:

Towards the end of incubation period, the colour of the egg changed from white to pale yellow and became more turgid. The spherical nature was found transformed to oval and on the surface, a slit appeared which gradually extended in either directions to meet each other at the rear side. The larva emerged out of the egg case by the thrusting action of propodosoma and legs. Hatching process lasted for nearly 15-20 minutes. The remnants of the egg case and the faecal pellets of the various life stages were seen scattered along with eggs under the webs.

3) Duration of developmental stages:

a) Incubation period: The impact of varied temperature and humidity conditions was significant on the durations of the developmental stages of *T.urticae* also. At 30± 2ºC & 70± 5%RH, the eggs were hatched within 4.1±0.23 days while at 20±2ºC & 80± 5%RH, the eggs took 5.28± 2.1 days for hatching (Table 17 & Fig. 87).

b) Larval Period: The larva which hatched out of the eggs was white in colour with three pairs of legs and devoid of any segmentation. Shortly after hatching, the larva initiated sucking the plant sap by inserting its cheliceral stylet into the leaf and it appeared very active under the web. The duration of larval period was 1.9 ± 0.03 days and 2.56 ± 0.07 days under 30± 2ºC & 70± 5% RH and 20±2ºC & 80± 5%RH respectively (Table 17 & Fig. 87).

c) Protonymphal period: Subsequent to the larval period, the first inactive phase (quiescent period) was noted and which moulted to release the eight legged protonymph. Like the larval period, the protonymphal period was also found influenced by changes in temperature and humidity conditions. In the present study, the duration of protonymphal period was observed to be 2.1±0.08 days at 30± 2ºC & 70± 5%RH, but the same was slightly extended to 2.23± 0.06 days at 20±2ºC & 80± 5%RH (Table 17 & Fig. 87).

d) Deutonymphal Period: At the end of the active feeding period, the protonymph arrested its feeding activity, became lethargic and stretched its legs and entered into the second quiescent period. The end of the second quiescent phase ended in mouting, leading to the release of the deutonymph, the latter formed the largest among the juveniles. The deutonymph actively sucked the leaf sap by remaining under the silken strands of the web and the duration of its feeding period could be recorded as 2.4± 0.06 days under 30± 2ºC & 70± 5%RH. The deutonymphal period was slightly extended to 2.75± 0.08 days under 20±2ºC & 80± 5%RH (Table 17 & Fig. 87).

e) Quiescent Stages: As observed in all other tetranychid species studied, the life cycle of *T. urticae* also was found to comprise three quiescent stages viz. the Protochrysalis, Deutochrysalis and Teleiochrysalis. The protochrysalis was the quiescent stage between the larva and protonymph and the duration of which was recorded to be 0.9± 0.02 days at 30± 2ºC & 70± 5%RH and 0.9± 0.76 days at 20±2ºC & 80± 5%RH. The inactive stage which followed the active protonymphal stage was called deutochrysalis and this stage lasted for 0.46 ±2.34 days at 30± 2ºC & 70± 5%RH and 0.9± 0.83 days under 20±2ºC & 80± 5%RH. Teleiochrysalis was the third quiescent phase which was observed between the deutonymphal and adult stages. The teleiochrysalis stage was found to last for 0.42± 1.23 days under 30± 2ºC & 70± 5%RH and 0.75± 1.43 days under 20±2ºC & 80± 5% RH (Table 17 & Fig. 87).

f) Moulting:Shedding of the cuticle, the so called moulting was found to occur towards the end of protochrysalis, deutochrysalis and teleiochrysalis. During moulting, as in *S. schizopus*, a small slit was found developed almost at the middle of the cuticle, and subsequently got extended in either direction by the thrusting movement of the emerging instar inside, to meet each other so as to release the moulting individual. The moulting process required 6-9 min to complete. The moulting skin of the various instars along with the remnants of the egg cases were found scattered under the webs on the abaxial surface of the leaves.

g) Adults: Males were smaller than the females and could be easily distinguished from the female based on the narrow and wedge shape of its hysterosoma. The females were conspicuously greenish white in colour when compared to the males and the number of males was much lower than that of the females.

4) Mating:

As soon as the female deutonymph completed its quiescent phase and entered into the adult stage, the male initiated the mating process by crawling beneath the hysterosoma of the female. The male then bent its body in such a position that it could insert its aedeagus into the female genital aperture for copulation. The mating process lasted for 2-3 min. after completion of which the male moved away in search of a new virgin female.

5) Parthenogenetic Development:

Like all other tetranychids, *T. urticae* also showed both sexual as well as parthenogenetic modes of reproduction. The developmental pattern and features were similar under both modes of reproduction, but the duration and sex ratio showed much deviation. The male-female ratio was recorded to be 1:10 under the sexual mode of reproduction whereas the parthenogenetic offsprings were found to comprise entirely of male progeny (Table 18 & Fig. 88).

D. Morphological description of life stages of *Tetranychus urticae* C.L. Koch, 1836: (Plate 75, 76,77)

The genus *Tetranychus* is characterized by the presence of two pairs of anal setae and one pair of para anal setae, two pairs of duplex setae set well apart on tarsus I; aedeagus in males with both anterior and posterior angulations; empodium claw like with proximoventral hairs.

Egg:

Colour: Creamy colour

Diameter: 130-135

Spherical, smooth and transparent. Eye spots and small part of gnathosoma could also be seen through the egg case before a few hours of hatching.

Larva:

Colour: Pale Yellow

Measurements: Length: 210- 218

Width: 125- 140

Dorsal region: Body almost spherical and finely striated at various regions; rostrum conical and protruding anteriorly; short stylets projecting beyond rostral apex; peritreme hooked; three pairs of propodosomal and ten pairs of hysterosomal setae present; seta v_2 near the edge of anterior propodosoma; sc_1 longer than other setae.

Ventral: Genital area not distinct; two pairs of medioventral setae; two pairs of anal and two pairs of para anal setae; three pairs of legs present with six segment each, terminating in empodium .

Protonymph:

Colour: Pale Yellow

Measurements: Length : 350- 358

Width : 190- 205

Dorsal region: Body larger than that of the larva, and more yellowish in colour. Peritreme directed posteriorly; seta sv_2 moved slightly interiorad; seta sc_2 moved towards laterally; hysterosomal setae arranged more spaciously.

Ventral region:

Genital area not distinct; two pairs of medioventral setae present; two pairs of anal and two pairs of para anal setae, the latter longer than the anal setae; four pairs of legs present; ventral integument striated.

Deutonymph:

Colour: Yellowish green

Measurements: Length: 350- 360

Width: 190-200

Dorsal region: Body of the deutonymph larger than that of the protonymph; peritreme well developed; three pairs of propodosomal and ten pairs of hysterosomal setae; all smooth and spaciously arranged; striations of different pattern visible.

Ventral region: Ventral plate with three pairs of medio- ventral setae, all smooth and elongate; genital area distinct with one pair of smooth setae. Anal plates with two pairs of setae. Two pairs of para-anal setae also detected, all smooth and short.

Adult Female:

Colour: Yellowish Green

Measurements: Length : 360- 370

Width : 250-290

Dorsal region: Body oval and finely striated with gnathosoma protruded anteriorly. Peritreme hooked; All propodosomal and hysterosomal setae more elongate than that of the previous stage. Striae between setae e_1 and e_1 longitudinal and between e_1 and f_1 diamond shaped.

Ventral region: Genital area well developed; ventral striae devoid of lobes; pregenital striae entire; genital area distinct with one pair of setae. Three pairs of medio- ventral setae present, all smooth and elongate. Two pairs of anal and two pairs of para anal setae present.

Leg: Tarsus I with four tactile setae inserted proximal to the proximal duplex setae. Empodia with six proximoventral hairs and lack spurs.

Adult Male:

Colour : Yellowish Green

Measurements: Length : 340 – 360

Width : 240- 280

Adult male differs from the female in the following features: Body elongate; idiosoma slender and pointed posteriorly; empodia I-II bear dorsal spur, empodium I claw like, empodia II- IV with long and free proximoventral hairs; aedeagus with a small knob, axis of which parallel to the axis of the shaft, anterior and posterior angulations of the knob small and similar.

Bamboos represent a group of woody grass and is designated as the 'emperor' among the grasses. These plants are vulnerable to various disorders and diseases in plantations, nurseries as well as in natural stands. Nearly 170 species of bamboos under 26 genera are known to be affected by various disorders and diseases (Mohanan, 1997), of which the major attack is done by insect and mite pests (Mathew and Nair, 1988; Mathew and Varma, 1988; Tewari, 1988; Singh and Bhandari, 1988; Paduvil, 2008). During the present study, a total of 27 species of bamboos had been surveyed to explore the faunal diversity of mites. Mites belonging to 43 species under 34 genera, 14 families and 3 orders were collected from the bamboo plants during the study and *Schizotetranychus* of the family Tetranychidae and order Trombidiformes was found to be the most dominant genus on bamboos of Kerala. Under *Schizotetranychus*, the species *S. schizopus* was observed to cause the maximum degree of damage to bamboos by building up of colonies under the nests constructed of silk and sucking out the cell contents from the foliage. Therefore in the present study, attention was focused to gather information on the feeding and breeding attributes of the above species under specific temperature-humidity conditions.

Generally, plant mites which feed primarily on leaf surfaces, were found to occur more on the abaxial surface of leaves than the adaxial surface (Jeppson *et al.,* 1975). With the help of paired and partially fused cheliceral stylets, which constitute the feeding apparatus, these mites pierce the plant tissue and disrupt the mesophyll cells lying below the epidermis (Hislop and Jeppson, 1976). The feeding stylets of spider mites have been proved to reach up to the photosynthetically active mesophyll tissues of the leaves, damaging not only the injured individual cells but also the adjacent uninjured ones (Park and Lee, 2002). Species of *Schizotetranychus*, mostly preferred to feed near the midrib region of bamboo leaves, and thus would destroy the ability of host plants to transport nutrients and water between the leaf and the stem, resulting in the premature defoliation (Zhang *et al.,* 2001f). Spider mites are also known to release toxins along with their salivary secretions, and which are supposed to interfere with the host plant metabolism, in turn leading to reduction in fruits, seeds and fibers, as well as causing chlorosis, defoliation and simultaneously death of the host plant (Huffaker *et al.,* 1969).

In the present study, the spider mites were found to feed on the undersurface of bamboo leaves, leading to formation of small chlorotic spots at the feeding sites. This was in concordance with the earlier findings (Sivritepe *et al.,* 2009), that spider mite feeding would result in the collapse of mesophyll tissue, which in turn would impart a stippled –bleached effect, resulting in the yellowing and ultimately to the bronzing of leaves. Morphological injury at the feeding site was stamped by the presence of punctured and collapsed epidermal cells, disrupted cuticle, collapse or reduction in cells of spongy and palisade parenchyma, alterations to stomatal apparatus, loss of chloroplasts and the debris of cell wall which was pierced from the mesophyll cells (Blair, 1951; Avery and Briggs, 1968; Tanigoshi and Davis, 1978; Sances *et al.,* 1979, Mothes and Seitz, 1982; Bondada *et al.,* 1995 and Skaloudova *et al.,* 2006).

Physiological performance is considered as an index to determine the general health and vitality of plants. For a better understanding of the plant - arthropod interaction it is necessary to gather information on the alterations in the major physiological processes of plants such as photosynthesis, respiration etc. in response to arthropod feeding, as these constitute the crucial determinants to assess plant growth, fitness and development (Peterson and Higley, 1993). In the present study, assessment of mite-host interaction was done both qualitatively and quantitatively by recording visible symptoms of infestation, as well as analyzing the histological and biochemical alterations induced by the feeding activity of the most injurious species like *S. schizopus* on two species of bamboo hosts. The feeding activity of the species on *B. bambos* and *B. vulgaris*, was found to induce alterations in cell structure, extensive disruption of mesophyll cells, reduction in the chloroplasts of adjacent unpunctured cells, increased number of damaged cells, reduction in the number of cells etc. The punctured cells would lose their ability to participate further in the metabolic processes of host plants, and which in turn would adversely affect the health and vigor of the plant (Geijskes, 1938; Avery and Briggs, 1968).

Results of biochemical estimations revealed a significant decrease in photosynthetic pigments such as chlorophyll a, chlorophyll b, total chlorophyll and carotenoids in mite infested leaves of both species of bamboo hosts. The respective loss in photosynthetic pigments could be recorded as 75% for chlorophyll a, 85% for chlorophyll b, 78% for total chlorophyll and 48% for total carotenoids as observed in *B. bambos*. In *B. vulgaris, S. schizopus* induced 62 % loss in chlorophyll a, 70% loss in chlorophyll b, 62% loss in total chlorophyll and 46% loss in carotenoids. This observation confirms the potential of spider mites in impairing photosynthsis of host plants and thereby supporting the earlier reports on chlorophyll loss in okra leaves

(55%) induced by *T. macfarlanei* (Haq, 1997), *Eichhornia* crassipes (54%) by *T. ludeni* (Sumangala and Haq, 2000) and cucumber leaves (80%) by *T.urticae* (Park and Lee, 2002). The leaf chlorophyll content was reported to be decreased with an increase in mite population on various host plants (Iatrou *et al.,* 1995; Nachman and Zemek, 2002; Sangeetha and Ramani, 2007). However, the present finding on the significant loss in chlorophyll pigments seems to contradict the earlier observation which could not record any significant decrease due to feeding of *T. urticae* on strawberries (Sances *et al.,* 1979). The chlorophyll reduction would adversely affect the photosynthetic efficiency of the host plants and a close linkage was also established between the decrease in chlorophyll and reduced photosynthetic activity of mite infested plants (Sances *et al.,* 1979; Bondada *et al.,* 1995; Haile and Higley, 2003; Rilling and During, 1990). The decrease in chlorophyll content might be due to the mechanical injury to the chloroplast due to mite infestation and also due to the effect of reactive oxygen species mediated lipid peroxidation of chlorophyll pigments (Tomczyk and Kropczynska, 1985; Khattab, 2007). Previous studies also support these by recording a reduction in the rates of photosynthesis and transpiration as a primary response to spider mite infestation in many plants like grapevine, rose, cotton, strawberry and even in bamboos (Candolfi *et al.,* 1992; Zhang *et al.,* 1998c; Landeros *et al.,* 2004; Reddall *et al.,* 2004; Klamkowski *et al.,* 2006). Earlier studies on the gut contents of spider mites, also revealed the presence of thylakoid granules inside the digestive tract, suggesting their role in the destruction of the key photosynthetic engines of plant cells (Walsh, 2001).

Change in the value of Fv/Fm is a typical response in many plants against a wide range of environmental stresses, and which is indicative of the reduced photochemistry efficiency of photosystem II. Fluorescence emission represents a function of light harvesting and photoelectron transport (Macedo *et al.,* 2003). In bamboos infested by *S. schizopus*, a significant decrease in Fv/Fm was observed during the present study. A decrease of 30.10% was observed in Fv/Fm value of *B. bambos* and a decrease of 18.18% was observed in *B. vulgaris*. However, this result contradicts the earlier finding (Iatrou *et al.* 1995) which could not record any significant change in the value of Fv/Fm in bean leaves due to the feeding of spider mites, though the leaf chlorophyll content showed a decrease with increase in the number of mites.

A significant reduction in the water content of bamboos was also recorded during the present study owing to infestation by *S. schizopus*. The species was found to feed on the lower epidermis of bamboo leaves with its piercing and sucking mouthparts as recorded earlier (Zhang *et al.,* 1998b,c). A decrease of 11.85% in the leaf moisture content was observed in the leaves of *B. bambos* and in *B. vulgaris,* a decrease of 15.79% was noted. Generally, plants regulate their water loss with the help of stomata and when the stomata become closed, leaves become resistant to water loss. This regulatory mechanism would become disrupted by the feeding activity of spider mites, as these mites produce holes which allow water to escape from leaves and which in turn dehydrates the leaves, inducing heavy stress on plants. The stressed plants are more vulnerable to further attack by spider mites, resulting in chlorosis and bronzing of foliage and stunted growth. Feeding by spider mites was reported to result in an increase in the cuticular transpiration, leading to induction of day time water- stress (De Angelis *et al.,* 1982). The water deficiency in mite infested plants could be due to the big drain of water and nutrients from leaf tissue due to the filter feeding by spider mites (Walsh, 2001). The water stress induced by feeding of mites, might influence the chlorophyll metabolism of injured cells or due to cell disturbances and chloroplast removal as pointed out by earlier workers (Tomczyk and Kropzynska, 1985).

It is also well known that biotic stress could also lead to oxidative stress through overproduction of reactive oxygen species (Tomczyk, 2001; Mithofer *et al.,* 2004; Leitner *et al.,* 2005 and Khattab, 2007). These reactive oxygen species would disrupt normal metabolism by denaturing proteins and nucleic acids and peroxidating lipids, which in turn would cause degradation of structural components. Thus, reactive oxygen species induced peroxidation of lipid membrane is both a reflection and measure of stress induced cellular damage (Jain *et al.,* 2006).

The results of the present study thus indicated that infestation by *S. schizopus* induced significant changes in the biochemical components of both species of bamboos. Earlier studies also indicated that an increase or decrease in population density of spider mites are associated with the tissue quality of the host plant, which ultimately depends on the quantity and nature of both primary and secondary metabolites (Lege *et al.,* 1995; Van den Boom *et al.,* 2003).

The sap sucking mites also have been proved to control and modify the metabolic substances of the surrounding tissues also. This is supported in the current work also by recording significant variations in the total carbohydrate and total protein contents of bamboo leaves infested by *S. schizopus*. During the present study, 58.87% decrease in the total carbohydrate content was observed in the leaves of *B. bambos* owing to infestation by *S. schizopus*, following the Anthrone method. Similarly, a reduction of 54.04% could be recorded in the total carbohydrate content in *B. vulgaris*. These results seem to be in concordance with the earlier studies made on bamboo leaves infested by *S. nanjiensis* indicating a reduction of 57% sugar content (Zhang *et al.,* 1998b). Infestation by another species of spider mite, viz. *A. corpuzae*, also was reported to induce 67% reduction of total sugars in bamboo leaves (Zhang *et al.,* 1998a), thereby establishing that spider mite infestation could induce drastic changes in biochemical constituents of their host plants.

The total protein content of mite infested and unintested leaves of *B. bambos* and *B. vulgaris* when analysed through AOAC (1990), showed a respective decrease of 21.02% and 21.8%. This observation is in conformity with the finding made on bamboos infested with *S. nanjingensis* which showed a decrease in the concentrations of 18 amino acids (Zhang *et al.,* 1998a). *A. corpuzae* also induced similar variations in the physiological and biochemical parameters of *P. pubescens* (Zhang *et al.,* 1998c). Reduction in protein levels was also observed in fruit crops owing to infestation by false spider mites like *Tenuipalpus pernicis* which induced 5.56% decrease in total protein content in the leaves of guava plant (Ghoshal and Barman, 2012). Higher levels of protein depletion, reaching to 57.50% were reported in mulberry leaves infested by *E. suginamensis* (Nangia *et al.,* 1999). This is a clear indication that plant mites make use of nutritional resources available in their host plants, amino acids and sugars provide better nutritional conditions for their development and reproduction. On depletion of nutrient levels in infested leaves, the mites will immediately migrate to the adjacent fresh leaves of host plants, in search of nutrients (Crooker, 1985).

The phloem feeding mites are known to cause several biochemical variations including changes in minerals, organic and inorganic compounds in plants which in turn would lead to several morphological and physiological changes (Herbert and Butler, 1973; Shree and Nataraj, 1993). This is supported by the present work also, where a decrease in concentrations of nitrogen, phosphorus and magnesium was recorded, owing to spider mite infestation. A decrease of 21.03% was recorded in total nitrogen content in the mite infested leaves of *B. bambos* and the leaves of *B. vulgaris* showed a decrease of 21.84% in the total nitrogen content. This observation is in agreement with the earlier report (Farouk and Osman, 2012) which recorded a significant decrease in nitrogen, phosphorus and potassium in beans infested with the two spotted spider mite. A reduction in the nitrogen content would also occur in plants in stress conditions (Liu *et al.,* 2014) as observed in dwarf bamboos when exposed to drought, affecting the carbon and nitrogen metabolism. The reduction observed in the nitrogen and other minerals might be a reflection of the adverse effect of spider mite feeding through the uptake or drain of phloem sap (Wu *et al.,* 2004).

Results of the present study also revealed a decrease in the concentration of phosphorus owing to feeding of *S. schizopus* and the loss in phosphorus was recorded as 8.22% in *B. bamboos* and 18.52% in *B. vulgaris*. Similarly, a depletion of 3.55% was recorded for magnesium in the mite infested leaves of *B. bambos* while the loss was 3.17% in *B. vulgaris*. These results are in agreement with the studies on infestation by the tarsonemid mite, *Polyphagotarsonemus latus* (Ghoshal *et al*., 2005) by recording a loss of 8.33% in magnesium. Feeding activity of other spider mite species also was reported to induce depletion of magnesium content in the leaves of respective host plants (Golek, 1975; Sadana and Goyal, 1984; Sivritepe *et al.,* 2009).

Plants elicit a broad range of defense responses against pest invasion, which include generation of reactive oxygen species (Mur *et al.,* 2005) such as hydrogen peroxide, superoxide, singlet oxygen and hydroxyl radicals, and which could initiate destructive oxidative processes such as lipid peroxidation, chlorophyll bleaching, protein oxidation and damage to nucleic acids, ultimately leading to cell death (Lu and Finkel, 2008; Nasir Kham *et al.,* 2010). Production of phenolic compounds is an important component of such defense- related system in plants to counteract with the stress, as certain phenolics could precipitate plant proteins and make them indigestible to herbivores. The level of total phenol was also found to be high in some resistant varieties of plants (Gogoi *et al.,* 2001). Phenolics are considered to be the most widely distributed secondary plant products (Harborne, 1980) and a very rapid synthesis of phenolic compounds and their polymerization in the cell walls is often suggested as an important first line of defense response of plants against infection (Matern and Kneusel, 1988). The present study disclosed an increase in the level of total phenol in both *B. bambos* and *B. vulgaris* in response to infestation by *S. schizopus,* thereby indicating the stress undergone by these plants due to mite infestation. An increase of 22.86% and 33.18% in total phenol could be recorded in *B.bambos* and *B. vulgaris* respectively. These results are in support of the earlier studies made on *M. esculenta,* eucalyptus and castor, which also experienced a similar increase in the total phenolics due to pest attack (Ananthakrishnan *et al.,* 1992), thereby leading to the conclusion that an increase in phenolic content could impart resistance to plants against herbivory. Further supporting evidences are provided by various authors in different host plants like Conica leaves in which 50% reduction in photosynthetic rate was observed due to the infestation of *O. ununguis* (Puchalska, 2006), cassava which experienced an increase of 11.67% (Sangeetha and Ramani, 2011), guava which showed an increase of 4.09% (Ghoshal and Barman, 2012) due to infestation by spider mites. Accumulation of phenolic compounds in plant tissues is often considered as one of the causes of photosynthetic suppression (Puchalska, 2006).

Proline is another important component of defense- related compounds present in plants. During the present study, an increase of 69.05% was observed in the proline content of the leaves of *B. bambos* and an increase of 57.35%, was noted in the leaves of *B. vulgaris* up on infestation by *S. schizopus*. This observation further confirms the results on the feeding impact of *T. urticae* recorded in grapewine cultivars (Sivritepe *et al.,* 2009) and that of the carmine spider mite in tomato (Kielkiewiez, 2002). Proline has the ability to move between tissues, and thus believed to protect plants against stress by acting as storage component for both nitrogen and carbon sources, thereby protecting both cellular structure and cytoplasmic enzymes (Serrano and Gaxiola, 1994). Proline also plays additional roles in plants such as reactive oxygen species detoxification and stabilization of cell membranes (Kavir Kishor *et al.,* 2005).

To date, data on relationship between mite feeding and variations in mineral composition of bamboo tissues are scarce. The present study enabled to record significant increase in the concentrations of Calcium, Potassium, Zinc and Copper in the leaves of *B. bambos* and *B. vulgaris,* owing to feeding by *S. schizopus*. An increase of 18.87% was recorded in Potassium, 36.66% in Calcium, 48.76% in Copper and 19.62% in Zinc in the mite infested leaves of *B. bambos*. The leaves of *B. vulgaris* also displayed similar increase in the concentrations of Potassium (29.41%), Calcium (24.08%), Copper (25.62%) and Zinc (6.97%) and these results are in agreement with the increase in concentrations of K, Ca, Cu and Zn in grapevine infested by *T. urticae* (Sivritepe *et al.,* 2009). However, contradictory results recording a decrease in Zinc concentration due to mite feeding on respective host plants also exist (Chatterjee & Gupta, 1997; Das, 1987).

The accumulated inorganic ions might be contributing to the osmotic adjustments in the leaves due to the spider mite induced water stress as suggested by several authors (Patakas *et al.,* 2002; Sivritepe *et al.,* 2009). As a self- defense mechanism against herbivory, plants are known to absorb high concentrations of metals such as Copper and Zinc from the soil (Poschenrieder *et al.,* 2006). The maintenance of adequate potassium levels in plants is necessary as it help in controlling water balance. The decrease in the concentration of potassium in plants due to herbivory, results in the water stress induced stomatal closure via ethylene synthesis and thus act as a self defence mechanism of plants against excessive water loss (Wang *et al.,* 2013).

Mite feeding also induced a decrease in the concentrations of Iron, Sulphur, Manganese and Boron in the leaves of bamboos. When the leaves of *B. bambos* were subjected to these mineral analyses, the percent decrease was 1.54% in Sulphur, 11.46% in Iron, 13.64% in Manganese and 30.09% in Boron. In the leaves of *B. vulgaris*, the decrease was 14.8% in Sulphur, 21.73% in Iron, 10.46% in Manganese and 26.33% in Boron. This observation supports the results of studies made on *Luffa acutangula* infested by *T. ludeni* (Chaterjee and Gupta, 1997) which recorded a depletion of 66.4% in iron. Feeding by false spider mites like *Dolichotetranychus floridanus* also was reported to cause a decrease in the concentration of iron by 42.9% in pineapple (Das, 1987). Further support was made through the detection of 8.66% reduction in iron content in jute leaves infested by *P. latus* (Ghoshal *et al.,* 2005) and10.15% reduction in iron in guava leaves (Ghoshal *et al.,* 2011) due to feeding by *T. pernicis*. The present finding seems to contradict earlier results (Sivritepe *et al.,* 2009) which showed an increase in the concentration of Manganese in one of the grapevine cultivars in response to infestation by *T. urticae*.

Detailed biological observations made on *S. schizopus* clearly indicated the parasocial behavior of the species in which multiple females very actively took part in webbing the nest prior to initiation of oviposition. Co-ordinated nest cleaning activity was also observed among the females of the species. The members of the colony laid faecal pellets on the inner margin of the nest and all individuals maintained this regulated defecation habit, in accordance with the earlier reports (Kanazawa *et al.,* 2011). The presence of a communal toilet was also under report for each colony of *Schizotetranychus* (Sato *et al.,* 2003). Up on increase in population density, the toilets appeared as regularly spaced dark spots on the underside of leaves. Possession of these behavioural traits in the species, despite of their small size, was a solid evidence of sociality, as met with in other arthropod relatives like the termites, ants and bees (Saito, 1995a).

In *S. schizopus,* one to several fertilized females were found to construct a new web/nest and reproduced under it for a long period. Subsequent to reproduction and development of immatures, the females enlarged their nest. Some individuals seldom left their nests, while all others remained in the nest for the rest of their life time (Saito, 1987; Saito and Takahashi, 1982). The large united nests of *Schizotetranychus* would permit the mites to live for a long duration with their kin, sharing substantial amount of resources and also to impart them a mark of defence (Saito, 1986b). The present study also helped to note that the females of *S.schizopus* were taking care of their young ones living underneath the nest alone and those which were outside the nest were never attended. This observation strongly supports the earlier findings (Mori *et. al.* 1999), thereby enabling to conclude that nests would serve as an effective shelter for these mites to survive for several generations.

Females of *S. schizopus* were found to defend their nests successfully. In accordance with the earlier findings, the adult females of the species defended very effectively when the webs were well developed and there were many males and females inside the nests (Mori *et al.,* 1999). The females and males of the species were found to counterattack their predators when they intruded into the nests to prey up on their offsprings. Quite often, the predatory larvae and nymphs were found killed by the adult males and females of the species and sometimes the predators were driven away by these mites from their nests (Saito 1986 a, b). The counter attack was more successful towards the immature stages of the predators as observed earlier (Saito 1986a).

The dense, mature nests constructed by the mites would reduce the risk of nest entries by generalist predatory mites. Despite the colony protection afforded by the nests, the individuals of *S. schizopus* were found prone to the threat of predation from specialized predators which could easily intrude the webs through the small holes/openings, without breaking the webs further, and this observation seems to support the findings of others (Saito, 1986b; Mori *et al.,* 1999). The specialized predators of *Schizotetranychus*, could easily locate their faecal pellets laid near the web openings and thereby orienting them towards the nests. Among the predatory mites, the phytoseiid and stigmaeid members were proved to be non- visual hunters which relied solely on chemical and tactile cues (Sabelis and Dicke, 1985; Sabelis and Van de Baan, 1983; Walter and Proctor, 1999). Thus, webbing as well as the faecal matter of prey mites would serve as cues,which help the specialist predators to locate the webs of *Schizotetranychus* (Sabelis *et al.,* 1984). *T. bambusae* was considered as one such specialist predator of *S. longus* (Takahashi, 1987; Saito, 1990b; Chittenden and Saito, 2001; Horita *et al.,* 2004) and *A. orientalis* was designated as a specific predator of *A. corpuzae* (Chittenden, 2002).

Results of developmental studies carried out on the two dominant and injurious species of pest mites on bamboos viz. *S. schizopus* and *T. urticae* enabled to record a uniform developmental pattern in both the species. The life stages were found to comprise the egg, larva, protonymph, deutonymph and adult stages and each of the active instar was followed by an inactive (quiescent) phase which culminated in the moulting process. Like other tetranychid mites, both the species preferred to oviposit on the abaxial surface of bamboo leaves. Resembling majority of spider mites, the females of *S. schizopus* first constructed the web near the midrib or leaf edges, and preferred to lay eggs under these webs. This midrib preference for oviposition among the females of the species is in agreement with findings of earlier workers (Banu and Channabasavanna, 1972; Barrion and Corpuz-Raros, 1975; Sangeetha and Ramani, 2007).

T. urticae enjoys a wide range of host plants including herbaceous plants, vegetables, ornamentals and woody landscape plants and found to feed on more than 1200 plant species (Dermauw *et al.,* 2013), The species was found to infest bamboos during the present study. The females of *T. urticae* laid eggs under the sparse webs and showed no specific preference for oviposition. Instead, the eggs were laid in a very random fashion, scattered all over the leaf lamina. Laying eggs near the midrib region of leaves on the abaxial surface, ensures better protection to eggs from desiccation and washing effect of rain, thereby enhancing the survival rate (Sobha and Haq, 1999; Sangeetha and Ramani, 2007). Sparse webbing probably would serve protection to eggs and nymphal stages, and which might be the possible reason for randomized deposition of eggs (Banu and Channabasavanna, 1972).

The morphological features like the shape, colour and size of eggs as well as the pattern of oviposition in the species observed during the present study were more or less in agreement with the reports of several workers on various tetranychid species (Saito & Ueno, 1979; Gotoh, 1983; Sejalia *et al.,* 1993; Singh and Singh, 1993; Zhang *et al.,* 2001b,d; Kasap, 2004; Rajkumar *et al.,* 2005). In both *S. schizopus* and *T. urticae*, early emergence of males could be observed. These males were then found waiting near the quiescent female deutonymphs for their emergence. As soon as the adult females emerged, the male crawled beneath the female hysterosoma and bent its posterior tip of hysterosoma in a characteristic position, so as to initiate copulation. The mating process was found to last for 2-3 minutes and soon after completion of mating, the male moved away from the female.

The mated female was found to produce progeny of both sexes whereas unmated female always gave rise to male progenies alone as observed during the present study. Almost similar sexual modes and mating behavior were reported in *T. macfarlanei* (Sejalia *et al.,* 1993) and *T. urticae* on carnation plants under laboratory conditions (Patil *et al.,* 2014). These observations are also in concordance with the earlier findings on *T. urticae* (Penman and Cone1972), *T. evansi* (Qureshi *et al.,* 1969), *P. citri* (Beavers and Hampton, 1971) and *E. orientalis* (Banu and Channabasavanna, 1972). This type of mediation of males towards female deutonymphs was attributed to be due to the release of sex pheromones (Cone *et al.,* 1971; Hazan *et al.,* 1973). It was also reported that the males preferred virgin females who were more active (Banu and Channabasavanna, 1972; Nandagopal and Gedia, 1995; Sangeetha and Ramani, 2007).

Female- biased sex ratio could be recorded in both *S. schizopus* (1:9) and *T. urticae* (1:10) during the present study thereby supporting the earlier findings (Wilson, 1971; Saito, 1986a). However, a higher sex ratio (3:16) was reported in another species of the genus *Schizotetranychus* viz. *S. celarius* (Saito and Ueno, 1979). Similarly, *T. urticae* was also recorded to have higher sex ratio (1: 25) when the breeding biology was performed on carnation plants (Patil *et al.,* 2014). This suggests that variations in host plants exert a great impact on the breeding and sex ratio of pest mites. The presence of male – haploidy and female- biased sex ratio are common in tetranychid mites and these traits could be regarded as some of the intrinsic factors which can be related to the subsocial life of these mites.

The impact of temperature and relative humidity on the development and reproduction of tetranychid mites has been well proved through previous studies (Das and Das, 1967; Puttaswamy and Channabasavanna, 1980; Boyne and Hain, 1983; Pande and Sharma, 1986; Bonato *et al.,* 1990; Saito, 1990b; Bonato *et al.,* 1995; Bounfour and Tanigoshi, 2001; Zhang *et al.,* 2001 a,b; Kasap, 2003; Sakunwarin *et al.,* 2003; Kasap, 2004; Sangitha and Bhardwaj, 2004; Ghoshal *et al.,* 2006; Sangeetha and Ramani, 2008). In the present study, the development of *S. schizopus* and *T. urticae* was studied on the fresh leaves of *B. bambos* under two different temperature and humidity conditions viz. 20 ± 2ºC and 80 ± 5% RH & 30 ± 2ºC and 70 ± 5% RH. The results of the study showed that the duration of pre- oviposition period of *S. schizopus* under 30± 2ºC & 70± 5%RH was 1.9± 0.02 days and under 20±2ºC & 80± 5%RH was 2.1± 0.03 days. The duration of pre- oviposition period showed a decrease with an increase in temperature and decrease in relative humidity. Similar results were obtained in *T. urticae* also during the present study by recording the pre-oviposition period as 0.5± 0.01 days and 1.2 ± 0.19 days at 30± 2ºC & 70± 5%RH and 20±2ºC & 80± 5%RH respectively. A similar duration of pre-oviposition period was recorded in *S. schizopus* (1.027± 0.061days) under the temperature and humidity conditions of 25± 1ºC and 50-60% RH (Gotoh, 1983). However, in another species of the genus *Schizotetranychus* viz. *S. tenuinidus* which showed foliar infestation of moso bamboos, the pre-oviposition period was reported to be significantly extended to 4.6± 1.1 days under the same temperature of 24-26ºC (Zhang *et al.,* 2001b).

Reports from other workers on the developmental durations of tetranychid mites also would substantiate those of the present results (Puttaswamy and Channabasavanna, 1982; Mallik and Channabasavanna, 1983; Ghoshal *et al.,* 2006; Sangeetha and Ramani, 2007). The present results further confirm the results of developmental studies carried out on five species of spider mites infesting dwarf bamboos (Gotoh and Shida, 2007), which recorded a decrease in development time in accordance with an increase of temperature from 15 to 28ºC.

The oviposition and post- oviposition period in *S. schizopus* could be recorded as 9 ±0.47 days and 1±0.3 days respectively under the temperature and humidity conditions of 30± 2ºC & 70± 5%RH, as revealed through the present study. As the temperature and humidity conditions changed to 20±2ºC & 80± 5%RH, the duration of oviposition and post- oviposition periods also showed variation as 10.25± 0.5 days and 1.1± 0.4 days respectively. This observation seems to support the results of studies conducted in the same species, *S. schizopus* on another host, *Salix subfragilis* which enabled to record an oviposition period of 11.346± 0.879 days at 25± 1ºC and 50-60% RH (Gotoh, 1983). Other species of the genus *Schizotetranychus* also exhibited a similar trend when cultured on bamboo leaves. The respective oviposition and post- oviposition periods of *S. bambusae* were recorded as 16.0± 1.9 days and 1.0± 0.2 days under the laboratory conditions of 24- 26ºC (Zhang *et al.,* 2001d) and in *S. tenuinidus* the oviposition period was higher, accounting 19.9± 6 days at a temperature of 24-26ºC (Zhang *et al.,* 2001b). The post- oviposition period of *S. tenuinidus* also was slightly extended to 1.5± 1.9 days under the same temperature.

During the present study, the mean duration of oviposition period of *T.urticae* was registered as 8.3± 0.48 days under 30± 2ºC & 70± 5%RH, it got extended to 10.25± 0.42 days at 20±2ºC & 80± 5%RH. The post- oviposition period of the species was on an average 0.53± 0.17 days and 1.1± 0.32 days respectively under 30± 2ºC & 70± 5%RH and 20±2ºC & 80± 5%RH. Being a highly polyphagous species with very wide host range, the biology of *T. urticae* varied depending upon the variations in the host parameters such as the type of host plant, leaf age, plant nutrition, moisture stress etc. (Naher *et al.,*2008). *T. urticae* is known to be a typical warm weather species of spider mites and it completes its development from egg to adult in 7-8 days at 27.5 – 32.5ºC whereas the development gets slowed down, taking almost 4 weeks to complete, when the temperature is minimum (Helle and Sabelis, 1985). An oviposition period of 9.28 days was reported for the species at 30.46ºC (Naher *et. al*., 2008), thereby confirming the present result. However, oviposition period of the species was recorded to be much higher (18.75 days) at a lower temperature of 25-23ºC, and this is contradictory to the present observation. However, the present as well as earlier studies have very clearly established the significant effect of temperature and relative humidity on the durations of individual stages as well as total duration of development of *T. urticae*.

Longevity of adult mites was also found influenced by variations in temperature, humidity, mating as well as phenology of host plants. In *S. schizopus* , the longevity was recorded to be 12.5± 1.6 days for females and 8.5± 1.5days for males at 30± 2ºC & 70± 5%RH. When the temperature and humidity conditions were lowered to 20±2ºC & 80± 5%RH, the longevity was found increased by 13.5± 2.3 days for females and 10.2± 0.5 days in males. Earlier studies revealed a mean longevity of 13.308± 0.800 days for *S. schizopus* at 25± 1ºC and 50-60%RH (Gotoh, 1983), thereby helping to establish a negative influence of higher temperature on the longevity of mites (Puttaswamy and

Reddy, 1980; Puttaswamy and Channabasavanna, 1981b; Manjunatha and Puttaswamy, 1989; Ghoshal *et al.,* 2006). A higher longevity of 24.8±6 days was recorded for the females of *S. tenuinidus* at 24-26ºC, while feeding on moso bamboos (Zhang *et al.,* 2001). Similarly, the life span of *S. bambusae* also was high, reaching 19.1± 2.4 days while feeding on young leaves of moso bamboos at 24-26ºC (Zhang *et al.,* 2001c).

The longevity of the female of *T. urticae* was found to be 12.5± 2.5 days and 14.9± 3.5 days at 30± 2ºC & 70± 5%RH and 20±2ºC & 80± 5%RH respectively. The life span of the male longevity was comparatively shorter, averaging to 8± 2.1 days at 30± 2ºC & 70± 5% RH and 9.5± 2.3 days at 20±2ºC & 80± 5%RH. These results would serve to confirm the earlier data on longevity of the species (Kaur and Zalom, 2017) at three different temperatures (15ºC, 20ºC and 25ºC) on strawberries. The longevity was recorded as 8.50 days at 15ºC, 13.60 days at 20ºC and 11.40 days at 25ºC, thereby confirming that temperature has an essential role in determining the life span of phytophagous mites.

The mean fecundity in *S. schizopus* was observed to be 40± 2.5 at 30±2ºC & 70± 5%RH while it was reduced to 34± 2.5 at 20± 2ºC & 80± 5%RH, when the species was fed on bamboo leaves. Thus, a decrease in fecundity was evident during the prevalence of higher humidity and lower temperature as recorded in several species earlier (Nandagopal and Gedia, 1995; Biswas *et al.,* 2004; Sangeetha and Ramani, 2008). Similar results were gathered on *S. schizopus* earlier (Gotoh, 1983) on the leaves of *S. subfragilis* also by recording a fecundity of 39.269± 3.954 under 25±1ºC and 50-60% RH. Other species of the genus viz. *S. bambusae* also disclosed similar rate of fecundity of 45.2± 4.9 at 24-26ºC while feeding on young leaves of moso bamboos (Zhang *et al.,* 2001c). However, species like *S. tenuinidus* presented a contradictory result, by disclosing a lowered fecundity of 21.8± 8.1 at 24-26ºC when it was fed on moso bamboos (Zhang *et al.,* 2001b). This observation also helps to make the conclusion that fecundity of the species, though seems to be dependent on temperature, various other regulatory factors also play their own roles.

In *T. urticae*, the mean rate of egg production was recorded to be 44± 2 at 30±2ºC & 70± 5%RH and 30± 2.5 at 20±2ºC & 80± 5%RH. The same species was reported to have a higher fecundity of 49.15 when fed on strawberries at 25ºC (Kaur and Zalom, 2017) whereas it got decreased to 39.70 and 11.80 at 20ºC and 15ºC respectively.

Prevalence of these types of development rate among adult females of plant mites is more or less in conformation with the earlier reports (Sejalia *et al.,*1993; Kasap, 2004; Rajkumar *et al.,* 2005; Sekhar *et al.,* 2008).

During the present study, an attempt was also made to trace the durations of the various life stages of *S. schizopus* and *T. urticae* under combinations of different temperature and humidity conditions. At 30±2ºC & 70± 5%RH, the incubation period was nearly 4.3± 0.04 days, while it showed an increase to 6 ±0.03 days at 20±2ºC & 80± 5%RH, thereby recording the positive impact of temperature in promoting development by reducing the incubation period. This seems to support the findings made on *S. schizopus* by rearing it on *S. subfragils* (Gotoh, 1983) where the incubation period of the species was extended to 5.595± 0.125 days under 25± 1ºC and 50-60% RH. The incubation period of *S. bambusae* was not found much affected by variations in temperature (Zhang *et al.,* 2001d), as its incubation period was 2.3 ± 0.9 days at 24-26ºC and 2.2 ± 0.7 days at 28- 30ºC. Other species like *S. celarius* infesting dwarf bamboos displayed an incubation period of 6.27± 0.12 days at 25± 1ºC, 50-60%RH and 15L-9D (Saito and Ueno, 1979).

In *T. urticae*, the incubation period was observed to be 4.1± 0.23 days at 30±2ºC & 70± 5%RH and 5.28± 2.1 days at 20±2ºC & 80± 5%RH conditions, thereby clearly indicating that low temperature will slow down the developmental process by extending the duration of life stages. The same species was reported to have an incubation period of 2.2± 0.84 days at 28± 2ºC and 75± 2%RH (Amala *et al.,* 2016), while feeding on grape wines. On carnation plant, the incubation period of the species was 3.36± 0.56 under 27.79± 4.40ºC and 79± 5.75% RH (Patil *et al.,* 2014) and on okra plants the incubation period of the species was 2.92± 0.003 days under the 30± 3ºC and 61.5± 7%RH (Krishna and Bhaskar,2014). This is clear indication that apart from variations in temperature-humidity conditions, host plant variation also exert tremendous impact on duration of life stages of spider mites.

The duration of larval stage of *S. schizopus* was found to be 1.6± 0.02 days under 30±2ºC & 70± 5%RH and 1.8± 0.05 days under 20±2ºC & 80± 5%RH conditions. Similar results were also obtained in *T. urticae* also, in which the larval duration was 1.9± 0.03 days under 30±2ºC & 70± 5%RH and 2.56± 0.07 days under 20±2ºC & 80± 5%RH. These results seem to confirm the earlier reports on *S. schizopus*, by recording the duration of larval stage as 0.973± 0.027 days (Gotoh, 1983) on the host plant, *S. subfragilis*. The present results also support the observations made on another species dwelling on moso bamboos viz. *S. bambusae* (Zhang *et al.,* 2001c), the larva of which lasted for 1.2± 0.4 days at 24- 26ºC and 1± 0.2 days under 28- 30ºC. More prolonged duration of larval stage was observed in *S. celarius* inhabiting the dwarf bamboos (Saito and Ueno, 1979) in which the larval stage took 2.64± 0.08 days. The present results on the larval duration in *T. urticae* provide confirmation of the earlier findings made on the species on different host plants and different temperature-humidity combinations, by recording 1.19± 0.25 days of larval stage on okra at 27.79± 4.40ºC and 79± 5.75% RH (Krishna & Bhaskar, 2014), 2.79± 0.53 days for larva on carnation plants at 27.79± 4.40ºC and 79± 5.75% RH (Patil *et al.,* 2014), and a higher duration of larval stage 3.4± 0.89 days on grapevine under 28± 2ºC and 75± 2% RH (Amala *et al.,* 2016).

The durations of the nymphal stages in both *S. schizopus* and *T. urticae* were also found influenced by variations in temperature and humidity as observed during the present study. The protonymphal and deutonymphal period for *S. schizopus* was observed to be 1.5± 0.07 days and 1.5 ± 0.03 days under the laboratory conditions of 30±2ºC & 70± 5%RH these were 1.6± 0.03 days and 1.6± 0.04 days respectively for protonymphal and deutonymphal stages under 20±2ºC & 80± 5%RH. When compared with the earlier works, a higher protonymphal period of 2.23±0.1 days and deutonymphal period of 2.91± 0.09 days was observed (Saito and Ueno, 1979) in *S. celarius* on moso bamboos at 25± 1ºC, 50-60% RH and 15L-9D. Results of the present study also agree with the findings on *S. bambusae* (Zhang *et al.,* 2001c) which recorded a protonymphal period of 1.1± 0.4 days and deutonymphal period of 1.1± 0.5 days at 24- 26ºC and a nearly similar durations for the protonymph (1.0± 0.4days) and deutonymph (1±0.2days) at 28- 30ºC. However, contradictory results also were in report (Gotoh, 1983) in *S. schizopus,* where a shorter protonymphal period (0.657± 0.081 days) and deutonymphal period (0.657± 0.091 days) was observed.

The protonymphal and deutonymphal durations of *T. urticae* could be recorded as 2.1± 0.08 days and 2.4± 0.06 days respectively under laboratory conditions of 30±2ºC & 70± 5%RH. Similarly, under lowered temperature-humidity conditions of 20±2ºC & 80± 5%RH, the proto and deutonymphal durations were 2.23± 0.06 days and 2.75± 0.08 days respectively. These results were in confirmation with the earlier observation made on the species on the host, grapevine (Amala *et al.,* 2016) which revealed the durations of protonymphal and deutonymphal periods as 2.6± 0.89 and 2.4± 0.89 days respectively. However, lowered durations were recorded for the protonymphal (0.58± 0.05 days) and deutonymphal periods (1.05± 0.05 days) in the species, *T. urticae* infesting okra (Krishna and Bhaskar, 2014) under the temperature and humidity conditions of 30 ±3^{o}C and 61.5± 7% RH. The results of the present study seem to contradict the above findings on the species.

