STUDIES ON MITES (ACARI) ASSOCIATED WITH SELECTED SPECIES OF INVASIVE PLANTS OF KERALA

Thesis submitted to
the Faculty of Science, University of Calicut
For the Award of the Degree of

DOCTOR OF PHILOSOPHY IN ZOOLOGY

By

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MARCH 2021

CERTIFICATE

This is to certify that the thesis entitled **"STUDIES ON MITES (ACARI) ASSOCIATED WITH SELECTED SPECIES OF INVASIVE PLANTS OF KERALA"** is an authentic record of the research work carried out by **Ms. Saritha. C** under my supervision and guidance in partial fulfilment of the requirements for the degree of **Doctor of Philosophy in Zoology** in the Division of Acarology, Department of Zoology, University of Calicut and that no part thereof has been presented before for any other degree or diploma.

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The adjudicators of the thesis entitled "Studies on mites (Acari) associated with selected species of invasive plants of Kerala" submitted by Ms. Saritha.C, have not suggested for any major corrections. However some minor corrections suggested by the examiners are incorporated in the revised thesis. Hence, as instructed by the Directorate of Research, two copies of the revised thesis and one soft copy of the same in PDF format on CD is being sent to the office.

Dr. N. RAMANI

DECLARATION

I, Saritha.C do hereby declare that this thesis entitled **"STUDIES ON MITES (ACARI) ASSOCIATED WITH SELECTED SPECIES OF INVASIVE PLANTS OF KERALA"** is an authentic record of the research work carried out by me under the supervision and guidance of **Dr. N. Ramani,** Professor (Retd.), Division of Acarology, Department of Zoology, University of Calicut and that no part of this thesis has been submitted before for the award of any other Degree or Diploma.

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Plate 32: Morphological features of Second nymph of *Phyllocoptruta merremiae* sp. nov.

Plate 33: Morphological features of Adult female of *Phyllocoptruta merremiae* sp. nov.

PREFACE

Biological invasion has been rated as a global phenomenon, imposing a massive threat to the ecosystem, environment, biodiversity, agriculture, and in total, the welfare of mankind. Invasion is the second most wide-spread threat to global biodiversity, next to habitat destruction (Akter and Zuberi, 2009) and is a form of biological pollution which induce significant global environmental change, leading to species extinction (Reddy, 2008). A steady increase in the number of invasive species was reported since 1800 and the rate of introduction also showed an increase after 1950 (Seebens *et al.,* 2017, 2018). Presently, one -sixth of the global land surface is reported to be under the high risk of bio-invasion (Early *et al.,* 2016). Various factors contribute to the introduction and rapid spread of invasive species and which could be short listed as the speedy travel, international trade and transportation of pets, ornamental plants, seeds, grains, fruits etc., enhanced rate of globalization and so on. Invasive plants lead to biological pollution, thereby exerting a greater impact on the world's biota than any other known aspect of global environmental change (Vitousek *et al.,* 1996). Through their vital ecological and environmental roles, and potential to make rapid spread outside their normal distribution range and successive colonization in new locations, invasive plants have attracted public attention. After their successful introduction, these plants usually escape the predator pressure and compete and displace native species. India also hosts a total of 169 invasive alien species, of which 53 species are terrestrial plants (Sandilyan *et al.,* 2018). Over 3,200 plants have been introduced to India by the East India Company to establish the Royal Botanical Garden (now Acharya Jagadish Chandra Bose Indian Botanical Garden) in Calcutta in 1786 (Royle, 1840). The root

cause for habitat destruction observed in the Western Ghat forests also are said to be the invasive alien species of plants.

In India, documentation of invasive alien species has been found initiated by many research organizations, state and central universities, colleges etc. and the impact of these species on the ecosystems has also been a focus of study by these organizations. Indian researchers adopted numerous methodologies and approaches to study the alien flora during the last two decades. Various approaches and methologies have been adopted to undertake surveys on the invasive flora and fauna in order to make their successful documentation. However, most of the above attempts being of local scale and often being species specific, have been identified as of little value for working on a pan-Indian status of invasive alien species (Adhikari *et al.*, 2015). Despite the amazing taxonomic diversity and large geographical area of India, extremely low amount of research works have been carried out here on the invasive alien species when compared to those of other countries which possess less biodiversity (Adhikari *et al.*, 2015).

In the state of Kerala also, a large number invasive plants are known to be introduced to meet specific purposes in various fields of human interest such as agriculture, forestry, horticulture etc. Once got successfully introduced, either intentionally or accidentally, these plants have been found established here and spreading very rapidly. Most of the invasive plants are reported to induce great REDUCTION by destroying the habitat, hampering the growth of native species and thereby adversely affecting the biodiversity, social life and human health and economy. Despite these adverse impacts, invasive plants on agro-ecosystems are usually found ignored as unimportant and no attempts have been undertaken to quantify the impacts of these plants to the ecosystem, environment and biodiversity.

Resembling the various economic crops and agricultural plants, invasive plants and weeds also support a rich and diverse fauna of organisms, especially the arthropods. These organisms exhibit diversity in their distribution, host range, feeding habits as well as breeding attributes. However, little attention has been focused by the scientific and public sectors to study the faunal composition associated with the invasive plants which have already got established in our terrestrial ecosystem and the diverse roles played by the individual faunal entity on respective host plants. In this context, the present study becomes relevant by being the first attempt in Kerala to trace the faunal diversity of mites associated with invasive plants of Kerala. Among the various components which effectively utilize plants as their habitats, mites deserve to be highlighted because there is a good range of plant dwelling mites which have got considerable agricultural relevance (Moraes and Flechtmann, 2008). Kerala, being the land with plenty of floral and faunal ingredients, it is the most apt place to conduct studies on faunal diversity and alterations in the biodiversity resources, by many reasons. Invasion by alien plants leads to ecological and economic imbalance. A total of 82 alien invasive plant species have been recorded from Kerala, of which 20 species were proved to be the high risk plants, and these included notorious weeds like *Chromolaena odorata*, *Lantana camara, Mikania micrantha, Mimosa diplotricha* var. *diplotricha, Merremia vitifolia* and *Sphagneticola trilobata* (Sankaran *et al.,* 2012).

The present investigation was undertaken duly considering the increasing rate of introduction and spread of invasive plants in Kerala and the dearth of knowledge on the faunal diversity associated with these plants. The present study was concentrated on the faunal diversity and distribution pattern of mite fauna associated with 25 species of most common and widely distributed invasive plants growing in different localities of Kerala. Studies on seasonal population and feeding attributes of a few selected species of highly

host specific species of mites have also been performed and included in the present work.

The objectives of the present study included the following parameters:

1. To study the faunal diversity and distribution pattern of mites inhabiting various groups of invasive plants growing in different localities of Kerala.

2. To study the feeding habits of selected species and to assess the damage potential of dominant species with host specificity, through qualitative and quantitative methods.

3. To elucidate the breeding habits of most common and injurious species on selected invasive plants.

4. To assess the influence of different combinations of temperature-humidity conditions on the postembryonic development of selected species of host specific mites so as to gather information on the ideal conditions for mass rearing of the above species.

The outcome of the study is thought to become the baseline for the future workers to make further contributions on the probable use of these mites for successful management of the population of their host invasive plants under field conditions.

CHAPTER II
INTRODUCTION

Over 80 % of the total animal diversity described so far represent the members of phylum Arthropoda, of which the class Insecta of the subphylum Mandibulata constitute the most dominant and diverse group. The Arthropod class Arachnida included under the subphylum Chelicerata also forms a major group, comprised of extremely diverse animal groups like the Acari, spiders, scorpiones, pseudoscorpiones, opiliones, solifugae (sun spiders/false spiders), ricinulei (hooded tick spiders), schizomida (short tailed whip scorpion), palpigradi (micro-whip scorpions), amblypygi (whip spiders) and uropygei (whip scorpions/vine garoons). The subclass Acari embracing the two cousin groups like the mites and ticks, is the only group of arachnids which includes phytophagous members and its fossil history going back at least to the early Devonian period. While the ticks form a macroscopic and exclusively parasitic group with characteristic haematophagous habit on vertebrates, the mites with their microscopic size range and amazing diversity in shape, are extremely diverse in habits, habitats, behaviour, life style, reproduction, development and so on. Acari presently includes over 55,000 described species (Krantz and Walter, 2009) categorized under two superorders *viz.* Parasitiformes (Anactinotrichida) and Acariformes (Actinotrichida). Parasitiformes is further divided in to four orders *viz.* Opilioacarida, Holothyrida, Ixodida and Mesostigmata while Acariformes includes two orders *viz.* Trombidiformes and Sarcoptiformes. The former includes two suborders *viz.* Sphaerolichida and Prostigmata while the latter is divided in to two suborders *viz.* Endeostigmata and Oribatida.

Mites are easily discernible from other arthropods based on their minute size, body being divided into an anterior gnathosoma and posterior

idiosoma, and with their four pairs of five segmented legs, except in eriophyids, the latter possess two pairs of legs. Mites are slow moving, except the predatory forms, which are faster than the other groups. Despite the possession of eye spots in some species (McEnroe, 1969; McEnroe and Dronka, 1969), mites are not capable of vision, but can sense light intensity and direction, and explore objects by tactile and olfactory means (Sabelis and Dicke, 1985; Radwan *et al,*. 2002). They colonize all available habitats on earth including terrestrial, freshwater and marine environments.

Mites which form the subject matter of the present investigation, come second to insects among the arthropod pests on all crops. The crop reduction due to mite infestation shows variation and in India, this has been estimated to be 50-80% in mango, 10-15% in rice, 15-20% in tea, 10-25% in sugarcane, 13-31%in brinjal, 25%in okra 27-39% in chillies (Chhillar *et al.*, 2007). Around 7,000 species of phytophagous mites belonging to five families *viz.* Tetranychidae, Tenuipalpidae, Tarsonemidae, Eriophyidae and Tuckerellidae have been reported world-wide, of which 169 species are distributed in India, which include 17 species of major and 30 species of minor pests (Chhillar *et al.*, 2007). Owing to their high economic significance, plant mites have attracted the attention of many, long time back, in multiple ways not only as phytophages but also as plant pests, predators, fungivores, pollen feeders, saprophages, scavengers, phycophages, lichenophages and so on. Plant parasitism has been met with in several lineages of mites and presently, almost all groups of plants harbor one or the other species of mites (Jeppson *et al.*, 1975; Helle and Sabelis 1985; Lindquist *et al.*, 1996). Plant parasitic mites mostly belong to the suborder Prostigmata and they survive and multiply successfully by draining out the plant sap. Under Prostigmata, atleast seven clades show phytophagous habit, of which members of two superfamilies *viz.* Tetranychoidea and Eriophyoidea are obligate phytophages, attacking all species of vascular plants.

Among the Prostigmata, the superfamily Tetranychoidea represents an exclusively plant parasitic taxon, exhibiting specific preference to feed on vascular plants (Krantz and Walter, 2009). The mouthparts of these mites are suitably modified for a true phytophagous life style, with their cheliceral bases being fused to form an eversible stylophore and the movable digits forming a recurved hollow stylet. Of the five families included under Tetranychoidea *viz.* Tetranychidae, Tenuipalpidae, Tuckerellidae, Linotetranidae and Allochaetophoridae, the most dreadful plant pests belong to the family Tetranychidae, the popularly called 'spider mites'. As designated by the common name, these mites spin copious webbing on their host plants and this habit is solely restricted to the members of the subfamily Tetranychinae, while the other subfamily Bryobiinae do not construct webs (Gutierrez and Helle, 1985; Gerson, 1985).

Tetranychidae produce silken webbing on their host plants to meet various life activities and that form an adaptation to survive on their host plants. Most tetranychids are cosmopolitan, highly polyphagous, causing an array of direct damages on their hosts, such as chlorosis, necrosis, severe leaf drop, stunting of plant growth, yield reduction, and ultimately leading to the death of host plant, particularly in herbaceous plants. Apart from direct feeding injuries mentioned above, many species transmit phyto- pathogenic viruses also, as reported in *T. urticae* which transmits the potato virus-Y(Schulz, 1963), *T. ludeni* which transmits the Dolichos Enation Mosaic Virus (Rajagopalan, 1974) etc. Tetranychidae currently embrace over 1,300 species, belonging to 84 genera categorized under two subfamilies *viz.* Tetranychinae and Bryobiinae and six tribes (Migeon and Dorkeld, 2006-2017). With the possession of a combination of supreme adaptive features like shorter generation time, rapid population build up, wind dispersal, easy colonization of new habitats, development of resistance against chemical pesticides etc., tetranychids very successfully flourish in various

agroecosystems. These mites assumed the status of economic pests subsequent to the second world war, owing to the introduction of modern agricultural practices such as the indiscriminate use of synthetic pesticides and large scale application of nitrogenous fertilizers. Tetranychidae include members of many economically important genera *viz. Tetranychus, Eutetranychus, Eotetranychus, Oligonychus, Aponychus, Schizotetranychus, Panonychus, Aponychus* and so on, all of which are characteristically polyphagous in habit on plants of varied economic categories. Some important agricultural pests distributed in Kerala include species like *T. urticae, T. ludeni, T. macfarlanei, T. neocaledonicus, O. biharensis, O. indicus, O. coffeae, E. orientalis, E. africanus, P. ulmi* etc. *T. urticae*, the so called two spotted spider mite has been identified as one of the most injurious species, enjoying cosmopolitan distribution over 1200 species of host plants and with regular pest status on of more than 150 species of agriculturally, medicinally and horticulturally important plants world wide (Zhang, 2003;Sheela and Ramani, 2012;Vacante, 2016;Migeon and Dorkeld, 2006-2017, updated in 2019). Species like *T. desertorum, T. lintearius* etc. have been exploited as promising biocontrol agents of invasive noxious weeds (Vasquez *et al.*, 2015).

Tenuipalpidae commonly called as the false spider mites/ flat mites constitute the second important family of Tetranychoidea, next to Tetranychidae. The family shows worldwide distribution, comprising over 1100 valid species belonging to 38 genera, included under three subfamilies, Brevipalpinae, Tenupalpinae and Tegolophinae. These mites resemble the spider mites in several respects, but do not produce silken strands /webs and their infestation is usually confined to the lower surface of host plant leaves. Mite infested sites on the foliar surface develop a brown, scabby discolouration, which spreads from either sides of the main vein on the leaf blade. Presence of collapsed patches, scarring and leprotic blotches etc. are

very common on infested leaves, stem and fruits. Mite feeding often leads to premature ageing of their host plants. Apart from the direct feeding injuries mentioned above, many species transmit different kinds of phytopathogenic bacteria, fungi, viruses etc. Species which are recognized as important plant pests are included under the genera *viz. Brevipalpus, Tenuipalpus, Dolochotetranychus, Raoiella, Larvacarus* and *Cenopalpus.* Of these, *Brevipalpus* includes the maximum number of injurious species like B. *phoenicis, B. californicus, B. obovatus, B. chilensis* and *B.lewisi. R. indica*, the popularly called Red Palm Mite has been recognized as a highly injurious mite pest of palms like coconut, areca , and also banana plants . Examples for some severe plant diseases vectored by these mites are the Citrus leprosis induced by the Citrus leprosis virus C (CiLV-C) and vectored by *B. phoenicis* (Rodrigues *et al.,* 2003), Green spot viral disease in passion fruit transmitted by *B. phoenicis*, coffee ringspot viral disease transmitted by *B. phoenicis* and orchid fleck viral disease transmitted by *B. californicus* (Kondo *et al.,* 2003).

Apart from the above mentioned economically important families of plant mites, Tetranychoidea also comprise members of three more families *viz.* Tuckerellidae, Linotetranidae and Allochaetophoridae. However, the species diversity and agricultural significance of these mites are comparatively very rare and only less than 30 species have been described (Meyer and Ueckermann, 1997). Tuckerellids, the so called 'peacock mites' are phytophahous, occur on woody stems or in cracks/crevices of small twigs and a single genus, *Tuckerella* has been described so far (Dhooria, 2016). Linotetranid mites are commonly called as cryptic false spider mites and are usually seen associated with grass sheaths and rootlets, mosses, rotting trees etc. and these are not at all considered as pests. Allochaetophoridae is also a very small family and it includes a genus *viz. Allochaetophora*. The members are seen in association with grass sheaths.

Another major and exclusively plant parasitic prostigmatid superfamily is Eriophyoidea, the association of which with vascular plants has got a very ancient history (Lindquist, 1998; Schmidt *et al.*, 2012). Eriophyid mites are commonly known as bud or gall or blister mites and these are minute and worm like in appearance with two pairs of legs in all stages of their development. About 4,000 species of eriophyids have been described under three families *viz.* Phytoptidae, Diptilomiopidae and Eriophyidae. Over 500 species of eriophyid mites are reported in India, of which 13 species have been categorized as crop pests (Chhillar *et al.*, 2007). All the species are plant feeders and most of them are highly host specific, inducing varied types of malformations on their host plants such as leaf curling, blistering, russeting, stunting, leaf and bud deformation, erinea formation, gall formation, witches broom effect and so on. These mites infest all parts of their host plants except the roots. About a dozen species are known as vectors of plant pathogenic viruses (Oldfield and Proesler 1996). The important genera accommodating most of the injurious species are *Aceria* and *Eriophyes*. Other economically significant genera are *Aculus, Phyllocoptes, Phyllocoptruta, Vasates, Cecidophyopsis, Acalitus, Acaphylla, Calacarus, Cisaberoptus* etc. Possession of a combination of features like the ability for wind dispersal to ensure wide spread, high rate of reproduction and short development time, potential to induce damage to the vegetative and reproductive parts of host plants so as to reduce their vigor substantially contributed the exploitation of quite a good number of eriophyid species as promising candidates for the control of many well established invasive weed populations, in different countries (Rosen and Huffaker , 1983; Lindquist *et al.*, 1996; Cullen and Briese, 2001). Examples for some successful biocontrol programmes are those of the Rush Skeleton Weed, *Chondrilla juncea* using the skeleton weed gall mite, *Aceria chondrillae* in Australia, United States and Argentina*; Convolvulus arvensis* with the gall mite, *A. malherbae* in the United States

and South Africa; *Hypericum perforatum* with *Aculus hyperici* in Australia *Lantana camara* with the lantana gall mite, *A. lantanae* in different countries (McClay and Clerck-Floate, 2002; Craemer, 1995; Cullen and Briese, 2001). A good number of eriophyid species are warranting their adequate evaluation for their future consideration as potential agents for the control of invasive plants and weeds (Cromroy 1983; Amrine 1996; Rosenthal, 1996).

Various other families of Prostigmata such as Bdellidae, Cunaxidae, Tydeidae, Stigmaeidae, Eupodidae, Suidasiidae, Erythraeidae, Cheyletidae, Rhaphignathidae, Tarsonemidae etc. also share the arboreal ecosystem available on the foliage of plants, where they enjoy utilization of microhabitats by displaying diverse types of diets. Many of the above families are predatory, preying upon pest mites, soft bodied insects like the scale insects, aphids, thrips, white flies etc. by puncturing their body with their stylet-like mouthparts and draining out the internal contents (Lindquist, 1998). Some prostigmatid families like the Labidostommatidae, Rhagidiidae etc. possess chelate chelicerae and are predatory in habit. However, species like *Balaustium medicagoense* of Erythraeidae is an exception, by exhibiting both predation and phytophagy and acts as a pest of past crops and grains (Arthur *et al.,* 2011). The family Tarsonemidae also share varied feeding trends such as phytophagy, fungivory and parasitism and these mites are reported to evolve vascular plant parasitism from a mycophagous ancestry (Lindquist, 1986, 1998). Most of the Tarsonemid mites found on plants feed on fungi and algae and a few species predate on the eggs of pest mites (Lindquist, 1986). Tarsonemids usually infest tender plant parts like the buds, flowers, leaves, stem sheaths etc. which in turn become crinkled, curled or brittle. The important genera of Tarsonemidae include *Polyphagotarsonemus*, *Hemitarsonemus* and *Steneotarsonemus.*

Plant associated species of Tydeidae enjoy varied food items like pollen, algae and fungi and some species act as facultative predators (André 1986; Walter and O'Dowd 1995a, b). Plant dwelling cheyletid mites are always predatory in habit, feeding on the eggs of pest mites and those of other predatory mites. Stigmaeid mites are also predatory and many species serve as promising biocontrol agents of agricultural pests (Hessein and Perring, 1976). Some examples are *Zetzellia mali, Agistemus exsertus* etc. *which feed on spider mite eggs.* Species like *A. olivi* show specific preference to eriophyoid mites and has been rated as a useful biocontrol agent of eriophyid mite pests (Momen, 2012). Despite this, the stigmaeid genus *Eustigmaeus is plant parasitic, especially on mosses* (Gerson, 1972).

Apart from the Trombidiformes group of mites discussed above, various species of Sarcoptiformes mites, especially those belonging to the suborder Oribatida also show association with plants. Oribatid mites, despite their traditional habitat in the soil ecosystem have become adapted to live as foliar specialists, by developing several distinct structural and behavioural features required for arboreal mode of life (Walter and Behan-Pelletier, 1993; Behan-Pelletier and Walter, 2007). Being the most dominant mesofaunal elements of the soil ecosystem, these mites are equipped with pincer- like chelicerae to enjoy diets comprised of fungal hyphae and spores, algal strands, decomposing plant matter etc. These mites play vital roles in enhancement of soil fertility through biodegradation and turn over of nutrients, bioindication of physico-chemical conditions of soil including radioactive pollution, biological control, forensic science helping in the detection of post-mortem intervals and thereby helping in crime detection. These mites rarely thrive on live green tissue of plants except the pollen grains. Despite this, some species of oribatid mites have undergone a transition from their original mycophagy and detritivory, to a phytophagous

life style, by consuming live plant tissues. This is especially true in aquatic or semiaquatic species belonging to the genus *Hydrozetes*, which usually are found associated with the duck weed (*Lemna* spp.). The immature stages of the above species burrow inside the floating thallus of the weeds. Another excellent example of a truly phytophagous oribatid species is a member of the family Galumnidae *viz. Orthogalumna terebrantis*, which shows close association with the notorious invasive aquatic weed, *Eichhornia crassipes*, the commonly called waterhyacinth. The adult females cut ovipositional holes on the pseudolaminae of the weed and the developing larval and nymphal stages burrow into the leaf tissues and produce feeding tunnels and galleries inside the leaves of water hyacinth. Feeding activity of the juveniles of the species reduce the photosynthetic efficiency of the weed and thereby causing a decline in plant vigor (Marlin *et al.*, 2013). The above species of mite has been successfully imported by various countries and established successfully for the control of the weed.

Apart from the Acariformes mites, arboreal ecosystem has been successfully exploited by the members of Parasitiformes mites too, especially by the members of the suborder Mesostigmata. Phytoseiidae, Ascidae, Laelapidae, Blattisociidae and Otopheidomenidae are some of the well known mesostigmatid families which colonise plants. Among these, phytoseiids dominate, contributing around 20 % of the total mesostigmatids. These mites represent the most important group of predators, which show world-wide distribution, encompassing 2,521 valid species belonging to 94 genera under three sub-families (Demite *et al.*, 2014, 2020). The wide food range of food items of these mites include fungi, pollen, nematodes, small arthropods like mites, scale insects, whiteflies, thrips and so on. Having high rate of reproduction, shorter development time and exceedingly high response to increased prey density etc., phytoseiids are easily mass cultured for field release as potential biological control agents (Chant and McMurtry, 1994;

Kostiainen and Hoy, 1996). Other mesostigmatid families like the Laelapidae, Ascidae etc. also show varied life styles like free living, parasitism , predation etc. and some species have been rated to have great potential as promising biocontrol agents of pests like mites, nematodes, insects etc.

Despite the indispensable roles of mites in all areas of human interest and their multiple functions , either in the beneficial or injurious ways, Acari still represents a very poorly explored group in India. Kerala, being a state blessed with a rich and diverse flora and fauna, is the most apt place to undertake studies on biodiversity and related issues, by many reasons. For the last few decades, Kerala has experienced an increasing rate of invasion by both the floral and faunal ingredients and during most occasions, such invasions would lead to ecological and economic imbalance which in turn would impose tremendous adverse impact on existing biodiversity, agroecosystem and animal health. A total of 82 alien invasive plant species have been recorded from Kerala(Sankaran *et al.*, 2012), of which 20 species including *Chromolaena odorata*, *Lantana camara*, *Mikania micrantha*, *Mimosa diplotricha* var. *diplotricha, Merremia vitifolia* and *Sphagneticola trilobata* have been proved to impose high risk to the environment. Duly considering the increasing incidence of invasive plants in Kerala and the dearth of knowledge on the faunal composition associated with these plants, the present study was undertaken by focusing on the collection, identification and making taxonomic description of the mite fauna associated with 25 species of invasive plants distributed in 88 localities of Kerala. A total of 124 species of mites including two new species of eriophyid mites, belonging to 50 genera and 22 families categorized under three orders and two superorders were collected during the study. Part I of the thesis provides data on the faunal composition and diversity of the various species of mites on their respective host plants, their distribution and host range, systematic position, classification and taxonomic descriptions of the total 12 species collected

including three new species. Molecular bar coding of a noval species of eriophyid mite collected and described during the study was also carried out and the data of which also have been included and presented in this part. The influence of geographical variations on the species richness and evenness of the mites harbouring on the invasive plants also was also evaluated based on studies on diversity indices such as Shannon-Wiener Diversity Index and Simpson's Index and data have been included in Part I. Further, the impact of climatic factors such as temperature, relative humidity, rain fall and wind velocity on the distribution pattern and population density of four selected species of highly host specific species of eriophyid mites was also studied to record the most favourable climatic parameters which could support the maximum population build up of these mites. Data on the population parameters of the four species of eriophyid mites including three new species have also been presented in this part.

CHAPTER III
REVIEW OF LITERATURE

The present day knowledge on the faunal diversity and biological aspects of mites associated with invasive plants is very much scanty on a global level and as far as India is concerned, it is relatively an unexplored area. Hence, earlier data on the incidence, taxonomy and biological aspects of mites associated with invasive plants is practically meager and considering this lacuna, in the present review, attention has been focused to incorporate research works carried out on mite pests/associates of other crop plants also, apart from the isolated reports on invasive weed plants. Thus, a consolidated account is presented here on the invasive plant inhabiting mites in general, highlighting their incidence, systematic aspects, distribution pattern etc. In addition, data on other aspects such as molecular analysis, population dynamics and seasonal distribution pattern of eriophyid mites, especially those of invasive/weed plants also have been incorporated here, considering its relevance in the present investigation.

It was Siebold (1850) who included Eriophyoid mites as a distinct taxon under Acari. The incidence of phytophagous mites in India was reported by Peal (1868), based on the collection of specimens recovered from the North-East region and he named these mites as red-spider. Gutierrez and Schicha (1983) collected mite specimens mainly from cultivated plants and weeds in New South Wales and examination of the collected specimens disclosed the presence of 25 species of tetranychid mites belonging to nine genera, of which five were the first report from the Australian continent. Wood Mason (1884) was the first to make a published reference on Indian plant mites of agricultural importance by describing the species, *Tetranychus*

bioculatus. Nalepa (1887) made a detailed study of mites under two genera of eriophyid mites *viz. Eriophyes* and *Phytoptes*. Banks (1900) carried out studies on plant mites and reported two genera *Tetranychus* and *Stigmaeus* in the United States. Cook (1909) described a new species of eriophyid mite, *viz. E. lantanae* (now *A. lantanae*) infesting the notorious invasive weed, *Lantana camara* from Cuba. Incidence of the tea red spider mite, *T bioculatus* on jute was reported by Misra (1913). Six new species of mites were described under the family Tetranychidae by Hirst (1923 and1924) from India, which included *Paratetranychus indicus*, *T.* (*Schizotetranychus*) *hindustanicus, P. iseilemae*, *T.* (*Schizotetranychus*) *andropogoni, P. oryzae* and *P. punicae*. A new species of gall mite, infesting on *Pongamia glabra* in South India was described by Massee (1933).

Yokoyama and Ishii (1934) conducted detailed studies on the mites infesting mulberry leaves and on the morphology and biology of *Panonychus mori*. Putman (1939) reported the occurrence of a deuterogynous stage in eriophyoid mites for the first time in *Aculus fockeui*. The false spider mite, *Brevipalpus phoenicis* was first described by Geijskes (1939) on *phoenix* species in Holland. Rahman and Sapra (1940) made a significant contribution by describing seven species of tetranychid mites including four new species. The new species described were *T.mori, T. cucurbitae*, *Paratetranychus mangiferus* and *Anychus ricini*. Four subfamilies *viz.* Phytoptinae, Sierraphytoptinae, Eriophyinae and Phyllocoptinae were erected by Keifer (1944) under the family Eriophyidae and the author regrouped the known genera under these subfamilies.

Batchelor (1952) prepared a list of eriophyid mites inhabiting plants of various economic categories in Washington and conducted a detailed study on the symptoms induced by each species on its host plant. Muma (1955) gave an account on the phytoseiid mites associated with citrus plantations in

Florida. Bindra and Kittur (1961) recorded the serious infestation and damage caused by the spider mite pest, *T. macfarlanei* on various vegetable crops in Madhya Pradesh and Gwalior. The authors also provided information on the heavy infestation by the broad mite, *Petrobia latens* on wheat and the serious levels of damage induced by the species. Incidence of two species of coconut foliage mites *viz. T. fijiensis* and and *T. neocaledonicus* was reported in Philippines by Rimando (1962). Detailed studies were undertaken by Manson (1963) on the phytophagous mites belonging to families Tenuipalpidae and Tetranychidae associated with citrus plantations in South East Asia. Ghai (1964) prepared a complete list of the mite diversity described from India and she had included 65 species of mites belonging to 29 genera and 11 families.

Extensive taxonomic investigation carried out by Channabasavanna (1966) on the eriophyid mites of India enabled to provide descriptions of 61 species, of which 44 were new to science. Haramoto (1969) enlisted the host plants of *B. phoenicis* and clearly indicated the aerial dispersal of the species from heavily infested papaya plant in Hawaii. Gupta *et al.,* (1971) made a preliminary survey of phytophagous and predatory mite fauna associated with the temperate and sub-tropical fruit trees of Punjab and Himachal Pradesh. The influence of webbing on the behavioural response of males to quiescent female deutonymphs of the two spotted spider mite, *T. urticae* was analysed by Penman and Cone (1972) and the authors observed that webbing could facilitate attraction by males towards the female deutonymphs of the species. Banu and ChannaBasavanna (1972) conducted studies on the host range and biology of *Eutetranychus orientalis* and further collected information on the natural enemies of the species in the field. Caresche and Wapshere (1974) conducted observations on the biology and host specificity of the Chondrilla gall mite, *Aceria chondrillae*. Prasad (1974) revised the list prepared by Ghai on the number of mites described from India and the revised list included 769 species categorized under 279 genera and 102 families. A preliminary report

on the mites associated with the invasive weed, *L. camara* in the neotropical region was prepared by Flechtmann and Harley (1974). Kovalev *et al.*, (1975) conducted studies on a new species of eriophyid mite, *viz. A. acroptiloni* with respect to its potential in controlling the Russian knapweed, *Acroptilon repens.* Gupta (1975) described eight new species of the genus *Amblyseius viz. A. aceriae, A. coccineae, A. daturae, A. officinaria, A. polyantheae, A. pruni* and *A. syzygii* from India and a key was also prepared for all known Indian species of the genus. A new record on the association of the eriophyid mite, *A. drabae* on the weed *Cardaria draba* was made by Lipa (1976) in Poland. Cromroy (1977) highlighted the potential use of eriophyoid mites in the control of weeds. Preliminary studies were completed by Lipa (1978) on the use of *A. drabae* in the biocontrol of the weed, *C. draba*. Studies conducted by Boczek and Chyczewski (1978) provided information on the eriophyid mites associated with weed plants in Poland.

Lal and Mukherji (1979) conducted studies on the association of *E. orientalis* on citrus in Varanasi, India and they showed that hot dry wind favoured the buildup of the population density of the mite. Morphological variations between the populations of false spider mite species like *B. phoenicis, B. californicus* and *B. obovatus* were recorded by Smith-Meyer (1979) and the author also reported that each species had more than 50 host plant species on a global level. Helle *et al.*, (1980) studied the types of parthenogenesis in 19 species belonging to six genera of tenuipalpid mites and the results of their studies revealed the prevalence of thelytokous parthenogenesis with female haploidy in *B. phoenicis* and *B. obovatus.* Gutierrez and Bolland (1981) provided morphological description of *Tenuipalpus inophylli* along with preliminary data on its biology as well as the occurrence of thelytokous parthenogenesis in the species. From India, Mohanasundaram (1981) erected two new species of eriophyid mites infesting the invasive terrestrial weed, *L.camara*. The new species described were

Diptilomiopus camarae and *Eriophyes lantanae* (now *A. lantanae*). Abou-Awad (1981) conducted population studies on the eriophyid species, *E. mangiferae* and observed that mite population density reached its peak level in late May and October, and the species completed eight annual generations. The author provided descriptions of the male and immatures of the species. The pink mite of tea, *Acaphylla theae* was reported to build up its population density to peak levels in late May with fluctuations during the months of June, July, August, followed by an increase to reach peak formation in late October, as evidenced through the studies of Muraleedharan and Chandrasekharan (1981).

While studying the population dynamics of the scarlet mites infesting tea bushes in Indonesia, Oomen (1982) observed that the infestation of these mites would drastically affect tea production in the country. Gutierrez and Schicha (1983) screened 251 mite samples collected mainly from cultivated plants and weeds in New South Wales and identified 25 species of tetranychid mites belonging to nine genera, of which five species *viz. Aplonobia citri*, *Schizotetranychus celarius*, *O. grypus*, *O. tiwakae* and *T. lombardinii* formed the first records from the Australian continent. Mohanasundaram (1983) described two new species of tenuipalpid mites belonging to the genus *Brevipalpus viz.*, *B. cucurbitae* and *B. euphorbiaceae* from Tamil Nadu. The same author (1984) subsequently reported 15 new species of eriophyid mites from Tamil Nadu and Himachal Pradesh. Information on the negative impact of relative humidity on the population density of the phytoseiid predator, *Phytoseius oleivora* was reported by Gonzalez *et al.*, (1984) based on their studies carried out in Havana. Association of various species of oribatid mites with the terrestrial weed, *Chromolaena odorata* was reported by Ramani and Haq (1984) from Kerala.

A new species of *Aceria* was described by Nuzzaci *et al.,* (1985) from the weed, *Convolvulus arvensis*. The authors also provided notes on other species of eriophyid mites associated with convolvulaceous plants. Extensive studies undertaken by ChannaBasavanna (1985) on the mite pests of various crops in India revealed that infestation by spider mites, false spider mites and gall mites would induce severe problems to these crops. Seasonal fluctuations in the population density of *A. litchi* were traced by Sharma *et al.*, (1986) and the authors reported maximum field population of the species during the months of April- May and the minimum density during November-December. The possible role of oribatid mites in the control of the noxious aquatic weed, *Eichhornia crassipes* and the terrestrial weed, *C. odorata* was disclosed by Haq and Ramani (1987). The association of members of the eriophyid mite genus *Aceria* with some economically important plants in South India was reported by Mohanasundaram (1987).

Boczek and Chandrapatya (1989) described a new species of eriophyid mite of the genus *Calacarus viz. C. lantanae* infesting the leaves of the invasive weed, *L.camara* in Thailand. Amrine and Stasny (1989) reported the incidence of an eriophyid mite, *Paraphytoptus pannolus* on the giant ragweed, *Ambrosia trifida*. Data on the feeding potential of the phytoseiid predator, *A. tetranychivorus* on selected species of tetranychid and tenuipalpid mite pests were gathered by Nangia and Channa Basavanna (1989) and the authors reported that the life cycle of the predator was short and with high fecundity when fed on tetranychid mites. Gupta (1991) enlisted 1800 species of mites included under 550 genera and 160 families. Abou-Awad and El-Banhawy (1992) described a new species of eriophyid mite belonging to the genus *Phyllocoptes viz. P. lantanae* which was found to infest *L.camara* in Kenya. Gerson (1992) conducted studies on the biology and control of the broad mite, *Polyphagotarsonemus latus* and reported that the mite could infest on more than 60 plant families and exhibited extremely polyphagous habit.

Amrine and Stasny (1994) provided a worldwide representation of eriophyoid species approximating 4600 known species, described under 420 genera. Detailed studies of Haque *et al.,* (1994) on the seasonal abundance of the eriophyid species *Calacarus quisqualis* on the host plant, *Quisqualis indica* at Rajshahi disclosed that the mite population differed from month to month and area to area. Bacic and Petanovic (1995) performed population studies of the eriophyid species, *Aculus euphorbiae* inhabiting on weeds like *Euphorbia* spp. and they observed that the species had a lower population during winter season, resulted from slow growth as well as presence of predators. The results of extensive surveys conducted in Mexico and the southern United States on the phytophagous arthropod fauna associated with four closely related species of lantana *viz. L. camara, L. urticifolia, L. urticoides* and *L. hirsuta* undertaken by Palmer and Pullen (1995) revealed the presence of only two species of mites. The species recovered included the oribatid mite, *Mochloribatula calcyifera* and the eriophyoid mite, *A. lantanae*. McFadyen (1995) provided information on the ability of an eriophyid species, *Acalitus odoratus* to infest and induce erinea formation on the leaves of the invasive terrestrial weed, the so called Siam weed, *Chromolaena odorata*. Boczek and Maciejczyk (1995) carried out observations on the bionomics of a species of *Aceria viz. A. artemisiae* and evaluated the possibilities of using the species for the control of the weed, *Artemisia vulgaris*.

Craemer (1996) conducted studies on eriophyoid mites infesting the weed, *L.camara* and erected two new species *viz. Shevtchenkella stefneseri* and *Paraphytoptus magdalenae* infesting the invasive weed plant, *L. camara*. A key to the eriophyid species associated with the host plant was also prepared by the author. From South Africa, Creamer (1996) described two new species *viz. Paraphytoptus magdalenae* and *Tegonotus stefneseri* collected from the leaves of the weed plant, *L. camara.* Jupp and Cullen

(1996) conducted observations on the effects of the eriophyid mite, *A. hyperici* on an invasive weed, St. John's wort, *Hypericum perforatum*, in Australia. Rosenthal (1996) made a review on the biocontrol potential of eriophyid mites and highlighted the importance of eight species of these mites with high potential in weed control. Amrine (1996) highlighted the potential role of the eriophyid species, *Phyllocoptes fructiphilus* for the regulation of the invasive plant, *Rosa multiflora* in the United States by transmitting an unidentified virus that could cause rose rosette disease (RRD) in *R. multiflora*.

Data on the diversity, geographic distribution and the abundance of predatory mites inhabiting on citrus plants in South Africa were procured by El-Banhawy (1997). The direct impact of climatic factors like temperature, relative humidity and rainfall on the oviposition, hatchability, mortality and seasonal occurrence of an eriophyid species, *Cosella purpureusi*, infesting on bean plant was revealed through the studies of Haque *et al.,* (1997). Petanovic *et al.,* (1997) provided an account on the taxonomy and bioecology of eriophyid mites associated with the Canada thistle, *Cirsium arvense*. The procedures adopted for collection of *Calepitrimerus vitis* from the leaves and buds of the grapewine, *Vitis vinifera* were elaborated by Duffner (1999). Haq (1999) provided information on the distribution of the coconut mite, *A.guerreronis* in Peninsular India. Through a survey carried out in Queensland on the cryptic inhabitants of the noxious invasive weed, *L. camara*, Walter (1999) reported the association of more than 50 species of phytophagous mites belonging to tetranychidae, tenuipalpidae, eriophyhidae, tuckerellidae and 37 species of predatory mites with the weed. Mc Clay *et al.,* (1999) established the biocontrol potential of the eriophyid species, *A. malherbae* for the control of field bindweed in the northern Great Plains. Abou-Awad *et al.,* (2000) conducted studies on the population density of the eriophyid mite, *A. ficus* on fig plant and found that the highest population of the mite in the buds occurred during late June and it was the lowest in late

July. The number of mites showed drastic variation during the winter season. Ebrahim (2000) studied the influence of temperature and relative humidity on the biology and life table parameters of *P. oleivora* and *A. pelekassi* in central Florida and recorded that optimum temperature range for the development of these mites was between 30- 32°C. The potential of *A. centaureae* as a prospective biocontrol agent of the diffuse knapweed, *Centaurea diffusa* was evaluated by Littlefield *et al.*, (2000). While studying the spatial distribution pattern of *B. phoenicis* on coffee plants, Reis *et al.*, (2000) observed that the preferred site of the mite was the lower surface of coffee leaves.

Briese and Cullen (2001) published a list of 29 species of eriophyid mites which possessed high potential to serve as better candidates in biological control of weeds. Childers *et al.*, (2001) reported 16 species of tenuipalpid mites from citrus worldwide, of which 10 species were members of the genus *Brevipalpus*. In North, Central and South America also, the authors reported infestation of *B. californicus, B. obovatus* and *B. phoenicis* on citrus and they provided information on the vector status of these mites in transmitting citrus leprosis. A survey made by Mehrnejad and Ueckermann (2002) on the mites infesting pistachio trees in Iran helped to identify *Brevipalpus* species as the most injurious forms among the phytophagous mites present on the trees. Camacho *et al.*, (2002) conducted a taxonomic survey on the insects and mites of guava fruits and they observed that *B. phoenicis* was the most common phytophagous species among the mite fauna. Through their studies on the monthly population density of the eriophyid species, *A. dalbergiae* infesting on Sissoo plants, in relation to physical parameters *viz.* temperature, relative humidity and rainfall, Hossain *et al.*, (2002) showed that the peak population of the mite was in May and the lowest population was in the month of August.

Studies of Chen *et al.,* (2003) and Zhou *et al.,* (2003) disclosed that *B. phoenicis* could induce leaf scorching within 1-3 months of infestation when placed on leaves of the invasive plant, *M. micrantha* under laboratory or field conditions. Welbourn *et al.,* (2003) compared the morphological features of *B. phoenicis* with *B. californicus* and *B. obovatus* and recorded the number of dorsal setae, number of solenidia on tarsus II and dorsal reticulation of the species. Childers *et al.,* (2003a) conducted studies on the host plants of *B. californicus, B. obovatus, B. phoenicis* and *B. lewisi* and their potential involvement in the spread of viral diseases vectored by these mites. They recorded a total of 928 plant species under 513 genera and 139 families as hosts for these mites. The same authors (2003b) published an account on citrus leprosis and its status in Florida and Texas. In South Africa, Baars and Heystek (2003) conducted a survey on the geographical range and impact of five insect biocontrol agents *viz. Calycomyza lantanae, Octotoma scabripennis, Uroplata girardi, Ophiomyia lantanae* and *Teleonemia scrupulosa* established on the weed, *L. camara*. The authors observed that the above biocontrol agents could not bring any significant reduction in the weed density to a manageable situation, and the introduction of additional candidates was found essential for weed control in South Africa. Haq and Sumangala (2003) screened the mite fauna associated with the noxious aquatic weed, *Eichhornia crassipes*, the so-called water hyacinth, in 25 localities distributed throughout in Kerala and listed 21 phytophagous species belonging to nine families. Through an experimental set-up, the authors assessed the injury caused by these mites and the relative merits of two species as potential biocontrol agents of water hyacinth.

The distribution and diversity of mites associated with the invasive plant, *Schinus terebinthifolius* in Florida were studied by Wiggers *et al.,* (2005). While conducting studies on the faunal diversity of mites associated with the invasive plant, *Schinus terebinthifolius* in Florida, Wiggers *et al.,*

(2005) concluded that the mite diversity was high in one-third of the sampled leaves with greatest species diversity in the Prostigmata, followed by Mesostigmata, Astigmata and Cryptostigmata, respectively. Greco *et al.,* (2005) identified the phytoseiid predator, *Neoseiulus californicus* as a potential control agent of *T. urticae* and further carried out studies on the impact of pest/predator ratio on pest abundance on strawberry. Muniappan *et al.,* (2005) conducted studies on the distribution and biological control of the invasive plant, *C. odorata*. Accurate method to estimate the population density of coconut mite, *A. guerreronis* was developed by Siriwardena *et al.,* (2005) using simple equipment. Navia *et al.,* (2005) made a detailed study on the geographical origin, host associations and colonization history of the coconut mite, *A. guerreronis* through DNA sequence analysis of two mitochondrial and one nuclear regions from samples of 29 populations from the Americas, Africa and the Indian Ocean region.

Rancic *et al.,* (2006) provided experimental evidence to confirm that feeding by the eriophyid member of the genus *Aceria viz. A. anthocoptes* induced visible damage symptoms such as folding, leaf edge curling, lamina distortion, bronzing and russeting, on its host weed, *Cirsium arvense*. Gotoh *et al.,* (2006) studied the influence of prey on developmental performance, reproduction and prey consumption of *N. californicus*. Further, the authors (2007) observed the species composition and seasonal changes of spider mite density on a harmful invasive weed plant, *Pueraria lobata*. The colonies of the spider mite, *T. lintearius* were found to reduce the dry weight of the foliage of gorse bushes by 36% over a period of 21/2 years after their release in Tasmania, as reported by Davies *et al.,* (2007).

Studies on the population dynamics of *B. phoenicis* and its predatory mites, as well as the interactions among these mite species in Brazil were made by Carvalho *et al.,* (2008). The impact of climatic factors *viz.*

temperature, relative humidity and rainfall on the phenology of leaf rolls and mite density under natural conditions of an eriophyid species, *Floracarus perrepae* infestiung on the subpinnae of *L. microphyllum,* was studied by Muthuraj and Alexander (2008). The authors observed that the number of mites per leaf reached the peak level in August and a significant positive correlation could be established between the mite density and climatic factors. A detailed review on the successful and unsuccessful approaches for the collection of eriophyoid mites was made by Monfreda *et al.,* (2009) and the authors provided suitable recommendations for their detection, collection etc. for supporting studies in taxonomy, ecology, biology, molecular systematics and population genetics and also for their control. Shahini *et al.,* (2009) conducted a preliminary survey on the population dynamics of some eriophyid mites associated with olives in Albania, and found that the most common eriophyid mites were *A. oleae, D.athiasella* and *T. hassani*. Extensive surveys were undertaken by Xue and Zhang (2009) on the eriophyoid mites infesting various plants in Southeast Asia and they reported 104 genera of these mites. The authors also provided an identification key to the families and genera of these mites and prepared a checklist of 325 species. The authors also made a description of a new species, *Paniculatus curcasis* infesting on *Jatropha curcas* from Java, Indonesia. From India, two new species of eriophyid mites *viz. Cosetacus sharadi* and *A. delhiensis* inhabiting inside the leaf erinea of *Cordia dichotoma* and *Salvadora persica* respectively were described by Pratibha *et al.*, (2009). Migeon *et al.,* (2009) performed modelling of the potential distribution of the invasive tomato red spider mite, *T. evansi.* The host specificity of eriophyid mites was discussed in detail by Skoracka *et al.,* (2009) and they reported that about 80% of currently known species of eriophyoid mites showed association with a single species of host plant, 95% on a single host genus and 99% on a single family. Potential of an eriophyid member of the genus, *Aceria viz. A. thalgi*, a native

of Australia was known to become highly injurious to an introduced weed, *Sonchus oleraceus* as reported by Knihinicki *et al.,* (2009). As per the report of Gupta (2010), out of the total 1,700 species collected from different parts of India, 998 species could be recognized as phytophagous. The total number of mite species estimated in India including the phytophagous species was 2,670 as reported by Singh and Raghuraman (2010). Skoracka and Dabert (2010) conducted studies on the cereal rust mite, *A. hystrix* and discriminated the three populations of *A. hystrix* inhabiting on different hosts (like quack grass, rye grass and smooth brome) on the basis of mitochondrial (COI) and nuclear (D2 region of 28S rDNA) DNA sequences. The mitochondrial studies revealed that the cereal rust mite *A. hystrix* comprised of a complex of species. Navajas and Navia (2010) pointed out the advantages and limitations of the most commonly used genetic markers and the authors evaluated the prospects and challenges of new molecular approaches. Muthuraj and Jesudasan (2011) studied the impact of weather parameters such as temperature, rainfall, and relative humidity on the phenology of leaf rolls and the population density of the eriophyid species, *Floracarus perrepae* damaging the weed, *Lygodium microphyllum* under natural conditions in Tamil Nadu and Kerala and they established a significant positive correlation between mite density and climatic factors. Byrne *et al.,*(2010) reported that in South Africa, the oribatid mite *Orthogalumna terebrantis* represented one among the seven species of biocontrol agents successfully used against the water hyacinth population, by becoming established at 17 out of the 66 water hyacinth infestation cites across the country. Xue *et.al.* (2011) described and illustrated nine species of eriophyid mites from Iran and which included two new species and five new records.

De Souza *et al.,* (2012) conducted studies on the population dynamics of *A. guerreronis* and other mites associated with coconut fruits in

northeastern Brazil. Taylor *et al.* (2012) conducted monthly based field surveys to compare the population dynamics of the red palm mite, *Raoiella indica* on two host plants *viz. Areca catechu* and *Cocos nucifera*, from December 2008 and July 2009 in Kerala. Sheela and Ramani (2012) made a brief survey on the mites infesting medicinal plants collected from the Kannur district of Kerala, India. The result of their study revealed a total of six species of mites belonging to Tetranychidae, Tenuipalpidae and Eriophyidae damaging five species of important medicinal plants. El- Halawany (2012) carried out surveys on the eriophyid mites infesting some fruit trees in Egypt, and they collected a total of 16 species of eriophyid mites from eight species of host plants, of which two species were new records to Egypt. The authors redescribed the newly recorded species and prepared a checklist of the eriophyid mites of Egypt . Studies on the spatial distribution pattern and seasonal abundance of an eriophyid vagrant species, *Anthocoptes vitexae* on the medicinal shrub, *Vitex negundo* were conducted by Sheela and Ramani (2012) in Kerala. Skoracka *et al.,* (2012) made detailed studies on the cryptic species within the wheat curl mite, *A. tosichella* which could be revealed by assessing different data such as the mitochondrial, nuclear and morphometric.

Navasero and Corpuz-Raros (2014) screened the weed hosts in Luzon Island to collect the predatory mites associated with *Polyphagotarsonemus latus* and other Acari. Nasareen and Ramani (2014) conducted a survey on the gall forming eriophyid mite fauna associated with 29 species of economically important plants grown in four districts of North Kerala. The authors observed that out of the 29 species of host plants screened, 22 species harbored distinctly developed galls, and seven species showed open galls called the erinea, induced by mites belonging to four genera *viz.*, *Aceria*, *Eriophyes*, *Acalitus*, and *Diptilomioptus*. The genetic and morphological diversity observed among members of the eriophyid mite genus *Trisetacus*, associated with coniferous trees in Poland were studied by Lewandowski *et al* (2014).

The authors gave special emphasis on the phylogeny, barcoding, host and habitat specialization of these mites. Domingos *et al.,* (2014) identified the mite fauna associated with grapevine in northeast Brazil and evaluated the population fluctuations of the most abundant species of phytophagous mites and associated predators for a period of one year. Vijay Singh and Usha Chauhan (2014) conducted studies on the diversity of mite fauna associated with 16 varieties of vegetable crops and ornamental plants in mid hill conditions of Himachal Pradesh, India and collected a total of 32 species under 15 genera and seven families, of which six species were phytophagous mites and 26 species were predatory mites. Al-Nasser (2014) set a field experiment to study the population density of phytophagous and predatory mites infesting grape trees, *Vitis vinifera*. Besides, the author evaluated the efficacy of two commercial biological pesticides against phytophagous mites and the side effect of which on the beneficial predatory mites. Observations on the eriophyoid mites infesting solanaceous plants in Argentina were made by Flechtmann *et al.* (2014) and the author described a new species under the family Diptilomiopidae and genus *Rhynacus* along with a key to help in species level identification. While assessing the seasonal impact on the population density of the gall mite, *A. pongamiae* within the leaf galls of *P. pinnata*, Nasareen and Ramani (2014) could establish a positive correlation between mite population density and temperature and relative humidity whereas a negative correlation between mite density and rainfall .

Elhalawany and Ueckermann (2015) erected four new species of *Aceria* found in association with the invasive plant, *Acacia nilotica* from Egypt. Saritha and Ramani (2015) performed a detailed study on population density and distribution pattern of mites infesting the invasive plant, *Bidens sulphurea* and reported that temperature favoured the build up of mite population, supporting the maximum mite density during the dry season. Lotfollahi *et al.,* (2015) conducted studies on the mite fauna associated with

plants belonging to the family Compositae in Southwest of East Azerbaijan during 2010 and 2011 and their study disclosed five species of eriophyoid mites, of which two species were new to science.

Results of extensive surveys carried out by Denizhan *et al.*, (2015) on the eriophyoid fauna of Turkey, with a special focus on species affecting weeds and ornamental plants revealed more than 100 species of these mites. The authors prepared a catalogue on eriophyoid mites recorded from Turkey and they provided information on the taxonomc status of the species published till March, 203 along with remarks and details of distribution in Turkey. Guo *et al.*, (2015) described a new species of eriophyoid mite, *Tegolophus celtis* infesting an ornamental tree in China called the Chinese hackberry, *Celtis sinensis*. Phylogenetic studies strongly supported the occurrence of both the protogyne and deutogyne forms in the life cycle of the species, and which were identified using fragments of three genes, a mitochondrial gene (COI) and two nuclear genes (18S rRNA and 28S rRNA). Through an extensive survey carried out during 2009–2010, on the weed plant, *Datura stramonium*, Kumral and Çobanoğlu (2015) collected 26 species of mites representing the phytophagous, predaceous and other general categories, from two localities in Turkey. Out of the seven species of phytophagous mites recorded, *T.urticae* was the predominant species harbouring the leaves of the weed.

Han *et al.*, (2016) collected eriophyid mites from *Cytisus scoparius*, *Ulex europaeus*, and related plants of Fabaceae in the western USA and their study helped to clarify the taxonomic problems within the eriophyid mite, *A. genistae* complex infesting different host plants. Chetverikov *et al.*, (2016) initiated a two year project entitled “Reconditioning of the Nalepa collection at NHMW” to recondition the eriophyid mite collection made by Nalepa in order to make it available for future reference and the wide use of scientists.

A simple but fast protocol was also developed through the project for recovering mites from vials and making good slides and all digital data obtained from the Nalepa archives, database of the vials, copies of the jotter, reprints and drawings of mites etc. were made available for the use of scientists.