The presence of male deutonymphal stage could be noted in the present study during the development of *S. schizopus*. This observation is in contrast to several other species of the genus *Schizotetranychus* like *S. nanjingensis* (Zhang *et al.,* 1999c), *S. bambusae* (Zhang *et al.,* 2001c) and *S. tenuinidus* (Zhang *et al.,* 2001b). However, the study seems to support the earlier findings made on species like *S. bambusae* (Sun *et al.,* 1997; Lin *et al.,* 2000) and *S. schizopus* (Gotoh, 1983) by recording the presence of both the male and female deutonymphal stages during the course of development of these species.

Resembling the other tetranychid species studied, inactive/ quiescent stages were found intervened between the active stages in both the species, *S. schizopus* and *T. urticae*. Three such inactive stages viz. protochrysalis, deutochrysalis and teleiochrysalis were found for both *S. schizopus* and *T. urticae* and the durations of which showed variation with respect to temperature –humidity conditions. The present study revealed that the duration of protochrysalis was 0.3± 0.06 days, that of deutochrysalis was 0.4± 0.02 days and that of teleiochrysalis was 1± 0.02 days in *S. schizopus* under 30± 2^{o}C and 70± 5% RH. In *T. urticae*, the durations of protochrysalis, deutochrysalis and teleiochrysalis were 0.9± 0.02, 0.46± 2.34 and 0.42±1.23 days respectively under 30± 2^{o}C and 70± 5% conditions. In the lowered temperature and humidity conditions of 20± 2^{o}C and 80 ±5% RH, the protochrysalis, deutochrysalis and teleiochrysalis of *S. schizopus* were found to be 0.8± 0.03, 0.8± 0.02 and 1.1± 0.06 days respectively whereas the protochrysalis, deutochrysalis and teleiochrysalis of *T. urticae* under the lowered temperature-humidity conditions were 0.9± 0.76, 0.9± 0.83 and 0.75± 1.43 days respectively. The above results thus indicated a higher duration for quiescent stages in both the species under lowered temperature condition, thereby confirming the influence of temperature on the developmental stages of these mites.

The results of the present study supports the earlier findings made on another species of the genus *Schizotetranychus*, such as *S. bambusae* (Zhang *et al.,* 2001c) in which quiescent stages were of longer duration under low temperature conditions, when the biology was studied on *P. pubescens*. The respective durations of protochrysalis, deutochrysalis and teleiochrysalis were recorded as 1.2± 0.6, 1.1± 0.4 and 1.1± 0.4 days under 24-26ºC and when the temperature was increased to 28- 30ºC, the respective durations were reduced to 1.0± 0.3, 0.9± 0.2 and 0.9± 0.2 days, thereby recording the positive impact of temperature in reducing the durations of quiescent phases. This observation also supports the findings on another species, *S. schizopus* infesting on *S. subfragilis* (Gotoh, 1983) in which the respective durations were 0.622±0.081, 0.575± 0.082 and 0.919± 0.045 days for protochrysalis, deutochrysalis and teleiochrysalis at 25± 1ºC and 50-60%RH. Similar influence of temperature could be recorded on the quiescent stages of *T. urticae* also and the present results thus support the earlier reports of Riahi *et al.,* (2013), who studied the impact of seven different temperatures on the biology of *T. urticae* on the leaves of peach. A lower temperature of 13ºC did not support any hatching success while the quiescent stages showed varied durations based on variations in the higher temperatures and 33ºC induced nymphal mortality also.

Parthenogenesis, a natural form of asexual reproduction, was reported by several authors in mites. In several families of acarines, arrhenotokous parthenogenesis has been reported as the major mode of reproduction, in which haploid males are produced from unfertilized eggs whereas fertilized eggs give rise to diploid females (Oliver, 1971). The arrhenotokous mode of reproduction has been reported in several species of spider mites (Schrader,1923; Helle and Bolland, 1967; Nandagopal and Gedia ,1995). *S. schizopus* and *T. urticae* were reported as arrhenotokous species with chromosome number n=3; 2n= 6 (Helle *et al.,* 1970). During the present study, eggs laid by virgin females were developed in to males only whereas mated females of both species deposited eggs which developed into both males and females. Mated females laid more number of eggs when compared to the unmated females. This higher fecundity of mated females seems to support the findings of Rajkumar *et al.,* (2005), thereby confirming the prevalence of arrhenotoky in both *S. schizopus* and *T. urticae*.

Results of biological studies also disclosed a progressive decrease in the duration of active stages (larva, protonymph, deutonymph and adult) in both species. Results of morphological studies revealed the variations in the number and position of hysterosomal setae in different developmental stages of both the species. A progressive increase was observed in the body size and number of body setae during development from larval to deutonymphal stage. In both species, the larva was found devoid of pre-genital and post-genital setae and possessed two pairs of medioventral setae, though genital area made its appearance during this stage. Only in the deutonymphal stage, the complete dorsal setae could be observed. These results indicated a progressive trend in the formation of morphological traits during the developmental process in mites and would further support the significance of chaetotaxy in the recognition of developmental stages of mites.

Results of the present study also disclosed the positive impact of higher temperature and relative humidity (30±2ºC & 70± 5%RH) on both species. This combination of temperature and humidity conditions resembles the field conditions prevailing during summer months, which might be the possible reason for the high population density of these species in the field, as observed during the present study. Thus, the results of the study very clearly indicated the impact of climatic factors, mainly the temperature, relative humidity as well as rainfall on the population density of bamboo mites, thereby enabling to conclude that temperature and relative humidity of the study sites during summer season would serve ideal condition for the survival of these mites on the bamboos of Kerala.

SUMMARY

Bamboos represent a highly significant group of economic crops with tremendous use in more than 1500 ways globally, especially among the people of Asian countries. Like all other plants, bamboos are also prone to the attack of a variety of pests, mainly the arthropods. Among the bamboo dwelling arthropods, insects and mites constitute the major biodiversity component, serving a variety of crucial roles. However, despite the increasing commercial and economic utility of bamboos, and the increasing instances of pest invasion, very little information is available on bamboo mites and no attempts have been made neither in Kerala nor in India, especially the South India to explore the rich diversity of mites associated with bamboos and to trace their probable roles on this arboreal ecosystem. Considering the lacuna of knowledge on bamboo mites in India, especially in Kerala the present study was undertaken with an intention to unravel the faunal diversity of mites, study the impact of seasonal and geographical variations in their distribution pattern, nature and extent of damage induced by the most dominant and injurious species, analyse the qualitative and quantitative impact of feeding by the injurious species on respective bamboo hosts, to trace the developmental parameters and life history pattern of the injurious species with respect to varied temperature - humidity conditions etc. The study forms the first of its kind to present data on the morphological features of the various species of bamboo mites, their systematic position, population fluctuations and biological parameters of the selected most injurious species.

During the present study, 27 species of bamboos under nine genera were surveyed from 18 localities distributed over five districts of Kerala namely, Kannur, Wayanad, Kozhikode, Malappuram and Thrissur for a period of November 2012 to 2017. Samples of bamboo foliage were collected and examined under a steromicroscope to locate the associated mite species and the specimens collected were preserved in 70% alcohol, mounted in Hoyer's medium and identified following identification keys and relevant literature. Data on population density and habitat preference etc. of individual species were recorded. Highly sclerotized specimens like the members of Oribatida were cleared in a clearing medium prepared by mixing equal volumes of ethyl alcohol and lactic acid and mounted in Hoyer's medium for subsequent identification. Drawings of the morphological features of individual species were made using a prism type Camera Lucida attached to a research microscope and measurements of the specimens were taken using ocular and stage micrometers. Systematic position of the various species was analysed following Krantz and Walter (2009) and Subías (2004, updated in February, 2017).

Fluctuations in the population density of the selected most injurious species viz. *Schizotetranychus schizopus* with respect to three seasonal factors like temperature, relative humidity and rainfall were studied for a period of one year from November 2012 to October 2013. Results of population studies were correlated with the data procured on seasonal parameters from the nearest meteorological station at Karipur, Malappuram Dt. of Kerala to comfirm the exact nature of their impact on mite density. Studies on the feeding impact of *S. schizopus* on two species of bamboo hosts were also made by adopting qualitative and quantitative measures to assess variations in photosynthetic pigments, photosynthetic efficiency, anatomical features, biochemical parameters like total phenol, total carbohydrate, total protein, total nitrogen, proline, and other macro and micronutrients in mite infested as well as uninfested leaves of bamboo hosts. Variations in the leaf moisture content due to mite infestation were also analysed. Studies on the developmental parameters of two selected species of pest mites viz. *S. schizopus* and *Tetranychus urticae* were also made under two combinations of temperature-humidity parameters like 30± 2ºC & 70± 5%RH and 20±2ºC & 80± 5% RH. Salient features of the various life stages of the above two species were described along with appropriate drawings and photographs.

Results of taxonomic analysis of the bamboo mites collected during the study enabled to identify 43 species under 34 genera, 18 families, 14 superfamilies, 3 suborders and 3 orders coming under the two superorders, Parasitiformes and Acariformes of the subclass Acari. Of the three orders recognized, representatives of two orders viz. Trombidiformes and Sarcoptiformes were recovered during the study under the superorder Parasitiformes while members of only one order viz. Mesostigmata could be collected under the superformer Acariformes. The results of faunal diversity studies disclosed that order Trombidiformes was the dominant group of mites on bamboos by recording the presence of 21 species out of the total 43 identified from bamboo hosts. The 21 species of Trombidiformes could be categorized under 19 genera and 9 families. Most of these mites showed a general preference to inhabit on the lower surface of bamboo leaves and when their population increased rapidly, extended their distribution to the upper leaf lamina also. The important families of mites recovered under

Trombidiformes were Tetranychidae, Tarsonemidae, Eriophyidae, Cheyletidae, Tydeidae, Cunaxidae, Stigmaeidae, Eupodidae and Bdellidae. The most dominant injurious species collected under this group were members of the phytophagous family Tetranychidae, under the genus *Schizotetranychus*.

The second large acarine order recovered from bamboos was Mesostigmata which included 13 species under 7 genera and 2 families. The mesostigmatid mites were mainly predatory, without making any damage to the bamboo hosts. The family Phytoseiidae was recognized as the dominant taxon under Mesostigmata comprising 12 species under 6 genera. Another predatory family recorded from bamboos was Ascidae which included a single species viz. *Asca afroaphidiodes* and it colonized the foliage of *B.nutans*. Results of the study disclosed the presence of members of the order Sarcoptiformes also on bamboos by collecting 9 species under 8 genera, 2 subgenera and 7 families. All the 9 species of Sarcoptiformes were representatives of Oribatida under which one subgenus and a species could be identified as new. The new subgenus and new species of oribatid mite was *Uracrobates (Ovouracrobates) keralensis sub.gen.nov.* and *sp.nov*. In the suborder Oribatida, one member, *Tyrophagus putrescentiae* was assigned to the cohort Astigmata.

Results of the present study enabled to record nine species viz. *Agistemus aimogastaensis, Cunaxoides decastroae, Schizotetranychus schizopus, S.recki, Stigmaeopsis longus, Diadalotarsonemus serratus, Knorella blumeanae, Asca afroaphidiodes* and *Hemileius (Tuberemaeus) singularis* as first reports from India. Species like *Stylophoronychus bambusae, Aponychus corpuzae, Paraponematus acacia*, *Paraphytoseius orientalis* formed the first records from Kerala and species like *Oligonychus biharensis*, *S.spinki*, *Tydeus interruptus*, *T.caudatus*, *Lorryia stricta*, *Cheyletus rosensis*, *Octobdellodes guajavae*, *Eupodes parafusifer*, *Amblyseius aerialis*, *A.bhadrakshae*, *A.channabasavannai*, *A. kundurukkae, A. malabarensis, A. orientalis, A.sativae, P. punicae* and *Neoseiulus longispinosus* formed the first reports from bamboos. The dominant genera recognized during the present study were *Schizotetranychus* followed by *Aponychus* and their distribution could be recorded on bamboos growing in four districts viz. Kozhikode, Thrissur, Malappuram and Kannur. Two vagrant species of eriophyid mites viz. *Aceria bambusae* and *Knorella blumeanae* also were found to infest bamboos. Infestation of eriophyid mites was more prevalent on bamboos growing in the Wayanad Dt.

Results of the study also helped to shed light on the web construction behavior among the bamboo spider mites. Species like *S. schizopus*, *S. recki*, *S. longus*, *T. urticae* and *O. biharensis* were found to protect their colony by constructing webs with silken strands, woven on the undersurface of their host leaves with specific preference to the adjacent regions of midrib or the depressions along the leaf edges. The webs of *Schizotetranychus* species were constructed in a zig-zag manner, appeared denser and opaque, often designated as web nests which ensured complete protection to the underlying immatures of the colony. The webs constructed by *T. urticae* and *O. biharensis* were thin and quite often represented by scattered silken strands alone. Other spider mite species like *S. bambusae* and *A. corpuzae* were not found to construct any webs. Initial infestation of mites was found established slowly, near the midrib region or along the leaf edges. Simultaneously, white spots started to appear on the upper surface of leaves. As the mite population got established on the leaves and started to spread on the entire foliar area, development of white chlorotic patches also progressed well and slowly transformed in the form of white parallel lines on the upper surface of bamboo leaves. Later, chlorosis and intense bronzing of the leaves occurred which ultimately resulted in the drying up of leaves.

Results of studies on the impact of climatic factors up on the population density of *S. schizopus* on three host plants namely *B. bambos, B. vulgaris* and *B. multiplex*, enabled to record a significant positive correlation between temperature and mite population density (r values: 0.78, 0.82 and 0.84 respectively) and a significant negative correlation between rainfall and mite density (r values: -0.44, -0.55 and -0.57 respectively). A slight negative correlation was observed between relative humidity and mite population density (r values: -0.16, -0.28 and -0.31 respectively).

Observations made on the feeding damage caused by the bamboo spider mite, *S. schizopus* disclosed a decrease in the vigour of bamboo plants. This was confirmed through biochemical studies also by recording a reduction in the concentration of photosynthetic pigments like chlorophyll a, chlorophyll b, total chlorophyll and carotenoids in mite infested leaves. The respective loss in photosynthetic pigments was recorded as 75% for chlorophyll a, 85% for chlorophyll b, 78% for total chlorophyll and

48% for total carotenoids in the leaves of *B. bambos*. In *B. vulgaris,* 62 % loss in chlorophyll a, 70% loss in chlorophyll b, 62% loss in total chlorophyll and 46% loss in carotenoids was observed owing to the feeding activity of the above species. The values for Fv/Fm ratio showed a decrease by 30.10% in *B. bambos* and 18.18% in *B. vulgaris* due to the feeding activity of mite.

The feeding activity of *S. schizopus* also induced a significant decrease in the total carbohydrate concentration of bamboo leaves. A loss of 58.87% in total carbohydrate was recorded in the mite infested leaves of *B. bambos* whereas 54.04% loss was observed in *B. vulgaris*. Similarly, mite infested leaves of *B. bambos* showed 21.02% loss in total protein while that of *B. vulgaris* was 21.8 % .

The amount of total phenol and proline showed an increase in bamboos owing to the feeding activity of mites. The increase in concentration of total phenol was observed as 22.86% in *B. bambos* and 33.18 % in *B. vulgaris*. The proline concentration also showed a similar increase in both species of bamboos (69.05% increase in *B. bambos* and 57.35% in *B. vulgaris*), due to mite infestation.

The results of the study disclosed an increase in the concentrations of several micro and macronutrients like Potassium, Calcium, Copper and Zinc in mite infested leaves of both species of bamboos studied. This increase could be recorded as 18.87% in Potassium and 36.66% in Calcium in the leaves of *B. bambos* whereas 29.41% in Potassium and 24.08% in Calcium in the leaves *B. vulgaris*. Similarly, mite feeding caused 48.76% increase in Copper and 19.62 % increase in Zinc in *B. bambos* and 25.62% increase of Copper and 6.97% increase of Zinc in *B. vulgaris* as observed during the present study.

Infestation by *S. schizopus* was found to result in a decrease in the concentration of various micronutrients like Phosphorus, Magnesium, Sulphur, Iron, Manganese and Boron . Mite infested leaves of *B. bambos* showed a loss of 8.22% of Phosphorus, 3.55% of Magnesium, 1.54% of Sulphur, 11.46% of Iron, 13.64% of Manganese and 30.09% of Boron. Similarly, a decrease was recorded in the concentration of Phosphorus (18.52%), Magnesium (3.17%), Sulphur (14.8%), Iron (21.73%), Manganese (10.46%) and Boron (26.33%) in *B. vulgaris* as a result of feeding by *S. schizopus.*

A decrease in leaf moisture content was monitored in both species of bamboos as a result of feeding by *S. schizopus*. In *B. vulgaris*, a decrease of 11.85% was noted while it was 15.79% in *B. vulgaris*. Alterations in the various biochemical constituents resulted through the feeding activity of *S. schizopus* were found significant in both species of bamboos, when subjected to statistical analysis using SPSS software version 16 and the significance were tested at $p< 0.05$ using Mann- Whitney't' – test.

Results of developmental studies of the two common, dominant and most injurious species of bamboo mites viz. *S. schizopus* and *T. urticae* carried out under two different combinations of temperature-humidity parameters enabled to record the prevalence of both parthenogenetic and sexual modes of reproduction in both the species. The sequence of developmental events beginning from the egg to the adult stage was similar in both the species under both modes of reproduction. In the sexual mode of reproduction, the male-female ratio was observed to be 1: 10, while in parthenogenetic mode, only male progeny was produced. The durations of the life stages showed slight variations in both types of reproduction and were found influenced by temperature-humidity variations. Under the two temperature-humidity combinations tested, higher longevity of the mites was observed at 20 ± 2ºC and 80 ± 5% RH and lower longevity was recorded at 30 ± 2ºC and 70 ± 5%RH. The durations of pre- oviposition, oviposition and post- oviposition periods recorded for *S. schizopus* at 30 ± 2ºC and 70± 5%RH were 1.9±0.02, 9± 0.47 and 1.0± 0.3 days respectively whereas the respective durations at 20 ± 2ºC and 80 ± 5% RH were 2.1±0.03, 10.25±0.5 and 1.1±0.4 days. At 30 ± 2ºC and 70± 5%RH, the durations of pre- oviposition, oviposition and post-oviposition periods of *T. urticae* were observed as 0.5 ±0.01, 8.3 ± 0.48 and 0.53± 0.17 days respectively. At 20 ± 2ºC and 80 ± 5% RH, the respective durations could be recorded as 1.2 ± 0.19, 10.25 ± 0.42 and 1.1± 0.32 days. The fecundity of *S. schizopus* under 30 ± 2ºC and 70± 5% RH was found to be 40± 2.5 whereas under 20 ± 2ºC and 80 ± 5% RH, it was 34 ± 2.5. Similarly the fecundity of *T. urticae* under 30 ± 2ºC and 70± 5%RH and 20 ± 2ºC and 80 ± 5% RH was 44± 2 and 30 ± 2.5 respectively. Thus, the optimum temperature-humidity combination observed during the study was 30 ± 2ºC and 70± 5%RH.

The results of the present study also helped to erect a new subgenus and new species of oribatid mite from bamboos. Further, the study helped to make new report on nine species from India, four species as new records from Kerala and eighteen species as first report from bamboos. Mite infestation was found to lead to the genesis of biotic stress in bamboos as revealed through the elevated levels of stress factors like proline, phenolic compounds etc. The concentrations of various biochemical components including the macro and microelements were found altered due to mite infestation and all the above parameters would affect the normal health and vigour of bamboo plants, raising a significant threat to the bamboo plantation and bamboo based industries of the country and hence should be considered seriously, warranting proper attention by the public and private sectors.

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Table 1: List of bamboos surveyed in five districts of Kerala during 2012- 2016, showing mite infestation

S. No	Name of Species	Common Name	Key Characteristics of Bamboo	Soil & Habitat preference	Distribution in India	Uses
1.	*Bambusa balcooa* Roxb.	Female bamboo	12-20m height, 20-40 cm internode length, greyish green culm colour, 15-30cm length & oblong lanceolate leaf	Heavy textured soils & Moist deciduous forest	Meghalaya, Assam, West Bengal, Bihar, Eastern Uttar Pradesh and Orissa	Agarbathi sticks, boats, construction, electric poles, edible shoots, frames, ladder, pulp & paper, scaffoldings
2.	*Bambusa bambos* (L.) Voss	Thorny bamboo	30m height, 15-30 cm internode length, dark green culm, 15-30 cm long and lanceolate leaf	Moist fertile & alluvial soil; Moist deciduous forest	South East Asia, Meghalaya, Madhya Pradesh, Andhra Pradesh, Tamil Nadu, Maharashtra, Karnataka, Goa, Gujarat and Rajasthan	Construction, edible shoots, medicine, fence, floor boards, fodder, pulp & paper, rafters, scaffoldings and sprints
3.	*Bambusa longispiculata* Gamble ex Brandis	Mahal bamboo	10-15m height, 30-70cm internode length, green culm, 18-30cm long linear oblong leaf	-	Mizoram	Excellent shelter for Waterfowl, soil stabilization on dam faces, Construction, Baskets
4.	*Bambusa membranacea* (Munro) Stapleton & N.H. Xia	White bamboo	20-24m height, 22-38cm internode length, green culm, 12-25cm long lanceolate leaf	laterite & black limestone soils, mixed or deciduous forest	South East Asia	Handicrafts, Baskets, Buildings, Furniture, Paper, chopsticks, shoots edible
5.	*Bambusa multiplex* (Lour.) Raeusch. Ex Schult.	Hedge Bamboo	2-4m height, 20-40cm internode length, green yellow culm, 5-10cm long linerar lanceolate leaf	Sandy loam soil	China, Nepal, Bhutan, Assam, Srilanka and Taiwan	Paper, canes, handicrafts, baskets, mats, umbrella handle, and edible shoots
6.	*Bambusa nutans* Wall. ex Munro	Nodding Bamboo	6-15m height, 25-45cm internode, green culm, 15-25cm long linear lanceolate leaf	Evergreen and Semi-evergreen	Orissa,West Bengal, Bangladesh, Thailand, Himachal, Sikkim, Uttar Pradesh, West Bengal, Kerala, Karnataka	Decoration, pulp and paper, poles, rafters
7.	*Bambusa pallida* Munro	-	13-20m height, 45-70cm internode, Olive green culm, 10-20cm long linear lanceolate leaf	Moist evergreen forest	Assam, Meghalaya, Mizoram, Nagaland,Tripura, Himachal, West Bengal, Orissa, Uttar Pradesh, Kerala, Karnataka	Baskets, construction, plates, screens, toys, wall hangers
8.	*Bambusa polymorpha* Munro	Burmese bamboo	16-25m height, 40-60cm long internode, Grayish green colour, 7-18cm long linear lanceolate leaf	Low hilly slopes	Coimbatore, Palakkad, Nilambur, Waynad, Coorg , Arunachal pradesh, Manipur, Meghalaya, Tripura, Kerala, Andhra Pradesh, Karnataka	Agarbathi sticks, construction, edible shoots, pulp and paper, fibre boards, landscaping

S. No	Name of Species	Common Name	Key Characteristics of Bamboo	Soil & Habitat preference	Distribution in India	Uses
9.	*Bambusa tulda* Roxb.	Indian timber bamboo	7-23m height, 40-70cm long internode, gray green culm, 15-25cm long linear lanceolate leaf	Semi evergreen & Mixed deciduous forest	Assam, Bihar, Meghalaya, Mizoram, Nagaland, Tripura, Arunachal Pradesh, Uttarakhand, Kerala, Andhra Pradesh, Karnataka	Construction, scaffoldings, reinforced concrete, edible, baskets, fences, stakes, handicraft, pulp and paper, flutes, boards, hats, plates, containers
10.	*Bambusa vulgaris* Schrad. ex Wendl.	Common bamboo	8-20m height, 45cm long internode, yellowish culm, 15-25cm long narrowly or broadly lanceolate	Evergreen Forests	North-East India, Arunachal Pradesh, Assam, Bihar, Madhya Pradesh, Manipur, Mizoram, Odisha, Tripura, West Bengal, Kerala, Andhra Pradesh, Tamil Nadu, Karnataka	Construction, scaffoldings, pulp and paper, fence, decoration, handicraft
11.	*Bambusa wamin* Camus	Dwarf Buddha Belly Bamboo	4-8m height, 10-15cm long internode, dark green culm, 18-30 cm long leaf	-	South East Asia, China	Ornamental, Soil erosion control, handicrafts
12.	*Dendrocalamus asper* (Schult.) Backer	Sweet bamboo	20-30m height, 40-50cm long internode, green culm, 15-30 cm long lanceolate leaf	Tropical forests	Tropical Asia, Kerala, Karnataka, Tamil Nadu, Malaysia, Indonesia, Madagascar, Srilanka, Australia	Construction, pots, baskets, edible shoots, furniture, tooth picks
13.	*Dendrocalamus brandisii* (Munro) Kurz	Burma bamboo	19-33m height, 30-38cm long internode, Ashy green culm, 20-30cm long oblong-lanceolate leaf	Wet evergreen tropical forests	Manipur, Andaman islands, Andhra Pradesh, Tamil Nadu, Karnataka, Kerala	Construction, Pulp and paper, baskets, handicrafts, edible shoots, decoration, boat masts
14.	*Dendrocalamus giganteus* Munro	Giant bamboo	24-30m height, 35-40cm long internode, dull green culm, 50cm long lanceolate leaf	Tropical high lands	Arunachal Pradesh,Assam, Manipur, Nagaland, West Bengal, Indonesia,China	Construction, Pulp and paper, Vases, Boat masts, Buckets, Water pitchers, decoration
15.	*Dendrocalamus hamiltonii* Nees & Arn.ex Munro	Hamilton's bamboo	12-20m height, 30-50cm long internode, dull green culm, 37cm long broadly lanceolate leaf	Semi evergreen forests	North - West Himalaya, Assam, Manipur, Sikkim, Mizoram, Meghalaya Tripura, Nagaland	Construction, baskets, mats, edible shoot, vessels, rafts, chairs
16.	*Dendrocalamus longispathus* Kurz	long-sheath bamboo	10-18m height, 25-60cm long internode, grayish green culm, 10-30cm long linear lanceolate leaf	Mixed forests, Evergreen forest	Mizoram, Tripura, Bihar, Bangladesh, Myanmar , West Bengal, Eastern India	Construction, Pulp and paper, baskets, tooth picks, landscaping, edible shoot, sprints, containers

S. No	Name of Species	Common Name	Key Characteristics of Bamboo	Soil & Habitat preference	Distribution in India	Uses
17.	*Dendrocalamus strictus* (Roxb.) Nees	Male bamboo	8-16m height, 30-45cm long internode, dull green culm, 25cm long linear lanceolate leaf	Deciduous forests	Uttar Pradesh, Madhya pradesh, Orissa, Assam, Manipur, Tripura, Meghalaya, Africa, Eastern and tropical Asia, India, China, Malaysia	Construction, Musical Instruments, furniture, Agricultural implements, pulp and paper, medicine, food
18.	*Gigantochloa atroviolacea* Widjaja	Java Black Bamboo, or Tropical Black Bamboo	8-12m length, 30-50cml long internode, purple culm colour, 20-30cm long lanceolate leaf	-	Banten, Sukabani, Indian Botanic Garden calcutta	Construction, musical instruments, handicrafts, furniture
19.	*Melocanna baccifera* (Roxb.) Kurz	Chittagong forest bamboo	10-20m height, 20-25cm long internode, green or straw coloured culm, 15-30cm long oblong lanceolate leaf	Sandy loam, alluvial soils	Assam, Manipur, Orissa, Meghalaya, Mizoram, Tripura, Asia tropical India	Construction, pulp and paper, edible fruit, woven
20.	*Ochlandra ebracteata* Raizada & chatterji	Etta	4.6m height, 45.7cm long internode, green culm, 40-50cm long oblong lanceolate leaf	Evergreen and semi-evergreen forests	Kerala	Pulp and paper, baskets, mats, feed
21.	*Ochlandra scriptoria* (Dennst.) C.E.C.Fisch.	Kar-etta (Mal.) Elephant grass (English)	5m height, 45cm long internode, purplish culm sheath colour, 10-25cm long linear lanceolate leaf	Evergreen and semi evergreen forests	Karnataka, Tamil nadu, Kerala	Pulp and paper, baskets, mats, flutes, floats, rafts
22.	*Ochlandra travancorica* (Benth) Gamble	Etta (Mal.) Elephant grass (English)	2-6 height, 45-60cm long internode, Grayish green culm, 9-30cm long oblong lanceolate leaf	Evergreen and semi-evergreen forests	Kerala, Tamil Nadu, Asia tropical India	Basket, Handicrafts, pulp and paper, ply, Mat, Umbrella handles, Fishing rods, thatching, edible fruit
23.	*Oxytenanthera abyssinica* (A. Rich.) Munro	Savannah Bamboo	6-10m height, Bright green culm, 20cm long inernode, 5-25 cm long linear lanceolate leaf	Tropical forests	Tropical Africa, Dehra dun	Canoes, pulp and paper, paddle, spears, shaft
24.	*Pseudoxytenanthera ritcheyi* (Munro) H.B. Naithani	-	3-4.5m height, 37-45cm long internode, 5-20cm long linear lanceolate leaf	Deciduous forests	Maharashtra, Karnataka, Kerala, Tamil nadu	Fence, baskets, umbrella handles, walking sticks

S. No	Name of Species	Common Name	Key Characteristics of Bamboo	Soil & Habitat preference	Distribution in India	Uses
25.	*Sinarundinaria griffithiana* (Munro) C.S Chao & Renvoize	-	8m height, 14.5cm long internode, olive green culm, 12.5cm long linear lanceolate leaf	Evergreen forests	Arunachal Pradesh, Meghalaya, Mizoram, Nagaland, West Bengal	Construction, Fencing
26.	*Thyrsostachys oliveri* Gamble	-	15-25m height, 40-60cm long internode, Dull green or yellow culm,15-20cm long lanceolate leaf	Mixed deciduous forest	Nilambur, Coimbatore	Construction, Baskets, handicrafts, slabs, poles, edible
27.	*Thyrsostachys regia* (Munro) Bennet	Umbrella bamboo	8-10m height, 20-30cm long internode, 8-15cm long leaf	Deciduous forest	Malaysia, India, China, Indonesia,Bangladesh,Taiwan, Myanmar	Construction, baskets, pulp and paper, edible shoots, ornamental, pickles, vegetable

Table 2: Faunal diversity & systematic position of mites collected from bamboos during 2012- 2016.

<table>
<tr><th></th><th>Species</th><th>Genera</th><th>Family</th><th>Superfamily</th><th>Suborder</th><th>Order</th><th>Superorder</th></tr>
<tr><td>1</td><td>Amblyseius aerialis (Muma, 1955)</td><td rowspan="7">Amblyseius Berlese, 1914</td><td rowspan="12">Phytoseiidae Berlese, 1916</td><td rowspan="12">Phytoseioidea Berlese, 1916</td><td rowspan="13">Monogynaspida Camin and Gorirossi, 1955</td><td rowspan="13">Mesostigmata G. Canestrini, 1891</td><td rowspan="13">Parasitiformes Reuter, 1909</td></tr>
<tr><td>2</td><td>Amblyseius bhadrakshae Sadanandan and Ramani, 2006</td></tr>
<tr><td>3</td><td>Amblyseius channabasavannai Gupta and Daniel, 1978</td></tr>
<tr><td>4</td><td>Amblyseius kundurukkae Anithalatha and Ramani, 2004</td></tr>
<tr><td>5</td><td>Amblyseius largoensis (Muma, 1955)</td></tr>
<tr><td>6</td><td>Amblyseius malabarensis Anithalatha and Ramani, 2004</td></tr>
<tr><td>7</td><td>Amblyseius orientalis Ehara,1959 Species</td></tr>
<tr><td>8</td><td>Typhlodromalus sativae (MaryAnitha and Ramani, 2009)</td><td>Typhlodromalus Muma, 1961</td></tr>
<tr><td>9</td><td>Phytoseius punicae Chinniah and Mohansundaram, 2001</td><td>Phytoseius Ribaga, 1904</td></tr>
<tr><td>10</td><td>Paraphytoseius orientalis Narayan, Kaur and Ghai, 1960</td><td>Paraphytoseius Swirski and Shechter, 1961</td></tr>
<tr><td>11</td><td>Neoseiulus longispinosus (Evans, 1952)</td><td>Neoseiulus Hughes, 1948</td></tr>
<tr><td>12</td><td>Amblydromella bambusicolus (Gupta, 1977)</td><td>Amblydromella Muma</td></tr>
<tr><td>13</td><td>Asca afroaphidiodes Hurlbutt, 1971</td><td>Asca Von Hayden,1826</td><td>Ascidae Voigts and Oudemans, 1905</td><td>Ascoidea Voigts and Oudemans, 1905</td></tr>
</table>

14	*Octobdellodes guajavae* Chatteerjee and Gupta, 2002	Octobdellodes Atyeo, 1960	Bdellidae Duges, 1834	Bdelloidea Duges, 1834	Prostigmata Kramer, 1877	Trombidiformes Reuter, 1909	Acariformes Zakhvatkin, 1952
15	*Cunaxa bambusae* Gupta and Ghosh, 1980	*Cunaxa* Von Heyden, 1826	Cunaxidae Thor, 1902				
16	*Cunaxoides decastroae* Den Heyer, 2013	*Cunaxoides* Baker and Hoffmann, 1948					
17	*Tydeus interruptus* Thor, 1932	*Tydeus* Koch, 1836	Tydeidae Kramer, 1877	Tydeoidea Kramer, 1877			
18	*Tydeus caudatus* (Duges, 1834)						
19	*Parapronematus acacia* Baker, 1965	*Parapronematus* Baker, 1965					
20	*Lorryia stricta* Gupta, 1991	*Lorryia* Oudemans, 1925					
21	*Aceria bambusae* Channabasavanna, 1956	*Aceria* Keifer, 1944	Eriophyidae Nalepa, 1898	Eriophyoidea Nalepa, 1898			
22	*Knorella blumeanae* Xue and Zhang, 2009	*Knorella* Keifer, 1975					
23	*Eupodes parafusifer* Meyer and Ryke, 1960	*Eupodes* Koch, 1835	Eupodidae Koch, 1842	Eupodoidea Koch, 1842			
24	*Aponychus corpuzae* Rimando, 1966	*Aponychus* Rimando, 1966	Tetranychidae Murray, 1877	Tetranychoidea Donnadieu, 1875			
25	*Oligonychus biharensis* (Hirst, 1924)	*Oligonychus* Berlese, 1886					
26	*Tetranychus urticae* Koch, 1836	*Tetranychus* Dufour, 1832					
27	*Schizotetranychus schizopus* (Zacher, 1913)	*Schizotetranychus* Tragardh, 1915					
28	*Schizotetranychus recki* Ehara, 1957	*Schizotetranychus* Tragardh, 1915					
29	*Stigmaeopsis longus* (Saito, 1990)	*Stigmaeopsis* Banks, 1917					

30	*Stylophoronychus vannus* (Rimando, 1968)	*Stylophoronychus* Prasad, 1975					
31	*Cheyletus rosensis* MaryAnitha and Ramani, 2009	*Cheyletus* Latereille, 1796	Cheyletidae Leach, 1815	Cheyletoidea Leach, 1815			
32	*Agistemus aimogastaensis* Leiva, Fernandez, Theron and Rollard, 2013	*Agistemus* Summers, 1960	Stigmaeidae Oudemans, 1931	Raphignathoidea Kramer, 1877			
33	*Diadalotarsonemus serratus* Rezende, Ochoa and Lofego, 2015	*Diadalotarsonemus* De Leon, 1956	Tarsonemidae Kramer, 1877	Tarsonemoidea Kramer, 1877			
34	*Steneotarsonemus spinki* Smiley, 1967	*Steneotarsonemus* Beer, 1954	Tarsonemidae Kramer, 1877				
35	*Hemileius (Tuberamaeus) singularis* (Sellnick, 1930)	*Hemileius* Berlese,1916	Hemileiidae J and P Balogh, 1984	Oripodoidea Jacot, 1925	Oribatida van der Hammen, 1968	Sarcoptiformes Reuter, 1909	
36	*Siculobata malabarica* (Ramani and Haq, 1998)	*Siculobata* Grandjean, 1953					
37	*Uracrobates indicus* Ramani and Haq, 1990	*Uracrobates* Balogh and Mahunka, 1967	Mochlozetidae Grandjean, 1960				
38	*Uracrobates (Ovouracrobates) keralensis* sp. nov.	*Uracrobates* Balogh and Mahunka, 1967					
39	*Scheloribates decarinatus* Aoki, 1984	*Scheloribates* Berlese, 1908	Scheloribatidae Grandjean, 1933				
40	*Zetorchella sejugata* (Ramani and Haq, 1997)	*Zetorchella* Berlese, 1916	Caloppiidae Balogh, 1960				
41	*Lamellobates (Paralamellobates) misella* Berlese, 1910	*Lamellobates* Hammer, 1958	Heterozetidae Kunst, 1971	Ceratozetoidea Jacot, 1925			
42	*Galumna (Galumna) flabellifera orientalis* Aoki, 1965	*Galumna* Heyden, 1826	Galumnidae Jacot, 1925	Galumnoidea Jacot, 1925			
43	*Tyrophagus putrescentiae* Shrank, 1781	*Tyrophagus* Oudemans, 1924	Acaridae Latreille, 1802	Acaroidea Latreille, 1802			

Table 3: Numerical density of the various taxa of bamboo mites collected from the five districts of Kerala during the study period 2012- 2016.

Sl.No	Bamboo Species screened	Taxa of bamboo mites collected		
		No. of Families	No. of Genera	No. of Species
1	*Bambusa balcooa* Roxb.	7	17	23
2	*Bambusa bambos* (L.) Voss	12	29	37
3	*Bambusa longispiculata* Gamble ex Brandis	5	10	17
4	*Bambusa membranacea* (Munro) Stapleton & N.H. Xia	5	10	13
5	*Bambusa multiplex* (Lour.) Raeusch. Ex Schult.	3	8	9
6	*Bambusa nutans* Wall. ex Munro	8	13	17
7	*Bambusa pallida* Munro	4	6	6
8	*Bambusa polymorpha* Munro	4	8	10
9	*Bambusa tulda* Roxb.	6	15	24
10	*Bambusa vulgaris* Schrad. ex Wendl.	9	19	28
11	*Bambusa wamin* Camus	5	9	16
12	*Dendrocalamus asper* (Schult.) Backer	5	10	13
13	*Dendrocalamus brandisii* (Munro) Kurz	3	8	11
14	*Dendrocalamus giganteus* Munro	5	10	13
15	*Dendrocalamus hamiltonii* Nees & Arn.ex Munro	5	10	14
16	*Dendrocalamus longispathus* Kurz	4	9	13
17	*Dendrocalamus strictus* (Roxb.) Nees	4	4	5
18	*Gigantochloa atroviolacea* Widjaja	5	8	14
19	*Melocanna baccifera* (Roxb.) Kurz	5	6	6
20	*Ochlandra ebracteata* Raizada & Chatterji	5	6	11
21	*Ochlandra scriptoria* (Dennst.) C.E.C.Fisch.	4	7	8
22	*Ochlandra travancorica* (Benth) Gamble	5	4	6
23	*Oxytenanthera abyssinica* (A. Rich.) Munro	4	7	7
24	*Pseudoxytenanthera ritcheyi* (Munro) H.B. Naithani	5	9	12
25	*Sinarundinaria griffithiana* (Munro) C.S Chao & Renvoize	2	3	3
26	*Thyrsostachys oliveri* Gamble	3	5	12
27	*Thyrsostachys regia* (Munro) Bennet	4	8	15

Table 4: District-wise distribution pattern of bamboo mites on respective host plants.

S. No	Bamboo Species	District wise distribution of Mites				
		Kozhikode	Kannur	Malappuram	Wayanad	Thrissur
1	*Bambusa balcooa* Roxb.	–	–	++	–	+++
2	*Bambusa bambos* (L.) Voss	+++	+++	+++	+++	+++
3	*Bambusa longispiculata* Gamble ex Brandis	–	–	+++	–	++
4	*Bambusa membranacea* (Munro) Stapleton & N.H. Xia	–	–	++	–	+
5	*Bambusa multiplex* (Lour.) Raeusch. Ex Schult.	++	+	+++	++	+++
6	*Bambusa nutans* Wall. ex Munro	–	–	–	–	+++
7	*Bambusa pallida* Munro	++	+	+++	++	+++
8	*Bambusa polymorpha* Munro	–	–	++	–	++
9	*Bambusa tulda* Roxb.	+++	+	+++	+	+++
10	*Bambusa vulgaris* Schrad. ex Wendl.	+++	+++	+++	+++	+++
11	*Bambusa wamin* Camus	++	+	+++	++	+++
12	*Dendrocalamus asper* (Schult.) Backer	–	–	++	–	+
13	*Dendrocalamus brandisii* (Munro) Kurz	–	–	+++	–	++
14	*Dendrocalamus giganteus* Munro	+	+	++	++	++
15	*Dendrocalamus hamiltonii* Nees & Arn.ex Munro	–	–	–	–	++
16	*Dendrocalamus longispathus* Kurz	–	–	+	–	+
17	*Dendrocalamus strictus* (Roxb.) Nees	–	–	++	–	+
18	*Gigantochloa atroviolacea* Widjaja	–	–	+	–	+
19	*Melocanna baccifera* (Roxb.) Kurz	–	–	+	–	+
20	*Ochlandra ebracteata* Raizada & Chatterji	–	–	–	–	++
21	*Ochlandra scriptoria* (Dennst.) C.E.C.Fisch.	–	–	+	–	+
22	*Ochlandra travancorica* (Benth) Gamble	+	–	++	+	++
23	*Oxytenanthera abyssinica* (A. Rich.) Munro	–	–	+	–	+
24	*Pseudoxytenanthera ritcheyi* (Munro) H.B. Naithani	–	–	+	–	+
25	*Sinarundinaria griffithiana* (Munro) C.S Chao & Renvoize	–	–	–	–	+
26	*Thyrsostachys oliveri* Gamble	–	–	+	–	+
27	*Thyrsostachys regia* (Munro) Bennet	–	–	+	–	+

Criterion used for calculating abundance of mites:

+++ = more than 80 mites/leaf, ++ = 50-80 mites/leaf, + = less than 50 mites/ leaf, - = Absence of mites

Table 5: List of mites collected from bamboos in five districts of Kerala during 2012- 2016

S.No	Scientific Name	Family	Order	Host Plants	Remarks
1	*Stylophoronychus vannus* (Rimando, 1968)	Tetranychidae	Trombidiformes	*B. vulgaris, B. bambos, B.balcooa, B.tulda, B.membranacea, B.multiplex, B.pallida, B.wamin, D.asper, D.brandisii, T.regia*	First report from Kerala
2	*Aponychus corpuzae* Rimando, 1966	Tetranychidae	Trombidiformes	*B. vulgaris, B. bambos, B.balcooa, B.tulda, B.nutans, B.longispiculata, D.giganteus, B.polymorpha, M.bacciferra, B.membranacea, B.multiplex, B.pallida, B.wamin, D.asper, D.brandisii, T.regia*	First report from Kerala
3	*Oligonychus biharensis* (Hirst, 1924)	Tetranychidae	Trombidiformes	*B.bambos, B.tulda, B.vulgaris, G.atroviolacea*	First report from bamboos
4	*Tetranychus urticae* C.L. Koch, 1836	Tetranychidae	Trombidiformes	*B. vulgaris, B. bambos, B.balcooa, B.tulda, B.nutans, B.longispiculata, B.wamin, B.polymorpha, D.asper, B.membranacea, D.hamiltonii, P.ritcheyi, G.atroviolacea, S.griffithiana*	-
5	*Schizotetranychus schizopus* (Zacher, 1913)	Tetranychidae	Trombidiformes	*B. vulgaris, B. bambos, B.balcooa, B.tulda, B.nutans, B.longispiculata, B.wamin, B.polymorpha, D.asper, B.membranacea, D.hamiltonii, P.ritcheyi, G.atroviolacea, B.multiplex,O.scriptoria.*	First report from India
6	*Schizotetranychus recki* Ehara, 1957	Tetranychidae	Trombidiformes	*B. vulgaris, B. bambos, B.balcooa, B.tulda, B.nutans, B.longispiculata, B.wamin, D.giganteus, P.ritcheyi, G.atroviolacea, B.membranacea, S.griffithiana.*	First report from India

S.No	Scientific Name	Family	Order	Host Plants	Remarks
7	*Stigmaeopsis longus* (Saito, 1990)	Tetranychidae	Trombidiformes	*B.vulgaris, B.bambos, B.longispiculata, D.asper, D.brandisii, G.atroviolacea*	First report from India
8	*Diadalotarsonemus serratus* Rezende, Ochoa and Lofego, 2015	Tarsonemidae	Trombidiformes	*B. bambos*	First report from India
9	*Steneotarsonemus spinki* Smiley, 1967	Tarsonemidae	Trombidiformes	*B.bambos, B.pallida,B.vulgaris*	First report from the host plant
10	*Aceria bambusae* Channabasavanna, 1966	Eriophyidae	Trombidiformes	*B. vulgaris,B.balcooa,B.bambos, B.multiplex,B.polymorpha, B.tulda, D.asper, D. longispathus, D.strictus, O.scriptoria,O.abyssinica, P.ritcheyi, T.oliveri*	First report from bamboos other than *B.vulgaris*
11	*Knorella blumeanae* Xue and Zhang, 2009	Eriophyidae	Trombidiformes	*B.bambos, B.balcooa,B.longispiculata, B.multiplex, B.tulda, B.vulgaris, B.wamin, D.longispathus, O.travancorica, O.abyssinica, P.ritcheyi,*	First report from India
12	*Tydeus interruptus* Sig Thor, 1932	Tydeidae	Trombidiformes	*B. balcooa*, *B. longispiculata*, *B.bambos*, *B. nutans*, *B. tulda*, *B. vulgaris*, *D. giganteus*, *D. hamiltonii*, *D. longispathus*, *D.strictus*, *D. brandisii, M. bacciferra*, *O. scriptoria*.	First report from bamboos
13	*Tydeus caudatus* (Duges, 1834) Sensu Baker, 1970	Tydeidae	Trombidiformes	*B. balcooa*, *B.tulda*, *B. bambos, T. oliveri*	First report from bamboos

S.No	Scientific Name	Family	Order	Host Plants	Remarks
14	*Paraproneematus acacia* Baker, 1965	Tydeidae	Trombidiformes	*B. balcooa*, *B.membranacea*, *B. nutans*, *B. vulgaris*, *B. wamin*, *B.tulda*,*D.asper*, *B.bambos*, *D. brandisii*, *D. giganteus*, *D. longispathus*, *O. travancorica*, *O. abyssinica*, *G. atroviolacea*	First report from Kerala
15	*Lorryia stricta* Gupta, 1991	Tydeidae	Trombidiformes	*B. balcooa*, *B. vulgaris*, *D. longispathus*, *O. scriptoria*, *P. ritcheyi, B. bambos*	First report from the host plant
16	*Agistemus aimogastaensis* Leiva, Fernandez, Theron and Rollard, 2013	Stigmaeidae	Trombidiformes	*B. bambos*, *B. nutans, O. abyssinica*	First report from India
17	*Cheyletus rosensis* Mary Anitha and Ramani, 2009	Cheyletidae	Trombidiformes	*B. bambos*, *B. tulda*, *B.vulgaris, O. travancorica*, *D. giganteus*, *O. ebracteata*	First report from the bamboos
18	*Cunaxa bambusae* Gupta and Ghosh, 1980	Cunaxidae	Trombidiformes	*B. balcooa*, *B. membranacea*, *B. tulda*, *B. pallida*, *B. polymorpha*, *D. asper*, *D. hamiltonii*, *D. longispathus*,*T. regia*, *B. bambos, M. bacciferra*, *B. vulgaris, O. abyssinica*, *P. ritcheyi*, *O.ebracteata G. atroviolacea*	-
19	*Cunaxoides decastroae* Den Heyer, 2013	Cunaxidae	Trombidiformes	*B. bambos*, *B. nutans* and *G. atroviolacea, B. vulgaris*	First report from India
20	*Octobdellodes guajavae* Chatterjee and Gupta, 2002	Bdelloidea	Trombidiformes	*B. balcooa*, *B. nutans*, *B. vulgaris*, *B. wamin*, *T. regia*, *S. griffithiana* and *O. ebracteata, B. bambos*	First report from bamboos

S.No	Scientific Name	Family	Order	Host Plants	Remarks
21	*Eupodes parafusifer* Meyer and Ryke, 1960	Eupodidae	Trombidiformes	*B. balcooa, B. longispiculata, D. giganteus, M. bacciferra, O. ebracteata, B.bambos*	First report from bamboos
22	*Amblyseius aerialis* (Muma, 1955)	Phytoseiidae	Mesostigmata	*B. balcooa*, *B. longispiculata*, *B.tulda*, *B.membranacea*, *B.nutans*, *B.wamin*, *D. hamiltonii*, *B.bambos, B. vulgaris, D.longispathus*, *D.strictus*, *M.bacciferra*, *T.oliveri* and *T.regia*	First report from bamboos
23	*Amblyseius bhadrakshae* Mary Anitha and Ramani, 2006	Phytoseiidae	Mesostigmata	*B. balcooa*, *B. longispiculata*, *B. tulda*, *B. wamin*, *D. giganteus*, *D. hamiltonii*, *D. longispathus*, *D.strictus*,*B. bambos* *O. scriptoria*, *T. oliveri*, *T. regia*, *G. atroviolacea*, *O. ebracteata, B.vulgaris*	First report from bamboos
24	*Amblyseius channabasavannai* Gupta and Daniel, 1978	Phytoseiidae	Mesostigmata	*B.balcooa*,*B.longispiculata*, *B. vulgaris* *B.membranacea*, *D.asper*, *D. brandisii*, *O.ebracteata*,*G.atroviolacea*, *T. oliveri*, *T. regia*, *B.wamin*,*B. tulda, B.bambos*	First report from bamboos
25	*Amblyseius kundurukkae* Mary Anitha and Ramani, 2004	Phytoseiidae	Mesostigmata	*B.longispiculata*,*B.multiplex*, *B. nutans*, *B. polymorpha*, *B. tulda*, *B. wamin*, *D. asper*, *D. brandisii*, *D. giganteus*, *D.hamiltonii*,*D.longispathus*, *T.oliveri*, *O.scriptoria*,*O.travancorica*,*P. ritcheyi*, *T. regia*, *G.atroviolacea*, *O. ebracteata.*	First report from bamboos
26	*Amblyseius largoensis* (Muma, 1955)	Phytoseiidae	Mesostigmata	*B.balcooa*,*B.longispiculata*,*B.multiplexB.nutans*,*B . polymorpha*, *B. tulda*, *B. bambos* *B. wamin*, *D.asper*, *D. brandisii*, *B.vulgaris* *D.giganteus*,*D.hamiltonii, O.scriptoria* *D.longispathus*,*O.travancorica*, *T.regia* *P.ritcheyi*, *T.oliveri*, *G.atroviolacea*, *O. ebracteata*	-

S.No	Scientific Name	Family	Order	Host Plants	Remarks
27	*Amblyseius malabarensis* Mary Anitha and Ramani, 2004	Phytoseiidae	Mesostigmata	*B.balcooa*, *B. longispiculata*, *B. nutans*, *B. polymorpha*, *B.tulda*, *B.wamin*, *D.asper*, *O.scriptoria*,*O.travancorica*, *P.ritcheyi*, *T.oliveri*, *T.regia*, *B.bambos* *G.atroviolacea*, *O. ebracteata*	First report from bamboos
28	*Amblyseius orientalis* Ehara, 1959	Phytoseiidae	Mesotigmata	*B.bambos*,*B.longispiculata*, *B.wamin*, *B.membranacea*, *B.tulda*, *D. brandisii*, *D.giganteus*,*D.hamiltonii*, *T. oliveri*, *D.longispathus*,*O.abyssinica*, *T. regia, B.vulgaris*	First report from bamboos
29	*Typhlodromalus sativae* (Mary Anitha and Ramani, 2009)	Phytoseiidae	Mesostigmata	*B. balcooa*, *B. vulgaris*, *D. giganteus*, *O. scriptoria*, *T. oliveri*, *T. regia*, *O.ebracteata,B.tulda,B.bambos,B.vulgaris*	First report from bamboos
30	*Phytoseius punicae* Chinniah and Mohansundaram, 2001	Phytoseiidae	Mesostigmata	*B. balcooa*, *B. bambos*, *D. hamiltonii*, *P. ritcheyi*, *B. tulda, T. regia.*	First report from bamboos
31	*Neoseiulus longispinosus* (Evans, 1952)	Phytoseiidae	Mesostigmata	*B. balcooa*, *B. bambos*, *B. multiplex*, *B. nutans*, *B. pallida*, *B. polymorpha*, *B. tulda*, *B. wamin*, *D. brandisii*, *D. giganteus*, *D. hamiltonii*, *M.bacciferra*, *O. scriptoria*, *T. oliveri*, *T. regia*, *O. ebracteata, B.vulgaris*	First report from bamboos
32	*Paraphytoseius orientalis* (Narayanan, Kaur and Ghai, 1960)	Phytoseiidae	Mesostigmata	*B. longispiculata*, *B. membranacea*, *B. nutans*, *B. pallida*, *B. polymorpha*, *D.asper*, *D. hamiltonii*, *D. longispathus P. ritcheyi*, *B. vulgaris*	First report from Kerala
33	*Amblydromella bambusicolus* (Gupta, 1977)	Phytoseiidae	Mesostigmata	*B. balcooa*, *B. longispiculata*, *B. membranacea*, *B.tulda*, *D. brandisii*, *D. giganteus*, *D.hamiltonii*, *D.longispathus*, *O. abyssinica*, *T. oliveri T. regia, B. bambos, B.vulgaris, B.multiplex*	-

S.No	Scientific Name	Family	Order	Host Plants	Remarks
34	*Asca afroaphidiodes* Hurlbutt, 1971	Ascidae	Mesostigmata	*B.nutans*	First report from India
35	*Tyrophagus putrescentiae* (Shrank, 1781)	Acaridae	Sarcoptiformes	*B. membranacea*, *B. nutans*, *D. hamiltonii*, *D.strictus*, *G. atroviolacea*, *B.bambos*, *B.vulgaris*	First report from bamboos
36	*Lamellobates (Paralamellobates) misella* (Berlese, 1910)	Heterozetidae	Sarcoptiformes	*B. bambos*	-
37	*Siculobata malabarica* (Ramani and Haq, 1998)	Hemileiidae	Sarcoptiformes	*B. bambos*	-
38	*Uracrobates (Ovouracrobates) keralensis* sp. nov.	Mochlozetidae	Sarcoptiformes	*B. bambos*	New to Science
39	*Uracrobates indicus* (Ramani and Haq, 1990)	Mochlozetidae	Sarcoptiformes	*B. bambos*	-
40	*Zetorchella sejugata* (Ramani and Haq, 1997)	Caloppidae	Sarcoptiformes	*B.vulgaris*	-
41	*Hemileius (Tuberamaeus) singularis* (Sellnick, 1930)	Hemileiidae	Sarcoptiformes	*B. bambos*	First report from India
42	*Galumna (Galumna) flabellifera orientalis* (Aoki, 1965)	Galumnidae	Sarcoptiformes	*B. bambos*	-
43	*Scheloribates decarinatus* (Aoki, 1984)	Scheloribatidae	Sarcoptiformes	*D.strictus*	-

Table 6: Number of Species and Genera of mites recovered from the five districts of Kerala in association with bamboos collected during 2012- 2016.

	Number of Species	Number of Genera	Number of Families	Number of Order
Kozhikode	30	20	9	03
Thrissur	43	34	14	03
Malappuram	43	34	14	03
Kannur	15	8	04	02
Wayanad	32	23	12	03

Table 7: List of bamboo mite species reported for the first time from India

S. No	Scientific Name	Family	Order	Host Plants	Collection sites				
					Kozhikode	Malappuram	Kannur	Wayanad	Thrissur
1	*Schizotetranychus schizopus* (Zacher, 1913)	Tetranychidae	Trombidiformes	*B. vulgaris, B. bambos, B.balcooa, B.tulda, B.nutans, B.longispiculata,*	VMK Botanical Garden	University of Calicut	-	Muttanga	Velupadam
2	*Schizotetranychus recki* Ehara, 1957	Tetranychidae	Trombidiformes	*B. vulgaris, B. bambos, B.balcooa, B.tulda, B.nutans,*	Vanaparvam	Nilambur	Iritty	Muttanga	Velupadam
3	*Stigmaeopsis longus* Saito, 1990	Tetranychidae	Trombidiformes	*B.vulgaris, B.bambos, B.longispiculata, D.asper, D.brandisii, G.atroviolacea*	VMK Botanical Garden	University of Calicut/ Nilambur	Kottiyoor	Kuruvadweep	Velupadam
4	*Diadalotarsonemus serratus* Rezende, Ochoa & Lofego, 2015	Tarsonemidae	Trombidiformes	*B. bambos*	-	Nilambur	-	-	Velupadam
5	*Knorella blumeanae* Xue & Zhang, 2009	Eriophyidae	Trombidiformes	*B.bambos, B.balcooa,B.longispiculata , B.multiplex,*	Vanaparvam	Nilambur	-	Kuruvadweep /Muttanga	Velupadam
6	*Agistemus aimogastaensis* Leiva, Fernandez, Theron and Rollard, 2013	Stigmaeidae	Trombidiformes	*B. bambos, B. nutans, O. abyssinica*	-	Nilambur	-	Muttanga	Velupadam
7	*Cunaxoides decastroae* Den Heyer, 2013	Cunaxidae	Trombidiformes	*B. bambos, B. nutans and G. atroviolacea, B. vulgaris*	-	Nilambur	-	-	Velupadam
8	*Asca afroaphidiodes* Hurlbutt, 1971	Ascidae	Mesostigmata	*B.nutans*	-	Nilambur	-	-	Velupadam
9.	*Hemileius (T.) singularis* (Sellnick, 1930)	Hemileiidae	Sarcoptiformes	*P. ritcheyi, B. bambos*	-	Nilambur	-	-	-

Table 8: List of mites reported for first time from Kerala

S. No	Scientific Name	Family	Order	Host Plants	Collection Sites				
					Kozhikode	Malappuram	Kannur	Wayanad	Thrissur
1	*Stylophoronychus vannus* (Rimando, 1968)	Tetranychidae	Prostigmata	*B. vulgaris, B. bambos, B.balcooa, B.tulda.*	Raviz Kadavu	Nilambur	Iritty	Kuruvadweep	Velupadam
2	*Aponychus corpuzae* Rimando, 1966	Tetranychidae	Prostigmata	*B. vulgaris, B. bambos, B.balcooa, B.tulda, B.nutans*	VMK Botanical Garden	University of Calicut	Iritty	Muthanga	Velupadam
3	*Paraponematus acacia* Baker, 1965	Tydeidae	Prostigmata	*B. balcooa*, *B.membranacea*, *B. nutans*, *B. vulgaris*, *B. wamin*	VMK Botanical Garden	Nilambur	-	Muthanga	Velupadam
4	*Paraphytoseius orientalis* (Narayanan, Kaur and Ghai, 1960)	Phytoseiidae	Mesostigmata	*B. ongispiculata*, *B. membranacea*	Janakikaadu	Nialmbur	-	Muthanga	Velupadam

Table 9: List of mite species recorded for the first time from Bamboos

S. No	Scientific Name	Family	Order	Host Plants	Collection Sites				
					Kozhikode	Malappuram	Kannur	Wayanad	Thrissur
1	*Oligonychus biharensis* (Hirst, 1924)	Tetranychidae	Trombidiformes	*B.bambos, B.tulda, B.vulgaris, G.atroviolacea*	VMK Botanical Garden	Nilambur	Iritty	Kuruvadweep	Velupadam
2	*Steneotarsonemus spinki* Smiley, 1967	Tarsonemidae	Trombidiformes	*B.bambos, B.pallida, B.vulgaris*	-	University of Calicut	-	Muttanga	Velupadam
3	*Tydeus interruptus* Sig Thor, 1932	Tydeidae	Trombidiformes	*D.strictus*, *D. brandisii*, *M. bacciferra*, *O. scriptoria*.	Vanaparvam	Nilambur	-	Muttanga	Velupadam
4	*Tydeus caudatus* (Duges, 1834) Sensu Baker, 1970	Tydeidae	Trombidiformes	*B. balcooa*, *B.tulda*, *B. bambos*, *T. oliveri*	VMK Botanical Garden	Nilambur	-	-	Velupadam
5	*Lorryia stricta* Gupta, 1991	Tydeidae	Trombidiformes	*B. balcooa*, *B. vulgaris*, *D. longispathus*, *O. scriptoria*, *P. ritcheyi, B. bambos*	-	Nilambur	-	-	Velupadam
6	*Cheyletus rosensis* Mary Anitha and Ramani,	Cheyletidae	Trombidiformes	*B. bambos*, *B. tulda*, *B.vulgaris,* *O. travancorica*, *D. giganteus*	-	Nilambur	-	Muttanga	Velupadam
7	*Eupodes parafusifer* Meyer and Ryke, 1960	Eupodidae	Trombidiformes	*B. balcooa,* *B. longispiculata,* *D. giganteus,* *M. bacciferra,*	Janakikaadu	University of Calicut	-	Muttanga	Velupadam

S. No	Scientific Name	Family	Order	Host Plants	Collection Sites				
					Kozhikode	Malappuram	Kannur	Wayanad	Thrissur
8	*Amblyseius aerialis* (Muma, 1955)	Phytoseiidae	Mesostigmata	*B. balcooa*, *B. longispiculata*, *B.tulda*, *B.membranacea*, *B.nutans*, *B.wamin*	Vanaparvam	University of Calicut/ Nilambur	-	Muttanga/ Kuruvadweep	Velupadam
9	*Amblyseius bhadrakshae* Mary Anitha and Ramani, 2006	Phytoseiidae	Mesostigmata	*B. balcooa*, *B. longispiculata*, *B. tulda*, *B. wamin*, *D. giganteus*, *D. hamiltonii*	Kakkadampoyil	Nilambur	-	Muttanga	Velupadam
10	*Amblyseius channabasavannai* Gupta and Daniel, 1978	Phytoseiidae	Mesostigmata	*O.ebracteata*, *G.atroviolacea*, *T. oliveri*, *T. regia*, *B.wamin*,*B. tulda*, *B.bambos*	Kakkadampoyil	Nilambur	-	Muttanga	Velupadam
11	*Amblyseius kundurukkae* Mary Anitha and Ramani, 2004	Phytoseiidae	Mesostigmata	*B.longispiculata*, *B.multiplex*, *B. nutans*, *T. regia*, *G.atroviolacea*, *O. ebracteata*.	VMK Botanical Garden	Nilambur	Kottiyoor	Kuruvadweep	Velupadam
12	*Amblysieus malabarensis* Mary Anitha and Ramani, 2004	Phytoseiidae	Mesostigmata	*P.ritcheyi*,*T.oliveri*, *T.regia*,*B.bambos* *G.atroviolacea*, *O. ebracteata*	Vanaparvam	University of Calicut/ Nilambur	-	Muttanga/ Kuruvadweep	Velupadam
13	*Amblyseius orientalis* Ehara, 1959	Phytoseiidae	Mesotigmata	*B.bambos*, *D.giganteus*, *D.hamiltonii*, *D.longispathus*, *O.abyssinica*, *T. regia*	VMK Botanical Garden	Nilambur	Kottiyoor	Kuruvadweep	Velupadam

S. No	Scientific Name	Family	Order	Host Plants	Collection Sites				
					Kozhikode	Malappuram	Kannur	Wayanad	Thrissur
14	*Typhlodromalus sativae* (Mary Anitha and Ramani, 2009)	Phytoseiidae	Mesostigmata	*B. balcooa*, *B. vulgaris*, *D. giganteus*	Vanaparvam	University of Calicut/ Nilambur	Iritty	Muttanga/ Kuruvadweep	Velupadam
15	*Phytoseius punicae* Chinniah and Mohansundaram, 2001	Phytoseiidae	Mesostigmata	*B. balcooa*, *B.bambos*, *D. hamiltonii*, *P. ritcheyi*, *B. tulda, T. regia.*	Raviz Kadavu	University of Calicut/ Nilambur	-	Muttanga/ Kuruvadweep	Velupadam
16	*Neoseiulus longispinosus* (Evans, 1952)	Phytoseiidae	Mesostigmata	*D. brandisii*, *D. giganteus*, *D. hamiltonii*, *M.bacciferra*, *O. scriptoria*	Janakikaadu	University of Calicut/ Nilambur	-	Muttanga/ Kuruvadweep	Velupadam
17	*Tyrophagus putrescentiae* (Shrank, 1781)	Acaridae	Sarcoptiformes	*B. membranacea*, *B. nutans*,	-	Nilambur	-	-	Velupadam
18	*Octobdellodes guajavae* Chatterjee and Gupta, 2002	Bdelloidea	Trombidiformes	*B. balcooa*, *B. nutans*, *B. vulgaris*, *B. wamin*, *T. regia*, *S. griffithiana* and *O. ebracteata, B. bambos*	-	Nilambur	-	-	-

Table 10: Shannon – Weiner diversity indices obtained for each district during the study period 2012- 2016.

Collection Sites	H ′ value
Kozhikode	2.829
Thrissur	2.685
Malappuram	2.823
Kannur	2.204
Wayanad	2.303

PLATE 6

Fig 1: Percentage composition of mites recovered from bamboos under the two superorders of Subclass Acari.

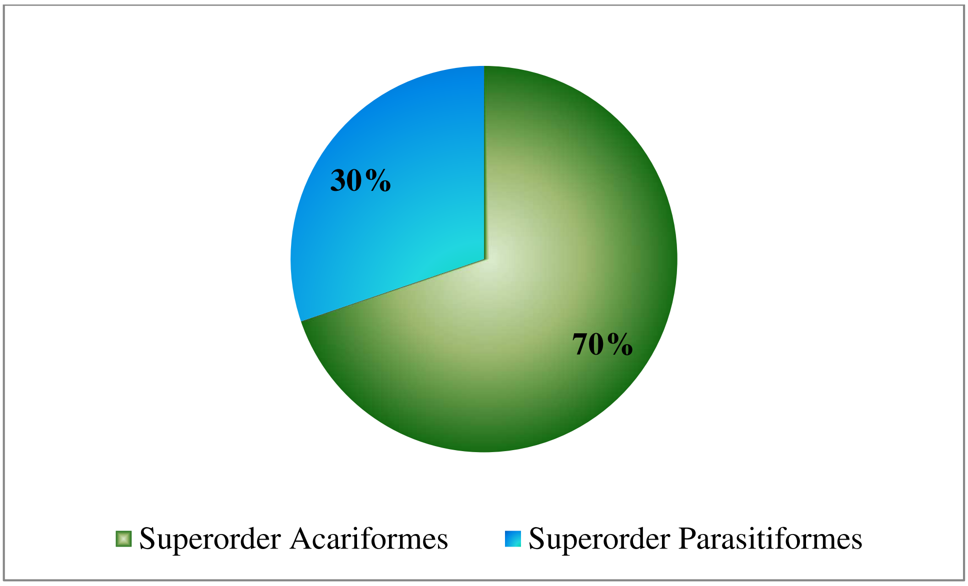


Fig 2: Numerical density of the various taxa of bamboo mites recovered during the study

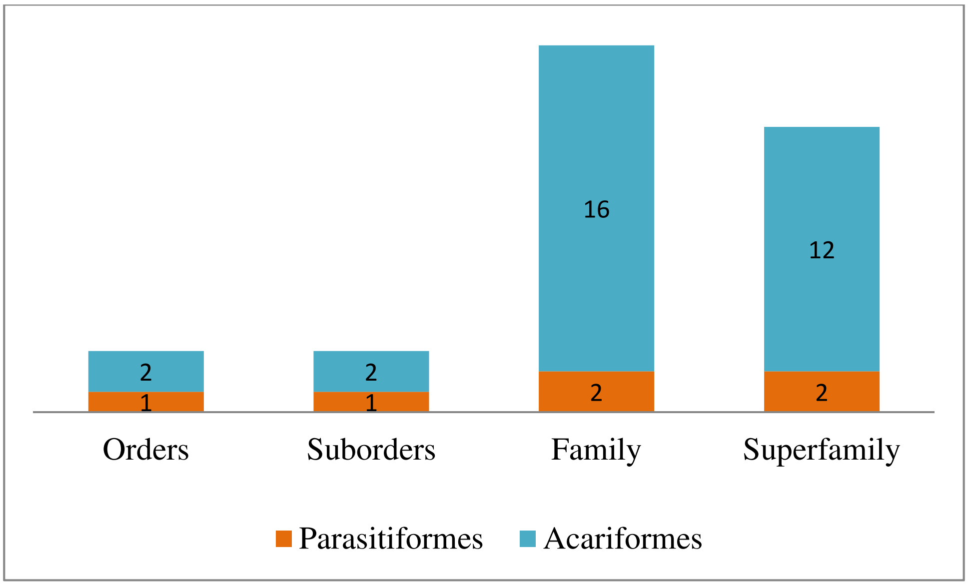


PLATE 7

Fig 3: Percentage of mites recovered from bamboos under each family of the order Mesostigmata

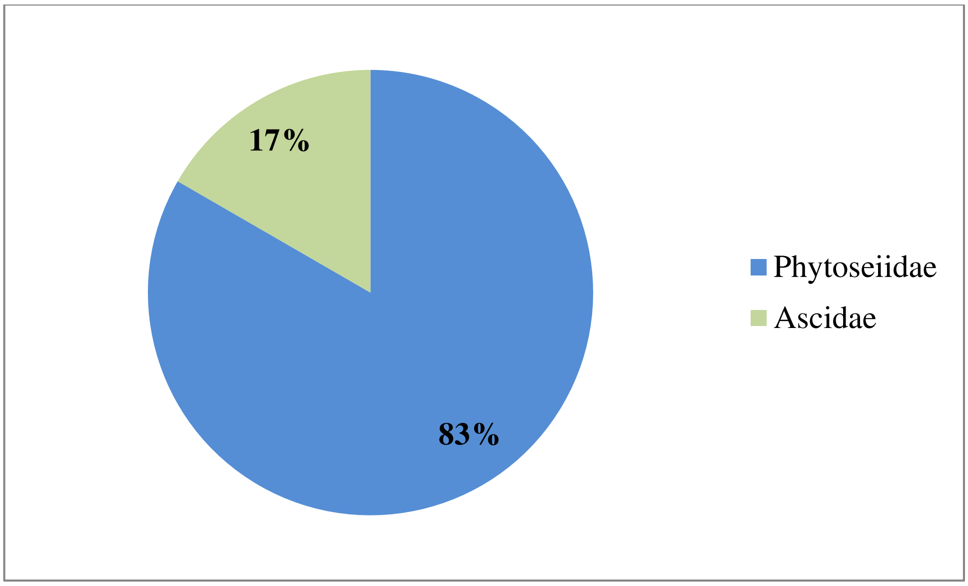


Fig 4: Generic diversity of bamboo mites recovered under the order Mesostigmata

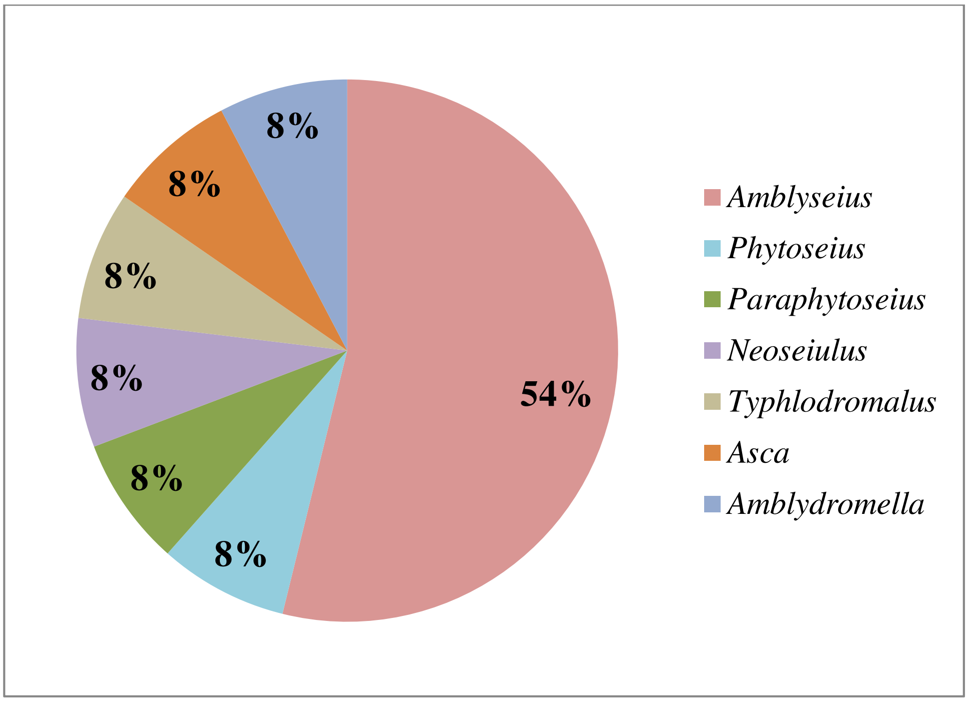


PLATE 8

Fig 5: Number of species under different genera of the order Mesostigmata.

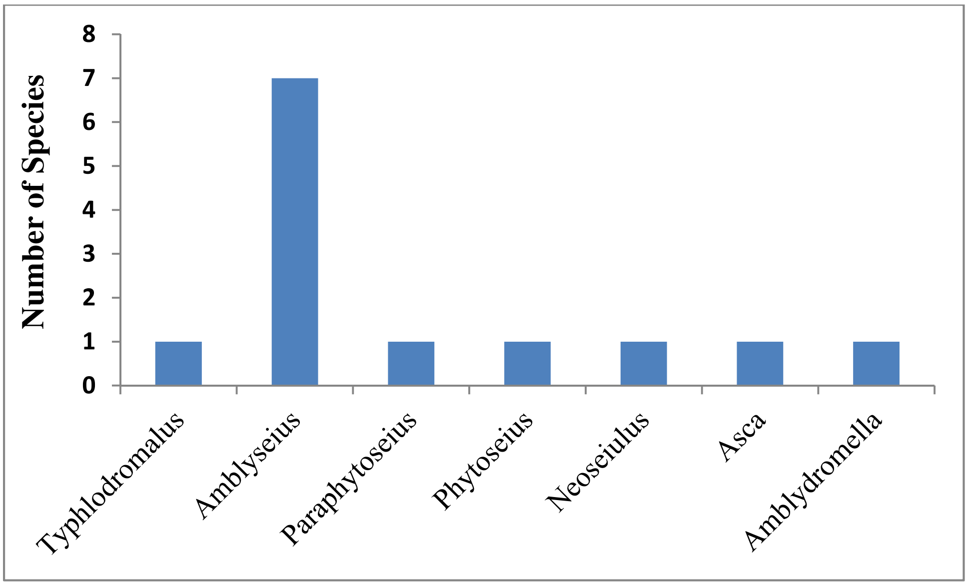


Fig 6: Generic diversity of bamboo mites under the different families of the order Trombidiformes.

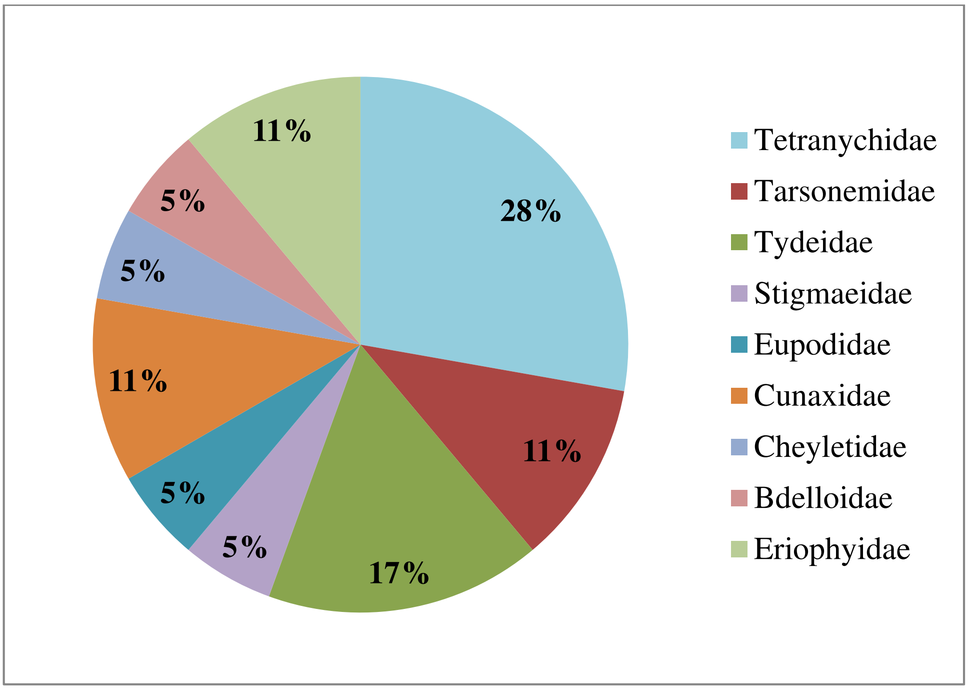


PLATE 9

Fig 7: No. of genera of bamboo mites under the different families of the Order Trombidiformes

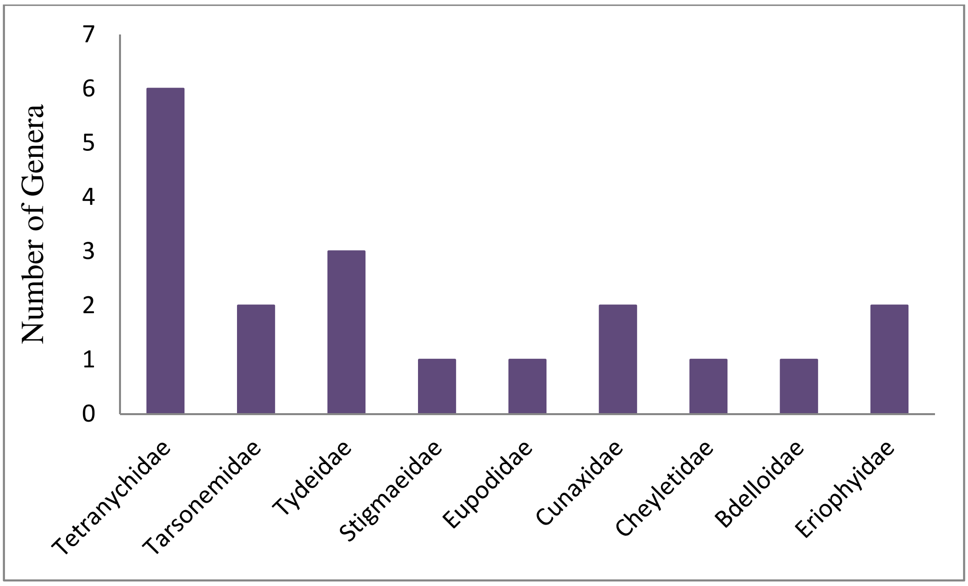


Fig 8: Family diversity and abundance in the various superfamilies of bamboo mites belonging to the order Sarcoptiformes.

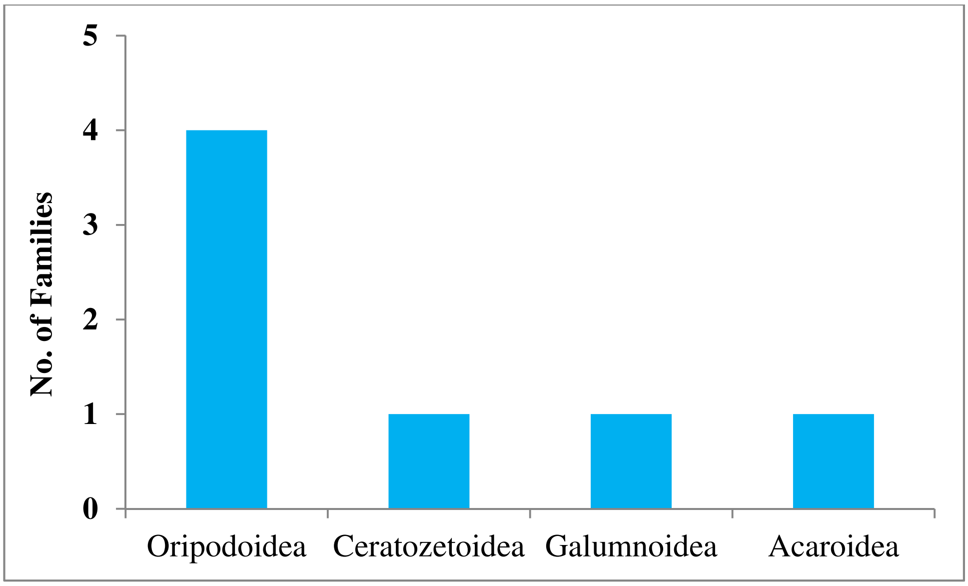


PLATE 10

Fig 9: Species diversity and density of bamboo mites under the various genera of the order Sarcoptiformes.

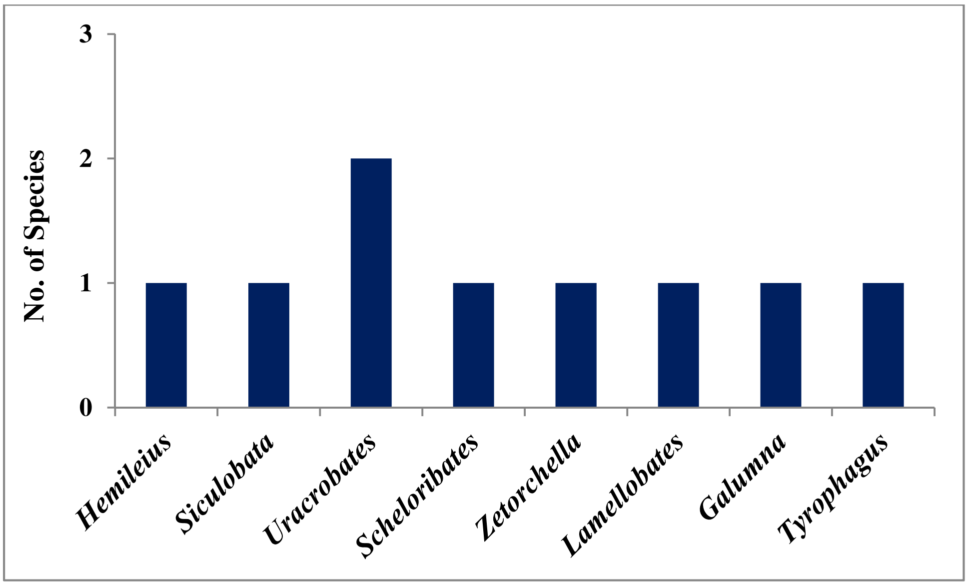


Fig 10: Relative distribution of bamboo mites on 7 most common species of bamboos grown in the five districts of Kerala during the study period 2012- 2016.

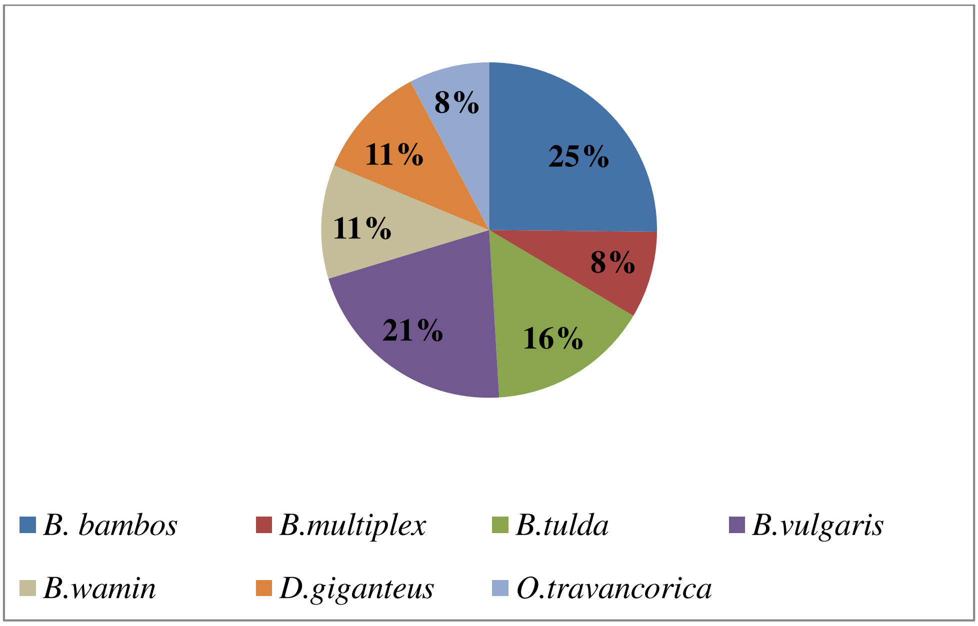


PLATE 11

Fig 11: Number of bamboo hosts recorded for the Trombidiformes group of mites

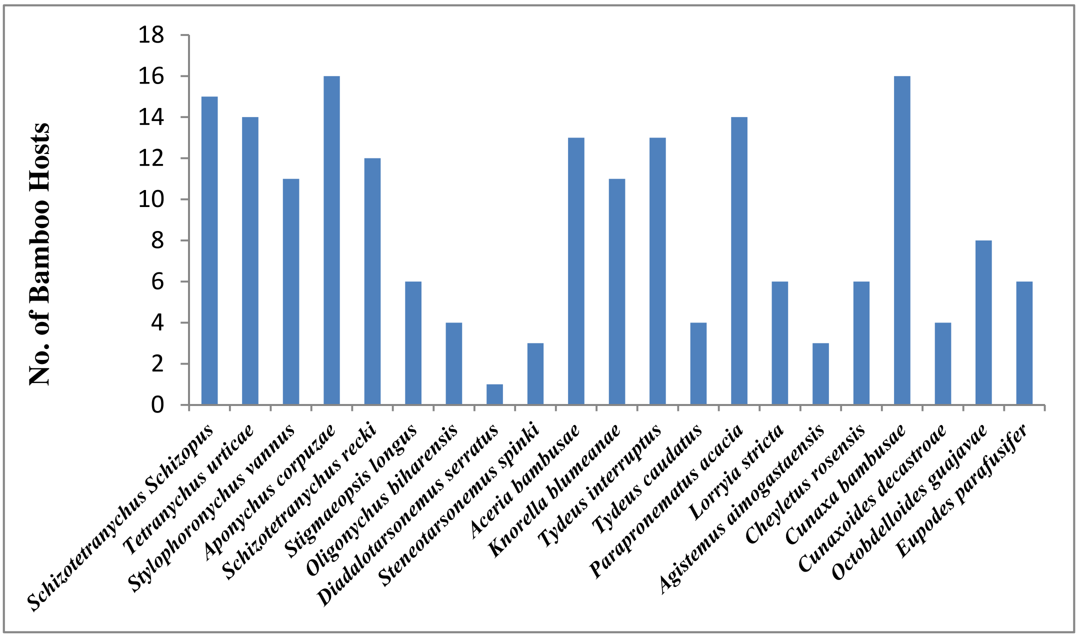


Fig 12: Distribution of mites associated with bamboos in the five districts of Kerala during the study period 2012-2016

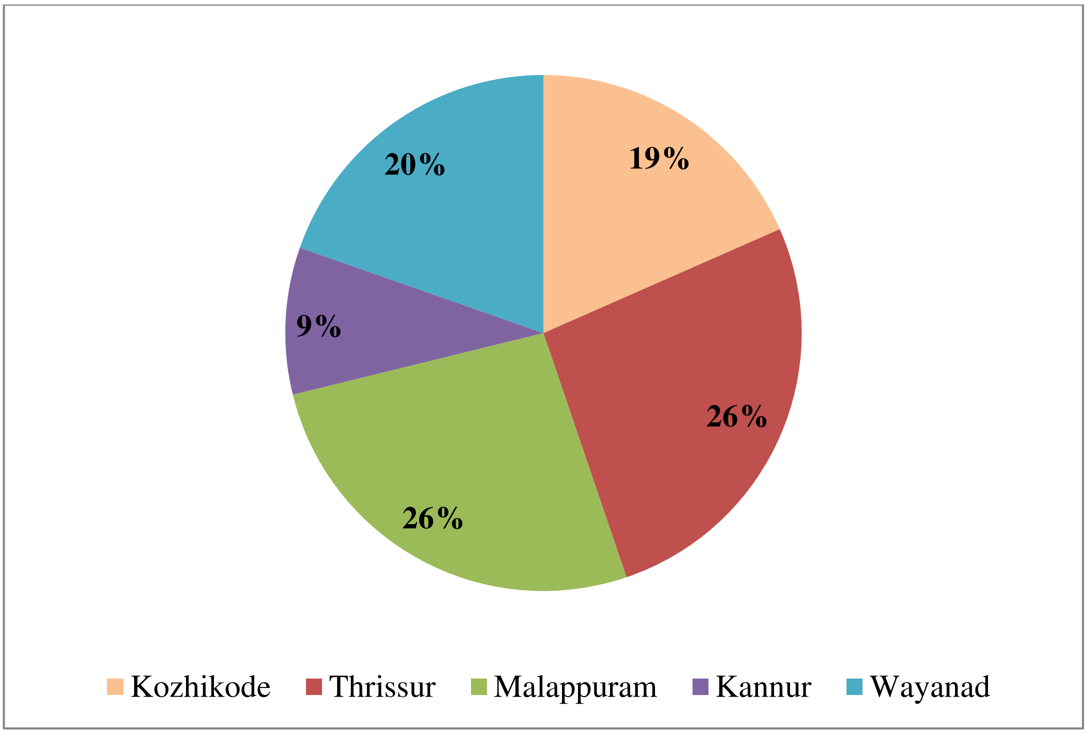


PLATE 12

Fig 13: Effect of Rainfall on the population density of *Schizotetranychus schizopus* infesting *Bambusa bambos*. Mean ± SEM (n= 20).

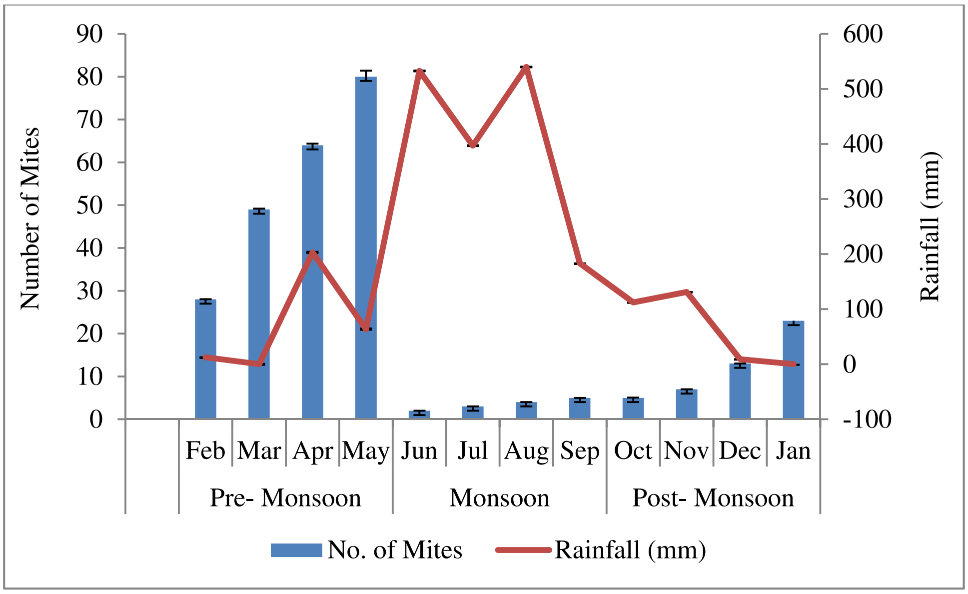


Fig 14: Effect of Rainfall on the population density of *Schizotetranychus schizopus* infesting *Bambusa vulgaris*. Mean ± SEM (n= 20).

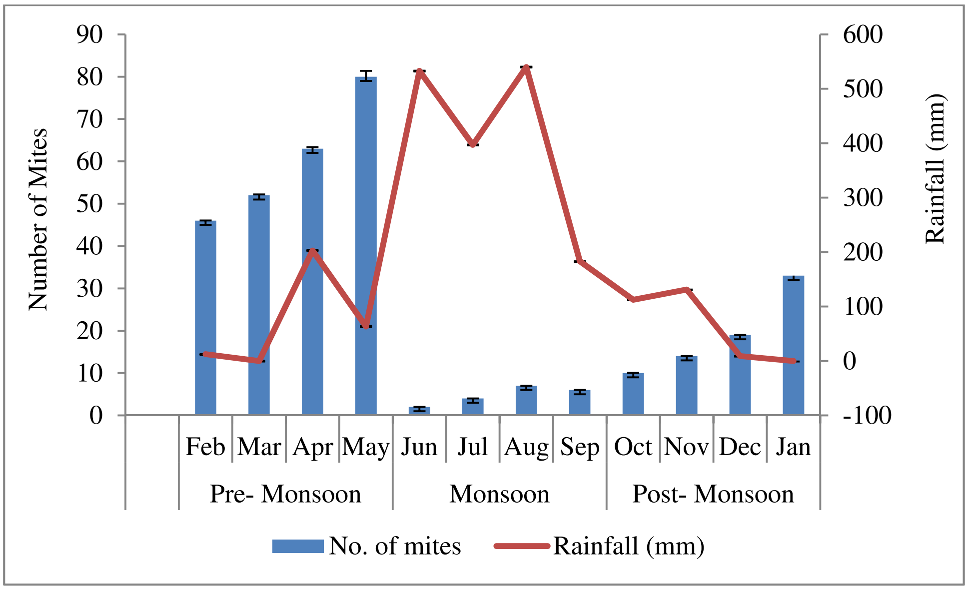


PLATE 13

Fig 15: Effect of Rainfall on the population density of *Schizotetranychus schizopus* infesting *Bambusa multiplex*. Mean ± SEM (n= 20).