Kiedrowicz *et al.,* (2016) provided descriptions and illustrations of five new species of eriophyoid mites *viz. A. vanensis*, *A.onosmae*, *A. lydii*, *A.gebeliae*. and *A. spectabilis*. found in association with the respective weed plants, *Amaranthus retroflexus*, *Onosma isauricum*, *Hypericum lydium*, *Lotus gebelia* and *Stachys spectabilis* . The above species of mites were recognized as vagrant forms on their host plants, without inducing any visible damage symptoms. Lotfollahi and de Lillo (2017) surveyed the ferns in the Arasbaran forests, Iran and collected and described a phyllocoptine member, *Leipothrix pterisfolii* from *Polypodium vulgarae*, which formed the first record of the tribe Phyllocoptini on Polypodiaceae. The authors provided illustrations as well as a key to the eriophyoid mite species collected from ferns worldwide along with a table containing summary of information on their type of hosts, type locality and habitats. A new species of *Aceria, viz. A. pycnocomi* associated with *Pycnocomon rutifolium* was described and illustrated by Ripka and Sanchez (2017) from Spain. Moreover, the authors redescribed two other species of *Aceria viz. A. eucricotes* and *A. kuko* infesting solanaceous plants of the genus *Lycium* collected from Spain and Hungary respectively, based on the morphological differences of the adult females, males and nymphs. Elhalawany (2017) provided the description and illustration of a new vagrant species of eriophyid mite of the genus *Epitrimerus* from Egypt, *viz. E. lantanae* infesting the weed, *L.camara*. The author also prepared a key to the known species under the genus *Epitrimerus* described from Egypt. Devi *et al.,* (2017) conducted studies on the seasonal occurrence of the jasmine eriophyid mite, mango bud mite and mulberry bud

mites in Tamil Nadu and observed that the above species of eriophyids developed into dense populations during the summer months, and assumed the major population peak above the trend line from May to June.

Based on the inference procured through analysis of sequences of mitochondrial genomes and a nuclear small subunit (18S) rRNA gene, Xue *et al.,* (2017) made a critical evaluation of the phylogenetic position of eriophyoid mites in Acariformes. Zivkovic *et al.,* (2017) examined the phenetic and phylogenetic relationships among *Aceria* spp. inhabiting host plants belonging to the family Brassicaceae in Serbia. Klimov *et al.,* (2018) made a comprehensive study on the phylogeny of acariformes mites to provide an insight on their early evolution. A new vagrant species of Diptilomiopid species *viz. Diptacus rubuscolum* inhabiting on the lower leaf surface of black berry in Brazil was described with illustrations by Trinidad *et al.,* (2018). The authors also provided supplementary description of *A. orthomerus*. Tajaddod *et al.,* (2018) conducted a survey on the eriophyoid mites infesting plants growing in the Ajabshir region of Iran and they described two new species of *Aceria* by providing scanning electron micrographic illustrations. Karmakar (2018) prepared a consolidated list on the mites occurring on the ornamental and fruit plants of South Bengal and he provided data on their hosts, nature of damage etc. Laska *et al.,* (2018) made an accurate estimation of the cryptic diversity within grass associated eriophyid mite, *Abacarus* species complex and the authors described a new species under the genus *viz. A. plumiger*. The authors made use of 78 *Abacarus* mtDNA COI sequences for the study, in which 10 were highly supported clades.

Chetverikov *et al.,* (2019) described approximately 30 species of eriophyoid mites from Crimea, Eastern Europe, mainly from introduced trees planted in Nikitsky Botanical Gardens (NBG). The authors also described two

new phyllocoptine species *viz. Abacarus denticulifer* and *P. sanctus* and new records for six species of phyllocoptine eriophyoid mites. Yuan and Xue (2019) described and illustrated two new species of eriophyid mites from Mount Trusmadi, Malaysia, *viz. Neodicrothrix grandcaputus* and *Latitudo asiaticis* infesting on respective host plants like *Stachyurus himalaicus* and *Psychotria asiatica*. Both of the two new species were recognized as vagrant forms on the lower leaf surface of their respective hosts, without inducing any visible symptoms of damage. In addition to the description, the authors provided a key to species of *Neodicrothrix* also. One new genus and two new species of eriophyid mites were described with illustrations by Zhang and Xue (2019) from China. The newly erected taxa were *Grandiscapitis camelliae* gen. nov. sp.nov. infesting on *Camellia oleifera* and *Prominens photiniae* sp. nov. infesting on *Photinia serratifolia* . Zhang *et al.,* (2019) erected three new species of mites belonging to the tribe Phyllocoptini from China. The recorded species were *P. gaotainensus* infesting on *Populus euphratica*, *Calepitrimerus anomalus* infesting on *Paeonia anomela* and *Paraepitrimerus stellarus* infesting on *Stellaria* sp. The seasonal patterns of the population density of *F. perrepae* within the leaf galls of the noxius weed, *L. microphyllum* were studied by David *et al.,* (2019) during the summer and winter seasons. Jung *et al.,* (2019) conducted a field survey for the rapid diagnosis and monitoring of infestation by the zoysiagrass mite, *A. zoysiae* in turfgrass fields in Korea. The authors provided valuable information on the molecular identification of the species. Souza *et al.,* (2020), using in- situ free-choice and confinement tests evaluated the potential of native species of palm trees in Northeast Brazil to serve as hosts for the invasive species of tenuipalpid mites called the Red Palm Mite, *R. indica*. Ersin *et al.,* (2020) made a significant study on the diversity and population dynamics of eriophyid mites on Olive trees in Western Turkey and they found that the highest population density was in late April.

CHAPTER IV
MATERIALS AND METHODS

During the present study, the faunal diversity of mites associated with 25 species of most common and nuisant invasive plants of Kerala was explored by conducting extensive surveys, for a period of five years, from 2015-2019. For the collection of mite specimens, invasive plants were screened from 88 sampling localities distributed over 12 districts of Kerala *viz.* Thiruvananthapuram, Alappuzha, Kottayam, Idukki, Ernakulam, Thrissur, Palakkad, Malappuram, Kozhikode, Wayanad, Kannur and Kasaragod. The sampling sites selected for collection of invasive plants are listed below:

Sampling localities (Plate 1)

1) Thiruvananthapuram District

Three sites were selected in the Thiruvananthapuram Dt. for collection of invasive plants and these sites were. Karyavattom, Thampanoor and Kizhakkekotta. The major species of invasive plants dominant over these mites included *Lantana camara*, *Chromolaena odorata*, *Mikania micrantha*, *Merremia vitifolia*, *Antigonon leptopus*, *Mimosa diplotricha, Tridax procumbens, Clidemia hirta*, *Synedrella nodiflora* and *Senna tora*.

2) Kottayam District

In the Kottayam Dt. a total of four sampling localities were selected *viz.* Puthuppally, Athirampuzha, Mannanam and Kumarakom. The invasive plant species collected from the these sites were *L. camara, C. odorata*, *M. micrantha, A. leptopus*, *M. vitifolia T.procumbens, S. nodiflora, Ageratina adenophora, Alternanthera bettzickiana, Mimosa diplotricha*, and *S. tora*.

3) Alappuzha District

Three sites *viz.* Mararikulam, Thiruvambady and Champakulam were selected in the Alappuzha district for collection of invasive plant samples. The dominant species of invasive plants growing in these sites were *L. camara*, *C. odorata*, *M. micrantha*, *A. leptopus*, *T.procumbens*, *M. vitifolia A. adenophora*, *A. bettzickiana*, and *S. tora.*

4) Idukki District

In the Idukki Dt., four localities *viz.* Vagamon, Munnar, Parunthumpara and Thangalpara were considered for collection of invasive plants. The invasive plants screened from the above sites included *L. camara*, *C. odorata*, *M. micrantha*, *T. procumbens*, *M. vitifolia A. adenophora*, *A. bettzickiana*, *S. trilobata*, *A. conizoides*, *P. chrysophylla*, *S. jamaicensis*, *D. tortuosum*, *P. aquilinum*, *P. phaseoloides*, *P. hysterophorus* and *S. tora*.

5) Ernakulam District

Collection of invasive plant samples was made from five selected sites in the Ernakulam Dt. *viz.* Vyttila, Kochi, Aluva, Angamaly and Athani. The invasive plants collected from these sites were *L. camara*, *C. odorata*, *M. micrantha*, *A. leptopus*, *T.procumbens*, *M. vitifolia*, *A. adenophora*, *A. bettzickiana*, *S. trilobata*, *S. nodiflora* and *Leucaena leucocephala*.

6) Thrissur District

A total of nine collection sites were considered from the Thrissur district for collection of invasive plants. These sites included Peechi, Pattikkadu, Mannuthi, Vaniyampara, Kuthiran, Ramavarmapuram, Guruvayur, Kodungallur and Koorkenchery. The major species of invasive plant species collected from the above sites were *L. camara*, *C. odorata*, *M. micrantha*, *A.leptopus*, *T.procumbens*, *M. vitifolia A. adenophora*, *A.*

bettzickiana, S. trilobata, M. diplotricha, *A. conizoides*, and *P. hysterophorus, Cissampelopsis corymbosa, Euphorbia heterophylla* and *S. tora*.

7) Palakkad District

Fourteen sites were considered during the present study in the Palakkad Dt.for the recovery of invasive plants. The sites selected included Kuzhalmannam, Alathur, Perinkunnam, Thenkurissi, Yakkara, Chithali, Tharekkad, Malampuzha, Kollengode, Koduvayur, Cherpulassery, Kongad, Sreekrishnapuram and Nelliyampathy. The above sites revealed the growth of a good number of invasive plant species like *L. camara*, *C. odorata*, *M. micrantha, A.leptopus, T.procumbens, M. vitifolia A. adenophora, S. trilobata, A. conizoides, A. bettzickiana, Ipomoea nil, L. leucocephala, Calotropis procera, M. diplotricha*, *P. hysterophorus, C. corymbosa*, *E. heterophylla* and *S. tora*.

8) Malappuram District

Malappuram district formed the major collection locality, from which 19 sites were selected as the sampling sites for collection of invasive species of plants. The sampling localities were Thazhekodu, Thootha, Kondotty, Vettukadu, Pulikkal, Olavattur, Aroor, Muthuvalloor, Vengara, Parappanangadi, Kottakkunnu, Villoonniyal, Calicut University Campus, Olipramkadavu, Kakkanchery, Pallikkal Bazar, Arimbra Hills, Manjeri and Edappal. The various species of invasive plants screened from the above sites included *L. camara*, *C. odorata*, *M. micrantha*, *C. hirta*, *A.leptopus, T.procumbens, M. vitifolia A. adenophora*, *A. bettzickiana, S. trilobata, A. conizoides, I. nil, C. procera, D. tortuosum , M. diplotricha*, *P. hysterophorus, P. chrysophylla*, *C. corymbosa*, *E. heterophylla, L. leucocephala* and *S. tora*.

9) Kozhikode District

In the Kozhikode district, 13 localities *viz.* Ramanattukara, Thondayadu, Chaliyam, Beypore, Mananchira, Nadakkavu, Kovoor,

Madavoor, Feroke, Cheruvennur, Vengeri, Maikave and Thamarassery were selected for sample collection. The invasive plants collected from the above localities were *L. camara, C. odorata, M. micrantha, M. diplotricha, A.leptopus, T.procumbens, M. vitifolia, A. bettzickiana, S. trilobata, A. conizoides, I. nil, C. procera, D. tortuosum P. hysterophorus, P. chrysophylla, C. corymbosa, E. heterophylla, L. leucocephala, P. phaseoloides* and *S. tora*.

10) Wayanad District

A total of eight localities were selected in the Wayanad district, such as Lakkidi, Pookode, Kattikkulam, Tholppetty, Thirunelli, Thrissilery, Mananthavady and Ambalavayal for invasive plant collection. The invasive plant species collected from the above sites were *L. camara, C. odorata, M. micrantha, T.procumbens, M. vitifolia A. bettzickiana, S. trilobata, A. conizoides, P. chrysophylla, S.jamaicensis, D. tortuosum, P. aquilinum, M. diplotricha, P. phaseoloides, C. corymbosa, S. tora* and *P.hysterophorus.*

11) Kannur District

The leaf samples of invasive plants were collected from five localities of Kannur district *viz.* Iritty, Kololam, Thalassery, Thottada and Dharmadom. The major species of invasive plants collected from the above sites included *L. camara, C. odorata, M. micrantha, T.procumbens, M. vitifolia, S. trilobata, A. conizoides, P. chrysophylla, S.jamaicensis, D. tortuosum, C. corymbosa, S. tora , M. diplotricha* and *E. heterophylla.*

12) Kasaragod District

A single site was selected in the Kasaragod district for collection of invasive plants and the site was Cheruvathur. From this locality, leaf samples were collected from seven species of invasive plants such as *L. camara, C. odorata, M. micrantha, T.procumbens, M. vitifolia, S. tora* and *M. diplotricha*

Table1: List of collection localities

Districts	**Collection sites**
Thiruvananthapuram	Karyavattom, Thampanoor, Kizhakkekotta
Kottayam	Puthuppally, Athirampuzha, Mannanam, Kumarakom.
Alappuzha	Mararikulam, Thiruvambady, Champakulam.
Idukki	Parunthumpara, Vagamon, Munnar, Thangalpara
Ernakulam	Vyttila, Kochi, Aluva, Angamaly,Athani
Thrissur	Peechi, Pattikkadu, Mannuthi, Vaniyampara, Kuthiran, Ramavarmapuram, Guruvayur, Kodungallur, Koorkenchery
Palakkad	Kuzhalmannam, Alathur, Perinkunnam, Thenkurissi, Yakkara, Chithali, Tharekkad, Malampuzha, Kollengode, Koduvayur, Cherpulassery, Kongad, Sreekrishnapuram, Nelliyampathy
Malappuram	Thazhekodu, Thootha, Kondotty, Vettukadu, Pulikkal, Olavattur, Aroor, Muthuvalloor, Vengara, Parappanangadi, Kottakkunnu, Villoonniyal, Calicut University Campus, Olipramkadavu, Kakkanchery, Pallikkal Bazar, Arimbra Hills, Manjeri, Edappal
Kozhikode	Ramanattukara, Thondayad, Chaliyam, Beypore, Mananchira, Nadakkavu, Kovoor, Madavoor, Feroke, Cheruvennur, Vengeri, Maikave, Thamarassery
Wayanad	Lakkidi, Pookode, Kattikkulam, Tholppetty,Thirunelli, Thrissilery, Mananthavady, Ambalavayal
Kannur	Iritty, Kololam, Thalassery, Thottada, Dharmadom
Kasaragode	Cheruvathur

Table 2: Latitude and longitude of collection sites

PLACE	Latitude	Longitude
Karyavattom	8.5678ºN	76.8908ºE
Thampanoor	8.4908ºN	76.9527ºE
Kizhakkekotta	8.4810ºN	76.9455ºE
Puthuppally	9.5653ºN	76.5661ºE
Athirampuzha	9.6597ºN	76.531ºE
Mannanam	9.6479ºN	76.5228ºE
Kumarakom	9.5963ºN	76.4304ºE
Mararikulam	9.5987ºN	76.3116ºE
Thiruvambady	9.4825ºN	76.3427ºE
Champakulam	9.4109ºN	76.4102ºE
Parunthumpara	9.5477ºN	77.0351ºE
Vagamon	9.6861ºN	76.9052ºE
Munnar	10.0889ºN	77.0595ºE
Thangalpara	9.6655ºN	76.9078ºE
Vyttila	9.9681ºN	76.3182ºE
Kochi	9.9312ºN	76.2673ºE
Aluva	10.1003ºN	76.3570ºE
Angamaly	10.1926ºN	76.3869ºE
Athani	10.1562ºN	76.3542ºE
Peechi	10.5270ºN	76.3608ºE
Pattikkadu	10.5568ºN	76.3271ºE
Mannuthi	10.5332ºN	76.2656ºE
Vaniyampara	10.5787ºN	76.4129ºE
Kuthiran	10.5736ºN	76.3870ºE
Ramavarmapuram	10.5599ºN	76.2334ºE
Guruvayur	10.5945ºN	76.0368ºE
Kodungallur	10.2276ºN	76.1971ºE
Koorkenchery	10.5052ºN	76.2104ºE
Kuzhalmannam	10.7191ºN	76.6012ºE
Alathur	10.6453ºN	76.5458ºE
Perinkunnam	10.6875ºN	76.6065ºE
Thenkurissi	10.6909ºN	76.6196ºE
Yakkara	10.7535ºN	76.6503ºE
Chithali	10.6865ºN	76.5825ºE

Tharekkad	10.7831ºN	76.6560ºE
Malampuzha	10.8280ºN	76.7368ºE
Kollengode	10.6139ºN	76.6907ºE
Koduvayur	10.6632ºN	76.6470ºE
Cherpulassery	10.8789ºN	76.3113ºE
Kongad	10.8587ºN	76.5170ºE
Sreekrishnapuram	10.9066ºN	76.4158ºE
Nelliyampathy	10.5353ºN	76.6936ºE
Thazhekodu	10.9618ºN	76.3039ºE
Thootha	10.9201ºN	76.2855ºE
Kondotty	11.1456ºN	75.9642ºE
Vettukadu	11.1957ºN	75.9628ºE
Pulikkal	11.1776ºN	75.9188ºE
Olavattur	11.2130ºN	75.9429ºE
Aroor	11.2141ºN	75.9303ºE
Muthuvalloor	11.1799ºN	75.9651ºE
Vengara	11.051ºN	75.9825ºE
Parappanangadi	11.0539ºN	75.8555ºE
Kottakkunnu	11.0481ºN	76.0831ºE
Villoonniyal	11.1316ºN	75.8886ºE
Calicut University Campus	11.1340ºN	75.8952ºE
Olipramkadavu	11.1294ºN	75.8648ºE
Kakkanchery	11.1556ºN	75.8911ºE
Pallikkal Bazar	11.1390ºN	75.9151ºE
Arimbra Hills	11.0870ºN	76.0359ºE
Manjeri	11.1202ºN	76.1198ºE
Edappal	10.7837ºN	76.0076ºE
Ramanattukara	11.1759ºN	75.8734ºE
Thondayad	11.2662ºN	75.8055ºE
Chaliyam	11.1559ºN	75.8112ºE
Beypore	11.1735ºN	75.804ºE
Mananchira	11.2537ºN	75.7763ºE
Nadakkavu	11.2725ºN	75.7800ºE
Kovoor	11.2705ºN	75.8312ºE
Madavoor	11.3486ºN	75.8795ºE
Feroke	11.1734ºN	75.8352ºE
Cheruvennur	11.1903ºN	75.8283ºE

Vengeri	11.3044ºN	75.7967ºE
Maikave	11.4011ºN	75.9775ºE
Thamarassery	11.4145ºN	75.9363ºE
Lakkidi	11.5218ºN	76.0246ºE
Pookode	11.5411ºN	76.0217ºE
Kattikkulam	11.8467ºN	76.0631ºE
Tholppetty	11.9516ºN	76.0594ºE
Thirunelli	11.9081ºN	75.9971ºE
Thrissilery	11.8514ºN	76.0165ºE
Mananthavady	11.8013ºN	76.0043ºE
Ambalavayal	11.6197ºN	76.2102ºE
Iritty	11.9818ºN	75.6702ºE
Kololam	11.9411ºN	75.5029ºE
Thalassery	11.7491ºN	75.4890ºE
Thottada	11.8424ºN	75.4213ºE
Dharmadom	11.7775ºN	75.4703ºE
Cheruvathur	12.2165ºN	75.1626ºE

Invasive plants screened:

During the present study, a total of 25 species of invasive plants (Table 3) were screened for the recovery of mites and these plants represented different categories like herbs, shrubs, trees, ferns, creepers and climbers. The species level identity and other details of the invasive plants were procured by referring the "Handbook on Invasive plants of Kerala" published by K.V. Sankaran *et al.* (2012), relevant literature, news paper citations and also through internet data. Confirmation of plant species identity was made by seeking expertise from Dr. A. K. Pradeep, Assistant Professor of the Department of Botany, University of Calicut. Photographs of the plants were taken using 48 MP camera with Sony IMX586 camera sensor.

1) *Lantana camara* L. (Plate 2, fig. a)

Family : Verbenaceae

Native place: Central and South America

L .camara or red sage is an erect and vigorously growing aromatic shrub with wide ecological tolerance and diverse geographical distribution. The plant is designated as a notorious weed, popular ornamental garden plant as well as a useful plant in folk medicine in several parts of the world. It grows best in open un-shaded conditions like wetlands, forests, agricultural sites, roadsides, beach fronts, plantations etc. imposing great threat to the natural flora and fauna by disrupting their succession and leading to biodiversity depletion. This weed is widely distributed in Kerala. Several variants are known for *L.camara* complex and some of which are toxic to small ruminants. In warm regions, *L. camara* is a pest in farms, pastures and forests, providing breeding places for various pathogens, vectors etc. The plant produces several bioactive principles like triterpenes, lantadene A and B etc. which are toxic to livestock , causing damage to liver, kidney, intestine, paralysis and finally death . Green, unripe fruits induce fatality in children.

2) *Chromolaena odorata* (L.) King and H. Rob. (Plate 2, fig. b)

Family : Asteraceae

Native: Tropical and subtropical America

This plant has been introduced to various parts of Asia, Africa and Australia. It is a fast growing upright perennial shrub and is included in the top 100 of the world's worst invaders in the Global Invasive Species Database (GISD). It is found in a wide range of habitats like plantation, orchards, roadsides, river banks, railway tracks, natural forests, grasslands, wetlands etc. and its aggressive growth and allelopathic effect affects the natural habits of native

species. It spreads very rapidly after disturbances like fire or land clearing etc. The seeds of this weed are wind dispersed, often attached to particles like fur, clothes, etc and thereby getting dispersed covering long distances. It is toxic to cattle, and allergenic to humans.

3) *Mikania micrantha* Kunth (Plate 2, fig. c)

Family : Asteraceae

Native place : Tropical and subtropical America

M. micrantha is a fast growing perennial climber known by different local names such as bitter vine, American rope, mile-a-minute vine, climbing hemp vine etc. The plant got introduced in to India as a ground cover for tea plantations (Prabu *et al*., 2014). With its high potential for vigorous growth, it has become a serious threat to several plantation crops and forest areas all over the country. The plant grows as a weed more commonly in wet places, forest boarders, roadsides, railway tracks, electric lines, river banks, forest plantations, agricultural areas, open disturbed areas and barren lands. Its invasion leads to a reduction in the growth of natural vegetation. It is considered as the one among 100 of the world's worst invaders in the Global Invasive Species Database (GISD).

4) *Antigonon leptopus* Hook and Arn. (Plate 2, fig. d)

Family: Polygonaceae

Native place: Mexico

A. leptopus is naturalized in India. It is considered as an invasive species showing wide spread in the tropics and is commonly called as Coral Vine, Mountain-rose Coralvine, Rosa de Montana etc. It is a fast growing perennial evergreen vine forming thick foliage and can quickly cover walls, climb on

palms, trees and electric lines. The plant occurs in almost all districts of Kerala. It invades in to disturbed areas, roadsides, along railway tracks, forest edges etc.

5) *Mimosa diplotricha* C. Wright *ex* Sauvalle (Plate 2, fig. e)

Family : Fabaceae

Native place: Tropical America

M. diplotricha is a fast growing, annual/perennial leguminous woody shrub, commonly known as giant sensitive plant. It is adapted to tolerate a wide range of climatic conditions and grows very commonly in barren lands, near to the agricultural field, forest edges, wastelands, along roadsides, riverbanks, roadsides, railway tracks etc. It is extremely invasive and has the potential to rapidly colonize the newly invaded habitats. The plant spreads as impenetrable thickets within a short period, adversely affecting the movement of flora and fauna. The dense growth of the plant exerts a negative impact on existing native vegetation by preventing their regeneration, reproduction and growth, and thereby posing great threat to biodiversity, agriculture and human livelihoods. A toxin called mimosin produced by the plant is highly toxic to grazing animals. The economic impact of the plant is reflected in dynamic levels which could be enumerated as increased cultivation costs, reduced crop yield, crop reduction, land value depletion, soil degradation and so on.

6**) *Merremia vitifolia* (Burm.f.) Hallier f. (Plate 2, fig. f)**

Family : Convolvulaceae

Native place: South Asia

M.vitifolia is a climber, capable of easily invading the natural habitats by its twining habit. It is shade tolerant and shows wide spread. This plant has the

ability to extinguish the native flora. It grows well in forest edges, along roadsides, railway tracks, vacant areas, agricultural zones, urban areas, electric lines etc.

7) *Sphagneticola trilobata* (L.) Pruski (Plate 2, fig. g)

Family : Asteraceae

Native place : Tropical America

S. trilobata is a creeping, mat forming perennial herb, spreading vegetatively, and through seeds. The plant has several common names such as Singapore daisy, trailing daisy, Bay Biscayne creeping-oxeye, creeping-oxeye and wedelia and has been included in the IUCN's List of the world's 100 worst invasive species. The plant belongs to the category 1b weeds. It is widely cultivated as an ornamental groundcover, but soon spreads to surrounding areas through garden wastes. The plant spreads very rapidly assuming to form dense ground cover, competes with other crops for nutritional and physical resources and thereby checking regeneration of other plant.

8) *Tridax procumbens* L. (Plate 2, fig. h)

Family: Asteraceae

Native place: Tropical America

T. procumbens is a semi prostrate, perennial flowering herb belonging to the daisy family and commonly known as coatbuttons or tridax daisy. It is a widespread weed and pest with distribution in all tropical, subtropical, and mild temperate regions of the world, growing well in fields, meadows, croplands, disturbed areas, lawns, and roadsides. It has been included in the list of noxious weeds by the United states Department of Agriculture. This plant is very common in all districts of Kerala.

9) *Ageratum conizoides* L. (Plate 2, fig. i)

Family: Asteraceae

Native place: Central America

A. conizoides is an annual herb, growing up to a height of 2.5 feet and is known by different common names like the billy goat-weed, white weed, chick weed etc. It is considered as an invasive weed in many regions of the world and has been naturalized all over the word. The plant has the potential to easily invade and spread in to new and preferred habitats such as agricultural fields, plantations, orchards and along roadsides, and preventing the growth of native plants. It is common in all places of Kerala.

10) *Clidemia hirta* (L.) D. Don (Plate 3, fig. a)

Family: Melastomataceae

Native place: Tropical Central and South America

C. hirta is an invasive perennial shrub, commonly called as Koster's curse. The plant causes serious damage by successfully growing in the humid climates of the tropics and invading to both disturbed and undisturbed habitats. The plant is adapted to tolerate wide range of climatic conditions and is a potential weed of open grasslands, wetter open woodlands, pastures, plantations etc. With its ability to form dense thickets, the plant smothers over other plantations and replaces them, and also invades into the forest gaps and adversely affect the regeneration of the native species. It is considered as one among the world's worst invaders by the Global Invasive Species Database. In the present study, this plant could be collected from various localities of the Idukki district.

11) *Pueraria phaseoloides* (Roxb.) Benth (Plate 3, fig. b)

Family : Fabaceae

Native place: Tropical Asia

P. phaseoloides is a climbing legume, extensively used as a cover crop in plantations of rubber and other crops. It is called as tropical kudzu in most of the tropical regions. It is widely adapted to different types of soils, and grows vigorously in vacant lands and along the margins of cultivated areas. It has the habit of aggressive climbing /smothering on other trees and displacing them. Under humid environmental situations of the tropics, *P. phaseoloides* grows as a noxious weed and become an invasive species due to its fast growth, its wide seed distribution and its ability to fully cover other plants. This plant shows wide distribution in Kerala.

12) *Pityrogramma chrysophylla* (Sw.) Link (Plate 3, fig. c)

Family: Pteridaceae

Native place: Caribbean territories

The plant occurs in two forms like the yellow form and the white form. Yellow form is quite rare and occurs in very wet open and semi-open areas. They are seen in earth banks, in and around forests. The white form grows on walls, near to sea.

13) *Pteridium aquilinum* (L.) Kuhn (Plate 3, fig. d)

Family : Dennstaedtiaceae

Native place: Tropical America

P. aquilinum is one of the most widespread species of the world, enjoying cosmopolitan distribution, including the Antarctica. It is a perennial

gregarious fern, which spreads fast through its extensive network of underground rhizomes and also by the spores, which are dispersed by wind. *Pteridium* has the potential to replace the native species by its gregarious growth. This fern is very common in disturbed areas and its best growth is observed in open areas. It is a threat to livestock and affects human health.

14) *Ageratina adenophora* (Spreng.)King and Robins (Plate 3, fig. e)

Family : Asteraceae

Native place : Central America

A. adenophora is a perennial shrub that produces thousands of seeds and has allelopathic effects that prevent other plants from growing near it, and forms a monoculture. It is considered as a worldwide invasive species and is included in the official site of noxious weeds list in USA and Australia. It is reported to alter native soil microbiology in ways that promote its own growth, and prevent other species from germinating in its vicinity (Niu *et al*., 2007). The plant invades undisturbed areas, forest edges, roadsides, near to agricultural fields etc. This noxious and toxic weed has become a threat to livestock also. Reports of its spread in the Western Ghats and the North-eastern Himalayas indicate the emergence of the weed as a major threat to biodiversity.

15) *Ipomoea carnea* Jacq ssp. *fistulosa* (Mart.ex. Choisy) Austin (Plate 3, fig. f)

Family: Convolvulaceae

Native place: Tropical America

It is cultivated in gardens as an ornamental plant, but occurs as a weed along roadsides, near to the small water systems like ponds, canals, marshy areas,

cultivated crop lands etc. The plant grows as a thick cover along introduced areas, replacing the native flora and thereby reducing the natural diversity.

16) *Calotropis procera* (Aiton) W.T. Aiton (Plate 3, fig. g)

Family : Asclepiadaceae

Native place : North, West and Tropical Africa

C. procera, commonly called as the Giant milkweed is a xerophytic perennial shrub or small tree with milky latex throughout. The plant possesses lots of medicinal property even though considered as a weed along roadsides, lagoon edges and in overgrazed native pastures. It has a preference to become dominant in areas of abandoned cultivation, especially in sandy soils, in areas of low rainfall. It grows on a variety of soils, from fine to coarse texture, with varying degrees of salinity. It acts as a food plant to arthropods and it plays an important role in phytoremediation of contaminated soils.

17) *Luecaena luecocepha* (Lam.) de Wit (Plate 3, fig. h)

Family : Leguminosae

Native place: Mexico and Central America

L. leucocephala is a small, ever-green fast-growing leguminous tree known in various names such as white leadtree, jumbay, river tamarind, ipil-ipil white popinac etc. The plant has multiple uses like fencing, firewood, fiber, enhancement of soil fertility, livestock fodder etc. Based on its use in multiple ways, the plant was designated as a "miracle tree" during 1970s-1980s and as “conflict tree" based on its spread as a weed. The tree can easily invade in to agricultural fields, natural forests, coastlands, planted forests, roadsides, waste lands etc. and converts large areas as non productive lands. With its high potential to grow quickly, it forms dense thickets and conflicts all native

flora and hence it has been given the status of one of the 100 worst invasive species by the IUCN Species Survival Commission. This weed is considered as one among 100 of the world's worst invaders in the Global Invasive Species Database (GISD).

18) *Synedrella nodiflora* (L.) Gaertn (Plate 3, fig. i)

Family : Asteraceae

Native place : West Indies

S. nodiflora is an erect herb, enjoying propagation mainly through wind. It is found as a weed of cultivated crops and lawns, roadsides, waste lands and plantations and even prefers to grow in the partial shade under plantations of tea, coffee, banana etc. This plant is adapted to a wide variety of environmental conditions, and can replace the natural flora by acquiring their place. It is palatable to livestock.

19) *Senna tora* (L.) Roxb. (Plate 4, fig. a)

Family : Caesalpiniaceae

Native place : South America

S. tora is an annual subshrub, easily grown as a weed in the tropics . Though the plant is very commonly called Sickle Senna or Sickle Wild sensitive-plant in English, it is known by several other common names such as sickle pod, tora, coffee pod, tovara, chakvad, thakara (in Malayalam) and *foetid cassia*. It can tolerate a wide range of climatic conditions and has the ability to quickly colonize open and vacant lands, plantations, agricultural lands, roadsides and areas close to water ways etc. and alter the native floral composition.

20) *Alternanthera bettzickiana* (Rigel) G. Nichols (Plate 4, fig. b)

Family: Amaranthaceae.

Native place: Tropical America

It is commonly known as calico-plant and is widely used as an ornamental edging plant. In India, the plant is reported to be accidentally introduced with an impression of a low risk of spreading and a short term escape (Sankaran *et al*., 2014). But with its much branched habit, the herb exhibits a quick spread to new open areas, growing over native plants and commonly occupying abandoned areas, agricultural fields, roadsides, vacant and waste lands.

21) *Stachytarpheta jamaicensis* (L.) Vahl (Plate 4, fig. c)

Family : Verbenaceae

Native place : Tropical America

S. jamaicensis is a perennial subshrub, commonly known as Gervao, Brazilian tea, verbena cimarrona, rooter comb, or blue porter weed. It is a weed in forests and forest margins, roadsides, disturbed sites, waste areas, waterways, floodplains, coastal environs, gardens, plantation crops and pastures. *S. jamaicensis* is used in traditional and folk medicinal systems for the treatment of allergies, respiratory disorders, cough, cold, fever, constipation, dysentery and menstrual disorders etc. It is considered as a weed also for a long time.

22) *Desmodium tortuosum* (Sw.) DC. (Plate 4, fig. d)

Family : Fabaceae

Native place : Tropical America

D. tortuosum, commonly called as the Beggar weed, is an erect annual or perennial shrub, cultivated as cover crop or green manure. Later, the plant

was known to have escaped from cultivation, became naturalized and was classified as an invasive species. Thus the plant got established among the other cultivated crops, plantation crops, roadsides and waste lands, and through seed propagation developed dense growth. The thick growth of the plant affects the vigor and growth of other native flora, thereby leading to their replacement.

22) *Cissampelopsis corymbosa* (Wall. ex DC.) C. Jeffrey and Y.L. Chen (Plate 4, fig. e)

Family : Asteraceae

Native place : Tropical America

C. corymbosa is a climbing shrub, with the stem covered with fulvous-woolly hairs.

24) *Parthenium hysterophorus* L. (Plate 4, fig. f)

Family : Asteraceae

Native place : North and South America

P. hysterophorus is an annual herb, known as invasive in various Asian and African countries as well as in several parts of America and Oceania. This plant is considered as one of the '100 most invasive species in the world' by the IUCN (GISD, 2018). It has been accidentally introduced into several countries and assumed the status of a serious agricultural and rangeland weed in more than 45 countries (Bajwa *et al*., 2016; Shabbir *et al*., 2019), leading to considerable yield reductiones. It aggressively colonizes disturbed sites and is adapted to grow in any soil type, affecting the vigor and health of other crops and animals and in total the biodiversity of various habitats. Various features like wide range of adaptability, drought tolerance, potential to

compete with native flora, allelopathic effects, photo- and thermo-insensitivity etc. of the weed promote its rapid introduction world-wide (Manpreet *et al*., 2014; Bajwa *et al.*, 2016). Since its accidental introduction into India, the plant encroached well in most of the waste and vacant lands, agricultural fields, forest edges, urban areas along railway tracks etc., in all Indian states, leading to degradation of natural ecosystem.

25) *Euphorbia heterophylla* L. (Plate 4, fig. h)

Family : Euphorbiaceae

Native place : Central America

E. heterophylla is an erect annual herb, popularly known by the name Mexican fireplant. It was introduced as an ornamental plant in many countries, but later turned into major weed problem in some places and became the principal weed in several other places. Because of its very rapid growth, the plant was proven to be a serious competitor in the early growth phase of many economic crops, competing for physical and nutritional resources. It can spread rapidly and invade in to crop lands, roadsides, agricultural areas, wetlands and open areas. The milky latex produced by the plant is toxic. This plant acts as a weed in agricultural system and is found in various localities of Kerala.

Table 3: List of Invasive plants screened during the study

Sl. No.	Invasive plant screened	Family	Native place
1	*Lantana camara* L.	Verbenaceae	Central &South America
2	*Chromolaena odorata* (L.) R. M. King and H.Robinson	Asteraceae	Tropical and subtropical America
3	*Mikania micrantha* Kunth	Asteraceae	Tropical and subtropical America
4	*Antigonon leptopus* Hook&Arn.	Polygonaceae	Mexico
5	*Mimosa diplotricha var. diplotricha*C.Wight ex Sauvalle	Fabaceae	Tropical America
6	*Merremia vitifolia* (Burm.f.) Hallier f.	Convolvulaceae	South Asia
7	*Sphagneticola trilobata* (L.) Pruski	Asteraceae	Tropical America
8	*Tridax procumbens* L.	Asteraceae	Tropical America
9	*Ageratum conizoides* L.	Asteraceae	Central America
10	*Clidemia hirta* (L.) D. Don	Melastomataceae	Tropical Central and South Americaa
11	*Pueraria phaseoloides* (Roxb.) Benth	Fabaceae	Tropical Asia
12	*Pityrogramma chrysophylla* (Sw.) Link	Pteridaceae	Caribbean territories
13	*Pteridium aquilinum* (L.) Kuhn.	Dennstaeditaceae	Tropical America
14	*Ageratina adenophora* R.M. King & H.Robinson	Asteraceae	Central America
15	*Ipomoea carnea Jacq ssp. fistulosa (Mart.ex. Choisy) Austin*	Convolvulaceae	Tropical America
16	*Calotropis procera* (Ait.) R. Br.	Apocynaceae	North, West and Tropical Africa
17	*Leucaena leucocephala* (Lam.) de Wit	Leguminosae	Mexico and Central America
18	*Synedrella nodiflora* (L.) Gaertn	Asteraceae	West Indies
19	*Senna tora* (L.) Roxb.	Caesalpiniaceae	South America
20	*Alternanthera bettzickiana*	Amaranthaceae	Tropical America

	(Regl.) G. Nicholson		
21	*Stachytarpheta jamaicensis* (L.)Vahl	Verbenaceae	Tropical America
22	*Desmodium tortuosum* (SW.) DC.	Fabaceae	Tropical America
23	*Cissampelopsis corymbosa* (Wallich ex DC.) C. Jeffrey and Y.L. Chen	Asteraceae	Tropical America
24	*Parthenium hysterophorus* L	Asteraceae	North and South America
25	*Euphorbia heterophylla L.*	Euphorbiaceae	Central America

Sampling of mite infested leaves:

During the present study, mite infested leaf samples were collected every two months, from the above mentioned 25 species of invasive plants growing in different localities of Kerala, for a period of January, 2015 to June, 2019. To evaluate diversity indices, evenness and richness etc., sampling of mite infested leaves of invasive plants was performed on a monthly basis from different localities of three districts of Kerala *viz.* Kozhikode, Malappuram and Palakkad. Mite infestation was identified on the aerial parts of invasive plants under field conditions, based on the presence of visual symptoms such as yellowing, curling, chlorotic spot formation, bronzed appearance, presence of erineal patches, web formation etc. Such mite infested leaves were cut randomly from the host plants with the help of a scissors and transferred carefully to polythene bags. Slight alterations were also followed during field sampling, depending up on the size and nature of leaves to be collected from individual host plant. Accordingly, the collected samples included the entire leaves, leaf bits or quite often leaflets and a total of 25 leaf samples were collected at a time from each of the host plant. Appropriate field labels were also prepared, providing details of collection locality, date of collection, host plant etc. and kept inside the polythene covers containing the samples. The polythene covers containing the leaf samples and

field labels were loosely tied with a rubber band and transported to the laboratory as early as possible giving proper attention to ensure minimum disturbance. Separate field labels were prepared for the leaf samples of each plant and the polythene covers carrying the samples were loosely tied with a rubber band and transported as early as possible to the laboratory for microscopic observation in the laboratory.

I) TAXONOMIC STUDIES:

1.Seggregation of mite specimens:

The leaf samples collected from the field and brought to the laboratory were subjected to thorough screening under a stereo zoom microscope (Labovision) and trinocular stereo zoom microscope (NSZ-606) for locating the mite specimens associated with them. Live mite specimens were segregated with the help of a moistened camel hair brush and transferred to 70% alcohol in separate vials and labelled, giving all details of collection. These specimens were subsequently processed for taxonomic studies.

1. 1. Preparation of Hoyer's medium:

Hoyer's medium was prepared by mixing the ingredients listed below in the following proportions:

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

1. Weighed 30 gm of gum arabic and 200 gm of chloral hydrate and transferred the same in to a 1000 ml beaker.

2. Added 50 ml of distilled water.

3. Added 20 ml of glycerine and thoroughly mixed at room temperature.

4. Filtered this mixture using muslin cloth.

5. The mountant was stored in an amber coloured bottle and used for permanent mounting of specimens.

1.2. Modified mountant

Hoyer's medium : 100 ml

Potassium iodide : 1 g

Iodine, resublimed : 0.3 g

Mixed the above-mentioned chemicals and stirred until Potassium iodide and Iodine got dissolved. The mountant was ready to use when there were no small air bubbles left in the mixture (12–24 h).

2. Clearing and mounting of specimens:

The mite specimens segregated from the various species of invasive plants described above and preserved in 70% alcohol were dehydrated by passing through different grades of ethyl alcohol such as 80%, 90% and 100% (absolute alcohol) taken in cavity blocks. Properly dehydrated mite specimens were subjected to subsequent clearing process by transferring them to a clearing medium, prepared by mixing equal proportions of absolute alcohol and lactic acid. When the specimens were cleared properly, they were slide mounted in Hoyer's medium. For slide mounting, a drop of Hoyer's medium was poured at the centre of a cleaned glass slide and a cleared specimen was transferred to the mounting medium, using a camel hair brush, without trapping any air bubbles/ dirt particles. The specimen was then oriented carefully to facilitate the morphological features well visible for subsequent identification of taxa. Small glass bristles of equal or larger size

than that of the specimen were also placed adjacent to the specimen on the microslide to prevent the damage of the specimen while mounting the cover glass. The properly oriented specimen was then mounted by placing a cover glass of 18 mm over the specimen, without trapping any air bubbles. In the case of mites belonging to Oribatida, lactic acid was used for making temporary mounts of specimens on cavity slides, instead of the normal glass slides. The slide mounted specimens were labelled giving details of collection locality, name of respective host plant species, date of collection etc. and were kept in an oven, at 40^0 C for a period of 2-5 days, depending upon the sclerotization of specimens. Properly dried slide mounts of specimens were sealed with nail polish along the periphery of the cover glass for ensuring protection to specimens from damage through penetration of atmospheric moisture and dust particles. The sealed slides were then shifted to the slide boxes for long term storage and future reference.

3. Identification of specimens and analysis of morphological features

Identification of specimens to various levels of taxa such as family/genus/species was carried out following relevant keys and descriptions available in standard text books and concerned literature in Acarology authored by Krantz and Walter (1975, 2009), Jeppson *et al*., (1975), Gupta (1986, 2003), Zhang (2003), Baker and Pritchard (1960), Hughes (1976), Chant and McMurtry (2007), Mary Anithalatha Sadanandan and Ramani (2009), Balogh and Balogh (1992, 2002), Balogh (1972), Smiley (1992) and other relevant research publications. The morphological features of the various species of mites were examined under the high power bright field and phase contrast objectives of research microscopes (models: Leitz- Diapan, Zeiss-Axiolab, Lynx trinocular microscope (N 800 M) and Zeiss-Scope.A1). Important features useful for identification of various taxa were studied and compared feature by feature with those available in the relevant keys and

concerned literature. Accordingly, the taxonomic identity and systematic position of various species were fixed, confirmed and presented. Measurements of morphological characters of specimens were taken using the research microscope, Zeiss-Scope.A1, based on Zen 2.5 lite software. Photographs of various species were taken using the camera (Leica DFC295) attached to the research microscope -Leica S8APO, Zeiss-Scope.A1 and Lynx trinocular microscope (N 800 M) and 48 MP camera with Sony IMX586 camera sensor. Drawings of morphological features of the new species included in the study were drawn with the help of a drawing tube attached to the research microscope (Nikon Eclipse-80i).

4. Scanning Electron Microscopic studies

Scanning Electron Microscopic pictures of six species of mites, *viz. Phyllocoptruta merremiae* sp. nov., *E. camarae* sp. nov., *Brevipalpus phoenicis*, *Tetranychus urticae*, *Oligonychus biharensis* and *Amblyseius largoensis* (Plate 12, Fig. a-g) were taken using the FE- SEM (Zeiss- Gemini 300) available in the Central Sophisticated Instrument Facility (CSIF), University of Calicut. The procedures adopted for performing scanning electron microscopic studies are presented below:

4.1. Sample processing

The mite samples were fixed in 2.5% glutaraldehyde in 0.2 molar phosphate buffer for 5 minutes. The samples were then dehydrated by passing through acetone gradients of 70, 80%, 90% and 100% for 3 minutes each. The samples were then kept in an oven at 30^0C for 30 minutes.

II. MEASUREMENT OF SPECIES DIVERSITY THROUGH ANALYSIS OF DIVERSITY INDICES

Evaluation of the species diversity indices *viz.* Shannon-Wiener Diversity Index, Simpson's Index, evenness and richness in the various localities distributed over three districts of Kerala *viz.* Kozhikode, Malappuram and Palakkad was also made during the present investigation. The above three districts were considered for the study of diversity indices based on the ease of conducting regular fortnightly collection of mites from the selected localities. Diversity indices were calculated based on the evaluation of different ecological parameters such as the species diversity, species richness, and evenness, following Shannon-Wiener Diversity Index and Simpson's Index of Diversity (Magurran 2004).

Shannon-Wiener Diversity Index was calculated using the formula:

$H' = -\Sigma pi \ln pi$

Where, pi is the proportion of individuals found in species i.

Ln pi is the natural logarithm of pi.

Simpson's Index of Diversity was calculated by using the formula:

$D = \Sigma pi^2$

Where, pi is the proportion of individuals found in species i

Evenness was calculated following the equation:

$I' = H'/Hmax = H'/\ln S$

Species richness was calculated based on the following equation:

$Dmg = (S-1)/\ln N$

Where S is the total number of species in the community (richness), pi is the proportion of S represented by the ith species and lnpi is the natural logarithm of this proportion.

The maximum diversity possible (Hmax) is the natural logarithm of S.

III) MOLECULAR PHYLOGENETIC ANALYSIS

1) Collection and Preservation of Specimens

The eriophyid mite specimen representing the new species *viz. Eriophyes camarae* sp.nov. selected for molecular studies was collected in sufficient numbers from its host plant, *Lantana camara* growing in different localities of Malappuram and Kozhikode districts of Kerala. Confirmation of species identity was found essential for subjecting the specimens for molecular identification through barcoding of their mitochondrial DNA. For this, pure culturing of the selected species was made in the laboratory, to rule out contamination by other mite species. The pure cultured specimens were transferred to 1.5 ml eppendorf tubes containing 95% alcohol with the help of a moistened camel hair brush (Plate 13, Fig. a). The specimens were then labeled properly and stored at -20^0 C for further molecular analysis.

2) Mitochondrial DNA Extraction

The genomic DNA was extracted using commercially available genomic DNA purification kit (HiPurA™ Genomic DNA Purification Kit) following manufacturer's instructions. Ethanol was removed from the collected specimens carefully and homogenized using a sterilized needle. Complete tissue lysis was done with lysis buffer (AL) and Proteinase K and the sample was incubated overnight, at 56^0C followed by incubation at 70^0C with buffer C1 in a water bath for 20 minutes. The genomic DNA bound

tightly towards the positively charged silica particles in the silicate column were eluted using TrisEDTA buffer (TE buffer).

3) Primers used

PCR amplification of barcoding region of mitochondrial cytochrome oxidase subunit I (COI) gene from the DNA sample was performed using universal primers *viz.* forward primers, LCO1490:5'-GGTCAACAAAT CATAAAGATATTGG-3' and reverse primers, HCO2198: 5'-TAAACT TCAGGGTGACCAAAAAATCA-3' respectively (Folmer *et al*., 1994)

4) PCR amplification and DNA sequencing

The mitochondrial COI gene of the collected specimen was amplified using LCO-149 and HCO-2198 primers. The PCR reaction mixture consisted of 1µl genomic DNA, 1 µl each of forward and reverse primer, 2.5 µl of dNTPs, 1µl taq polymerase and 43.5 µl distilled water. The PCR profile was run consisted of 95^0C of 10 min initial denaturation, 35 cycles of 95^0C for 10 sec (denaturation), 56^0 C of 45 sec (annealing), 72^0 C of 45 sec (elongation) and finally 72^0C of 3 min (final elongation). The PCR product was column purified using Mo Bio Ultra Clean PCR Clean-up Kit (Mo Bio Laboratories, Inc. California) as per the manufacturer's instructions. The PCR products were resolved in 50 µl (1.5%) Tris EDTA buffer. Agarose gel stained with Ethidium Bromide was used and visualized using a gel documentation system (Bio-Rad EZ imager) (Plate 13, Fig. b). The sequencing of the purified DNA template was done from both ends using the Sanger's dideoxy chain termination sequencing method (Sanger and Coulson, 1975) at Agrigenome Laboratories Ltd., Cochin with ABI 3730XL automated sequencer.

5) Sequence analysis

The forward and reverse sequences were trimmed and assembled in Sequencher (Gene Codes Corporation, Arbor, MI, USA) to get a consensus

sequence. The resulted cytochrome oxidase subunit 1 (COI) gene sequences were aligned and translated to amino acids to assess the sequencing errors. The FASTA format of the final sequence was used to search for its similarity using the Basic Local Alignment Search Tool (BLAST) (Altschul *et al*., 1997) of NCBI (http://www.ncbi.nlm.nih.gov). The BLAST search identified the sequences which were homologous to the query sequence obtained from the current study. The nucleotide sequences obtained in the study were deposited in the public databases system and have been assigned with accession numbers in NCBI GenBank (National Centre for Biotechnology Information, USA) of INSDC (International Nucleotide Sequence Database Collaboration).

6) Phylogenetic analysis

The evolutionary history was inferred using the Neighbor-Joining method (Saitou and Nei, 1987) and Maximum Likelihood method and JTT matrix-based model (Jones *et al*., 1992). The percentage of replicate trees in which the associated taxa clustered together in the bootstrap test (100 replicates) was shown next to the branches (Felsenstein, 1985). The tree was drawn to scale, with branch lengths in the same units as those of the evolutionary distances used to infer the phylogenetic tree. The evolutionary distances were computed using the Poisson correction method (Zuckerkandl and Pauling, 1965) and are in the units of the number of amino acid substitutions per site. Evolutionary analyses were conducted in Molecular Evolutionary Genetics Analysis, MEGA X (Kumar *et al*., 2018). The results were depicted in the form of respective figures.

IV) Studies on the impact of climatic factors on mite population:

Regular fortnightly sampling of mite infested leaves was carried out from four selected dominant species of invasive plants *viz. C. odorata*, *L.*

camara, *A. leptopus* and *M. vitifolia* harboured by four species of highly host specific eriophyid mites *viz. Acalitus adoratus, Eriophyes camarae* sp.nov., *Eriophyes antigonus* sp. nov. and *Phyllocoptruta merremiae* sp. nov. respectively for a period of one year, from September 2016 to August 2017. While sampling, 20 heavily infested leaves, particularly the middle aged leaves were collected fortnightly, on a random basis from the above host plants grown in and around the Calicut University Campus, Malappuram Dt. The leaf samples thus collected from the invasive plants were thoroughly examined under a Labovision (KSz0850 model) stereo zoom microscope and Lynx trinocular microscope (N 800 M) for recording the presence of mites. Quantitative assessment of population density of individual mite species was made following Per Leaf Counting method. The leaf samples of each plant were immersed for 5-7 minutes in a petriplate containing 70% alcohol. The leaves were thoroughly washed in 70% alcohol to extract the entire mite population from the leaf surface. The mite specimens thus extracted from the leaves in to the petriplate were then examined under the stereo zoom microscope. Simple hand picking method was also used to obtain the different life stages of mite population. In order to study the population density of individual mite species, the numbers of different life stages *viz.* the eggs, nymphal stages and adults, were counted separately for each species. The number of live individuals representing each species present on 10 leaves of each of the above four species of invasive host plants were recorded during each sampling occasion. The meteorological data such as temperature, relative humidity, rainfall and wind velocity were collected from the Centre for Water Resources Development and Management *(*CWRDM), Kozhikode. Data on the population density of the above four species thus collected during each sampling time were recorded, subjected to statistical analysis, using IBM SPSS Statistics (version 23) and presented through tables/figures/graphs.

CHAPTER V
OBSERVATION

I) FAUNAL DIVERSITY

Attention was focused during the present study to elucidate the faunal diversity of mites associated with 25 species of invasive plants belonging to 25 genera and 13 families (Table 3) collected from 12 districts of Kerala (Tables 1&2, Plate 1). Results of detailed field sampling undertaken in 88 collection localities distributed over the above 12 districts enabled to yield a total of 124 species of mites belonging to 50 genera and 22 families categorized under three orders *viz.* Mesostigmata, Trombidiformes and Sarcoptiformes representing two superorders, Parasitiformes and Acariformes (Table 4; Fig.1 & 2). Of these, the superorder Parasitiformes was found represented by 53 species, all of which could be categorized under a single order, Mesostigmata. The remaining 71 species were recognized as members of the superorder Acariformes, which were assigned to two orders *viz.* Trombidiformes and Sarcoptiformes. Thus, 42.7% of the total mite fauna collected from the invasive plants of Kerala could be assigned to the superorder Parasitiformes and 57.3% of mites represented taxa under the superorder Acariformes (Fig.1).

All the 53 species of mites collected under the order Mesostigmata were identified as members of a single suborder *viz.* Monogynaspida. The above 53 species could be assigned to two superfamilies *viz.* Phytoseiodea and Ascoidea, of which the former comprised members of a single family, Phytoseiidae while the latter included members of two families *viz.* Ascidae and Blattisociidae (Fig. 4). Under the family Phytoseiidae, 48 species belonging to nine genera were identified thereby constituting 90.6% of the

total species of Mesostigmatid mites collected during the study. The families Ascidae and Blattisociidae were found to include members of one and two genera respectively. Thus the three mesostigmatid families could be presented based on the order of their generic abundance as : Phytoseiidae> Blattisociidae> Ascidae.

The family Phytoseiidae was found represented by members of nine genera *viz. Amblyseius, Euseius, Neoseiulus, Typhlodromus, Typhlodromips, Paraphytoseius, Phytoseius, Scapulaseius* and *Platyseiella.* The genus *Amblyseius* showed a dominance over the others, with a total of 16 species. *Neoseiulus* was the second dominant genus with eight species followed by *Phytoseius* with six species, *Euseius* and *Typhlodromus* with five species each and *Typhlodromips* with two species. *Scapulaceius* and *Platysiella* were found represented by a single species each. Thus the generic abundance under the family Phytoseiidae could be presented as *Amblyseius*>*Neoseiulus*> *Phytoseius*>*Euseius*=*Typhlodromus*>*Paraphytoseius* >S*capulaceius*= *Platy-siella*. The family Ascidae included a single genus *viz. Asca* and the family Blattisociidae comprised of members of two genera *viz. Lasioseius* and *Arctoseius* (Fig. 5).