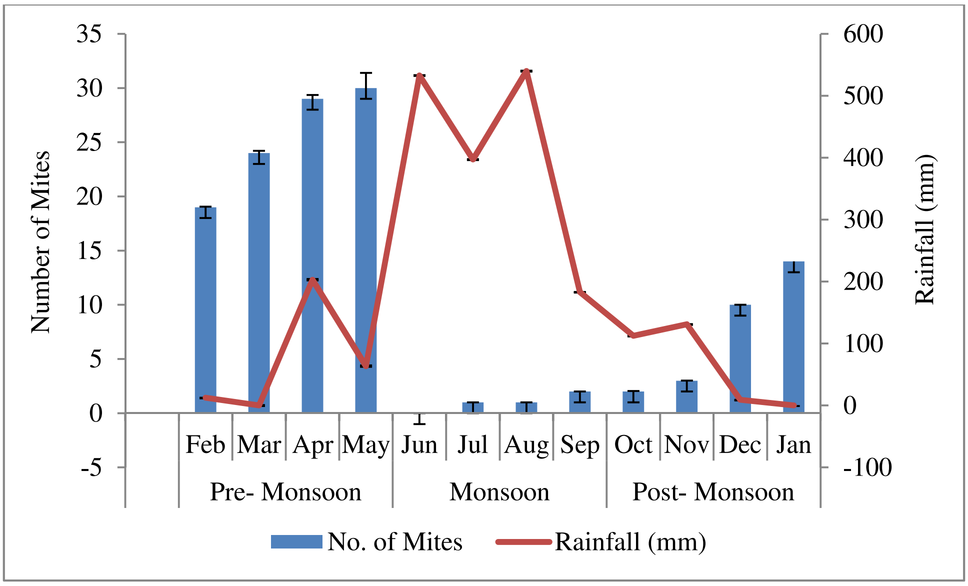


Fig 16: Effect of Relative Humidity on the population density of *Schizotetranychus schizopus* infesting *Bambusa bambos*. Mean ± SEM (n= 20).

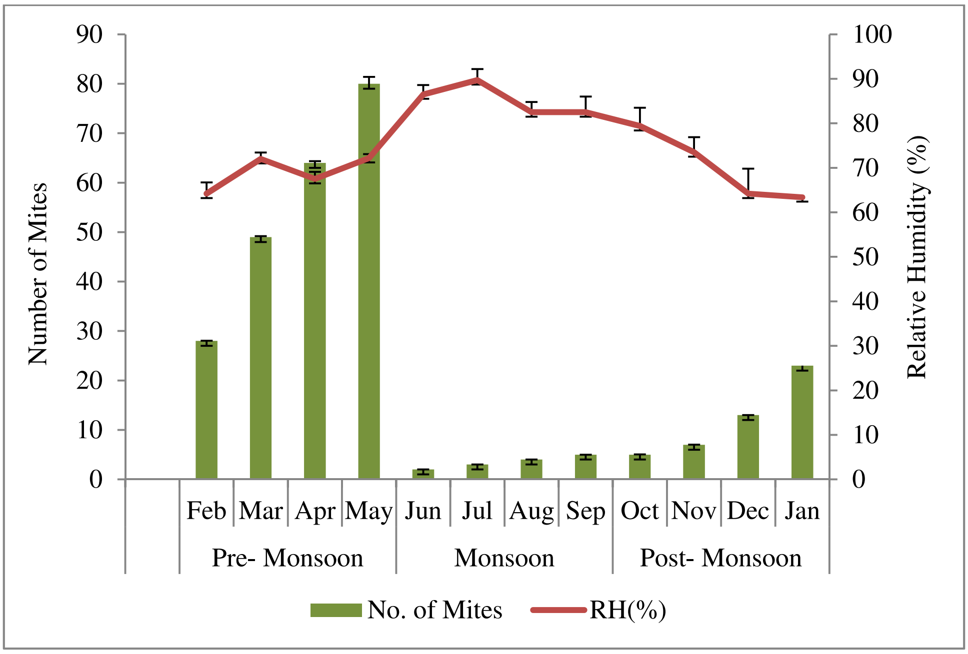


PLATE 14

Fig 17: Effect of Relative Humidity on the population density of *Schizotetranychus schizopus* infesting *Bambusa vulgaris*. Mean ± SEM (n= 20).

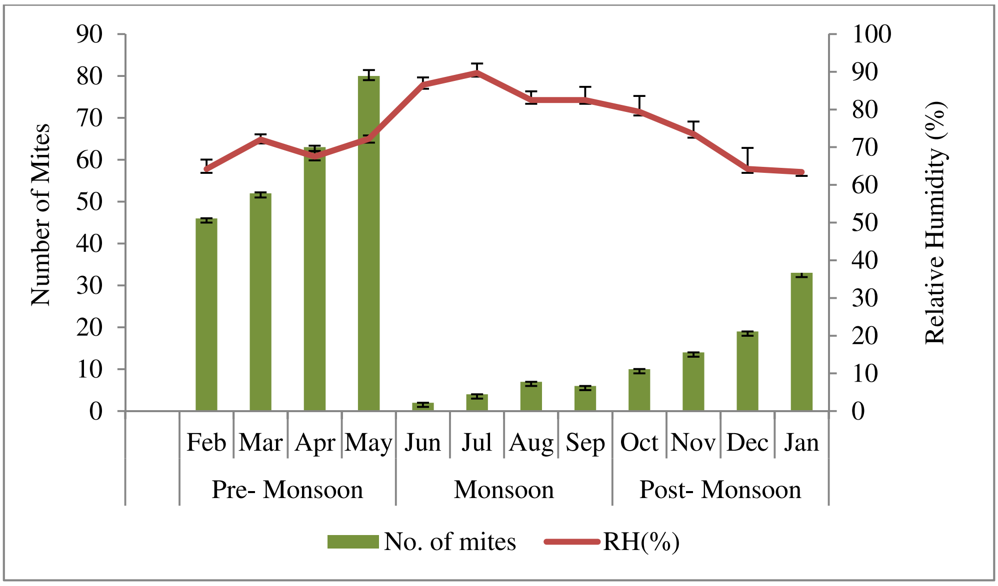


Fig 18: Effect of Relative Humidity on the population density of *Schizotetranychus schizopus* infesting *Bambusa multiplex*. Mean ± SEM (n= 20).

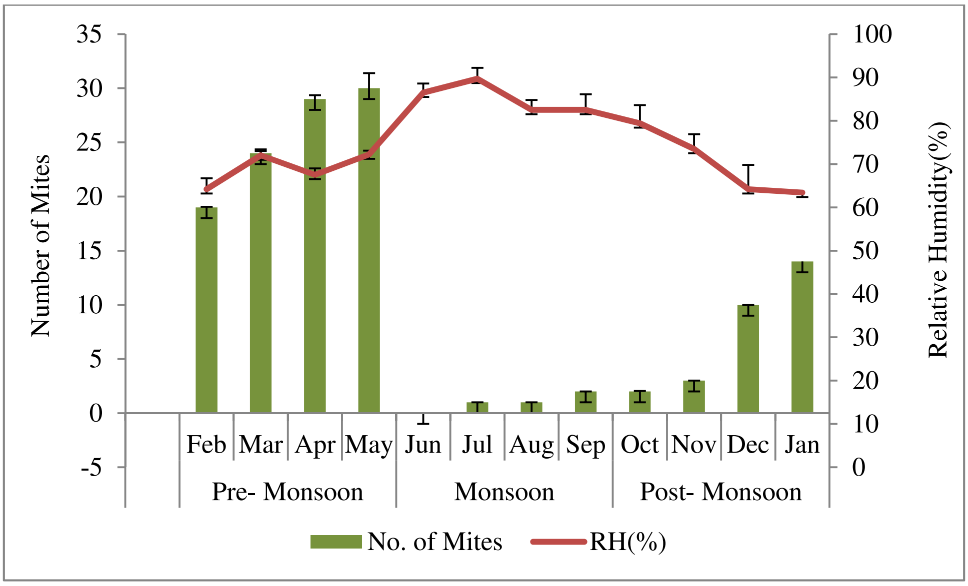


PLATE 15

Fig 19: Effect of Temperature on the population density of *Schizotetranychus schizopus* infesting *Bambusa bambos*. Mean ± SEM (n= 20).

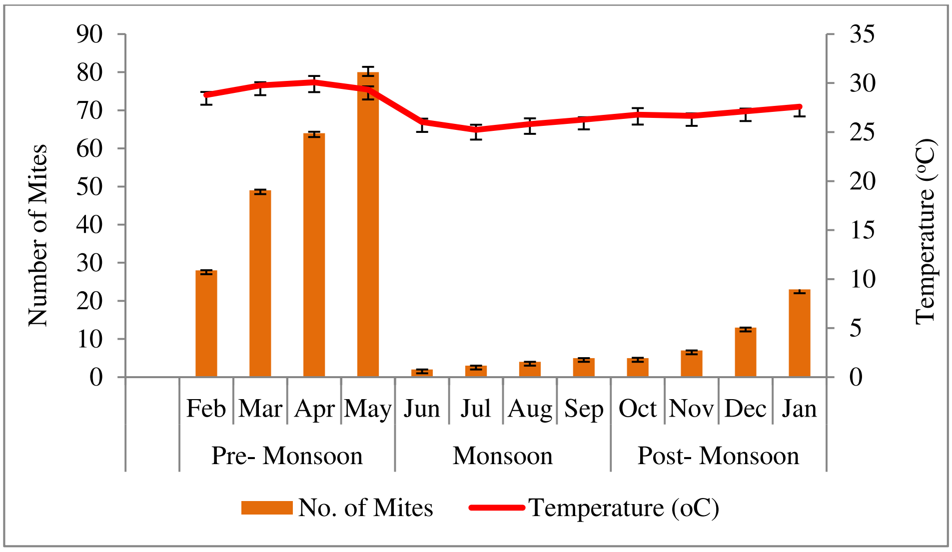


Fig 20: Effect of Temperature on the population density of *Schizotetranychus schizopus* infesting *Bambusa vulgaris*. Mean ± SEM (n= 20).

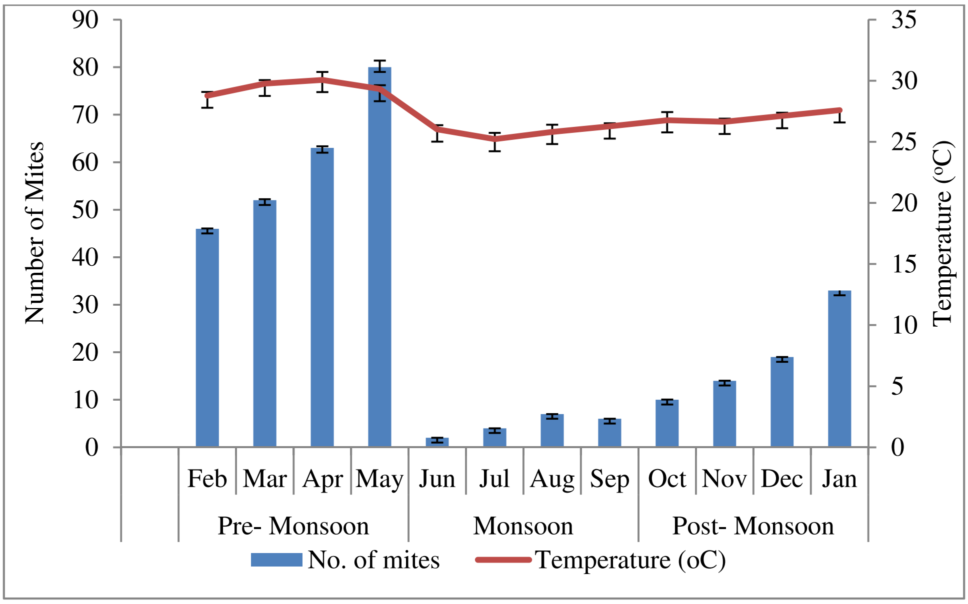


PLATE 16

Fig 21: Effect of Temperature on the population density of *Schizotetranychus schizopus* infesting *Bambusa multiplex.* Mean ± SEM (n= 20).

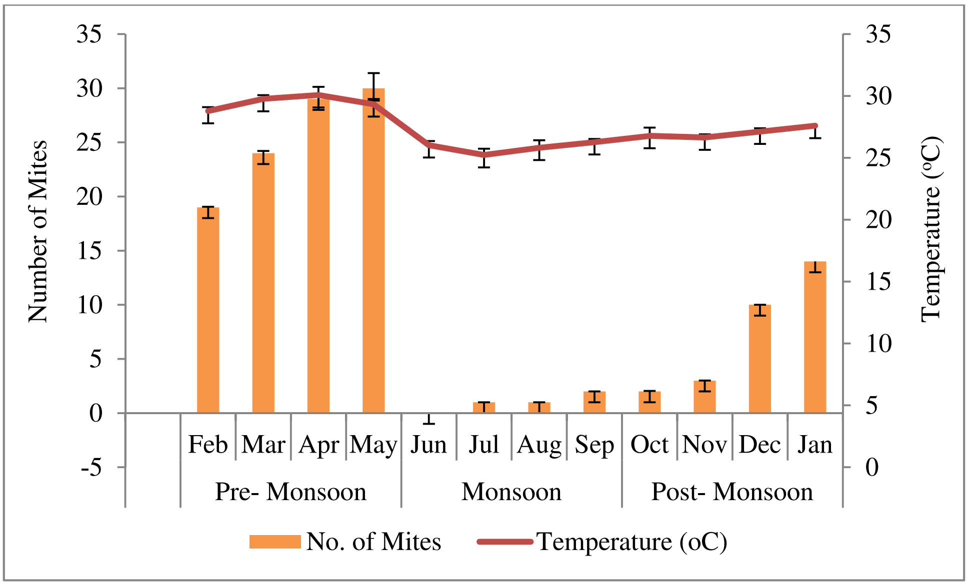


Fig 22: Scatter diagram showing correlation between Rainfall and population density of Schizotetranychus schizopus on *B. bambos*, *B. vulgaris* and *B. multiplex*. Mean ± SEM (n= 20).

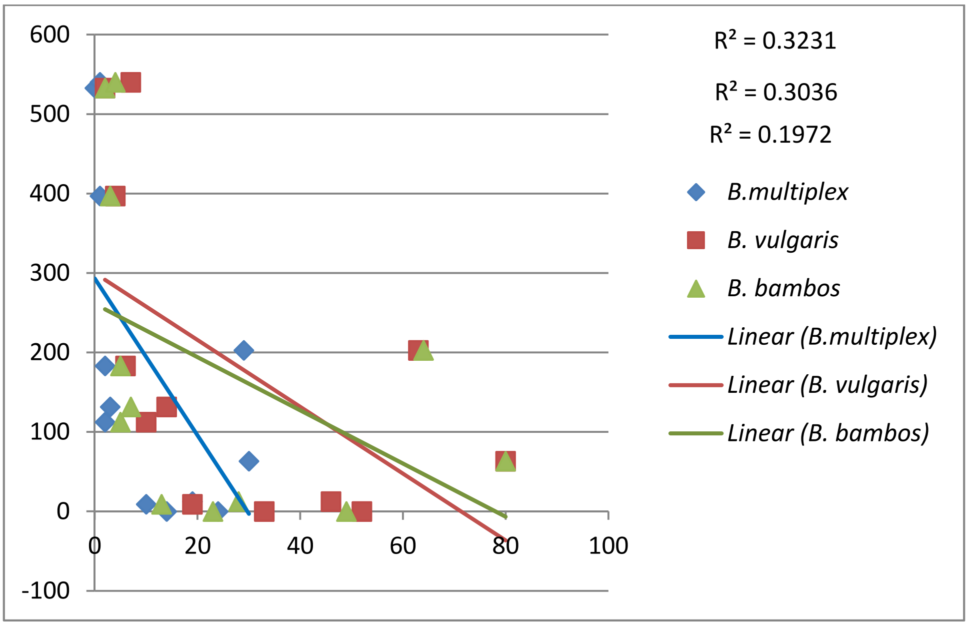


PLATE 17

Fig 23: Scatter diagram showing correlation between Relative Humidity and population density of *Schizotetranychus schizopus* on *B. bambos*, *B. vulgaris* and *B. multiplex*. Mean ± SEM (n= 20).

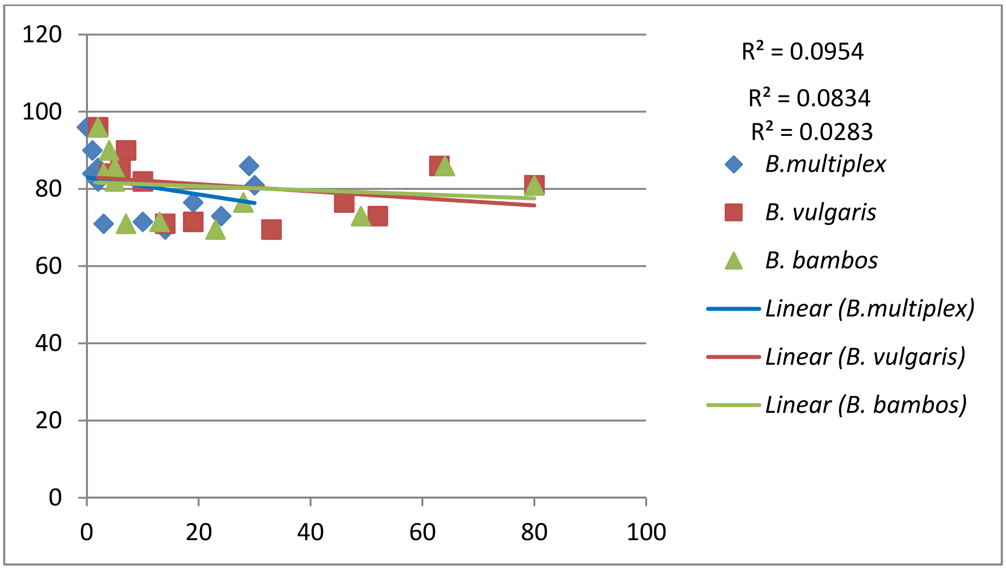


Fig 24: Scatter diagram showing correlation between Temperature and population density of *Schizotetranychus schizopus* on *B. bambos*, *B. vulgaris* and *B. multiplex*. Mean ± SEM (n= 20).

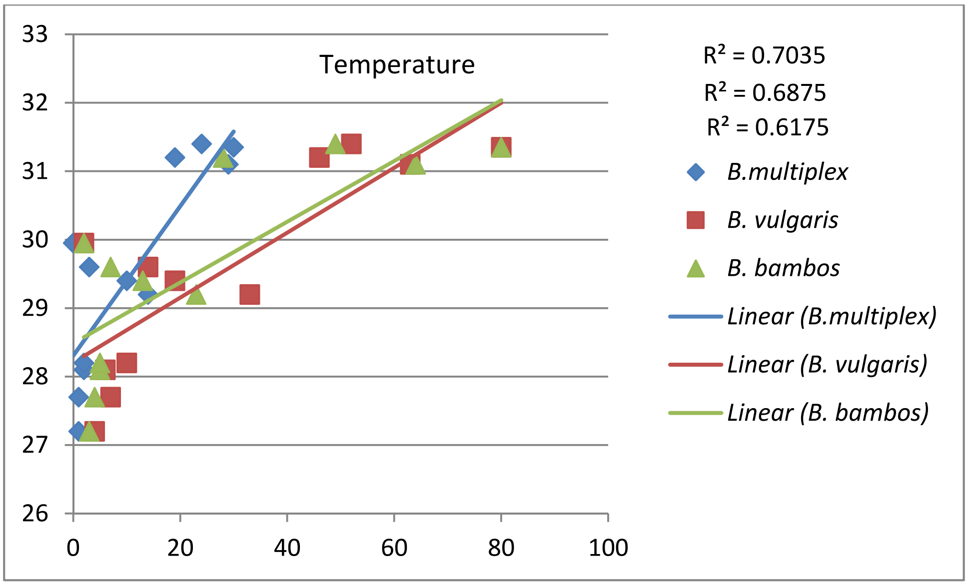


Table 11: Concentration of Chlorophyll in the uninfested and *Schizotetranychus schizopus* infested leaves of *Bambusa bambos* and *Bambusa vulgaris,* expressed in µg/g. Mean ± SEM (n=9)

Chlorophyll Pigments	*Bambusa bambos*		*Bambusa vulgaris*	
	Uninfested	Infested	Uninfested	Infested
Chlorophyll a	3592.89 ± 3.25	877.38 ± 3 .87*	3835.16 ± 14.77	1428.43 ± 17.58*
Chlorophyll b	3015.36 ± 11.03	439.86 ± 8.34*	2704.53 ± 20.85	810.86 ± 6.61*
Total Chlorophyll	6574.66 ± 41.11	1429.04 ± 27.87*	6542.14 ± 17.89	2429.74 ± 41.64*
Carotenoids	4096.27± 80.53	2125.28 ± 54.53*	4694.59 ± 4.95	2515.88 ± 17.32*

*Statistically significant using Mann- Whitney ‘t’ Test with $p < 0.05$

Table 12: Fv/Fm value and Leaf Moisture content in uninfested and *Schizotetranychus schizopus* infested leaves of *Bambusa bambos* and *Bambusa vulgaris*. Mean ± SEM (n=9)

	Bambusa bambos		*Bambusa vulgaris*	
	Uninfested	Infested	Uninfested	Infested
Fv/Fm	0.763 ± 0.005	0.534 ± 0.005*	0.77 ± 0.01	0.63 ± 0.01*
Leaf Moisture (%)	89.25 ± 0.36	78.67 ± 3.2*	88.03 ± 1.01	74.13 ± 1.73*

*Statistically significant using Mann- Whitney ‘t’ Test with $p < 0.05$

Table 13: Concentration of Total carbohydrate, Total phenol, Proline, Total Protein and Total Nitrogen content of uninfested and *Schizotetranychus schizopus* infested leaves of *Bambusa bambos* and *Bambusa vulgaris*. Mean ± SEM (n=9)

Plant Samples Taken		Total Carbohydrate (mg/g)	Total Phenol (mg/g)	Proline (µmol/g)	Total Protein (%)	Total Nitrogen (%)
B. bambos	Uninfested	76.82 ± 1.29	47.78 ± 2.33	11.26 ± 0.01	14.56 ± 0.26	2.33± 0.12
	Infested	31.59± 2.32*	61.94±1.49*	23.84 ±0.26*	11.5 ± 0.19*	1.84± 0.03*
B. vulgaris	Uninfested	77.74±1.73	47.23 ±0.87	12.84 ±0.49	16.312 ± 0.02	2.61± 0.01
	Infested	35.73± 3.45*	70.69 ±2.41*	30.11 ±3.33*	12.75 ± 0.19*	2.04± 0.01*

* Statistically significant using Mann- Whitney 't' Test with $p < 0.05$

Table 14: Concentration of Macronutrients in uninfested and *Schizotetranychus schizopus* infested leaves of *Bambusa bambos* and *Bambusa vulgaris,* expressed in mg/g unit. Mean ± SEM (n=9)

Macronutrients	*Bambusa bambos*		*Bambusa vulgaris*	
	Uninfested	Infested	Uninfested	Infested
Phosphorus	1.16141 ± 0.009	1.06592 ± 0.003*	1.2542 ± 0.005	1.0218 ± 0.008*
Potassium	6.9289 ± 0.05	8.5411 ± 0.08*	6.5238 ± 0.08	9.2428 ± 0.09*
Calcium	4.0236 ± 0.09	6.3532 ± 0.07*	4.3855 ± 0.03	5.7769 ± 0.01*
Magnesium	2.4272 ± 0.02	2.3409 ± 0.06*	2.4074 ± 0.05	2.3309 ± 0.06*
Sulphur	5.2458± 0.53	5.1651 ± 0.29*	6.6832± 0.99	5.6939 ± 0.33*

* Statistically significant using Mann- Whitney 't' Test with $p < 0.05$

Table 15: Concentration of Micronutrients in uninfested and *Schizotetranychus schizopus* infested leaves of *Bambusa bambos* and *Bambusa vulgaris,* expressed in mg/g unit. Mean ± SEM (n=9)

Micronutrients	*Bambusa bambos*		*Bambusa vulgaris*	
	Uninfested	Infested	Uninfested	Infested
Iron	0.595 ± 0.61	0. 5268 ± 0.79*	0.6559 ± 0.65	0.5134 ± 0. 29*
Copper	0.0132 ± 0.005	0.025 ± 0.004*	0.0245 ± 0.001	0.0329 ± 0.006*
Zinc	0.0411± 0.004	0.0511 ± 0.005*	0.0554 ± 0.004	0.0595 ± 0.003*
Manganese	0.5932 ± 0.003	0.5123 ± 0.002*	0.6067 ± 0.004	0.5432 ± 0.003*
Boron	0.0438 ± 0.001	0.0306 ± 0.007*	0.0343 ± 0.002	0.0253 ± 0.001*

* Statistically significant using Mann- Whitney ‘t’ Test with $p < 0.05$

Table 16: Mean (± SEM) duration (days) of various developmental attributes (Preoviposition, Oviposition and Postoviposition, Adult longevity and fecundity) of *Schizotetranychus schizopus* and *Tetranychus urticae* at two different temperature and relative humidity conditions. (n= 30)

Developmental features	*Schizotetranychus schizopus*		*Tetranychus urticae*	
	30 ± 2ºC and 70± 5%	20 ± 2ºC and 80 ± 5%	30 ± 2ºC and 70± 5%	20 ± 2ºC and 80 ± 5%
Pre- oviposition	1.9± 0.02	2.1± 0.03*	0.5± 0.01	1.2± 0.19*
Oviposition	9± 0.47	10.25± 0.5*	8.3± 0.48	10.25± 0.42*
Post- oviposition	1± 0.3	1.1± 0.4*	0.53± 0.17	1.1± 0.32*
♂ longevity	8.5 ± 1.5	10.2 ± 0.5*	8 ± 2.1	9.5 ± 2.3*
♀ longevity	12.5 ± 1.6	13.5 ± 2.3*	12.5 ± 2.5	14.9 ± 3.5*
Fecundity	40 ± 2.5	34 ± 2.5*	44 ± 2	30 ± 2.5*

* Statistically significant using Mann- Whitney ‘t’ Test with $p < 0.05$

Table 17: Durations (in days) of different life stages of *Schizotetranychus schizopus* and *Tetranychus urticae* at two different temperature and relative humidity conditions. Mean (± SEM) (n= 30)

Developmental Stages	*Schizotetranychus schizopus*		*Tetranychus urticae*	
	30 ± 2° C and 70± 5%	20 ± 2°C and 80 ± 5%	30 ± 2° C and 70± 5%	20 ± 2°C and 80 ± 5%
Egg	4.3 ± 0.04	6 ± 0.03*	4.1 ± 0.23	5.28 ± 2.1*
Larva	1.6 ± 0.02	1.8 ± 0.05*	1.9 ± 0.03	2.56 ± 0.07*
Protochrysalis	0.3 ± 0.06	0.8 ± 0.03*	0.9 ± 0.02	0.9 ± 0.76*
Protonymph	1.5 ± 0.07	1.6 ± 0.03*	2.1 ± 0.08	2.23 ± 0.06*
Deutochrysalis	0.4 ± 0.02	0.8 ± 0.02*	0.46 ± 2.34	0.9 ± 0.83*
Deutonymph	1.5 ± 0.03	1.6 ± 0.04*	2.4 ± 0.06	2.75 ± 0.08*
Teliochrysalis	1 ± 0.02	1.1 ± 0.06*	0.42 ± 1.23	0.75 ± 1.43*
Egg to adult	10.6 ± 0.16	12.9 ± 0.08*	11.5 ± 0.25	13.1 ± 0.24*
Egg to egg	12.8 ± 0.12	15.3 ± 0.01*	13.8 ± 0.12	15.5 ± 0.57*

* Statistically significant using Mann- Whitney ‘t’ Test with $p < 0.05$

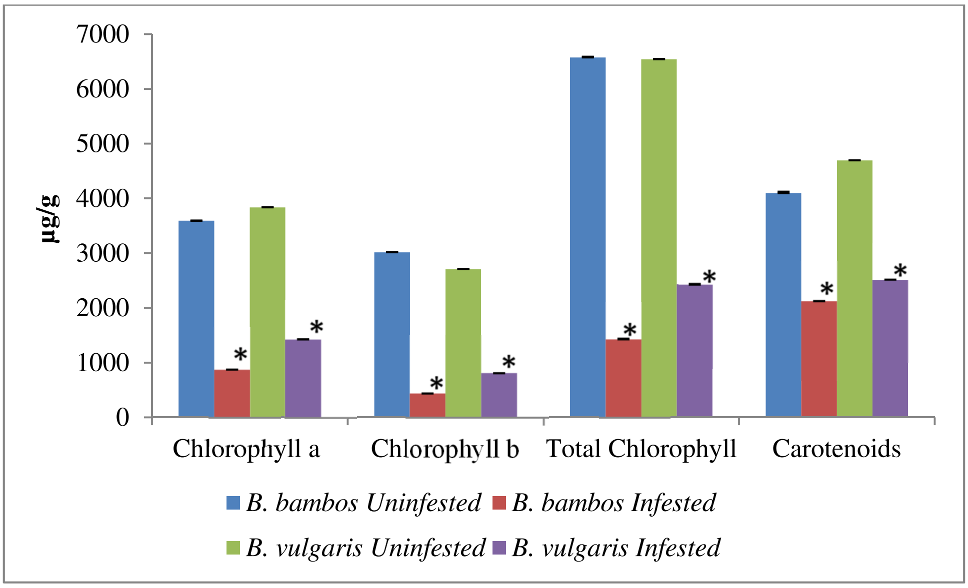
Table 18: Durations (in days) of different life stages of *Schizotetranychus schizopus* and *Tetranychus urticae* at two different temperature and relative humidity conditions under parthenogenetic mode of reproduction Mean (± SEM) (n= 30).

Developmental Stages	*Schizotetranychus schizopus*		*Tetranychus urticae*	
	30 ± 2° C and 70± 5%	20 ± 2° C and 80 ± 5%	30 ± 2° C and 70± 5%	20 ± 2° C and 80 ± 5%
Egg	4 ± 0.02	5 ± 0.03*	3.5 ± 0.15	5 ± 2.25*
Larva	1.6 ± 0.02	1.8 ± 0.05*	1.9 ± 0.03	2.56 ± 0.07*
Protochrysalis	0.3 ± 0.06	0.8 ± 0.03*	0.9 ± 0.02	0.9 ± 0.76*
Protonymph	1 ± 0.45	1.2 ± 0.21*	2.1 ± 0.08	2.23 ± 0.06*
Deutochrysalis	0.4 ± 0.02	0.8 ± 0.02*	0.46 ± 2.34	0.75 ± 0.83*
Deutonymph	1.5 ± 0.03	1.6 ± 0.04*	2.2 ± 0.05	2.75 ± 0.08*
Teliochrysalis	1 ± 0.02	1.1 ± 0.06*	0.42 ± 1.23	0.75 ± 1.43*
Egg to adult	10.2 ± 0.16	11.9 ± 0.32*	10.5 ± 0.5	12.1 ± 0.5*
♂ longevity	8 ± 0.5	9.52 ± 0.5*	7.5 ± 2.4	9 ± 2.5*

* Statistically significant using Mann- Whitney ‘t’ Test with $p < 0.05$

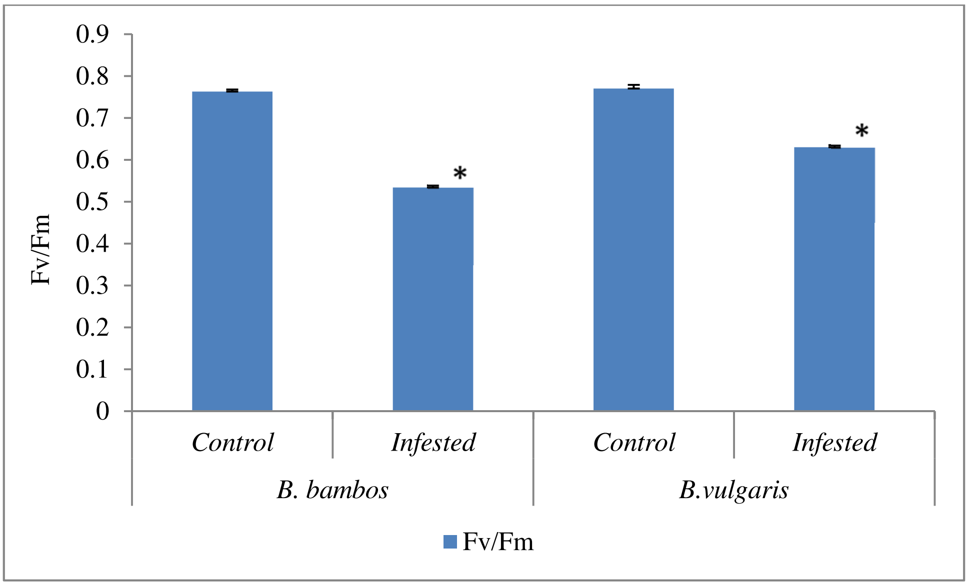
PLATE 63

Fig 70: Concentration of photosynthetic pigments (Chlorophyll a, b, Total Chlorophyll and Carotenoids) in uninfested and *Schizotetranychus schizopus* infested leaves of *Bambusa bambos* and *Bambusa vulgaris*.Mean ± SEM (n= 9)



*Statistically significant using Mann- Whitney 't' Test with $p < 0.05$

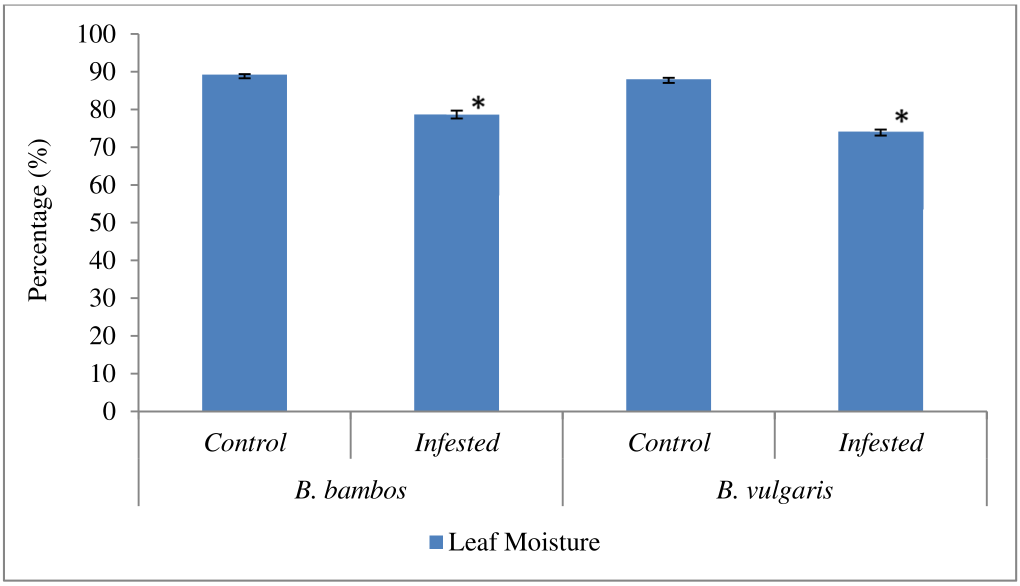
Fig 71: Fv/Fm values recorded for uninfested and *Schizotetranychus schizopus* infested leaves of *Bambusa bambos* and *Bambusa vulgaris*. Mean ± SEM (n= 9)



*Statistically significant using Mann- Whitney 't' Test with $p < 0.05$

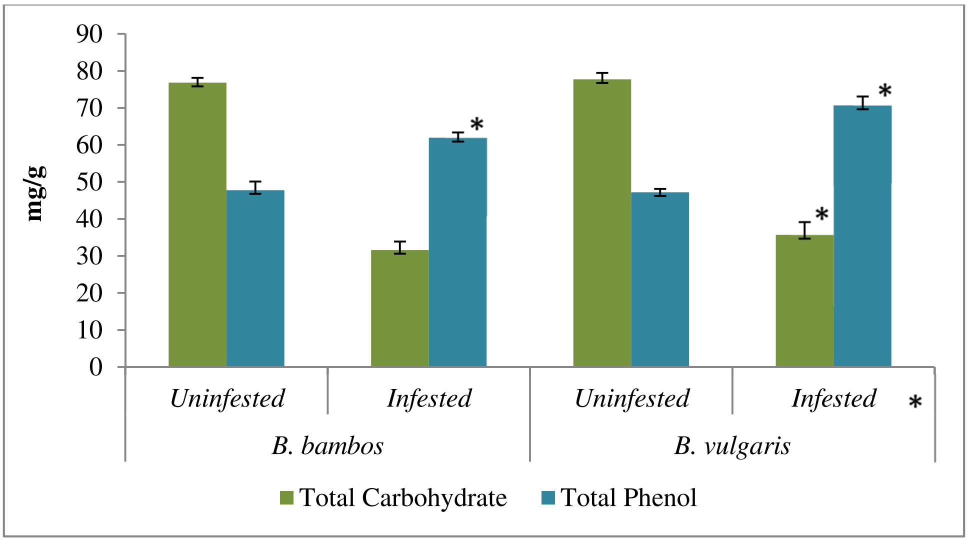
PLATE 64

Fig 72: Leaf Moisture content in uninfested and *Schizotetranychus schizopus* infested leaves of *Bambusa bambos* and *Bambusa vulgaris*. Mean ± SEM (n= 9)



*Statistically significant using Mann- Whitney 't' Test with $p < 0.05$

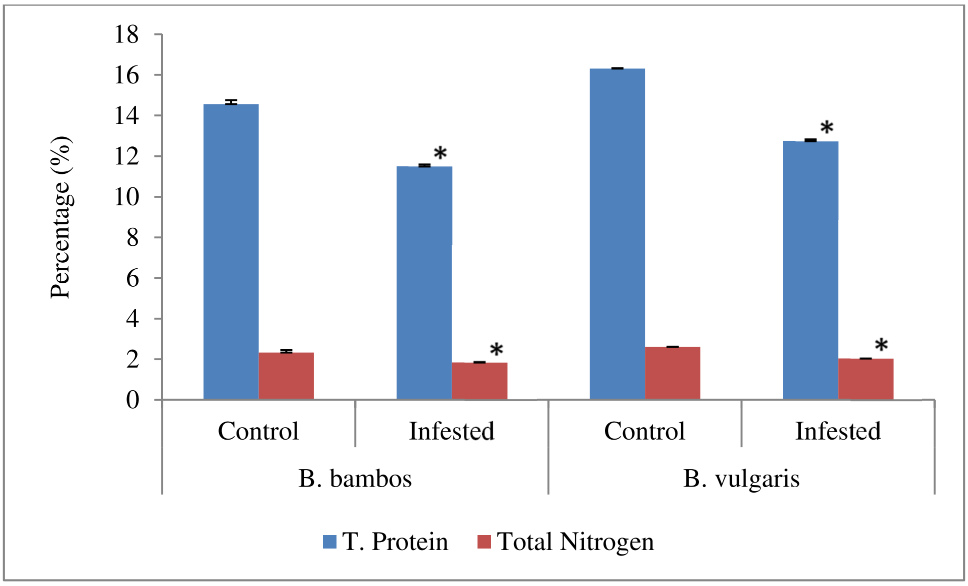
Fig 73: Concentration of Total Carbohydrate and Total Phenol in uninfested and *Schizotetranychus schizopus* infested leaves of *Bambusa bambos* and *Bambusa vulgaris*. Mean ± SEM (n= 9)



*Statistically significant using Mann- Whitney 't' Test with $p < 0.05$

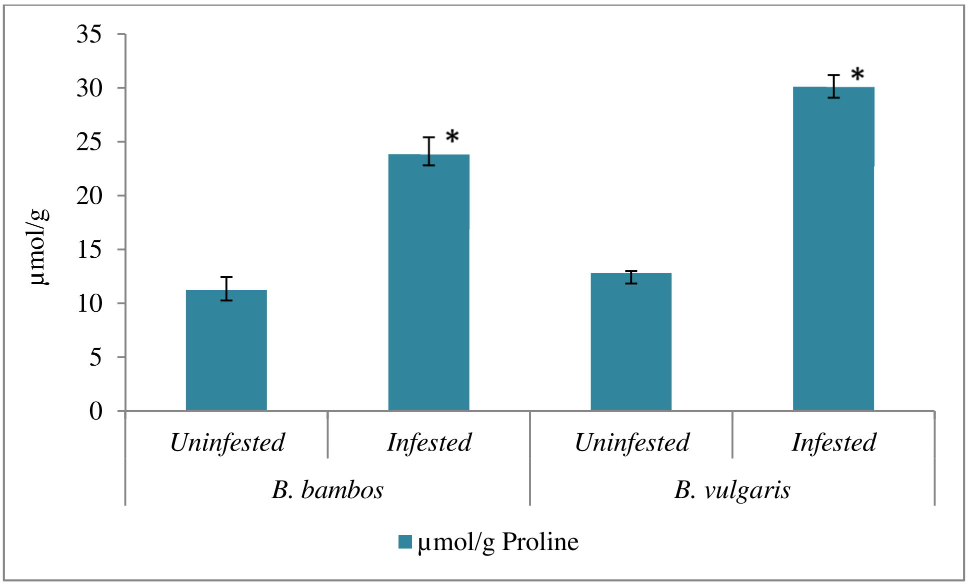
PLATE 65

Fig 74: Concentration of Total Nitrogen and Total Protein in uninfested and *Schizotetranychus schizopus* infested leaves of *Bambusa bambos* and *Bambusa vulgaris*. Mean ± SEM (n= 9).



*Statistically significant using Mann- Whitney 't' Test with $p < 0.05$

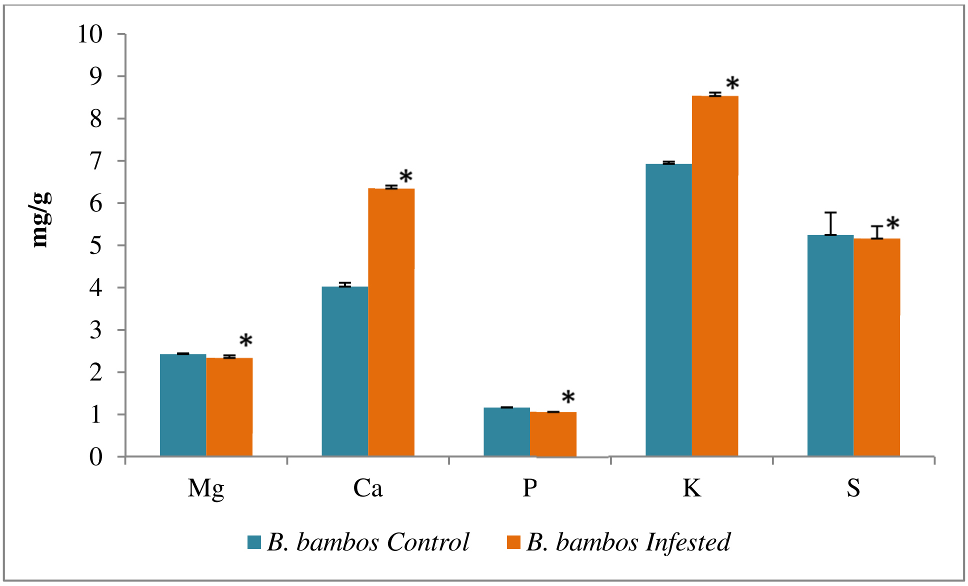
Fig 75: Concentration of Proline in uninfested and *Schizotetranychus schizopus* infested leaves of *Bambusa bambos* and *Bambusa vulgaris*. Mean ± SEM (n= 9).