The species diversity of the various genera recognized under the family Phytoseiidae showed considerable variation. Accordingly, *Amblyseius* constituted the largest genus of the family Phytoseiidae with 16 species *viz. A.adhatodae, A.bhadrakshae, A.largoensis, A.orientalis, A.channabasavannai, A.shoreae, A.neorykei, A.paraaerialis, A. malabarensis, A.muraleedharani , A. indirae, A. herbicolus, A. aerialis, A. kundurukkae, A. mohanasundarami* and *A.dioscoreae.* The species diversity of the second large genus of Phytoseiidae recovered during the study *viz. Neoseiulus* was eight and the species identified under this genus were *N. longispinosus, N.fallacis, N. indicus, N. cucumeris, N. villoonniyensis, N. californicus,*

N.fraterculus and *N. baraki*. *Phytoseius* was the third genus recognized with respect to species diversity by accommodating six species and species collected were *P. rachelae, P. roseus, P. macropilis, P. kapuri, P. mixtus* and *P. huangi*. The fourth position in terms of species diversity was shared by two genera of Phytoseiidae *viz. Euseius* and as *Typhlodromus,* both of which included five species each. The latter genus included one species under the subgenus *Anthoseius* also. The *Euseius* members collected from the invasive plants were *E. finlandicus, E.macrospatulatus, E. rhododendronis, E. sacchari* and *E. coccosocius* and the five species collected under *Typhlodromus* were *T. (Anthoseius) rickeri, T. (Amblydromella) fleschneri, T. (Typhlodromus) occidentalis, T. (Typhlodromus) pyri* and *T. (Anthoseius) dahungensis*. The genus *Paraphytoseius* was found represented by four species *viz. P. multidentatus, P. orientalis, P. scleroticus* and *P. nicobarensis*. The remaining two genera of Phytoseiidae collected during the study *viz. Scapulaseius* and *Platyseiella* exhibited very low species diversity, represented by a single species each *viz. S. suknaensis* and *P. mumai* respectively. The species diversity of the genera under the remaining two families of the order Mesostigmata *viz.* Ascidae and Blattisociidae was comparatively very low than that of Phytoseiidae, on the invasive plants screened during the study. The genus *Asca* was found represented by two species *viz. A.afroaphidiodes* and *A. evansi* whereas three species could be recovered under two genera *viz. Laseoseius* and *Arctoseius* of the family Blattisociidae**.** The species collected were *L. parberlesei, A. pristinus* and *A. magnanalis* respectively.

The superorder Acariformes, was found represented by 71 species out of the total 124 species of mites collected, thereby constituting 57.3% of the acarine fauna, harboured by the invasive plants of Kerala. Under this superorder, species belonging to two orders *viz.* Trombidiformes and Sarcoptiformes were recovered. The order Trombidiformes included 65

species belonging to 33 genera, 14 families and eight superfamilies and all of which were categorized under a single suborder *viz.* Prostigmata. The Prostigmatid mites were assigned to 14 families and their percentage-wise distribution was as follows: Bdellidae (3.1%), Cunaxidae (7.7%), Tydeidae (16.9%), Stigmaeidae (9.2%), Eupodidae (3.1%), Suidasiidae (1.5%), Erythraeidae (1.5%), Eupalopsellidae (1.5%), Cheyletidae (6.2%), Tarsonemidae (3.1%), Tetranychidae (18.5%), Tenuipalpidae (9.2%), Eriophyidae (16.9%), and Diptilomiopidae (1.5%) (fig.6).

Eriophyidae was the largest prostigmatid family identified under the order Trombidiformes with the maximum generic representation. A total of eight genera could be identified under Eriophyidae *viz. Eriophyes, Aceria, Acalitus, Calacarus, Aculus, Tegolophus, Diptilomiopus* and *Phyllocoptruta.* Based on their species richness, the above genera could be presented in the sequence: *Calacarus*> *Eriophyes=Aculus>Aceria=Phyllocoptruta= Diptilomiopus= Tegolophus.* Of these, *Calacarus* showed the presence of three species *viz. C.carinatus, C.lantanae* and *C. kalyaniensis.* This was followed by the genus *Eriophyes* which disclosed two new species such as *E. camarae* sp.nov. and *E. antigonus* sp. nov. The remaining five genera of Eriophyidae were represented by a single species each, including a noval species identified and described under *Phyllocoptruta.*

Tetranychidae was the second large family in terms of generic diversity by including species belonging to five genera. The genera identified under Tetranychidae were *Bryobia*, *Tetranychus*, *Eutetranychus*, *Oligonychus* and *Schizotetranychus*. Considering their species diversity, the above five genera could be arranged as : *Tetranychus>Oligonychus>Eutetranychus> Schizotetranychus=Bryobia,* with the number of species being five, three, two, one and one respectively. The five species collected under the genus *Tetranychus* were *T. urticae*, *T. neocaledonicus*, *T. ludeni, T.marianae* and

T. macfarlanei. The three species collected under the genus *Oligonychus* were *O. biharensis*, *O.indicus* and *O. coffeae*. The genus *Eutetranychus* was found to consist of two species *viz. E. orientalis* and *E. africanus* and a single species each was recorded under *Schizotetranychus* and *Bryobia viz. S. lespedezae* and *B. ehari* respectively. The third position in terms of generic diversity was secured by the family Tydeidae which revealed the presence of four genera *viz. Tydeus, Pronematus, Lorryia* and *Brachytydeus.* Of these, *Pronematus* formed the most diverse genus, being represented by five species *viz. P. elongatus*, *P. ubiquitus*, *P.sextoni*, *P. fleschneri* and *P.rykei.*The genus *Tydeus* had a representation by members of three species *viz. T. interruptus*, *T. caudatus* and *T. kenyensis*. *Lorryia* was found to include two species *viz. L. formosa* and *L. stricta* and the study enabled to collect a single species of *Brachytydeus viz. B. incertus.*

The Prostigmatid families like Tenuipalpidae and Cheyletidae shared the fourth position, being represented by members of three genera each. The three genera of Tenuipalpidae collected during the study were *Brevipalpus, Tenuipalpus* and *Raoiella* with the order of arrangement being *Brevipalpus>Tennuipalpus>Raoiella* based on their species complexity. The genus *Bevipalpus* revealed the presence of three species *viz. B. phoenicis*, *B. obovatus* and *B. californicus*. The two species recovered under *Tenuipalpus* were *T. granati* and *T. punicae* and the single species identified under *Raoiella* was *R. macfarlanei.* The three genera identified under Cheyletidae were *Cheyletus, Hemicheyletia* and *Cheletomimus,* with the species diversity being two, one and one respectively. The two species of *Cheyletus* recovered from invasive plants were *C. eruditus* and *C. malaccensis* and the single species each collected under respective genera *Hemicheyletia* and *Cheletomimus* were *H. indica* and *C.bakeri.* The families Tarsonemidae and Cunaxidae showed representation by two genera each, and the species diversity was greater in the latter when compared to that of the former. The

two genera recognized under Tarsonemidae were *Polyphagotarsonemus* and *Hemitarsonemus*, each with a single species *viz. P. latus* and *H. biconvexa*. Cunaxidae was found represented by five species, distributed under two genera *viz. Cunaxa* and *Cunaxoides* with the number of species in the proportion 4:1. The four species collected under *Cunaxa* were *C. myabunderensis, C. setirostris, C. capreolus* and *C. reticulatus* while the single species of *Cunaxoides* collected was *C. nicobarensis.*

The remaining families of Trombidiformes mites collected during the study showed minimum generic diversity, being represented by members of a single genus each. These families were Bdellidae, Stigmaeidae, Eupodidae, Suidasiidae, Erythraeidae and Eupalopsellidae. Of these, the maximum species representation was disclosed by Stigmaeidae, revealing six species under the genus *Agistemus viz. A. gamblei, A. industani, A. fleschneri, A. exsertus, A. aimogastaensis* and *A. floridanus.* Two species were recovered under the familiy Eupodidae belonging to the genus *Eupodes,* and the species collected were *E. parafusifer* and *E. indentatus.* A single species each could be recovered under the families Bdellidae, Suidasiidae, Erythraeidae and Eupalopsellidae, under the respective genera *Bdella*, *Suidasia*, *Sphaerolophus* and *Exothorhis.* The species collected under the above genera were *Bdella radhikae, S. nesbitti, S. minutus* and *E. nadiaensis* respectively.

Species diversity of the various genera of Trombidiformes mites recovered under the different families showed considerable variation, as evidenced during the study. Thus, *Agistemus* was observed as the largest genus under the suborder Prostigmata , by revealing the presence of six species, followed by *Tetranychus* and *Pronematus* with five species each. The genus *Cunaxa* was found to comprise four species, while three species each could be identified under genera like *Oligonychus, Brevipalpus , Tydeus* and *Calacarus.* Species diversity was still lower among prostigmatid genera like

Bdella, Lorryia, Eupodes, Cheyletus, Eutetranychus, Tenuipalpus, Aculus and *Eriophyes,* each of which included two species each . The remaining prostigmatid genera *viz. Cunaxoides, Brachytydeus, Sphaerolophus, Exothorhis, Hemicheyletia, Cheletomimus, Polyphagotarsonemus, Hemitarsonemus, Bryobia, Raoiella, Acalitus, Aceria, Phyllocoptruta* and *Tegolophus* showed extremely low species diversity, by revealing the presence of a single species each. Table 4 and Fig. 7 represent the generic/species diversity of the mites collected under Prostigmata of the superorder Acariformes.

The association of six species of mites belonging to the order Sarcoptiformes of the superorder Acariformes was also recognized on the invasive plants screened during the study. All the six species were identified as representatives of a single suborder *viz.* Oribatida and were found belonging to five superfamilies and five families. As shown in table 4 and fig. 8, the five families of Sarcoptiformes mites collected were Mochlozetidae, Heterozetidae, Trhypochthoniidae, Caloppiidae and Acaridae and the respective genera collected under the above families were *Uracrobates (Uracrobates), Lamellobates (Paralamellobates) , Allonothrus, Zetorchella* and *Tyrophagus* (Fig. 9). The respective species collected under the above genera were *U. (U.) indicus, L. (P.) misella, L. (P.) bengalensis, A. russeolus russeolus, Z. sejugata* and *T. putrescentiae.*

Thus, the results of faunistic studies revealed the association of 124 species belonging to three suborders, three orders and two superorders of the subclass Acari. Of these, three species belonging to the family Eriophyidae of the suborder Prostigmata were found new to science. The noval species collected and described during the study were *E. camarae* sp.nov., *E. antigonus* sp.nov. and *P. merremiae* sp.nov. (Table 8; Fig. 12) from respective host plants, *L.camara, A. leptopus* and *M. vitifolia*. Further,

results of field surveys carried out during the present investigation helped to record six species, *viz. C. reticulatus, T. kenyensis, H. biconvex, A. magnanalis, A. pristinus* and *L. parberlesei* as new reports from India (Table 9; Fig. 12). Further, the study also helped to record 51 species as new reports from Kerala (Table 10; Fig. 12) and 111 species as new reports from respective invasive host plants (Table 11; Fig.12).

Results of relative distribution pattern and population density of the various species of mites showed considerable variation on their respective host plants. Accordingly, *B.phoenicis* was the species which showed the maximum host range by enjoying distribution on 11 species of host plants *viz. L. camara, C. odorata, A.leptopus, M. vitifolia, S. trilobata, C. hirta, T.procumbens, M. micrantha, C. tora, C. procera* and *L.luecocephala* (Table 5; Fig.3). Species like *T.interruptus* and *A. largoensis* occupied the second position after *B.phoenicis* by showing distribution on five species of host plants each. *T. interruptus* showed distribution on plants *viz. L. camara, C. odorata, A. leptopus, M. vitifolia* and *M. micrantha* and its population density was low on all host plants screened. *A. largoensis* was found associated with plants like *L. camara, C. odorata, M. micrantha, A. leptopus* and *M. vitifolia,* of which the maximum population was observed on *L. camara.* Moderate populations of the mite were seen on two hosts like *C. odorata* and *M. vitifolia* whereas low population density of the mite was evident on *M. micrantha* and *A. leptopus.* Spidermite species like *T. urticae* and *T. neocaledonicus* were found infesting on four species of invasive host plants, the former species on plants like *M. micrantha, M. vitifolia, T. procumbens* and *S. nodiflora* and the latter species inhabiting on *A. leptopus, M. vitifolia,* and *M. micrantha*. As presented in Table 5, the population density of *T. urticae* was particularly high on *M. micrantha* and *M. vitifolia* while low populations of the mite were supported by the other two host plants. *T. neocaledonicus* showed distribution in moderate populations on *A. leptopus*

and *M. vitifolia* and the remaining two species of host plants supported only low populations of the mite. Species like *E. orientalis* and *P. rachelae* showed association with three species of host plants each, the former species showed high population density on *A. leptopus* while the other two host plants supported moderate populations of the species. The latter species showed high population density on the invasive weeds like *L. camara* and *C. odorata*, and low population on the remaining host plant, *S. jamaicens.* As shown in Table 5, two species of invasive plants each were found to serve as hosts for 20 species of mites *viz. O. biharensis, B. obovatus, B. maldahensis, T. caudatus, P. elongatus, P. ubiquitus, A. floridanus, A. gamblei, A. fleschneri, P. latus, A. mohanasundarami, A. kundurukkae, N. californicus, N. fallacies, P. multidentatus, P. roseus, P. macropilis, T. rickeri , A. pristinus* and *Z. sejugata.*

Majority of the species collected during the study showed association with a single species of host plant. This was particularly true in the case of mites belonging to the superfamily Eriophyoidea. Eriophyid mites were observed to be highly host specific, inhabiting on a single species of invasive plant. In the present study, 12 species of erioiphyid mites could be recovered from eight species of host plants and which included three new species, eight species as new reports from Kerala and one species as new report from respective host plant. The new species recovered during the present study were *E. antigonus* sp. nov., *E. camarae* sp. nov and *P. merremiae* sp. nov. The remaining species were *A. adoratus, C. lantanae, C. kalyaniensis, C. carinatus, T. calotropi, A. mikaniae, A. cassiae, A. indicus* and *D. camerae.* Seven species of eriophyid mites collected during the present study *viz. C. lantanae, C. kalyaniensis, T. calotropi, A. mikaniae, A. cassiae, A. indicus* and *D. camerae* formed the first report from Kerala. *C. carinatus* was the species which formed the first report on a new host plant, *T. procumbens*.

Among the 25 species of invasive hosts screened during the study, 24 species showed the presence of mites, with considerable variation in their number, density and diversity. The plant, *M. diplotricha* was detected as totally free of mite infestation, irrespective of variations in the geographical localities. *L. camara* was the invasive plant which showed infestation by the maximum number of mite species. This noxious invasive weed supported 35 species of mites, of which 11 species showed high population density also (Table 5). Another notorious invasive terrestrial weed *viz.* the Siam weed, *C. odorata* was the second in terms of mite infestation, by revealing the association of 32 species, of which nine species showed high population density. By harbouring 24 species of mites, *M. vitifolia* reached the third position and on this weed, four species were found to occur in high populations, as presented in Table 5. On *A. leptopus,* 15 species of mites showed infestation, out of which four species showed high population density. *M. micrantha* disclosed the association of 14 species of mites, of which three species were found to occur in high population density. The remaining species of invasive plants screened showed either moderate or low levels of infestation by different species of mites, without showing any striking species diversity and population density. Plants like *P. chrysophylla, C. hirta, C. corymbosa, E. heterophylla, P. aquilinum* and *L. leucocephala* showed the presence of moderate/low population density of a single mite species each, as presented in Table 5. As shown in the table, *M. diplotricha* showed a total absence of mite fauna.

The faunal diversity and species composition of the various taxa of mites recovered from the invasive plants varied considerably with respect to geographical variation. Table 6; Fig. 10 illustrates the faunal diversity and species composition of mites associated with the various species of invasive plants collected from different districts of Kerala. As shown in Table 7; Fig. 11, the maximum species diversity of mites was recorded on plants collected

from Malappuram Dt. and it revealed 78 species, belonging to 37 genera, 17 families and three orders. The plants collected from Palakkad Dt. disclosed association of 53 species, under 33 genera, 14 families and three orders, thereby occupying the second place in terms of species diversity. Invasive plants collected from the sampling localities selected in the Kozhikode Dt. were found harboured by 31 species, under 20 genera, 11 families and 2 orders, thereby occupying the third position in terms of mite diversity. Lowest faunal diversity was recorded on the invasive plants screened from the Kasaragod Dt. and only five species coming under five genera, four families and two orders could be recovered (Fig. 11).

Fig. 1: Graphical representation of Acarine superorders collected

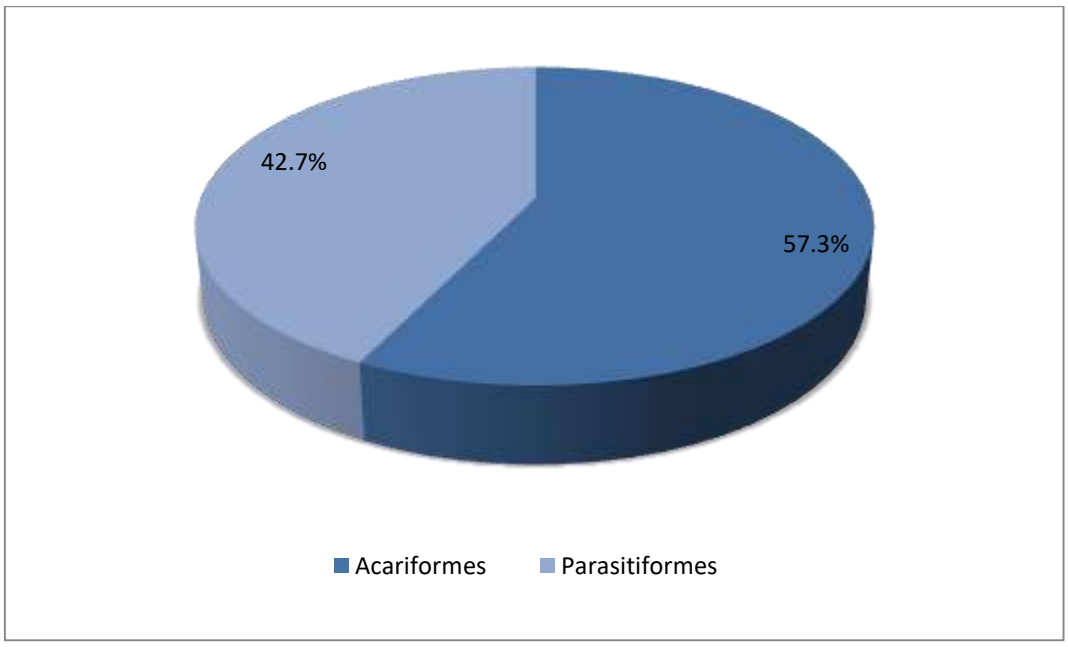


Fig. 2: Graphical representation of Acarine orders collected

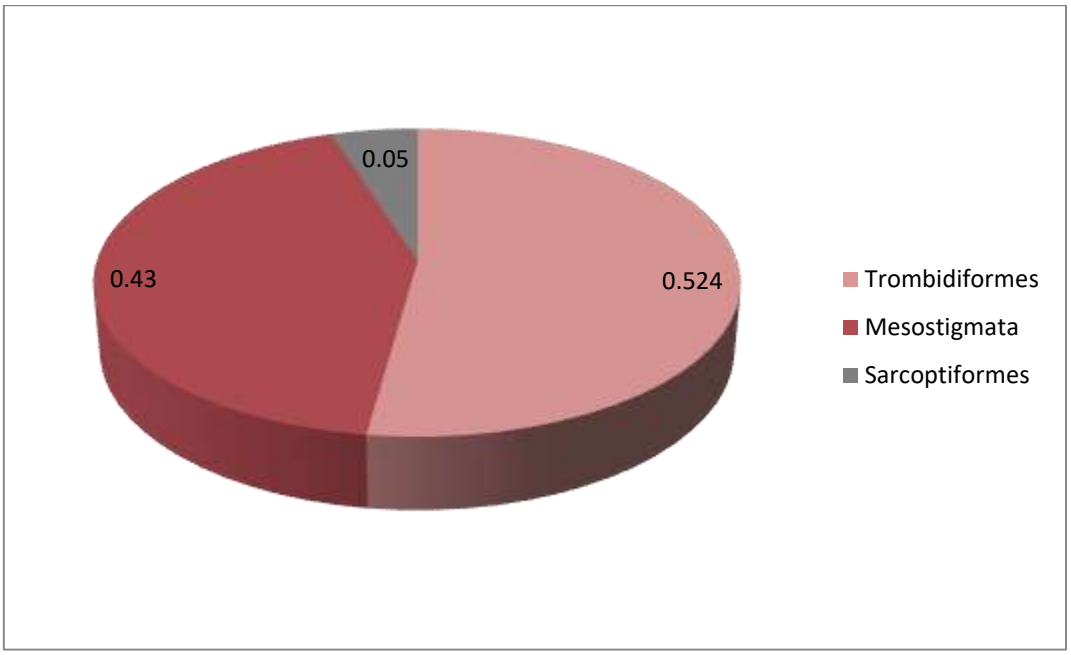


Fig. 3: Numerical abundance of various taxa of mites associated with selected species of Invasive plants

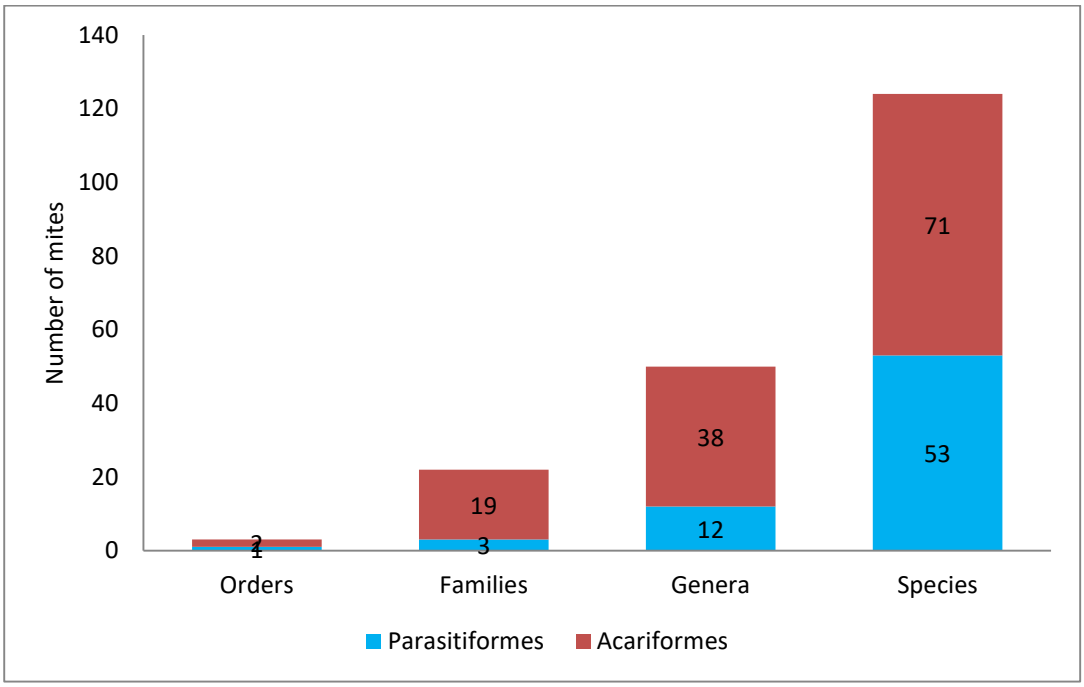


Table 4: Mite species recovered during the study

Sl. No.	MITE SPECIES RECOVERED	FAMILY	ORDER	HOST PLANT
1	*Amblyseius largoensis* Muma,1955	Phytoseiidae	Mesostigmata	*Antigonon leptopus, Lantana camara, Chromolaena odorata,Mikania micrantha, Merremia vitifolia*
2	*Amblyseius orientalis* Ehara,1959	Phytoseiidae	Mesostigmata	*Antigonon leptopus*
3	*Amblyseius malabarensis* Mary Anitha and Ramani, 2004	Phytoseiidae	Mesostigmata	*Chromolaena odorata*
4	*Amblyseius mohanasundarami* Anithalatha, 2005	Phytoseiidae	Mesostigmata	*Merremia vitifolia, Chromolaena odorata*
5	*Amblyseius kundurukkae* Mary Anitha and Ramani, 2004	Phytoseiidae	Mesostigmata	*Merremia vitifolia, Chromolaena odorata*
6	*Amblyseius bhadrakshae* Mary Anitha and Ramani, 2006	Phytoseiidae	Mesostigmata	*Chromolaena odorata*
7	*Amblyseius channabasavannai* Gupta and Daniel,1978	Phytoseiidae	Mesostigmata	*Merremia vitifolia*
8	*Amblyseius dioscoreae* Rahul, Mary Anithalatha and Santhosh,216	Phytoseiidae	Mesostigmata	*Antigonon leptopus*
9	*Amblyseius neorykei* Gupta 1977	Phytoseiidae	Mesostigmata	*Stachytarpeta jamaicensis*
10	*Amblyseius muraleedharani* Gupta, 1986	Phytoseiidae	Mesostigmata	*Sphagneticola trilobata*
11	*Amblyseius aerialis* (Muma, 1955)	Phytoseiidae	Mesostigmata	*Mikania micrantha*

12	*Amblyseius herbicolus* Chant,1959	Phytoseiidae	Mesostigmata	*Mikania micrantha*
13	*Amblyseius indirae* Gupta, 1985	Phytoseiidae	Mesostigmata	*Synedrella nodiflora*
14	*Amblyseius paraaerialis* Muma, 1967	Phytoseiidae	Mesostigmata	*Merremia vitifolia*
15	*Amblyseius shoreae* Gupta, 1977	Phytoseiidae	Mesostigmata	*Merremia vitifolia*
16	*Amblyseius adhatodae* Muma, 1967	Phytoseiidae	Mesostigmata	*Ageratum conizoides*
17	*Euseius finlandicus* Oudemans, 1915	Phytoseiidae	Mesostigmata	*Pueraria phaseoloides*
18	*Euseius macrospatulatus* Gupta, 1986	Phytoseiidae	Mesostigmata	*Alternanthera betzickiana*
19	*Euseius sacchari* (Ghai and Menon,1967)	Phytoseiidae	Mesostigmata	*Chromolaena odorata*
20	*Euseius coccosocius* (Ghai and Menon,1967)	Phytoseiidae	Mesostigmata	*Lantana camara*
21	*Euseius rhododendronis* (Gupta, 1970)	Phytoseiidae	Mesostigmata	*Lantana camara*
22	*Neoseiulus californicus* McGregor, 1954	Phytoseiidae	Mesostigmata	*Lantana camara, Parthenium hysterophorus*
23	*Neoseiulus cucumeris* (Oudemans, 1930)	Phytoseiidae	Mesostigmata	*Lantana camara*
24	*Neoseiulus fallacis* (Garman, 1948)	Phytoseiidae	Mesostigmata	*Mikania micrantha, Lantana camara*
25	*Neoseiulus villoonniyensis*Anithalatha, 2006	Phytoseiidae	Mesostigmata	*Merremia vitifolia*
26	*Neoseiulus indicus* (Narayanan &	Phytoseiidae	Mesostigmata	*Merremia vitifolia*

	Kaur, 1960)			
27	*Neoseiulus longispinosus* (Evans,1952)	Phytoseiidae	Mesostigmata	*Synedrella nodiflora*
28	*Neoseiulus fraterculus* Gupta, 1986	Phytoseiidae	Mesostigmata	*Lantana camara*
29	*Neoseiulus baraki* Athias-Henriot, 1966	Phytoseiidae	Mesostigmata	*Pueraria phaseoloides*
30	*T. (Typhlodromus) occidentalis* (Davis, 1970)	Phytoseiidae	Mesostigmata	*Chromolaena odorata*
31	*T. (Typhlodromus) pyri* Scheuten, 1857	Phytoseiidae	Mesostigmata	*Lantana camara*
32	*Typhlodromus (Anthoseius) rickeri* Chant, 1960	Phytoseiidae	Mesostigmata	*Lantana camara,Chromolaena odorata*
33	*T. (Anthoseius) dahungensis* Pramanik and Karmakar, 2016	Phytoseiidae	Mesostigmata	*Merremia vitifolia*
34	*Typhlodromus (Amblydromella) fleschneri* Chant, 1960	Phytoseiidae	Mesostigmata	*Desmodium tortuosum*
35	*Typhlodromips tetranychivorus* Gupta, 1978	Phytoseiidae	Mesostigmata	*Chromolaena odorata*
36	*Typhlodromips syzygi* Gupta,1975	Phytoseiidae	Mesostigmata	*Merremia vitifolia*
37	*Paraphytoseius multidentatus* Swirski and Shechter, 1961	Phytoseiidae	Mesostigmata	*Lantana camara,Chromolaena odorata*
38	*Paraphytoseius orientalis* Narayanan,Kaur and Ghai,1960	Phytoseiidae	Mesostigmata	*Lantana camara*
39	*Paraphytoseius scleroticus* (Gupta & Ray, 1981)	Phytoseiidae	Mesostigmata	*Stachytarpeta jamaicensis*

40	*Paraphytoseius nicobarensis* (Gupta, 1977)	Phytoseiidae	Mesostigmata	*Lantana camara*
41	*Phytoseius mixtus* Narayanan, Kaur & Ghai, 1960	Phytoseiidae	Mesostigmata	*Lantana camara*
42	*Phytoseius roseus* Gupta,1969	Phytoseiidae	Mesostigmata	*Lantana camara, Chromolaena odorata*
43	*Phytoseius rachelae* Swirski and Shechter, 1961	Phytoseiidae	Mesostigmata	*Chromolaena odorata, Lantana camara, Stachytarpeta jamaicensis*
44	*Phytoseius kapuri* Gupta,1969	Phytoseiidae	Mesostigmata	*Chromolaena odorata*
45	*Phytoseius macropilis* Banks, 1909	Phytoseiidae	Mesostigmata	*Stachytarpeta jamaicensis, Lantana camara*
46	*Phytoseius huangi* Ehara, 1970	Phytoseiidae	Mesostigmata	*Chromolaena odorata*
47	*Scapulaceius suknaesis* Gupta,1970	Phytoseiidae	Mesostigmata	*Merremia vitifolia*
48	*Platysiella mumai* Ray and Gupta,1981	Phytoseiidae	Mesostigmata	*Chromolaena odorata*
49	*Asca afrophidioides* Hurlbutt,1971	Ascidae	Mesostigmata	*Lantana camara*
50	*Asca evansi* Genis, Loots & Ryke, 1969	Ascidae	Mesostigmata	*Chromolaena odorata*
51	*Lasioseius parberlesei* Bhattacharyya, 1968	Blattisociidae	Mesostigmata	*Lantana camara*
52	*Arctoseius magnanalis* Evans, 1958	Blattisociidae	Mesostigmata	*Senna tora*
53	*Arctoseius pristinus* Karg, 1962	Blattisociidae	Mesostigmata	*Senna tora, Lantana camara*
54	*Bdella maldahensis* Gupta, 1992	Bdellidae	Trombidiformes	*Desmodium tortuosum,*

				Shagneticola trilobata
55	*Bdella radhikae* Sadanandan, Suresh and Ramani, 2009	Bdellidae	Trombidiformes	*Chromolaena odorata*
56	*Cunaxa myabunderensis* Gupta & Ghosh, 1980.	Cunaxidae	Trombidiformes	*Lantana camara*
57	*Cunaxa reticulatus* Bashir MH, Afzal M, Ali S,2005	Cunaxidae	Trombidiformes	*Chromolaena odorata*
58	*Cunaxa capreolus* Berlese, 1890	Cunaxidae	Trombidiformes	*Chromolaena odorata*
59	*Cunaxa setirostris* Hermann, 1804	Cunaxidae	Trombidiformes	*Parthenium hysterophorus*
60	*Cunaxoides nicobarensis* Gupta & Ghosh 1980	Cunaxidae	Trombidiformes	*Lantana camara*
61	*Tydeus interruptus* Sig Thor,1932	Tydeidae	Trombidiformes	*Antigonon leptopus, Lantana camara, Mikania micrantha, Merremia vitifolia, Synedrella nodiflora*
62	*Tydeus caudatus* (Duges,1834) Sensu Baker,1970	Tydeidae	Trombidiformes	*Tridax procumbens,Lantana camara*
63	*Tydeus kenyensis* Baker, 1970	Tydeidae	Trombidiformes	*Ageratina adenophora*
64	*Brachytydeus incertus* Kazmierski, 2009	Tydeidae	Trombidiformes	*Antigonon leptopus*
65	*Lorryia formosa* Cooreman,1958	Tydeidae	Trombidiformes	*Lantana camara*
66	*Lorryia stricta* Gupta, 1991	Tydeidae	Trombidiformes	*Antigonon leptopus*
67	*Pronematus elongatus* Baker, 1968	Tydeidae	Trombidiformes	*Lantana camara, Euphorbia heterophylla*

68	*Pronematus rykei* (Meyer and Rodrigues, 1966)	Tydeidae	Trombidiformes	*Merremia vitifolia*
69	*Pronematus ubiquitus* McGregor, 1932	Tydeidae	Trombidiformes	*Lantana camara, Chromolaena odorata*
70	*Pronematus fleschneri* Baker, 1968	Tydeidae	Trombidiformes	*Alternanthera bettzickiana*
71	*Pronematus sextoni* Baker, 1968	Tydeidae	Trombidiformes	*Lantana camara*
72	*Agistemus aimogastensis* Leiva et al.,2013	Stigmaeidae	Trombidiformes	*Merremia vitifolia*
73	*Agistemus floridanus* Gonzalez, 1965	Stigmaeidae	Trombidiformes	*Lantana camara,Chromolaena odorata*
74	*Agistemus industani* Gonzalez,1965	Stigmaeidae	Trombidiformes	*Lantana camara*
75	*Agistemus gamblei* Gupta,1991	Stigmaeidae	Trombidiformes	*Chromolaena odorata, Parthenium hysterophorus*
76	*Agistemusfleschneri* Summers, 1960	Stigmaeidae	Trombidiformes	*Antigonon leptopus,Desmodium tortuosum*
77	*Agistemus exsertus* Gonzalez-Rodriguez, 1963	Stigmaeidae	Trombidiformes	*Chromolaena odorata*
78	*Eupodes indentatus* Olivier & Theron, 1997	Eupodidae	Trombidiformes	*Antigonon leptopus*
79	*Eupodes parafusifer* Meyer & Ryke, 1960	Eupodidae	Trombidiformes	*Merremia vitifolia*
80	*Suidasia nesbitti* Hughes, 1948	Suidasiidae	Sarcoptiformes	*Chromolaena odorata*
81	*Sphaerolophus minutus* Khot, 1965	Erythraeidae	Trombidiformes	*Lantana camara*

82	*Exothorhis nadiaensis* Chatterjee and Gupta, 1994	Eupalopsellidae	Trombidiformes	*Lantana camara*
83	*Cheyletus eruditus* Schrank, 1781	Cheyletidae	Trombidiformes	*Chromolaena odorata*
84	*Cheyletus malaccensis* Oudemans, 1903	Cheyletidae	Trombidiformes	*Ipomoea nil*
85	*Hemicheyletia indica* Gupta, 1991	Cheyletidae	Trombidiformes	*Cissampelopsis corymposa*
86	*Cheletomimus bakeri* Ehara, 1962	Cheyletidae	Trombidiformes	*Stachytarpeta jamaicensis*
87	*Polyphagotarsonemus latus* Banks,1904	Tarsonemidae	Trombidiformes	*Antigonon leptopus, Lantana camara*
88	*Hemitarsonemus biconvexa* (Lin & Zhang, 1994)	Tarsonemidae	Trombidiformes	*Mikania micrantha*
89	*Bryobia ehari* Pritchard and keifer, 1958	Tetranychidae	Trombidiformes	*Chromolaena odorata*
90	*Eutetranychus orientalis* Klein,1936	Tetranychidae	Trombidiformes	*Chromolaena odorata, Merremia vitifolia,Antigonon leptopus*
91	*Eutetranychus africanus* Tucker, 1926	Tetranychidae	Trombidiformes	*Merremia vitifolia*
92	*Oligonychus biharensis* Hirst,1924	Tetranychidae	Trombidiformes	*Synedrella nodiflora, Antigonon leptopus*
93	*Oligonychus coffeae* Nietner, 1861	Tetranychidae	Trombidiformes	*Sphagneticola trilobata*
94	*Oligonychus indicus* Hirst, 1923	Tetranychidae	Trombidiformes	*Desmodium tortuosum*
95	*Schizotetranychus lespedezae* Beglyarov and Mitrofanov, 1973	Tetranychidae	Trombidiformes	*Desmodium tortuosum*
96	*Tetranychus urticae* C.L. Koch, 1836	Tetranychidae	Trombidiformes	*Tridax procumbens,Mikania*

				micrantha, Merremia vitifolia, Synedrella nodiflora
97	*Tetranychus neocaledonicus* André, 1933	Tetranychidae	Trombidiformes	*Antigonon leptopus, Mikania micrantha, Merremia vitifolia,Ageratum conizoides*
98	*Tetranychus marianae* McGregor, 1950	Tetranychidae	Trombidiformes	*Merremia vitifolia*
99	*Tetranychus ludeni* Zacher, 1913	Tetranychidae	Trombidiformes	*Merremia vitifolia*
100	*Tetranychus macfarlanei* Baker and Pritchard, 1960	Tetranychidae	Trombidiformes	*Senna tora*
101	*Brevipalpus phoenicis* Geijskes,1936	Tenuipalpidae	Trombidiformes	*Lantana camara, Chromolaena odorata,Antigonon leptopus,Merremia vitifolia,Sphagneticola trilobata,Clidemia hirta, Tridax procumbens,Mikania micrantha,Senna tora, Calotropis procera,Lucaena luecocephala, Ipomoea nil*
102	*Brevipalpus obovatus* Donnadieu, 1875	Tenuipalpidae	Trombidiformes	*Lantana camara,Antigonon leptopus*
103	*Brevipalpus californicus* Banks, 1904	Tenuipalpidae	Trombidiformes	*Merremia vitifolia*
104	*Raoiella macfarlanei* Pritchard and Baker, 1958	Tenuipalpidae	Trombidiformes	*Pteridium aquilinum*

105	*Tenuipalpus granati* Sayed, 1946	Tenuipalpidae	Trombidiformes	*Chromolaena odorata*
106	*Tenuipalpus punicae* Pritchard and Baker, 1958	Tenuipalpidae	Trombidiformes	*Desmodium tortuosum*
107	*Acalitus adoratus Keifer*, Keifer,1970	Eriophyidae	Trombidiformes	*Chromolaena odorata*
108	*Aceria mikaniae* Nalepa, 1918	Eriophyidae	Trombidiformes	*Mikania micrantha*
109	*Aculus cassiae* Mondal and Chakrabarti, 1981	Eriophyidae	Trombidiformes	*Senna tora*
110	*Aculus indicus* ChannaBasavanna, 1966	Eriophyidae	Trombidiformes	*Tridax procumbens*
111	*Calacarus lantanae* Boczek & Chandrapatya ,1989	Eriophyidae	Trombidiformes	*Lantana camara*
112	*Calacarus kalyaniensis* Debnath & Karmakar, 2016	Eriophyidae	Trombidiformes	*Chromolaena odorata*
113	*Calacarus carinatus* Green, 1890	Eriophyidae	Trombidiformes	*Tridax procumbens*
114	*Diptilomiopus camerae* Mohanasundaram, 1981	Eriophyidae	Trombidiformes	*Lantana camara*
115	*Eriophyes camarae* sp.nov.	Eriophyidae	Trombidiformes	*Lantana camara*
116	*Eriophyes antigonus* sp.nov.	Eriophyidae	Trombidiformes	*Antigonon leptopus*
117	*Phyllocoptruta merremiae* sp.nov.	Eriophyidae	Trombidiformes	*Merremia vitifolia*
118	*Tegolophus calotropi* Chakrabarti and Mondal, 1979	Eriophyidae	Trombidiformes	*Calotropis procera*
119	*Allonothrus russeolus russeolus* Wallwork, 1960	Trhypochthoniidae	Sarcoptiformes	*Sphagneticola trilobata*

120	*Lamellobates (Paralamellobates) misella* Berlese, 1910	Austrachipteriidae	Sarcoptiformes	*Mikania micrantha*
121	*Lamellobates (Paralamellobates) bengalensis* Bhaduri and Raychaudhuri, 1968	Austrachipteriidae	Sarcoptiformes	*Chromolaena odorata*
122	*Uracrobates (Uracrobates) indicus* Ramani and Haq, 1990	Mochlozetidae	Sarcoptiformes	*Mikania micrantha*
123	*Zetorchella sejugata* Ramani and Haq, 1997	Caloppiidae	Sarcoptiformes	*Mikania micrantha,Sphagneticola trilobata*
124	*Tyrophagus putrescentiae* Shrank, 1781	Acaridae	Sarcoptiformes	*Mikania micrantha*

Table 5: Distribution and relative abundance of mite species on the various invasive host plants screened

Sl. No.	Mite species	Invasive plant species screened																								
		L.camara	***C.odorata***	***M.micrantha***	***A. leptopus***	***M.diplotricha***	***M. vitifolia***	***S. trilobata***	***T. procumbens***	***A. conizoides***	***C. hirta***	***P. phaseoloides***	***P. chrysophylla***	***P. aquilinum***	***A. adenophora***	***I. carnea***	***C. procera***	***L. leucocephala***	***S. nodiflora***	***S. tora***	***A. bettzickiana***	***S.jamaicensis***	***D. tortuosum***	***C. corymbosa***	***P. hysteronhorus***	***E. heterophylla***
1	*Amblyseius largoensis* Muma,1955	+++	++	+	+	-	++	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2	*Amblyseius orientalis* Ehara,1959	-	-	-	++	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3	*Amblyseius malabarensis* Mary Anitha and Ramani, 2004	-	++	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4	*Amblyseius mohanasundarami* Anithalatha, 2005	-	+	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5	*Amblyseius kundurukkae* Mary Anitha and Ramani, 2004	-	+	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6	*Amblyseius bhadrakshae* Mary Anitha and Ramani, 2006	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
7	*Amblyseius channabasavannai* Gupta and Daniel,1978	-	-	-	-	-	++	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

8	*Amblyseius dioscoreae* Rahul, Mary Anithalatha and Santhosh,216	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
9	*Amblyseius neorykei* Gupta 1977	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-
10	*Amblyseius muraleedharani* Gupta, 1986	-	-	-	-	-	-	++	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
11	*Amblyseius aerialis* (Muma, 1955)	-	-	++	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-
12	*Amblyseius herbicolus* Chant,1959	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
13	*Amblyseius indirae* Gupta, 1985	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-
14	*Amblyseius paraaerialis* Muma, 1967	-	-	-	-	-	++	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15	*Amblyseius shoreae* Gupta, 1977	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
16	*Amblyseius adhatodae* Muma, 1967	-	-	-	-	-	-	-	-	++	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
17	*Euseius finlandicus* Oudemans, 1915	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-
18	*Euseius macrospatulatus* Gupta, 1986	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	++	-	-	-	-	-
19	*Euseius sacchari* (Ghai and Menon,1967)	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
20	*Euseius coccosocius*	++	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

	(Ghai and Menon,1967)																										
21	*Euseius rhododendronis* (Gupta, 1970)	++	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
22	*Neoseiulus californicus* McGregor, 1954	+++	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-
23	*Neoseiulus cucumeris* (Oudemans, 1930)	++	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
24	*Neoseiulus fallacis* (Garman, 1948)	+++	-	++	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
25	*Neoseiulus villoonniyensis*Anitha latha, 2006	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
26	*Neoseiulus indicus* (Narayanan & Kaur, 1960)	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
27	*Neoseiulus longispinosus* (Evans,1952)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+++	-	-	-	-	-	-	-	-
28	*Neoseiulus fraterculus* Gupta, 1986	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
29	*Neoseiulus baraki* Athias-Henriot, 1966	-	-	-	-	-	-	-	-	-	-	++	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
30	*Typhlodromus(Typhlodromus) occidentalis* (Davis, 1970)	-	+++	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
31	*Typhlodromus (Typhlodromus) pyri* Scheuten, 1857	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

32	*Typhlodromus (Anthoseius) rickeri* Chant, 1960	++	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
33	*Typhlodromus (Anthoseius) dahungensis* Pramanik and Karmakar, 2016	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
34	*Typhlodromus (Amblydromella) fleschneri* Chant, 1960	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	++	-	-	-	-
35	*Typhlodromips tetranychivorus* Gupta, 1978	-	++	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
36	*Typhlodromips syzygi* Gupta,1975	-	-	-	-	-	++	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
37	*Paraphytoseius multidentatus* Swirski and Shechter, 1961	+++	+++	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
38	*Paraphytoseius orientalis* Narayanan,Kaur and Ghai,1960	++	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
39	*Paraphytoseius scleroticus* (Gupta & Ray, 1981)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	++	-	-	-	-	-
40	*Paraphytoseius nicobarensis* (Gupta, 1977)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
41	*Phytoseius mixtus* Narayanan, Kaur & Ghai, 1960	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
42	*Phytoseius roseus*	++	++	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

	Gupta,1969	+	+																							
43	*Phytoseius rachelae* Swirski and Shechter, 1961	+++	+++	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-
44	*Phytoseius kapuri* Gupta,1969	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
45	*Phytoseius macropilis* Banks, 1909	++	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-
46	*Phytoseius huangi* Ehara, 1970	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
47	*Scapulaceius suknaesis* Gupta,1970	-	-	-	-	-	+++	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
48	*Platysiella mumai* Ray and Gupta,1981	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
49	*Asca afrophidioides* Hurlbutt,1971	++	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
50	*Asca evansi* Genis, Loots & Ryke, 1969	-	++	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
51	*Lasioseius parberlesei* Bhattacharyya, 1968	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
52	*Arctoseius magnanalis* Evans, 1958	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-
53	*Arctoseius pristinus* Karg, 1962	++	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-
54	*Bdella maldahensis* Gupta, 1992	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	++	-	-	-
55	*Bdella radhikae* Sadanandan, Suresh and Ramani, 2009	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

56	*Cunaxa myabunderensis* Gupta & Ghosh, 1980.	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
57	*Cunaxa reticulatus* Bashir MH, Afzal M, Ali S,2005	-	++	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
58	*Cunaxa capreolus* Berlese, 1890	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
59	*Cunaxa setirostris* Hermann, 1804	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-
60	*Cunaxoides nicobarensis* Gupta & Ghosh 1980	++	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
61	*Tydeus interruptus* Sig Thor,1932	+	-	+	+	-	+	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-
62	*Tydeus caudatus* (Duges,1834) Sensu Baker,1970	++	-	-	-	-	-	-	+	-	-	-	++	-	-	-	-	-	-	-	-	-	-	-	-	-
63	*Tydeus kenyensis* Baker, 1970	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-
64	*Brachytydeus incertus* Kazmierski, 2009	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
65	*Lorryia formosa* Cooreman,1958	++ +	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
66	*Lorryia stricta* Gupta, 1991	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
67	*Pronematus elongatus* Baker, 1968	++ +	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	++
68	*Pronematus rykei* (Meyer and	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

	Rodrigues, 1966)																									
69	*Pronematus ubiquitus* McGregor, 1932	++	+++	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
70	*Pronematus fleschneri* Baker, 1968	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	++	-	-	-	-	-
71	*Pronematus sextoni* Baker, 1968	++	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
72	*Agistemus aimogastensis* Leiva et al.,2013	-	-	-	-	-	++	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
73	*Agistemus floridanus* Gonzalez, 1965	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
74	*Agistemus industani* Gonzalez,1965	++	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
75	*Agistemus gamblei* Gupta,1991	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
76	*Agistemusfleschneri* Summers, 1960	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-
77	*Agistemus exsertus* Gonzalez- Rodriguez, 1963	-	++	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
78	*Eupodes indentatus* Olivier & Theron, 1997	-	-	-	+++	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
79	*Eupodes parafusifer* Meyer & Ryke, 1960	-	-	-	-	-	++	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
80	*Suidasia nesbitti* Hughes, 1948	-	++	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
81	*Sphaerolophus minutus* Khot, 1965	++	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

82	*Exothorhis nadiaensis* Chatterjee and Gupta, 1994	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
83	*Cheyletus eruditus* Schrank, 1781	-	+++	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
84	*Cheyletus malaccensis* Oudemans, 1903	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-
85	*Hemicheyletia indica* Gupta, 1991	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	++	-	-	-
86	*Cheletomimus bakeri* Ehara, 1962	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-
87	*Polyphagotarsonemus latus* Banks,1904	+++	-	-	++	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
88	*Hemitarsonemus biconvexa* (Lin & Zhang, 1994)	-	-	++	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
89	*Bryobia ehari* Pritchard and keifer, 1958	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
90	*Eutetranychus orientalis* Klein,1936	-	++	-	+++	-	++	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
91	*Eutetranychus africanus* Tucker, 1926	-	-	-	-	-	++	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
92	*Oligonychus biharensis* Hirst,1924	-	-	-	++	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
93	*Oligonychus coffeae* Nietner, 1861	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
94	*Oligonychus indicus* Hirst, 1923	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-
95	*Schizotetranychus lespedezae* Beglyarov	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-

	and Mitrofanov, 1973																									
96	*Tetranychus urticae* C.L. Koch, 1836	-	-	+++			+++	-	+	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-
97	*Tetranychus neocaledonicus* André, 1933	-	-	+	++	-	++	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
98	*Tetranychus marianae* McGregor, 1950	-	-	-	-	-	+++	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
99	*Tetranychus ludeni* Zacher, 1913	-	-	-	-	-	++	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
100	*Tetranychus macfarlanei* Baker and Pritchard, 1960	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-
101	*Brevipalpus phoenicis* Geijskes,1936	+++	+++	+++	+++	-	+++	+	+	-	+	-	-	-	-	+	+	+	-	-	-	-	-	-	-	-	-	-
102	*Brevipalpus obovatus* Donnadieu, 1875	+	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
103	*Brevipalpus californicus* Banks, 1904	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
104	*Raoiella macfarlanei* Pritchard and Baker, 1958	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-
105	*Tenuipalpus granati* Sayed, 1946	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
106	*Tenuipalpus punicae* Pritchard and Baker, 1958	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-
107	*Acalitus adoratus Keifer*, Keifer,1970	-	+++	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
108	*Aceria mikaniae*	-	-	++	-	-	-	-	-	-	-	-	-	-	-	-	++	-	-	-	-	-	-	-	-	-	-

	Nalepa, 1918																									
109	*Aculus cassiae* Mondal and Chakrabarti, 1981	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+++	-	-	-	-	-	-
110	*Aculus indicus* ChannaBasavanna, 1966	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-
111	*Calacarus lantanae* Boczek & Chandrapatya ,1989	++	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
112	*Calacarus kalyaniensis* Debnath & Karmakar, 2016	-	++	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
113	*Calacarus carinatus* Green, 1890	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
114	*Diptilomiopus camerae* Mohanasundaram, 1981	++	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
115	*Eriophyes camarae* sp.nov.	+++	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
116	*Eriophyes antigonus* sp.nov.	-	-	-	+++	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-
117	*Phyllocoptruta merremiae* sp.nov.	-	-	-	-	-	+++	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
118	*Tegolophus calotropi* Chakrabarti and Mondal, 1979	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	++	-	-	-	-	-	-	-	-	-
119	*Allonothrus russeolus russeolus* Wallwork, 1960	-	-	-	-	-	-	++	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
120	*Lamellobates (Paralamellobates)*	-	-	++	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

	misella Berlese, 1910																									
121	*Lamellobates (Paralamellobates) bengalensis* Bhaduri and Raychaudhuri, 1968	-	+++	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
122	*Uracrobates (Uracrobates) indicus* Ramani and Haq, 1990	-	-	+++	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
123	*Zetorchella sejugata* Ramani and Haq, 1997	-	-	++	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
124	*Tyrophagus putrescentiae* Shrank, 1781	-	-	++	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

'+++' = more than 50 mites/leaf, '++' = 25 – 50 mites/leaf, '+' = less than 25 mites/leaf, '-' = absence of mites

Table 6: Relative abundance of mite fauna on respective host plants recovered from the various districts surveyed

Invasive plants screened	District wise distribution of mites											
	Thiruvananthapuram	**Kottayam**	**Alappuzha**	**Idukki**	**Ernakulam**	**Thrissur**	**Palakkad**	**Malappuram**	**Kozhikode**	**Wayanad**	**Kannur**	**Kasaragode**
Lantana camara L.	++	++	++	+++	++	+++	+++	+++	+++	+++	+	+
Chromolaena odorata (L.) R. M. King and H.Robinson	+++	++	+	++	+	++	+++	+++	++	+++	++	++
Mikania micrantha Kunth	+	+	+	++	++	+++	+++	+++	++	++	+	+
Antigonon leptopus Hook&Arn.	+	-	+	-	++	++	++	+++	++	-	-	-
*Mimosa diplotricha var. diplotricha*C.Wight ex Sauvalle	-	-	-	-	-	+	+	+	-	+	-	-
Merremia vitifolia (Burm.f.) Hallier f.	+	++	-	-	+	++	++	+++	+++	++	+	-
Sphagneticola trilobata (L.) Pruski	-	-	-	+	++	++	+	+++	++	+	-	-
Tridax procumbens L.	+	-	+	-	-	+	+	++	+	-	-	-

Ageratum conizoides L.	-	-	-	+	+	+	+	+	-	+	-	-
Clidemia hirta (L.) D. Don	+	-	-	++	-	-	-	+	-	-	-	-
Pueraria phaseoloides (Roxb.) Benth	-	-	-	-	-	-	-	-	++	+++	-	-
Pityrogramma chrysophylla (Sw.) Link	-	-	-	+	-	-	-	+	-	-	-	-
Pteridium aquilinum (L.) Kuhn.	-	-	-	++	-	-	-	-	++	+	-	-
Ageratina adenophora R.M. King & H.Robinson	-	+	-	+	-	-	+	+	-	-	-	-
Ipomoea nil (L.) Roth	-	-	-	-	-	-	++	+	-	-	-	-
Calotropis procera (Ait.) R. Br.	-	-	-	-	-	+	+	-	-	-	-	-
Leucaena leucocephala (Lam.) de Wit	-	-	-	-	+	-	+	+	-	-	-	-

Synedrella nodiflora (L.) Gaertn	-	-	-	-	+	+	+	-	+	-	-	-
Senna tora (L.) Roxb.	+	-	-	+	-	-	+	++	-	++	+	-
Alternanthera bettzickiana (Regl.) G. Nicholson	-	-	-	+	+	-	+	+	+	-	-	-
Stachytarpheta jamaicensis (L.)Vahl	-	-	-	+	-	-	-	+	-	-	-	-
Desmodium tortuosum (SW.) DC.	-	-	-	+	-	-	-	++	++	+	-	-
Cissampelopsis corymbosa (Wallich ex DC.) C. Jeffrey and Y.L. Chen	-	-	-	-	-	+	-	+++	-	+	-	-
Parthenium hysterophorus L	-	-	-	+	-	+	+	-	-	+	-	-
Euphorbia heterophylla L.	-	-	-	-	-	+	-	+	+	-	-	-

‘+++’ = more than 50 mites/leaf, ‘++’ = 25 – 50 mites/leaf, ‘+’ = less than 25 mites/leaf, ‘-’ = absence of mites