*Statistically significant using Mann- Whitney 't' Test with $p < 0.05$

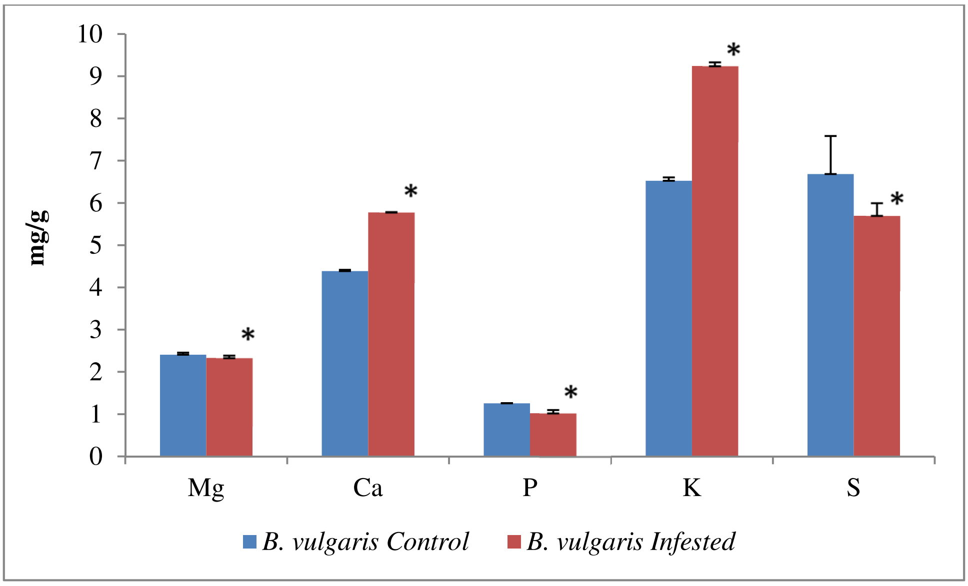
PLATE 66

Fig 76: Concentration of macronutrients in uninfested and *Schizotetranychus schizopus* infested leaves of *Bambusa bambos*. Mean ± SEM (n= 9)



*Statistically significant using Mann- Whitney ‘t’ Test with $p < 0.05$

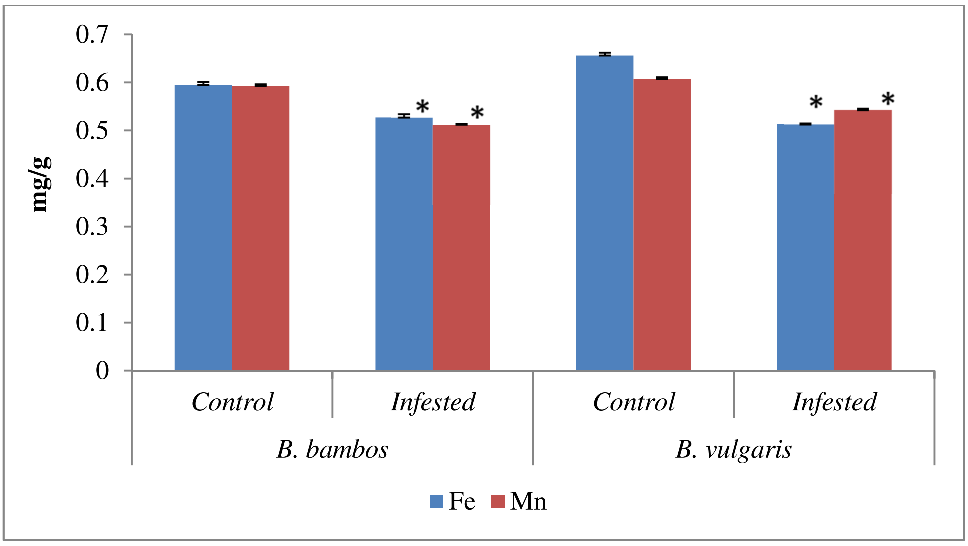
Fig 77: Concentration of macronutrients in uninfested and *Schizotetranychus schizopus* infested leaves of *Bambusa vulgaris*. Mean ± SEM (n= 9)



*Statistically significant using Mann- Whitney ‘t’ Test with $p < 0.05$

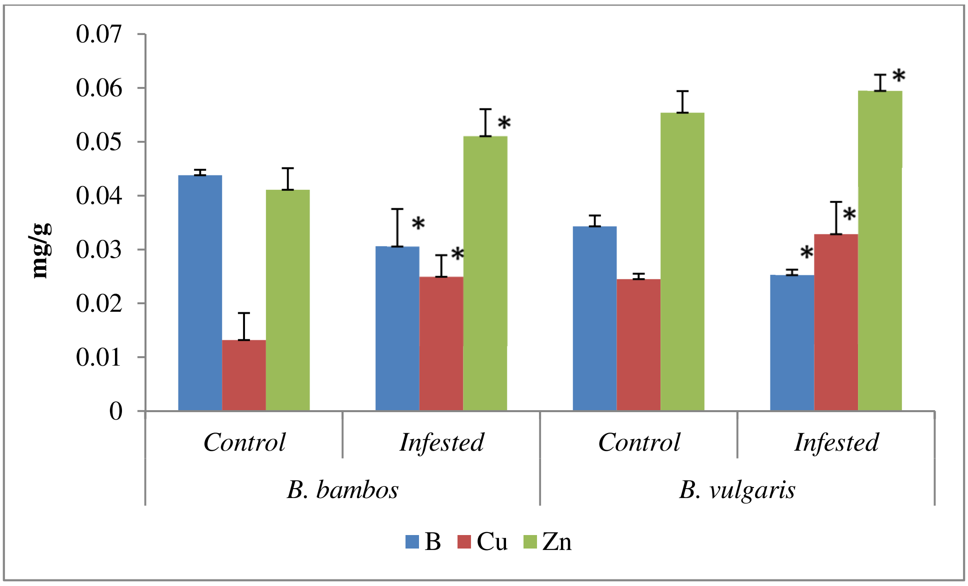
PLATE 67

Fig 78: Concentration of micronutrients (Iron and Manganese) in uninfested and *Schizotetranychus schizopus* infested leaves of *Bambusa bambos* and *Bambusa vulgaris*. Mean ± SEM (n= 9)



*Statistically significant using Mann- Whitney 't' Test with $p < 0.05$

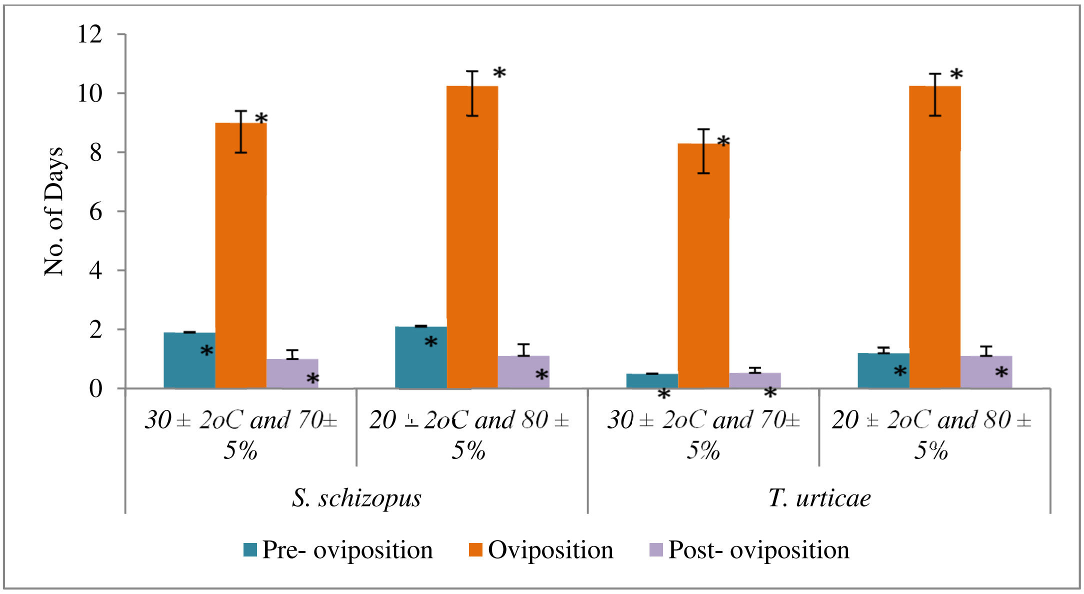
Fig 79: Concentration of micronutrients (Boron, Copper and Zinc) in uninfested and *Schizotetranychus schizopus* infested leaves of *Bambusa bambos* and *Bambusa vulgaris*. Mean ± SEM (n= 9)



*Statistically significant using Mann- Whitney 't' Test with $p < 0.05$

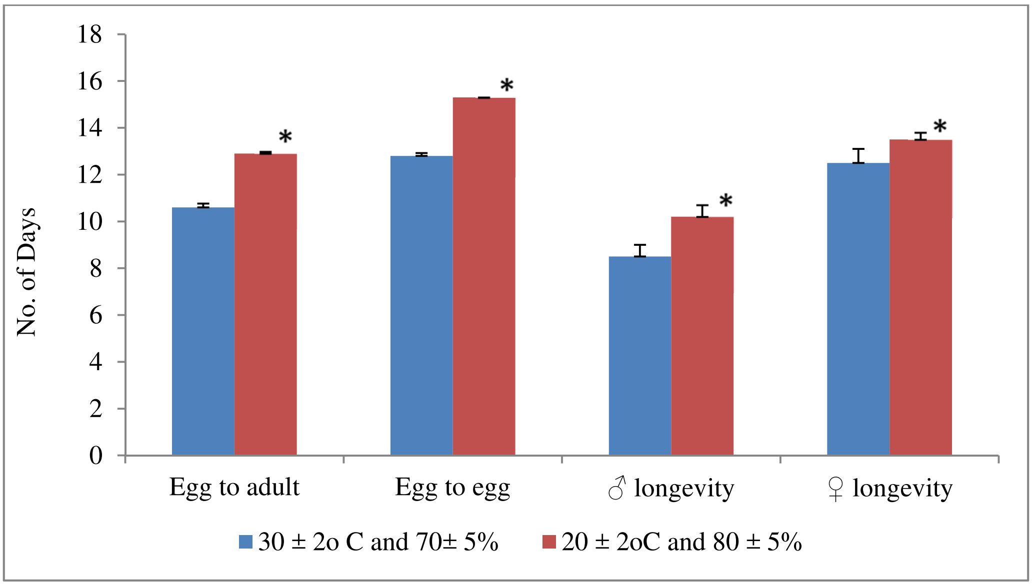
PLATE 68

Fig 80: Impact of different Temperature- humidity conditions on durations of preoviposition, oviposition and postoviposition periods of *Schizotetranychus schizopus* and *Tetranychus urticae*. Mean ± SEM (n= 30)



*Statistically significant using Mann- Whitney ‘t’ Test with $p < 0.05$

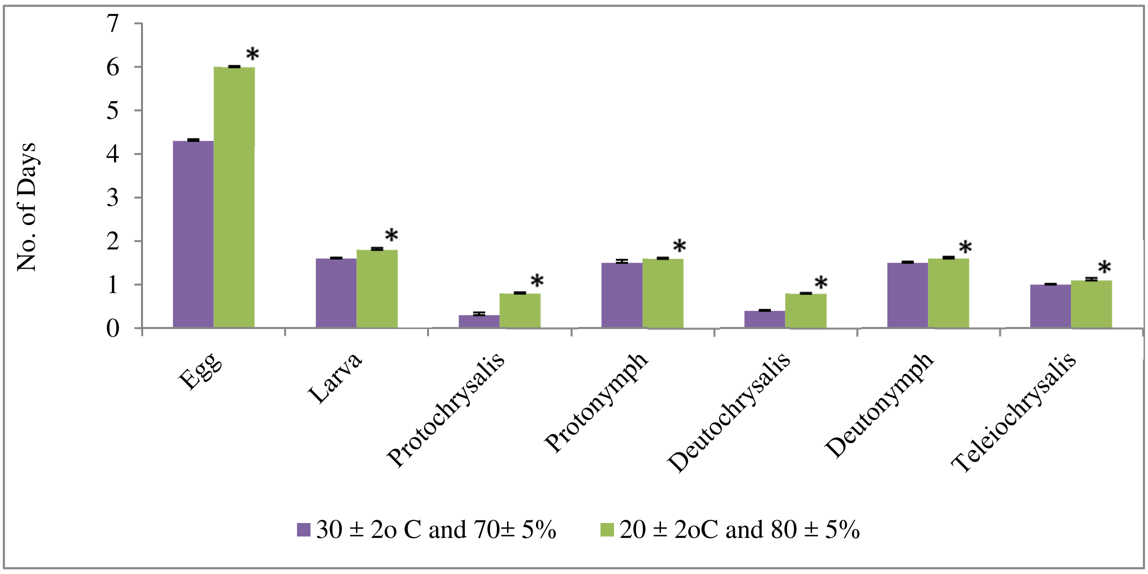
Fig 81: Impact of varied Temperature- humidity conditions on durations of life stages (egg to adult, egg to egg and longevity) of *Schizotetranychus schizopus*. Mean ± SEM (n= 30)



*Statistically significant using Mann- Whitney ‘t’ Test with $p < 0.05$

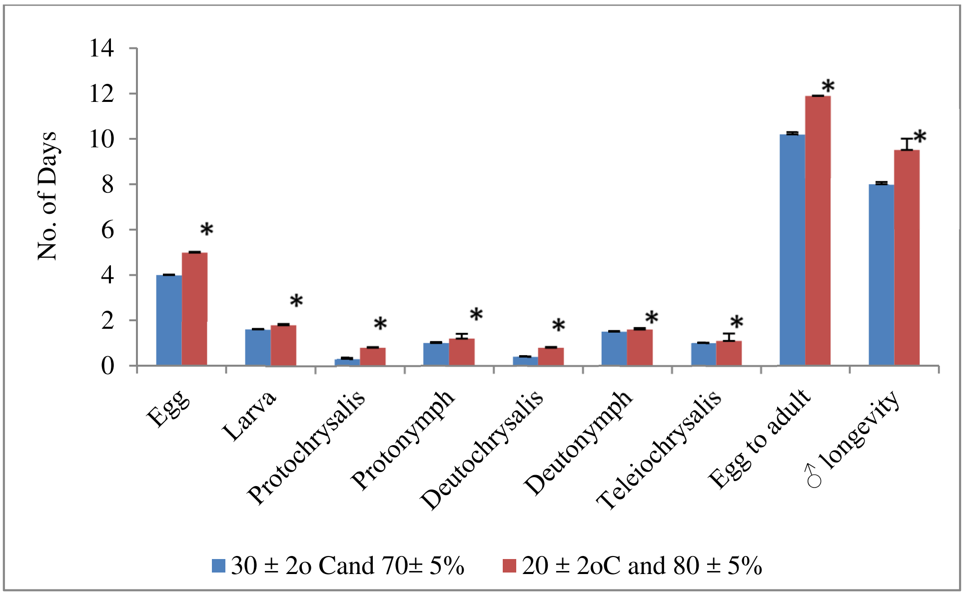
PLATE 69

Fig 82: Impact of varied Temperature- humidity conditions on durations of life stages of *Schizotetranychus schizopus* (under sexual mode or reproduction), Mean ± SEM (n= 30)



*Statistically significant using Mann- Whitney 't' Test with $p < 0.05$

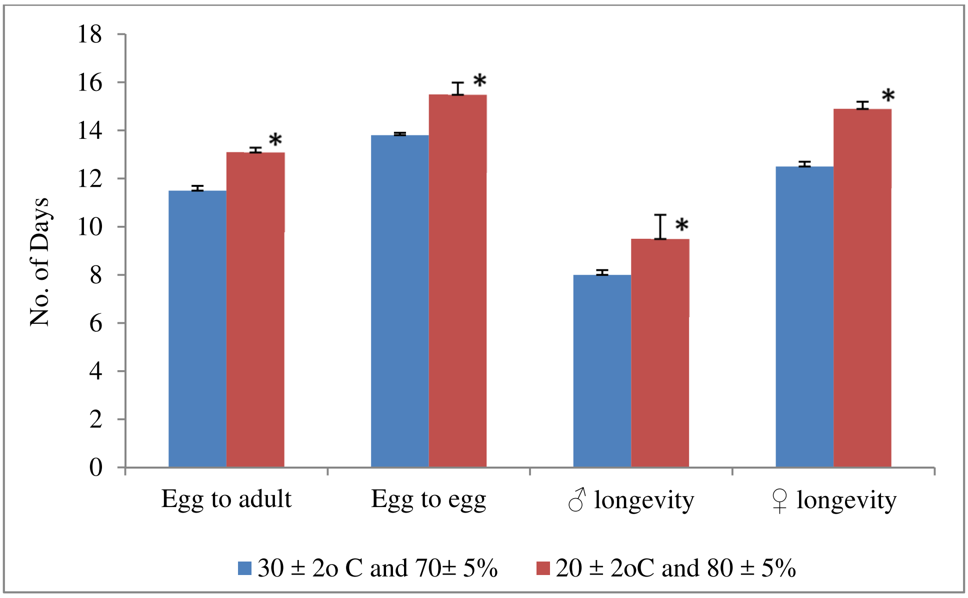
Fig 83: Impact of varying Temperature- humidity conditions on duration of life stages of *Schizotetranychus schizopus* (under parthenogenetic mode of reproduction). Mean ± SEM (n= 30)



*Statistically significant using Mann- Whitney 't' Test with $p < 0.05$

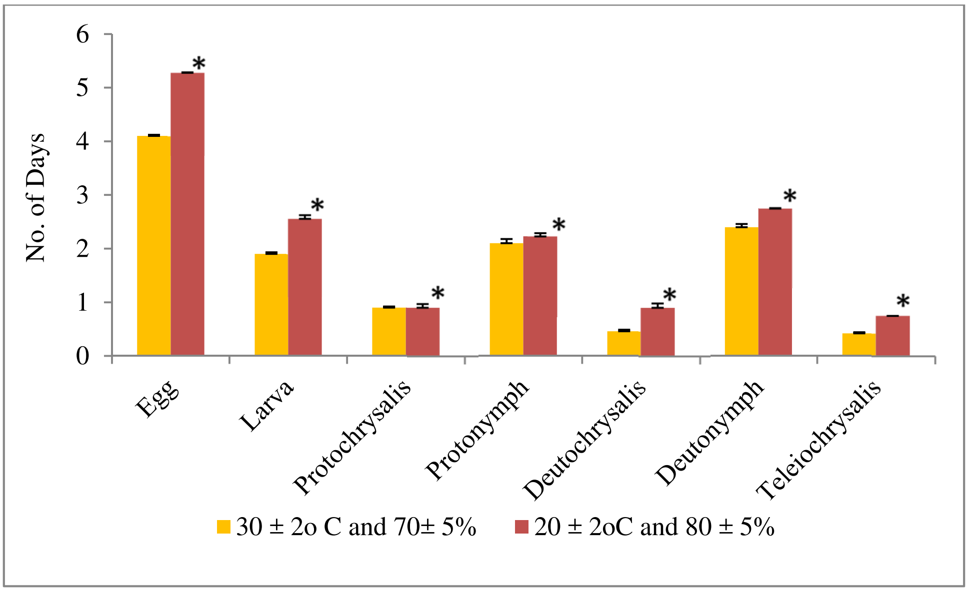
PLATE 73

Fig 86: Impact of varied Temperature- humidity conditions on durations of life stages (egg to adult, egg to egg and longevity) of *Tetranychus urticae*. Mean ± SEM (n= 30)



*Statistically significant using Mann- Whitney 't' Test with $p < 0.05$

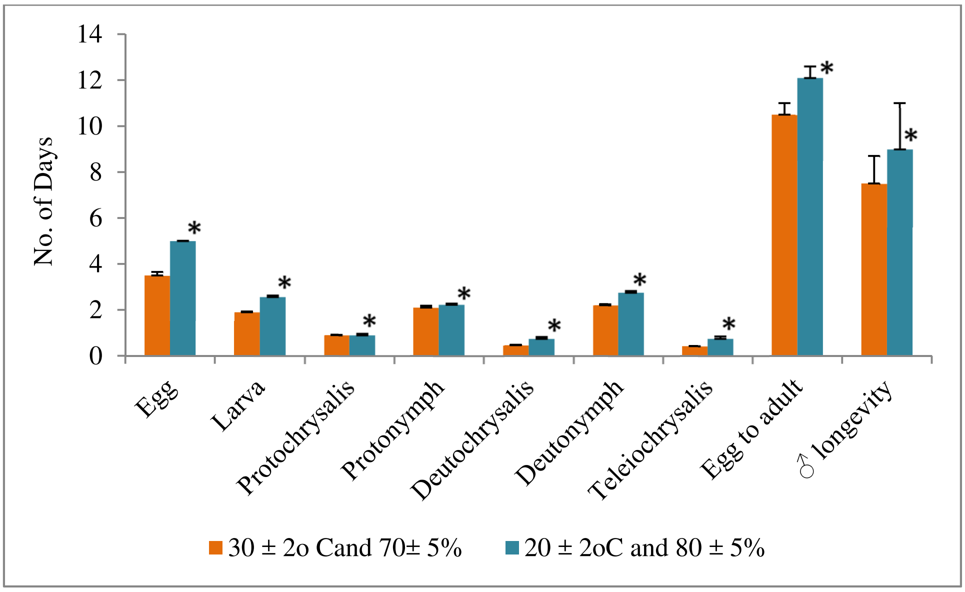
Fig 87: Impact of varied Temperature- humidity conditions on durations of life stages of *Tetranychus urticae* (under sexual mode or reproduction), Mean ± SEM (n= 30)



*Statistically significant using Mann- Whitney 't' Test with $p < 0.05$

PLATE 74

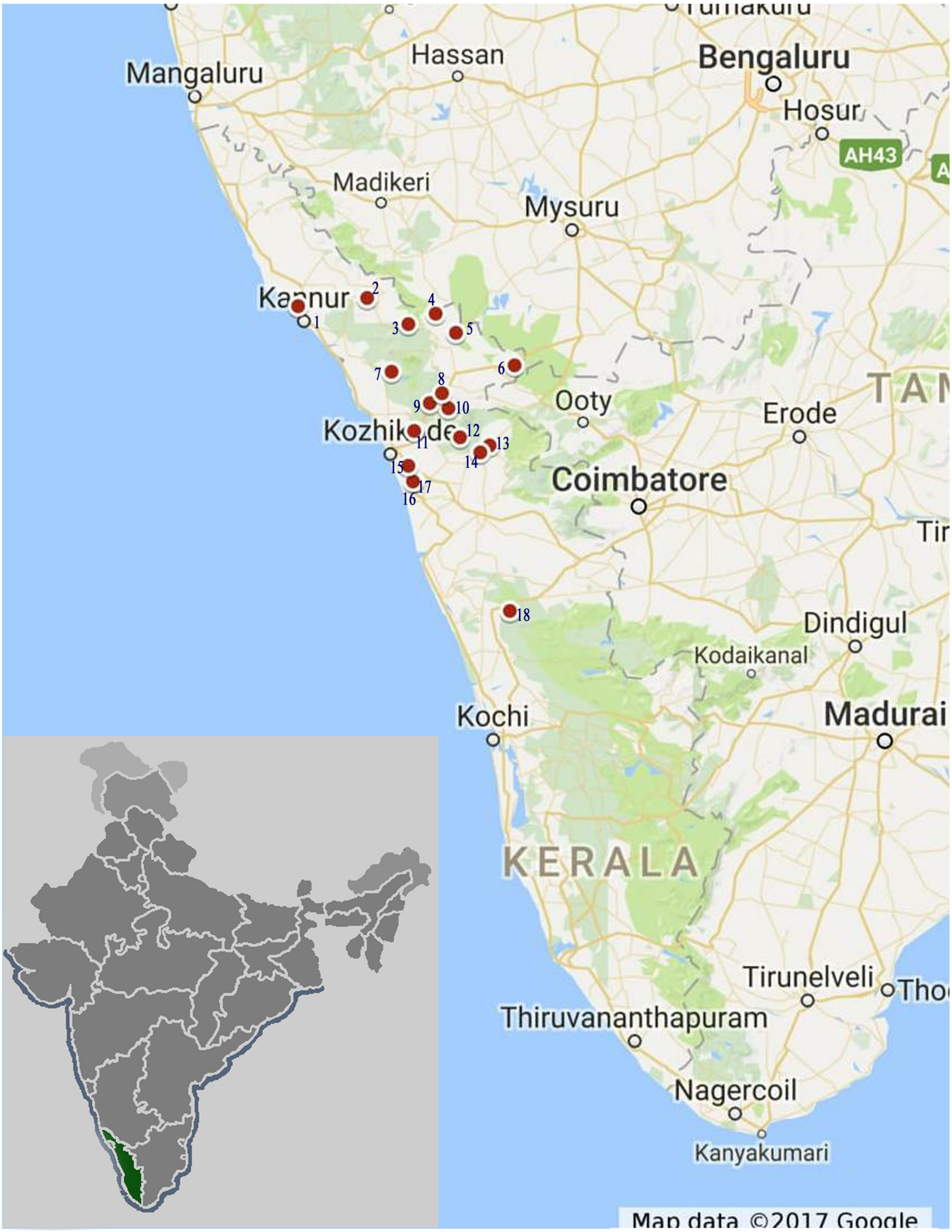
Fig 88: Impact of varying Temperature- humidity conditions on duration of life stages of *Tetranychus urticae* (under parthenogenetic mode of reproduction) Mean ± SEM (n= 30)



*Statistically significant using Mann- Whitney ‘t’ Test with $p < 0.05$

PLATE 1

Map of Kerala showing study sites



1. Pappinisseri , 2. Iritty , 3. Kottiyoor , 4. Thirunelli , 5. Kuruvadweep , 6. Muthanga Wildlife Sanctuary, 7. Janakikkad, 8. Pookode Lake, 9. Vanaparvam Biodiversity Park, 10. Thusharagiri, 11. VMK Botanical Garden, 12. Kakkadampoyil, 13. Nilambur Teak Museum, 14.Canolly's Plot, 15.The Raviz Resort, Kadavu, 16.Villooniyal, 17.University of Calicut Campus, 18. Velupadam (KFRI)

PLATE 3

Bamboo vegetation in the study site

Bambusa bambos

Bambusa multiplex

Dendrocalamus strictus

Bambusa tulda

Bambusa pallida

Bambusa vulgaris

PLATE 4

Mites found in association with bamboos

Aponychus corpuzae Rimando, 1996

Stylophoronychus vannus (Rimando,1968)

Tydeus interruptus SigThor, 1932

Oligonychus biharensis (Hirst,1924)

PLATE 5

Mites found in association with bamboos

Cheyletus rosensis Mary Anitha and Ramani, 2009

Amblyseius largoensis (Muma, 1955)

Aceria bambusae Channabasavanna, 1966

Schizotetranuchus schizopus (Zacher,1913)

PLATE 18

Amblyseius aerialis (Muma, 1955)

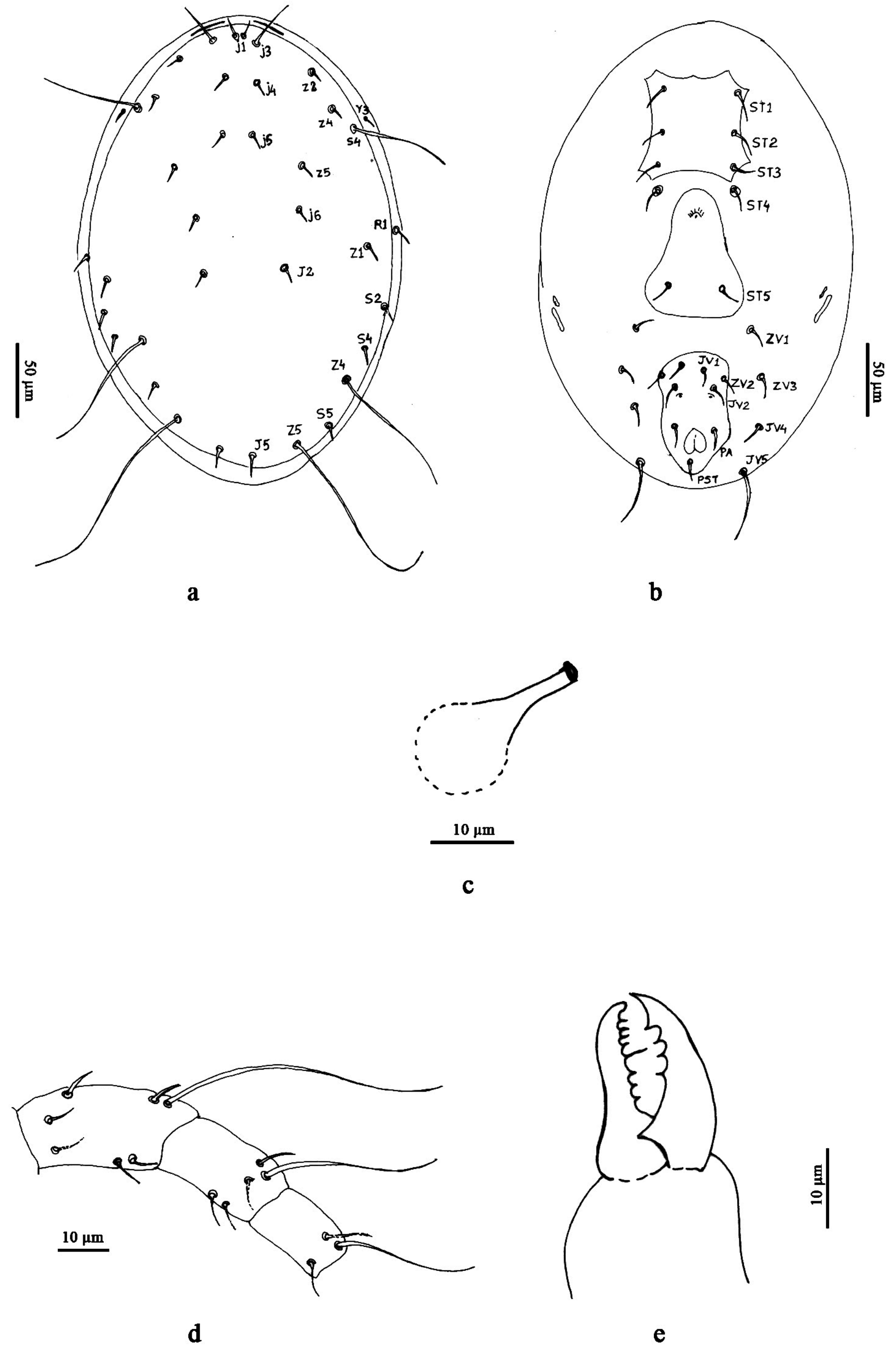


Fig. 25 : *Amblyseius aerialis* (Muma, 1955) ; a-dorsal; b- ventral; c-spermatheca; d- IVth leg; e- chelicera

PLATE 19

Amblyseius bhadrakshae Mary Anitha and Ramani, 2006

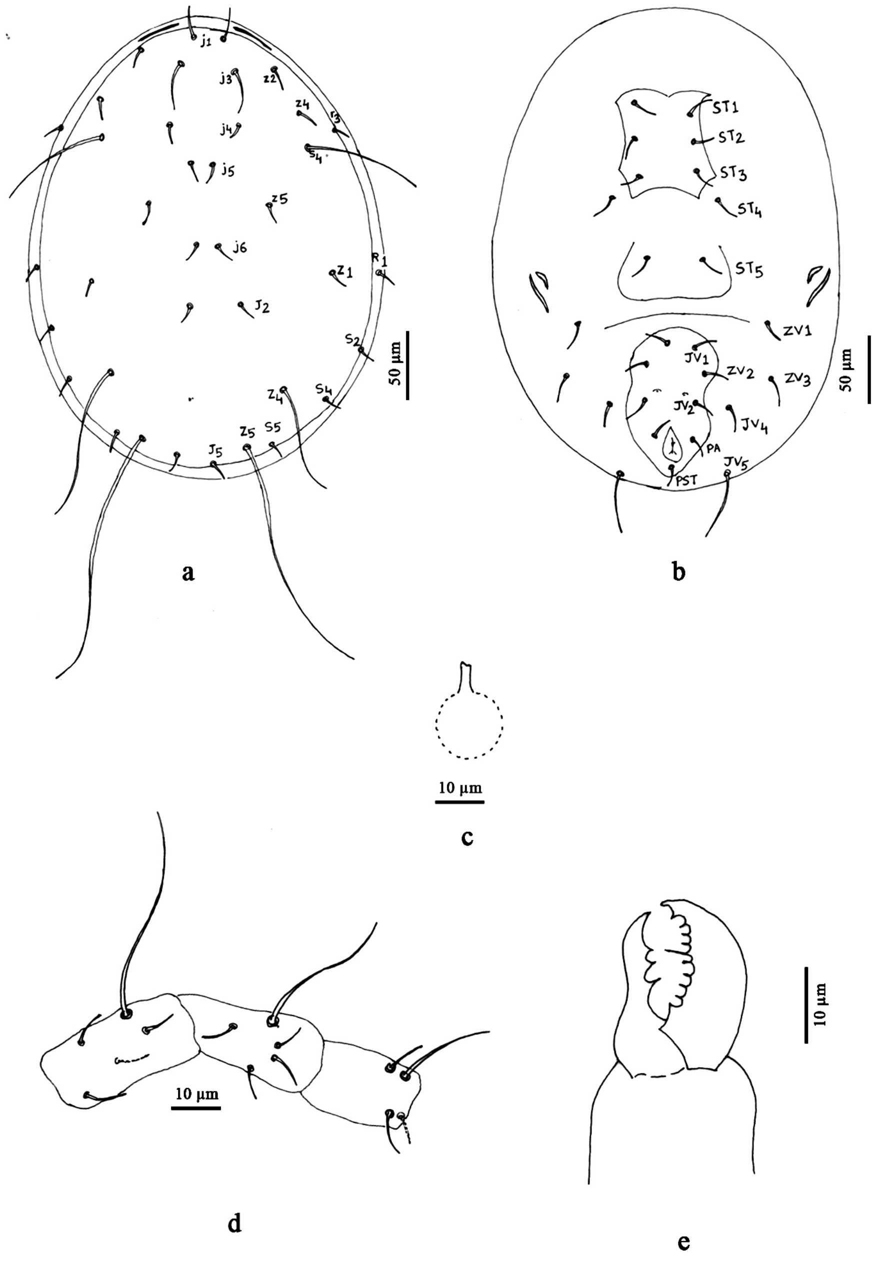


Fig. 26 : *Amblyseius bhadrakshae* Mary Anitha and Ramani, 2006 ; a- dorsal; b-ventral; c- spermatheca; d- IVth leg; e- Chelicera

PLATE 20

Amblyseius channabasavannai Gupta and Daniel, 1978

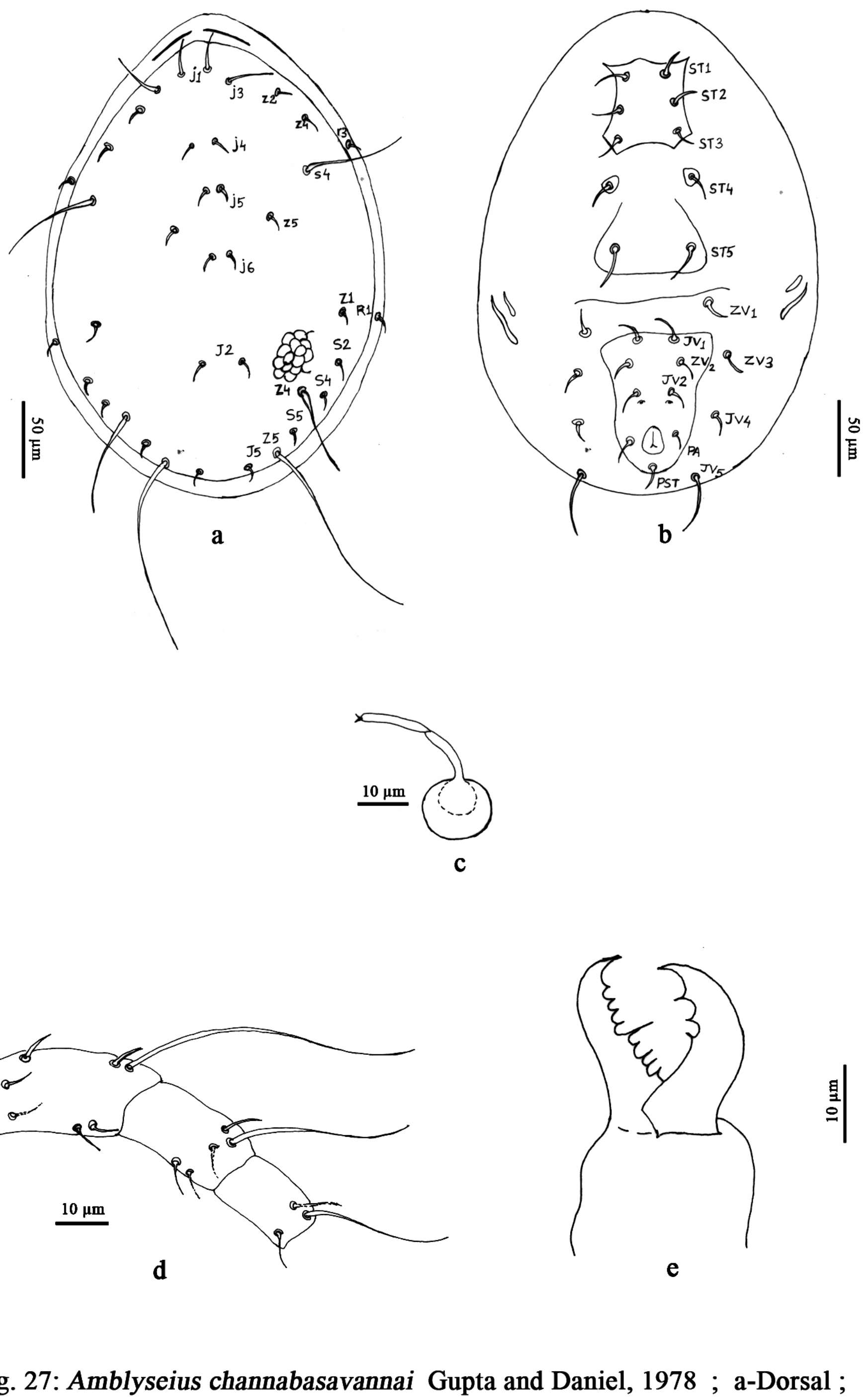


Fig. 27: *Amblyseius channabasavannai* Gupta and Daniel, 1978 ; a-Dorsal ; b- ventral; c- Spermatheca; d- IVth leg; e- Chelicera

PLATE 21

Amblyseius kundurukkae Mary Anitha and Ramani, 2004

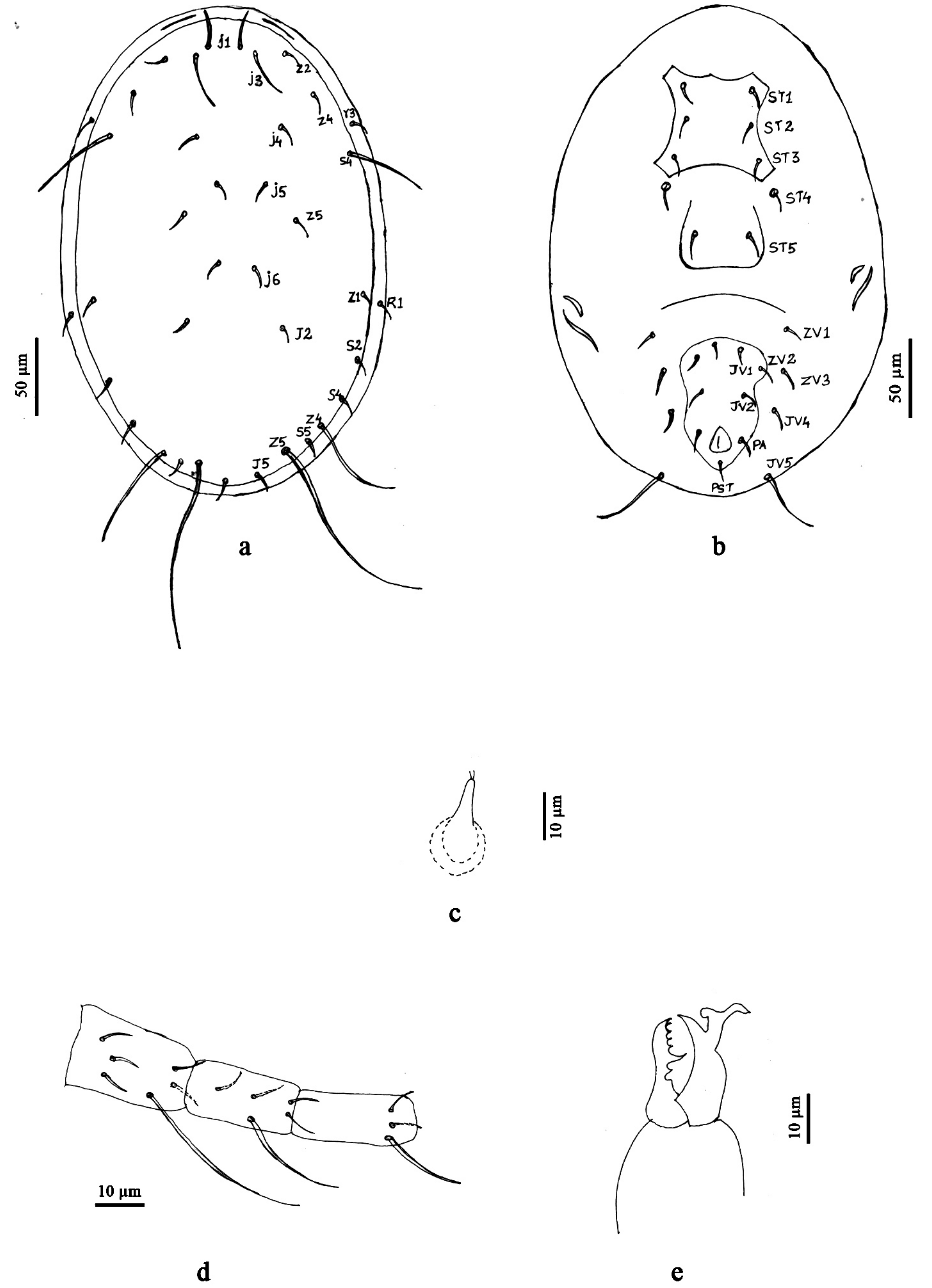


Fig. 28 : *Amblyseius kundurukkae* Mary Anitha and Ramani, 2004 : a-dorsal; b-ventral; c- spermatheca; d- IVth leg; e- spermatodactyl

PLATE 22

Amblyseius largoensis (Muma, 1955)

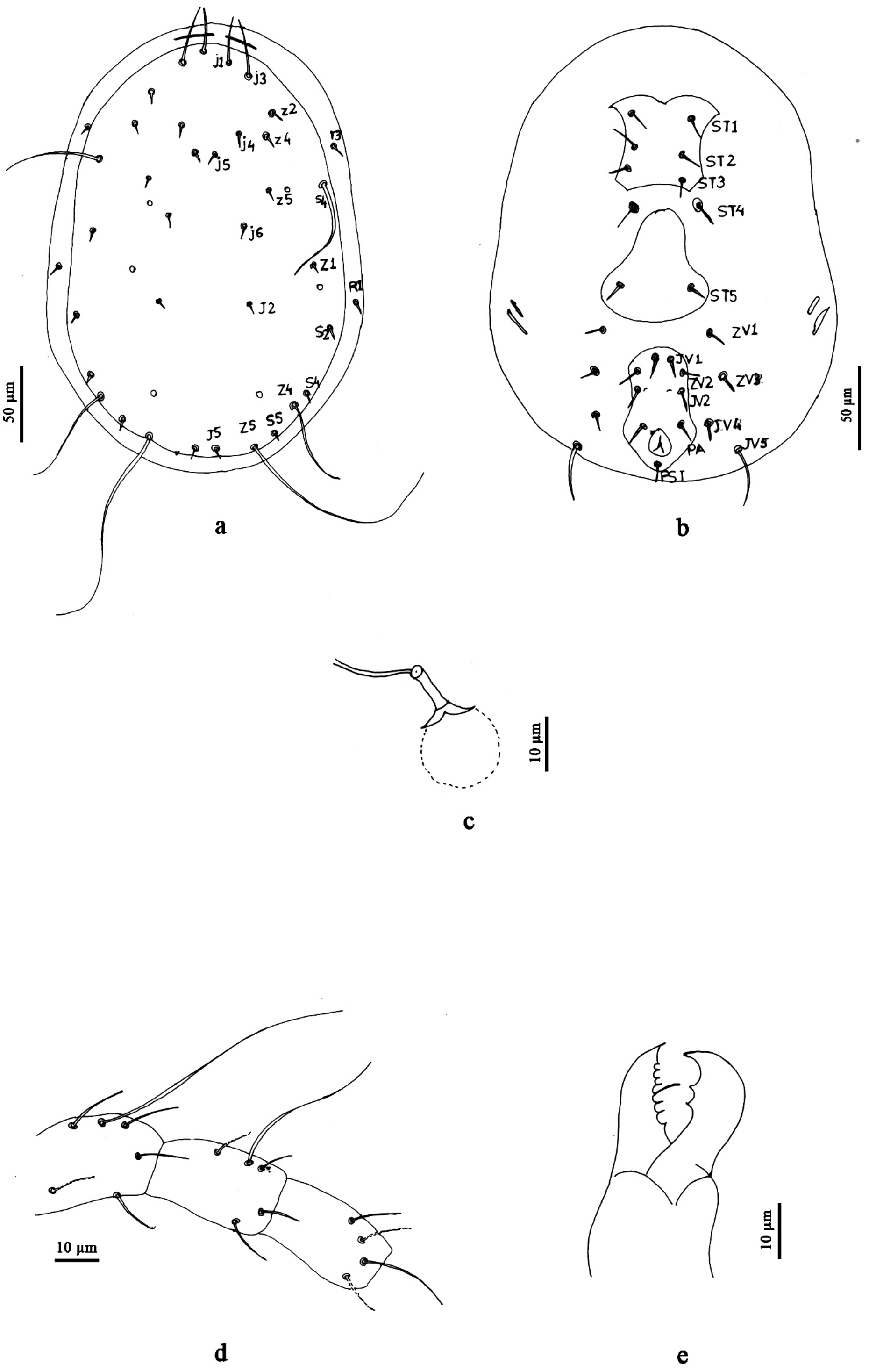


Fig. 29 : *Amblyseius largoensis* (Muma, 1955); a-dorsal; b-ventral ; c-spermatheca ; d- IVth leg ; e- chelicera

PLATE 23

Amblysieus malabarensis Mary Anitha and Ramani, 2004

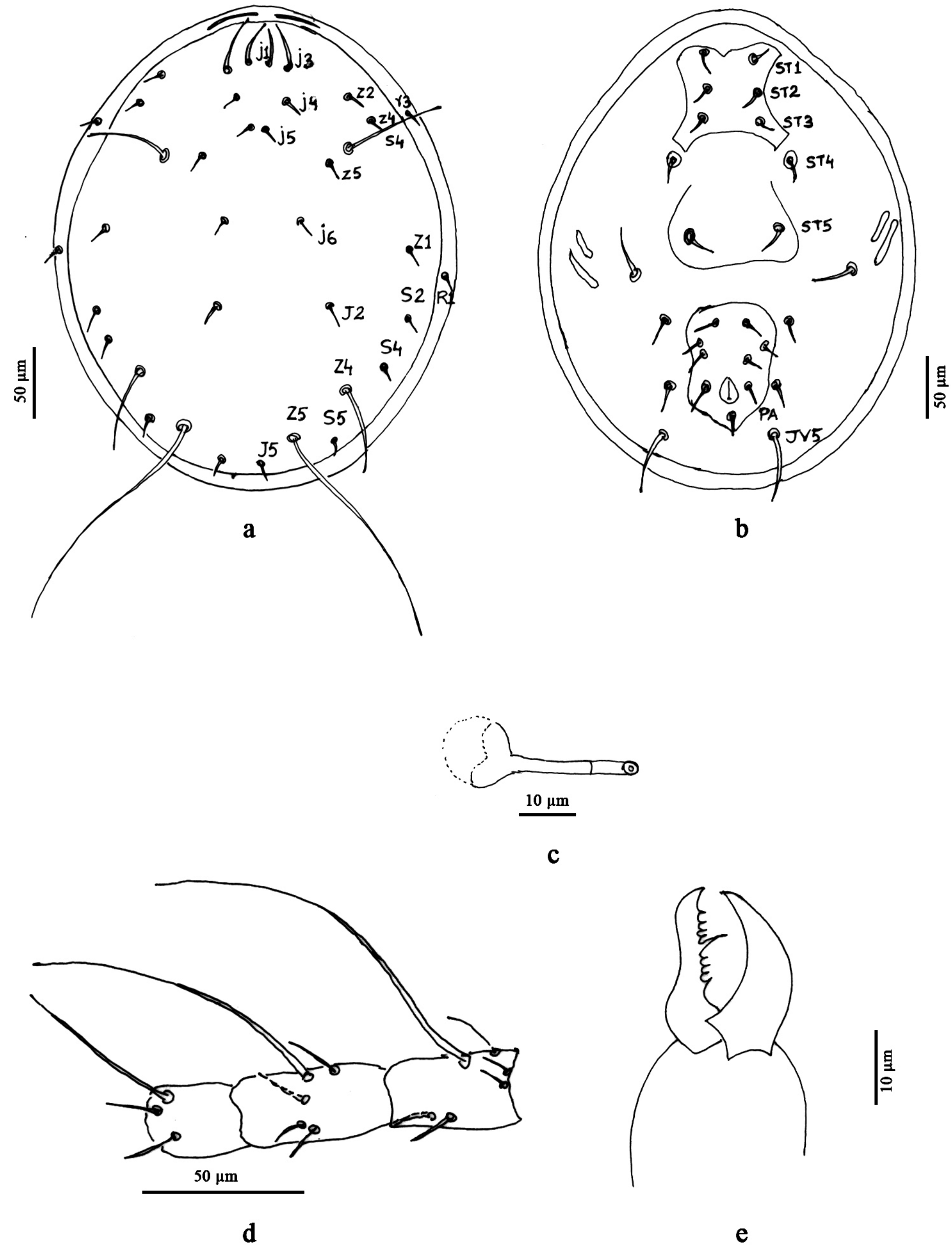


Fig. 30 : *Amblysieus malabarensis* Mary Anitha and Ramani, 2004 ; a-dorsal ; b- ventral; c- spermatheca; d- IVth leg; e- chelicera