Fig. 4: Mesostigmatid familes recovered

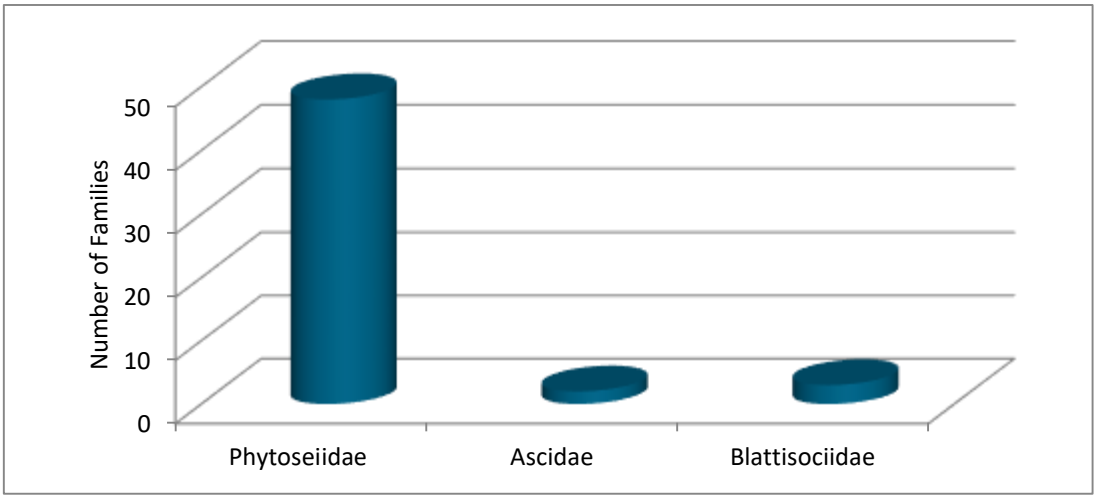


Fig. 5: Generic diversity of Mesostigmatid mites collected

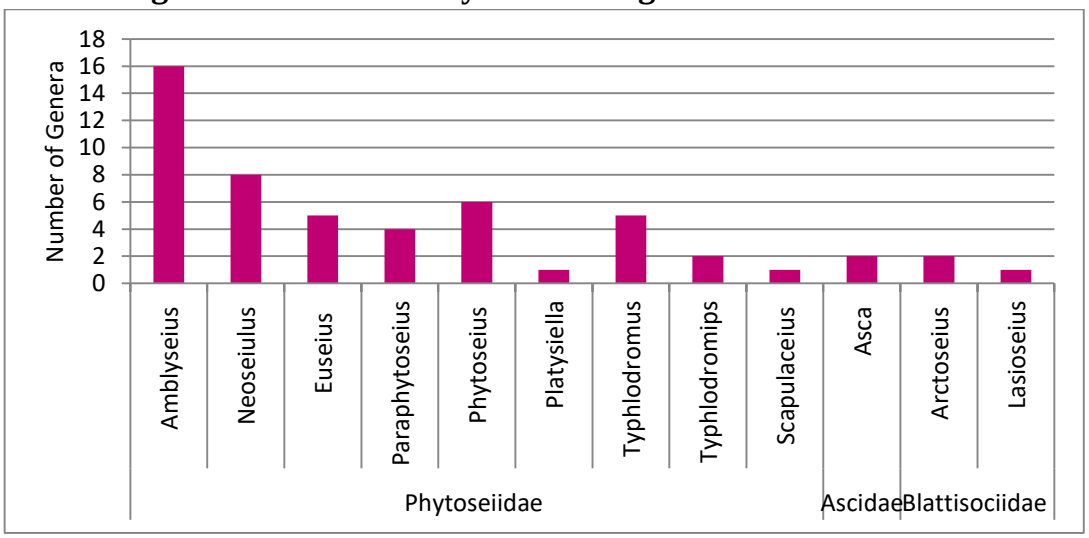


Fig. 6: **family diversity of Trombidiformes mites collected**

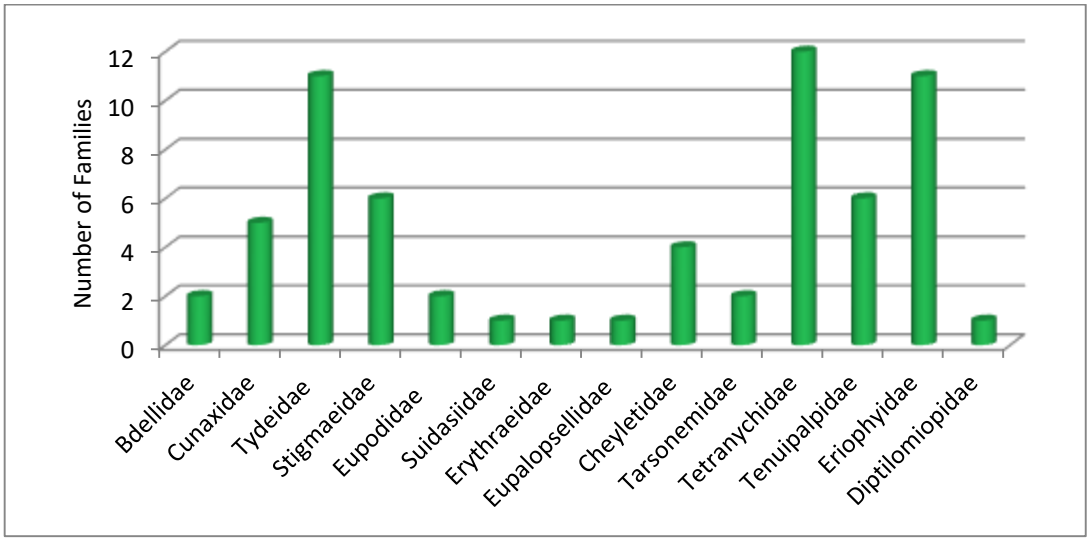


Fig. 7: Generic diversity of Trombidiformes mites collected

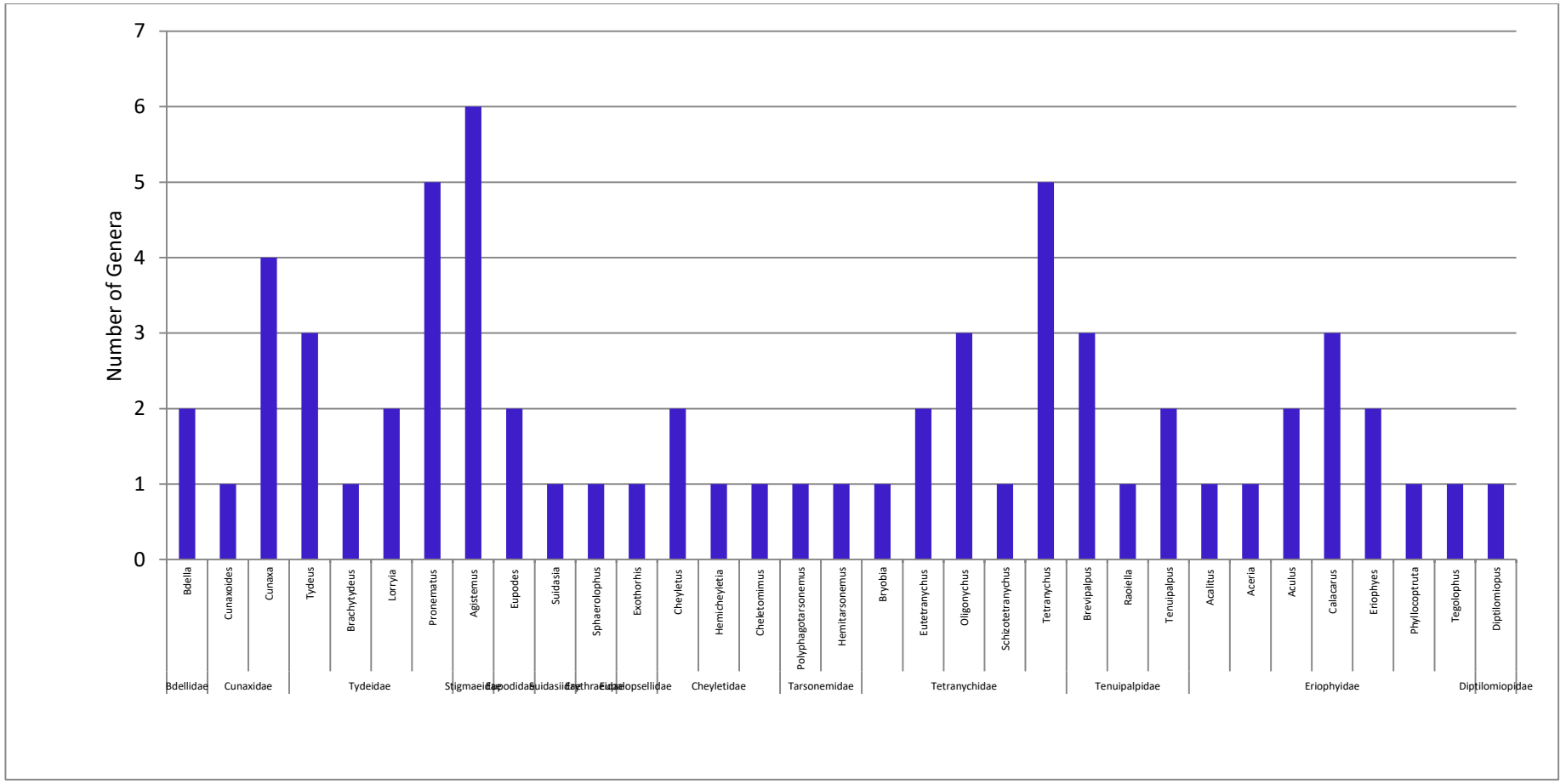


Fig. 8: Sarcoptiformes families recovered

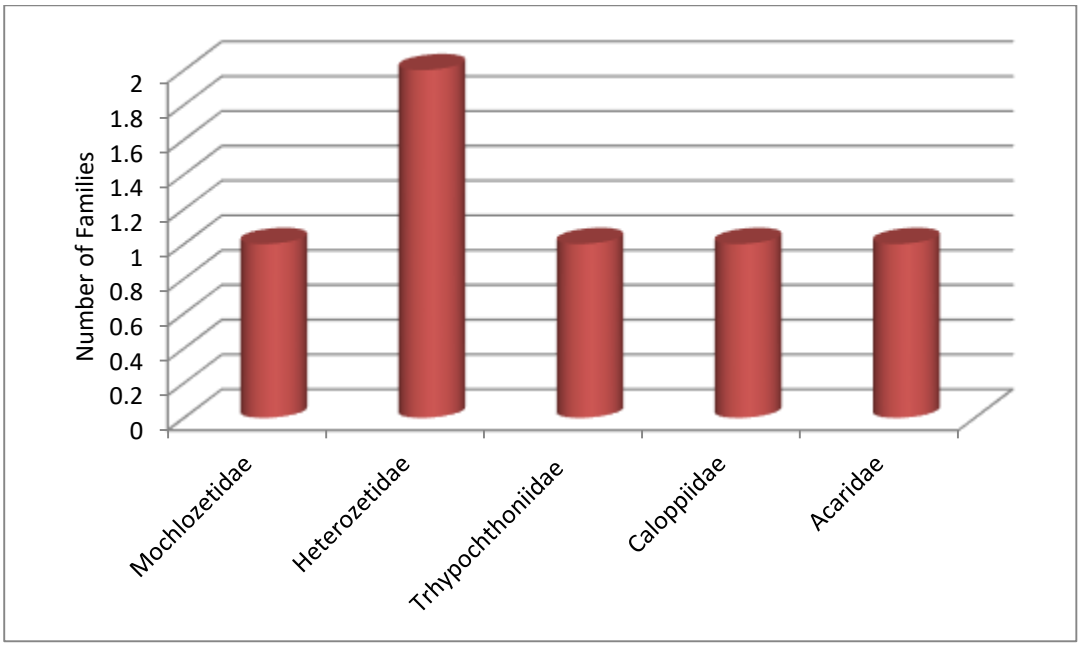


Fig. 9: Generic diversity of Sarcoptiformes mites collected

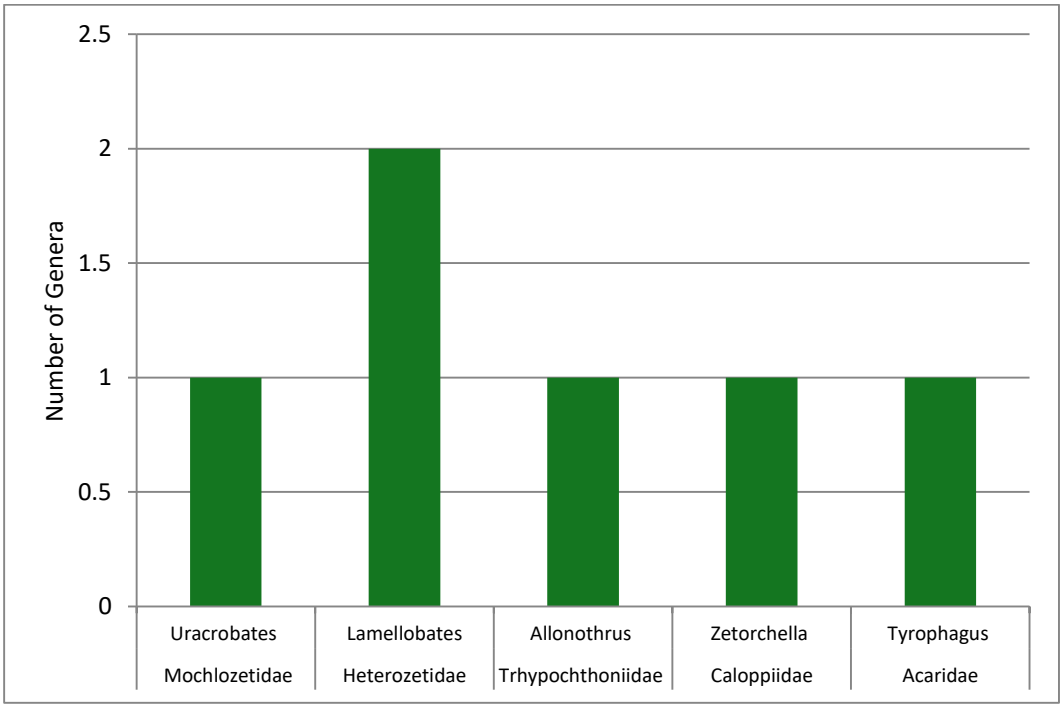


Table 7:No. of species/ genera/ family of mites recovered from the various districts surveyed during the study

SL. NO.	DISTRICTS	NO. OF SPECIES	NO. OF GENERA	NO. OF FAMILY	NO. OF ORDER
1	Thiruvananthapuram	17	13	6	2
2	Kottayam	12	11	9	2
3	Alappuzha	7	7	5	2
4	Idukki	20	16	8	3
5	Ernakulam	9	7	6	2
6	Thrissur	14	12	9	2
7	Palakkad	53	33	14	3
8	Malappuram	78	37	17	3
9	Kozhikode	31	20	11	2
10	Wayanad	27	18	6	2
11	Kannur	12	11	7	2
12	Kasaragode	5	5	4	2

Fig.10: Number of mite species associated with 25 species of Invasive plants collected from 12 districts of Kerala

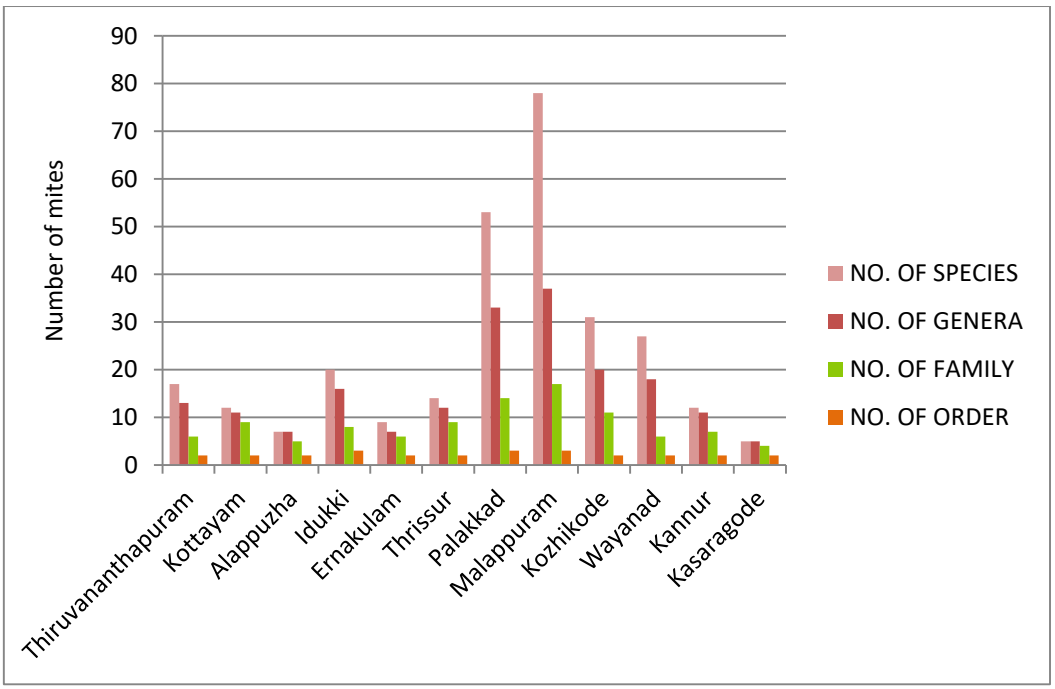


Fig. 11: Distribution of mites associated with 25 species of invasive plants from 12 districts of Kerala

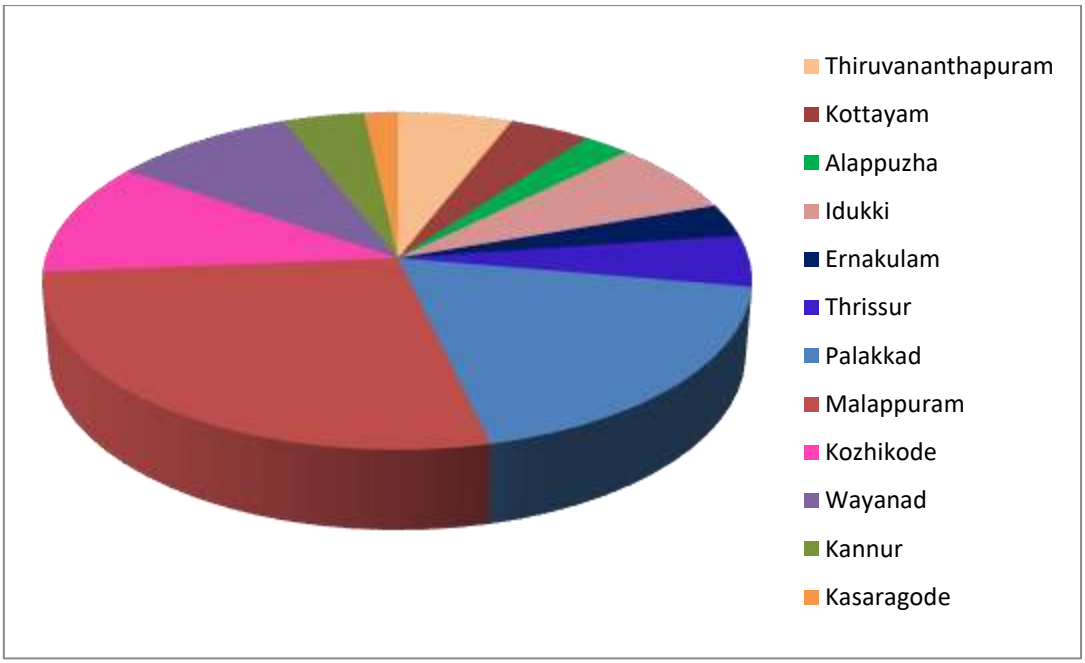


Table 8: List of new species of mites recovered during the study

Sl.No.	Name of mite species
1	*Eriophyes antigonus* sp.nov.
2	*Phyllocoptruta merremiae* sp.nov.
3	*Eriophyes camarae* sp.nov.

Table 9: New records of mite species from India

Sl.No.	Name of mite species
1	*Lasioseius parberlesei* Bhattacharyya, 1968
2	*Arctoseius magnanalis* Evans, 1958
3	*Arctoseius pristinus* Karg, 1962
4	*Cunaxa reticulatus* Bashir MH, Afzal M, Ali S,2005
5	*Tydeus kenyensis* Baker, 1970
6	*Hemitarsonemus biconvexa* (Lin & Zhang, 1994)

Table 10: New records of mite species from Kerala

Sl.No.	Name of mite species
1	*Amblyseius orientalis* Ehara,1959
2	*Amblyseius herbicolus* Chant,1959
3	*Neoseiulus cucumeris* (Oudemans, 1930)
4	*Neoseiulus indicus* (Narayanan & Kaur, 1960)
5	*Neoseiulus fraterculus* Gupta, 1986
6	*Typhlodromus (Typhlodromus) occidentalis* (Davis, 1970)
7	*Typhlodromus (Typhlodromus) pyri* Scheuten, 1857
8	*Typhlodromus (Amblydromella) fleschneri* Chant, 1960
9	*Typhlodromips tetranychivorus* Gupta, 1978
10	*Paraphytoseius scleroticus* (Gupta & Ray, 1981)
11	*Paraphytoseius nicobarensis* (Gupta, 1977)
12	*Phytoseius rachelae* Swirski and Shechter, 1961
13	*Phytoseius kapuri* Gupta,1969
14	*Platysiella mumai* Ray and Gupta,1981
15	*Asca evansi* Genis, Loots & Ryke, 1969
16	*Lasioseius parberlesei* Bhattacharyya, 1968
17	*Arctoseius magnanalis* Evans, 1958
18	*Arctoseius pristinus* Karg, 1962
19	*Bdella maldahensis* Gupta, 1992
20	*Cunaxa myabunderensis* Gupta & Ghosh, 1980.
21	*Cunaxa reticulatus* Bashir MH, Afzal M, Ali S,2005
22	*Cunaxoides nicobarensis* Gupta & Ghosh 1980
23	*Tydeus caudatus* (Duges,1834) Sensu Baker,1970
24	*Tydeus kenyensis* Baker, 1970
25	*Lorryia formosa* Cooreman,1958
26	*Lorryia stricta* Gupta, 1991
27	*Pronematus ubiquitus* McGregor, 1932
28	*Pronematus fleschneri* Baker, 1968
29	*Agistemus floridanus* Gonzalez, 1965
30	*Agistemus industani* Gonzalez,1965

31	*Agistemus exsertus* Gonzalez- Rodriguez, 1963
32	*Eupodes indentatus* Olivier & Theron, 1997
33	*Suidasia nesbitti* Hughes, 1948
34	*Sphaerolophus minutus* Khot, 1965
35	*Exothorhis nadiaensis* Chatterjee and Gupta, 1994
36	*Hemicheyletia indica* Gupta, 1991
37	*Cheletomimus bakeri* Ehara, 1962
38	*Eutetranychus africanus* Tucker, 1926
39	*Oligonychus indicus* Hirst, 1923
40	*Tetranychus marianae* McGregor, 1950
41	*Brevipalpus californicus* Banks, 1904
42	*Tenuipalpus granati* Sayed, 1946
43	*Tenuipalpus punicae* Pritchard and Baker, 1958
44	*Aceria mikaniae* Nalepa, 1918
45	*Aculus cassiae* Mondal and Chakrabarti, 1981
46	*Aculus indicus* ChannaBasavanna, 1966
47	*Calacarus lantanae* Boczek & Chandrapatya ,1989
48	*Calacarus kalyaniensis* Debnath & Karmakar, 2016
49	*Diptilomiopus camerae* Mohanasundaram, 1981
50	*Eriophyes lantanae* Mohanasundaram, 1980
51	*Tegolophus calotropi* Chakrabarti and Mondal, 1979

Table 11: New records on mite species from invasive host plants

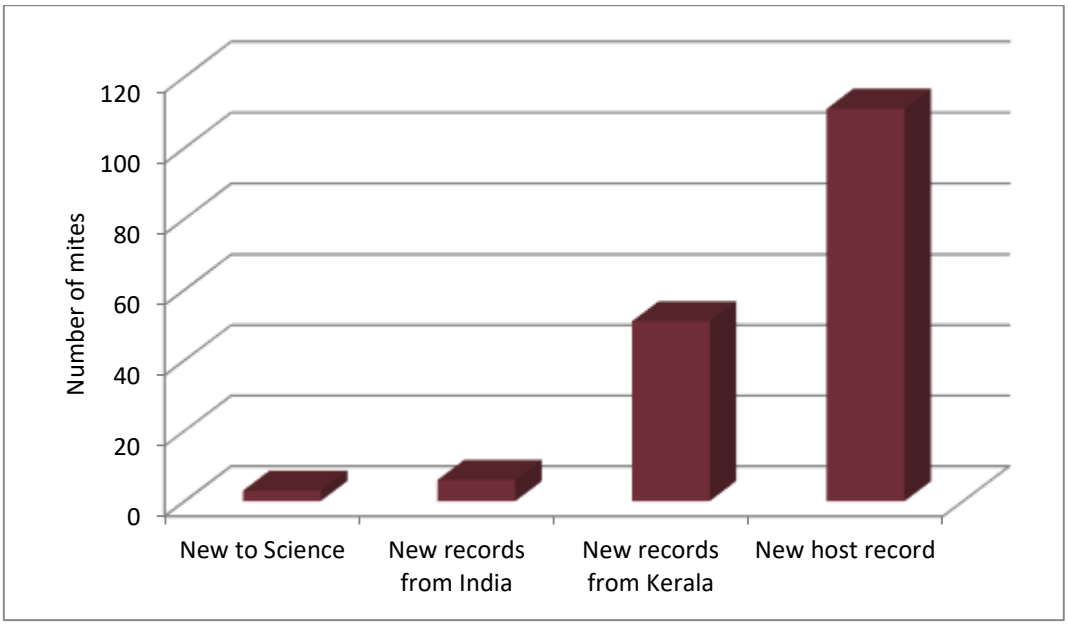
Sl. No.	Name of mite species
1	*Amblyseius largoensis* Muma,1955
2	*Amblyseius orientalis* Ehara,1959
3	*Amblyseius malabarensis* Mary Anitha and Ramani, 2004
4	*Amblyseius mohanasundarami* Anithalatha, 2005
5	*Amblyseius kundurukkae* Mary Anitha and Ramani, 2004
6	*Amblyseius bhadrakshae* Mary Anitha and Ramani, 2006
7	*Amblyseius channabasavannai* Gupta and Daniel,1978
8	*Amblyseius dioscoreae* Rahul, Mary Anithalatha and Santhosh,216

9	*Amblyseius neorykei* Gupta 1977
10	*Amblyseius muraleedharani* Gupta, 1986
11	*Amblyseius aerialis* (Muma, 1955)
12	*Amblyseius herbicolus* Chant,1959
13	*Amblyseius indirae* Gupta, 1985
14	*Amblyseius paraaerialis* Muma, 1967
15	*Amblyseius shoreae* Gupta, 1977
16	*Amblyseius adhatodae* Muma, 1967
17	*Euseius finlandicus* Oudemans, 1915
18	*Euseius macrospatulatus* Gupta, 1986
19	*Euseius sacchari* (Ghai and Menon,1967)
20	*Euseius coccosocius* (Ghai and Menon,1967)
21	*Euseius rhododendronis* (Gupta, 1970)
22	*Neoseiulus californicus* McGregor, 1954
23	*Neoseiulus cucumeris* (Oudemans, 1930)
24	*Neoseiulus fallacis* (Garman, 1948)
25	*Neoseiulus villoonniyensis* Anithalatha, 2006
26	*Neoseiulus indicus* (Narayanan & Kaur, 1960)
27	*Neoseiulus longispinosus* (Evans,1952)
28	*Neoseiulus fraterculus* Gupta, 1986
29	*Neoseiulus baraki* Athias-Henriot, 1966
30	*Typhlodromus (Typhlodromus) occidentalis* (Davis, 1970)
31	*Typhlodromus(Typhlodromus) pyri* Scheuten, 1857
32	*Typhlodromus (Anthoseius) rickeri* Chant, 1960
33	*Typhlodromus (Anthoseius) dahungensis* Pramanik and Karmakar, 2016
34	*Typhlodromus (Amblydromella) fleschneri* Chant, 1960
35	*Typhlodromips tetranychivorus* Gupta, 1978
36	*Typhlodromips syzygi* Gupta,1975
37	*Paraphytoseius multidentatus* Swirski and Shechter, 1961
38	*Paraphytoseius orientalis* Narayanan,Kaur and Ghai,1960
39	*Paraphytoseius scleroticus* (Gupta & Ray, 1981)
40	*Paraphytoseius nicobarensis* (Gupta, 1977)
41	*Phytoseius mixtus* Narayanan, Kaur & Ghai, 1960
42	*Phytoseius roseus* Gupta,1969
43	*Phytoseius rachelae* Swirski and Shechter, 1961
44	*Phytoseius kapuri* Gupta,1969

45	*Phytoseius macropilis* Banks, 1909
46	*Phytoseius huangi* Ehara, 1970
47	*Scapulaceius suknaesis* Gupta,1970
48	*Platysiella mumai* Ray and Gupta,1981
49	*Asca afrophidioides* Hurlbutt,1971
50	*Asca evansi* Genis, Loots & Ryke, 1969
51	*Lasioseius parberlesei* Bhattacharyya, 1968
52	*Arctoseius magnanalis* Evans, 1958
53	*Arctoseius pristinus* Karg, 1962
54	*Bdella maldahensis* Gupta, 1992
55	*Bdella radhikae* Sadanandan, Suresh and Ramani, 2009
56	*Cunaxa myabunderensis* Gupta & Ghosh, 1980.
57	*Cunaxa reticulatus* Bashir MH, Afzal M, Ali S,2005
58	*Cunaxa capreolus* Berlese, 1890
59	*Cunaxa setirostris* Hermann, 1804
60	*Cunaxoides nicobarensis* Gupta & Ghosh 1980
61	*Tydeus interruptus* Sig Thor,1932
62	*Tydeus caudatus* (Duges,1834) Sensu Baker,1970
63	*Tydeus kenyensis* Baker, 1970
64	*Brachytydeus incertus* Kazmierski, 2009
65	*Lorryia formosa* Cooreman,1958
66	*Lorryia stricta* Gupta, 1991
67	*Pronematus elongatus* Baker, 1968
68	*Pronematus Pronematus rykei* (Meyer and Rodrigues, 1966)
69	*Pronematus ubiquitus* McGregor, 1932
70	*Pronematus fleschneri* Baker, 1968
71	*Pronematus sextoni* Baker, 1968
72	*Agistemus aimogastensis* Leiva et al.,2013
73	*Agistemus floridanus* Gonzalez, 1965
74	*Agistemus industani* Gonzalez,1965
75	*Agistemus gamblei* Gupta,1991
76	*Agistemusfleschneri* Summers, 1960
77	*Agistemus exsertus* Gonzalez- Rodriguez, 1963
78	*Eupodes indentatus* Olivier & Theron, 1997
79	*Eupodes parafusifer* Meyer & Ryke, 1960
80	*Suidasia nesbitti* Hughes, 1948
81	*Sphaerolophus minutus* Khot, 1965

82	*Exothorhis nadiaensis* Chatterjee and Gupta, 1994
83	*Cheyletus eruditus* Schrank, 1781
84	*Cheyletus malaccensis* Oudemans, 1903
85	*Hemicheyletia indica* Gupta, 1991
86	*Cheletomimus bakeri* Ehara, 1962
87	*Polyphagotarsonemus latus* Banks,1904
88	*Bryobia ehari* Pritchard and keifer, 1958
89	*Eutetranychus orientalis* Klein,1936
90	*Eutetranychus africanus* Tucker, 1926
91	*Oligonychus biharensis* Hirst,1924
92	*Oligonychus coffeae* Nietner, 1861
93	*Oligonychus indicus* Hirst, 1923
94	*Schizotetranychus lespedezae* Beglyarov and Mitrofanov, 1973
95	*Tetranychus urticae* C.L. Koch, 1836
96	*Tetranychus neocaledonicus* André, 1933
97	*Tetranychus marianae* McGregor, 1950
98	*Tetranychus ludeni* Zacher, 1913
99	*Tetranychus macfarlanei* Baker and Pritchard, 1960
100	*Brevipalpus phoenicis* Geijskes,1936
101	*Brevipalpus obovatus* Donnadieu, 1875
102	*Brevipalpus californicus* Banks, 1904
103	*Raoiella macfarlanei* Pritchard and Baker, 1958
104	*Tenuipalpus granati* Sayed, 1946
105	*Tenuipalpus punicae* Pritchard and Baker, 1958
106	*Calacarus carinatus* Green, 1890
107	*Uracrobates (Uracrobates) indicus* Ramani and Haq, 1990
108	*Lamellobates (Paralamellobates) misella* Berlese, 1910
109	*Allonothrus russeolus russeolus* Wallwork, 1960
110	*Zetorchella sejugata* Ramani and Haq, 1997
111	*Tyrophagus putrescentiae* Shrank, 1781

Fig. 12: New records of mite species



II) HABITAT PREFERENCE AND DISTRIBUTION PATTERN OF MITE FAUNA ASSOCIATED WITH INVASIVE PLANTS:

Microscopic examination of leaf samples collected from the invasive plants growing in various geographical localities revealed the presence of a total of 124 species of mites belonging to varied taxa. Most of the species showed preference to colonise the middle aged leaves, where they were found confined to the abaxial surface of host leaves. Depending upon the nature of the host plants such as the shrubs, trees etc. these mites showed distribution at different heights. These mites were found to co-exist with various insect groups such as thrips, aphids, coccinellids, mealy bugs and very rarely white flies. Larval forms of thrips were more common in the collections and they were found feeding on the different life stages of the mites. The nature of association of individual mite species with its respective host plants showed variation depending up on its feeding habits and breeding attributes. Accordingly, the various species of mites included in the study could be assigned to different feeding groups such as predators, phytophagous forms,

wandering forms, pests, injurious forms, parasitic forms, saprophages, fungivores, unspecialized feeders, and also species with diverse feeding trends.

The species collected under the order Mesostigmata, especially members of families like Phytoseiidae, Ascidae and Blattisociidae showed a preference to the middle aged leaves of respective host plants and showed fast running habit. These mites preferred to occupy the lower laminar surface of host plants where sufficient number of prey mites were also available. All the life stages including the eggs and nymphal stages were seen scattered on the abaxial leaf surface of respective host plants along with the adult stages, especially when their population density was high. The presence of these mites was mostly observed in association with the members of the same group or with members of other mites such as pest mites or insect pests like the aphids, scale insects etc. These mites were found actively wandering on the lower surface of host leaves, in search of prey and while searching for prey, these mites often visited the upper leaf surface also. Several species of phytoseiids were found actively feeding on the different life stages of phytophagous mites belonging to families Tetranychidae, Eriophyidae, Tenuipalpidae etc. On the terrestrial weed *C.odorata*, the mesostigmatid mites were found to exist in high populations, on the foliar surface, especially close proximity to the erineal patches, induced by the eriophyid mite, *A. adoratus.*

Mites belonging to various families of the order Trombidiformes such as Bdellidae, Tydeidae, Stigmaeidae, Eupodidae, Suidasiidae, Cheyletidae, Cunaxidae, Eupalopsellidae and Erythraeidae were also found actively wandering on the lower leaf surface of host leaves, showing preference to the middle aged leaves. Though these mites were found to wander on the foliar surface in search of prey, they were not fast runners as the Mesostigmatid members and their presence could be recorded usually in

association with phytophagous mites and insects. These mites also could be recognized as excellent predators of phytophagous mites. The species belonging to Prostigmatid families like Tetranychidae, Tenuipalpidae, Tarsonemidae and Eriophyidae showed a very close association with leaf lamina of their respective host plants, with particular preference to the abaxial surface. The above taxa of mites though exhibited a general preference to the middle aged leaves, during heavy infestation their presence could be observed on all age groups of leaves, without any special preference. These mites were seen confined to regions adjacent to the midrib and other veins/veinlets. Of these, the most dominant phytophagous group identified during the study was the members of Tetranychidae, under which 13 species were collected under the genera *viz. Tetranychus, Bryobia, Eutetranychus, Oligonychus* and *Schizotetranychus.* These tetranychid mites were found sucking the leaf sap and their feeding activity induced varying damage symptoms like chlorosis, white colouration, yellowing, brown colouration etc. Tetranychid species were observed to build up high populations to form varying number of colonies on the abaxial leaf surface. The population density of these mites was exceedingly high along the mid rib and veins and often these mites assumed peak populations, especially during summer months. When their number got multiplied to assume high populations, these mites exhibited a tendency to crawl upon to the upper leaf surface also where they established successful colonies. Each colony of these mites was found to comprise all life stages such as the eggs, larvae, nymphal stages, quiescent stages etc. along with scattered moulting skins and faecal pellets. The various life instars in each of the colony of these mites were found protected over by silken strands woven by the female members of the colony. Other phytophagous mites collected during the study were members of families like Eriophyidae and Tydeidae, each represented by 11 species. Eriophyid mites were found to enjoy an exclusively phytophagous habit and they were proved to be highly

host specific also. These mites were found to infest all age groups of leaves of respective host plants where they disclosed a very high preference to occupy the lower surface, closely adhered to the leaf veins and midrib and were found sucking out the leaf sap and laid a good number of eggs also. The population density of eriophyids appeared very high and all life stages of the 11 species could be observed on respective host plants. The eggs and early life stages of eriophyid mites displayed very close association with the midrib, veins, cracks and crevices of host leaves. In several instances, the eriophyid mites were found to serve as prey for other fast running and wandering forms of predatory mites.

During the present study, the order Sarcoptiformes was found solely represented by members of the suborder oribatida and these mites showed a preference to occupy the abaxial surface of host plant leaves. However, quite often, their presence was recorded on the adaxial leaf surface also, especially in the case of species like *L. (P.) misella*. Life stages of various species of Sarcoptiformes mites also could be recovered from the leaves of respective host plants, along with the adults. Most of the species showed their distribution on the older leaves while some other species showed a tendancy to occupy the middle aged leaves. Many species of oribatid and astigmatid mites were found confined to the lower laminar surface where accumulation of dust particles was very common. Most of the sarcoptiformes mites were found to enjoy saprophagous feeding mode while some others showed mycophagous habit too. In no instance, these mites exhibited any predatory tendency upon other groups of mites.

III. Systematic account and description of 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: *A. adhatodae* Muma, 1967

2: *A. bhadrakshae* Mary Anitha and Ramani, 2006

3: *A. largoensis* (Muma, 1955)

4: *A. orientalis* Ehara,1959

5: *A. channabasavannai* Gupta and Daniel, 1978

6: *A. shoreae* Gupta, 1977

7: *Amblyseius neorykei* Gupta 1977

8: *A. paraaerialis* Muma, 1967

9: *A. malabarensis* Anithalatha and Ramani, 2004

10: *A. muraleedharani* Gupta, 1986

11: *A. indirae* Gupta, 1985

12: *A. herbicolus* Chant, 1959

13: *A. aerialis* (Muma, 1955)

14: *A. kundurukkae* Anithalatha and Ramani, 2004

15: *A. mohanasundarami* Anithalatha, 2005

16: *A. dioscoreae* Rahul, Anithalatha and Santhosh, 2016

2. Genus: *Euseius* De Leon, 1967

17: *E. finlandicus* Oudemans, 1915

18: *E. macrospatulatus* Gupta, 1986

19: *E. rhododendronis* (Gupta, 1970)

20: *E. sacchari* (Ghai and Menon, 1967)

21: *E. coccosocius* (Ghai and Menon, 1967)

Tribe: Neoseiulini Chant and Mc Murtry, 2003

3. Genus: *Neoseiulus* Hughes, 1948

22: *N. longispinosus* (Evans, 1952)

23: *N. fallacis* (Garman, 1948)

24: *N. indicus* (Narayanan and Kaur, 1960)

25: *N. cucumeris* (Oudemans, 1930)

26: *N. villoonniyensis* Anithalatha, 2006

27: *N. californicus* McGregor, 1954

28: *N. fraterculus* Gupta, 1985

29: *N. baraki* Athias-Henriot, 1966

Subfamily: Typhlodrominae

4. Genus: *Typhlodromus* Scheuten, 1857

30: *T. (Anthoseius) rickeri* Chant, 1960

31: *T. (Amblydromella) fleschneri* Chant, 1960

32: *T. (Typhlodromus) occidentalis* (Davis, 1970)

33: *T. (Typhlodromus) pyri* Scheuten, 1857

34: *T. (Anthoseius) dahungensis* Pramanik and Karmakar, 2016

Tribe: Typhlodromipsini

5. Genus: *Typhlodromips* De Leon, 1965

35: *T. syzygii* Gupta, 1975

36: *T. tetranychivorus* Gupta, 1978

Tribe: Kampimodromini Kolodochka, 1998

Subtribe: Paraphytoseiina Chant and Mc Murtry, 2003

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

37: *P. multidentatus* Swirski and Shechter,1981

38: *P. orientalis* Narayanan Kaur and Ghai, 1960

39: *P. scleroticus* (Gupta and Ray, 1981)

40: *P. nicobarensis* (Gupta, 1977)

Subfamily: Phytoseiinae Berlese, 1913

7. Genus: *Phytoseius* Ribaga, 1904

41: *P. rachelae* Swirski and Shechter habitus, 1961

42: *P. roseus* Gupta, 1969

43: *P. macropilis* Banks, 1909

44: *P. kapuri* Gupta, 1969

45: *P. mixtus* Narayanan, Kaur & Ghai, 1960

46: *P. huangi* Ehara, 1970

Tribe: Typhlodromipsini

8. Genus: *Scapulaseius* Karg and Oomen – Kalsbeek, 1987

47: *S. suknaensis* Gupta, 1970

9. Genus: *Platyseiella* Muma, 1961

48: *P. mumai* Ray and Gupta, 1981

ii) Superfamily: Ascoidea Voigts and Fauzago, 1877

b) Family: Ascidae Oudemans, 1905

10. Genus: *Asca* Von Hayden, 1826

49: *A. afroaphidiodes* Hurlbutt, 1971

50: *A. evansi* Genis, Loots and Ryke, 1969

c) Family: Blattisociidae

11. Genus: *Lasioseius* Berlese, 1916

51: *L. parberlesei* Bhattacharyya, 1968

12. Genus: *Arctoseius* Thor, 1930

52: *A. pristinus* Karg, 1962

53: *A. magnanalis* Evans, 1958

II. Superorder: Acariformes Zakhvatkin, 1952

B) Order: Trombidiformes Reuter, 1909

Suborder: Prostigmata Kramer, 1877

iii) Superfamily: Bdelloidea Duges, 1834

d) Family: Bdellidae Duges, 1834

13. Genus: *Bdella* Latreille, 1795

54: *B. maldahensis* Gupta, 1992

55: *Bdella radhikae* Sadanandan, Suresh and Ramani, 2009

e) Family: Cunaxidae Thor, 1902

14. Genus: *Cunaxa* von Heyden, 1826

56: *C. myabunderensis* Gupta and Ghosh, 1980

57: *C. setirostris* Hermann, 1804

58: *C. capreolus* Gupta and Ghosh, 1980

59: *C. reticulatus* Bashir MH, Afzal M, Ali S, 2005

15. Genus: *Cunaxoides* Baker and Hoffman, 1948

60: *C. nicobarensis* Gupta and Ghosh, 1980

iv) Superfamily: Tydeoidea Kramer, 1877

f) Family: Tydeidae Kramer, 1877

16. Genus: *Tydeus* Koch, 1836

61: *T. interruptus* Sig Thor, 1932

62: *T. caudatus* (Duges, 1834) S.Baker, 1970

63: *T. kenyensis* Baker, 1970

17. Genus: *Brachytydeus* Thor, 1931

64. *Brachytydeus incertus* Kazmierski, 2009

18. Genus: *Lorryia* Oudemans, 1925

65: *L. formosa* Cooreman, 1958

66: *L. stricta* Gupta, 1991

19. Genus: *Pronematus* Canestrini, 1886

67: *P. elongatus* Baker, 1968

68: *P. ubiquitus* McGregor, 1956

69: *P. sextoni* Baker, 1968

70: *P. fleschneri* Baker, 1968

71: *Pronematus rykei* (Meyer and Rodrigues, 1966)

v) Super family: Raphignathoidea Kramer, 1877

g) Family: Stigmaeidae Oudemans, 1931

20. Genus: *Agistemus* Summers, 1960

72: *A. gamblei* Gupta, 1991

73: *A. industani* Gonzalez-Rodriguez, 1965

74: *A. fleschneri* Summers, 1960

75: *A. exsertus* Gonzalez, 1963

76: *A. aimogastaensis* Leiva, Fernandez, Theron and Rollard, 2013

77: *A. floridanus* Gonzalez, 1965

vi) Superfamily: Eupodoidea Koch, 1842

h) Family: Eupodidae Koch, 1842

21. Genus: *Eupodes* Koch, 1836

78: *E. parafusifer* Meyer and Ryke, 1960

79: *E. indentatus* Olivier and Theron, 1997

i) Family: Suidasiidae Hughes, 1948

22. Genus: *Suidasia* Oudemans, 1905

80: *S. nesbitti* Hughes, 1948

j) Family: Erythraeidae Oudemans, 1902

23. Genus: *Sphaerolophus* Berlese, 1910

81: *S. minutus* Khot, 1965

k) Family: Eupalopsellidae Willmann, 1952

24. Genus: *Exothorhis* Summers, 1960

82: *E. nadiaensis* Chatterjee and Gupta, 1994

vii) Superfamily: Cheyletoidea Leach, 1815

l) Family: Cheyletidae Leach, 1815

25. Genus: *Cheyletus* Latereille, 1796

83: *C. eruditus* Schrank, 1781

84: *C. malaccensis* Oudemans, 1903

26. Genus: *Hemicheyletia* Volgin, 1969

85: *H. indica* Gupta, 1991

27. Genus: *Cheletomimus* Oudemans, 1940

86: *C. bakeri* Ehara, 1962

viii) Superfamily: Tarsonemoidea Canestrini and Fanzago, 1877

m) Family: Tarsonemidae Kramer, 1877

28. Genus: *Polyphagotarsonemus* Beer and Nucifora, 1965

87: *P. latus* Banks, 1904

29. Genus: *Hemitarsonemus* Ewing, 1939

88: *H. biconvexa* (Lin & Zhang, 1994)

ix) Superfamily: Tetranychoidea Donnadieu, 1876

n) Family: Tetranychidae Murray, 1877

Subfamily: Bryobinae Reck, 1950

Tribe: Bryobini Berlese, 1913

30. Genus: *Bryobia* Koch, 1836

89: *Bryobia ehari* Pritchard and keifer, 1958

Subfamily: Tetranychinae, Berlese, 1950

Tribe: Eurytetranychini Reck, 1950

31. Genus: *Eutetranychus* Banks, 1917

90: *E. orientalis* Klein, 1936

91: *E. africanus* Tucker, 1926

Tribe: Tetranychini Reck, 1950

32. Genus: *Oligonychus* Berlese, 1886

92: *O. biharensis* Hirst, 1924

93: *O. indicus* Hirst, 1923

94: *O. coffeae* Nietner, 1861

33. Genus: *Schizotetranychus* Tragardh, 1915

95: *S. lespedezae* Beglyarov and Mitrofanov, 1973

34. Genus: *Tetranychus* Dufour, 1832

96: *T. urticae* Koch, 1836

97: *T. neocaledonicus* Andre, 1933

98: *T. ludeni* Zacher, 1913

99: *T. marianae* McGregor, 1950

100: *T. macfarlanei* Baker and Pritchard, 1960

o) Family: Tenuipalpidae Berlese, 1913

35. Genus: *Brevipalpus* Donnadieu, 1875

101: *B. phoenicis* Geijskes, 1939

102: *B. obovatus* Donnadieu, 1875

103: *B. californicus* Banks, 1904

36. Genus: *Raoiella* Hirst, 1924

104: *R. macfarlanei* Pritchard and Baker, 1958

37. Genus: Tenuipalpus Donnadieu, 1875

105: *T. granati* Sayed, 1946

106: *T. punicae* Pritchard and Baker, 1958

x) Superfamily: Eriophyoidea Nalepa, 1898

p) Family: Eriophyidae Nalepa, 1898

Sub family: Eriophyinae Nalepa

38. Genus: *Acalitus* Keifer, 1965

107: *A. adoratus* Keifer, 1970

39. Genus: *Aceria* Keifer, 1944

108: *A. mikaniae* Nalepa, 1918

40. Genus: *Aculus* Keifer, 1959

109: *A. cassiae* Mondal and Chakrabarti, 1981

110: *Aculus indicus* ChannaBasavanna, 1966

41. Genus: *Calacarus* Keifer, 1940

111: *C. carinatus* Green, 1890

112: *C. lantanae* Boczek and Chandrapatya, 1989

113: *C. kalyaniensis*, Debnath, Pranab and Karmakar, Krishna, 2016

42. Genus: *Eriophyes* von Siebold, 1851

114: *E. camarae* sp.nov.

115: *E. antigonus* sp.nov.

Sub family: Phyllocoptinae Nalepa, 1891

Tribe Phyllocoptini Nalepa, 1892

43. Genus: *Phyllocoptruta* Keifer, 1938

116: *P. merremiae* sp. nov.

44. Genus: *Tegolophus* Keifer, 1961

117: *T. calotropi* Chakrabarti and Mondal, 1979

q) Family: Diptilomiopidae Keifer, 1944

Sub family: Diptilomiopinae Newkirk & Keifer, 1971

45. Genus: *Diptilomiopus* Nalepa, 1917

118: *D. camerae* Mohansundaram, 1981

C) Order: Sarcoptiformes, Reuter, 1909

Suborder: Oribatida Duges, 1833

Infraorder: Holosomata Grandjean, 1969

xi) Superfamily: Crotonioidea Thorell, 1876

r) Family: Trhypochthoniidae Willmann, 1931

46. Genus: *Allonothrus* van der Hammen, 1953

119. *A. russeolus russeolus* Wallwork, 1960.

Infraorder : Brachypylina Hull, 1918

xii) Superfamily Oribatelloidea Jacot, 1925

s) Family : Oribatellidae Jacot, 1925

47. Genus : *Lamellobates* Hammer, 1958

Lamellobates (Paralamellobates) Bhaduri and Raychaudhuri, 1968

120. *L. (P.) misella* Berlese, 1910

121. *L.* (*P.) bengalensis* Bhaduri andRaychaudhuri, 1968

xiii) Superfamily: Oripodoidea Jacot, 1925

t) Family: Mochlozetidae Grandjean, 1960

48. Genus: *Uracrobates (Uracrobates)* Balogh and Mahunka, 1967

122: *U. (U.)indicus* Ramani and Haq, 1990

u) Family: Caloppiidae Balogh, 1960

49. Genus: *Zetorchella* Berlese, 1916

123: *Z. sejugata* (Ramani and Haq, 1997)

xiv) Superfamily: Acaroidea Latreille, 1802

v) Family: Acaridae Latreille, 1802

50. Genus: *Tyrophagus* Oudemans, 1924

124: *T. putrescentiae* Schrank, 1781

III) DESCRIPTION OF SPECIES

Phylum: Arthropoda von Siebold, 1848

Subphylum: Chelicerata Heymons, 1901

Class: Arachnida Cuvier, 1812

Subclass: Acari Leach, 1817

I) Superorder: Parasitiformes Leach, 1815

A) Order: Mesostigmata G. Canestrini, 1891

i) Superfamily: Phytoseioidea Berlese, 1916

a) **Family: Phytoseiidae Berlese, 1916**

Subfamily: Amblyseiinae Muma, 1961

1) Genus: *Amblyseius* Berlese, 1914

Generic Characters: Dorsal shield smooth or sclerotised with 17 pairs of setae. Setae Z5, S4 and Z4 being long and whip-like and serrate minutely. Ventrianal shield pentagonal or vase-shaped with three pairs of preanal setae. Peritreme extends anteriorly upto j1. Leg IV with macroseta on genu, tibia and basitarsus.

1. *Amblyseius adhatodae* Muma, 1967 (Plate 5, Fig. a)

Locality: Kerala: Thambanoor, Tholpetty, Thirunelli, Peechi

Habitat: *Ageratum conizoides*

Diagnosis

Female: Dorsal shield 352-361 long, 256-264 wide. Measurements of setae: j1- 37, j3- 55, j4 -5, j5 -5, j6 -6, J2-6, J5- 7, z2- 8, z4- 7, z5- 5, Z1- 5, Z4- 117,

Z5- 253, s4- 90, S2-8, S4- 7, S5- 8, r3- 14, R1 -6. Sternal shield 65 long, 81 wide with three pairs of setae. Genital shield 83 wide with a pair of setae. Ventrianal shield 131 long and 99 wide, with three pairs of preanal setae. Metapodal plates two pairs. Fixed digit of chelicera with eight teeth and four teeth on movable digit. Macrosetae on leg IV: genu 102, tibia 75, basitarsus 92.

Male: Not found while sampling.

Materials Examined: 2♀♀ from *A. conizoides* collected on 11.02.2017 from Thiruvananthapuram Dt., 5 ♀♀ collected on 25.09.2017 from Wayanad Dt., Kerala, India. Coll. Saritha, C.

Remarks: The present specimen resembles in all morphological features with *A. adhatodae* described by Muma (1967) and hence fixed as *A. adhatodae* .This is the first report from the present host plant.

2. *Amblyseius bhadrakshae* Sadanandan and Ramani, 2006

Locality: Kerala: Kololam, Calicut University Campus

Habitat: *Antigon leptopus, Chromolaena odorata*

Diagnosis

Female: Dorsal shield 363-381 long, 281-290 wide. Measurements of setae: j1- 30, j3- 41, j4 -5, j5 -5, j6 -5, J2-6, J5- 6, z2- 8, z4- 11, z5- 5, Z1- 6, Z4- 111, Z5- 230, s4- 119, S2-8, S4- 12, S5- 11, r3- 12, R1 -8. Sternal shield 79 long, 91 wide with three pair of setae. Genital shield 91 wide with one pair of setae. Ventrianal shield 120 long and 82 wide, with three pairs of preanal setae and one pair of preanal pores. Metapodal plates two pairs. Fixed digit of chelicera with nine teeth and movable digit with three teeth. Macrosetae on leg IV: genu 102, tibia 91, basitarsus 80.

Male: Not found while sampling.

Materials Examined: 2♀♀ from *A. leptopus*, collected on 4.03.2015 from Malappuram Dt., 7♀♀ from *C. odorata* collected on 15.04.2016 from Kannur Dt., Kerala, India. Coll. Saritha, C.

Remarks: The morphological features of the present specimen appears to be similar to those of *A. bhadrakshae* described by Sadanandan and Ramani (2006) and hence it is fixed so. This is the first report from both species of host plants mentioned above.

3. *Amblyseius largoensis* (Muma, 1955) (Plate 5, Fig. b)

Locality: Kerala: Palakkad, Cherpulassery, Vagamon, Parunthumpara, Perinkunnam, Calicut University Campus, Athirampuzha

Habitat: *Chromolaena odorata*, *Lantana camara*, *Antigonon leptopus*, *Mikania micrantha*, *Shagneticola trilobata*, *Merremia vitifolia*, *Clidemia hirta*, *Cassia tora*, *Synedrella nodiflora*

Diagnosis

Female: Dorsal shield 351 -368 long, 260-283 wide. Measurements of setae: j1- 38, j3 -54, j4- 6, j5- 6, j6- 6, J2- 9, J5- 10, z2- 11, z4 -10, z5 -6, Z1 -6, Z4- 102, Z5-261, s4 -103, S2 -11, S4 -12, S5- 13, r3 -13, R1- 13. Sternal shield 75, 87 wide with three pairs of setae. Genital shield 79 long and 77 wide with one pair of setae. Ventrianal shield 113 long 70 wide ,vase-shaped, with three pairs of preanal setae and one pair of pores. Two pairs of metapodal plates present. Fixed digit of chelicera with seven teeth and two teeth on movable digit. Macrosetae on leg IV: genu 112, tibia 79, basitarsus 61.