PLATE 24

Amblyseius orientalis Ehara, 1959

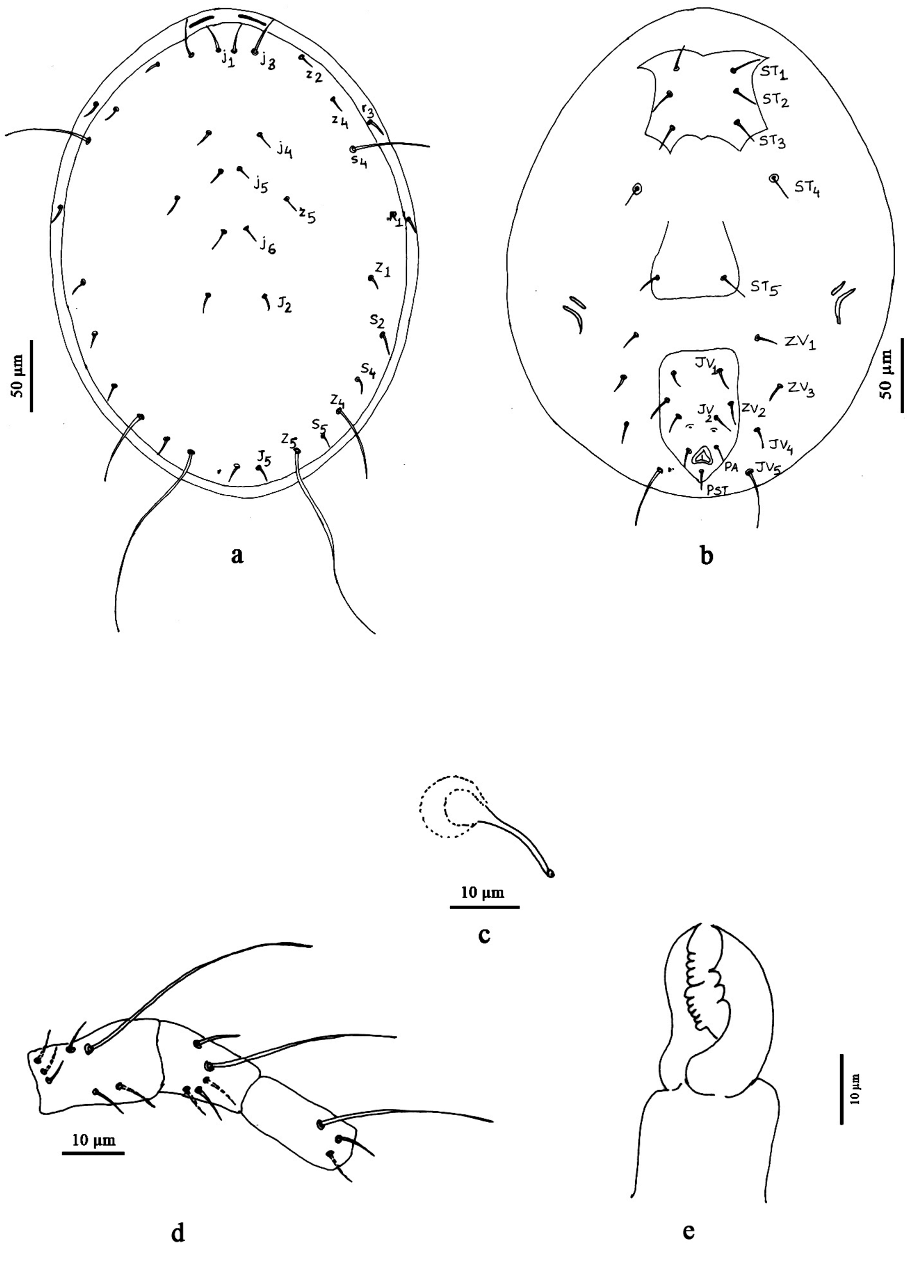


Fig. 31 : *Amblyseius orientalis* Ehara,1959, a-dorsal; b- ventral; c-spermatheca; d- IVth leg; e- chelicera

PLATE 25

Typhlodromalus sativae (Anithalatha and Ramani, 2009)

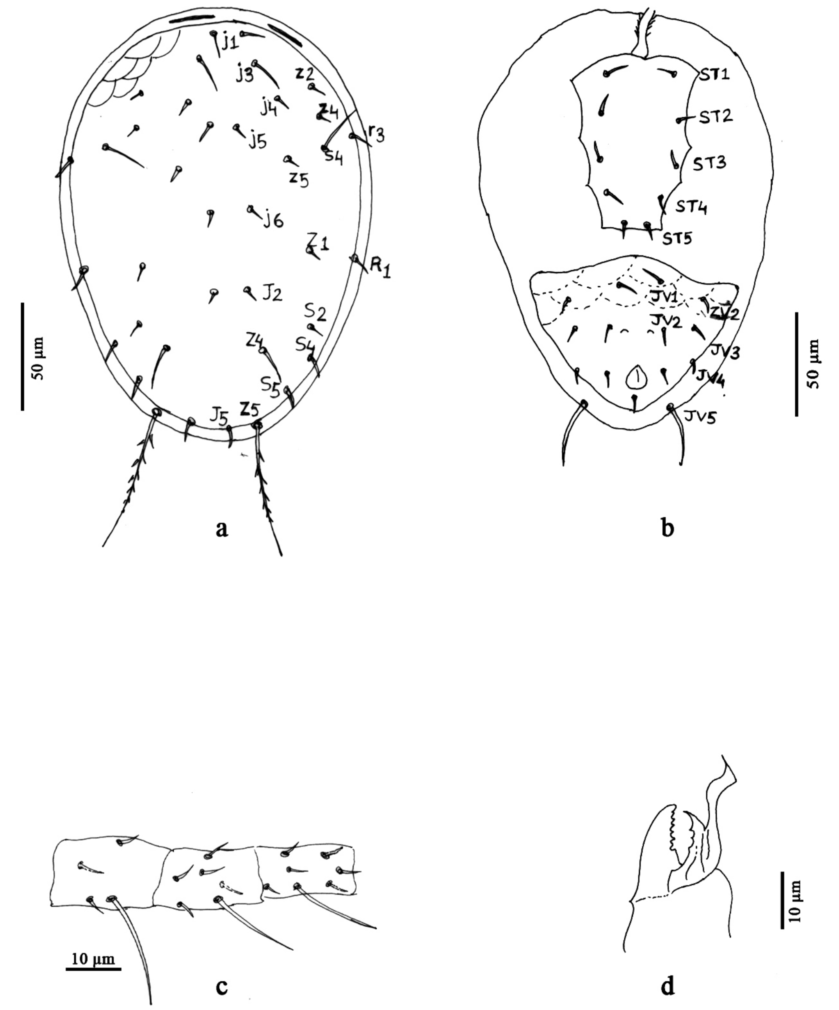


Fig. 32 : *Typhlodromalus sativae* (Anithalatha and Ramani, 2009); a-Dorsal; b-ventral; c-IVth leg; d- Spermatodactyl

PLATE 26

Phytoseius punicae Chinniah and Mohansundaram, 2001

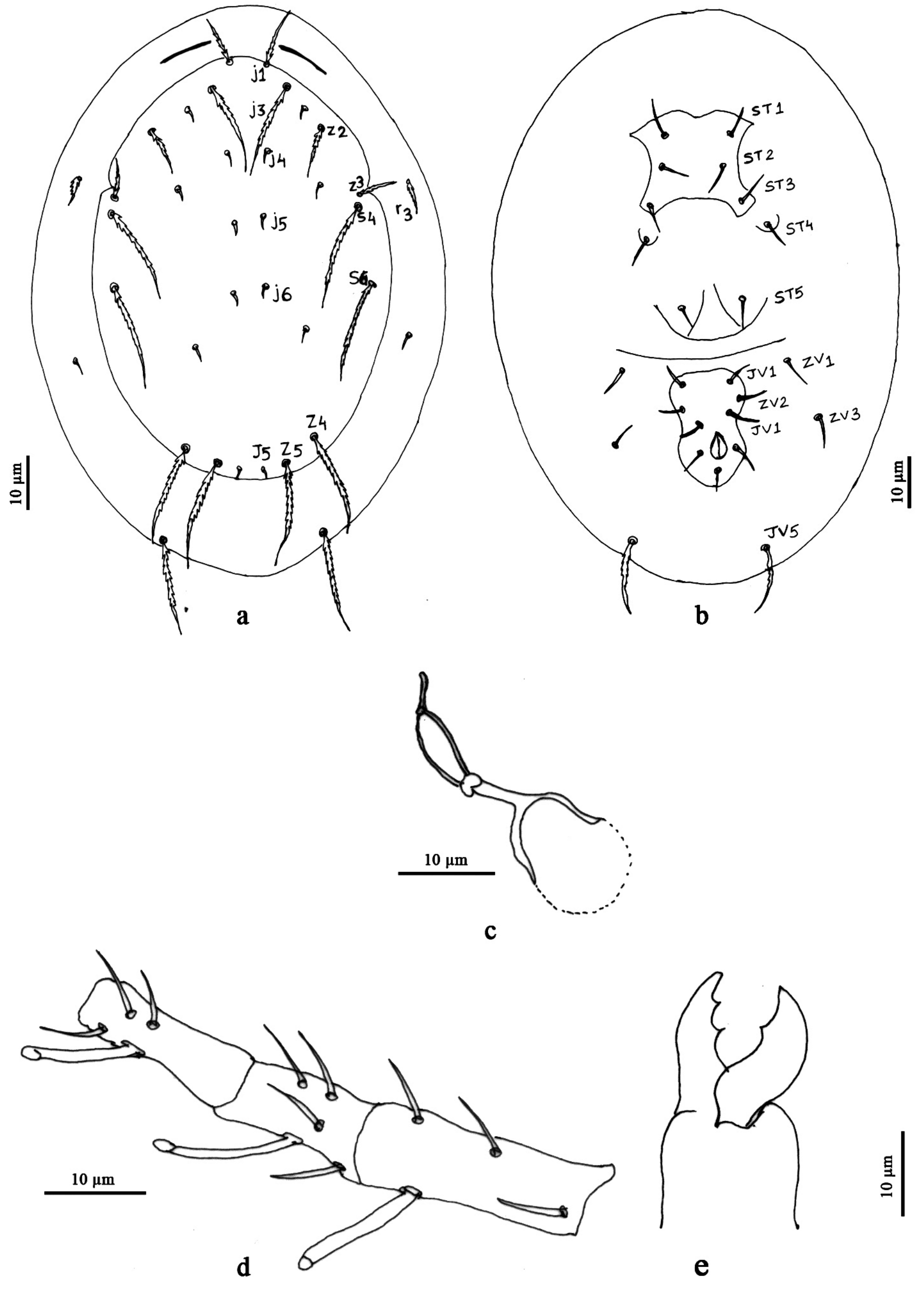


Fig. 33 : *Phytoseius punicae* Chinniah and Mohansundaram, 2001 ; a-dorsal; b-ventral; c- spermatheca; d- IVth leg; e- chelicera

PLATE 27

Paraphytoseius orientalis (Narayanan, Kaur and Ghai, 1960)

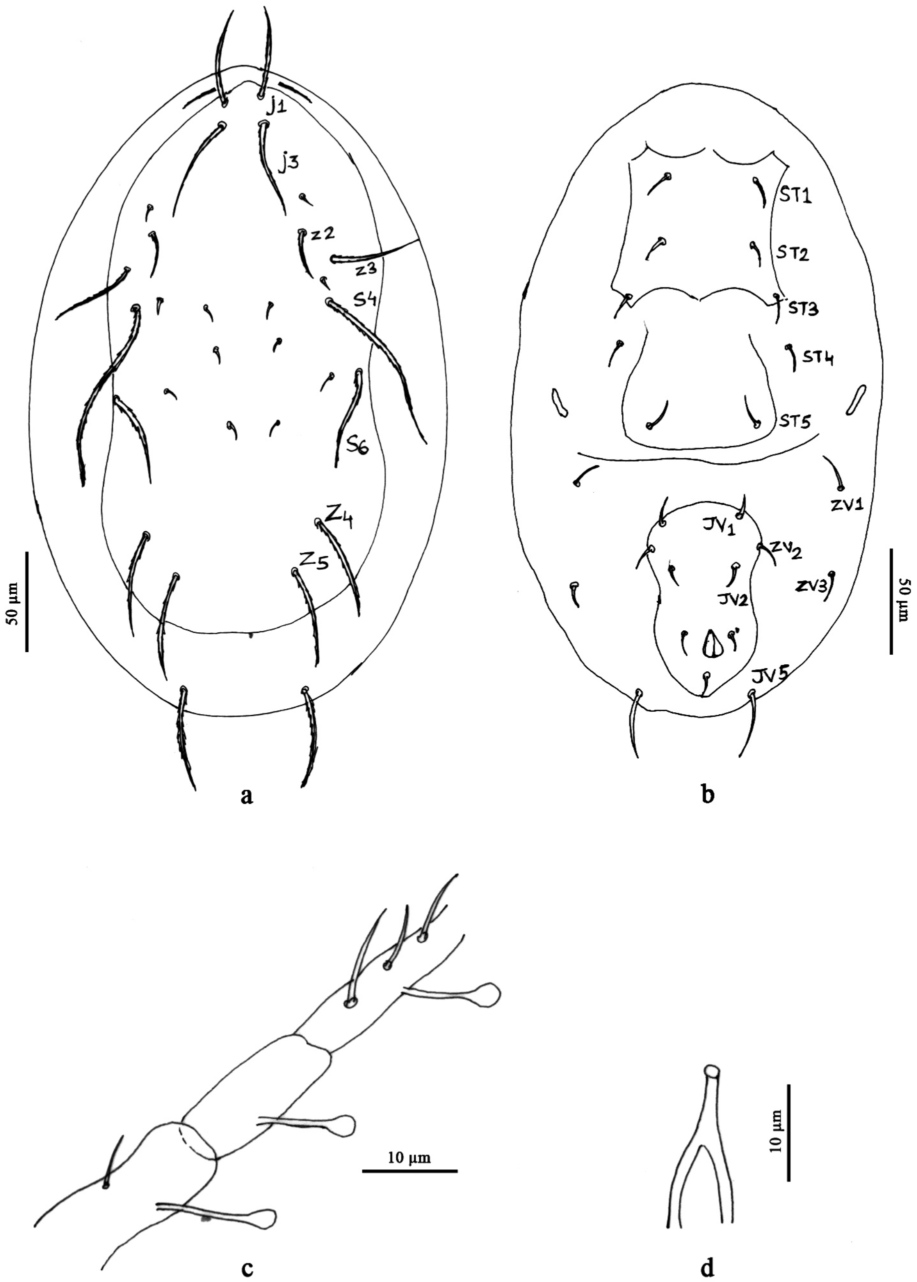


Fig. 34: *Paraphytoseius orientalis* (Narayanan, Kaur and Ghai, 1960); a-Dorsal; b- ventral; c- IV^th^ leg; d - Spermatheca

PLATE 28

Neoseiulus longispinosus (Evans, 1952)

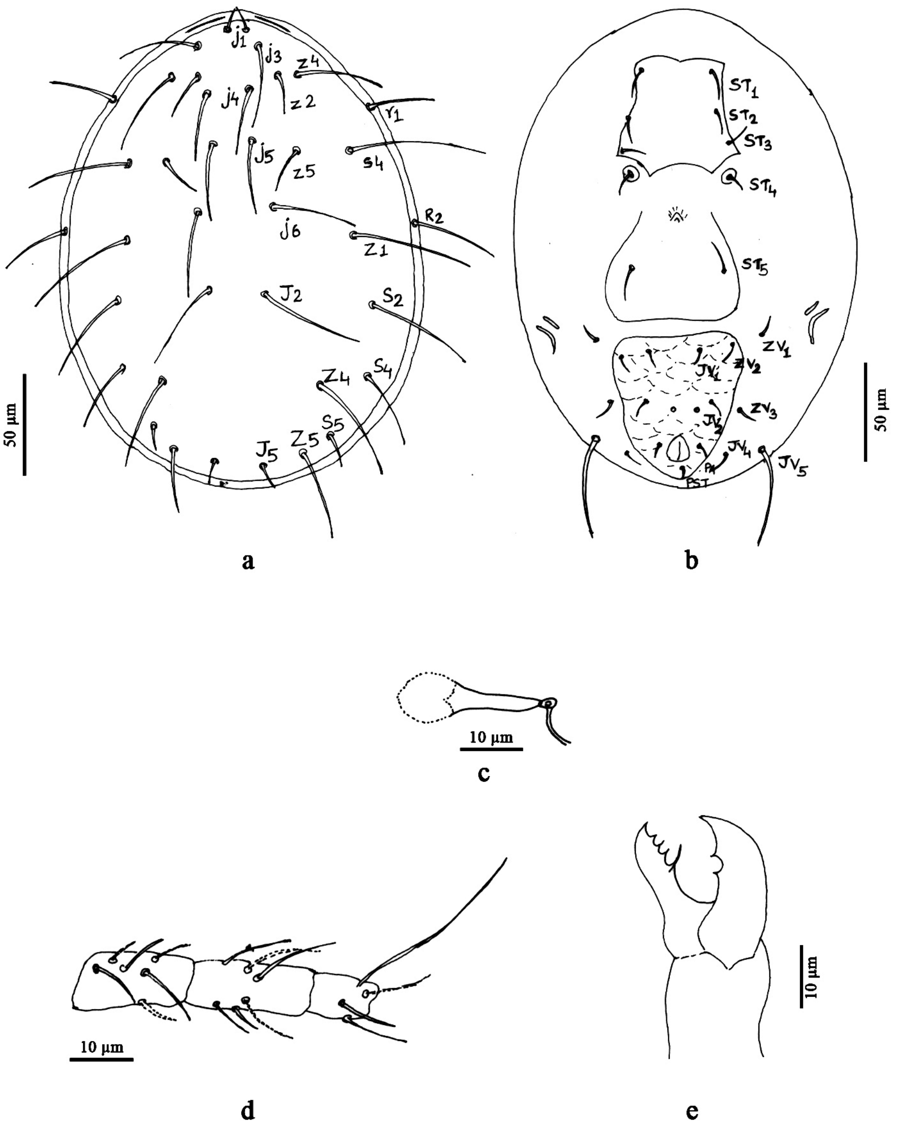


Fig. 35 : *Neoseiulus longispinosus* (Evans, 1952) a-Dorsal; b- ventral; c-Spermatheca; d- IVth leg; e- Chelicera

PLATE 29

Amblydromella bambusicolus (Gupta, 1977)

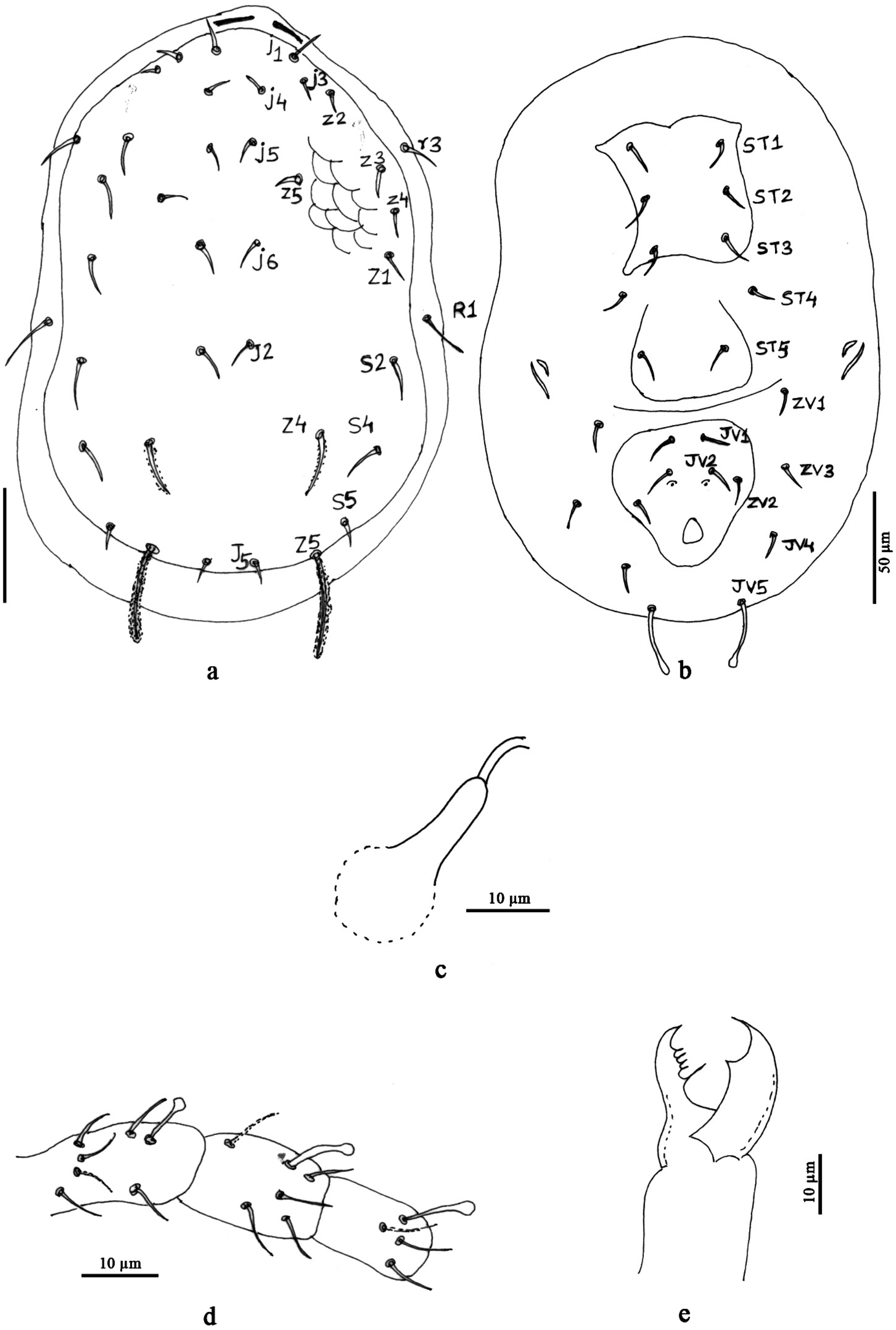
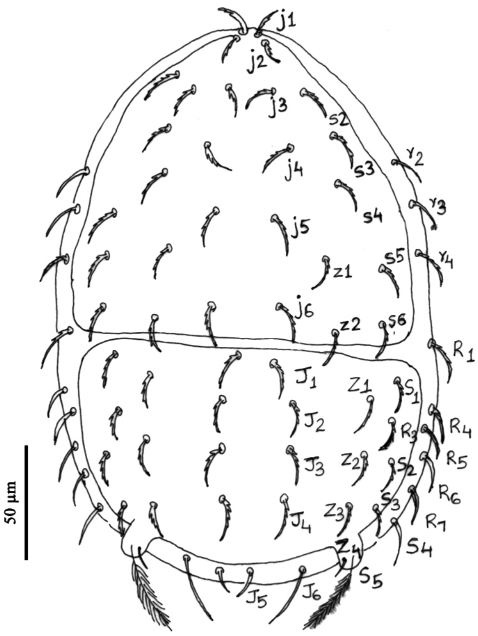


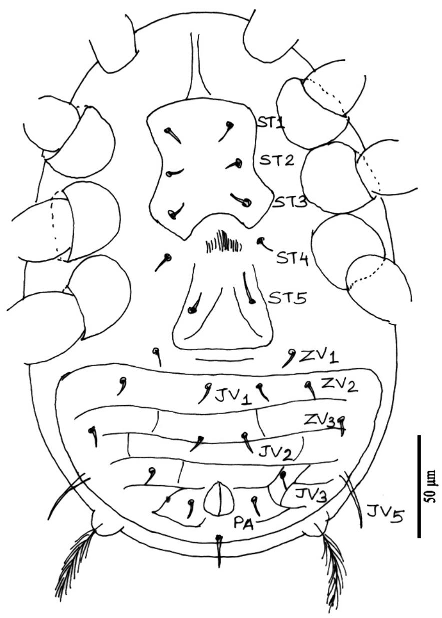
Fig. 36 : *Amblydromella bambusicolus* (Gupta, 1977) ; a-dorsal; b- ventral; c-spermatheca; d-IVth leg; e- chelicera

PLATE 30

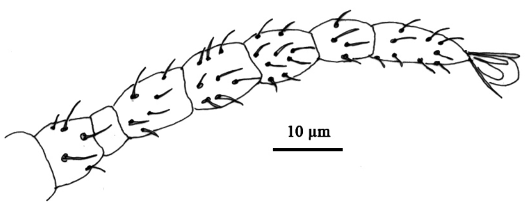
Asca afroaphidiodes Hurlbutt, 1971



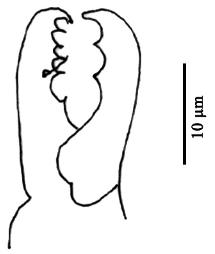
a



b



c



d

Fig. 37: *Asca afroaphidiodes* Hurlbutt, 1971 ; a-dorsal; b- ventral; c- IVth leg; d-chelicera

PLATE 31

Octobdellodes guajavae Chatterjee and Gupta, 2002

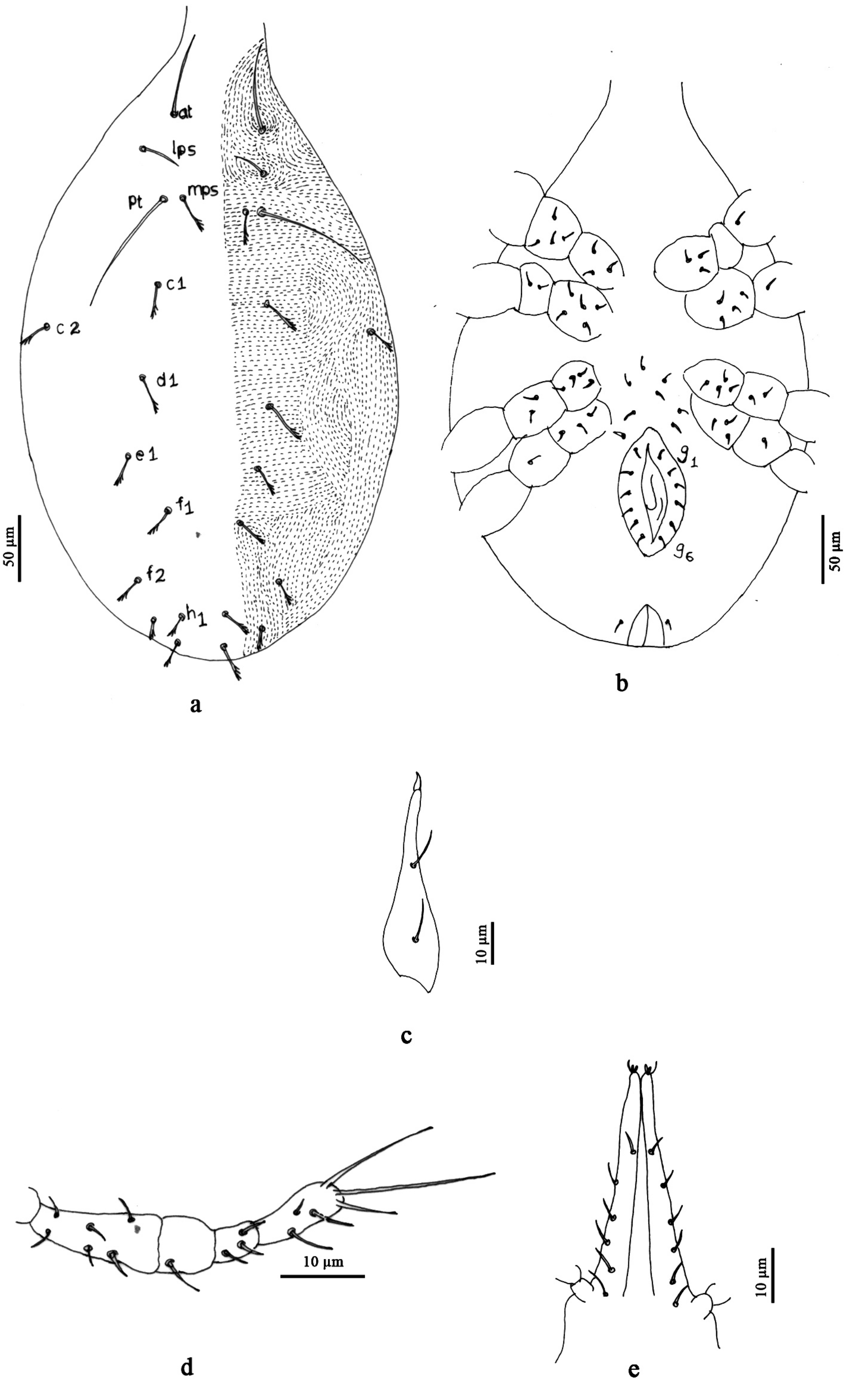


Fig. 38 : *Octobdellodes guajavae* Chatterjee and Gupta, 2002 ; a-dorsal; b-ventral; c- chelicera; d- I[st] leg; e- hypognathum

PLATE 32

Cunaxa bambusae Gupta and Ghosh, 1980

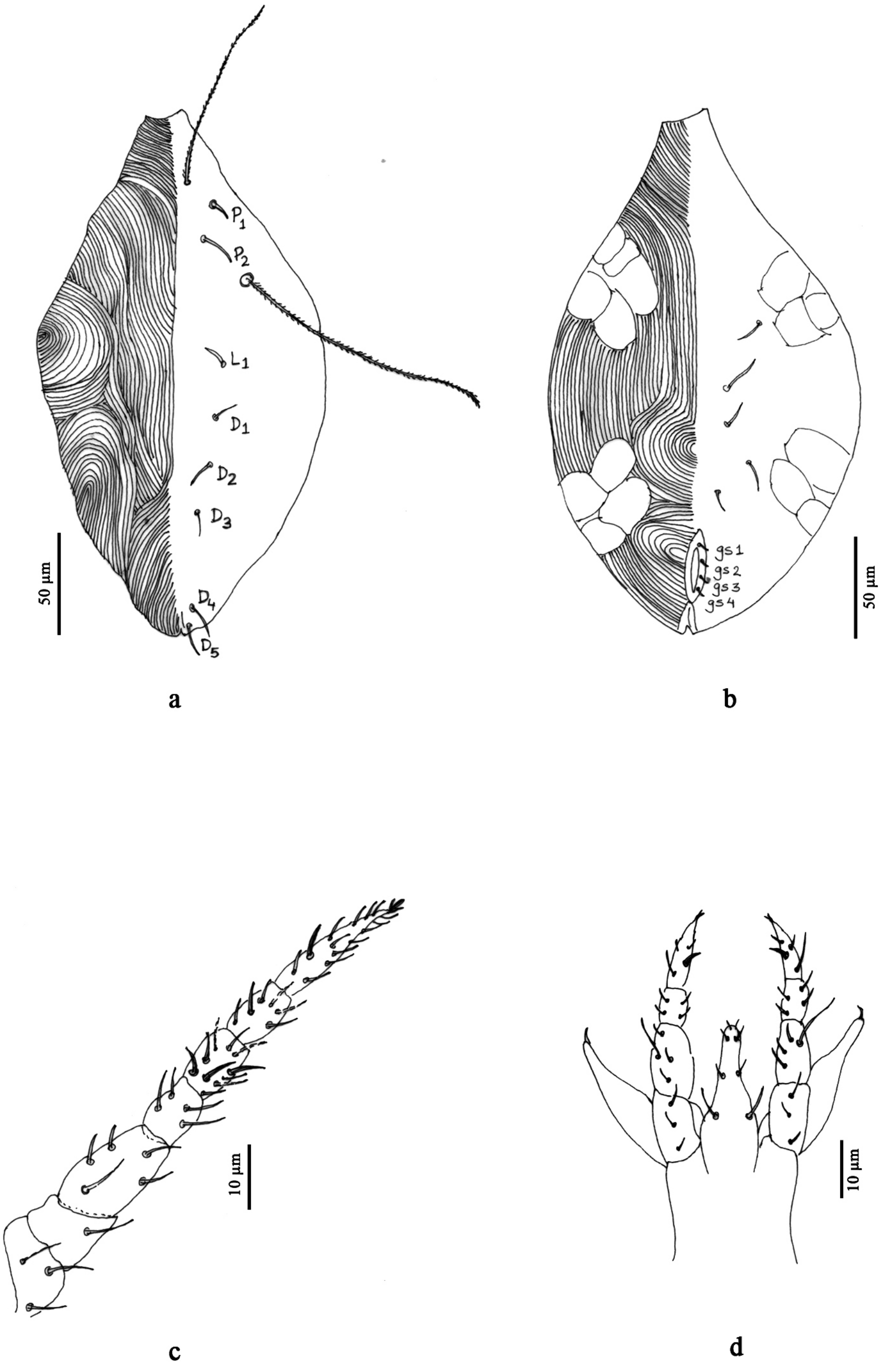


Fig. 39 : *Cunaxa bambusae* Gupta and Ghosh, 1980 a-dorsal; b- ventral; c-Ist leg; d- gnathosoma

PLATE 33

Cunaxoides decastroae Den Heyer, 2013

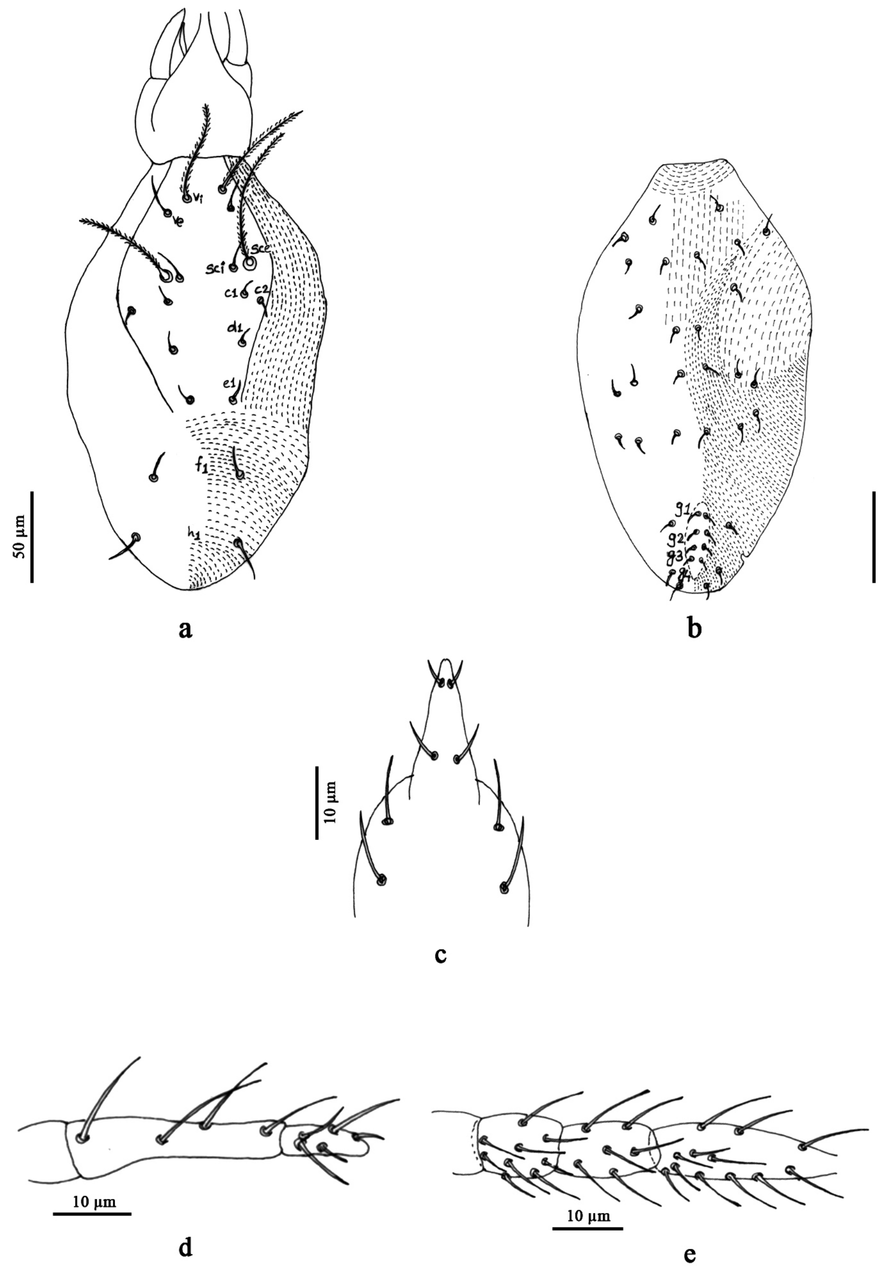
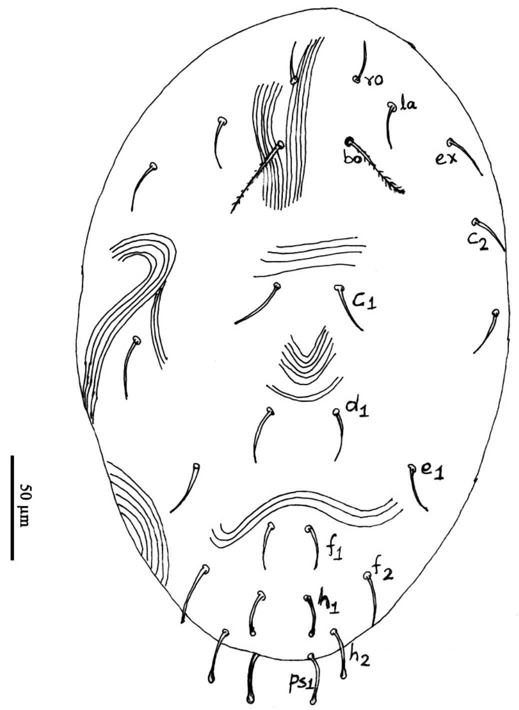


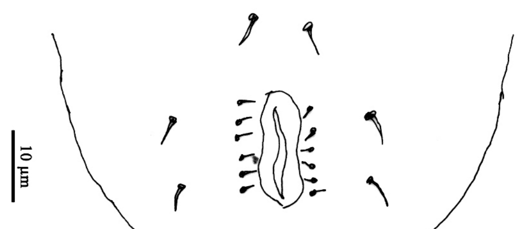
Fig. 40 : *Cunaxoides decastroae* Den Heyer, 2013 ; a-dorsal; b- ventral; c-hypognathum; d- palp ; e-I[st]leg

PLATE 34

Tydeus caudatus (Duges, 1834) Sensu Baker, 1970



a

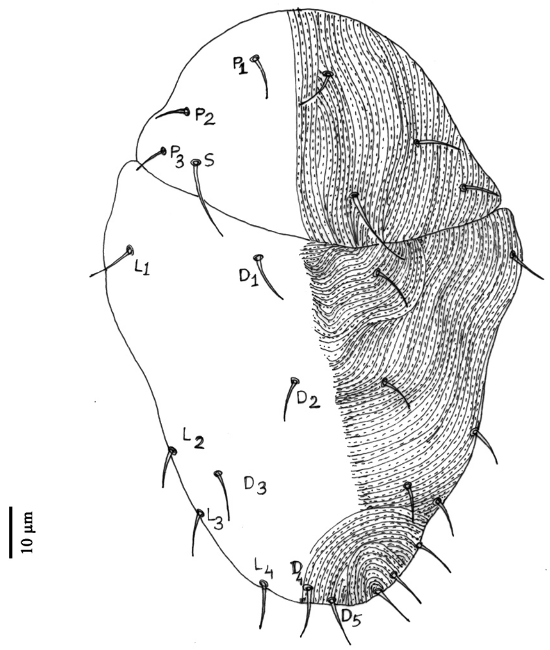


b

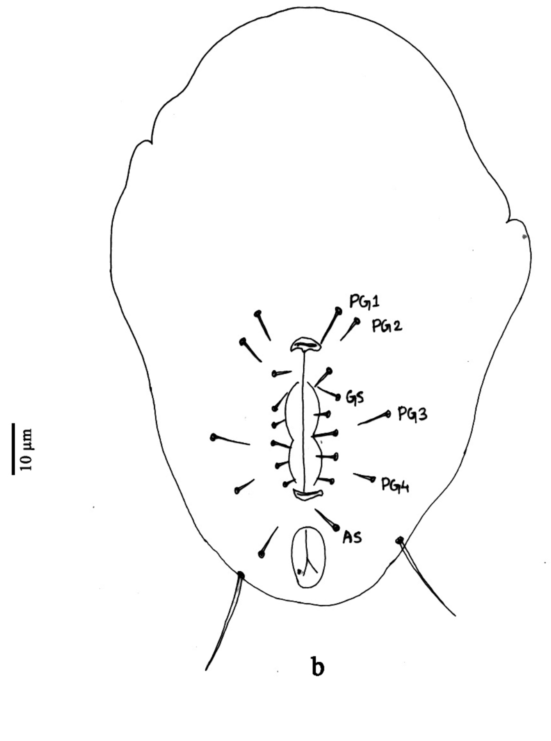
Fig. 41: *Tydeus caudatus* (Duges, 1834) Sensu Baker, 1970 ; a-dorsal; b- ventral

PLATE 35

Tydeus interruptus Sig Thor, 1932



a



b

Fig. 42 : *Tydeus interruptus* Sig Thor, 1932 ; a-dorsal ; b- ventral

PLATE 36

Parapronematus acacia Baker, 1965

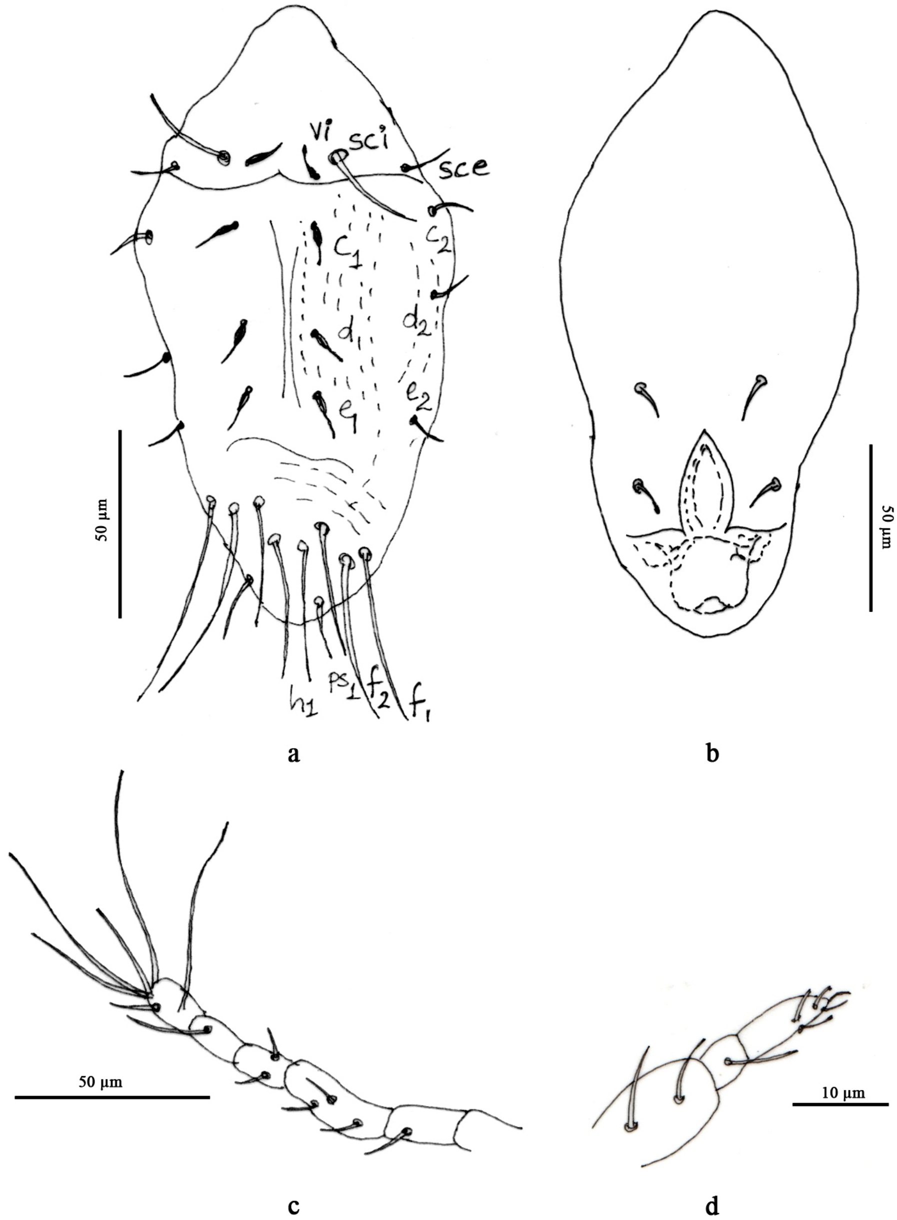
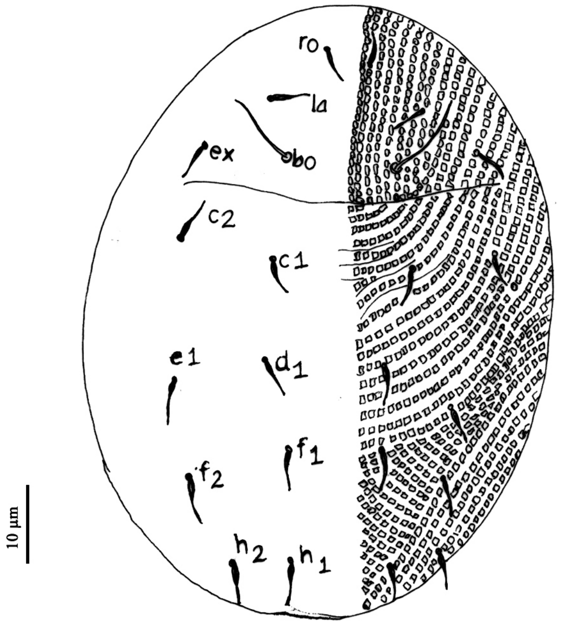


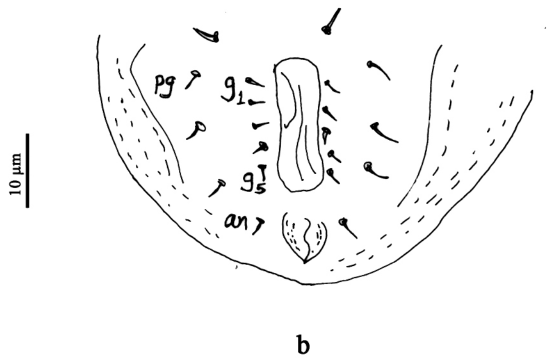
Fig. 43: *Parapronematus acacia* Baker, 1965 ; a-Dorsal; b- ventral; c- I[st] leg; d-palp

PLATE 37

Lorryia stricta Gupta, 1991



a



b

Fig. 44 : *Lorryia stricta* Gupta, 1991; a-Dorsal; b- ventral

PLATE 38

Aceria bambusae Channabasavanna, 1966

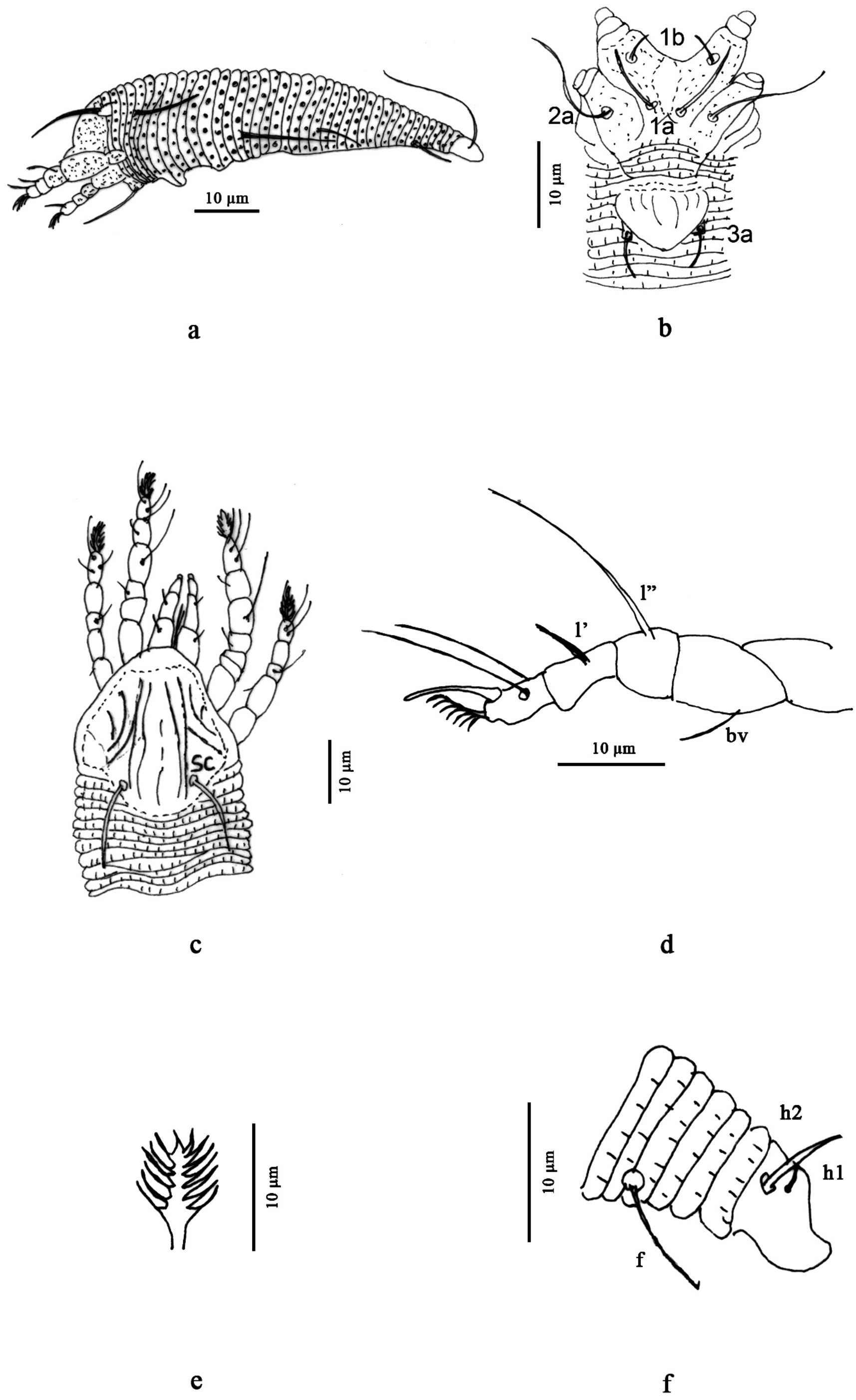


Fig. 45 : *Aceria bambusae* Channabasavanna, 1966 , a-lateral; b- coxa and genitalia female; c- anterodorsal; d- leg; e- empodium; f- posterolateral