Male: Dorsal chaetotaxy similar to that of female. Ventrianal shield with transverse striations, with three pairs of preanal setae.

Materials Examined: 5♀♀ from *C. odorata*, 2 ♀♀ from *Lantana camara*, 3 ♀♀ and 2 ♂♂from *M. vitifolia* collected on 4.11. 2016 from Malappuram Dt., 2♀♀ and 1 ♂ from *A. leptopus*, *M. micrantha*, 1♀ from *S. trilobata*, *C.tora*, *S.nodiflora* collected on 4.03.2015 and 5. 01. 2017 from Palakkad Dt., 3♀♀ from *C.hirta* collected on 11 .03.2016 from Idukki Dt., Kerala, India. Coll. Saritha, C.

Remarks: The characteristic features of the present specimen are in agreement with those given by Muma (1955) for *A. largoensis,* with the exception of some variations in the measurement of setae and hence fixed as *A. largoensis*. All species of plants except *L.camara* mentioned above are newly reported as hosts for the species.

4. *Amblyseius orientalis* Ehara, 1958 (Plate 5; Fig. e)

Locality: Kerala: Botanical Garden, Calicut University Campus, Villoonniyal, Koorkenchery

Habitat: *Antigonon leptopus*

Diagnosis

Female: Dorsal shield 341-355 long, 240-247 wide. Measurements of setae: jl-29, j3-60, s4-105, Z4 -110, Z5-259, r3 -14, Rl -14. Sternal shield 76 long and 84 wide with three pairs of sternal setae. Ventrianal shield 128 long, 86, wide with three pairs of preanal setae and one pair of preanal pores. Fixed digit of chelicera with eight teeth, movable digit with three teeth. Macrosetae on leg IV: genu-118, tibia-69, basitarsus-76.

Male: Not found while sampling.

Materials Examined: 2♀♀ from *A. leptopus* collected on 4. 03. 2017 from Malappuram Dt. and 3♀♀ collected on 12. 08.2017 from Palakkad Dt., Kerala, India. Coll. Saritha, C.

Remarks: The specimen collected from the present host plant resembles in all features with the species, *A. orientalis* described by Gupta (2003) and hence fixed it so. This is the first report from Kerala and also from the above host plant.

5. *Amblyseius channabasavannai* Gupta and Daniel, 1981

Locality: Kerala: Palakkad, Kollengode

Habitat: *Merremia vitifolia*

Diagnosis

Female: Dorsal shield 329-343 long, 240-254 wide. Measurements of setae: j1 -31, j3- 51, j4- 5, j5- 4, j6-5, J2- 6, J5 -7, z2- 11, z4 -11,z5- 4, Z1- 6, Z4 -104, Z5- 231, s4 -87, S2- 11, S4 -10, S5- 9, r3- 14, R1- 11. Sternal shield, 104 long, 81 wide, with three pairs of setae, 4th pair on metasternal plates. Genital shield 82 wide with a pair of setae. Ventrianal shield 131 long, 89 wide, with three pairs of preanal setae and one pair of preanal pores. Metapodal plates two pairs. Fixed digit of chelicera multidentate, movable digit with three teeth. Macrosetae on leg IV: genu-96, tibia-70, basitarsus-61.

Male: Not found while sampling.

Materials Examined: 3♀♀ from *M.vitifolia* collected on 14. 09. 2016 from from Palakkad Dt., Kerala, India. Coll. Saritha, C.

Remarks: The specimen examined during the present study closely resembles with the species, *A. channabasavannai*, described by Gupta and

Daniel (1981) in all respects and hence fixed it as such. The present host plant forms a new host record for the species.

6. *Amblyseius shoreae* Gupta, 1977

Locality: Calicut University Campus, Villoonniyal, Kozhikode

Habitat: *Merremia vitifolia*

Diagnosis

Female: Dorsal shield 329-345 long, 205-211 wide. Measurements of setae: j1- 25, j3- 49, j4- 6, j5- 6, j6 -7, J2- 8, J5- 8, z2-11, z4- 6, z5- 5, Z1- 9, Z4- 67, Z5- 118, s4- 64, S2- 8, S4- 8, S5 -7, r3- 16, R1- 10. Sternal shield smooth, wider than long, measuring 58 in length and 76 in width with three pairs of sternal setae, fourth pair of sternal setae inserted on small metasternal plates. Genital shield 71 wide with one pair of genital setae. Ventrianal shield pentagonal, 113 long and 85 wide, with three pairs of preanal setae and a pair of prominent preanal pores. Metapodal plates two pairs. Fixed digit of chelicera with seven teeth and movable digit with three teeth. Length of macrosetae on leg IV: genu 74, tibia 45, basitarsus 58.

Male: Not found while sampling.

Materials Examined: 2♀♀ from *M.vitifolia* collected on 24.08.2015 from Malappuram Dt., 2♀♀ on 25.04.2016 from Kozhikode Dt., Kerala, India. Coll. Saritha, C.

Remarks: Morphological details of the specimen examined during the present study are similar to those of *A. shoreae* described by Gupta (2003) and hence it is fixed so. The present host plant forms a new host record for the species.

7. Amblyseius neorykei Gupta 1977 (Plate 9, Fig. a)

Locality: Kerala: Calicut University Campus

Habitat: *Stachytarpheta jamaicensis*

Diagnosis

Female: Dorsal shield smooth, 339-357 long and 241-253 wide. Measurements of setae: j1 – 28, j3 – 44, j4-5, j5-5, j6-5, J2-6, J5-6, s4 - 93, S2 - 7, S4 - 6, S5 - 6, z2-8, z4-8, z5- 9, Z1 - 6, Z4 - 84, Z5 - 143, r3-21, R1-16. Sternal shield 55 long, 54 wide with postlateral angulation and three pairs of sternal setae. Metasternal plate with a pair of setae. Genital shield 86 wide with one pair of setae. Ventrianal shield 108 long, 76 wide with three pairs of preanal setae. Two pairs of metapodal plates present. Fixed digit of chelicerae with five teeth and movable digit with one tooth. Macrosetae present on leg IV: genu – 72, tibia – 59, basitarsus – 75.

Male: Unknown

Materials Examined: 2♀♀ from *S. jamaicensis* collected on 12.02.2018 from Malappuram Dt., Kerala, India. Coll. Saritha, C.

Remarks: This species resembles *A.neorykei* Gupta (1977) in all characters and general appearance and hence it is fixed as *Amblyseius neorykei*.This is the first report of the species from the host plant.

8. *Amblyseius paraaerialis* Muma, 1967

Locality: Kerala: Kozhikode**,** Karyavattom, Kuzhalmannam

Habitat: *Merremia vitifolia*

Diagnosis

Female: Dorsal shield 332-341 long, 246-259 wide. Measurement of setae j1 – 32, j3 – 49, j4 – 6, j5 – 3, j6 – 5, j2 – 6, z2 – 6, z4 – 6, z5 – 5, Z1 – 6, Z4 –

93, Z5 – 225, s4 – 93, S2 – 8, S4 – 6, S5 – 5. Sternal shield 75 long 77 wide with three pairs of setae, all measuring 30 long. Genital shield 88 wide with setae 32 long .Ventrianal shield 111 long and 90 wide, with three pairs of preanal seta. Metapodal plate two pairs. Fixed digit of chelicera with eight teeth, movable digit with three teeth. Macroseta on leg IV: genu –114, tibia – 59, basitarsus – 64.

Male: Not found while sampling.

Materials Examined: 3♀♀ from *M.vitifolia* collected on 22.10.2018 from Palakkad Dt., 2♀♀ on 25.04.2016 from Kozhikode Dt., Kerala, India. Coll. Saritha, C.

Remarks: The **s**pecimen examined during the present study possesses all characteristic features given by Muma (1976) for *A. paraarealis* and hence fixed so. The present host plant forms a new host record for the species.

9. *Amblyseius malabarensis* Sadanandan and Ramani, 2004

Locality: Kerala: Pulikkal, Kondotty

Habitat: *Chromolaena odorata*

Diagnosis

Female: Dorsal shield 378-384 long, 305-317 wide. Measurement of setae: j1 – 36, j3 – 50, j4 – 9, j5 – 9, j6 – 9, j2 – 9, z3 – 11, z4 – 7, z5 – 7, Z1 – 10, Z4 – 99, Z5 – 274, s4 – 91, S2 – 7, S4 – 6, S5 – 11. Sternal shield 91 long and 83 wide with three pairs of setae. Genital shield 81 wide with 1 pair of setae. Ventrianal shield 100 long and 89 wide, with three pairs of preanal setae. Metapodal plate two pairs. Fixed digit of chelicera multidendate, movable digit with three teeth. Macroseta on leg IV: genu –124, tibia – 114, basitarsus – 62.

Male: Not found while sampling.

Materials Examined: 2♀♀ from *C. odorata* collected on 13. 05. 2016 from Malappuram Dt., Kerala, India. Coll. Saritha, C.

Remarks: The features of the specimen examined during the study are similar to those of the species, *A. malabarensis* described by Sadanandan and Ramani (2004) and hence fixed so. This is the first report from the present host plant.

10. *Amblyseius muraleedharani* Gupta, 1986 (Plate 9, Fig. b)

Locality: Kerala: Calicut University Campus, Tholpetty

Habitat: *Sphagneticola trilobata*

Diagnosis

Female: Dorsal shield smooth, 399-415 long, 240-254 wide. Measurement of setae: j1 – 30, j3 – 49, j4 – 9, j5 – 9, j6 – 9, j2 – 9, z3 – 10, z4 – 7, z5 – 7, Z1 – 11, Z4 – 117, Z5 – 301, s4 – 99, S2 – 7, S4 – 6, S5 – 10. Sternal shield 78 long and 110 wide, with three pairs of sternal setae, 4th pair lie on metasternal plates. Genital shield 101 wide, with a pair of setae. Ventrianal shield 139 long, 131 wide, with three pairs of preanal setae. Two pairs of metapodal plates present. Fixed digit of chelicera multidentate, movable digit with one tooth. Macrosetae on leg IV: genu-119, tibia-92, basitarsus-69.

Male: Not found while sampling.

Materials examined: 4♀♀ from *S. trilobata* collected on 21.04.2017 from Wayanad Dt. and 2♀♀ collected on 13. 05. 2016 from Malappuram Dt., Kerala, India. Coll. Saritha, C.

Remarks: This species has almost all characters similar to those of *A. muraleedharani* described by Gupta (1986) and hence fixed so. This is the first report from the above host plant.

11. *Amblyseius indirae* Gupta, 1985 (Plate 5, Fig. d)

Locality: Kerala: Kuzhalmannam, Perinkunnam

Habitat: *Synedrella nodiflora*

Diagnosis

Female: Dorsal shield smooth, 348-362 long, 224-236 wide. Measurements of setae: jl-33, j3-34, J2-J5, s4-105, S2-6, S6-6, z2 -6, z4-6, z5-5, Z1-5, Z4 -104, Z6-230, r3-10, R1-l0 each. Sternal shield 93 long, 90 wide with three pairs of sternal setae. Genital shield 67 wide with one pair of setae. Ventrianal shield 107 long, 71 wide with three pairs of preanal setae and a pair of preanal pores. Metapodal plates two pairs. Fixed digit of chelicera with nine teeth, movable digit toothless. Macrosetae on leg IV: genu-120, tibia-99, basitarsus-76.

Male: Not found while sampling.

Materials examined: 3♀♀ from *S. nodiflora* collected on 22.06.2016 from Palakkad Dt., Kerala, India. Coll. Saritha, C.

Remarks: The specimen recovered during the present study possesses almost all characters similar to those of *A. indirae* described by Gupta (1985) and hence fixed so. This is the first report from the above host plant.

12.*Amblyseius herbicolus* Chant, 1959 (Plate 5, Fig. c)

Locality: Kerala: Kuzhalmannam, Perinkunnam, Mannuthi, Pattikkad

Habitat: *Mikania micrantha*

Diagnosis

Female: Dorsal shield 335-351 long, 233-239 wide. Measurement of setae: j1 – 26, j3 – 37, j4 – 6, j5-7, j6 – 7, j2 – 11, j5 – 6, z2 – 10, z4 – 10, z5 – 6, z1 – 12, Z4 – 141, Z5 – 220, s4 – 121, S2 – 6, S4 – 8, S5 – 11, r3 – 6, R1 – 7. Sternal shield 83 long and 91 wide with three pairs of setae. Genital shield 95 long and 77 wide with one pair of setae. Ventrianal shield 125 long, 79 wide with three pairs of preanal setae and a pair of preanal pores. Metapodal plates two pairs. Fixed digit of chelicera multidentate and movable digit with three teeth. Macrosetae on leg IV: genu-133, tibia-99 and basitarsus-71.

Male: Not found while sampling.

Materials examined: 3♀♀ from *M.micrantha* collected on 30.03.2016 from Palakkad Dt. and 2♀♀ collected on 13. 04. 2016 from Thrissur Dt., Kerala, India. Coll. Saritha, C.

Remarks: The specimen examined shows almost all characters similar to those of *A. herbicolus* described by Chant (1959) except in some variations observed in the measurements of setae, and hence fixed so. This is the first report of the species from Kerala and also from the above host plant.

13. *Amblyseius aerialis* (Muma, 1955)

Locality: Kerala: Calicut University Campus, Cheruvathur

Habitat*: Mikania micrantha*

Diagnosis

Female: Dorsal shield 361-376 long, 242-251 wide. Measurement of setae: j1-34, j3-43, j4-7, j5-5, j6- 6, z2-10, z4-6, z5-11, s4-125, J2-7, J5-5, Z1-6, Z4-151, Z5-290, S2- 110, r3- 30, R1-10. Sternal shield 80 long and 84 wide with three pairs of setae. Genital shield 80 long and 77 wide with one pair of setae.

Ventrianal shield 113 long and 73 wide with three pairs of preanal setae. Fixed digit of chelicera multidentate and movable digit with four teeth. Macrosetae on leg IV : genu-137, tibia-107 and basitarsus-76.

Male: Not found while sampling.

Materials examined: 3♀♀ from *M.micrantha* collected on 29.02.2017 from Malappuram Dt. and 2♀♀ collected on 11. 07. 2018 from Kasaragode Dt., Kerala, India. Coll. Saritha, C.

Remarks: The specimen collected during the study resembles with those described by Muma (1955) for *A. aerialis,* except in some differences in setal measurements and hence fixed so. This is the first report of the species from the above host plant.

14. *Amblyseius kundurukkae* Sadanandan and Ramani, 2004

Locality: Kerala: Calicut University Campus, Malappuram, Chaliyam

Habitat: *Chromolaena odorata*, *Mikania micrantha*

Diagnosis

Female: Dorsal shield 351-364 long, 251-269 wide. Measurements of setae: j1- 37, j3- 57, j4 -5, j5 -5, j6 -5, J2-2, J5- 6, z2- 8, z4- 7, z5- 5, Z1- 6, Z4- 97, Z5- 251, s4- 90, S2-6, S4- 7, S5- 6, r3- 10, R1 -10. Sternal shield 109 long and 81 wide with three pairs of setae. Genital shield 84 wide with a pair of setae. Ventrianal shield 109 long and 69 wide, with three pairs of preanal setae. Metapodal plates two pairs. Fixed digit of chelicera with seven teeth and movable digit toothless. Measurements of macrosetae on leg IV: genu 102, tibia 75, basitarsus 92.

Male: Not found while sampling.

Materials examined: 2♀♀ from *M.micrantha* collected on 05.10.2017 from Malappuram Dt. and 1♀ from *C. odorata* collected on 07. 01. 2018 from Kozhikode Dt., Kerala, India. Coll. Saritha, C.

Remarks: Morphological features of the present specimen resemble with those of *A. kundurukkae* erected by Sadanandan and Ramani (2004) and hence it is fixed as the same species. This is the first report of the species from both species of host plants.

15. *Amblyseius mohanasundarami* Sadanandan, 2005

Locality: Kerala: Thazhekodu, Palakkad, Yakkara, Pulikkal

Habitat: *Chromolaena odorata*, *Merremia vitifolia*

Diagnosis

Female: Dorsal shield 359- 366 long and 240- 253 wide. Measurements of setae: j1- 32, j3- 46, j4 -5, j5 -4, j6 -5, z2- 8, z4- 7, z5- 5, Z1- 6, Z4- 91, Z5- 251, s4- 98, S2-6, S4- 7, S5- 6, r3- 10, R1 -10. Sternal shield 81 long, 96 wide with three pairs of setae, 4th pair placed on the metasternal plates. Genital shield 133 wide, with a pair of setae. Ventrianal shield 101 long and 72 wide, with three pairs of preanal setae. Metapodal plates two pairs. Fixed digit of chelicera multidendate and movable digit toothless. Macrosetae on leg IV: genu 149, tibia 95, basitarsus 62.

Male: Not found while sampling.

Materials examined: 2♀♀ from *C. odorata* collected on 19.05.2015 from Malappuram Dt. and 2♀♀ from *M. vitifolia* collected on 19. 02. 2016 from Palakkad Dt., Kerala, India. Coll. Saritha, C.

Remarks: The specimen possesses all features similar to those of *A. mohanasundarami* described by Sadanandan (2005) and hence fixed so. This is the first report from both species of host plants mentioned above.

16. *Amblyseius dioscoreae* Rahul, Sadanandan and Santhosh, 2016

Locality: Kerala: Idukki, Vagamon

Habitat: *Stachytarpheta jamaicensis*

Diagnosis

Female: Dorsal shield smooth, 369- 381long and 260-274 wide. Measurements of setae: j1- 40, j3 -62, j4- 8, j5- 7, j6- 7, J2- 9, J5- 10, z2- 10, z4 -10, z5 -8, Z - 8, Z4 - 108, Z5-292, s4 -109, S2 -10, S4 -11, S5- 11, r3 -11, R1- 12. Sternal shield 85 long and 80 wide with three pairs of setae. Genital shield 100 wide, with a pair of setae. Ventrianal shield 100 long and 70 wide withthree pairs of preanal setae and a pair of preanal pores. Metapodal plates two pairs. Fixed digit of chelicera multidendate, movable digit with four teeth. Macrosetae on leg IV: genu- 123, tibia- 95, basitarsus 60.

Male: Not found while sampling.

Materials examined: 2♀♀ from *S. jamaicensis* collected on 11 .03.2016 from Idukki Dt. Kerala, India. Coll. Saritha, C.

Remarks: The specimen examined during the current study agrees in all respects with the species, *A.dioscoreae* described by Rahul *et al*. (2016) and hence, it is fixed so. This is the first report from the present new host plant, *S. jamaicensis*

2) Genus: *Euseius* De Leon, 1967

Generic Characters: Dorsal shield with 17 pairs of setae, Z5 longest. Sternal shield longer than wide, lobate posteriorly. Peritreme extends anteriorly upto

j1. Ventrianal shield elongate, vase-shaped. Genu, tibia and basitarsus of leg IV always with macrosetae.

1. *Euseius finlandicus* Oudemans, 1915 (Plate 5, Fig. f; Plate 8, Fig. e)

Locality: Kerala: Vengeri, Kozhikode

Habitat: *Pueraria phaseoloides*

Diagnosis

Female: Dorsal shield 312-324 long, 231-239 wide. Measurement of setae: j1-29, j3-23, j4-9, j5-8, j6-9, z2-15, z4-15, z5-12, s4-27, J2-13, Z1-15, S2-19, S4-20, S5-29, Z4-17, Z5-54, J5-6. Sternal shield 75 long and 66 wide with three pair of sternal setae. Genital shield 77 long and 86 wide, with one pair of setae. Ventrianal shield 92 long and 73 wide with three pairs of preanal setae. Chelicera with two teeth on fixed digit and movable digit with onetooth. Macrosetae on leg IV: genu-42, tibia-30 and basitarsus-53.

Male: Not found while sampling.

Materials examined: 4♀♀ from *P. phaseoloides* collected on 12.09.2017 from Kozhikode Dt. Kerala, India. Coll. Saritha, C.

Remarks: The morphological characters, dimensions of body shields and measurements of dorsal setae of the specimen examined currently are similar to those described by Oudemans (1915) for *E. finlandicus* and hence fixed so. This is the first report from Kerala and also from the above host plant.

2. *Euseius macrospatulatus* Gupta, 1986

Locality: Kerala: Ramanattukara, Kozhikode, Mararikulam, Kizhakkekotta

Habitat: *Alternanthera betzickiana*

Diagnosis

Female: Dorsal shield 319-324 long, 279-287 wide. Measurements of setae: j1 -49, j4-7, j5-8, j6-l0, J2-14, J5-5, j3-11, z2-12, z4-15, s4-27, Z1-14, S2-15, S4 -17, S5-16, Z5-66, z5-8, Z4- 15, r3-12, R1 -12. Peritremes extend upto the level between j3 and z2. Sternal shield with three pairs of sternal setae. Genital shield with 1 pair of genital setae. Ventrianal shield 121 long, 99 wide, with three pairs of preanal setae. Chelicera small and thick, fixed digit with four small teeth, movable digit with one tooth. Macrosetae on leg IV: genu-44, tibia-42, basitarsus-67, all with spatulate tip.

Male: Not found while sampling.

Materials examined: 2♀♀ from *A. betzickiana* collected on 11.12.2018 from Kozhikode Dt., 3♀♀ collected on 26. 07. 2016 Alappuzha Dt., and 2♀♀ collected on 02. 12. 2017 Thiruvananthapuram Dt., Kerala, India. Coll. Saritha, C.

Remarks: The morphological characters of the present specimen are similar to those of *E. macrospatulatus* described by Gupta (1986) and hence fixed so. This is the first report from the above host plant.

3. *Euseius rhododendronis* (Gupta, 1970)

Locality: Kerala: Villoonniyal, Calicut University Campus

Habitat: *Lantana camara*

Diagnosis

Female: Dorsal shield 317-324 long and 221- 234 wide, body reticulated laterally and with 17 pairs of dorsal setae, all setae small except jl and Z5 which appear longer and thicker. Measurements of setae: jl-26, j4-6, j5-6, j6-9, J2-10, J5-4, j3-16, z2-11, z4-12, s4-22, Z1-7, S2-11, S4-16, S5-10, Z5-57,

z5-5, Z4-10, Rl -8.Sternal shield as long as broad, with three pairs of setae. Genital shield 81 wide. Ventrianal shield 95 long and 74 wide with three pairs of preanal setae. Chelicera with two teeth on fixed digit and a toothless movable digit. Macrosetae on leg IV: genu-36, tibia-26, basitarsus- 42.

Male: Not found while sampling.

Materials examined: 2♀♀ from *L. camara* collected on 22.12.2016 from Malappuram Dt., Kerala, India. Coll. Saritha, C.

Remarks: The characters of the specimen examined during the present study resemble with those of *E. rhododendronis,* described by Gupta (1970) and hence fixed as such. This is the first report from the present host plant.

4. *Euseius sacchari* (Ghai and Menon, 1967)

Locality: Kerala: Puthuppally, Palakkad, Kollengode, Olavattur

Habitat: *Chromolaena odorata*

Diagnosis

Female: Dorsal shield 348-356 long, 236-240 wide. Measurements of setae: j_1-35, j_4-5, j_5-9, j_6-10, J_2-10, J_5-5, j_3-9, z_2-8, z_4-8, s_4-16, Z_I-12, S_2-14, S_4-18, S_5-17, Z_5-47, z_5-7, Z_4-11, r_3-8, R_1-8 on lateral integument. Sternal shield 68 long and 77 wide with three pairs of sternal setae. Genital shield 94 wide, with one pair of setae. Ventrianal shield 102 long and 73 wide, with three pairs of preanal setae and a pair of crescent-shaped preanal pores. Chelicera with two teeth on the fixed digit and without any tooth on the movable digit. Macrosetae on leg IV: genu- 30, tibia -32, basitarsus-48.

Male: Not found while sampling.

Materials examined: 5♀♀ from *C. odorata* collected on 04.11.2018 from Palakkad Dt., 3♀♀ from Malappuram Dt., and 2♀♀ from Kottayam Dt., Kerala, India. Coll. Saritha, C.

Remarks: The specimen examined during the study possesses characters similar to those of *E. sacchari* described by Ghai and Menon (1967) and hence fixed as such. This is the first report of the species from the present host plant.

5. *Euseius coccosocius* (Ghai and Menon, 1967)

Locality: Kerala: Perinkunnam, Vagamon, Aluva

Habitat: *Lantana camara*

Diagnosis

Female: Dorsal shield reticulate, 335-346 long, 214-221 wide. Measurements of setae: j_1-35, *j_4:-8,* j_5-9, *j_6-11,* j*2*-11, J_5-7, j_3-24, z_2-14, z_4-19, S_4-27, Z_1-13, S_2-17, S_4-18, S_5-25, Z_5-58, r_3 -14, R_1 -14 on lateral integument. Sternal shield 75 long and 63 wide with three pairs of sternal setae. Genital shield 83 wide with a pair of genital setae. Ventrianal shield 93 long and 85 wide, with three pairs of preanal setae and a pair of preanal pores. A single pair of metapodal plates. Chelicera with three teeth on the fixed digit and one small tooth on the movable digit. Macrosetae on leg IV: genu-40, tibia-33, basitarsus-46.

Male: Not found while sampling.

Materials examined: 2♀♀ from *L.camara* collected on 02.12.2016 from Palakkad Dt., 1♀ collected on 11 .03.2016 from Idukki Dt., and 2♀♀ collected on 14.12. 2016 from Ernakulam Dt., Kerala, India. Coll. Saritha, C.

Remarks: The specimen examined during the study shows resemblance with *E. coccosocius* described by Ghai and Menon (1967) in all features, with the

exception of some differences observed in the measurement of setae and hence fixed it as such. This is the first report from the present host plant.

3) Genus: *Neoseiulus* Hughes, 1948

Generic Characters: Dorsal shield sclerotized, smooth or reticulate, with 17 pairs of setae. Peritreme extends anteriorly upto j1. Ventrianal shield elongate, pentagonal with three pairs of preanal setae. Leg IV with macroseta.

1. *Neoseiulus longispinosus* (Evans, 1952) (Plate 5, Fig. J)

Locality: Kerala: Palakkad, Ramanattukara, Calicut University Campus, Karyavattom, Ambalavayal

Habitat: *Synedrella nodiflora, Merremia vitifolia*

Diagnosis

Female: Dorsal shield 326- 341 long, 177-184 wide at the point of S2; dorsal setae very long except j1, J5 and S5, which are shorter. Measurement of setae : j1 – 15, j3 – 54, j4 – 60, j5 – 72, j6 – 72, J2 - 76, J5 – 8, z2 – 70, z4 – 76, z5 – 40, Z1 – 73, Z4 – 75, Z5 – 87, s4 – 81, S2 – 80, S4 – 58, S5 – 17, r3 – 60, R1 – 66. Sternal shield 54 long and 67 wide with three pairs of setae. Genital shield 68 wide, with one pair of setae. Ventrianal shield 104 long and 89 wide, reticulated with three pairs of preanal setae and a pair of preanal pores. Chelicera with three teeth on fixed digit and two sharp teeth on movable digit. Macroseta on leg IV: basitarsus-76.

Male: Chaetotaxy of male is similar to that of the female, macrosetae on leg IV: 59.

Materials examined: 2♀♀ and 1♂ from *S. nodiflora* collected on 12. 04. 2015 from Palakkad Dt., 2♀♀ collected on 02. 12. 2017 from Thiruvananthapuram Dt., 2♀♀ and 2 ♂♂from *M. vitifolia* collected on 02.

05. 2017 from Kozhikode Dt., 2♀♀ from Malappuram Dt., Kerala, India. Coll. Saritha, C.

Remarks: The present specimen shows morphological identity except in some variations in the measurements with *N. longispinosus* described by Evans (1952) and hence fixed so. This species is reported for the first time from the two species of host plants mentioned above.

2. *Neoseiulus fallacis* (Garman, 1948) (Plate 8, Fig. g)

Locality: Kerala: Kuzhalmannam, Perinkunnam

Habitat: *Lantana camara*

Diagnosis

Female: Dorsal shield 370-381 long, 156-169 wide. Measurements of setae: jl-19, j4.-39, j5-40, j6-40, J2-46, J5-11, j3-42, z2-38, z4-38, s4. -47, Z1 -54, S2-51, S4 -52, S5-47, Z5-79, z5-29, Z4-69, rs-40, R1-40. Sternal shield smooth with three pairs of setae. Genital shield 73 wide, with a pair of setae. Ventrianal shield pentagonal in shape, 126 long and 117 wide, with three pairs of preanal setae and a pair of preanal pores. Metapodal plates two pairs. Fixed digit of chelicera multidentate and movable digit with one tooth. Macrosetae on leg IV: genu-29, tibia-38, basitarsus-59.

Male: Not found while sampling.

Materials examined: 3♀♀ from *L.camara* collected on 26.10.2015 from Palakkad Dt., Kerala, India. Coll. Saritha, C.

Remarks: The examined specimen agrees with *N. fallacis*, described by Garman (1948) in all features except in setal measurements. Hence the species was fixed so. This is the first report from Kerala and also from the above host plant.

3. *Neoseiulus indicus* (Narayanan and Kaur, 1960)

Locality: Kerala: Kuzhalmannam, Perinkunnam, Parunthumpara

Habitat: *Merremia vitifolia*

Diagnosis

Female: Dorsal shield 332-341 long, 166-178 wide. Measurements of setae: j1-16, j3-21, j4-14, j5-14, j6-19, J2-20, J5-10, z2-19, z4-19, S4-23, Z1-17, S2-24, S4-23, S5-20, Z5-56, z5-18, Z4-41, r3-17, Rl -17. Sternal shield 91 long, 86 wide, with 3 pairs of sternal setae. Genital shield 79 wide with one pair of setae. Ventrianal shield 122 long, 104 wide, with three pairs of setae and one pair of preanal pores. Chelicerae with three teeth on the fixed digit and movable digit with one tooth. Macroseta present only on basitarsus IV -56 long.

Male: Not found while sampling.

Materials examined: 2♀♀ from *M. vitifolia* collected on 21.02.2016 from Palakkad Dt., and 2♀♀ collected on 12 .03.2016 from Idukki Dt., Kerala, India. Coll. Saritha, C.

Remarks: The specimen examined during the study show morphological resemblance with *N. indicus* described by Narayanan and Kaur (1960), except in some variations in setal length and hence it was fixed as the above species. This is the first report from the present host plant.

4. *Neoseiulus cucumeris* (Oudemans, 1930) (Plate 8, Fig. f)

Locality: Kerala: Yakkara, Perinkunnam, Kovoor

Habitat: *Lantana camara*

Diagnosis

Female: Dorsal shield 376- 390 long, 203-209 wide. Measurements of setae: j1-23, j3-31, j5-15, j6-21, J2-24, J5-11, z2-29, z4-28, s4-41, Z1-29, S2-38, S5-35, Z5-76, z5-18, Rl -31. Sternal shield 87 long, 79 wide, with three pairs of sternal setae. Genital shield 68 wide with one pair of setae. Ventrianal shield 126 long, 109 wide, with three pairs of setae and one pair of preanal pores. Chelicerae with two teeth on the fixed digit and movable digit without any tooth. Macroseta present only on basitarsus IV -49 long.

Male: Not found while sampling.

Materials examined: 4♀♀ from *L.camara* collected on 24.01.2016 from Palakkad Dt., and 2♀♀ collected on 12 .10.2018 from Kozhikode Dt., Kerala, India. Coll. Saritha, C.

Remarks: The present specimen resembles *N. cucumeris* described by Oudemans (1930) in morphological characters, except in the length of some setae and hence its species status was fixed so. This is the first report from Kerala and from the above host plant.

5. *Neoseiulus villoonniyensis* Anithalatha, 2006 (Plate 5, Fig. g)

Locality: Kerala: Kozhikode, Calicut University Campus

Habitat: *Merremia vitifolia*

Diagnosis

Female: Dorsal shield 329-334 long, 207-216 wide. Measurement of setae : j1 – 9, j3 – 57, j4 – 60, j5 – 71, j6 – 80, J2 - 79, J5 – 9, z2 – 75, z4 – 75, z5 – 44, Z1 – 71, Z4 – 73, Z5 – 77, s4 – 81, S2 – 53, S4 – 80, S5 – 13, r3 – 64, R1 – 64. Sternal shield 71 long and 69 wide, with three pairs of setae. Genital shield 97 long and 63 wide, with one pair of setae. Ventrianal shield 111 long

and 80 wide, with three pairs of preanal setae and a pair of preanal pores. Two pairs of metapodal plates present. Chelicera with three teeth on the fixed digit and a single tooth on the movable digit. Macrosetae on leg IV: basitarsus-78 long.

Male: Not found while sampling.

Materials examined: 3♀♀ from *M.vitifolia* collected on 14.04.2017 from Kozhikode Dt., and 2♀♀ collected on 11 .08.2017 from Malappuram Dt., Kerala, India. Coll. Saritha, C.

Remarks: The present specimen shows morphological identity, except in lengths of some setae, with *N. villoonniyensis* described by Anithalatha (2006). Hence its species status was fixed as such. This is the first report from the above host plant.

6. *Neoseiulus californicus* McGregor, 1954 (Plate 8, Fig. a)

Locality: Kerala: Kuzhalmannam, Perinkunnam, Chithali

Habitat: *Lantana camara*

Diagnosis

Female: Dorsal shield 366- 379 long, 153-165 wide. Measurement of setae : j1 – 21, j3 – 29, j4 – 23, j5 – 21, j6 – 25, J2 - 33, J5 – 12, z2 – 27, z4 – 26, z5 – 22, Z1 – 31, Z4 – 50, Z5 – 67, s4 – 36, S2 – 40, S4 – 40, S5 – 33, r3 – 24, R1 – 24. Sternal shield subequal in length, with three pairs of setae. Genital shield 120 long and 71 wide with one pair of setae. Ventrianal shield 122 long and 98 wide, with three pairs of preanal setae and a pair of preanal pores. Two pairs of metapodal plates present. Chelicera with five teeth on the fixed digit and movable digit with three teeth. Macroseta on leg IV: basitarsus-49 long.

Male: Not found while sampling.

Materials examined: 4♀♀ from *L.camara* collected on 29.04.2016 from Palakkad Dt., Kerala, India. Coll. Saritha, C.

Remarks: Based on its morphological similarity with *N. californicus* described by McGregor (1954), the present specimen was assigned to the above species. This is the first report from the above host plant.

7. *Neoseiulus fraterculus* Gupta, 1985

Locality: Kerala: Tholpetty

Habitat: *Lantana camara*

Diagnosis

Female: Dorsal shield 277- 289 long, 185-190 wide. Some setae are very small. Measurement of setae: j4 - 18, j6 -19, J2-6, J5-6, z4-37, z2-31, *Z5-58, Z4-51,* s4-46, Zl- 42, S2- 42, S4-52, S5-52. Sternal shield with three pairs of sternal setae, 4th pair on metasternal plate. Genital shield narrower than wide with a pair of setae. Ventrianal shield almost as long as broad, with three pairs of preanal setae and a pair of preanal pores. Metapodal plates one pair. Macrosetae on leg IV: genu-27, tibia-39, basitarsus-51.

Male: Unknown.

Materials examined: 3♀♀ from *L.camara* collected on 19.08.2017 from Wayanad Dt., Kerala, India. Coll. Saritha, C.

Remarks: The specimen currently examined was given the status of the species, *N. fraterculus.* Described by Gupta (1985), based on its morphological similarities except in slight variations in setal length. This is the first report from Kerala and from the above host plant.

8. *Neoseiulus baraki* Athias-Henriot, 1966 (Plate 8, Fig. 8)

Locality: Kerala: Vengeri, Kozhikode

Habitat: *Pueraria phaseoloides*

Diagnosis

Female: Dorsal shield sclerotized, 368-375 long and 162-173 wide, Measurements of setae: j1-15, j3 16 j4-10, j5-12, j6-13, J2 -13, J5-11, z2-12, z4-14, z5-10, S4: -12-16, Z1-12, Z4-24, Z5-74, S2-14, S4 -25, S5-26, r3-15, Rl -14. Sternal shield slightly reticulated, 89 long and 60 wide with three pairs of sternal setae, 4th pair of setae lie on triangular metasternal plates. Genital shield 64-74 wide, narrower than the greatest width of ven trianal shield with a pair of setae. Ventrianal shield reticulate, 115-long, 96 wide, with three pairs of preanal setae and a pair of preanal pores. Two pairs of metapodal plates present. Chelicerae with 10 teeth on the fixed digit and movable digit with two teeth. Macroseta present only on basitarsus IV -43 long.

Male: Not found while sampling.

Materials examined: 3♀♀ from *P. phaseoloides* collected on 29.03.2017 from Kozhikode Dt., Kerala, India. Coll. Saritha, C.

Remarks: Based on the similarities shown by the present specimen in the morphology, excepting some setal lengths, its identity was fixed as *N. baraki* described by Athias-Henriot (1966). This is the first report from the host plant.

4) Genus: *Typhlodromus* Scheuten, 1857

Generic characters: Dorsal shield entire with 16-20 pairs of setae, short or long, smooth or serrate. Ventrianal shield with 1-4 pairs of preanal setae. Spermatheca well developed. Peritreme

extends anteriorly upto jl.

1. Typhlodromus (Anthoseius) rickeri **Chant, 1960**

Locality: Kerala: Vagamon, Parunthumpara, Pulikkal, Villoonniyal

Habitat: *Lantana camara, Chromolaena odorata*

Diagnosis

Female: Dorsal shield 296-311 long, 155-162 wide. Measurements of setae: jl- 27, j4 -22, j5-36, j6-47, J 2-63, J5-7, z2-67, z3-18, z4-25, s4-78, s6-85, S2-85, S4-49, S5-27, Z5-104, z5-16, Z4-78, r3-31, Rl -27.Sternal shield 111 long and 63 wide with three pairs of sternal setae. Genital shield 79 wide, with a pair of setae. Ventrianal shield 134 long, 89 wide with three pairs of preanal setae and a pair of preanal pores. Matapodal plates two pairs. Fixed and movable digits of chelicera with two teeth each. Macrosetae on leg IV: genu-45, tibia-49, basitarsus-54.

Male: Not found while sampling.

Materials examined: 2♀♀ from *L. camara* and *C.odorata* collected on 26. 04. 2016 from Idukki Dt. and 4♀♀ from *C.odorata* collected on 22. 03. 2015 from Malappuram Dt., Kerala, India. Coll. Saritha, C.

Remarks: The morphological characters, dimensions of body shields and measurements of dorsal setae of the specimen examined presently agree with those of *T. (Anthoseius) rickeri* described by Chant (1960) and hence its species status was fixed so. This is the first report of the species from both species of host plants mentioned above.

2. ***Typhlodromus (Amblydromella) fleschneri*** **Chant, 1960**

Locality: Kerala: Calicut University Campus, Alathur, Koduvayur

Habitat: *Desmodium tortuosum*

Diagnosis

Female: Dorsal shield elongate, 350-364 long and 178-189 wide. Measurements of setae: j1-13, j3-21, j4,-16, j5 - 17, j6-l8, J2-22, J5-9, z2-22, z3-22, z4 -22, s4 -24, s6-24, S2-24, S4 -24, S5-17, z5-18, Z5-49, Z4 -32, r3-14, Rl -24. Seta Z5 serrate and knobbed at the tip. Sternal shield 131 long and 86 wide with three pairs of sternal setae. Genital shield 90 wide with a pair of setae. Ventrianal shield 119 long and 83 wide with four pairs of preanal setae and a pair of preanal pores. Metapodal plates two pairs. Macrosetae present only on basitarsus IV -51 long, knobbed.

Male: Not found while sampling.

Materials examined: 3♀♀ from *D.tortuosum* collected on 18. 03. 2018 from Malappuram Dt. and 2♀♀ collected on 12. 03. 2018 from Palakkad Dt., Kerala, India. Coll. Saritha, C.

Remarks: The present specimen resembles with *T.(Amblydromella) fleschneri* described by Chant (1960) in all morphological characters, dimensions of body shields and measurements of dorsal setae and hence its species status was fixed as such. This is the first report from Kerala and also from the present host plant.

3. *Typhlodromus (Typhlodromus) occidentalis* (Davis, 1970) (Plate 8,Fig. b)

Locality: Kerala: Thiruvambady, Puthuppally

Habitat: *Chromolaena odorata*

Diagnosis

Female: Dorsal shield 287-296 long, 157-168 wide. Measurements of setae: jl- 25, j4 -22, j5-34, j6-45, J2- 61, J5-7, z2-17, z3-72, z4-25, s4-77, s6-83, S2-83, S4-49, S5-26, Z5-101, z5-16, Z4-76, r3-30, Rl -26. Metapodal plates two

pairs, small on the ventral surface. Ventrianal setae three pairs, setae shorter. Preanal setae four pairs.

Male: Not found while sampling.

Materials examined: 2♀♀ from *C. odorata* collected on 28. 09. 2017 from Malappuram Dt. and 2♀♀ collected on 12. 03. 2018 from Palakkad Dt., Kerala, India. Coll. Saritha, C.

Remarks: The morphological characters, dimensions of body shields and measurements of dorsal setae of the present specimen are similar to those of *T. occidentalis* described by Davis (1970) and hence placed it in the above species. This is the first report from Kerala and also from the host plant.

4. *Typhlodromus (Typhlodromus) pyri* Scheuten, 1857 (Plate 8, Fig. c)

Locality: Kerala: Kololam

Habitat: *Lantana camara*

Diagnosis

Female: Dorsal shield 281-293 long and 152-165 wide. Measurements of setae: jl- 20, j4 -20, j5-24, j6-31, J2-41, J5-6, z2-11, z3-42, z4-19, z5-11, s4-42, s6-53, S2-51, S4-29, S5-21, Z5-59, Z4-46, r3-21, Rl -20. Metapodal plates two pairs, small on the ventral surface. Ventrianal setae three pairs, setae shorter. Preanal setae four pairs.

Male: Not found while sampling.

Materials examined: 3♀♀ from *C. odorata* , collected on 21. 03. 2018 from Kannur Dt., Kerala, India. Coll. Saritha, C.

Remarks: The present specimen agrees in all morphological characters, dimensions of body shields and measurements of dorsal setae with *T. pyri*

described by Scheuten (1857) and hence fixed so. This is the first report from Kerala and also from the host plant.

5. *Typhlodromus (Anthoseius) dahungensis* Pramanik and Karmakar, 2016

Locality: Kerala: Calicut University Campus

Habitat: *Merremia vitifolia*

Diagnosis

Female: Dorsal shield 276-290 long, 150-153 wide. Measurements of setae: jl- 23, j4 -20, j5-32, j6-41, J2-60, J5-7, z2-16, z3-71, z4-24, z5-11, s4-72, s6-79, S2-81, S4-43, S5-24, Z5-99, Z4-71, r3-27, Rl -25. Metapodal plates two pairs, ventrianal setae four pairs, medium sized. Preanal setae four pairs.

Male: Not found while sampling.

Materials examined: : 4♀♀ from *M. vitifolia,* collected on 11. 05. 2017 from Malappuram Dt., Kerala, India. Coll. Saritha, C.

Remarks: The present specimen well accord with the characters of ***(****Anthoseius) dahungensis* described by Pramanik and Karmakar in 2016. This is the first report from Kerala and also from the host plant.

5) Genus: *Typhlodromips* De Leon, 1965

Generic characters: Dorsal shield with 17 pairs of setae, Z5 and Z4 serrate or plumose. Sternal shield as wide as or wider than long, with straight or concave posterior margin. Peritreme extends anteriorly upto jl. Ventrianal shield pentagonal or shield-shaped. Macrosetae on Leg IV.

1. *Typhlodromips syzygii* Gupta, 1975 (Plate 8, Fig. b)

Locality: Kerala: Calicut University Campus, Malappuram, Beypore,Tholpetty

Habitat: *Merremia vitifolia, Tridax procumbens*

Diagnosis

Female: Dorsal shield 341-352 long, 225-231 wide. Measurements of setae: j1- 15, j3 -20, j4 -10, j5- 10, j6 -12, J2- 15, J5 -8, z2 -13, z4 -13, z5 -10, Z1- 13, Z4- 35, Z5- 73, s4-20, S2- 12, S4 -11, S5 -9, r3- 15, R1- 13.Sternal shield 75 long and 63wide with three pairs of sternal setae. Genital shield 76 wide, with a pair of setae. Ventrianal shield 114 long and 79 wide with three pairs of preanal setae and a pair of preanal pores. Matapodal plates two pairs. Fixed digit of chelicera with seven teeth and movable digit with three teeth. Macrosetae on leg IV: genu-50, tibia-39, basitarsus-54.

Male: Not found while sampling.

Materials examined: 6♀♀ from *M. vitifolia*, and 2♀♀ from *T. procumbens* collected on 15. 04. 2017 from Malappuram Dt., 2♀♀ from *M. vitifolia*, collected on 31. 01. 2016 from Kozhikode Dt. and from *T. procumbens*, collected on 26. 08. 2017 from Wayanad Dt., Kerala, India. Coll. Saritha, C.

Remarks: The external morphology, body shield dimensions, and measurements of dorsal setae of the present specimens greatly resemble with those of *T. syzygii* described by Gupta (1975) and hence was assigned to it. This is newly reported from both species of host plants mentioned above.

2. Typhlodromips tetranychivorus Gupta, 1978

Locality: Kerala: Tholpetty, Thrissilery

Habitat: *Chromolaena odorata, Lantana camara*

Diagnosis

Female: Dorsal shield 310-318 long, 203-206 wide. Measurements of setae: j1- 22, j3- 45, j4- 8, j5- 7, j6- 8, J2- 7, J5 -8, z2- 16, z4- 34, z5- 7, Z1-9, Z4-68, Z5- 90, s4 -73, S2- 32, S4- 9,S5- 7, r3- 25, R1- 12. Sternal shield 117 long and 69 wide with three pairs of sternal setae. Genital shield 80 wide, with a pair of setae. Ventrianal shield 112 long, 94 wide, with three pairs of preanal setae and a pair of preanal pores. Matapodal plates two pairs. Fixed digit of chelicera multidentate, movable digit with three teeth. Macrosetae on leg IV: genu-47, tibia-40, basitarsus-67.

Male: Not found while sampling.

Materials examined: 2♀♀ from *C. odorata* and 3♀♀ *L.camara* collected on 2. 04. 2017 26. 08. 2017 from Wayanad Dt., Kerala, India. Coll. Saritha, C.

Remarks: The morphological characters, dimensions of body shields and measurements of dorsal setae of the specimens examined are similar to those given by Gupta (1978). This is the first report from Kerala as well as from the above two species of host plants.

6) Genus: *Paraphytoseius* Swirski and Shechter, 1961

Generic characters: Dorsal shield smooth, moderately sclerotized with 14 pairs of setae. Setae jl, j3, S4, Z4, Z5, r3 and R1 long, thick and serrate. Sternal shield with three pairs of sternal setae. Ventrianal shield with three pairs of preanal setae. Leg IV with macrosetae on genu, tibia and basitarsus, mostly spatulate or knobbed.

1. *Paraphytoseius multidentatus* Swirski and Shechter,1981 (Plate 5, Fig. l)

Locality: Kerala: Vagamon, Parunthumpara, Perinkunnam, Muthuvalloor, Calicut University Campus

Habitat: *Lantana camara*, *Stachytarpeta jamaicensis*

Diagnosis

Female: Dorsal shield 288-299 long, 143-158 wide. Measurements of setae: jl- 39, j3-97, j4- 4, j6-5, J5-6, z2-8, z4-8, z5-5, Z1-6, Z4-76, Z5-102, s4- 125, r3-47, R1-24. Sternal shield with three pairs of setae. Genital shield 79 wide with a pair of setae. Ventrianal shield 89 long, 60 wide, with three pairs of preanal setae, a pair of large metapodal plates present. Fixed digit of chelicera multidentate, movable digit with two teeth. Macrosetae on leg IV: genu-29, tibia-42, basitarsus-53.

Male: Not found while sampling.

Materials examined: 3♀♀ from *L.camara*, and 2♀♀ from *S. jamaicensis*, collected on 24. 01. 2017 from Malappuram Dt., 2♀♀ from *L.camara* collected on 12. 08. 2015 from Idukki Dt., and 2♀♀ from *L.camara* collected on 21. 03. 2016 from Palakkad Dt., Kerala, India. Coll. Saritha, C.

Remarks: The morphological characters and body setae of the present specimen show great similarity with those of *P. multidentatus* described by Swirski and Shechter (1981) and hence fixed so. This is the first report from the host plant, *S. jamaicensis*.

2. *Paraphytoseius orientalis* Narayanan, Kaur and Ghai, 1960

Locality: Kerala: Lakkidi, Pookode, Botanical Garden, Calicut University

Habitat: *Lantana camara, Chromolaena odorata, Mikania micrantha, Alternanthera bettzickiana*

Diagnosis

Female: Dorsal shield 289-288 long, 166-180 wide. Measurements of setae: jl-29, j3-36, j4- 6, j6-6, J5-6, z2-6, z3-29, z4-6, s4-116, s6-74, Z5-72, Z4-70, r3-47, R1-26. Sternal shield 74 long, 80 wide with three pairs of sternal setae. Genital shield 79 wide with a pair of setae. Ventrianal shield 87 long, 42 wide, with three pairs of preanal setae and a pair of preanal pores. Fixed digit of chelicera with three teeth and movable digit with a single tooth. Macrosetae on leg IV: genu-21, tibia-59, basitarsus 28, all with spatulate tip.

Male: Not found during sampling.

Materials examined: 2♀♀ from *L.camara,* and 2♀♀ from *C. odorata,* 1♀ from *M. micrantha* collected on 15. 02. 2017 from Wayanad Dt., 2♀♀ from *A. bettzickiana* collected on 22. 10. 2016 from Malappuram Dt., Kerala, India. Coll. Saritha, C.

Remarks: The specimen collected during the present study greatly resembles *P. orientalis* described by Narayanan, Kaur and Ghai (1960) in its morphological characters and measurements of body setae and hence fixed so. This is the first report from the above mentioned host plants.

3. *Paraphytoseius scleroticus* (Gupta and Ray, 1981)

Locality: Kerala: Vettukadu

Habitat: *Stachytarpheta jamaicensis*

Diagnosis

Female: Dorsal shield reticulate, 260-275 long and 141-143 wide. Measurements of setae: j1- 30, j3-80, j4-7, j5-7, j6- 7, J5- 5, z2- 11, z4- 11,

z5- 5, Z1- 6, Z4 -70, Z5- 96, s4- 112, S5- 11, r3- 34, R1- 29.Sternal shield smooth, 69 long and 72 wide, with 3 pairs of sternal setae, 4th pair of setae lie on metasternal plates. Genital shield 72 wide, with a pair of setae. Ventrianal shield 90 long, 50 wide and with three pairs setae. Metapodal plates one pair. Fixed digit of chelicera with 10 teeth and movable digit with three teeth. Macrosetae on leg IV: genu-27, tibia-33, basitarsus-42, all with knobbed tip.

Male: Not found during sampling.

Materials examined: 2♀♀ from *S. jamaicensis* collected on 22. 11. 2016 from Malappuram Dt., Kerala, India. Coll. Saritha, C.

Remarks: The present specimen greatly resembles *P. scleroticus* described by Gupta and Ray (1981) in the general morphology, nature, number, arrangement and size of body setae and hence fixed so. This is the first report from Kerala and also from the above host plant.

4. *Paraphytoseius nicobarensis* (Gupta, 1977)

Locality: Kerala: Cherppulassery

Habitat: *Lantana camara*

Diagnosis

Female: Dorsal shield reticulate, 277-289 long and 169-181 wide. Measurements of setae: j1- 32, j3-80, j4-6, j5-6, j6- 7, J5- 5, z2- 9, z4- 8, z5- 5, Z1- 6, Z4 -62, Z5- 87, s4- 100, S5- 11, r3- 32, R1- 31.Sternal shield 67 long and 70 wide with three pairs of sternal setae, 4th pair of setae lie on metasternal plates. Genital shield 71 wide and with a pair of setae. Ventrianal shield 85 long, 56 wide, and with three pairs of setae. Metapodal plates one pair. Fixed digit of chelicera multidendate and movable digit with three teeth. Macrosetae on leg IV: genu-26, tibia-36, basitarsus-42, all with knobbed tip.

Male: Not found while sampling.

Materials examined: 2♀♀ from *L.camara* collected on 27. 12. 2015 from Palakkad Dt., Kerala, India. Coll. Saritha, C.

Remarks: Based on the similarities in the external morphology, body setal characteristics etc. of the present specimen, it was assigned to the species, *P. nicobarensis* described by Gupta (1977). This is the first report from Kerala and also from the above host plant.

7) Genus: *Phytoseius* Ribaga, 1904

Generic characters: Dorsal shield smooth, moderately sclerotized with 14 pairs of setae, S4 and S6 large and erect. Sternal shield with three pairs of sternal setae. Ventrianal shield with three pairs of preanal setae. Leg IV with macrosetae on genu.

1. *Phytoseius rachelae* Swirski and Shechter, 1961

Locality: Kerala: Thampanoor, Perinkunnam, Aluva, Pulikkal, Vettukad, Villoonniyal, Kozhikode, Ramanattukara, Iritty

Habitat: *Lantana camara, Stachytarpeta jamaicensis, Chromolaena odorata*

Diagnosis

Female: Dorsal shield 270-283 long, 141-150 wide. Measurements of setae: j1- 28, j3- 34, j4- 5, j5- 5, j6-5, J5- 5, z2- 8, z3- 20, z4- 7, z5- 5, Z4- 74, Z5 - 73, s4- 104, s6 -75, r3- 46, R1-15. Sternal shield 56 long and 73 wide with three pairs of sternal setae. Genital shield 73 wide with a pair of setae. Ventrianal shield 94 long, 44 wide, with three pairs of preanal setae. Metapodal plate single paired. Fixed digit of chelicera with two teeth, and movable digit with one tooth. Macrosetae on leg IV: genu-20, tibia-52, basitarsus-32, all with spatulate tip.

Male: Not found while sampling.

Materials examined: 5♀♀ from *L.camara* and *C. odorata* collected on 22. 12. 2015 from Malappuram Dt., 2♀♀ from *L.camara* and *S. jamaicensis* collected on 11. 11. 2016 from Kozhikode Dt., 2♀♀ from *L.camara* and *C. odorata* collected on 02. 12. 2017 from Thiruvananthapuram Dt. and 2♀♀ from *C. odorata* collected on 16. 04. 2016 from Kannur Dt., Kerala, India. Coll. Saritha, C.

Remarks: The specimen collected during the study resembles *P. rachelae* described by Swirski and Shechter (1961) in all features, such as the nature and dimensions of body shields, setal configuration, measurements of setae etc. This is the first report from Kerala and also from the host plants mentioned above.