PLATE 39

Knorella blumeanae Xue and Zhang, 2009

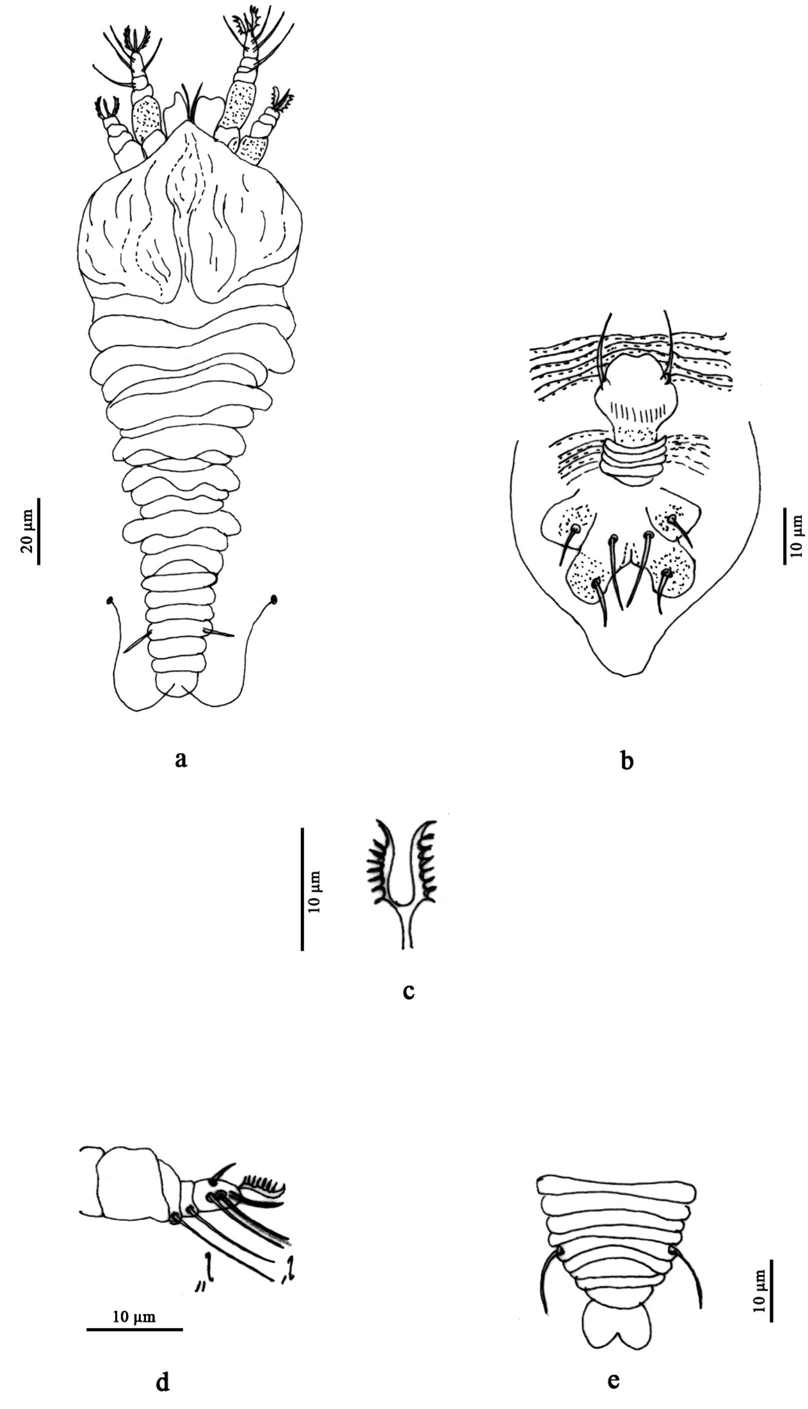


Fig. 46 : *Knorella blumeanae* Xue and Zhang, 2009; a-dorsal; b- ventral; c-empodium; d- I[st] leg; e- posterolateral

PLATE 40

Eupodes parafusifer Meyer and Ryke, 1960

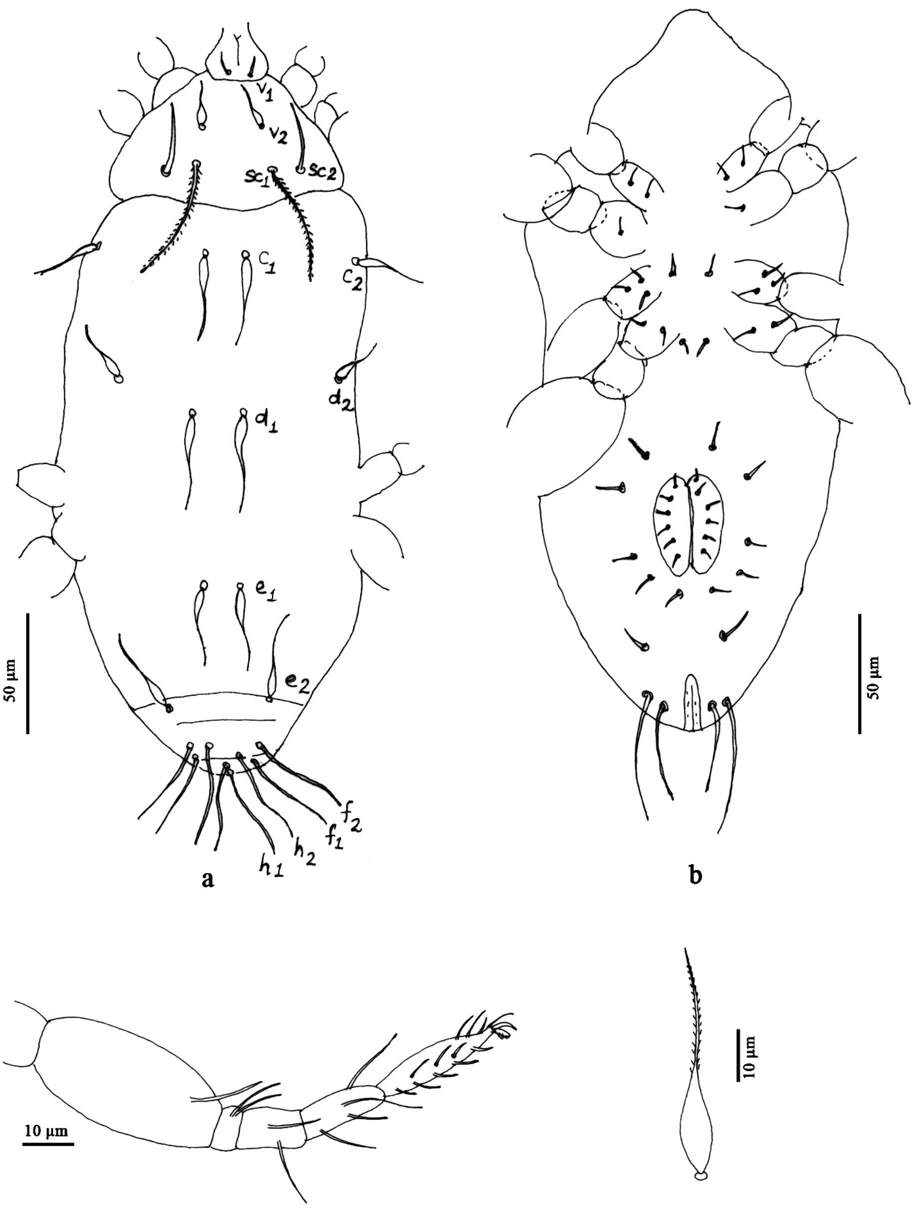
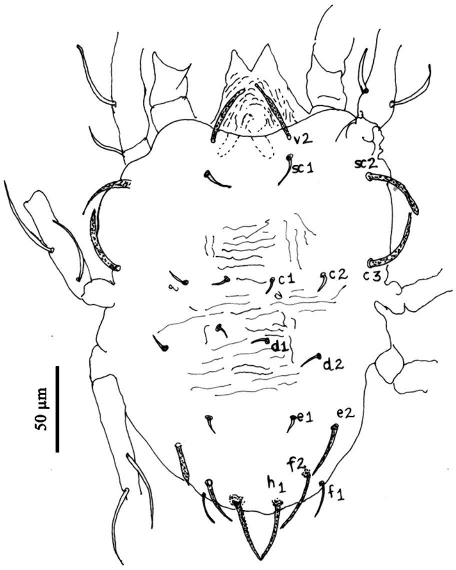


Fig. 47 : *Eupodes parafusifer* Meyer and Ryke, 1960 ; a- Dorsal ; b- ventral ; c-IV^th^ leg ; d- seta

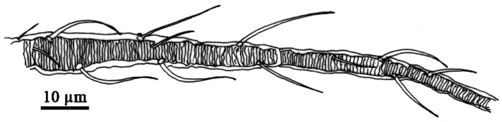
PLATE 41

Aponychus corpuzae Rimando, 1966

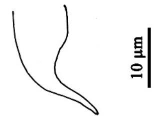


a

b



c



d

Fig. 48 : *Aponychus corpuzae* Rimando, 1966 a-Dorsal; b- ventral; c- IVth leg; d-Aedeagus

PLATE 42

Oligonychus biharensis (Hirst, 1924)

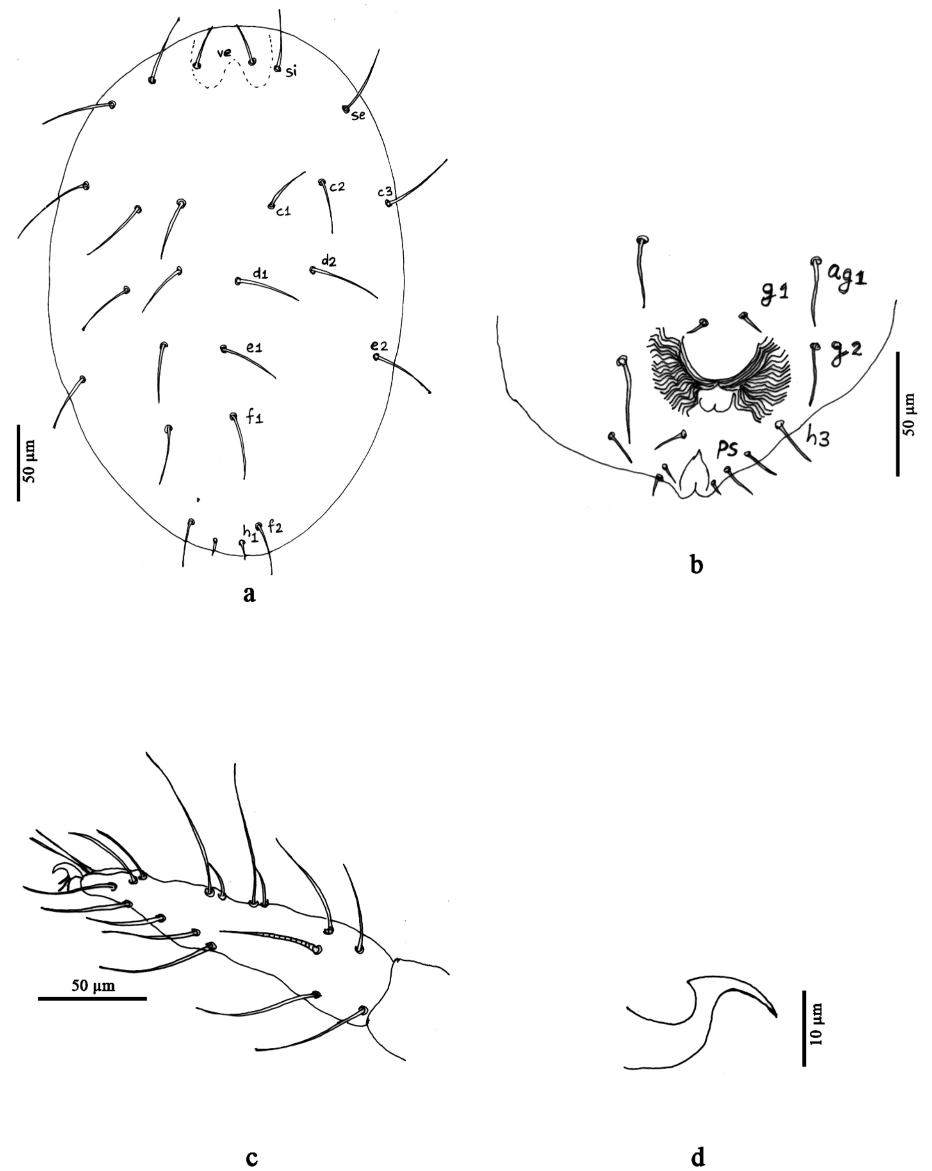
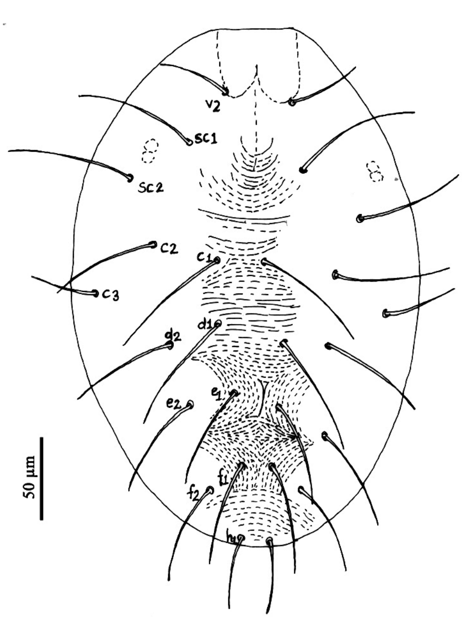


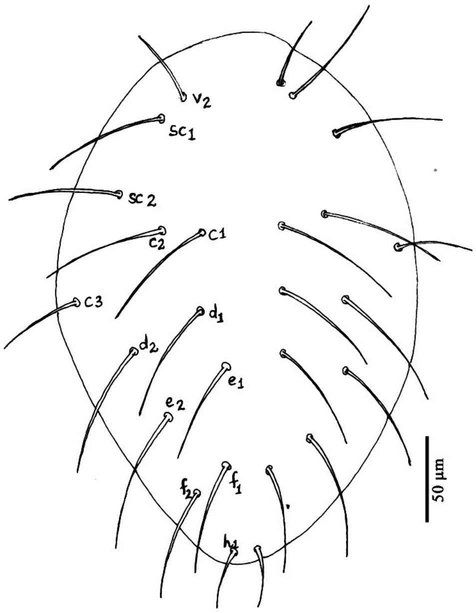
Fig. 49 : *Oligonychus biharensis* (Hirst, 1924); a-dorsal female; b-ventral; c-I[st]leg; d- aedeagus

PLATE 43

Tetranychus urticae C.L. Koch, 1836



a



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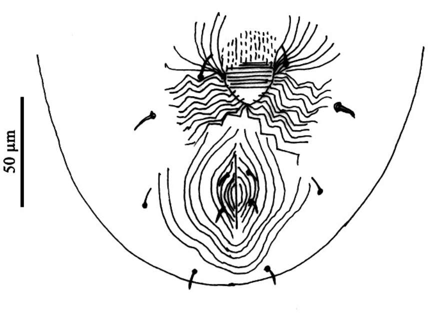
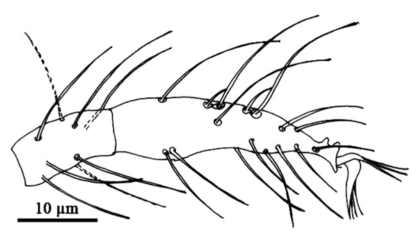
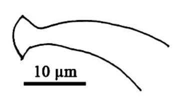


c



d



e

Fig. 50 ; *Tetranychus urticae* C.L. Koch, 1836; a-dorsal female; b-dorsal male ; c-ventral; d- I[st] leg; e-aedeagus

PLATE 44

Schizotetranychus schizopus (Zacher, 1913)

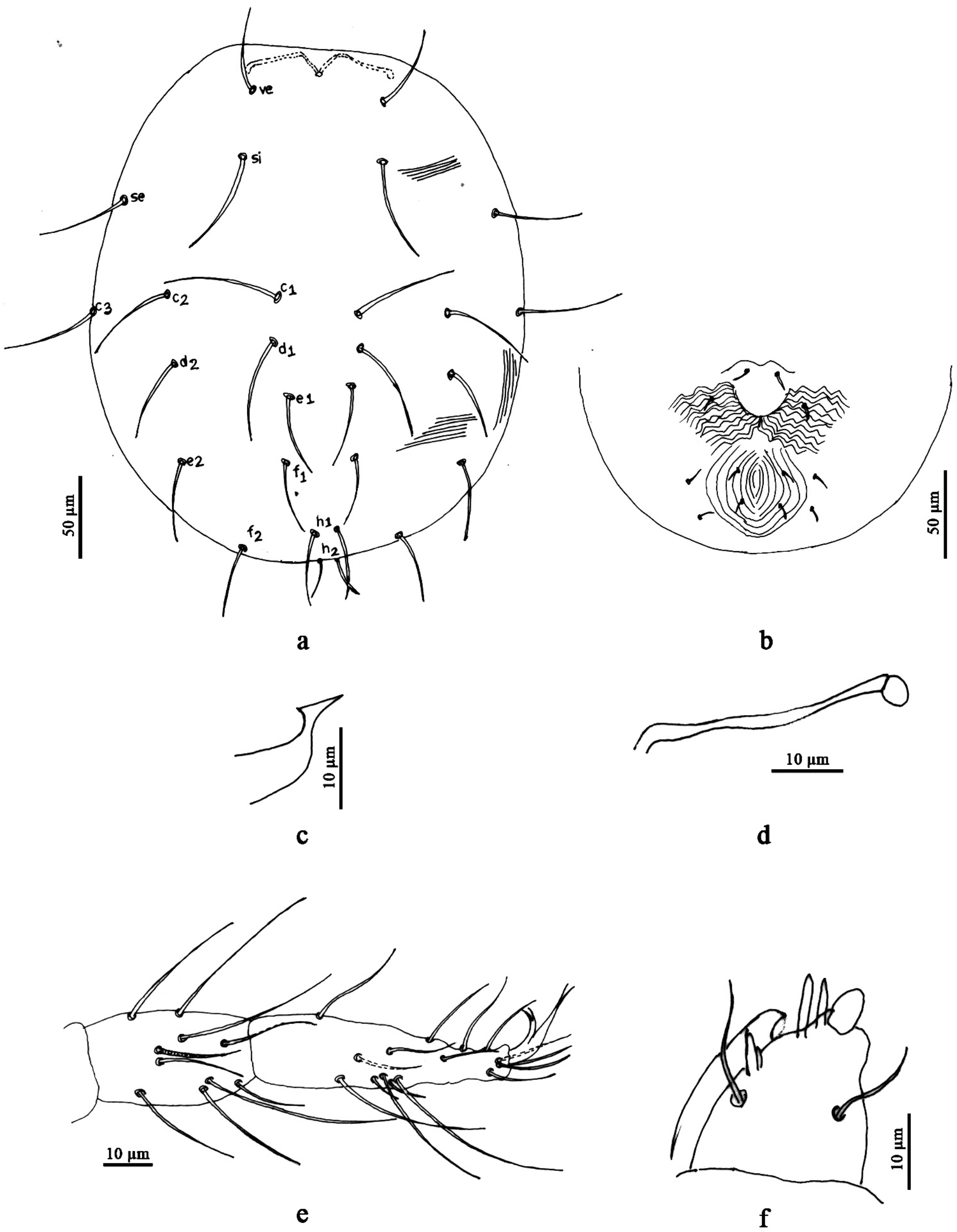


Fig.51: *Schizotetranychus schizopus* (Zacher, 1913); a-dorsal; b-ventral; c-aedeagus; d-peritreme; e- I[st] leg; f- palp

PLATE 45

Schizotetranychus longus Saito, 1990

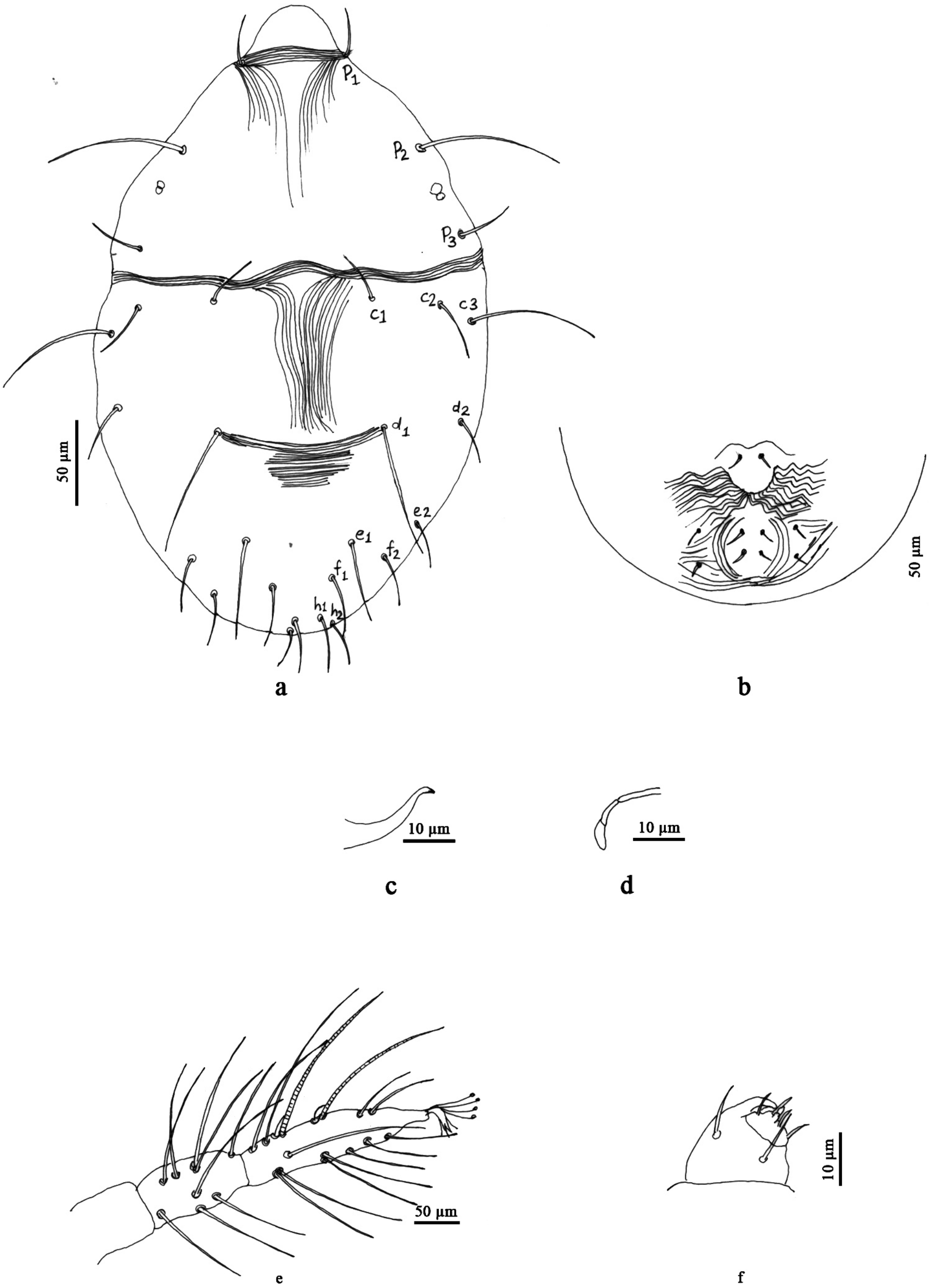


Fig. 52 : *Schizotetranychus longus* Saito, 1990; a-dorsal; b-ventral; c-Aedeagus; d-peritreme; e- I[st] leg; f- palp

PLATE 46

Schizotetranychus recki Ehara, 1957

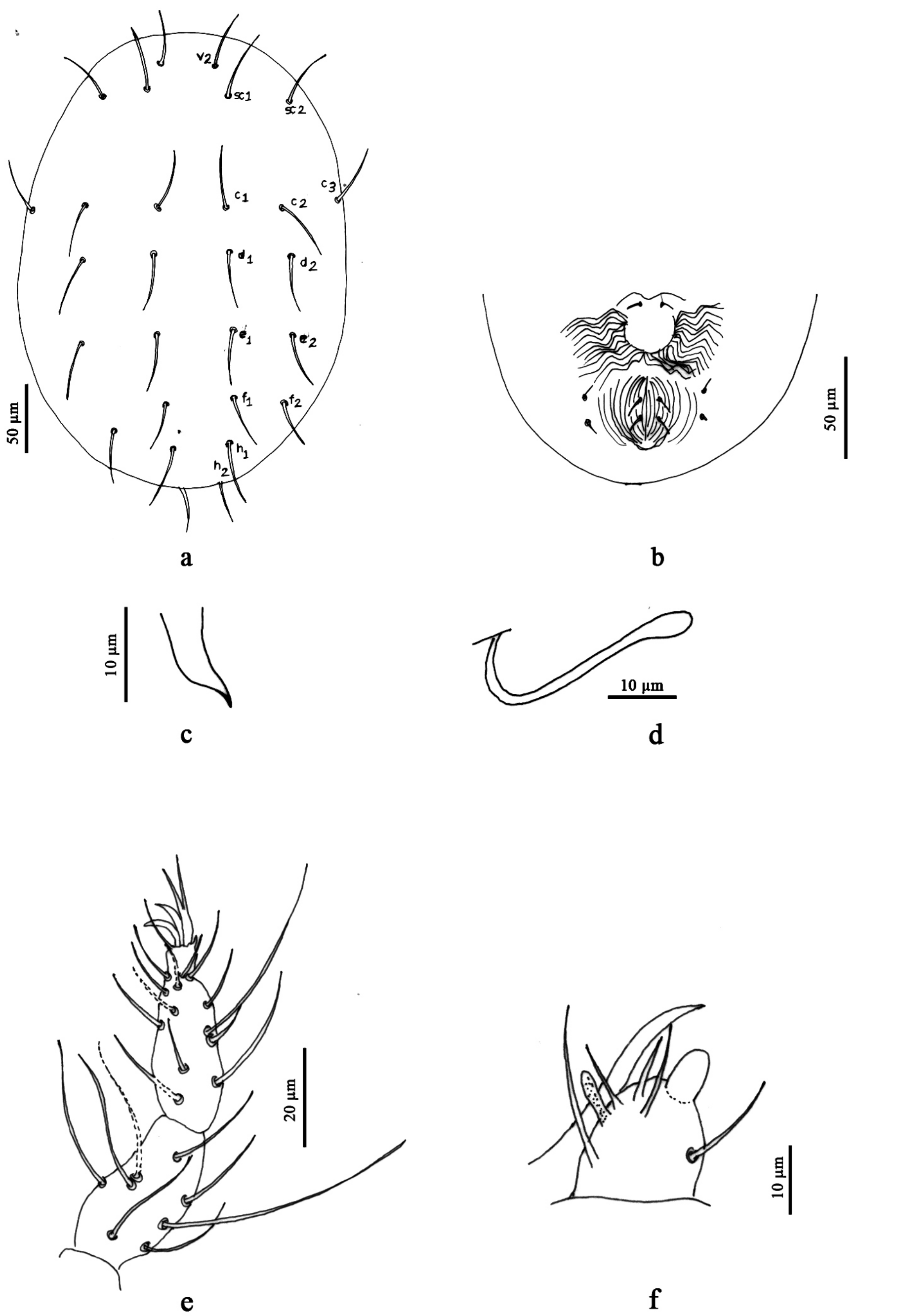


Fig. 53: *Schizotetranychus recki* Ehara, 1957 ; a-dorsal ; b-ventral; c-aedeagus; d-peritreme; e- I[st] leg; f- palp

PLATE 47

Stylophoronychus vannus (Rimando, 1968)

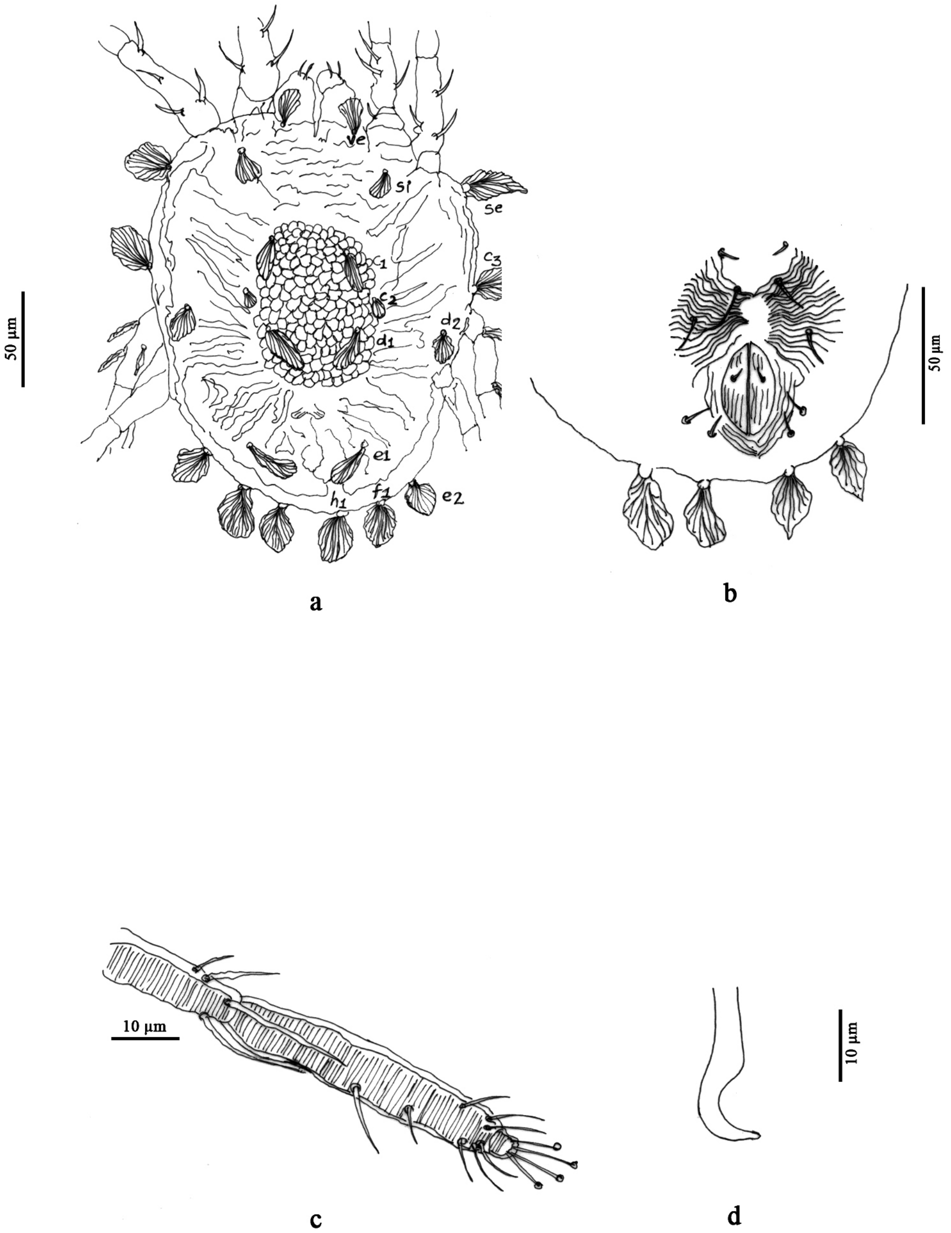


Fig. 54: *Stylophoronychus vannus* (Rimando, 1968) ; a-dorsal; b-ventral; c-I[st]leg ; d-aedeagus

PLATE 48

Cheyletus rosensis Mary Anitha and Ramani, 2009

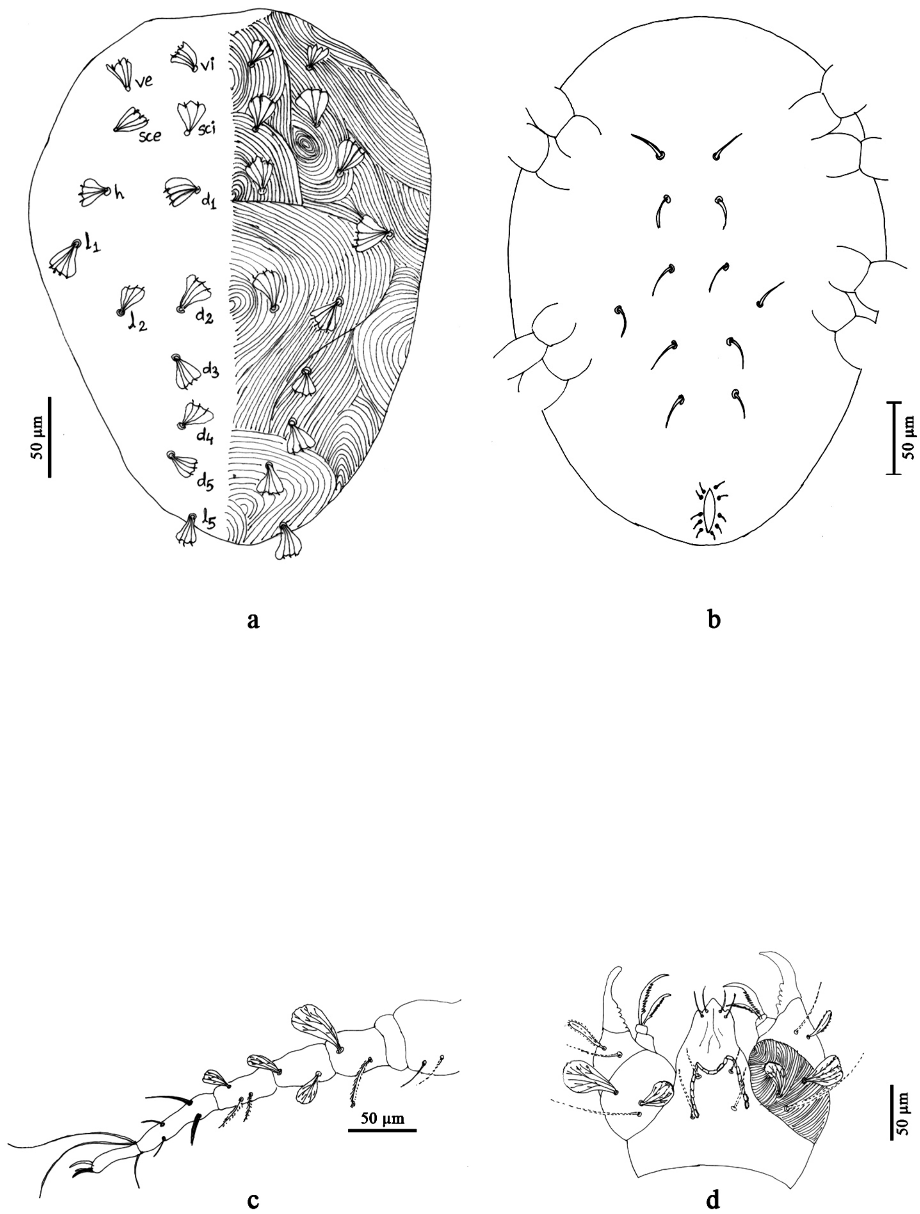
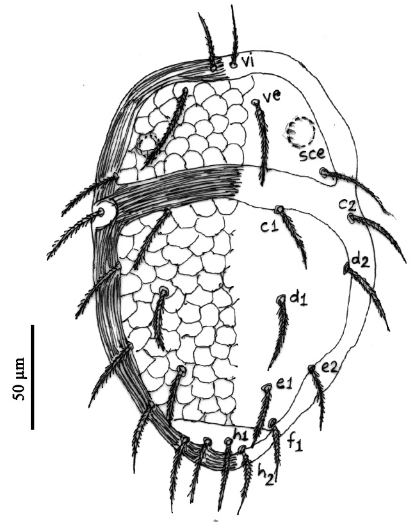


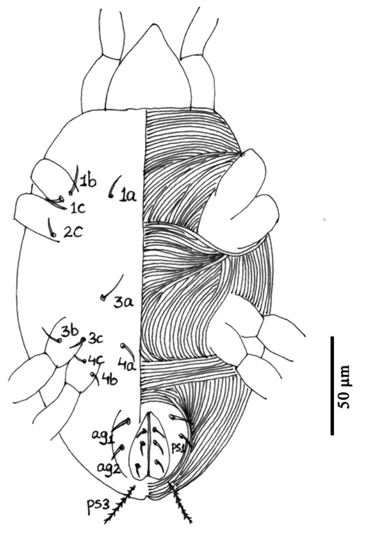
Fig. 55 : *Cheyletus rosensis* Mary Anitha and Ramani, 2009 ; a-dorsal; b-ventral;c- Ist leg; d-gnathosoma

PLATE 49

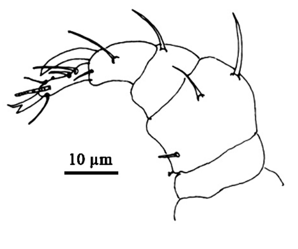
Agistemus aimogastaensis Leiva, Fernandez, Theron and Rollard, 2013



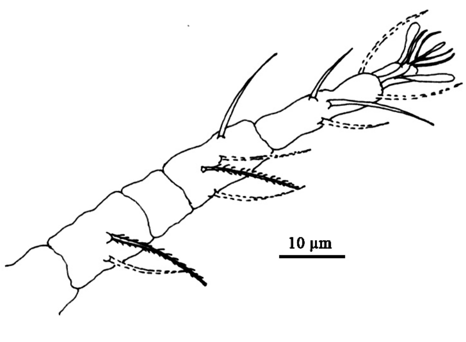
a



b



c

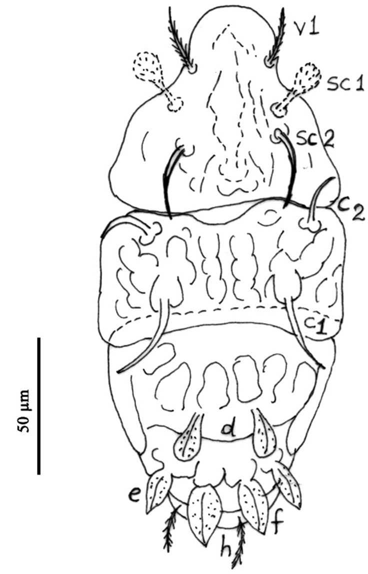


d

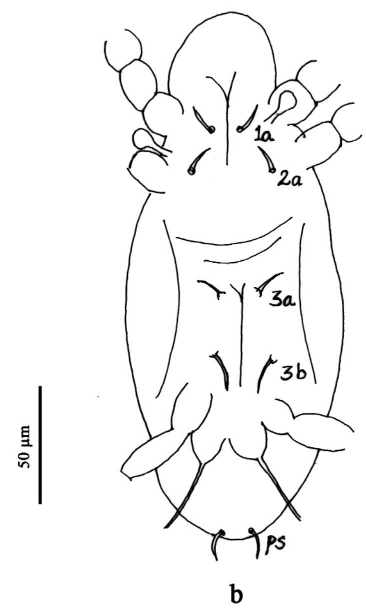
Fig. 56: *Agistemus aimogastaensis* Leiva, Fernandez, Theron and Rollard, 2013
a-dorsal; b-ventral; c- palp; d-IV[th]leg

PLATE 50

Diadalotarsonemus serratus Rezende, Ochoa and Lofego, 2015



a

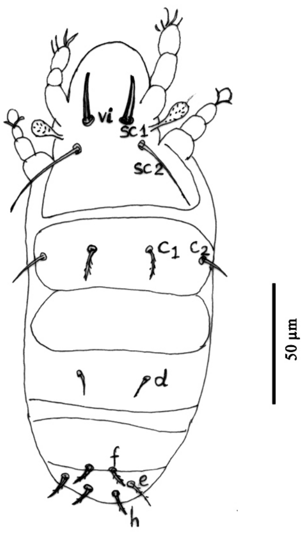


b

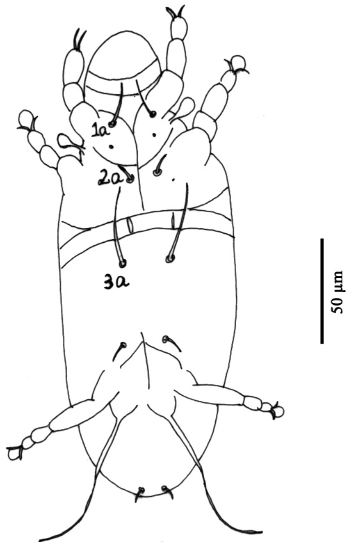
Fig. 57 : *Diadalotarsonemus serratus* Rezende, Ochoa and Lofego, 2015 ; a-Dorsal; b-ventral

PLATE 51

Steneotarsonemus spinki Smiley, 1967



a

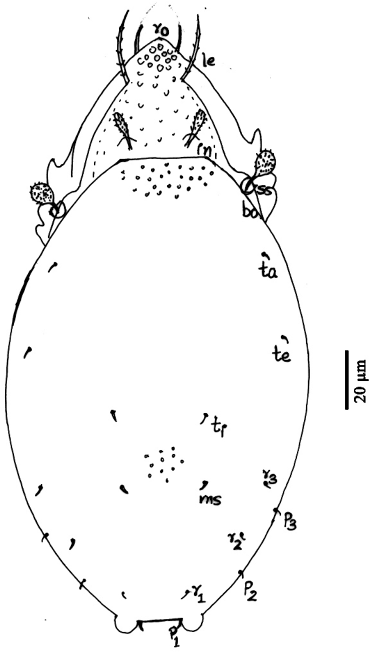


b

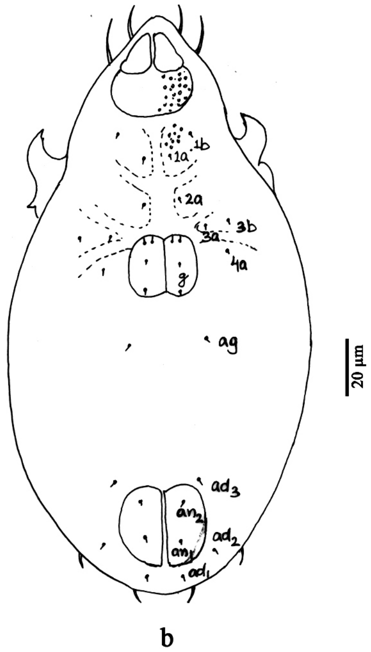
Fig. 58: *Steneotarsonemus spinki* Smiley, 1967 ; a-dorsal; b-ventral

PLATE 52

Hemileius (Tuberemaeus) singularis (Sellnick, 1930)



a



b

Fig 59: *Hemileius (Tuberemaeus) singularis* (Sellnick, 1930) ; a- dorsal ; b-ventral

PLATE 53

Siculobata malabarica Ramani and Haq, 1998

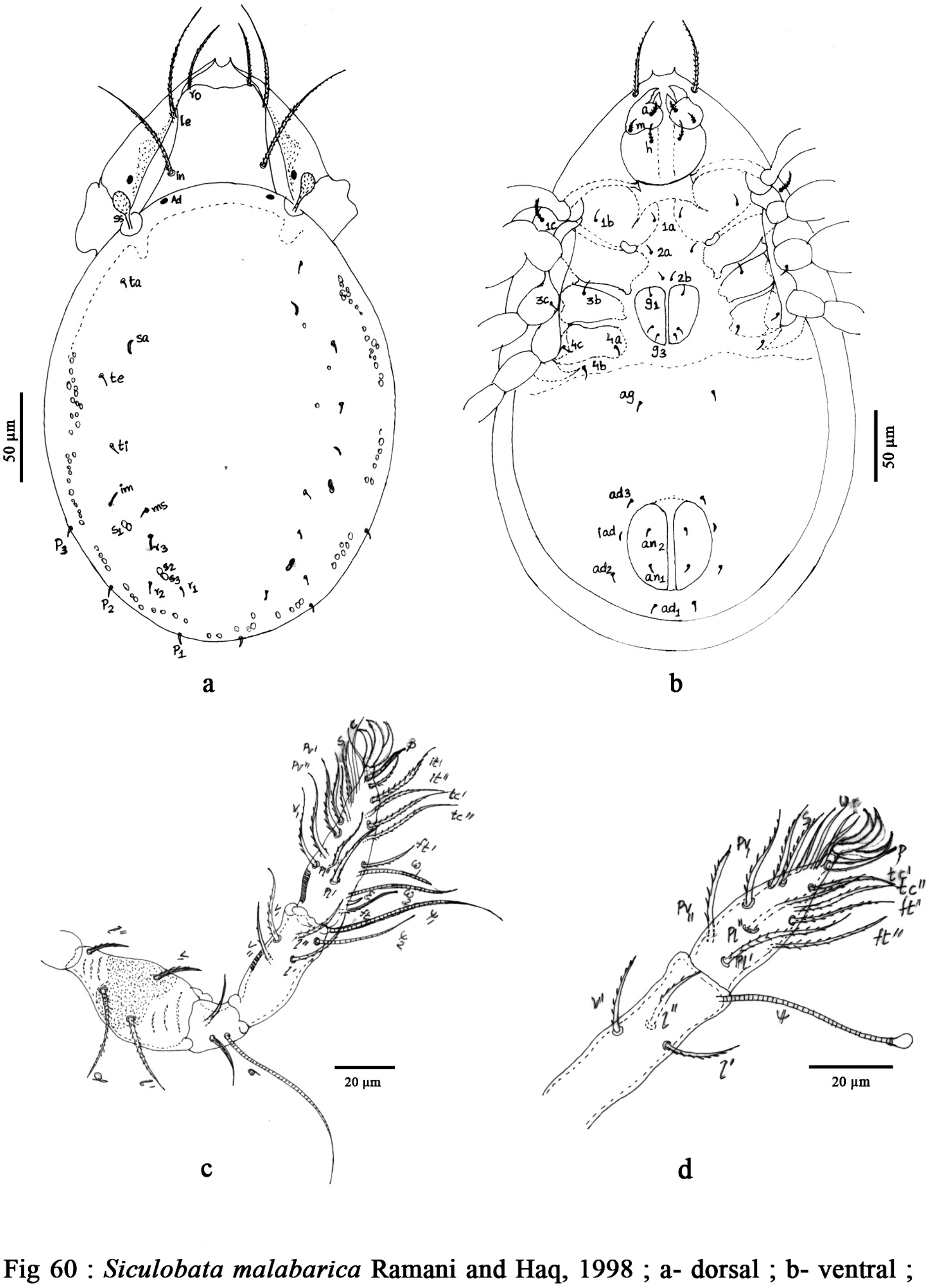


Fig 60 : *Siculobata malabarica* Ramani and Haq, 1998 ; a- dorsal ; b- ventral ; c-Ist leg ; d- IVth leg

PLATE 54

Uracrobates (Uracrobates) indicus Ramani and Haq, 1990

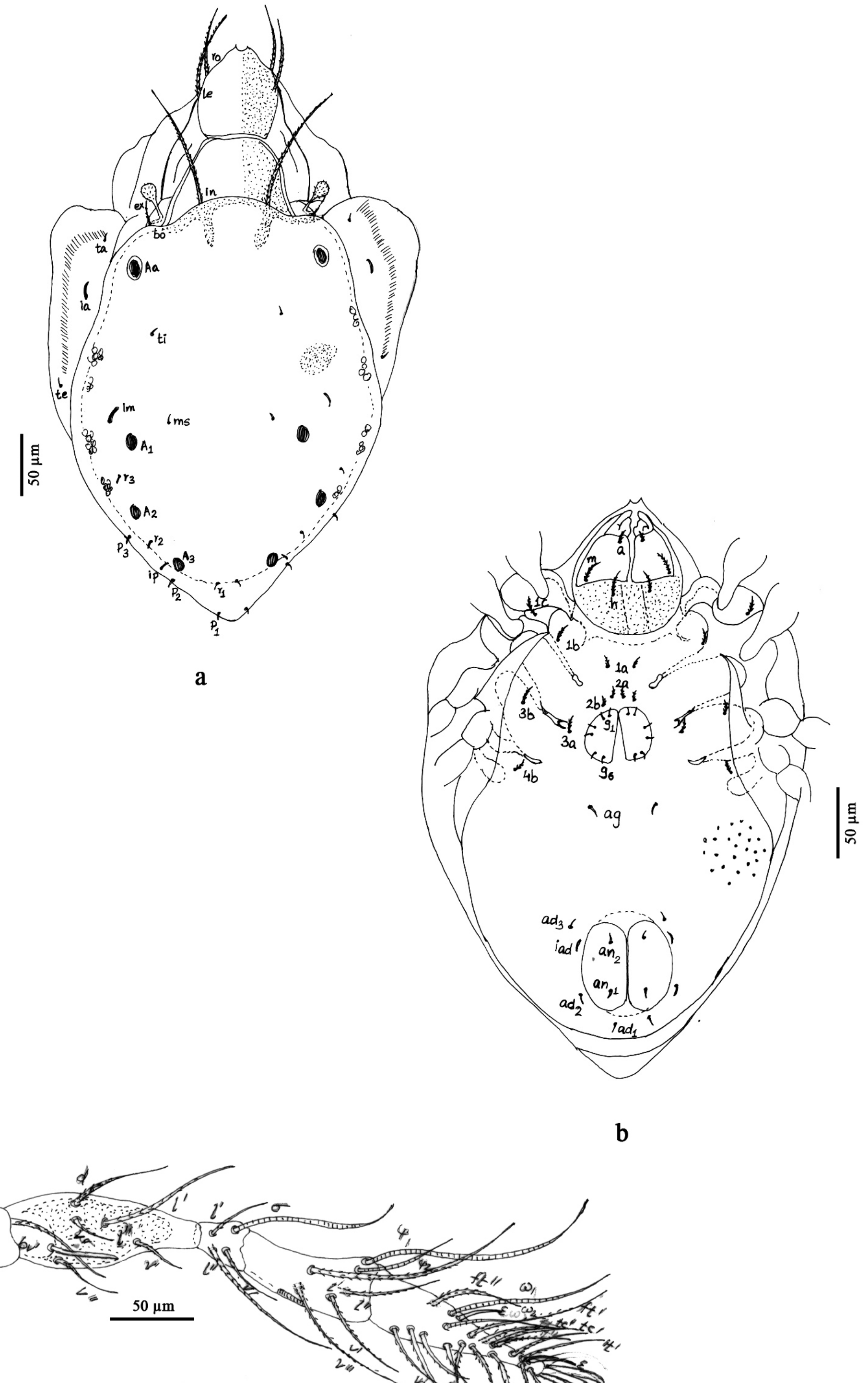


Fig 61 : *Uracrobates (Uracrobates) indicus* Ramani and Haq, 1990 ; a-dorsal; b-ventral ; c-Ist leg

PLATE 55

Uracrobates (Ovouracrobates) keralensis sp.nov.