2. *Phytoseius roseus* Gupta, 1969

Locality: Kerala: Thampanoor, Perinkunnam, Alathur, Aluva, Pulikkal, Villoonniyal, Kozhikode, Ramanattukara, Iritty

Habitat: *Lantana camara, Chromolaena odorata*

Diagnosis

Female: Dorsal shield 281-290 long, 150-158 wide. Measurements of setae: j1-30, j3- 32, j4 -6, j5- 5, j6- 6, J5- 6, z2 -12, z3- 32, z4- 11, z5- 5, Z4- 82, Z5- 72, s4- 122, s6- 82, r3- 44,R1- 19.Sternal shield slightly wider than long, with three pairs of sternal setae. Genital shield 72 wide and with a pair of setae. Ventrianal shield 91 long and 40 wide, with three pairs of preanal setae. A pair of metapodal plates present. Chelicera with four teeth on the fixed digit, and one tooth on the movable digit. Macrosetae on leg IV: genu-7, tibia-48, basitarsus-23, all with spatulate tip.

Male: Not found while sampling.

Materials examined: 3♀♀ from *L.camara* and *C. odorata* collected on 21. 11. 2015 from Malappuram Dt., 2♀♀ from *L.camara* and *C.odorata* collected on 11. 11. 2016 from Kozhikode Dt., 2♀♀ from *L.camara* and *C. odorata* collected on 02. 12. 2017 from Thiruvananthapuram Dt., 2♀♀ from *L.camara* and *C.odorata* collected on 19. 11. 2016 from Ernakulam Dt. and 2♀♀ from *C. odorata* collected on 16. 04. 2016 from Kannur Dt., Kerala, India. Coll. Saritha, C.

Remarks: The specimen collected during the present study resembles *P. roseus* described by Gupta (1969) in all morphological characters including the size of body setae and hence fixed so. This is the first report from the host plants mentioned above.

3. *Phytoseius macropilis* Banks, 1909

Locality: Kerala: Villoonniyal

Habitat: *Merremia vitifolia*, *Stachytarpeta jamaicensis*

Diagnosis

Female: Dorsal shield 292-299 long, 173-180 wide. Measurements of setae: jl-29, j3-36, j4- 6, j6-6, J5-6, z2-6, z3-29, z4-6, s4-116, s6-74, Z5-72, Z4-70, r3-47,R1- 18. Sternal shield 74 long, 80 wide with 3 pairs of sternal setae. Genital shield 79 wide, with a pair of setae. Ventrianal shield 87 long, 42 wide, with three pairs of preanal setae and a pair of preanal pores. Fixed digit of chelicera with three teeth and movable digit with 1 tooth. Macrosetae on leg IV: genu-21, tibia-59, basitarsus 28, all with spatulate tip.

Male: Not found while sampling.

Materials examined: 3♀♀ from *M. vitifolia* collected on 21. 11. 2015 and 2♀♀ from *S. jamaicensis* collected on 31. 12. 2015 Malappuram Dt., Kerala, India. Coll. Saritha, C.

Remarks: The morphological characters and the measurements of body setae of the specimen examined during the present study are similar to those of *P. macropilis* described by Banks (1909) and hence fixed so. This is the first report from both species of host plants.

4. *Phytoseius kapuri* Gupta, 1969

Locality: Kerala: Pulikkal, Kondotty

Habitat: *Chromolaena odorata*

Diagnosis

Female: Dorsal shield 274-282 long and 151-158 wide. Measurements of setae: j1- 28, j3- 67, j4- 4, j5- 4, j6- 5, J2- 9, J5- 5, z2- 15, z3- 46, z4-8, z5- 4, Z4- 80, Z5 -81, s4- 107, s6- 86, r3- 45, R1- 13. Sternal shield 70 long and 85 wide, with three pairs of sternal setae. Genital shield 69 wide with a pair of setae. Ventrianal shield 102 long and 54 wide, with three pairs of preanal setae and a pair of preanal pores. Fixed digit of chelicera with three teeth and movable digit with one tooth. Macrosetae on leg IV: genu-21, tibia-59, basitarsus 28, all with spatulate tip.

Male: Not found while sampling.

Materials examined: 3♀♀ from *C. odorata* collected on 29. 01. 2017 from Malappuram Dt., Kerala, India. Coll. Saritha, C.

Remarks: The present specimen resembles *P. kapuri* described by Gupta (1969) in all morphological features and setal measurements and

configuration and measurements of body setae and hence was assigned so. This is the first report from Kerala and also from the above host plant.

5. *Phytoseius mixtus* Narayanan, Kaur & Ghai, 1960

Locality: Kerala: Calicut University Campus

Habitat: *Lantana camara*

Diagnosis

Female:

Dorsal shield 298-312 long and 156-163 wide. Measurements of setae: j1 – 31, j3 – 27, j4 – 9, j5 – 9, j6 – 10, J5 – 10, z2 – 10, z3 – 31, z4 – 10, z5 - 10, Z4 – 82, Z5 – 70, s4 – 149, s6 – 89, r3 – 56, R1- 21 Setae j1, j3, z3 and r3 thick and barbed. Sternal shield measuring 52 long and 64 wide, with three pairs of sternal setae. Genital shield smooth, 70 wide. Ventrianal shield 70 long and 40 wide, with three pairs of prenal setae. Fixed digit of chelicera with three teeth, movable digit with one tooth. Macrosetae on genu IV absent.

Materials examined: 2♀♀ from *L. camara* collected on 19. 05. 2017 from Malappuram Dt., Kerala, India. Coll. Saritha, C.

Male: Not found during sampling.

Remarks: The present specimen resembles with P. mixtus described by Narayanan, Kaur & Ghai (1960) in all morphological characters and hence fixed so. This is the first report from Kerala and also from the above host plant.

6. *Phytoseius huangi* Ehara, 1970

Locality: Kerala: Peechi, Pattikkadu

Habitat: *Chromolaena odorata*

Diagnosis

Female: Dorsal shield 260-271 long, 142-153 wide and with 15 pairs of setae. Measurements of setae: j1-21, j4 -7, j6 -7, J5- 9, j3-21, z2-13, z3-24, z4-9, s4-72, s6-13, Z5-58, Z4-51,r3-39, RI-21. Sternal shield with three pairs of setae. Ventrianal shield elongate, lateral margins with three pairs of preanal setae. Fixed digit of chelicera with three teeth and movable digit with one tooth. Macrosetae on leg IV: genu-12, tibia-35, basitarsus-21.

Male: Not found while sampling.

Materials examined: 2♀♀ from *C.odorata* collected on 23. 05. 2018 from Thrissur Dt., Kerala, India. Coll. Saritha, C.

Remarks: The morphological characters are very similar to *P. huangi* Ehara (1970) and hence fixed so.

8) Genus: *Scapulaseius* Karg and Oomen – Kalsbeek, 1987

Generic characters: Dorsal shield with 17 pairs of setae, Z5 being longest. Sternal shield longer than wide, lobate posteriorly. Ventrianal shield vase shaped with three pairs of preanal setae. Macroseta present on genu, tibia and basitarsus of leg IV.

1. *Scapulaseius suknaensis* Gupta, 1970 (Plate 5, Fig. h)

Locality: Kerala: Tholpetty, Calicut University Campus

Habitat: *Merremia vitifolia, Synedrella nodiflora*

Diagnosis

Female : Dorsal shield 321-338 long, 211-225 wide Measurement of setae : j1 – 23, j3 – 21, j4-6, j5 – 6, j6 – 9, J2 – 9, J5 – 6, z2 – 15, z4 – 16, z5 – 6, s4 – 22, Z1 – 14, S2 – 15, S4 – 14, S5 – 10, Z4 – 55, Z5 – 79, r3 – 18, R1 – 15.

Sternal shield 69 long and 54 wide. Genital sheild 70 long with a pair of setae. Ventrianal shield 99 long and 220 wide, with three pairs of preanal setae and a pair of preanal pores. Metapodal plates two pairs. Fixed digit of chelicera with eight teeth, movable digit with three teeth. Macrosetae on leg IV: genu – 36, tibia – 30, basitarsus – 65.

Male: Unknown

Materials examined: 3♀♀ from *M. vitifolia* and 2♀♀ *S. nodiflora* collected on 21. 07. 2017 and 2♀♀ from *M. vitifolia* collected on 11. 12. 2015 from Wayanad Dt., Kerala, India. Coll. Saritha, C.

Remarks: In almost all characters, the present specimen resembles *S. suknaensis* described by Gupta (1970) and hence fixed so. The species is newly reported from both the host plants.

9) Genus: *Platyseiella* Muma, 1961

Generic characters: Dorsal shield lightly sclerotised with 13 pairs of setae, Rl absent. Peritreme extends anteriorly upto j1. Sternal shield smooth, as long as wide, with three pairs of sternal setae. Ventrianal shield smooth, elongate, vaseshaped, with 2-3 pairs of preanal setae. Spatulate macrosetae present on genu, tibia and basitarsus of leg IV.

1. *Platyseiella mumai* Ray and Gupta,1981

Locality: Kerala: Mararikulam

Habitat: *Chromolaena odorata*

Diagnosis

Female: Dorsal shield 284-298 long, 129-139 wide. Measurements of setae: j1- 20, j3-27 j4-7, j5-6, j6-5, J2-5, J5- 5, z2- 11, z4- 9, z5- 5, Z1- 61, Z4 -79, Z5- 80, s4- 145, s6-79, r3- 34, R1 absent. Sternal shield 79 long, 84 wide with

three pairs of sternal setae, 4th pair of setae lie on metasternal plates. Genital shield 78 wide with a pair of setae. Ventrianal shield 105 long and 69 wide, with three pairs of setae. Metapodal plates one pair. Fixed digit of chelicera multidendate and movable digit with two teeth. Macrosetae on leg IV: genu-39, tibia-45, basitarsus-52, all with knobbed tip.

Male: Not found while sampling.

Materials examined: 2♀♀ from *C. odorata* collected on 26. 07. 2016 from Alappuzha Dt., Kerala, India. Coll. Saritha, C.

Remarks: The specimen resembles *P. mumai* described by Ray and Gupta (1981) in all morphological traits and hence fixed so. This is the first report from Kerala and also from the above host plant.

ii) Superfamily: Ascoidea Voigts and Fauzago, 1877

b) Family: Ascidae Oudemans, 1905

10) Genus: *Asca* von Heyden 1826.

Generic characters: Dorsal shield well sclerotised with more than 24 pairs of setae, Z4 and S5 set on prominent tubercles. Presence of 12 setae on Genu I.

1. *Asca afroaphidiodes* Hurlbutt, 1971 (Plate 5, Fig. m)

Locality: Kerala: Palakkad, Thalassery

Habitat: *Lantana camara*

Diagnosis

Female: Dorsal shield 289-295 long and 167-172 wide. Measurements of setae: j1-14, J2-27, J3- 31, J4-40, z6-16, s6-21, S4-34, S5-43. Most of the setae, pilose type except S4, seta S5 arises from a protruded base. Sternal

shield 60 long. Ventrianal shield 113 long and 182 wide, with 15 setae. Fixed digit of chelicerae with five teeth, movable digit with two teeth.

Male: Not found while sampling

Materials examined: 2♀♀ from *L. camara* collected on 16. 05. 2016 from Palakkad Dt. and 2♀♀ collected on 26. 02. 2015 from Kannur Dt., Kerala, India. Coll. Saritha, C.

Remarks: All characters of the present specimen are similar to those of *A. afroaphidiodes* described by Hurlbutt (1971) and hence fixed so. This is the first report from the host plant**.**

2. Asca evansi Genis, Loots and Ryke, 1969 (Plate 5, Fig. k)

Locality: Kerala: Cherpulassery

Habitat: *Chromolaena odorata*

Diagnosis

Females: Idiosoma 281-296 long with 17 pairs of setae, ornamented with grooves and elliptical areas. Setae r2 to r6 on membrane. Most of the dorsal setae slightly pilose. Z4 fan-shaped and S5 curved and slightly fan-shaped. Sternal and jugular plates fused, forming a single shield which bears three pairs of setae. Ventrianal shield with six pairs of preanalsetae. Legs without knobs.

Male: Not found while sampling.

Materials examined: 2♀♀ from *C.odoratus,* collected on 27. 05. 2017 from Palakkad Dt., Kerala, India. Coll. Saritha, C.

Remarks: The morphological characters are similar to the original description given for *A. evansi* by Genis, Loots and Ryke (1969) and hence fixed so. This is the first report from Kerala and also from the host plant.

11) Genus: *Lasioseius* Berlese, 1916

Generic characters: Dorsal shield sculptured with many small polygons. Dorsal setae mostly pectinate, Setae Z3-Z5, S4, S5 slightly pilose distally. Only one metapodal plate on each side of the body, behind coxa IV.

1**. *Lasioseius parberlesei* Bhattacharyya, 1968**

Locality: Kerala: Chittur

Habitat: *Lantana camara*

Diagnosis

Female: Dorsal shield reticulated with 32 pairs of setae, most of them serrate lightly. Fixed digit of chelicerae with 13 teeth movable digit with three teeth. Legs I-IV with a pair of claws and pulvillus with three rounded lobules. Sternal shield lightly sclerotized with three pairs of setae.

Male: Not found while sampling

Materials examined: 2♀♀ from *L. camara,* collected on 12. 03. 2017 from Palakkad Dt., Kerala, India. Coll. Saritha, C.

Remarks: All features of the present specimen are found matching with those of *L. parberlesei* Bhattacharyya (1968) and hence fixed so. This is the first report from Kerala and also from the host plant**.**

12) Genus: *Arctoseius* **Thor, 1930**

Generic characters: The dorsal shield is entire or with lateral incisions midway along the lateral margin, with 14 pairs of setae arising from posterior region of dorsal shield. Anal shield present in female.

1. *Arctoseius pristinus* Karg, 1962

Locality: Kerala: Ambalachal, Thirunelli

Habitat*:* *Cassia tora*

Diagnosis

Female: Dorsal shield 404-419 long, 190-202 wide with lateral incisions. All dorsal setae spine like. Measurements of setae: i4 - 15, I1 -12, Z5- 20, I5 -13, i1 - 14 long. Sternal shield proximally rounded, laterally and caudally concave with three pairs of setae. Genital shield oval in shape with a pair of setae . Anal shield, oval, smaller than sternal shield and bears a pair of anal setae. Movable digit of chelicera with two teeth and fixed digit with five teeth. Tarsus I slender, claws on leg I smaller than those of legs II-IV.

Male: Not found while sampling

Materials examined: 2♀♀ from *C. tora,* collected on 29. 08. 2017 from Wayanad Dt., Kerala, India. Coll. Saritha, C.

Remarks: The present specimen possesses all features similar to those of the described species, *A. pristinus* Karg (1962) and hence fixed so. The species is newly reported from Kerala and also from the host plant**.**

2. *Arctoseius magnanalis* Evans, 1958

Locality: Kerala: Thondayadu, Mannuthi, Thenkurissi

Habitat*:* *Cassia tora*

Diagnosis

Female: Dorsal shield 436-448 long and 254-261 wide, characterized with pattern. Mediolateral incisions and five pairs of pores present on shield. Peritremes reaching coxae I. Measurements of setae: Z5 – 49, Z4 - 42, I5 - 12, i1 - 11, i4 -17, I4 -15. Sternal shield with lateral proximal sclerites. Genital shield narrow, posteriorly rounded, with short brokrn line like dotts. Ventral surface with 10 pairs of needle-shaped setae. Ventrianal shield with expressive net pattern, bearing two pairs of setae. Anal shield with two pairs of adanal setae.

Male: Not found while sampling

Materials examined: 2♀♀ from *C. tora*, collected on 19. 08. 2017 from Kozhikode Dt., 2♀♀ collected on 11. 05. 2017 from Thrissur Dt. and 1♀ collected on 22. 12. 2018 from Palakkad Dt., Kerala, India. Coll. Saritha, C.

Remarks: The present specimen possesses morphological similarity with the known species, *A. magnanalis* Evans (1958) and hence fixed so. This is the first report from Kerala and also from the host plant**.**

II. Superorder: Acariformes Zakhvatkin, 1952

B) **Order: Trombidiformes Reuter, 1909**

Suborder: Prostigmata Kramer, 1877

iii) Superfamily: Bdelloidea Duges, 1834

c) Family: Bdellidae Duges, 1834

13. Genus: *Bdella* Latreille, 1795

Generic characters: Palp tibiotarsus truncate, shorter than palpal basifemur, subequal end setae as long as or longer than palp femur. Four pairs of eyes discernible, lateral to unmodified pseudostigmatic organ.

1. Bdella maldahensis Gupta, 1992

Locality: Kerala: Cherpulassery, Palakkad

Habitat: *Chromolaena odorata*

Diagnosis

Female: Body 621-629 long, 306-311 wide. Gnathosoma 180 long, palp tibiotarsus with two long whip-like setae. Chelicera non-striate, base inflated with two pairs of setae. Hypostome ventrally with six pairs of setae, base striated. Dorsal propodosoma with five pairs of setae, including two pairs of sensory setae. Tarsus ends in a pair of claw. Tarsus I with seven plumose ventral setae, five dorsal setae, six lateral setae and two blunt sensory setae.

Male: Unknown.

Materials examined: 2♀♀ from *C.odorata* collected on 09. 08. 2016 from Palakkad Dt., Kerala, India. Coll. Saritha, C.

Remarks: The present specimen resembles in morphological characters, dimensions of body shields and measurements of dorsal setae with the known species, *B.maldahensis* described by Gupta (1992) and hence fixed so. This is the first report from Kerala and also from the host plant.

2. Bdella radhikae Sadanandan, Suresh and Ramani, 2009

Locality: Kerala: Athirampuzha

Habitat: *Chromolaena odorata*

Diagnosis

Female: Body 589-593 long and 300-306 wide. Dorsal setae 14 pairs, smooth and medium sized. Gnathosoma 172 long, palp tibiotarsus with two long whip-like setae. Chelicera non-striate, base inflated with three pairs of setae. Genital setae six, aggenital setae seven pairs. Hypostome ventrally with six pairs of setae, base not striated. Tarsi I and II end in a pair of claws, famulus situated near the base of the solenidion on both tarsi I and II.

Male: Unknown.

Materials examined: 2♀♀ from *C.odorata* collected on 06. 03. 2016 from Kottayam Dt., Kerala, India. Coll. Saritha, C.

Remarks: The present specimen resembles with *Bdella radhikae* described by Sadanandan *et al* (2009) in all morphological characters and hence fixed so.

d) Family: Cunaxidae Thor, 1902

14. Genus: *Cunaxa* von Heyden, 1826

Generic characters: Dorsal shield highly sclerotized. Propodosomal shield, smooth, reticulated or sriated. Palpi five segmented with spine like setae. Tarsi I-IV tapering distally, without lateral bilobed flanges.

1. *Cunaxa myabunderensis* Gupta and Ghosh, 1980 (Plate 5, Fig. n)

Locality: Kerala: Kodungallur, Malampuzha, Malappuram, Kozhikode

Habitat: *Lantana camara*

Diagnosis

Female: Body 414-428 long and 384-392 wide. Propodosoma with two pairs of long sensory setae and two pairs of short setae. Hysterosomal shield absent.

Hysterosoma with six pairs of short setae; Palp five segmented, palpal telofemur with one spine like seta on the inner surface and one outer lateral simple seta, genu with a sharp spine like seta at the inner surface and one small seta laterally with one median seta on the outer surface, tibiotarsus with one small sharp seta on the inner surface. Ventral surface with five pairs of setae.

Male: Not found while sampling.

Materials examined: 2♀♀ from *L. camara* collected on 26. 03. 2016 from Thrissur Dt., 2♀♀ collected on 21. 05. 2015 from Palakkad Dt. and 1♀collected on 16. 03. 2018 from Kozhikode Dt., Kerala, India. Coll. Saritha, C.

Remarks: The present specimen appears to be identical in morphological features and dimensions of body setae with the earlier species described by Gupta and Ghosh (1980) *viz. C. myabunderensis* and hence fixed so. This is the first report from Kerala and also from the host plant.

2. *Cunaxa setirostris* Hermann, 1804

Locality: Kerala: Mararikulam, Thampanoor

Habitat: *Calotropis procera*

Diagnosis

Female: Body 546-561 long and 303- 315wide. Palp five segmented, 148 long. Palpal telofemur with an elongated apophysis and one dorsomedian simple seta. Propodosoma with a reticulate subrectangular shield, bearing two pairs of finely branched sensory setae, anterior pair 251 long and posterior pair 312 long. Hysterosoma without any shield, and bears five pairs of simple

setae. Genital plate with four pairs of simple setae. Legs I-IV measure 412, 389, 398 and 494 respectively.

Male: Not found while sampling.

Materials examined: 2♀♀ from *C. procera* collected on 26. 07. 2016 from Alappuzha Dt., 2♀♀ collected on 11. 02. 2017 from Thiruvananthapuram Dt., Kerala, India. Coll. Saritha, C.

Remarks: The specimen collected during the present study closely resembles *C. setirostris* described by Hermann (1804) in the general morphology and dimensions of the various body setae and hence fixed so. This is the first report of the species from the above host plant.

3. *Cunaxa capreolus* Gupta and Ghosh, 1980

Locality: Kerala: Calicut University Campus, Malappuram

Habitat: *Chromolaena odorata*

Diagnosis

Female: Body 591-599 long and 306-315 wide. Palp five segmented and 157 long. Palpal telofemur with one elongated apophysis at the inner side and one dorsolateral simple seta. Propodosoma with a subrectangular shield and bears two pairs of finely branched sensory setae, anterior pair 249 long and posterior pair 322 long. Hysterosoma with a median plate, carrying five pairs of simple setae. Ventral side with six pairs of simple setae.

Male: Not found while sampling.

Materials examined: 2♀♀ from *C.odorata* collected on 16. 07. 2015 from Malappuram Dt., Kerala, India. Coll. Saritha, C.

Remarks: The poresent specimen resembles *C. capreolus* described by Gupta and Ghosh (1980) in all moraphological features including the setal measurements and hence fixed so. This is the first report from the above host plant.

4. *Cunaxa reticulatus* Bashir, Afzal & Ali , 2005

Locality: Kerala: Kodungallur, Cheruvathur

Habitat: *Chromolaena odorata*

Diagnosis

Female: Body 594-611 long and 389-396 wide. Palp five segmented, 172 long, palpal telofemur with one elongated apophysis at the inner side and one dorsolateral simple seta, genu with one spine like seta and two simple setae. Propodosoma with a subrectangular shield which originated from the base of gnathosoma and exteneded to the anterior part of hysterosoma. Hysterosoma separated from propodosoma by dotted lines. Hysterosoma with a median plate along with five pairs of simple setae, ventral side with six pairs of simple setae. Hysterosoma with one pair of pores, in lateral position between D_3 and D_4.

Male: Not found while sampling.

Materials examined: 2♀♀ from *C. odorata* collected on 24. 04. 2017 from Thrissur Dt. and 2♀♀ collected on 11. 07. 2018 from Kasaragode Dt., Kerala, India. Coll. Saritha, C.

Remarks: The specimen resembles *C. reticulatus* described by Bashir *et al.* (2005) in all external characters and measurements of setae and hence fixed so. This is the first report from Kerala and also from the above host plant.

15. Genus: *Cunaxoides* Baker and Hoffman, 1948

Generic characters: Dorsal hysterosoma with or without shield. Propodosoma with poorly sclerotised shield, and with two pairs of setae and two pairs of setose sensillae. Palpi three segmented, seta L4 absent. Leg IV with a trichobothrium.

1. Cunaxoides nicobarensis Gupta and Ghosh, 1980

Locality: Kerala: Palakkad, Calicut University Campus

Habitat: *Lantana camara*

Diagnosis

Female: Body 456-470 long, 279-286 wide. Propodosoma with two pairs of long sensory setae and two pairs of short setae. Palpi three segmented, 1st, 2nd and 3rd with 4, 3 and 5 setae respectively. Apophysis two on the inner surface and ends in a small claw. Hysterosoma set apart from propodosoma and dinstinguished by feebly developed striae. Genital plate with four pairs of setae. Ventral side with six pairs of setae.

Male: Not found while sampling.

Materials examined: 3♀♀ from *L.camara* collected on 20. 05. 2017 from Malappuram Dt. and 2♀♀ collected on 21. 04. 2018 from Palakkad Dt., Kerala, India. Coll. Saritha, C.

Remarks: The present specimen possesses all morphological features including the setal measurements with *C. nicobarensis* described by Gupta and Ghosh (1980) and hence fixed so. This is the first report from Kerala and also from the above host plant.

iv)Superfamily: Tydeoidea Kramer, 1877

e) Family: Tydeidae Kramer, 1877

16. Genus: *Tydeus* Koch, 1836

Generic characters: Propodosoma with fine longitudinal striation and hysterosoma with transverse striation on dorsomedian region. Genital setae 5-6 pairs, paragenital setae four pairs and anal setae one pair. All tarsi possess claws and empodium.

***1. Tydeus interruptus* Sig Thor, 1932**

Locality: Kerala: Karyavattom, Perinkunnam, Villoonniyal, Olavattur, Parappanangadi, Vagamon, Parunthumpara, Kozhikode, Nadakkavu, Mananthavady

Habitat: *Antigonon leptopus, Lantana camara, Merremia vitifolia, Mikania micrantha, Synedrella nodiflora*

Diagnosis

Female: Dorsal shield 278-291 long and 157-168 wide. Idiosoma diamond shaped. Gnathosoma short. Dorsal body with evenly spaced lines and with small tubercular projections. Palpi elongate. Propodosoma separated from the hysterosoma by a transverse groove, and with one pair of trichobothriae, the latter thin and longer than other body setae. Hysterosoma with five pairs of spatulate setae. Genital setae six pairs, four pairs of para genital setae. Legs slender, end in a pair of claws and an empodium. A solenidion and two setae arising on the tarsus I, tip of tarsus I encircled with three short additional setae. Tibia I, femur I and genu I with three setae each, trochanter I with a single seta.

Male: Not found while sampling.

Materials examined: : 3♀♀ from *L.camara*, 2♀♀ from *A.leptopus* and 2♀♀ from *M.vitifolia* collected on 13. 12. 2015 from Malappuram Dt., 2♀♀ from *L.camara* and *M. micrantha* collected on 21. 11. 2016 from Kozhikode Dt., 2♀♀ from *L.camara* and *S. nodiflora* collected on 02. 11. 2017 from Thiruvananthapuram Dt., 2♀♀ from *L.camara* collected on 19. 01. 2016 from Wayanad Dt. and 2♀♀ from collected on 11 .03.2016 from Idukki Dt., Kerala, India. Coll. Saritha, C.

Remarks: The specimen examined during the present study shows great morphological similarity with *T. interruptus* described by Sig Thor (1932) and hence fixed so. This is the first report of the species from all the above mentioned host plants.

2. *Tydeus caudatus* (Duges, 1834) Baker, 1970

Locality: Kerala: Perinkunnam, Vagamon

Habitat: *Cissampelopsis corymbosa, Lantana camara*

Diagnosis

Female: Dorsal shield 267-280 long and 161-173 wide. Dorsal surface of body with longitudinal and transverse striations. Palpi elongate. Propodosoma with a pair of trichobothriae and the latter being thin, longer than the other body setae. Hysterosoma with five pairs of spatulate setae. Genital setae six pairs. Setaton of legs I-IV: Trochanter: 1-0-1-0; Femur: 3-2-1-1; Genu: 3-2-1-1, Tibia: 4-2-2-2; Tarsi: 8-6-5-5.

Male: Not found while sampling.

Materials examined: 2♀♀ from *L.camara* collected on 29. 03. 2016 from Palakkad Dt. and 2♀♀ from *C. corymbosa,* collected on 11 .03.2016 from Idukki Dt., Kerala, India. Coll. Saritha, C.

Remarks: The specimen shows resemblance in general morphology with the described species, *T. caudatus* (Duges, 1834) Baker, 1970 and hence fixed as the above. This is the first report from Kerala and also from the above two species of host plants.

17. Genus: *Lorryia* Oudemans, 1925

Generic characters: Dorsal body surface covered with reticulate pattern, having spine like lobes. Hysterosomal setae arranged in four rows. Genital setae six pairs, paragenital setae four pairs, anal setae one pair, ventral setae three pairs.

1. *Lorryia formosa* Cooreman, 1958 (Plate 6, Fig. a)

Locality: Kerala: Perinkunnam, Palakkad, Villoonniyal

Habitat: *Lantana camara*

Diagnosis

Female: Dorsal body 239-248 long, 149-158 wide, elongate with reticulation. The reticulation covers the entire dorsal surface of the body, and broken in to each equally discrete areas. Propodosoma with a pair of sensory setae, the latter being larger when compared to the other body setae. All dorsal body setae lanceolate and curved distally, and more or less equaly sized. Tarsus I with one solenidion.

Male: Unknown

Materials examined: 5♀♀ from *L.camara* collected on 26. 04. 2016 from Palakkad Dt. and 2♀♀ collected on 21 .03.2015 from Malappuram Dt., Kerala, India. Coll. Saritha, C.

Remarks: The specimen closely resembles *L. formosa* Cooreman (1958) in all characters and hence fixed so. This is a new report from Kerala and from the above host plant.

2. *Lorryia stricta* Gupta, 1991

Locality: Kerala: Calicut University Campus

Habitat: *Antigonon leptopus*

Diagnosis

Female: Body elongate, 218-226 long and 130-138 wide, and with reticulation. Dorsal body setae long and lanceolate. Palpal segment longer than broad, distally. Terminal sensillum of palp with broader tip. Propodosoma with long whip like sensory setae Genital setae five pairs, paragenital setae four pairs and anal setae one pair. Tarsus I with one solenidion.

Male: Not found while sampling.

Materials examined: 3♀♀ from *A.leptopus* collected on 21 .03.2015 from Malappuram Dt., Kerala, India. Coll. Saritha, C.

Remarks: The specimen closely resembles *L. stricta* Gupta (1991) in all characters and hence confirmed so. This is the first report from Kerala and also from the above host plant.

18. Genus: *Pronematus* Canestrini, 1886

Generic characters: Hysterosomal setae arranged in four rows. Paragenital setae four pairs, anal setae one pair, ventral setae three pairs. Tarsus I without claws and empodium and it ends in four long terminal setae.

1. Pronematus elongatus Baker, 1968

Locality: Kerala: Mannanam, Athani, Thrissileri, Perinkunnam, Palakkad, Ramanattukara, Calicut University Campus

Habitat: *Lantana camara*

Diagnosis

Female: Body 260-264 long and 138-146 wide. Dorsal body setae very small, partly serrate. Propodosoma with fine longitudinal striae. Sensory seta finely serrate, whip-like, about three times as long as other setae, the latter being short, slightly lanceolate and serrate. Solenidion on tarsus I short and rounded.

Male: Unknown

Materials examined: 4♀♀ from *L. camara* collected on 06. 03. 2016 from Kottayam Dt., 2♀♀ collected on 21. 05. 2015 from Palakkad Dt. and 1♀collected on 16. 03. 2018 from Kozhikode Dt. and 2♀♀ collected on 14.12. 2016 from Ernakulam Dt., Kerala, India. Coll. Saritha, C.

Remarks: The specimen closely resembles *P. elongatus* described by Baker (1968) in all characters and hence confirmed so. This is the first report from Kerala and also from the above host plant.

2. *Pronematus ubiquitus* McGregor, 1956

Locality: Kerala: Vagamon, Parunthumpara, Kozhikode, Pulikkal, Calicut University Campus

Habitat: *Lantana camara, Chromolaena odorata, Merremia vitifolia*

Diagnosis

Female: Body 267-277 long and 132-141 wide. The longitudinal striae of the propodosoma reach to the D_2 setae on the hysterosoma. The ventral body

setae longer than the distance between their bases and arranged in a longitudinal line. Tarsus I longer than tibia I, solenidion on tarsus I located near the middle of the segment.

Male: Unknown

Materials examined: 5♀♀ from *L. camara*, 3♀♀ from *C.odorata* and 2♀♀ from *M. vitifolia* collected on 16. 03. 2015from Malappuram Dt., 4♀♀ from *M. vitifolia* , collected 16. 03. 2018 from Kozhikode Dt. and 2♀♀ from *L. camara*, 3♀♀ from *C.odorata* collected on 11. 03. 2016 from Idukki Dt., Kerala, India. Coll. Saritha, C.

Remarks: The specimen closely resembles *P.ubiquitus* McGregor (1956) in all characters and hence confirmed so. This is the first report from Kerala and also from the host plants mentioned above.

3. *Pronematus sextoni* Baker, 1968

Locality: Kerala: Perinkunnam, Palakkad

Habitat: *Lantana camara*

Diagnosis

Female: Body 256-266 long and 128-139 wide. Rostrum not much longer than broad at base. Propodosoma with many fine longitudinal striae, with minute lobes. Sensory setae similar to other propodosomal setae. Hysterosomal striae similar to that of propodosoma. Tarsus I longer than tibia I, distal setae serrate along entire length, solenidion on tarsus I strong and bent.

Male: Unknown

Materials examined: 2♀♀ from *L. camara*, collected on 23. 09. 2018 from Palakkad Dt., Kerala, India. Coll. Saritha, C.

Remarks: The specimen closely resembles *P.sextoni* Baker (1968) in all characters and hence confirmed so. This is the first report from the above host plant.

4. *Pronematus fleschneri* Baker, 1968

Locality: Kerala: Villoonniyal, Malappuram

Habitat: *Alternanthera bettzickiana*

Diagnosis

Female: Body 220-229 long and 123-128 wide. Rostrum elongate. Propodosomal striae longitudinal with minute lobes. Hysterosomal striae fine with minute lobes. Tibia I shorter than tarsus I, latter with one pair of setae, all setae serrate. Solenidion on tarsus I long, distally placed and surpassing the end of the segment. Solenidion on tibia I shorter.

Male: Unknown

Materials examined: 2♀♀ from *A. bettzickiana*, collected on 23. 04. 2018 from Malappuram Dt., Kerala, India. Coll. Saritha, C.

Remarks: The specimen closely resembles *P.fleschneri* Baker (1968) in all characters and hence confirmed so. This is the first report from Kerala and also from the above host plant.

5. *Pronematus rykei* (Meyer and Rodrigues, 1966)

Locality: Kerala: Madavoor

Habitat: ***Merremia vitifolia***

Diagnosis

Female: Body 267-273 long and 132-139 wide. The longitudinal striae of propodosoma reach to the D_2 setae on the hysterosoma. The ventral body setae more or less similar in distance between their bases. Tarsus I longer than tibia I, the solenidion on tarsus I located not near the middle of the segment.

Male: Unknown

Materials examined: 2♀♀ from *M. vitifolia* collected on 25.04.2016 from Kozhikode Dt., Kerala, India. Coll. Saritha, C.

Remarks: The specimen examined during the study closely resembles *Pronematus rykei* (Meyer and Rodrigues, 1966) and hence fixed so. This is the first report from Kerala and also from the host plant.

v) Superfamily: Raphignathoidea Kramer, 1877

f) Family: Stigmaeidae Oudemans, 1931

19. Genus: *Agistemus* Summers, 1960

Generic characters: Idiosoma broadly oval. Three unpaired plates present, *viz.* propodosomal, median and suranal, cover most of the dorsum. One pair of eyes and one pair of ocular bodies, situated between eyes and setae *ce*. Terminal sensillum trifid.

***1. Agistemus gamblei* Gupta, 1991 (Plate 11, Fig. f)**

Locality: Kerala: Malappuram

Habitat: *Chromolaena odorata*

Diagnosis

Female: Dorsal shield 432-440 long and 256-263 wide. Measurements of setae: ae-41, be-77, ce-69, a-44, la-47, 1m-56, c-56, he-40, Ii-51, le-25, e-35. Propodosomal and median plates distinct, reticulate. Propodosomal plate with three pairs of setae, median plate with five pairs of setae.

Male: Dorsal chaetotaxy same as that of female; body size smaller than that of female.

Materials examined: 2♀♀ from *C. odorata* collected on 05.04.2016 from Malappuram Dt., Kerala, India. Coll. Saritha, C.

Remarks: The morphological characters, dimensions of body shields and measurements of dorsal setae of the present specimen resemble with those of *A. gamblei* described by Gupta (1991). This is the first report from the above host plant.

2. *Agistemus industani* Gonzalez-Rodriguez, 1965

Locality: Kerala: Vagamon

Habitat: *Lantana camara*

Diagnosis

Female: Dorsal shield 478-488 long and 292-300 wide. Dorsal setae blunt tipped, set on tubercles.Measurements of setae: ae-54, be-78, ce-61, a-54, la-67, lm-68, c-70, he-50, Ii-62, le-25, e-39. Propodosomal and median plates distinct and smooth. Propodosomal plate with three pairs of setae and median plate with five pairs of setae. Genital plate with six pairs of setae.

Male: Not found while sampling.

Materials examined: 3♀♀ from *L.camara* collected on 11.03.2016 from Idukki Dt., Kerala, India. Coll. Saritha, C.

Remarks: Morphological characters, dimensions of body shields and measurements of dorsal setae of the present specimen clearly reveal its identity with the previously described species, *A. industani* Gonzalez-Rodriguez (1965) and hence confirmed so. This is the first report from Kerala and also from the above host plant.

3. *Agistemus fleschneri* Summers, 1960 (Plate 11, Fig. e)

Locality: Kerala: Calicut University Campus, Thottada

Habitat: *Antigonon leptopus, Desmodium tortuosum*

Diagnosis

Female: Body 356-362 long and 161-172 wide. Dorsal propodosomal plate with polygonal reticulations. 2/3rd of hysterosoma covered with reticulation. Dorsal setae of median size, set on tubercles and barbed at their tip, measurements of setae: ae-44, be-68, ce-60, a-51, la-47, b-44, lm-51, c-52, he-50, Ii-57, le-15, e-32. Genital plate with six pairs of setae.

Male: Dorsal chaetotaxy same as that of females.

Materials examined: 2♀♀ from *A. leptopus,* 5♀♀ from *D. tortuosum* collected on 18.03.2018 from Malappuram Dt. and 2♀♀ from *A. leptopus,* collected on 15.04.2016 from Kannur Dt., Kerala, India. Coll. Saritha, C.

Remarks: The specimen shows resemblance to *A. fleschneri* described by Summers (1960) in all morphological characters, dimensions of body shields and measurements of dorsal setae and hence confirmed so. This is the first report from the above mentioned host plants.

4. *Agistemus exsertus* Gonzalez, 1963 (Plate 6, Fig. b)

Locality: Kerala: Cherpulassery

Habitat: *Chromolaena odorata*

Diagnosis

Female: Dorsal shield 461-467 long and 352-359 wide. Dorsal setae nude, set on tubercles. Measurements of setae: ae-48, be-48, ce-51, a-53, b- 32, c-52, la-56, lm-35, he-39. Propodosomal and median plates distinct and smooth. Propodosomal plate with three pairs of setae, median plate with five pairs of setae, hysterosomal plate with five pairs of setae.

Male: Not found while sampling.

Materials examined: 4♀♀ from *C. odorata*, collected on 12.08.2016 from Palakkad Dt., Kerala, India. Coll. Saritha, C.

Remarks: The present specimen seems identical with A. *exsertus* described by Gonzalez (1963) in all morphological characters, dimensions of body shields and measurements of dorsal setae and hence fixed so. This is the first report from the above host plant.

5. *Agistemus aimogastaensis* Leiva, Fernandez, Theron and Rollard, 2013 (Plate 6, Fig. c)

Locality: Kerala: Villoonniyal, Peechi, Mannuthy, Ramanattukara

Habitat: *Merremia vitifolia*

Diagnosis

Female: Dorsal body shield 332-340 long and 152-161 wide. Propodosomal plate with polyhedral reticulate pattern.Eye spots on either side visible. Metapodosomal and propodosomal plates separated by transverse striae.

Dorsal setae denticulate slightly. Genital setae four pairs, paragenital setae two pairs and anal setae three pairs. Empodium with three pairs of fan shaped raylets.

Male: Not fond while sampling.

Materials examined: : 5♀♀ from *M. vitifolia* collected on 22.08.2015 from Malappuram Dt., 3♀♀ collected on 13.04.2016 from Thrissur Dt. and 1♀ collected on 23.04.2016 from Kozhikode Dt., Kerala, India. Coll. Saritha, C.

Remarks: The present specimen resembles with *A. aimogastaensis* Leiva, Fernandez,Theron and Rollard (2013) in all characters and and hence confirmed so. This is the first report from the above host plant.

6. *Agistemus floridanus* Gonzalez, 1965 (Plate 11, Fig. g)

Locality: Kerala: Calicut University Campus

Habitat: *Lantana camara, Chromolaena odorata*

Diagnosis

Female: Dorsal body shield 428-439 long and 206-213 wide Propodosomal and hysterosomal shields smooth, eye spots on either side visible. Metapodosomal and propodosomal plates separated by transverse striae. Dorsal setae slightly denticulate. Seta *c*1 shorter than their mutual distance. Genital setae four pairs, paragenital setae two pairs and anal setae three pairs. Leg tarsus with solenidia.

Male: Not fond while sampling.

Materials examined: 2♀♀ from *L.camara* collected on 12.05.2015 and 2♀♀ from *C. odorata* collected on 29.04.2016 from Malappuram Dt., Kerala, India. Coll. Saritha, C.

Remarks: The specimen collected and examined during the present study shows similarity with *A. floridanus* Gonzalez (1965) in all characters and and hence fixed so. This is the first report from both species of host plants mentioned above.the above host plants.

vi) Superfamily: Eupodoidea Koch, 1842

g) Family: Eupodidae Koch, 1842

20. Genus: *Eupodes* Koch, 1836

Generic characters: Body delicate and soft. Some of the dorsal setae inflated basally and tapering distally. Leg IV thicker than the other legs, with very thick femora.

***1. Eupodes parafusifer* Meyer and Ryke, 1960**

Locality: Kerala: Calicut University Campus, Vettukadu, Nelliyampathy, Perinkunnam, Ramanattukara, Thiruvambady

Habitat: *Merremia vitifolia*

Diagnosis

Female: Dorsal shield 439-446 long, 251-263 wide. Hysterosoma with 10 pairs of setae, six pairs spindle shaped and four pairs linear. Sejugal furrow prominent. Palp four segmented, tarsus with seven setae, tibia with three setae and femur with two setae, spindle shaped. Genital setae six pairs. Spindle shaped setae found on dorsum and legs. Femur IV prominently enlarged with prominent claws and empodia.

Male: Not found while sampling.

Materials examined: 3♀♀ from *M.vitifolia* collected on 22.05.2015 from Malappuram Dt., 2♀♀ collected on 29.10.2016 from Palakkad Dt., 1♀

collected on 11.12.2016 from Kozhikode Dt. and 2♀♀ collected on 25. 07.2016 from Alappuzha Dt., Kerala, India. Coll. Saritha, C.

Remarks: The specimen examined during the present study resembles in dimensions of body shields, measurements of dorsal setae and other morphological characters with the known species, *E. parafusifer* described by Meyer and Ryke (1960) and hence fixed so. This is the first report of the species from the above host plant.

2. *Eupodes indentatus* Olivier and Theron, 1997

Locality: Kerala: Calicut University Campus, Ramavarmapuram, Thrissur

Habitat: *Antigonon leptopus*

Diagnosis

Female: Dorsal shield 479-490 long, 281-289 wide. Prodorsum with four pairs of setae. Sejugal furrow prominent. Opisthosoma with 8 pairs of setae. Genital setae 6 pairs. Spindle shaped setae found on dorsum and legs. All legs slender except leg IV, femur IV prominently enlarged with prominent claws and empodia.

Male: Not found while sampling.

Materials examined: 2♀♀ from *A. leptopus* collected on 12.09. 2015 from Malappuram Dt., 2♀♀ collected on 14. 04.2016 from Thrissur Dt., Kerala, India. Coll. Saritha, C.

Remarks: The present specimen shows similarity in all morphological characters, with the species, *E. indentatus* described by Olivier and Theron (1997) and hence confirmed so. This is the new report from Kerala and also from the above host plant.

h) Family: Suidasiidae Hughes, 1948

21) Genus: *Suidasia* Oudemans, 1905

Generic characters: Setae *si* are microsetae, cuticle wrinkled, cable like, three obvious ventral spines, external pairs strongly hooked. Central spines placed posterior to and well separated from hooked pair.

1. *Suidasia nesbitti* Hughes, 1948

Locality: Kerala: Vagamon

Habitat: *Chromolaena odorata*

Diagnosis

Female: Idiosoma 329-336 long and 181-187wide. Propodosomal shield smooth while opisthosoma with wrinkles. Setae extended forward over gnathosoma, *ve* short. The supracoxal seta flattened with lateral pectinations.Dorsal setae smooth, hysterosomal setae short. Ventral apodemes stout. Chelicera toothed and with a mandibular spine on its ventral surface. Anal plate with five pairs of setae. Tarsus I with a slender curved rod like solenidion, omega.

Male: The males closely resemble the female in morphological features, except that their size smaller than the females.

Materials examined: 2♀♀ and1 ♂from *C. odorata* collected on 12. 03. 2016 from Idukki Dt., Kerala, India. Coll. Saritha, C.

Remarks: The morphological characters, dimensions of body shields and measurements of dorsal setae of the present specimen are in agreement with those of *S. nesbitti* described by Hughes (1948) and hence fixed so. This is the first report from Kerala and also from the above host plant.

i) Family: Erythraeidae Oudemans**, 1902**

22) Genus: *Sphaerolophus* Berlese, 1910

Generic characters: Dorsum densely covered with minute, curved setae. Both adults and nymphs possess one eye on each side, behind middle of crista. Palp tarsus greatly enlarged, globular or pyriform and extends beyond palpal tibial claw.

***1. Sphaerolophus minutus* Khot, 1965**

Locality: Kerala: Villoonniyal, Malappuram

Habitat: *Lantana camara*

Diagnosis

Female: Body bright orange red in colour, 1014-1022 long and 457-469 wide. Crista 241 long, extending posteriorly upto middle of dorsum. Anterior sensillary area triangular, with three plumose non-sensillary setae. Eyes situated on either side, lateral to posterior sensilIary area. Dorsal setae numerous, small, pointed. Leg I- 1096 long, Leg II-735 long, Leg III- 832 long, Leg IV -1310 long.

Male: Unknown.

Materials examined: 2♀♀ from *L. camara* collected on 12. 05. 2018 from Malappuram Dt., Kerala, India. Coll. Saritha, C.

Remarks: The morphological characters of the present specimen are found similar to those of *S. minutus* described by Khot (1965) and hence fixed so. This is the first report from Kerala and also from the above host plant.

j) Family: Eupalopsellidae Willmann, 1952

23) Genus: *Exothorhis* Summers, 1960

Generic characters: Dorsal idiosoma entirely covered by a thin skeletal sheath, not subdivided in to plates. Dorsal body setae long, thick, denticulate, all originate on strong tubercles.Humeral setae displaced upward. Tibial claw of palp reduced.

***1. Exothorhis nadiaensis* Chatterjee and Gupta, 1994**

Locality: Kerala: Villoonniyal, Malappuram

Habitat: *Lantana camara*

Diagnosis

Female: Body 382-389 long and 161-165 wide, with 13 pairs of setae, most setae long, thick and plumose. Transverse striation present between propodosoma and hysterosoma. Region below metapodosomal shield transversely striated. Peritreme hooked. Chelicerae with needle like stylets. Genital setae five pairs, paragenital setae two pairs and anal setae two pairs. A diagnostic character of this species is the presence of a small spine like solenidion on the distal part of tibia I.

Male: Unknown

Materials examined : 2♀♀ from *L. camara* collected on 12. 05. 2018 from Malappuram Dt., Kerala, India. Coll. Saritha, C.

Remarks: All morphological features of the present specimen resemble those of *E. nadiaensis* described by Chatterjee and Gupta (1994) and hence fixed so. This is the first report from Kerala and also from the above host plant.

vii) Superfamily: Cheyletoidea Leach, 1815

k) Family: Cheyletidae Leach, 1815

24) Genus: *Cheyletus* Latereille, 1796

Generic characters: Palp tarsus with two sickle like and two comb like setae. Palp claw with basal teeth. Peritreme M -shaped. Propodosomal plates cover most of propodosoma, hysterosomal plate quadrangular, incompletely covering hysterosoma.

***1. Cheyletus eruditus* Schrank, 1781 (Plate 6, Fig. d)**

Locality: Kerala: Kololam, Thondayadu

Habitat: *Chromolaena odorata*

Diagnosis

Female: Idiosoma diamond shaped and 548-556 long and 256-263 wide. Palp tarsus with 13 teeth on external comb and 15 teeth on internal comb. Dorsal seta on palp femur 135 long, barbed. Tegmen ornamented with broken striae. Peritreme M-shaped with 4-5 links. Area between propodosoma and hysterosoma with transverse striation. Dorsocentral setae 10 pairs, finely barbed, Dorsomedian seta absent. Humeral setae finely barbed. Ventral setae five pairs, genital setae three pairs and anal setae two pairs.

Male: Not found while sampling.

Materials examined : 2♀♀ from *C.odorata* collected on 26. 05. 2018 from Kozhikode Dt., 2♀♀ collected on 16. 04. 2016 from Kannur Dt., Kerala, India. Coll. Saritha, C.

Remarks: The present specimen resembles with *C. eruditus* Schrank (1781) in external morphology, dimensions of body shields and measurements of setae and hence fixed so. This is the first report from the above host plant.

2. *Cheyletus malaccensis* Oudemans, 1903 (Plate 6, Fig. e)

Locality: Kerala: Athirampuzha, Beypore

Habitat: *Ipomoea nil*

Diagnosis

Female: Idiosoma 588-595 long and 268-283 wide. Tegmen finely striated, eyes absent. Dorsal setae densely plumose including humerals. Peritreme M-shaped with five internal divisions. Pedipalpal tarsus with 13 teeth on external comb, nine teeth on internal comb. Propodosomal shield bears four pairs of peripheral and two pairs of central setae. Tibia I with five tactile and one sensory setae.

Male: Not found while sampling.

Materials examined: 2♀♀ from *C. odorata* collected on 06. 03. 2016 from Kottayam Dt. and 2♀♀ collected on 26. 04. 2015 from Kozhikode Dt., Kerala, India. Coll. Saritha, C.

Remarks: The presently examined specimen shows similarity in morphological characters, dimensions of body shields and measurements of setae with those *C. malaccensis* described by Oudemans (1903) and hence fixed so. This is the first report from the above host plant.

25) Genus: *Hemicheyletia* Volgin, 1969

Generic characters: Dorsolateral body setae relatively narrow, short, spatulate or fan shaped. Palp claw with 6-11 teeth. Peritreme horse shoe shaped. Eyes present, large. Tarsi I-IV with claws and rayed empodium.

1. Hemicheyletia indica Gupta, 1991

Locality: Kerala: Aluva, Athani

Habitat: *Cissampelopsis corymbosa*

Diagnosis

Female: Dorsal body shield 471-478 long and 234-256 wide. Tegmen covered with microtubercles. Eyes large. Dorsal setae 15 pairs in addition to humerals, marginal setae elongate, spatulate. Propodosoma with two pairs of setae and hysterosoma with one pair of setae. Palp claw with seven teeth. Cone shaped stylophore. Both outer and inner comb with seven teeth each. Tarsus I with solenidion, much longer than guard seta. Ventral setae five pairs, genital setae three pairs and anal setae two pairs.

Male: Unknown

Materials examined: 4♀♀ from *C. corymbosa* collected on 14. 12. 2016 from Ernakulam Dt., Kerala, India. Coll. Saritha, C.

Remarks: The present specimen shows resemblance with *H. indica* described by Gupta (1991) in morphological characters, dimensions of body shields and measurements of setae and hence fixed so. This is the first report from Kerala and also from the above host plant.

26) Genus: *Cheletomimus* Oudemans, 1940

Generic characters: Palp claw with variable number of teeth on its inner margin. Palp tarsus with two comb and two sickle like setae with varying number of teeth on inner margin. Eyes present. Tarsi I-IV with two claws.

1. Cheletomimus bakeri Ehara, 1962

Locality: Kerala: Calicut University Campus

Habitat: *Stachytarpeta jamaicensis*

Diagnosis

Female: Palpal claw with nine teeth. Dorsal and outer ventral setae thickened and plume-like. Dorsal, lateral and median setae of the idiosoma fan-like. Propodonotal shield with two pairs of median setae. Median hysteronotal shield well developed, with four pairs of lateral and one pair of median setae. Dorsal shields well punctated. Pregenital setae three pairs, genital setae two pairs and anal setae two pairs. Tibia- I with four setae.

Male: Not found while sampling.

Materials examined: 2♀♀ from *S. jamaicensis* collected on 04. 12. 2015 from Malappuram Dt., Kerala, India. Coll. Saritha, C.

Remarks: The morphological characters of the present specimen greatly resemble those of *C. bakeri* described by Ehara (1962) and hence fixed so. This is a new report from Kerala and also from the above host plant.

viii) Superfamily: Tarsonemoidea Canestrini and Fanzago, 1877

l) Family: Tarsonemidae Kramer, 1877

27) Genus: *Polyphagotarsonemus* Beer and Nucifora, 1965

Generic characters: Ventral metapodosomal setae four pairs, psuedostigmatic organs are expanded distally. Tibia and tarsus IV of the male are fused to form a tibiotarsal segment bearing a buttonlike claw and coxae III and IV of the male are distinctively contiguous.

1. Polyphagotarsonemus latus Banks, 1904

Locality: Kerala: Kuzhalmannam, Mannuthy, Kumarakam, Calicut University Campus, Kondotty

Habitat: *Antigonon leptopus, Lantana camara*

Diagnosis

Female: Body oval, tiny and 227-231 long and 126-132 wide. Propodosoma with four pairs of dorsal setae. Hysterosoma with one pair of ventral setae, situated between coxae IV. Large and well defined anal plate. Legs long, coxa rectangular in shape with a stout seta. Tibiotarsus I without empodium .

Male: Body laterally compressed; tibia and tarsus or tibiotarsus IV slender, elongate, more than three times as long as basal width of tibiotarsus.

Materials examined: 5♀♀ and 3♂♂ from *A.leptopus* collected on 04. 12. 2015 from Malappuram Dt., 2♀♀ and 1♂ from *L. camara* collected on 12. 04.2016 from Palakkad Dt.,1 ♀ from *L. camara* collected on 13. 04.2016 from Thrissur Dt. and 2♀♀ from *L. camara* collected on 25. 07.2016 from Alappuzha Dt., Kerala, India. Coll. Saritha, C.

Remarks: The specimen closely resembles *P.latus* Banks (1904) in all characters and hence confirmed so. This is the first report from the host plant, *A.leptopus.*

28) Genus: *Hemitarsonemus* Ewing, 1939

Generic characters: The stigmata are enlarged and aligned between the vertical and scapular setae. Femur I has three setae. Tarsi II and III have symmetrically developed paired claws.

1. *Hemitarsonemus biconvexa* (Lin & Zhang 1994)

Locality: Kerala: Calicut University Campus, Kondotty, Chaliyam

Habitat: *Mikania micrantha*

Diagnosis

Female: Not found while sampling

Male: Body oval in shape, stigmata large in size. Setae c2 and d 2 - 3 times longer than sc2, angulated protrusion present on the inner flap on femorogenu IV with. Seta v2 approximately same length as v1, seta c2 only somewhat shorter than c1. Ventral propodosomal setae small.

Materials examined : 2♂♂ from *M. micrantha* collected on 04. 12. 2015 from Malappuram Dt., 2♂♂ collected on 16. 04. 2015 from Kozhikode Dt., Kerala, India. Coll. Saritha, C.

Remarks: The specimen closely resembles *H. biconvexa* Lin & Zhang (1994) in all characters and hence confirmed so. This is the first report from the host plant *M.micrantha*.

ix) Superfamily: Tetranychoidea Donnadieu, 1876

m) Family: Tetranychidae Murray, 1877x

29) Genus: *Bryobia* Koch, 1836

Generic characters: The tarsal claws are uncinate or hooked and have tenent hairs. Empodium is pad-like with tenent hairs. There are four pairs of propodosomal setae and two pairs of prominent projections over the rostrum.

78. *Bryobia ehari* Pritchard and keifer, 1958

Locality: Kerala: Puthuppally

Habitat: *Chromolaena odorata*

Diagnosis

Female: Body 431-443 long and 304-308 wide. Prodorsal setae four pairs, placed on anterior lobes. Hysterosoma with 12 pairs of spatulate setae. Dorso-central setae short. Ventral setae smooth. A pair of pregenital and a pair of genital setae present, medium sized. Empodium of tarsus I with two pairs of tenant hairs.

Male: Not found while sampling.

Materials examined: 2♀♀ from *C.odorata* collected on 05. 03. 2016 from K ottayam Dt., Kerala, India. Coll. Saritha, C.

Remarks: This genus is a new report from Kerala and also from the host plant mentioned above.

30) Genus: *Eutetranychus* Banks, 1917

Generic characters: Tarsus I without duplex setae. The tarsi devoid of empodia, the claws padlike and with tenent hairs. Opisthosoma with 10 pairs of dorsal setae, anal setae two pairs.

1. *Eutetranychus orientalis* Klein, 1936 (Plate 6, Fig. f)

Locality: Kerala: Thampanoor, Vagamon, Calicut University Campus, Malappuram, Vengara, Parappanangadi, Kozhikode, Palakkad, Perinkunnam, Tholppetty,Thirunelli, Thrissilery, Thalassery.

Habitat: *Antigonon leptopus, Chromolaena odorata, Merremia vitifolia*

Diagnosis

Female: Body 512-521 long, 337- 348 wide. Peritreme dilated distally. Dorsal idiosomal setae 12 pairs set on strong tubercles and hairy, dorso lateral setae long and lanceolate and dorsocentral setae short and lanceolate. The region between second and third pair of dorsocentral setae with longitudinal striations. Tibia I with two sensory and eight tactile setae, tarsus I with one solenidion and 14 tactile setae. Tibia II with one solenidion and 11 tactile setae.

Male: Aedeagus more or less hook-like, with the distal bent portion longer than the dorsal margin of the shaft, the latter slightly concave. Tarsus I with one sensory and 11 tactile setae; tarsus II with one sensory and 11 tactile setae.

Materials examined: 2♀♀and 1♂ from *C.odorata* 3 ♀♀ and 2 ♂♂ collected on 31. 04. 2015 from Malappuram Dt., 2♀♀ from *C.odorata* collected on 02. 03. 2016 from Thiruvananthapuram Dt., 3♀♀ and 1 ♂ from *M. vitifolia* collected on 22. 03. 2015 from Kozhikode Dt., 2♀♀ from *C.odorata* collected on 12. 08. 2016 from Wayanad Dt. and 2♀♀from collected on 05. 03. 2016 from Idukki Dt., Kerala, India. Coll. Saritha, C.

Remarks: All the characters of the present specimen are similar to those of *E. orientalis* Klein (1936) and hence fixed so. This is the first report of the species from the species of host plants mentioned above**.**

2. *Eutetranychus africanus* Tucker, 1926

Locality: Kerala: Vettukadu, Kondotty

Habitat: *Merremia vitifolia*

Diagnosis

Female: Body 532-539 long, 340-346 wide. Dorsal setae10 pairs, subspatulate and long. Longitudinal striae between second and third pairs of dorsocentral hysterosomal setae. Anal setae two pairs. Empodium absent. Coxa II bears two setae, femur IV with one seta. Tarsi I and II with associated setae, length of the tactile setae more or less same as that of the solendion.

Male: Distal bent of aedeagus relatively shorter than dorsal margin of shaft. Coxa II bears two setae, femur IV with one seta.

Materials examine: 2♀♀ and 2♂♂ from *M. vitifolia* collected on 28. 05. 2015 from Malappuram Dt., Kerala, India. Coll. Saritha, C.

Remarks: All the characters of the present species are similar to those of *E. africanus* described by Tucker (1926) and hence fixed so. This is a new report of the species from Kerala and also from the above host plant**.**

31) Genus: *Oligonychus* Berlese, 1886

Generic characters: Empodium claw like with proximoventral hairs. The true claws are padlike with tenent hairs. Opisthosoma with 10 pairs of dorsal setae, two pairs of anal setae and one pair of para anal setae.

1. *Oligonychus biharensis* Hirst, 1924 (Plate 9, Fig. h)

Locality: Kerala: Calicut University Campus, Malappuram, Parappanangadi, Kuzhalmannam, Alathur, Perinkunnam, Thenkurissi, Yakkara, Cheruvennur,Vengeri

Habitat: *Antigonon leptopus, Synedrella nodiflora, Tridax procumbens*

Diagnosis

Female: Body 558-561 long, 342-345 wide. Dorsal body setae long, dorsal idiosomal setae thin, simple, slender and longer than the interval between their longitudinal bases. Peritreme turned backwards distally. Genital flap with transverse striae. Tarsus I with four tactile setae and one solenidion proximal to proximal duplex setae.

Male: Shaft of aedeagus bent dorsad, forming a long knob distally, the latter longer than the dorsal margin of the shaft, with a small and acute anterior projection and a long posterior projection. Tarsus I with four tactile setae and three solenidia proximal to proximal duplex setae. Tarsus II with three tactile setae and one solenidion proximal to duplex setae.

Materials examined: 5♀♀ and 2♂♂ from *A. Leptopus* and 2♀♀ and 1♂ from *S. nodiflora* collected on 18. 05. 2015 from Malappuram Dt., 3♀♀ and 2♂♂ from *T. procumbens* collected on 24.11. 2016 from Palakkad Dt. and 2♀♀ from *S. nodiflora* collected on 18. 08. 2015 from Kozhikode Dt., Kerala, India. Coll. Saritha, C.

Remarks: the specimen closely resembles *O.biharensis* described by Hirst (1924) in all the characters and hence confirmed so. This is the first report of the species from all species of host plants mentioned above.

2. *Oligonychus indicus* Hirst, 1923 (Plate 6, Fig. h; Plate 10, Fig. c)

Locality: Kerala: Calicut University Campus, Malappuram

Habitat: *Desmodium tortuosum*

Diagnosis

Female: Body including rostrum 524-527 long, 341 -346 wide. Distal portion of peritreme ending into bulb. Dorsal body setae long, simple and longer than

the interval between their longitudinal bases. Tibia I with one sensory and eight tactile setae, tarsus I with two sensory and two tactile setae proximal to duplex setae. Tibia II with one sensory and si x tactile setae, tarsus II with one sensory and three tactile setae proximal to duplex setae. Outer and inner sacrals of same length. Genital flap with transverse striae.

Male : Body including rostrum 390 long, 235 wide. Dorsal body setae longer than the interval between their longitudinal bases. Tibia I with two sensory and 11 tactile setae, tarsus I with two sensory and four tactile setae proximal to duplex setae. Aedeagus with distal knob very small, the bend of aedeagus forms a small angle with axis of the shaft.

Materials examined: 4♀♀ and 2♂♂ from *D. tortuosum* collected on 28. 01. 2019 from Malappuram Dt., Kerala, India. Coll. Saritha, C.

Remarks: The specimen examined shows all the characters similar to those of *O. indicus* Hirst (1923) and hence fixed so. This is the first report from Kerala and also from the above host plant**.**

3. *Oligonychus coffeae* Nietner, 1861

Locality: Kerala: Champakulam, Calicut University Campus, Cherpulassery, Kattikkulam, Tholppetty, Thrissilery

Habitat: *Sphagneticola trilobata*

Diagnosis

Female: Body 591-598 long, 383-391 wide. Dorsal body setae serrate, longer than distance between the base of subsequent setae. Genital flap with transverse striae and pre-genital striae longitudinal to transverse. Tarsus I with three tactile setae and one solenidion proximad to proximal duplex setae .

Tarsus II with three tactile setae and one solenidion proximal to duplex setae, one tactile seta present laterally at the level of duplex setae.

Male: Aedeagus bent ventrad at right angle to the axis of the shaft and gradually narrows to a slender truncated tip. Tarsus I with three tactile setae and three solenidia proximad to proximal duplex setae. Tarsus II with three tactile setae and one solenidion proximal to duplex setae, one tactile seta present laterally at the level of duplex setae.

Materials examined : 4♀♀ and 2♂♂ from *S.trilobata* collected on 26. 01. 2016 from Malappuram Dt., 2♀♀ and 2♂♂ collected on 06. 03. 2016 from Kottayam Dt., 2♀♀ collected on 16. 05. 2016 from Wayanad Dt ., Kerala, India. Coll. Saritha, C.

Remarks: All the characters of the present specimen are similar to those of *O. coffeae* Nietner (1861) and hence fixed so. This is the first report from the above host plant**.**

32) Genus: *Schizotetranychus* Tragardh, 1915

Generic characters: Tarsus I with two pairs of closely associated duplex setae. The empodium splits distally into two claws. Opisthosoma with 10 pairs of dorsal setae, two pairs of para anal setae and two pairs of anal setae.

***1. Schizotetranychus lespedezae* Beglyarov and Mitrofanov, 1973 (Plate 6, Fig. i)**

Locality: Kerala: Calicut University Campus

Habitat: *Desmodium tortuosum*

Diagnosis

Female: Body pale green in colour, 345-356 long and 226-232 wide. Peritreme dilated distally, bent near tip. Genital flap with transverse striae and

pre-genital area with variable striae, irregular to transverse. Empodium with two fine dorsal hairs on each of the claw like processess. Tarsus I with four tactile setae and one solenidion proximad to proximal duplex setae. Tarsus II with two tactile setae and one solenidion proximal to duplex setae.

Male: Aedeagus bent dorsad, knob long and slender, at an angle with the shaft. Empodium I spilts into two claws. Tarsus I with four tactile setae and three solenidia proximad to proximal duplex setae. Tarsus II with two tactile setae and one solenidion proximal to duplex setae.

Materials examined: 6♀♀ and 4♂♂ from *D. tortuosum* collected on 19. 05. 2018 from Malappuram Dt., Kerala, India. Coll. Saritha, C.

Remarks: The morphological features of the present specimen are identical with those of *S. lespedezae* Beglyarov and Mitrofanov (1973) and hence fixed so. This is a new record from Kerala and also from the above host plant.

33) Genus: *Tetranychus* Dufour, 1832

Generic characters: Empodium splits in to three pairs of hairs distally, empodial spur usually visible, duplex setae of tarsus I widely separated. Dorsal body setae long and slender. Paraanal setae one pair.

***1. Tetranychus urticae* Koch, 1836 (Plate 6, Fig. j; Plate 9, Fig. f; Plate 10, Fig. a & d)**

Locality: Kerala: Karyavattom, Kumarakom, Parunthumpara, Aluva, Peechi, Palakkad, Kuzhalmannam, Malappuram, Kondotty, Thondayadu, Kololam, Mananthavady

Habitat: *Tridax procumbens, Mikania micrantha, Merremia vitifolia, Synedrella nodiflora, Pueraria phaseoloides, Lantana camara*

Diagnosis

Female: Body 532-540 long and 373- 382 wide. Dorsal idiosomal setae much longer than the interval between their longitudinal bases. Peritreme hooked. Genital flap with transverse striae and the striae of the pre-genital area seen as few broken lines. Tarsus I with five tactile setae proximal to proximal duplex setae. Empodia with six proximoventral hairs.

Male: Smaller than females. Aedeagus small knob like and its axis forms a small angle with the axis of the shaft. Anterior and posterior projections of the knob more or less similar. Empodium I claw like, empodia II–IV with long proximoventral hairs.

Materials examined : 7 ♀♀ and 5♂♂ from *M.vitifolia,,* 4♀♀ and 3♂♂ from *S. nodiflora* , 2♀♀ and 2♂♂ from *M. micrantha* collected on 27. 03. 2015 from Malappuram Dt., 3♀♀ and 2♂♂ from *T. procumbens* 2♀♀ and 2♂♂ from *M.micrantha* and 4 ♀♀ and 2♂♂ from *M.vitifolia,* collected on 25.11. 2016 from Palakkad Dt., 2♀♀ from *S. nodiflora,* 3♀♀ and 2♂♂ from *L.camara* collected on 18. 08. 2015 from Kozhikode Dt., 2♀♀ and 1♂ from *L.camara,* 3♀♀ and 1♂ from *P. phaseoloides* collected on 28.09. 2017 from Wayanad Dt., 3♀♀ and 2♂♂ from *L.camara*, 2♀♀ and 1♂ from *P. phaseoloides* collected on 19.09. 2016 from Idukki Dt., 2♀♀ and 1♂ from collected on *L.camara* collected on 18. 02. 2015 from Thiruvananthapuram Dt., 2♀♀ and 2♂♂ from *M. micrantha* collected on 21. 02. 2016 from Ernakulam Dt., 2♀♀ and 2♂♂ from collected on *L.camara* and 2♀♀ *M.micrantha* collected on 11. 03. 2015 from Kannur Dt., Kerala, India. Coll. Saritha, C.

Remarks: All the characters of the specimen examined are similar to those of *T. urticae* Koch (1836) and hence fixed so. This is the first report from all the above mentioned host plants.

2. *Tetranychus neocaledonicus* Andre, 1933 (Plate 9, Fig. g)

Locality: Kerala: Karyavattom, Athirampuzha, Parunthumpara, Nelliyampathy, Palakkad, Calicut University Campus, Pulikkal, Kozhikode, Ambalavayal

Habitat: *Antigonon leptopus, Mikania micrantha, Merremia vitifolia, Ageratum conizoides*

Diagnosis

Female: Body 547-558 long, 313-319 wide. Hysterosomal striae form diamond shaped pattern between third (*e*1) and fourth (*f*1) dorsocentral setae. Genital flap with transverse striae and pre-genital area with broken lines. Tarsus I with four tactile setae proximad to proximal duplex setae. Tarsus II with three tactile setae and one solenidion proximal to duplex setae.

Male: Aedeagus bent dorsally, knob of the aedeagus berry-like, the rounded anterior projection more strongly developed than the posterior. Tarsus I with four tactile setae and two solenidia proximad to proximal duplex setae. Empodium I with a relatively small mediodorsal spur and long proximoventral spur. Tarsus II with three tactile setae and one solenidion proximal to duplex setae.

Materials examined: 5♀♀ and 3♂♂ from *M.vitifolia,*, 4♀♀ and 3♂♂ from *A. leptopus*, 2♀♀ and 2♂♂ from *A. conizoides* collected on 17. 09. 2015 from Malappuram Dt., 3♀♀ and 2♂♂ from *M.micrantha* and 4 ♀♀ and 2♂♂ from *A.conizoides* collected on 26.11. 2016 from Palakkad Dt., 2♀♀ and 2 ♂♂from *M. micrantha* collected on 28. 06. 2015 from Kozhikode Dt., 2♀♀ and 2♂♂ from *L.camara,* 3♀♀ and 1♂ from *M.micrantha* collected on 18.09. 2017 from Wayanad Dt., 3♀♀ and 2♂♂ from *L.camara,* 2♀♀ and 1♂ from *M. vitifolia* collected on 19.09. 2016 from Idukki Dt., 2♀♀ and 1♂ from

collected on *L.camara* collected on 18. 02. 2015 from Thiruvananthapuram Dt., 2♀♀ and 2♂♂ from *M. micrantha* collected on 21. 02. 2016 from Kottayam Dt., Kerala, India. Coll. Saritha, C.

Remarks: All the characters of the specimen agree with those of *T. neocaledonicus* Andre (1933) and hence fixed so. This is the first report from the host plants mentioned above.

3. *Tetranychus ludeni* Zacher, 1913 (Plate 10, Fig. b)

Locality: Kerala: Calicut University Campus, Malappuram, Ramanattukara, Lakkidi

Habitat: *Merremia vitifolia, Lantana camara*

Diagnosis

Female: Body 558-563 long, 378-384 wide. Palpus with terminal sensillum one and half times as long as wide. Peritreme hooked distally. Dorsal striae between *e1* and *f1* forming a diamond shape. Genital flap with transverse striae and pre-genital area with longitudinal striae along with few broken lines. Tarsus I with one sensory and three tactile setae proximal to duplex setae and one solenidion distal to proximal duplex setae. Tarsus II with three tactile setae and one solenidion proximal to duplex setae.

Male: Aedeagus bent dorsad at right angle and terminates distally with a knob. Anterior projection of the knob acute and no posterior projection. Knob with rounded dorsum. Tarsus I with one tactile seta and two solenidia proximal to proximal duplex setae and three tactile setae in line with proximal duplex setae. Tarsus II with three tactile setae and one solenidion proximal to duplex setae.

Materials examined: 3♀♀ and 3♂♂ from *M.vitifolia.*, 4♀♀ and 2♂♂ from *L. camara* collected on 17. 09. 2017 from Malappuram Dt., 3♀♀ and 2♂♂ from *M .vitifolia* and 4 ♀♀ and 2♂♂ from *L.camara* collected on 16.11. 2015 from Kozhikode Dt., 2♀♀ and 2♂♂ from *L.camara,* collected on 18.09. 2017 from Wayanad Dt., Kerala, India. Coll. Saritha, C.

Remarks: All the characters of the specimens examined were found similar to those of *T. neocaledonicus* Andre (1933) and hence fixed so. This is the first report from both species of host plants mentioned above.

4. *Tetranychus marianae* McGregor, 1950 (Plate 6, Fig. g)

Locality: Kerala: Calicut University Campus, Malappuram, Athani

Habitat: *Merremia vitifolia*

Diagnosis

Female: Body 582-587 long, 380-386 wide. Peritreme hooked distally. Hysterosomal striae transverse and longitudinal between *e*1 and *f*1 bases form diamond-shaped pattern. Genital flap with transverse and pre-genital area with broken longitudinal lines. Tarsus I with four tactile setae proximad to proximal duplex setae. Tarsus II with thee tactile setae and one solenidion proximal to duplex setae.

Male: Terminal sensillum thrice as long as broad. Aedeagal knob axis at an acute angle with the shaft. Knob with a small anterior angulation and with a long dorsocaudally oriented posterior angulation. Width of the knob more than the width of the neck. Tarsus I with four tactile setae and two solenidia proximad to proximal duplex setae. Tarsus II with three tactile and one solenidion proximal to duplex setae.

Materials examined: 2♀♀ and 2♂♂ from *M.vitifolia*, collected on 16. 01. 2016 from Malappuram Dt., 2♀♀ and 1♂ collected on 12.09. 2017 from Ernakulam Dt., Kerala, India. Coll. Saritha, C.

Remarks: All the characters of the present specimen are similar to those of *T. marianae* McGregor (1950) and hence fixed so. This is the first report from Kerala and also from the above host plant**.**

5. *Tetranychus macfarlanei* Baker and Pritchard, 1960

Locality: Kerala: Tharekkad, Palakkad

Habitat: *Cassia tora*

Diagnosis

Female: Body 561-569 long, 378-384 wide. Peritreme hooked distally. Dorsal striae irregularly longitudinal between third and fourth dorsocentrals, forming diamond shaped pattern. Genital flap with two types of striae anterior ones longitudinal and the posterior ones transverse, pregenital area shows a triangular pattern with few broken lines. Tarsus I with one tactile seta slightly proximal to proximal duplex setae and three tactile setae in line with proximal duplex setae and one solenidion distal to proximal duplex setae.

Male: Smaller than female. Aedeagal knob very short, with tiny anterior and posterior angulations and axis of knob parallel to that of the shaft. Tarsus I with one tactile seta and two solenidia proximad to proximal duplex setae, three tactile setae in line with proximal duplex setae. Tarsus II with three tactile setae and one solenidion proximal to duplex setae.

Materials examined: 4♀♀ and 2♂♂ from *C.tora*, collected on 26. 05. 2016 from Palakkad Dt., Kerala, India. Coll. Saritha, C.

Remarks: The present specimen possesses all characters similar to those of *T. macfarlanei* Baker and Pritchard (1960) and hence fixed so. This is the first report from the host plant mentioned above.

n) Family: Tenuipalpidae Berlese, 1913

34) Genus: *Brevipalpus* Donnadieu, 1875

Generic characters: Body oval and narrows posteriorly. The palpus consists of four segments. Dorsolateral hysterosomal setae five or six pairs, without dorsosublateral setae. Genital plate usually rectangular, similar to anterior ventral plate.

1. *Brevipalpus phoenicis* Geijskes, 1939 (Plate 6, Fig. m; Plate 9, Fig. e)

Locality: Kerala: Karyavattom, Thampanoor, Athirampuzha, Mararikulam,Vagamon, Parunthumpara, Aluva, Athani, Mannuthi, Kodungallur, Perinkunnam, Palakkad, Yakkara, Madavoor, Kovoor, Feroke, Cheruvannur, Vengeri, Maikave, ThamarasseryParappanangadi, Calicut University Campus, Vettukadu, Pulikkal, Olavattur, Aroor, Muthuvalloor,Tholpetty, Thirunelli, Kololam, Cheruvathur

Habitat: *Chromolaena odorata, Lantana camara, Antigonon leptopus, Mikania micrantha, Sphagneticola trilobata, Merremia vitifolia, Clidemia hirta, Cassia tora, Calotropis procera, Tridax procumbens, Synedrella nodiflora*

Diagnosis

Female: Dorsal shield 290-295 long and 163-169 wide. Hysterosoma with five pairs of dorsolateral setae and one pair of humeral setae. Tarsus II with two solenidia. A pair of hysterosomal pores present. Dorsocentral surface of

propodosoma covered with a scallop pattern whereas dorsocentral part of hysterosoma bears only irregular striae.

Male: Unknown

Materials examined: 5♀♀ from *M.vitifolia,* 6♀♀ from *L. camara,* 2♀♀ *A. leptopus,* 2♀♀ from *M. micrantha,* 3♀♀ from *T. procumbens,* 2♀♀ from *S.nodiflora* collected on 18. 04. 2016 from Malappuram Dt., 3♀♀ from *M.micrantha* and 4♀♀ from *C. hirta,* 6♀♀ from *L. camara,* 3♀♀ from *T. procumbens* collected on 25.11. 2016 from Palakkad Dt., 2♀♀ from *M. micrantha,* 6♀♀ from *L.camara* collected on 23.11.2017 from Kozhikode Dt., 2♀♀ from *L.camara,* 3♀♀ from *M.micrantha,* 2♀♀ from *L.camara*, 3♀♀ from *M.vitifolia , 2*♀♀ from *T.procumbens* collected on 18.09. 2017 from Wayanad Dt., 4♀♀ from *L.camara,* 2♀♀ from *C.hirta,* 2♀♀ *M* collected on 19.09. 2016 from Idukki Dt., 2♀♀ from collected on *L.camara* collected on 02. 12. 2017 from Thiruvananthapuram Dt., 2♀♀ from *M. micrantha* , collected on 21. 02. 2016 from Kottayam Dt., 3♀♀ from *M.vitifolia,* 3♀♀ from *M.micrantha,* 2♀♀ from *L.camara,* 2♀♀ from collected on 14.12. 2016 from Ernakulam Dt., 3♀♀ from *M.micrantha* collected on 31.12. 2015 from Kasaragode Dt., Kerala, India. Coll. Saritha, C.

Remarks: In almost all characters, the present specimen appears very close to *B .phoenicis* Geijskes (1939) and hence fixed so. This is the first report from the above mentioned species of host plants except *L.camara*.

2. *Brevipalpus obovatus* Donnadieu, 1875 (Plate 6, Fig. l; Plate 9, Fig. d)

Locality: Kerala: Chaliyam, Kozhikode, Parappanangadi, Calicut University Campus

Habitat: *Antigonon leptopus, Lantana camara, Desmodium tortuosum*

Diagnosis

Female: Dorsal shield 289-292 long and 164-168 wide. Dorsocentral surface of propodosoma covered with a scallop pattern and dorsocentral part of the hysterosoma with only irregular striae. Hysterosoma with six pairs of dorsolateral setae and one pair of humeral setae. A pair of hysterosomal pores present. Palps four-segmented, palptarsus with three setae. A single solenidion present on tarsus II.

Male: Unknown

Materials examined: 3♀♀ from *L. camara,* 4♀♀ *A. leptopus*, 2♀♀ from *D.tortuosum* collected on 13. 12. 2016 from Malappuram Dt., 2♀♀ from *L.camara*, 2♀♀ from *A. leptopus* collected on 23.11.2017 from Kozhikode Dt., Kerala, India. Coll. Saritha, C.

Remarks: The present spesent specimen strongly agrees in all features with *B.obovatus* Donnadieu (1875) and hence fixed so. This is the first report from all species of host plants mentioned above.

3. *Brevipalpus californicus* Banks, 1904 (Plate 6, Fig. k; Plate 9, Fig. c)

Locality: Kerala: Calicut University Campus

Habitat: *Merremia vitifolia, Desmodium tortuosum*

Diagnosis

Female: Body 282-290 long and 161-165 wide, pear shaped, flat with regular mediolateral reticulations on propodosoma, reticulation pattern usually covers the entire propodosoma. . Hysterosoma with five pairs of dorsolaterals setae. Palps four segmented. Tarsus II with two distal solenidia.

Male: Unknown

Materials examined : 3♀♀ from *M. vitifolia,* 2♀♀ from *D.tortuosum* collected on 13. 12. 2016 from Malappuram Dt., Kerala, India. Coll. Saritha, C.

Remarks: In all characters, the specimen resembles strongly with *B.californicus* Banks (1904) and hence fixed so. This is a new report from Kerala and also from both species of host plants mentioned above.

35) Genus: *Raoiella* Hirst, 1924

Generic characters: Body of female mite strongly rounded in shape. Rostral shield absent. Hysterosoma with four pairs of dorsosublateral setae. Palp two segmented.

***1. Raoiella macfarlanei* Pritchard and Baker, 1958**

Locality: Kerala: Munnar

Habitat: *Pteridium aquilinum*

Diagnosis

Female: Body 262-273 long and 192-199 wide. Dorsum of idiosoma smooth and round. Palpus two segmented. Dorsal opisthosoma with 13 pairs of setae, long and rod like with clavate tips. Hysterosoma with dorsocentrals clavate, about as long as longitudinal intervals between them.

Fourth dorsosublateral hysterosomal seta very long and longer than first three dorsosublateral ones.

Male: Not found while sampling.

Materials examined: 3♀♀ from *P.aquilinum* collected on 12. 03. 2016 from Idukki Dt., Kerala, India. Coll. Saritha, C.

Remarks: The present specimen closely resembles with *R. macfarlanei* Pritchard and Baker (1958) in all features and hence fixed so. This is the first report from the host plant.

36) Genus: *Tenuipalpus* Donnadieu, 1875

Generic characters: This genus characterized with varying number of palpal segments. The posterior margin of hysterosoma possesses a pair of long, flagellate setae, five or six pairs of dorsolateral plus the humeral setae. Podosoma broad and opisthosoma narrow.

***1. Tenuipalpus granati* Sayed, 1946**

Locality: Kerala: Villoonniyal

Habitat: *Chromolaena odorata*

Diagnosis

Female: Dorsal shield 243-252 long and 130-137 wide. Dorsum striated with most dorsal setae very short, serrate, except for setae sce on propodosoma and setae h1, h2 (flagellate), f3, f2 and e3 on hysterosoma; only one pair of dorsocentrals (c1) present; three pairs of ventral metapodosoma; hysterosoma with a pair of large pores. A single solenidion present on tarsus II.

Male: Unknown

Materials examined: 2♀♀ from *C.odorata* collected on 23. 09. 2018 from Malappuram Dt., Kerala, India. Coll. Saritha, C.

Remarks: The present specimen strongly agrees with *T. granati* Sayed (1946) in all characters and hence fixed so. This is the first report from Kerala and from the above host plant.

2. *Tenuipalpus punicae* Pritchard and Baker, 1958

Locality: Kerala: Calicut University Campus,Thirunelli

Habitat: *Desmodium tortuosum*

Diagnosis

Female: Dorsal shield 278-289 long and 122-129 wide. Propodosoma rugose mediodorsally. Hysterosoma with dorsocentrals minute and setiform. Dorsolateral seta flagellate and four pairs of nonflagellate setae caudally. Hysterosoma with six pairs of dorsolateral setae, one pair of humeral setae and a pair of hysterosomal pores. Palps four segmented, palptarsus with three setae. A single solenidion on tarsus II. Genu II and I each with a seta on outer side.

Male: Unknown

Materials examined: 2♀♀ from *D.tortuosum* collected on 13. 09. 2016 from Malappuram Dt., 2♀♀ collected on 25.09.2017 from Wayanad Dt., Kerala, India. Coll. Saritha, C.

Remarks: The present specimen stands identical in all respects with *T. punicae* Pritchard and Baker (1958) and hence fixed so. This is the first report from Kerala and from the above host plant.

x) Superfamily: Eriophyoidea Nalepa, 1898

o) Family: Eriophyidae Nalepa, 1898

37) Genus: *Acalitus* Keifer, 1965

Generic characters: Opisthosoma worm-like, annuli usually with many microtubercles dorsally and ventrally. The genital setae directed posteriorly.

1. ***Acalitus adoratus*** **Keifer, 1970 (Plate 7, Fig. b; Plate 10, Fig. g; Plate 24, Fig. a – g)**

Locality: Kerala: Karyavattom, Thampanoor, Kizhakkekotta, Puthuppally, Athirampuzha, Parunthumpara, Vagamon, Peechi, Pattikkadu, Mannuthi, Vaniyampara, Kuthiran, Perinkunnam, Alathur, Kuzhalmannam, Kongad, Parappanangadi, Vengara, Vettukad, Pulikkal, Calicut University Campus ,Vengeri, Kozhikode, Ramanattukara, Lakkidi, Pookode, Kattikkulam, Tholppetty,Thirunelli, Thrissilery, Kololam, Thalassery,Cheruvathur

Habitat: *Chromolaena odorata*

Diagnosis

Female: Body elongate, worm like, white in color, measuring 150-162 long and 51-56 wide. Rostrum 16 long. Prodorsal shield with setal tubercles set near to the rear margin, setae directed posteriorly, shield with clear lines. Abdomen with 62 rings or annuli with many microtubercles dorsally and ventrally arranged on the ring margins, which fill the gap between the rings. Lateral seta 12 long on ring 8, 1st ventral seta 11.5 long on 9 ring, 2nd ventral seta 14 long on 19 th ring , 3rd ventral seta 13 long on 48 ring and caudal seta19 long on the terminal knob, accessory seta absent. Genitalia 13 long and 11 wide, genital cover flap with longitudinal lines, genital seta 4 long. Leg I 24 long, Leg II 21 long, both with six segments. Feather claw four rayed, 4 long.

Male: Smaller than females, 147 long and 36 wide, genitalia 11 long and 19 wide.

Materials examined: 13♀♀ and 5♂♂ from *C.odorata,* collected on 13. 02. 2016 from Malappuram Dt., 6 ♀♀ collected on 13. 02. 2016 from Palakkad Dt., 5♀♀ and 4♂♂ collected on 13.11.2017 from Kozhikode Dt., 5♀♀ and 2♂♂ collected on 13.11.2017 from Wayanad Dt., 5♀♀ and 3♂♂ collected on

15. 04.2016 from Kannur Dt., 5♀♀ and 2♂♂ collected on 11. 02.2017 from Thiruvananthapuram Dt., 4♀♀ and 2♂♂ collected on 05.04.2016 from Kottayam Dt., 4♀♀ collected on 12. 03.2016 from Idukki Dt., 6 ♀♀ and 2♂♂ collected on 11.07.2017 from Kasaragod Dt., Kerala, India. Coll. Saritha, C.

Remarks: The specimen collected during the study resembles with *A. adoratus* described by Keifer (1970) in all morphological characters and hence fixed so.

38) Genus: *Aceria* Keifer, 1944

Generic characters: Body worm like, rostrum variable in size, shield usually subtriangular. Prodorsal shield setal tubercles set on or near margin of shield, the setae directed posteriorly, divergently.

***1. Aceria mikaniae* Nalepa, 1918 (Plate 10, Fig. e)**

Locality: Kerala: Perinkunnam, Tharekkad, Shornur, Calicut University Campus

Habitat: *Mikania micrantha*

Diagnosis

Female: Body 208-214 long, 66-74 wide, fusiform. Prodorsal shield 28 long, 43 wide, anterior lobe present. Prodorsal shield with several short lines at posterior and lateral sides. Seta (*sc*) directed backwards. Leg segments normal, solenidion ending as knob; empodium simple, six rayed. Opisthosoma with 84 microtuberculate rings. Genital coverflap 14 long and 21 wide, with about 15 longitudinal lines.

Male: Not found while sampling.

Materials examined : 3♀♀ from *M. micrantha* collected on 14. 09. 2016 from Malappuram Dt., 2♀♀ collected on 15.04.2017 from Palakkad Dt., Kerala, India. Coll. Saritha, C.

Remarks: The morphological characters of the present specimen show close resemblance with *A. mikania* described by Nalepa (1918) and hence fixed so. This is the first report from Kerala.

39) Genus: *Aculus* Keifer, 1959

Generic characters: Body fusiform. The feather claw is four rayed. The anterior shield lobe is moderately wide dorsally. Opisthosomal dorsum evenly rounded in cross section, not forming ridges or troughs. The female genital coverflap has 12 to 14 longitudinal ribs.

***1. Aculus cassiae* Mondal and Chakrabarti, 1981 (Plate 6, Fig. n)**

Locality: Kerala: Tholpetty, Thirunelli

Habitat: *Cassia tora*

Diagnosis

Female: Body 170-177 long and 61-68 wide, yellowish in colour, elongate, fusiform. Rostrum 22 long. Abdomen with 47 tergites and 69 microtuberculated sternites. Genital coverflap with 12 longitudinal scorings. Claw long, without knobs, featherclaw simple and six rayed.

Male: Unknown.

Materials examined : 3♀♀ from *C.tora* collected on 24. 09. 2017 from Wayanad Dt., Kerala, India. Coll. Saritha, C.

Remarks: The morphological characters, dimensions of body shields and measurements of dorsal setae of the present specimen appear similar to those

of *A. cassia* described by Mondal and Chakrabarti (1981). This is the first report from Kerala.

2. Aculus indicus ChannaBasavanna, 1966 (Plate 11, Fig. a)

Locality: Kerala: Calicut University Campus, Alathur

Habitat: *Tridax procumbens*

Diagnosis

Female: Body 162-170 long and 61-68 wide, fusiform, often flattened. Gnathosoma projecting obliquely down. Prodorsal shield with broad and round frontal lobe and prominent scapular setae, shield with scapular setae on or near rear margin; setae usually directed divergently posterior. Opisthosoma typically divided into broad and stout dorsal annuli, and narrow, microtuberculate ventral annuli.

Male: Smaller than females.

Materials examined: 3♀♀ and 2♂♂from *T.procumbens* collected on 21. 11. 2017 from Malappuram Dt., 2♀♀ and 1♂ collected on 04. 02. 2016 from Palakkad Dt., Kerala, India. Coll. Saritha, C.

Remarks: This is the first report from Kerala.

40) *Calacarus* Keifer, 1940

Generic characters: Purple coloured mites. Dorsal shield with white wax stripes, followed by longitudinal ridges. This mites lack prominent dorsal setae and dorsal tubercles. They have a characteristic lateral line of shield formed by longitudinal and diagonal ridges.

1. Calacarus carinatus Green, 1890 (Plate 10, Fig. f)

Locality: Kerala: Perinkunnam, Palakkad, Villoonniyal, Vettukad

Habitat: *Tridax procumbens*

Diagnosis

Female: Body 207-219 long, 82-91 wide, fusiform and purple coloured with five white ridges of waxy material running longitudinally on the dorsal side of the abdomen. Gnathosoma 55 long, large and projected downwards. Prodorsal shield 59 long, 76 wide. Dorsal annuli 64 with five dorsal longitudinal ridges, smooth. Ventral annuli 78, microtubercles small on rear annular margins. Genital coverflap smooth with short faint lines. Empodia five rayed, tarsal solenidia strongly knobbed.

Male: Not found while sampling.

Materials examined: 5♀♀ from *T.procumbens* collected on 25. 12. 2015 from Malappuram Dt., 2♀♀ collected on 04. 02. 2016 from Palakkad Dt., Kerala, India. Coll. Saritha, C.

Remarks: The morphological characters of the present specimen are similar to those given in the original description made by Green (1890), for *C. carinatus* and hence fixed so. This is the first report from the host plant.

2. *Calacarus lantanae* Boczek and Chandrapatya, 1989

Locality: Kerala: Perinkunnam, Palakkad, Kalpatta, Calicut University Campus

Habitat: *Lantana camara*

Diagnosis

Female: Body 203-210 long, 67-76 wide, fusiform, purple coloured with three white ridges of waxy material running longitudinally on the dorsal side of the abdomen. Gnathosoma relatively small with short form oral stylet. Empodial featherclaw simple. Lateral setae and first setiferous coxal tubercles present. Dorsal setae absent.

Male: Not found while sampling.

Materials examined: 4♀♀ from *L. camara* collected on 26. 12. 2015 from Malappuram Dt., 2♀♀ collected on 06. 04. 2016 from Palakkad Dt., 1♀ collected on 26. 04. 2017 from Wayanad Dt., Kerala, India. Coll. Saritha, C.

Remarks: The specimen resembles *C. lantanae* described by Boczek and Chandrapatya (1989), in all morphological features and hence fixed so. This is the first report from Kerala.

3. *Calacarus kalyaniensis* Pranab and Karmakar, 2016

Locality: Kerala: Thampanoor, Peechi, Perinkunnam, Palakkad, Thrissilery

Habitat: *Chromolaena odorata*

Diagnosis

Female: Body 232-238 long, 71-79 wide, fusiform, blackish in colour. Gnathosoma projecting downwards. Prodorsal shield suboval, frontal lobe 5; anterior middle with a hexagonal cell surrounded by smaller cells; median line cons picuous from middle to rear without touching rear shield margin. Prodorsal shield waxy. Scapular seta (*sc*) absent; with minute scapular setal tubercles slightly anterior to rear shield margin. Legs with all usual segments. Leg I with tarsal empodium five rayed, rays divided except for distal ray,

tarsal solenidion (ω) knobbed. Genital coverflap 26 wide. Opisthosoma with 78 dorsal annuli, all microtuberculated.

Male: Unknown

Materials examined: 4♀♀ from *C. odorata* collected on 06. 04. 2015 from Thiruvananthapuram Dt., 4♀♀ collected on 06. 04. 2016 from Palakkad Dt., 5♀♀collected on 26. 04. 2017 from Wayanad Dt., 2♀♀ collected on 17. 04. 2016 from Thrissur Dt., Kerala, India. Coll. Saritha, C.

Remarks: The morphological characters of the present specimen agree with those of *C. kalyaniensis* described by Pranab and Karmakar (2016) and hence fixed so. This is the first report from Kerala.

41) *Diptilomiopus* Nalepa, 1916

Generic characters: Body fusiform. Prodorsal shield without scapular setae, *sc*. Cheliceral stylets relatively long, bent down near base. Coxal setae absent. Empodial feather claw often with main shaft divided.

1. *Diptilomiopus camerae* Mohansundaram, 1981 (Plate 7, Fig. d)

Locality: Kerala: Palakkad, Tholpetty, Thrissilery

Habitat: *Lantana camara*

Diagnosis

Female: Body 193-199 long, 71-80 wide. Prodorsal shield with clear pattern of cells. Median, admedian and submedians forming three clear cells, one below the other on either side and four cells on each side along the anterior border. Gnathosoma large and abruptly curved downwards, with long-form oral stylet. Abdomen with 59 clear smooth tergites and 75 finely microtuberculate sternites. Genital coverflap without any line, basal portion of

coverflap with thick dot like granulations. Feather claw divided, each with six rays.

Male: Smaller than females.

Materials examined: 6♀♀ and 2♂♂ from *L.camara* collected on 06. 04. 2016 from Palakkad Dt., 5♀♀ and 1♂ collected on 26. 04. 2017 from Wayanad Dt., Kerala, India. Coll. Saritha, C. **Remarks:** Based on its morphological similarity with *D. camerae* described Mohansundaram (1981), the present specimen was assigned to the above species. This is the first report from Kerala.

42) *Eriophyes* von Siebold, 1851

Generic characters: Opisthosoma worm-like, annuli usually with many microtubercles dorsally and ventrally. Prodorsal shield setal tubercles usually set more or less ahead of rear margin of shield, directing setae anteriorly.

1. *Eriophyes camarae* sp.nov.(Plate 7, Fig. a; Plate 11, Fig. b; Plate 27, Fig. a – g)

Locality: Kerala: Vagamon, Palakkad, Tholpetty, Thrissilery, Calicut University Campus

Habitat: *Lantana camara*

Diagnosis: Median and admedian lines subequal in length; the latter converging towards the anterior end. Submedian lines short, present on the posterior part of shield. Opisthosoma with 71 dorsal and 89 ventral annuli, each annulus provided with about 19 microtubercles. Genital coverflap with 7 longitudinal lines and slightly granulated posterior part. Empodium entire 4 rayed.

Female:

Holotype and 10 paratypes. Body vermiform, 194 (196-190) long and 64 (62-66) wide, pale yellow in color.

Gnathosoma(17) long and curved downward.

Prodorsal shield triangular with clear lines; median line short, continuous; admedian lines as long as median line, slightly converging towards the anterior end. Submedian lines I and II located towards the posterior end of the shield. Prodorsal setae (sc) shorter than their mutual distance, projected anteriorly.

Legs; Leg I (24), Leg II (21), six segmented. Feather claw (4) four rayed.

Coxal plate slightly granulated. Seta1b as long as or longer than their mutual distance; setae 1a and 2a sub-equal in length.

Opisthosoma with 71 rings dorsally and 89 rings ventrally, each annulus with 19 microtubercles. Seta c_2 (12), inserted on ring 13th;seta d (54) long and set on 24th ring; seta*e*(14) long, placed on 53rd ring;seta f (23) long, observed on 66th ring; seta $h_1$hardly discernible and h_2 (37) on the terminal knob.

Female genitalia (13×11), slightly longer than wide. Coverflap with seven longitudinal lines, posterior part slightly granulated. Genital seta (9) long.

Male: Smaller than females (170 long and 48 wide) and resembles females morphologically except in their genital features; genitalia (10×16) wider than long, eugenital setae (10) shorter than their mutual distance (16).

Type material: Holotype female collected from *L. camara* in Vagamon, Kerala, India (9°41'02.3"N 76°54'16.8"E), 11thFebruary 2017, collected by Saritha, C. Paratypes: 10 ♀♀, 5 ♂♂, collected from *L. camara* in Vagamon,

Kerala, India (9°41'02.3"N 76°54'16.8"E), 11 February 2017, collected by Saritha, C.

Relation to the host plant: All stages of *E. camarae* sp.nov. were found on lower leaf surface of the invasive plant species, *L. camara* inducing damage symptoms like stippling, bronzing and rolling of leaves.

Etymology: The specific name "*camarae*" refers to the species name of the host plant, *L. camara,* from which the new species was collected.

Remarks: *E. camarae* sp.nov. shows resemblance to *E. morindae*Mohanasundaram, 1980 in the clear and prominent nature of prodorsal shield markings and the arrangement of tubercles on the shield. But the new species can be easily distinguished from the latter by the possession of four rayed feather claw (*versus* feather claw withmore than four rays in *E. morindae*); presence of longitudinal lines on genital coverflap (*versus* absent in *E. morindae*).

E. camarae sp.nov. also showssimilarity to another new species recovered during the present study *viz. Eriophyes antigonus* sp.nov.in its nature and arrangement of microtubercles on dorsal and ventral rings and the number of rays on feather claws. However, *E. camarae* sp.nov. differsclearly from the latter species by: Genital cover flap with 7 longitudinal lines (*versus* 12 in *E. antigonus*); longitudinal lines on genital coverflap extend throughout their length (*versus* longitudinal lines are restricted to anterior part and posterior part with granulations in *E. antigonus*)

2. *Eriophyes antigonus* sp.nov.(Plate 11, Fig. d; Plate 30, Fig. a – g)

Locality: Kerala: Parunthumpara, Aluva, Athani , Feroke, Cheruvannur, Parappanangadi,Calicut University Campus, Kondotty, Vettukadu, Pulikkal,

Olavattur,Yakkara, Chithali, Tharekkad, Kongad, Ramanattukara, Thondayadu

Habitat: *Antigonon leptopus*

Diagnosis: Median and admedian lines long and continuous. Submedian lines broken, located postero-lateral to admedian lines. Opisthosoma with 67 dorsal and ventral annuli, about 15 micro tubercles present on each annulus. Anterior part of genital flap with 12 longitudinal lines and posterior part with thick granulations. Empodium entire 4 rayed.

Female:

Holotype and 10 paratypes. Body vermiform, 162 (160-168) long and 64 (61-65) wide, yellowish white in colour.

Gnathosoma (17) medium sized, projected downwards.

Prodorsalshield broadly triangular with prominent lines; median linelong and continuous; admedian lines as long as median line, located close to the median line than to submedian lines. Submedian lines I, II and III are broken, located postero- lateral to admedian lines. Granules are oriented towards the lateral margin of the shield. Prodorsal setae (sc, 18) longer than their mutual distance (12), directed anteriorly.

*Legs***;** Leg I (24) shorter than Leg II (27), six segmented. Empodium (5) five rayed.

*Coxal plate*s parsely granulated.Seta 1b twice longer than their mutual distance; seta 1a inserted close to setal alveolus of 1a; seta 2a longer than other coxal setae.

Opisthosoma with 65 annuli dorsally and 71 annuli ventrally with about 17short microtubercles arranged on each annulus. Seta c_2 (18), inserted on

ventral annulus 9; seta d (61) longest, inserted on ventral annulus 24; seta e (13) shortest, placed on ventral annulus34; seta f (16) inserted on annulus 60; seta $h_1$in discernible and h_2 (46) directed posteriorly.

Female genitalia (18×22), wider than long. Anterior part of coverflap with 12 longitudinal ribs, posterior part with thick granulations. Genital seta (11) long posteriorly oriented.

Male: Smaller than females (150 long and 45 wide). Genitalia (11×15) wider than long. Eugenital seta (13) as long as longer than their mutual distance (12).

Type material: Holotype female collected from *Antigonon leptopus*in University of Calicut Campus, Kerala, India (11°08'02.5"N 75°53'42.8"E),20thSeptember, 2016, collected by Saritha, C. Paratypes: 10 ♀♀, 5 ♂♂, collected from *A. leptopus* in University of Calicut Campus, Kerala, India (11°08'02.5"N 75°53'42.8"E),20thSeptember, 2016, collected by Saritha, C. The species were also collected from the following localities *viz.*Parunthumpara, Aluva, Athani, Feroke, Cheruvannur, Parappanangadi, Kondotty, Vettukadu, Pulikkal, Olavattur,Yakkara, Chithali, Tharekkad,Kongad, Ramanattukara, Thondayadu of Kerala, India.

Relation to the host plant: All life stages of *E. antigonus* **sp.nov**. were found on the leaves of the invasive plant species *Antigonon leptopus*asvagrants, inducing varied damage symptoms like stippling, yellowing and bronzing of leaves.

Etymology: The specific name "*antigonus*" refers to the genus name of the host plant, *Antigonon leptopus,* from which the specimens were collected.

Remarks: This is the first record of eriophyid species from the respective host plant.The newspeciesshows resemblance to *E. morindae*

Mohanasundaram, 1980 in thenature of prodorsal shield markings and the arrangement of tubercles on prodorsal shield. But the new species can be easily distinguished from the latter by the possession of four rayed empodium (*versus* empodium withmore than four rays in *E. morindae*); genital coverflap with ribs at its anterior part and granulation on its posterior part (*versus* ribsabsent in *E. morindae*)

E. antigonus sp.nov. also shows similarity to *E.camarae* sp.nov.in the number of feather claw rays and arrangements of microtubercles on their dorsal and ventral annuli. However,*E. antigonus* sp.nov. differs clearly from the latter species by: anterior part of genital coverflap with 12 longitudinal ribs and posterior part with granulations (*versus*7ribsextending throughout its length in *E. camarae*); scapular setae longer than their mutual distance (*versus* shorter than their mutual distance in *E. camarae*)

43) *Phyllocoptruta*Keifer, 1938

Generic diagnosis: The anterior shield lobe projects well beyond the rostrum. The dorsal shield tubercles set well ahead of the rear margin, the dorsal setae short and project upwards. Dorsal thanosomal trough running the entire length.The dorsal half of annuli without microtubercles and the ventral half of annuli microtuberculated.

1. *Phyllocoptruta merremiae* sp.nov. (Plate 7, Fig. c; Plate 10, Fig. h; Plate 11, Fig. c; Plate 33, Fig. a – g)

Locality: Kerala: Karyavattom, Peechi, Pattikkadu, Mannuthi,Calicut University Campus, Kozhikode, Ramanattukara, Thondayadu,Shornur, Kuzhalmannam, Alathur, Thenkurissi, Yakkara,Tharekkad, Sreekrishnapuram, Tharekkad, Thirunelli, Tholpetty, Thottada, Cheruvathur

Habitat: *Merremia vitifolia*

Diagnosis: Median line short, admedian lines slightly longer than median line. Submedian lines longestarising from the anterior tip of prodorsal shield. Scapular setae directed backward. Opisthosoma with 48 dorsal and 76 ventral annuli, micro tubercles present on ventral annuli only. Anterior part of genital flap with thick granulationsand posterior part with12 longitudinal lines. Empodium entire, 4 rayed.

Female:

Holotype and 10 paratypes. Body fusiform, 212 (210-216) long and 82 (79-84) wide, white to straw in colour.

Gnathosoma(24) slightly curved downward.

Prodorsal shield broad basally, semicircular anteriorly without prominent frontal lobe. Prodorsal lines well discernible; median line short and continuous; admedian lines slightly longer than median line, converging towards anterior end. Submedian lines I longest and reaching anterior tip of prodorsal shield and slightly diverging posteriorly, all other prodorsal lines are delimited to the medial to posterior part of the shield; submedian lines IV shorter than II and III. Granules are localized to the marginal region of the shield. The scapular tubercles medium sized and set well ahead (25) of the rear shield margin. The scapular setae (sc, 9) projected posteriorly, reaches upto the first dorsal annulus.

*Legs***;** Leg I (31) longer than Leg II (27), six segmented. empodium (5) four rayed.

Coxal plate smooth. Setae 1b as long as their mutual distance; setae 1a inserted close to setal alveoli of 1a; setae 2a and 1a long and sub-equal in length.

Opisthosoma with 48 broad annuli dorsally and 76 annuli ventrally. Microtubercles present only on ventral annuli. Seta c_2 (18), inserted on ventral annulus 11; seta d (32) inserted on ventral annulus 28; seta e (12) located on ventral annulus 55; seta f (9) shortest, inserted on annulus 70; seta $h_1$hardly visible and h_2 (40) longest directed posteriorly.

Female genitalia (17×24), wider than long. Anterior part of coverflap with thick granulations, posterior part with 12 longitudinal ribs (visible under higher magnification). Genital seta (7) shorter than their mutual distance (14)

Male: Smaller than females (184 long and 73 wide). Eugenital seta (15) slightly longer than their mutual distance.

Type material: Holotype female collected from *Merremia vitifolia*in Kozhikode, Kerala, India (11°15'13.4"N 75°46'35.0"E), 15thJanuary, 2018, collected by Saritha, C. Paratypes: 10 ♀♀, 5 ♂♂, collected from *M. vitifolia*in Kozhikode, Kerala, India (11°15'13.4"N 75°46'35.0"E), 15January2018, collected by Saritha, C. The species was also collected from the following localities *viz.*Karyavattom, Peechi, Pattikkadu, Mannuthi,Calicut University Campus, Ramanattukara, Thondayadu,Shornur, Kuzhalmannam, Alathur, Thenkurissi, Yakkara,Tharekkad, Sreekrishnapuram, Tharekkad, Thirunelli, Tholpetty, Thottada, Cheruvathur of Kerala, India.

Relation to the host plant. All stages of *Phyllocoptruta merremiae* sp.nov. were found on the leaves of the invasive plant species *M. vitifolia*asvagrants, causing damage symptoms such as stippling, bronzing and ultimately leading to leaf drop.

Etymology: The specific name "*merremiae*" refers to the genus name of the host plant, *M. vitifolia,* from which the specimens were collected.

Remarks: This is the first record of eriophyid species from *M. vitifolia*.*Phyllocoptruta merremiae* sp.nov. shows close resemblance to *P. citricola* Chakrabarti & Sarkar, 2011 and *P. himalayana* (Chakrabarti & Roy, 1980)in the number of empodial rays, the prominent nature of prodorsal shield lines and the presence of setae h_1. However the new species can be clearly distinguished from *P. citricola* and *P. himalayana* by the procession of the following unique characters; the number of longitudinal ribs on the genital coverflap, posteromedially directed scapular setae and form of prodorsal shield lines.

44) *Tegolophus* Keifer,

Generic characters: Body fusiform. Cephalothoracic shield pitted, anterior lobe moderately acuminate over the rostrum. The rear edge of the shield between the doral tubercles partially furrowed. Genital coverflap with 16 longitudinal ribs. Feather claws four rayed.

1. *Tegolophus calotropi* Chakrabarti and Mondal, 1979

Locality: Kerala: Thazhekode, Palakkad

Habitat: *Calotropis procera*

Diagnosis

Female: Body 201-212 long, 67-76 wide. Shield with moderately developed anterior lobe. Anterior lobe provided with two spine like structures ventrally, admedian lines up to a small portion form anterior lobe and then move outwardly; median line present throughout the shield length. Feather claws five rayed. Abdomen with 62 tergites and 68 sternites. Genital cover flap with 14 longitudinal lines.

Male: Not found while sampling.

Materials examined: 4♀♀ from *C. procera* collected on 02. 04. 2015 from Palakkad Dt., Kerala, India. Coll. Saritha, C.

Remarks: The morphological characters of the present specimen look similar to those of *T. calotropi* described by Chakrabarti and Mondal (1979) and hence fixed so. This is the first report from Kerala.

C) Order: Sarcoptiformes, Reuter, 1909

Suborder: Oribatida Duges, 1833

Infraorder : Holosomata Grandjean, 1969

Superfamily : Crotonioidea Thorell, 1876

Family : Trhypochthoniidae Willmann, 1931

45. Genus: *Allonothrus* van der Hammen, 1953

Generic characters: Notogastral setae 15 pairs. Genital setae 9–13 pairs, aggenital setae lacking, anal setae two pairs, adanal setae three pairs, tarsi with three claws or occasionally with one claw.