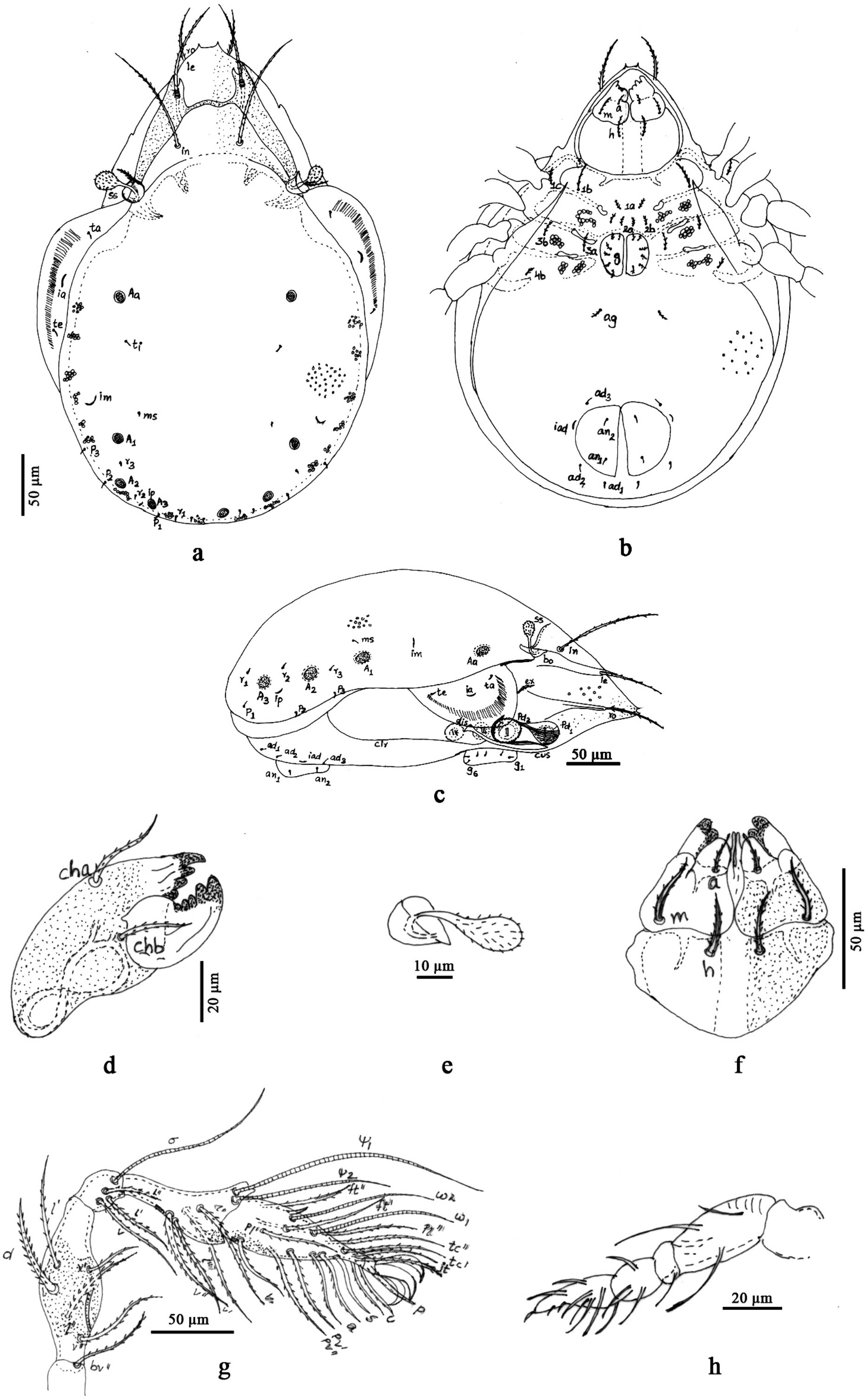


Fig 62 : *Uracrobates (Ovouracrobates) keralensis* sp.nov. ; a- dorsal; b-ventral; c-lateral; d-chelicera; e- sensillus; f- gnathosoma; g- Ist leg; h- pedipalp

PLATE 56

Scheloribates decarinatus Aoki, 1984

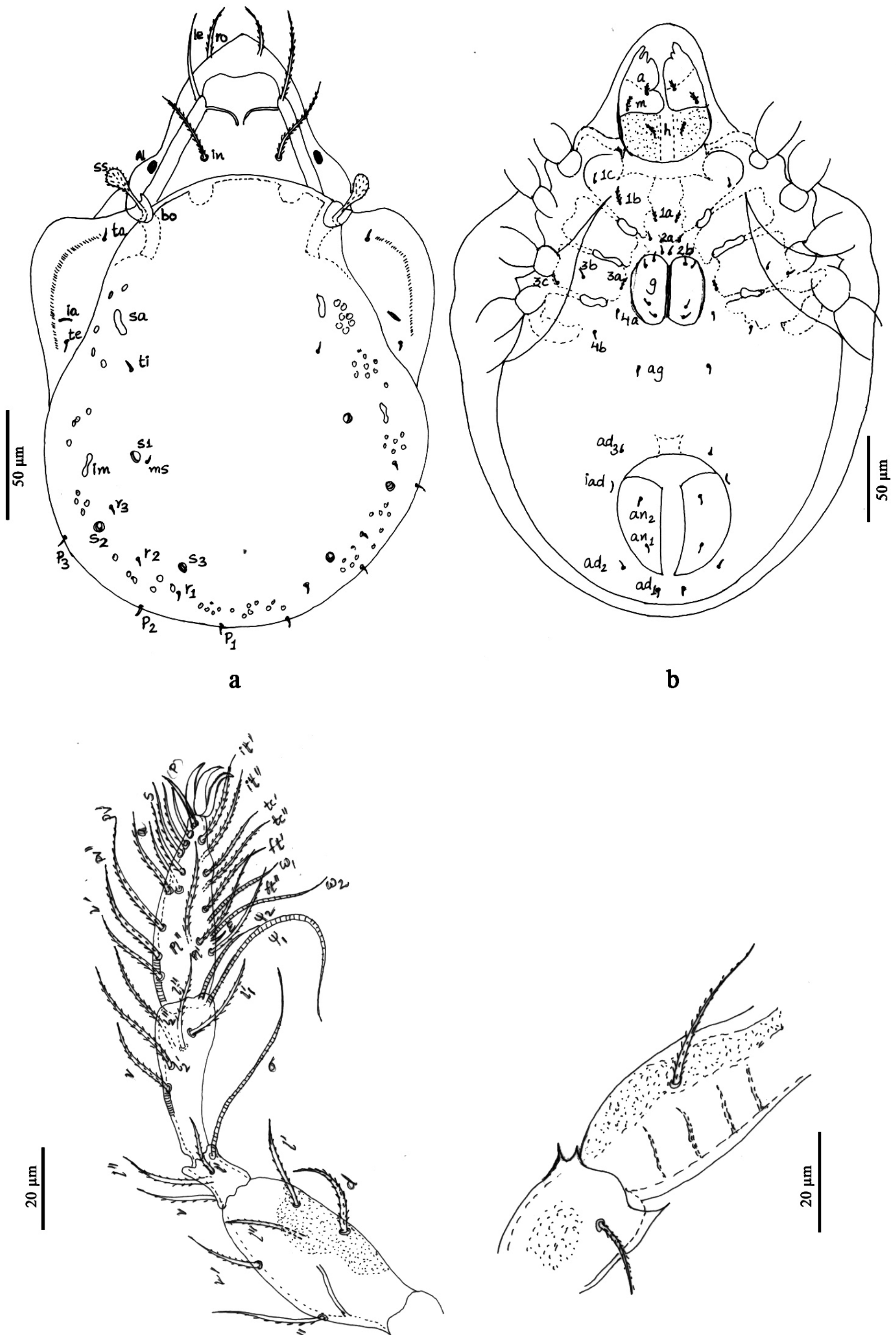
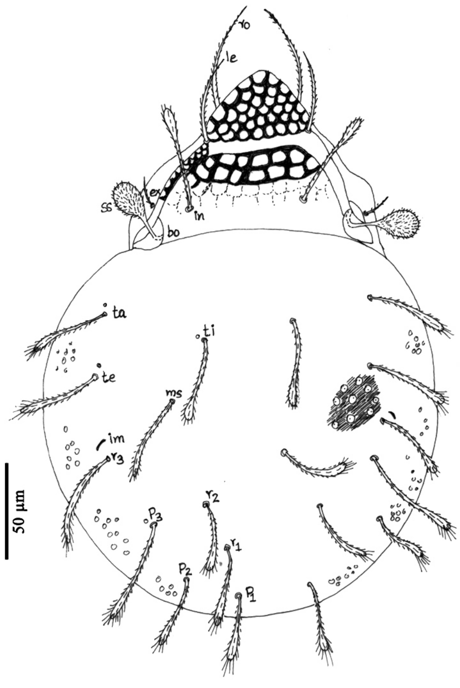


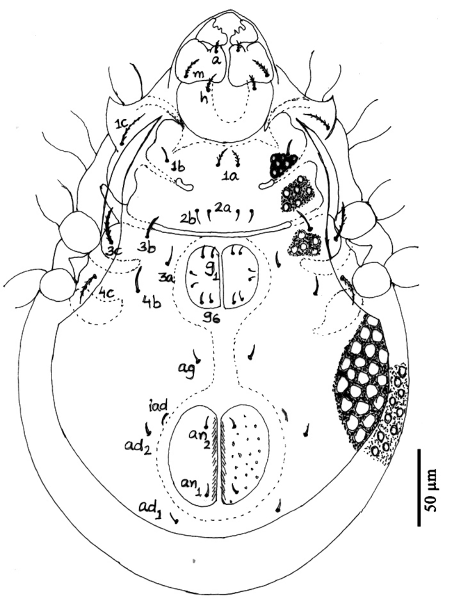
Fig 56 : *Scheloribates decarinatus* Aoki, 1984 ; a- dorsal ; b-ventral ; c- I[st] leg ; d-IV[th] leg trochanter

PLATE 57

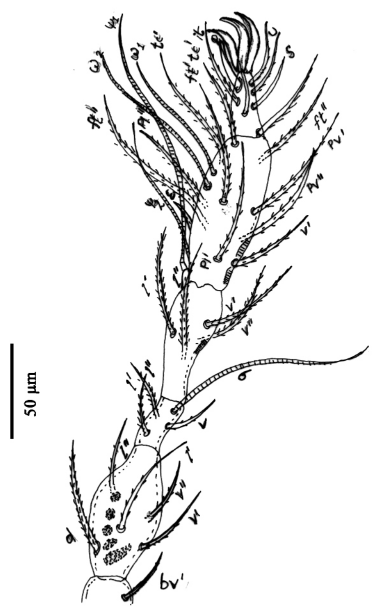
Zetorchella sejugata (Ramani and Haq, 1997)



a



b

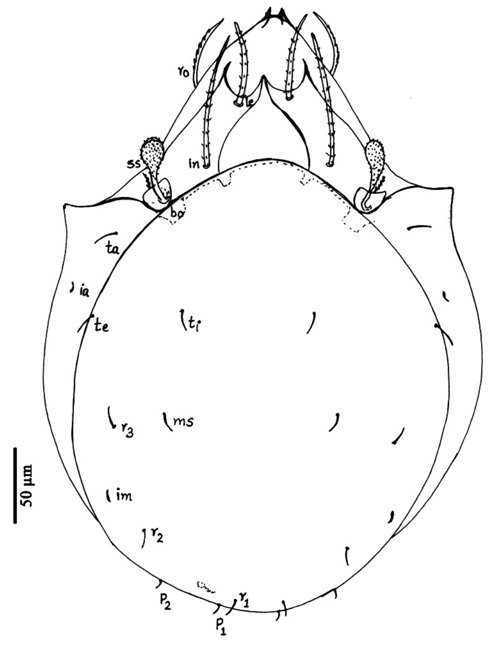


c

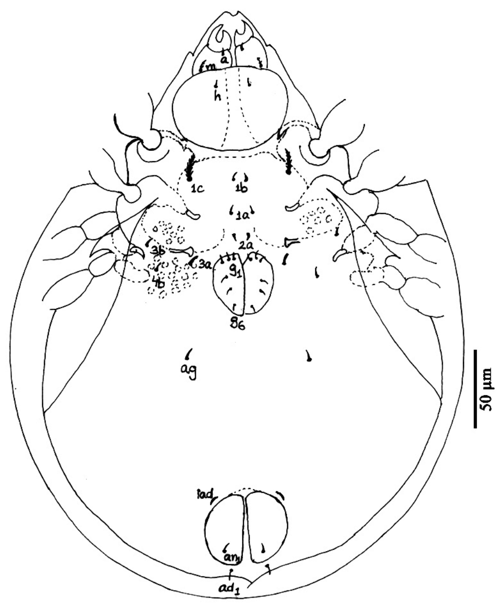
Fig 64 : *Zetorchella sejugata* (Ramani and Haq, 1997) ; a- dorsal ; b-ventral ; c-I[st]leg

PLATE 58

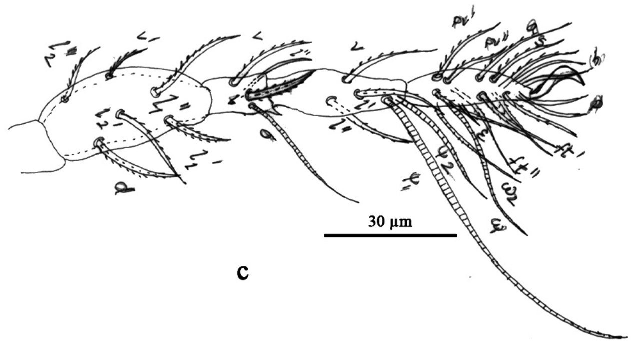
Lamellobates (Paralamellobates) misella (Berlese, 1910)



a



b



c

Fig 65: *Lamellobates (Paralamellobates) misella* (Berlese, 1910) ; a-dorsal ; b-ventral ; c-I^st^ leg

PLATE 59

Galumna (Galumna) flabellifera orientalis Aoki, 1965

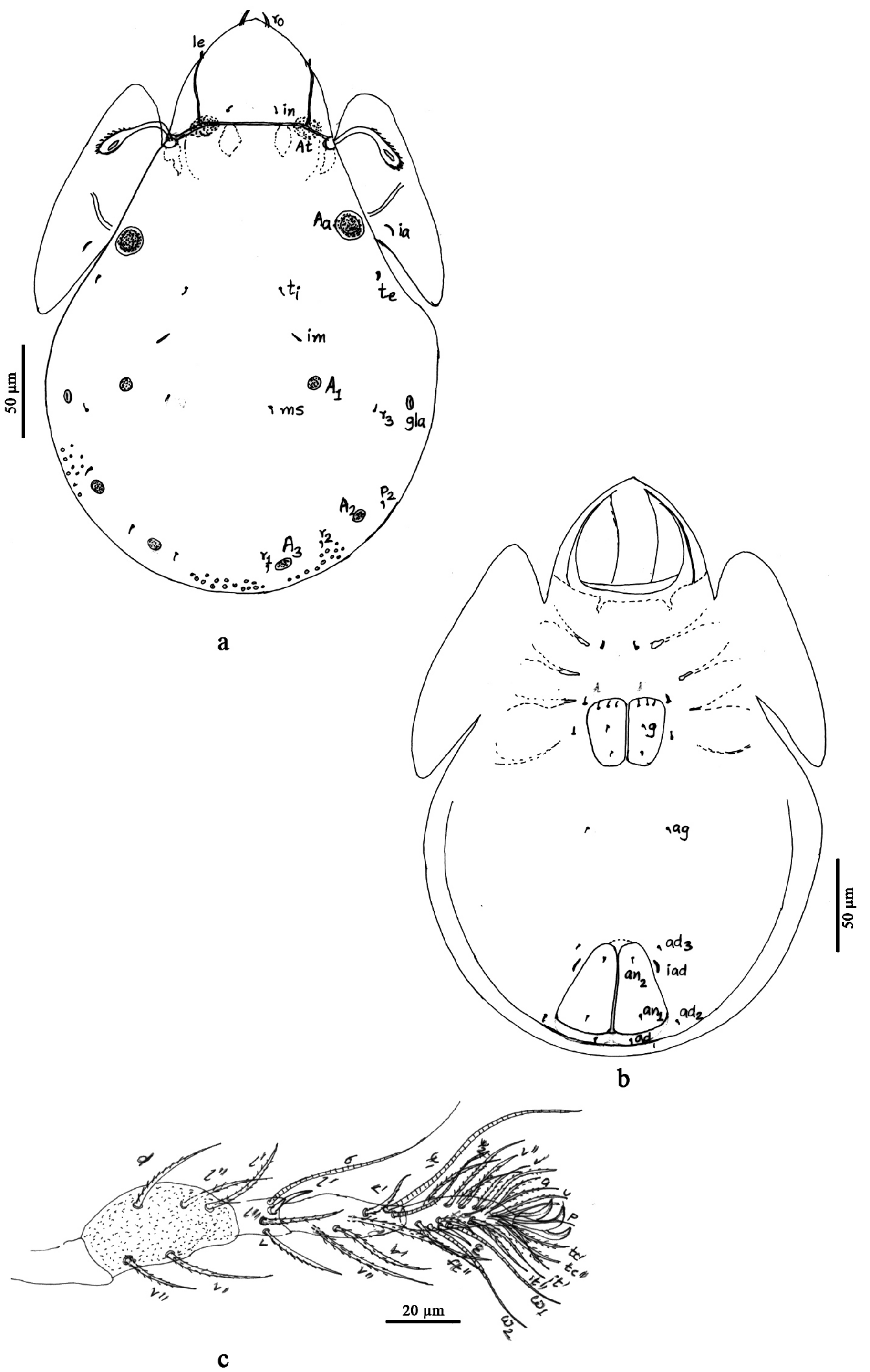


Fig 66: *Galumna (Galumna) flabellifera orientalis* Aoki, 1965 ; a- dorsal ; b-ventral ; c- I[st] leg

PLATE 60

Tyrophagus putrescentiae (Shrank, 1781)

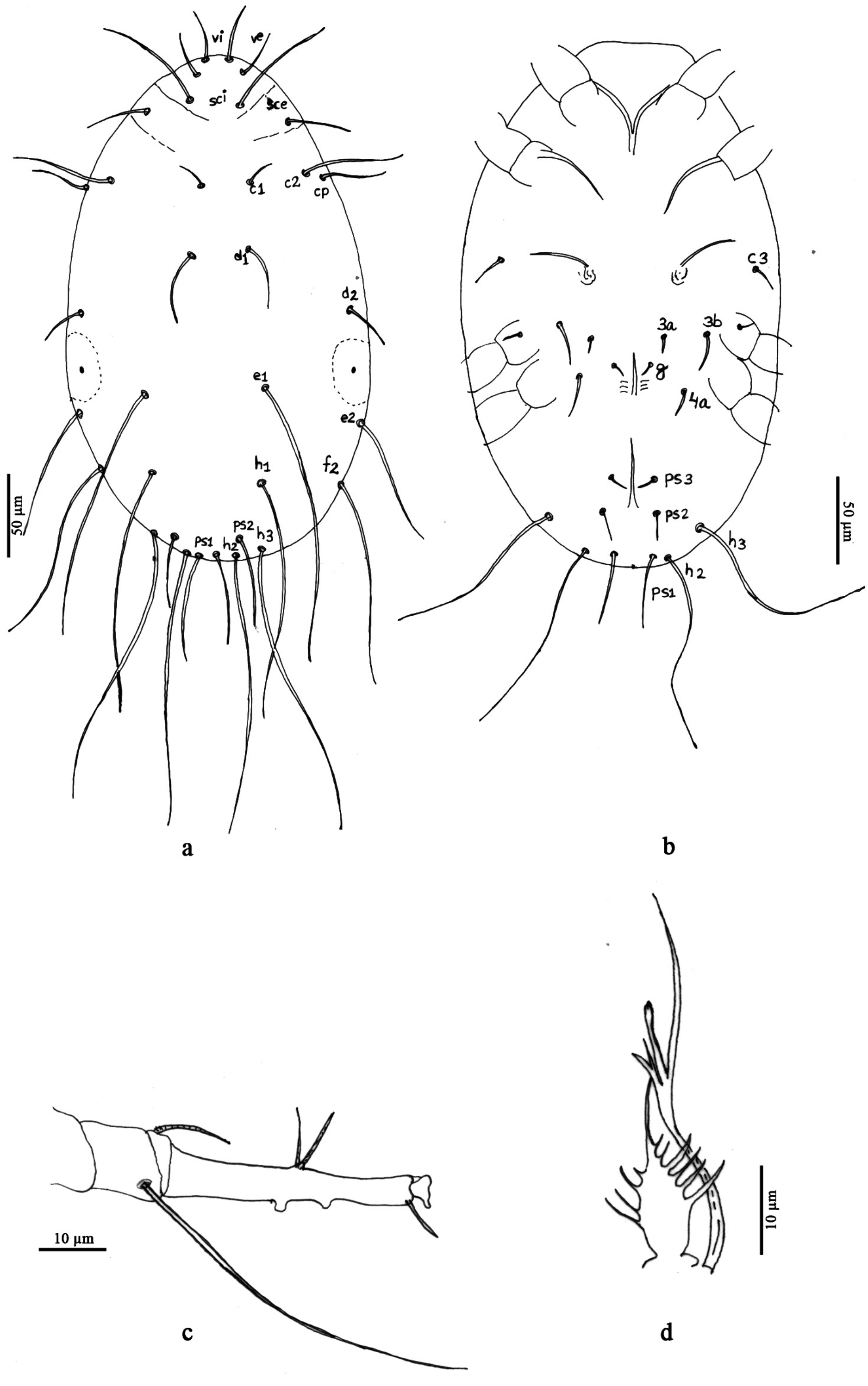


Fig. 67 : *Tyrophagus putrescentiae* (Shrank, 1781) ;a-dorsal; b-ventral; c-leg; d-supracoxal seta

PLATE 61

Culture cell

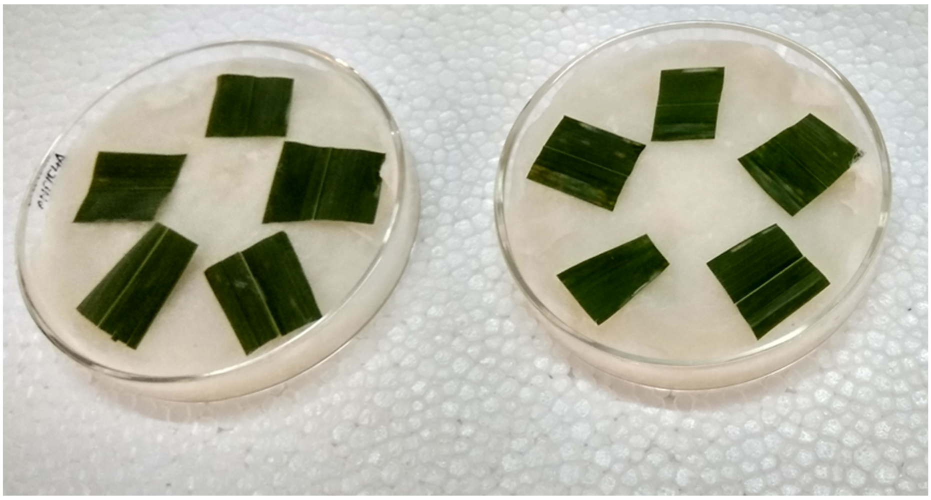


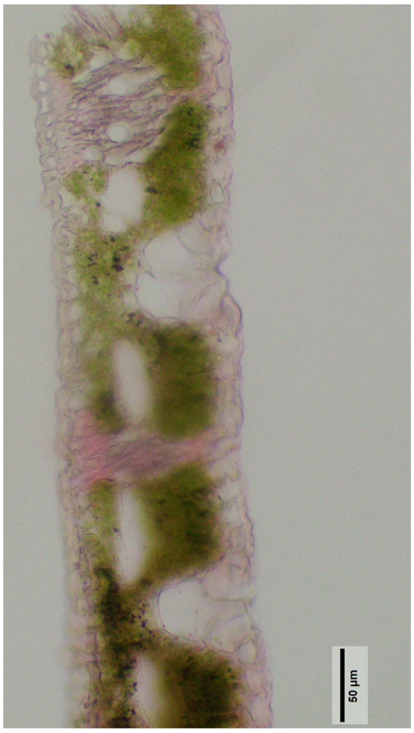
Fig 68 : A view of the culture cell used for rearing bamboo mites in the laboratory

PLATE 62

Feeding damage induced by *Schizotetranychus schizopus* (Zacher, 1913)

a

b



c

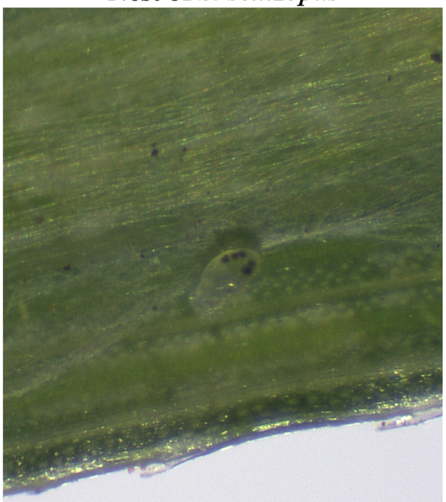
Fig 69: a- chlorotic spots on *Bambusa bambos*; b- stained leaf section of uninfested *Bambusa bambos* leaf; c- stained leaf section of infested *Bambusa bambos* leaf

PLATE 70

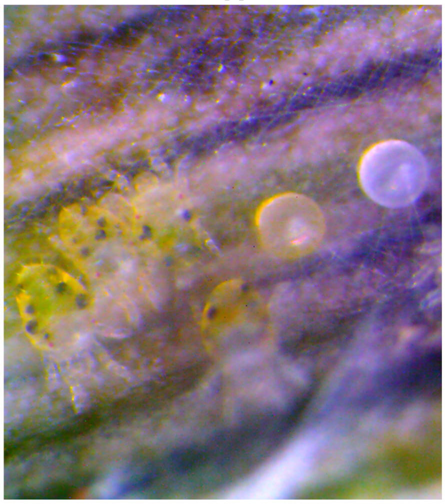
Developmental stages of
Schizotetranychus schizopus (Zacher, 1913)

Nest of *S. schizopus*

Egg



Larva



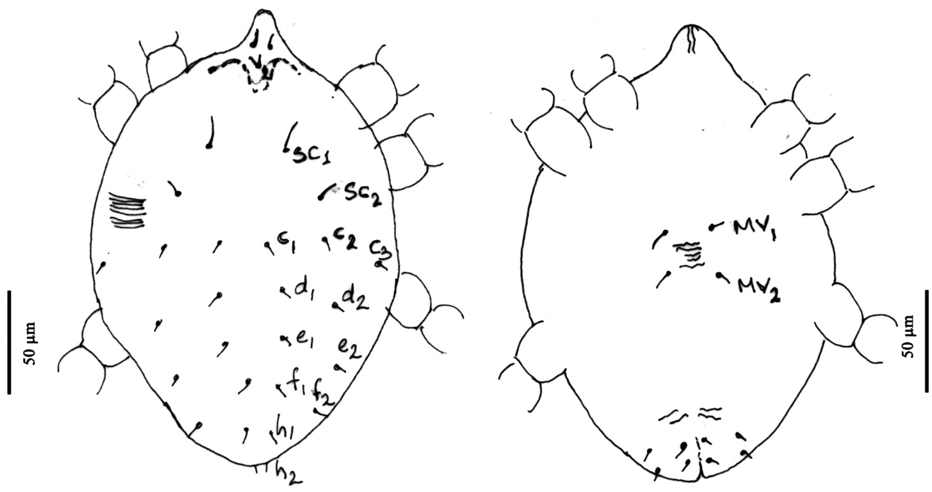
Protonymph

Deutonymph

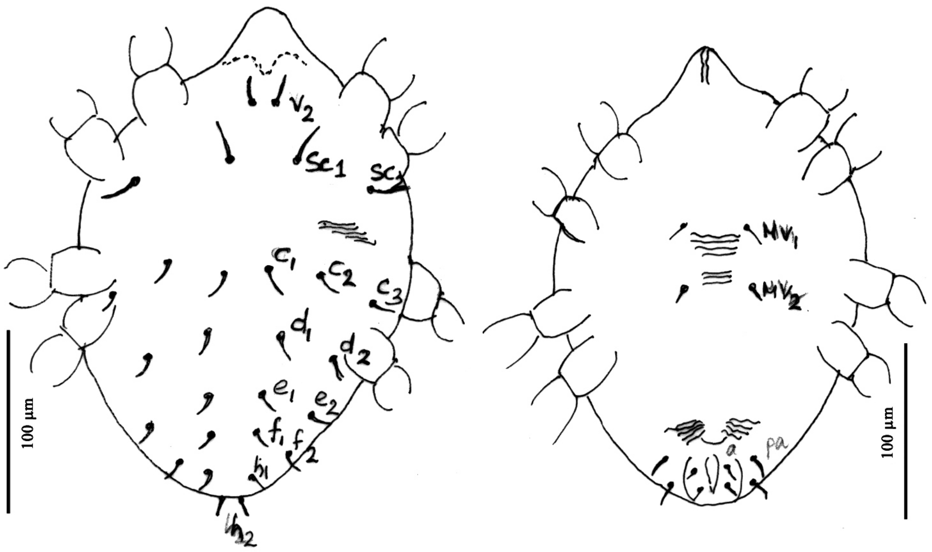
Adult female

PLATE 71

Morphological features of developmental stages of *S. schizopus* (Zacher, 1913)



a **b**

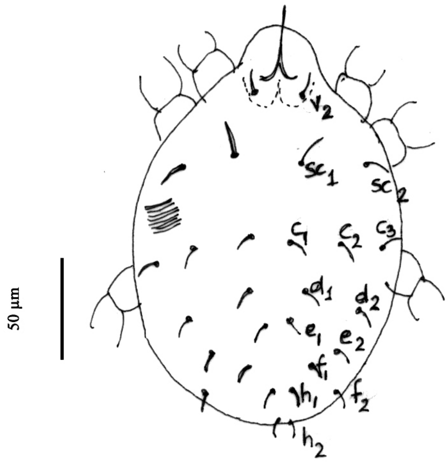


c **d**

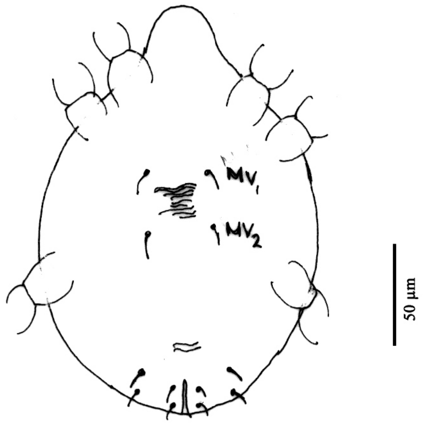
Fig. 87: *Schizotetranychus schizopus* (Zacher, 1913); a- larva dorsal; b-larva ventral; c-protonymph dorsal; d-protonymph ventral

PLATE 72

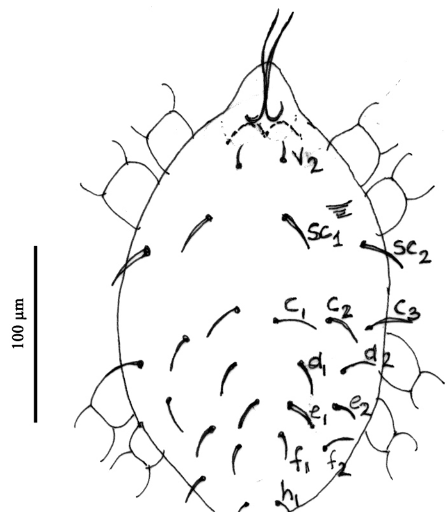
Morphological features of developmental stages of *Tetranychus urticae* C.L. Koch, 1836



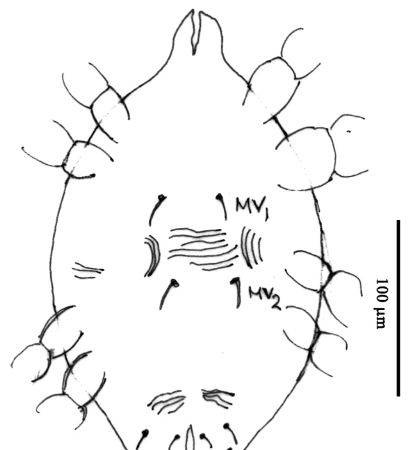
a



b



c



d

Fig. 88: *Tetranychus urticae* C.L. Koch, 1836; a- larva dorsal; b-larva ventral; c-protonymph dorsal; d-protonymph ventral

PLATE 72

Morphological features of developmental stages of *S. schizopus* (Zacher, 1913)

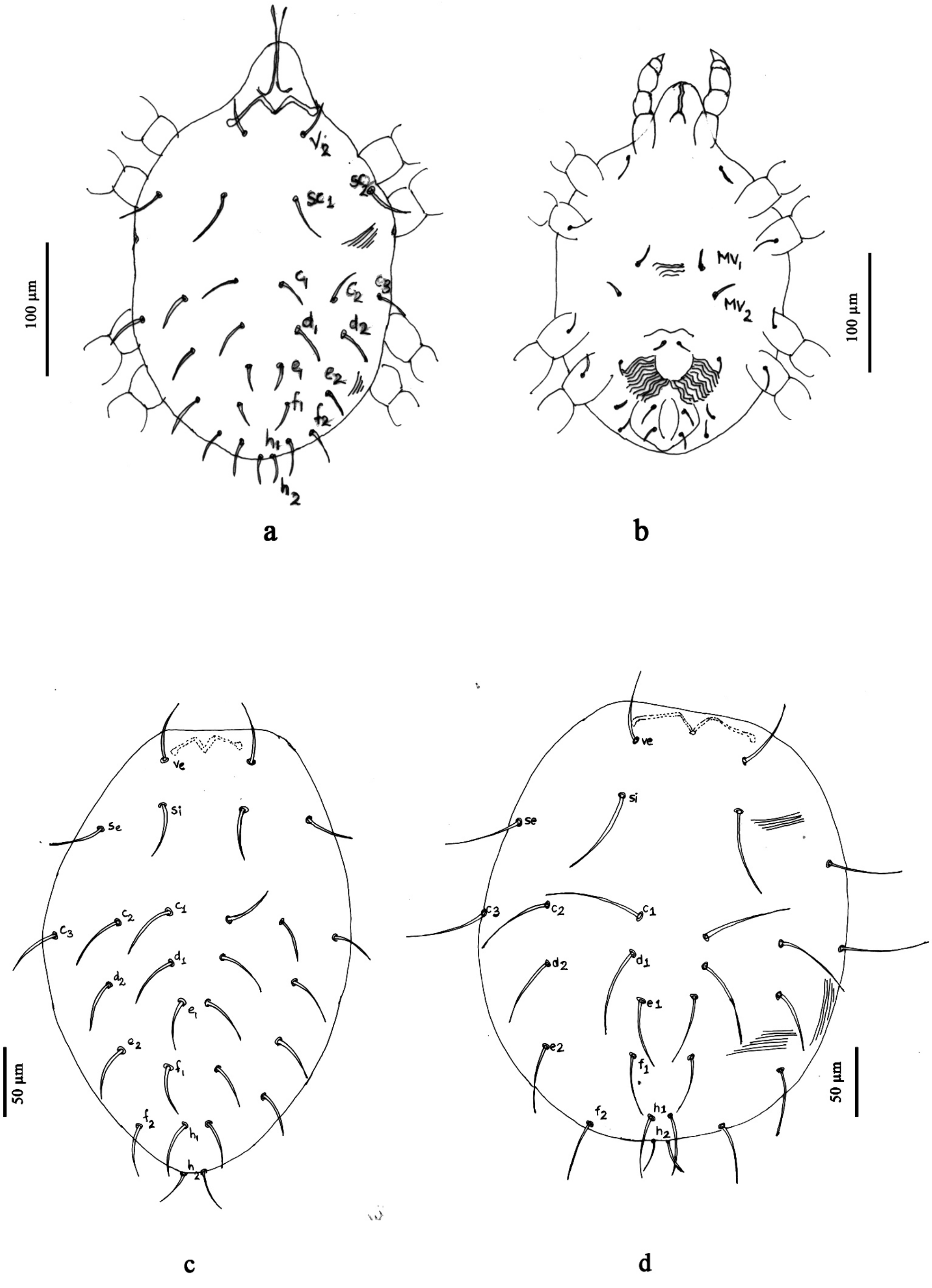
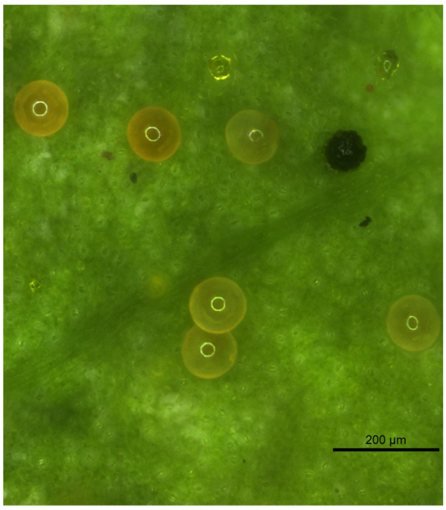


Fig. 88: *Schizotetranychus schizopus* (Zacher, 1913); a- deutonymph dorsal; b-deutonymph ventral; c-adult male dorsal; d-adult female dorsal

PLATE 75

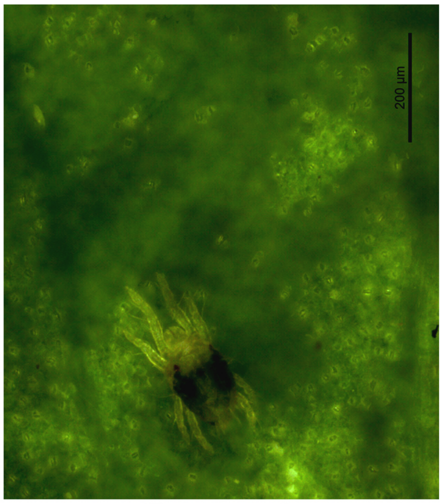
Developmental stages of *Tetranychus urticae* C.L. Koch, 1836



Egg

Larva

Protonymph



Deutonymph

Different life stages

Adult female

PLATE 76

Morphological features of developmental stages of *Tetranychus urticae* C.L. Koch, 1836

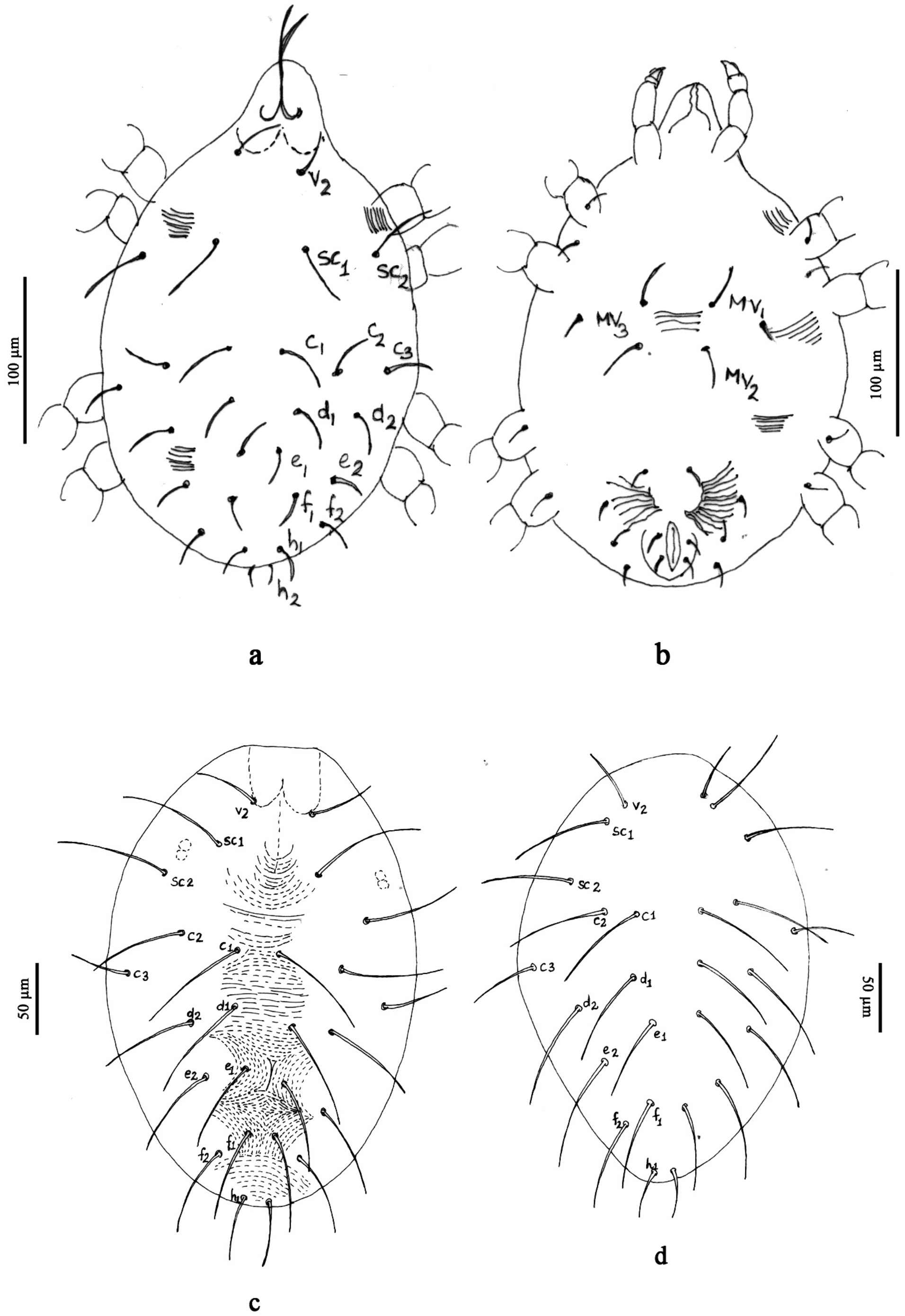


Fig. 93: *Tetranychus urticae* C.L. Koch, 1836; a- deutonymph dorsal; b-deutonymph ventral; c-adult male dorsal; d-adult female dorsal