1) ***Allonothrus russeolus russeolus* Wallwork, 1960 (Plate 7, Fig. f)**

Locality: Kerala: Calicut University Campus, Perinkunnam, Villoonniyal

Habitat: *Mikania micrantha*

Diagnosis

Body 571-585 long, 286-294 wide, colour reddish-brown. Prodrosal setae serrated and of varying size and nature. Prodorsal integument ornamented with round foveoles. Sensillus long, rod shaped and slightly expanding towards the tip amd heavily ciliated. Notogastral setae 15 pairs, slightly

variable in length and more or less flabelliform. Notogastral surface ornamented with foveoles. Epimeral setal formula 3-1-3-3. Genital plates with 13 pairs of setae and anal plates with two pairs of setae. Three pairs of adanal setae present. Legs tridactylous.

Materials examined: 3♀♀ from *M.micrantha* collected on 02. 04. 2015 from Palakkad Dt., 2♀♀ collected on 22. 06. 2016 from Malappuram Dt., Kerala, India. Coll. Saritha, C.

Remarks: The present specimens closely resemble in all morphological characters with *A. russeolus russeolus* described by Wallwork (1960) and hence fixed so. This is the first report of the species from the host plant mentioned above.

Infraorder: Brachypylina Hull, 1918

Superfamily Oribatelloidea Jacot, 1925

Family: Oribatellidae Jacot, 1925

46. Genus: *Lamellobates* Hammer, 1958

***Lamellobates (Paralamellobates)* Bhaduri & Raychaudhuri, 1968**

***1. Lamellobates (Paralamellobates) misella* Berlese, 1910 (Plate 7, Fig. g)**

Locality: Kerala: Calicut University Campus, Perinkunnam, Vagamon

Habitat: *Mikania micrantha*

Diagnosis

Body 271-285 long, 186-194 wide. Integument entirely microtuberculated. Rostrum with strong teeth. Lamellae broad. All prodorsal setae barbed. Sensillus with a short stalk and a barbed, clavate head. Prodorsum demarcated from notogaster by a well developed convex dorsosejugal suture. Notogaster

more or less oval, bearing nine pairs of smooth setae. Epimeral setae thin and smooth, setal formula 3-1-2-2. Epimeral seta 1*c* barbed, all others smooth. Genital plates with six pairs of setae. Aggenital setae one pair. Anal plates with one pair of setae. One pair of adanal setae present. All legs monodactylous.

Materials examined: 6♀♀ from *M.micrantha* collected on 02. 04. 2015 from Palakkad Dt., 2♀♀ collected on 22. 06. 2016 from Malappuram Dt., Kerala, India. Coll. Saritha, C.

Remarks: All the characters of the present specimen are similar to those of *L.*(*P.) misella* Berlese (1910) and hence fixed so. This is the first report from the host plant.

2. *Lamellobates* (*Paralamellobates) bengalensis* Bhaduri & Raychaudhuri, 1968. (Plate 11, Fig. h)

Locality: Kerala: Calicut University Campus

Habitat: *Chromolaena odorata*

Diagnosis

Body length 256-269 long, 180-187 wide. Integument microtuberculate over entire body and leg segments. Rostrum with pair of strongly developed lateral teeth, medial tooth absent. Prodorsal setae barbed. Lamellae broad. Sensillus with a barbed and clavate head. Bothridium cup shaped, with well-developed ventrolateral scale. Dorsosejugal suture highly convex. Notogaster more or less oval, with nine pairs of smooth setae. Epimere I with longitudinal striae on lateral region. Epimeral setal formula 3-1-2-2, all setae smooth. Six pairs of genital and one pair of aggnital setae present. Anal and adanal setae two pairs each. Tarsi of all legs monodactylous.

Materials examined: 5♀♀ from *C.odorata* collected on 22. 05. 2016 from Malappuram Dt., Kerala, India. Coll. Saritha, C.

Remarks: All the characters are similar to those of *L. (P.) bengalensis* described by Bhaduri and Raychaudhuri (1968) and hence fixed so.

xi) Superfamily: Oripodoidea Jacot, 1925

p) Family: Mochlozetidae Grandjean, 1960

47) Genus: *Uracrobates (Uracrobates)* Balogh and Mahunka, 1967

Generic characters: Presence of medially interrupted dorsosejugal suture. Notogastrum with 10-11 pairs of setae. Rostrum bidentate, lamellae well developed, their cusps with strong outer and small inner teeth, translamella considerably thinner than lamellae. Bothridial setae short, clavate.

1. Uracrobates (Uracrobates) indicus
Ramani and Haq, 1990 (Plate 7, Fig. e)

Locality: Kerala: Calicut University Campus

Habitat: *Mikania micrantha*

Diagnosis

Body length 569-578 long, 400-412 wide. Prodorsum bradly triangular. Rostrum with two incisions, one at the tip and other laterally. Prodorsal setae barbed. Sensillus with a smooth stalk and a clavate head , bearing short barbs. Notogaster with a medially interrupted dorsosejugal suture anteriorly and with pteromorphs anterolaterally. Notogaster bears 10 pairs of small setae and four pairs of area porose. Entire notogaster ornamented with more or less oval foveoles. Epimeral plates bear roughened setae, setal formula of epimeres being 3-2-2-1. Genital plates with six pairs of roughened setae. A single pair of roughened aggenital setae. Anal plates with two pairs of small, smooth

setae. Adanal setae three pairs, all smooth and short. Legs tridactylous with three smooth unequal claws.

Materials examined : 4♀♀ from *M. micrantha* collected on 22. 05. 2016 from Malappuram Dt., Kerala, India. Coll. Saritha, C.

Remarks: All the characters of the present specimen agree with those of *U.(U.) indicus* described by Ramani and Haq (1990) and hence fixed so. This is the first report from the host plant.

Family: Caloppiidae Balogh, 1960

48) Genus: *Zetorchella* Berlese, 1916

Generic characters: Prodorsum with high ornamentation, foveolate notogaster with stongly barbed setae, translamella present, presence of two pairs of adanal setae.

1) *Zetorchella sejugata* (Ramani and Haq, 1997)

Locality: Kerala: Calicut University Campus

Habitat: *Mikania micrantha*

Diagnosis

Body dark brown in colour, 367-378 long and 313-321 wide. Prodorsum broader than longer, narrowing towards rosral apex. Prodorsal setae long, barbed and show size variation. Seta *ex* located at the lateral border of prodosum . Sensillus with a smooth stalk and a heavily barbed, clavate head. Prodorsal integument with reticulation anteriorly. Notogasrer globular, with well developed sejugal suture anteriorly and with 10 pairs of long, barbed setae. Notogastral integument fuscous and densely foveolatd. Epimeral surface with foveoles and punctations, setation of epimeres 3-2-3-2. Genital plates with six pairs of setae. Aggenital setae one pair. Anal plates with feeble

surface foveolation, and with two pairs of small setae. Adanal setae two pairs. Legs tridactylous and heterodactylous, the central claw being thicker than the lateral ones.

Materials examined: 2♀♀ from *M. micrantha* collected on 12. 09. 2016 from Malappuram Dt., Kerala, India. Coll. Saritha, C.

Remarks: All the characters of the present specimen resemble with those of *Z. sejugata* (Ramani and Haq, 1997) and hence fixed so. This is the first report from the above host plant.

xv) Superfamily: Acaroidea Latreille, 1802

t) Family: Acaridae Latreille, 1802

49) Genus: *Tyrophagus* Oudemans, 1924

Generic characters: Seta *ve* pectinate, longer than the length of genu, and arise at almost the same level as *vi* and curved downwards. The dorsal terminal tarsal seta e needle shaped. Ventral tarsal setae five, of which three central ones are thickened.

***1. Tyrophagus putrescentiae* Schrank, 1781 (Plate 7, Fig. h)**

Locality: Kerala: Perinkunam, Kuzhalmannam

Habitat: *Mikania micrantha*

Diagnosis

Female: Body creamy coloured, 367-376 long and 231-239 wide. All dorsal setae sparsely pectinate. The supracoxal seta flattened. Chelicera toothed with spur like outgrowth, 82 long. Prodorsal shield nearly pentagonal. Eyespots present, anal setae five pairs, inserted around the anal opening. Legs terminate in claws and with a well developed pretarsus.

Male: Morphology of male is similar to that of female, except in the measurement of some setae.

Materials examined: 6♀♀ and 2♂♂ from *M. micrantha* collected on 02. 06. 2016 from Palakkad Dt., Kerala, India. Coll. Saritha, C.

Remarks: The morphological characters of the present specimen resemble those of *T. putrescentiae* Schrank (1781) and hence fixed so. This is the first report from the above host plant.

IV.Diversity indices

Results of diversity studies enabled to record a higher diversity index (H′) of mites in the Malappuram district (H′-2.94906) followed by Palakkad (H′-2.90259) and Kozhikode (H′-1.52363) districts. Result of studies involving calculation of Simpson's Index revealed a maximum diversity in the Palakkad Dt. (0.8834) followed by Malappuram (0.86991) and Kozhikode (0.51309) districts.

The maximum species richness was recorded in the Malappuram (10.0002) district followed by Palakkad (7.1953) and the minimum richness was observed in the Kozhikode (4.155752) district. Species evenness was found to be high in the Palakkad Dt. (0.73108) followed by Malappuram Dt. (0.6769) and the minimum evenness were recorded in the Kozhikode Dt. (0.44367) (Table 12).

Table 12: Diversity indices values on mites collected from selected districts of Kerala

Tests	DISTRICTS		
	Palakkad	Malappuram	Kozhikode
Shannon Index	2.902	2.949	1.523
SimpsonIndex	0.883	0.869	0.513
Richness	7.195	10.000	4.155
Evenness	0.731	0.676	0.443

V) MOLECULAR PHYLOGENETIC ANALYSIS:

The partial sequencing of mitochondrial cytochrome oxidase subunit I (COI) of *Eriophyes camarae* sp.nov. yielded 213 bp sequences (Fig.13). The forward and reverse chromatograms obtained and is given in Fig. 14 & 15. The nucleotide sequences of *E. camare* sp. nov. were recorded for the first time and were deposited in the Gen Bank and NCBI, with the accession number being MW748222. The BLAST analysis showed that the current species got 77.52% sequence similarity with the species of Eriophyidae (MG321183, MG311943, and MG310859) reported from Canada. The final data set included with 17 other sequences retrieved from NCBI (http://www.ncbi.nlm. nih.gov/nucleotide/) and all of the sequences were aligned and evaluated for their interrelationship (Table 13).

Fig. 13: the partial DNA sequence of the mitochondrial CO1 gene of *Eriophyes camarae* sp. nov.

> D2_P1_20241-4_P2806_Eriophyes_camarae

GGCAGGCATGATATATATTTCCCACGGATGAACAATTTGAGGTTTTGGCTTCTTT
TCCCTTCTATAATTTTTCTTGTTCTTTCATACCATATCTCCTTAGGAGCAGGGAC
TGGATGGACAGTGTATCCGGCTTTGTCCAGGCTAAGGTTTCATAACGATTACTCT
GTTGATTTTGCTATCTTTTCTTTTCATTTAGGGGGGCTTTCTTCTATT

Translation of ORF number 2 in reading frame 2 on the direct strand

>D2_P1_20241-4_P2806_*Eriophyes*_

GSHDMYFPRMNNLSFWLLFPSMIFLVLSYHISLGAGTGWTVYPALSSLSFHN
DYSVDFAIFSFHLGGLSSI

Fig. 14: Forward sequence Chromatogram

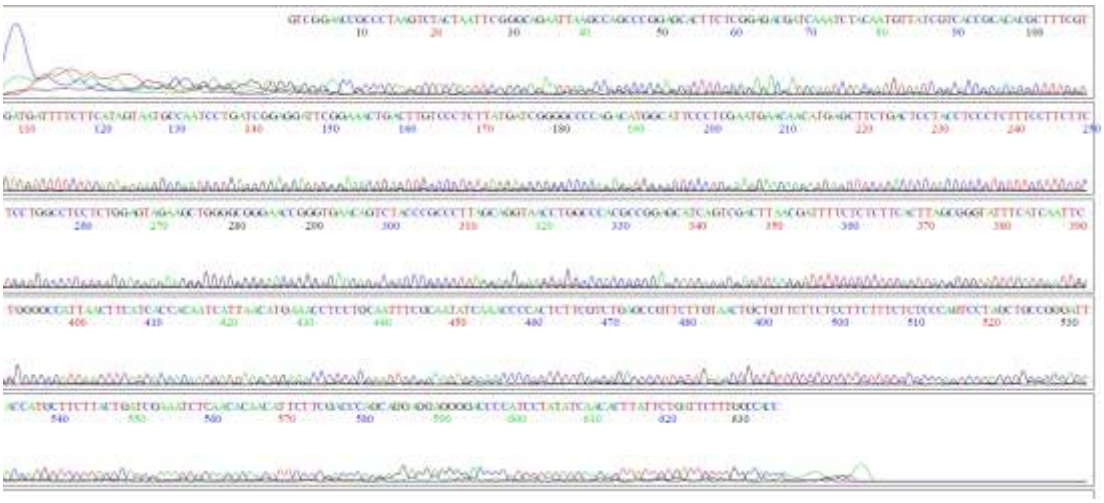


Fig. 15: Reverse sequence Chromatogram

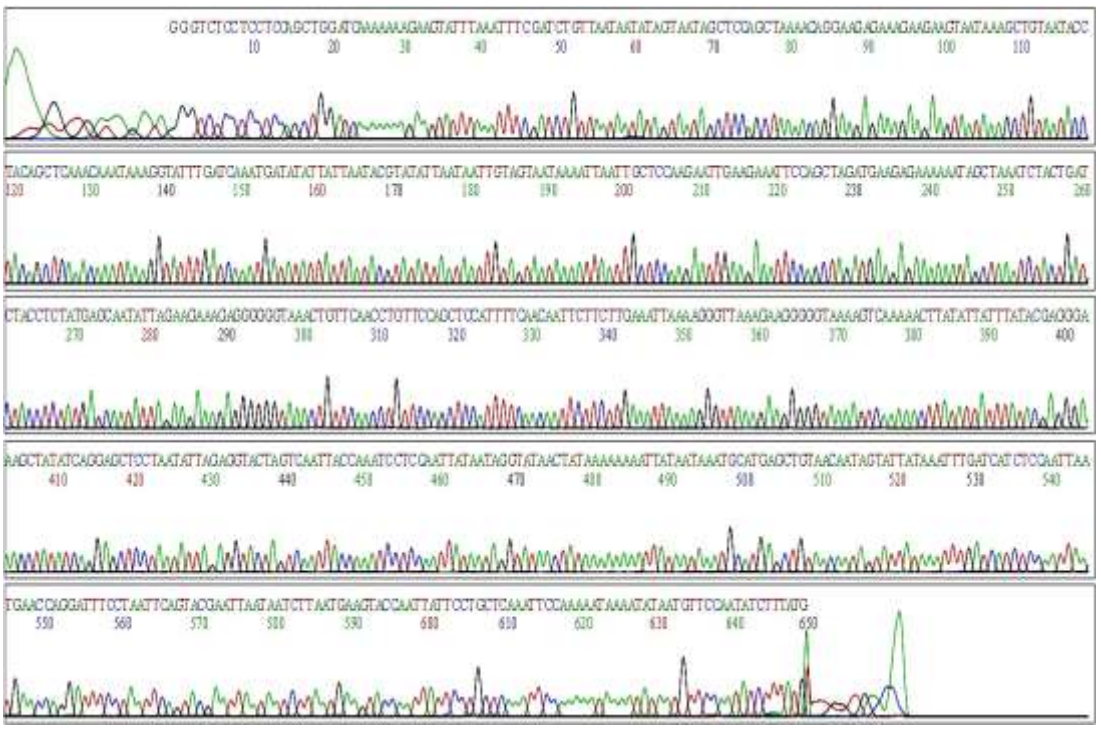


Table 13: BLAST hit table of important depositions taken from GenBank with their accessions and %similarity with *Eriophyes camarae* sp.nov.

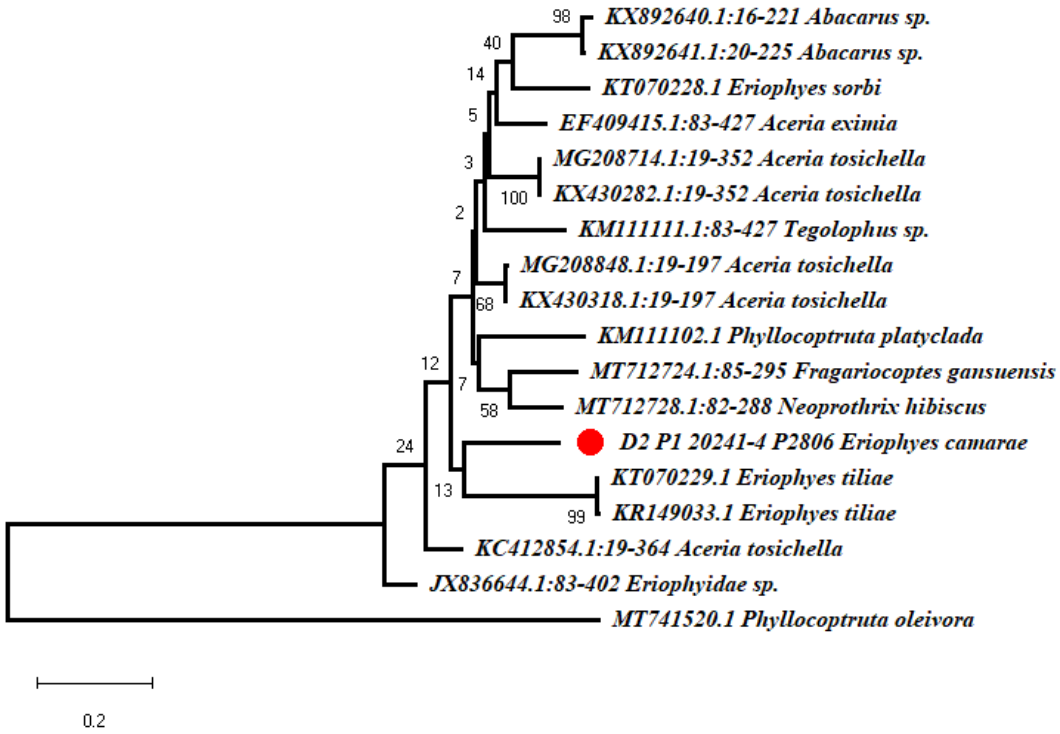
SI No.	Taxon Name	GenBank Accession	% Identity	Location
1	*Eriophyes tiliae*	KR149033	76.37	Austria
2	*Eriophyes tiliae*	KT070229	76.37	Austria
3	*Eriophyes sp.*	KY922369	75.79	USA
4	*Eriophyes sp.*	KU315232	75.72	Norway
5	*Eriophyes padi*	KT070227	75.43	Poland
6	*Eriophyes sp.*	KU315231	74.86	Russia
7	*Eriophyes sp.*	KU315230	74.20	Norway
8	*Eriophyes pyri*	EU254715	73.78	Germany
9	*Eriophyes sorbi*	KT070228	73.41	Poland
10	*Eriophyes lissonotus*	KU315235	70.52	Russia
11	*Aceria tosichella*	KC412860	76.81	Turkey
12	*Aceria erinea*	MW396748	76.81	Turkey
13	*Eriophyidae sp.*	MG321183	77.52	Canada
14	*Eriophyidae sp.*	MG311943	77.52	Canada
15	*Eriophyidae sp.*	MG310859	77.52	Canada
16	*Aceria sp.*	KY888663	76.59	Serbia
17	*Aceria erinea*	MW396745	76.52	Turkey

Phylogenetic analysis using Neighbor-Joining method revealed that the optimal tree with the sum of branch length was 3.53673639. The percentage of replicate trees in which the associated taxa clustered together in the bootstrap test (100 replicates) were shown next to the branches (Felsenstein, 1985). The tree was drawn to scale, with branch lengths in the same units as those of the evolutionary distances used to infer the phylogenetic tree. The evolutionary distances were in the units of the number of amino acid substitutions per site. This analysis involved 18 amino acid sequences. There were a total of 195 positions in the final dataset.

The phylogenetic tree generated by Neighbour joining method revealed that this species have a monophyletic ancestry as all members were separated

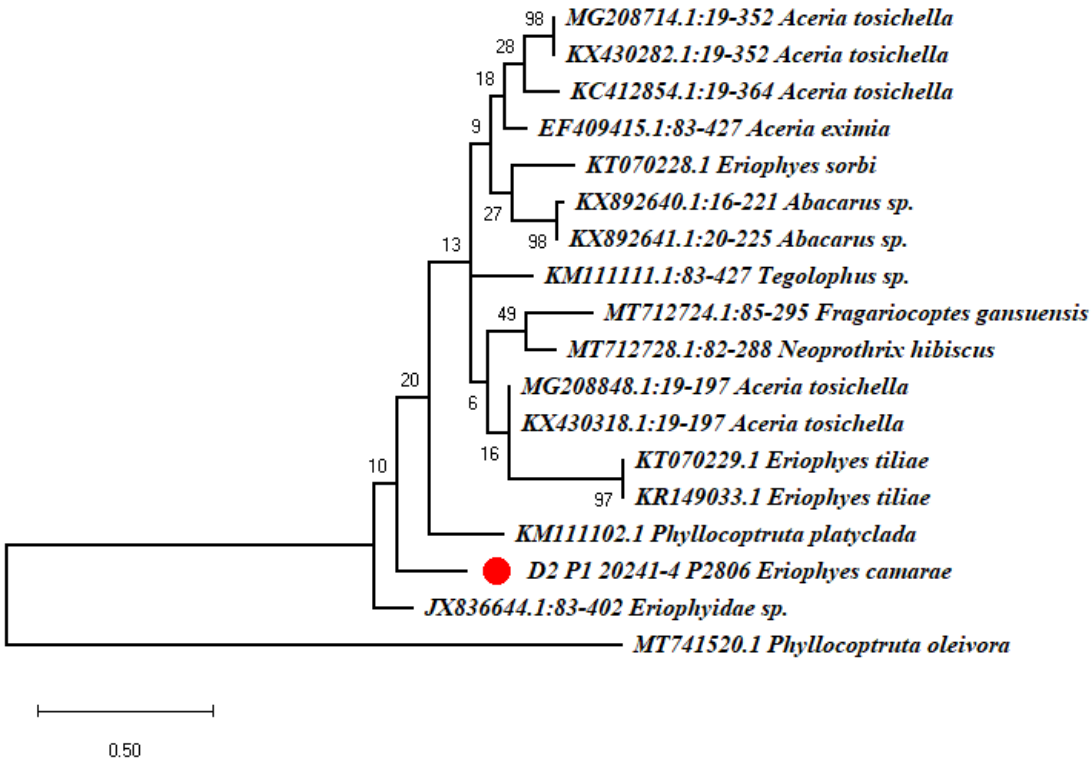
from a single clade. The phylogenetic tree constructed by using Neighbor-Joining method reveals the phylogenetic status of *Eriophyes camarae* sp.nov. isolated from Kerala showed a close relationship with *Eriophyes tiliae* from Austria represented within the same clade (Fig 16).

Fig. 16: Evolutionary analysis by Neighbor-Joining method



The phylogenetic analysis using Maximum likelihood method revealed that the tree with the highest log likelihood was (-2055.36). The percentage of trees in which the associated taxa clustered together was shown next to the branches (Fig.17). The tree was drawn to scale, with branch lengths measured in the number of substitutions per site. This analysis involved 18 amino acid sequences. There were a total of 195 positions in the final dataset.

Fig.17: Evolutionary analysis by Maximum Likelihood method



E.camarae sp.nov. showed variation in the total composition of nucleotide in each of the position of codons in comparison with other related species isolated from different geographical locations. Analyzing all the facts, this species appeared to be different from all the other related species and hence could be assigned to novel taxon.

VI) IMPACT OF CLIMATIC FACTORS ON THE POPULATION DENSITY AND DISTRIBUTION OF SELECTED SPECIES OF ERIOPHYID MITES ON INVASIVE PLANTS

Detailed studies were carried out on the impact of climatic factors like temperature, relative humidity, rain fall and wind velocity on the population density and distribution of four selected species of eriophyid mites, including

two new species. The species selected for population studies were *Acalitus adoratus*, *Eriophyes camarae* sp. nov. , *Eriophyes antigonus* sp. nov. and *Phyllocoptruta merremiae* sp. nov. on their respective host plants for a period of one year, from September 2016 to August 2017. Results of studies revealed that all the species irrespective of species variation, attained peak population during summer months and showed a population decline during the monsoon period of the year.

1. Impact of climatic factors on Population density and distribution of *Acalitus adoratus* infesting the Siam weed, *Chromolaena odorata*

Infestation by *A. adoratus* readily was easily visible in the field condition based on the presence of erineal patches. The mite was found to induce erineal patches of varying dimensions on the adaxial surface of the leaves of *C. odorata* and the number of patches per leaf showed great variation. During heavy infestation, the entire leaf surface was found covered by the erineal patches and both the adaxial and abaxial surfaces of showed the presence of erinea. Results of population studies disclosed the occurrence of the mite in moderate population up to February, 2017 and then the number showed a progressive increase with the increasing temperature and attained the maximum population during May, 2017. A subsequent decline in mite population was observed after May and it reached the minimum level in the month of June (Table 14). The mean temperature recorded during May, 2017 was 35.6 ^{0}C at which the mite population flourished to attain the peak level and it showed a decreasing trend during June, 2017 followed by the month of July (Fig. 18). Statistical analysis of the data on population distribution of the mite in relation to temperature revealed a significant positive correlation ($p \leq 0.05$) between mite population and temperature, with the correlation value being 0.661658 (Table 14; Fig. 19). A similar significant positive correlation ($p \leq 0.05$) could be established between the population density of *A. adoratus*

and wind velocity also with a corresponding correlation value of 0.632792 (Fig. 21). Despite the above observation, factors like relative humidity and rainfall were found to exert a negative impact on the population density of *A. adoratus*, by recording a significant negative correlation for both, with corresponding values of -0.78505 and -0.46155 respectively (Fig. 23 & 25). Coefficient of determination (R^2) value between temperature and mite population was recorded as 0.437 and hence the change between the variables was 43.7%. R^2- value recorded for the relationship between mite population and wind velocity was 0.400 (40%). The R^2- value recorded for the relationship between relative humidity and mite population was 0.616 (61.6%) and that of rainfall was 0.213 (21.3%).

Table14 : Fluctuations in the Population density of *Acalitus adoratus* on *Chromolaena odorata* with respect to Climatic factors

Month	Temperature max (ºC)	RH max (%)	Rainfall Max (mm)	Wind velocity max (ms)	Mite population
Sep-16	31.5	97	101.8	1	332
Oct-16	33.1	96	44.8	1.1	460
Nov-16	34.2	96	14.2	0.8	426
Dec-16	33.9	96	7	1	93
Jan-17	35	96	1.6	1.5	98
Feb-17	36	95	0	1.4	521
Mar-17	35.7	95	65	1.6	572
Apr-17	36.2	94	40.4	3.2	778
May-17	35.6	95	117.4	1.5	921
Jun-17	30	97	616.8	0.9	67
Jul-17	29.4	98	513.6	0.5	79
Aug-17	29.3	97	462.6	0.9	247
Pearson's correlation coefficient = *r*	0.662	-0.785	-0.461	0.632	
Coefficient of determination= R^2	0.437	0.616	0.213	0.4	

2. Impact of climatic factors on the population density and distribution of *Eriophyes camarae* sp.nov. infesting the invasive weed, *Lantana camara*

E. camarae sp.nov. was recognized as a leaf vagrant, showing infestation mainly on the abaxial surface of the leaf lamina of the noxious weed, *L. camara* , as evidenced through the present study. However, during heavy infestation, the mite showed infestation on both the adaxial and abaxial surfaces of the leaves of the host plant.

Results of population studies enabled to record an initial phase of increase in population density of *E. camarae* sp.nov. on the weed, from February, 2017 and a progressive increase was observed until May, 2017. The mite population assumed peak formation in the month of May, 2017 when the mean temperature recorded was 35.6 ^{0}C; relative humidity was 95% ; rain fall was 117.4mm and wind velocity was 1.5m/s. Then the population showed a decreasing trend in June and attained the minimum level during July, with the onset of monsoon. Again, the mite population showed an increase, in par with the decline of monsoon shower and it reached the moderate level from August to December (Table 15; Fig. 18). Statistical analysis of the data recorded on seasonal pattern of population distribution of *E. camarae* sp.nov. helped to establish a significant positive correlation ($p \leq 0.05$) between temperature and mite population, with the r- value being 0.547084 (Fig. 19). A significant positive correlation ($p \leq 0.05$) was observed between mite population and wind velocity also (Fig. 20), by recording a correlation value of 0.5733 (Fig. 21). Both relative humidity and rainfall exerted a significant negative impact ($p \leq 0.05$) on the population of *E. camarae* sp.nov., with respective correlation values of -0.70082 and -0.26676 (Fig. 23 & 25). Coefficient of determination (R^2) value between temperature and mite population was 0.299 and hence the change between the

variables was 29.9%. R^2- value recorded for the relationship between wind velocity and mite population was 0.328 (32.8%). The R^2-value between relative humidity and mite population was 0.491 (49.1%) and R^2-value between mite population and rainfall was 0.071 (7.1%).

Table 15: Fluctuations in the Population density of *Eriophyes camarae* sp.nov. on *Lantana camara* with respect to Climatic factors

Month	Temperature max (ºC)	RH max (%)	Rainfall Max (mm)	Wind velocity max (ms)	Mite population
Sep-16	31.5	97	101.8	1	38
Oct-16	33.1	96	44.8	1.1	42
Nov-16	34.2	96	14.2	0.8	40
Dec-16	33.9	96	7	1	29
Jan-17	35	96	1.6	1.5	21
Feb-17	36	95	0	1.4	41
Mar-17	35.7	95	65	1.6	56
Apr-17	36.2	94	40.4	3.2	72
May-17	35.6	95	117.4	1.5	102
Jun-17	30	97	616.8	0.9	40
Jul-17	29.4	98	513.6	0.5	13
Aug-17	29.3	97	462.6	0.9	32
Pearson's correlation coefficient = *r*	0.547	-0.701	-0.267	0.573	
Coefficient of determination= R^2	0.299	0.491	0.071	0.328	

3. Impact of climatic factors on population density and distribution of *Eriophyes antigonus* sp.nov. on *Antigonon leptopus*

E. antigonus sp.nov. was detected as a leaf vagrant, confining its infestation to the abaxial leaf surface of the host plant, *A. leptopus.* Under favourable conditions of population build up, the mite extended its infestation

to the adaxial leaf surface also. The mite appeared highly host specific and its feeding activity resulted in the development of severe leaf damage.

Results of population studies revealed that the mite population showed a moderate level of distribution during the months of September, October and November, 2016. Then a gradual increase was observed in mite population during the summer months. The mite density attained peak population during April, 2017 when the temperature was 36.2 (Fig. 18) relative humidity was 94; rain fall was 40.4 and wind velocity was 3.2 and then showed a decline to reach the minimum level in the month of July (Table 16). Results of correlation studies revealed that temperature exerted a significant positive impact ($p \leq 0.05$) on mite population, with a correlation value of 0.695719 (Fig. 19). A similar significant positive impact was recorded between wind velocity and mite population, (Fig. 20) where the correlation value was calculated to be 0.809257 (Table 60, Fig. 21). However, relative humidity and rainfall adversely affected the population density of *A. leptopus* (Fig. 22 & 24) as the correlation values of which were found significantly negative ($p \leq 0.05$), the values being -0.81475 and -0.5587 respectively (Fig. 23 & 25). Coefficient of determination (R^2) value between temperature and mite population was 0.484, thereby helping to record a change between these variables to the tune of 48.4%. The R^2- value between wind velocity and mite population was 0.654 (65.4%). The R^2- value between relative humidity and mite population was 0.744 (74.4%) and that of rainfall and mite population recorded was 0.312 (31.2%).

Table16 : Fluctuations in the Population density of *Eriophyes antigonus* sp. nov. on *Antigonon leptopus* with respect to climatic factors

Month	Temperature max (ºC)	RH max (%)	Rainfall Max (mm)	Wind velocity max (ms)	Mite population
Sep-16	31.5	97	101.8	1	139
Oct-16	33.1	96	44.8	1.1	156
Nov-16	34.2	96	14.2	0.8	102
Dec-16	33.9	96	7	1	73
Jan-17	35	96	1.6	1.5	65
Feb-17	36	95	0	1.4	91
Mar-17	35.7	95	65	1.6	197
Apr-17	36.2	94	40.4	3.2	310
May-17	35.6	95	117.4	1.5	239
Jun-17	30	97	616.8	0.9	19
Jul-17	29.4	98	513.6	0.5	11
Aug-17	29.3	97	462.6	0.9	32
Pearson's correlation coefficient = *r*	0.696	-0.815	-0.559	0.809	
Coefficient of determination= R^2	0.484	0.744	0.312	0.654	

4. Impact of climatic factors on population density and distribution of *Phyllocoptruta merremiae* sp.nov. infesting *Merremia vitifolia*

P. merremiae sp.nov. was identified as a leaf vagrant form of eriophyid mite, confining its distribution all over the abaxial surface of leaf lamina of *M. vitifolia*. When the mite assumed heavy population density, infestation was found extending to the adaxial surface of the host leaves also.

Results of population studies revealed moderate population distribution of the mite up to the month of February, 2017 and then it followed an increasing trend, with the increase in temperature. Maximum population density of *P. merremiae* sp.nov. was recorded during the month of May 2017 , and after which a decline was observed in the mite population to assume the lowest density during July, 2017 (Table 17). The mite population attained peak formation in May, when the temperature was 35.6 ^{0}C (Fig. 18) relative

humidity was 95%, rain fall was 117.4mm and wind velocity was 1.5. Results of statistical analysis of the data gathered on population studies revealed a significant positive correlation ($p \leq 0.05$) between temperature and mite population, with the r- value of 0.758651 (Fig. 19). Wind velocity also exerted a significant positive influence ($p \leq 0.05$) on mite population (Fig. 20) and the correlation value between wind velocity and mite population was 0.734563 (Table 17, Fig. 21). Mite population experienced a significant negative impact ($p \leq 0.05$) by both relative humidity and rainfall (Fig. 22 & 24), with the corresponding correlation values of -0.86264 and -0.51614 respectively (Fig. 23 & 25). The Coefficient of determination (R^2) value was calculated and it was recorded to be 0.575, thereby evidencing a change of 57.5% between temperature and mite population. R^2-value obtained between wind velocity and mite population was 0.539 (53.9%) and that between relative humidity and mite population was 0.663 (66.3%), and that between rain fall and mite population was 0.266 (26.6%).

Table 17: Fluctuations in the Population density of *Phyllocoptruta merremiae* sp. nov. on *Merremia vitifolia* with respect to climatic factors

Month	Temperature max (ºC)	RH max (%)	Rainfall Max (mm)	Wind velocity max (ms)	Mite population
Sep-16	31.5	97	101.8	1	232
Oct-16	33.1	96	44.8	1.1	260
Nov-16	34.2	96	14.2	0.8	226
Dec-16	33.9	96	7	1	93
Jan-17	35	96	1.6	1.5	98
Feb-17	36	95	0	1.4	421
Mar-17	35.7	95	65	1.6	472
Apr-17	36.2	94	40.4	3.2	608
May-17	35.6	95	117.4	1.5	621
Jun-17	30	97	616.8	0.9	47
Jul-17	29.4	98	513.6	0.5	39
Aug-17	29.3	97	462.6	0.9	83
Pearson's correlation coefficient = *r*	0.756	-0.863	-0.516	0.734	
Coefficient of determination= R^2	0.575	0.663	0.266	0.539	

Fig.18: Effect of Temperature on the population density of selected species of Eriophyid mites

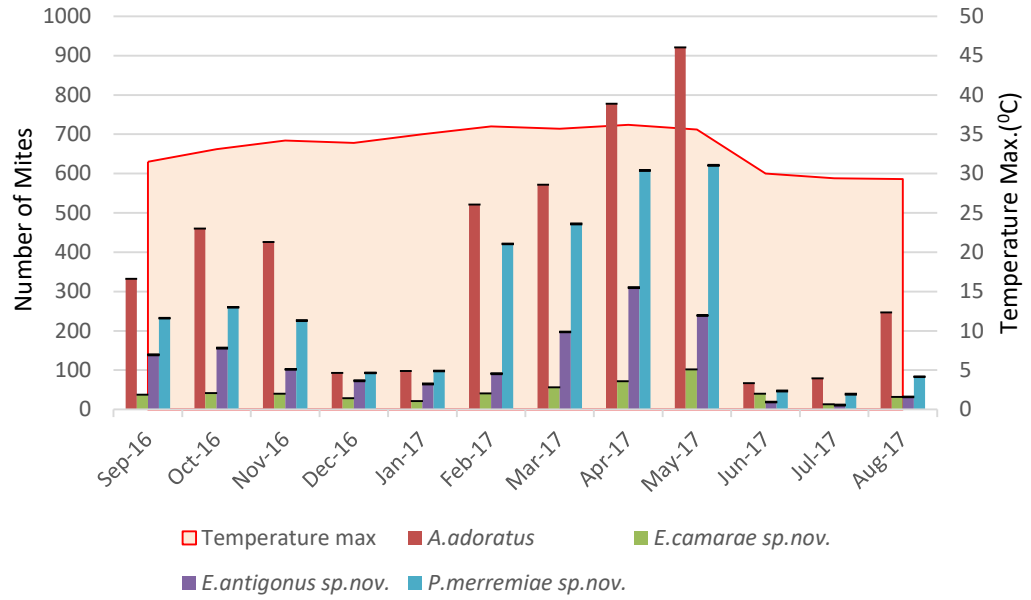


Fig.19: Correlation between mite population and temperature

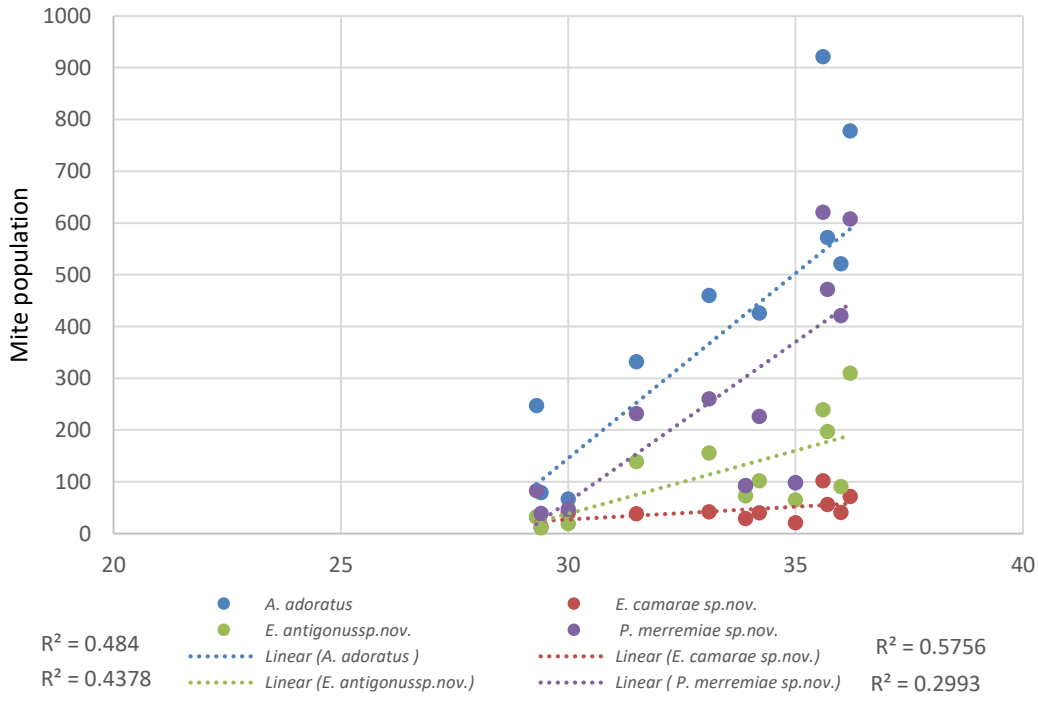


Fig.20: Effect of Wind velocity on the population density of selected species of Eriophyid mites

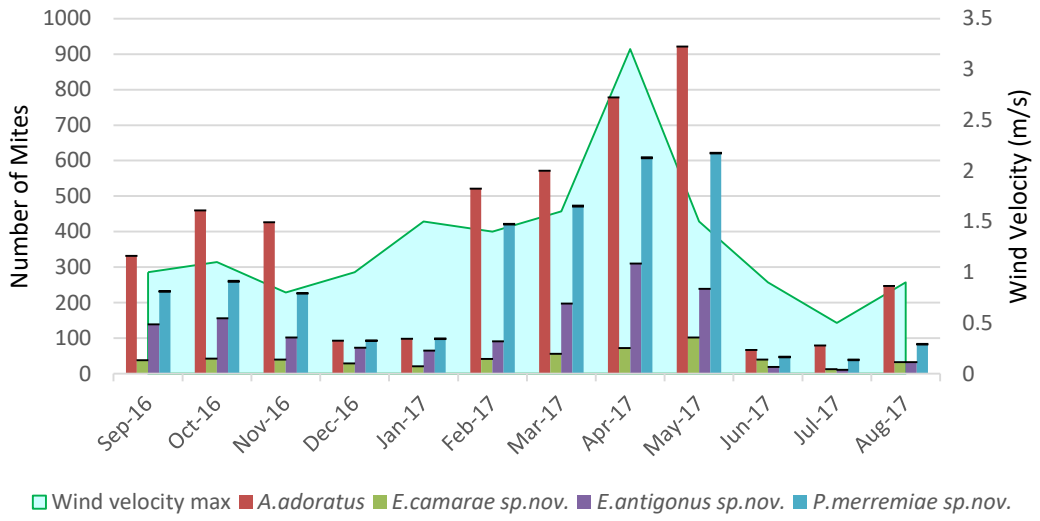


Fig. 21: Correlation between mite population and Wind Velocity

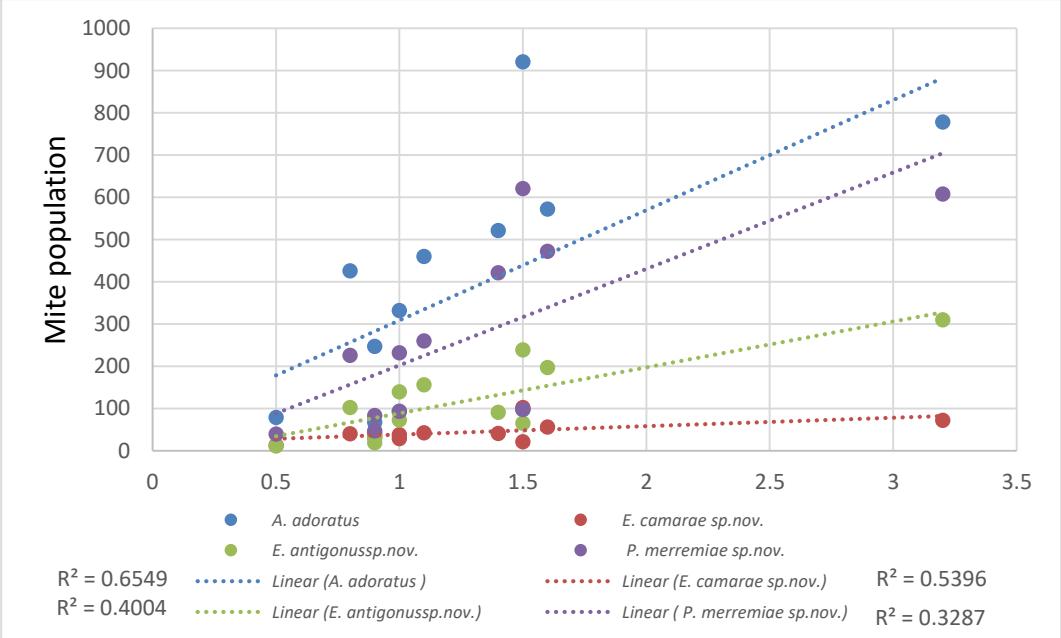


Fig. 22:Effect of Relative Humidity on the population density of selected species of Eriophyid mites

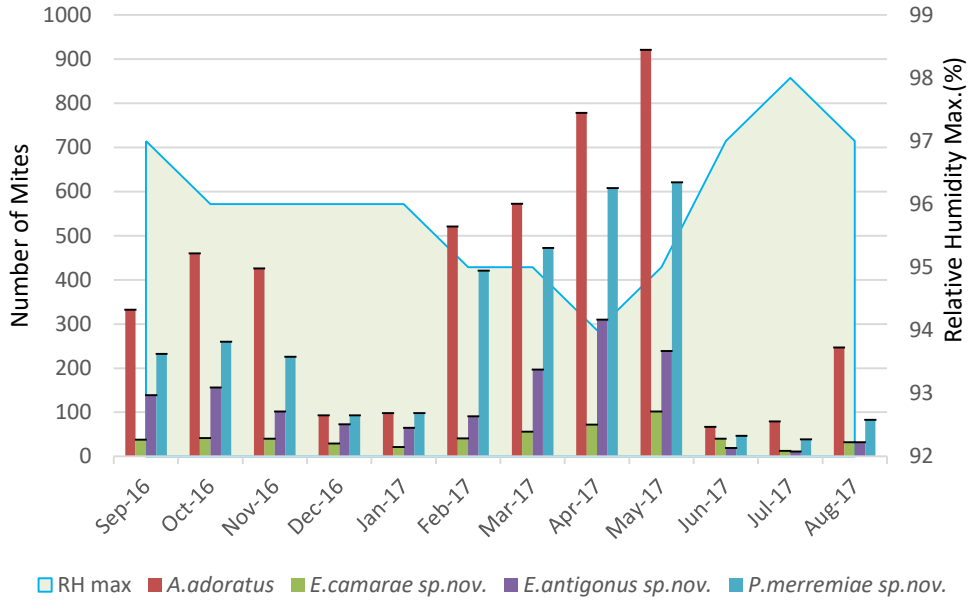


Fig. 23: Correlation between mite population and Relative Humidity

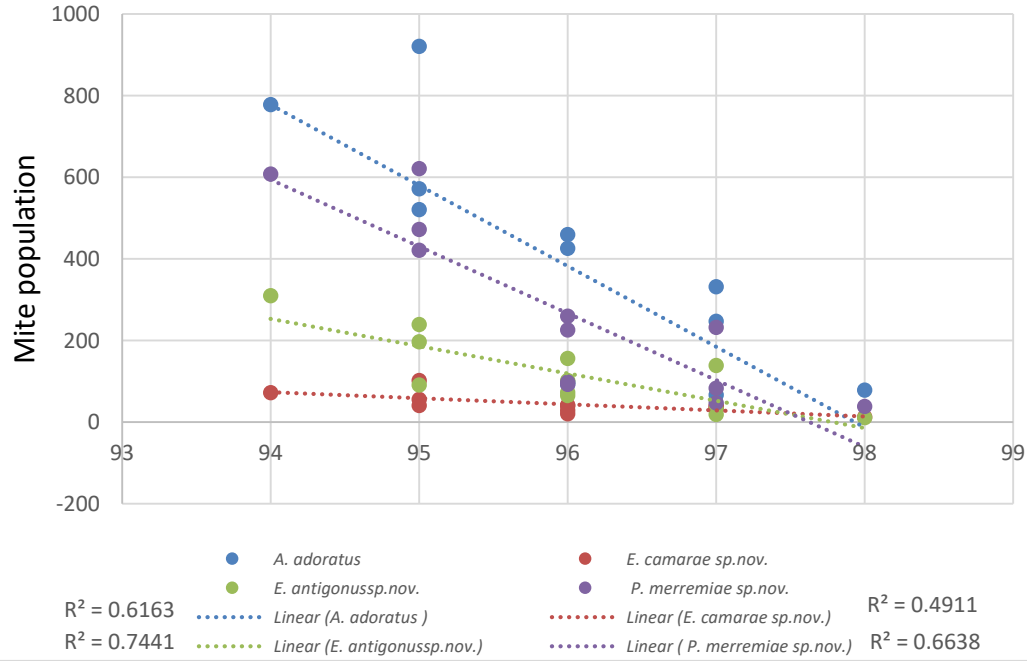


Fig. 24: Effect of Rainfall on the population density of selected species of Eriophyid mites

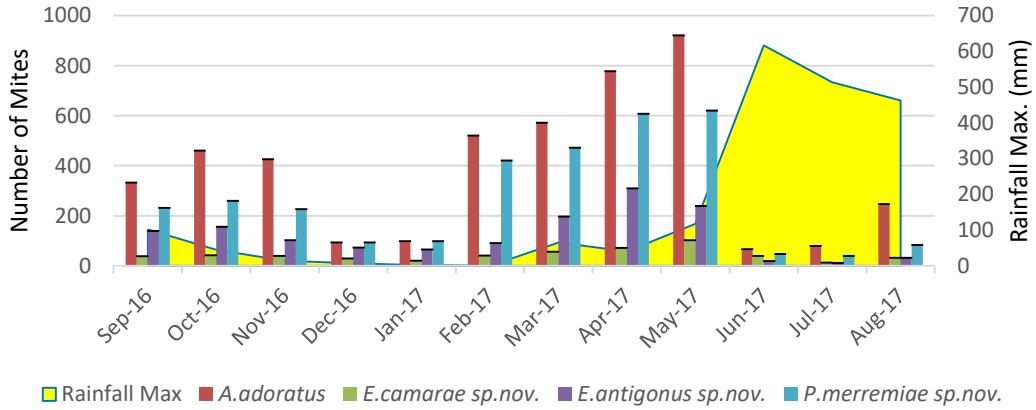
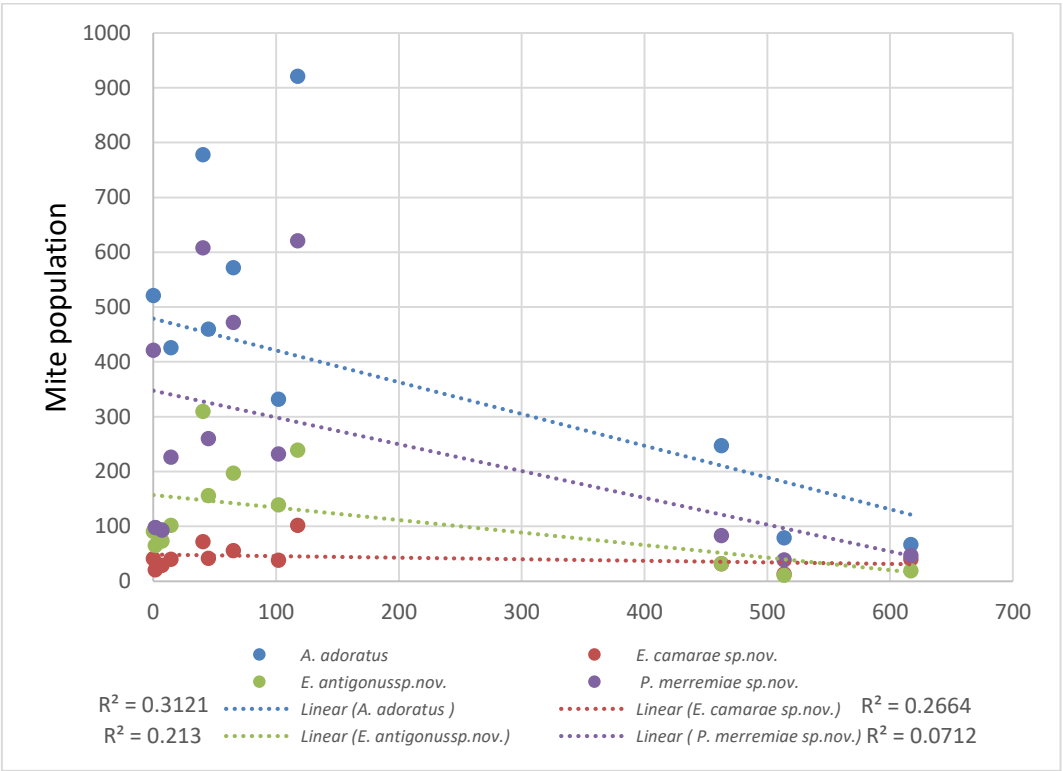


Fig.25: Correlation between mite population and Rainfall



CHAPTER VI
DISCUSSION

Invasive alien flora, fauna and microbes have become one of the most serious threats to natural communities and ecosystem processes worldwide and in India, 173 invasive alien species have been recognized out of which 54 species are terrestrial plants and eight species are aquatic plants (Sandilyan *et al*., 2018). Invasive alien plants, usually escape from cultivation and become one of the major threats to the agroecosystems and through their tremendous impact on environment, by displacing native plant species, reducing wildlife habitat, and greatly altering and interfering with the natural ecosystem. These plants act as the major drivers of biodiversity reduction and induce serious damage to agricultural systems (Wittensberg and Cock, 2001). They also extract a costly toll from human economies that depend on resources and services provided by healthy ecosystems. The major characteristic features of these plants are their undesirable attributes, unwanted occurrence and ability to adapt to a disturbed environment (Combellack, 1992). As far as India is concerned, invasive plants still remain as an unexplored or a very poorly explored entity, especially in Kerala where the livelihood of people is largely dependent on agricultural production.

Considering the dearth of knowledge on the invasive floral and faunal components of India, especially that of Kerala, the present study was undertaken with the prime intention to explore the faunal diversity of mites associated with selected common species of invasive plants growing in various localities of Kerala and also to study their distribution, abundance, injurious status and breeding strategies, especially of the highly host specific injurious species on their respective host plants. The study was based on extensive surveys carried out on the mite fauna associated with 25 species of

invasive plants collected from 88 localities distributed over 12 districts of Kerala. The findings of the study appeared quite overwhelming as it disclosed the occurrence of diverse fauna of mites on 24 out of the 25 species of plants examined. This seems to be encouraging as it revealed the richness of acarine fauna harboured by the invasive plants of Kerala, thereby indicating the need to undertake more extensive and indepth studies covering more geographical localities in future, which would disclose the existence of noval and so far unrecorded taxa of mites on the invasive flora and thereby helping in the documentation of biodiversity of plant mites in general. Mites, being a less explored group in India, especially in Kerala, detailed studies along the above line would become an incentive to explore possibilities in the near future for the detection of promising candidates to bring out adequate suppression of the growth of most nuisant invasive plants, by exploiting the phytophagous habit of highly host specific species with significant injurious status on their respective host plants.

Results of field sampling revealed the association of varied taxa of mites on 24 out of the 25 species of invasive plants screened during the study. This is a clear indication that the invasive plants of Kerala, like the other native species of plants, also support a rich and diverse acarine fauna, as 96% of plants revealed infestation by one or other species of mites. *M. diplotricha* was the plant which showed a total absence of mite infestation, irrespective of the variations in the sampling localities. When the diverse fauna of mites procured from the various invasive plants were subjected to detailed taxonomic analysis, 124 species could be identified under 50 genera and 22 families. The results of the study thus seem to support the earlier finding from the native forests of Queensland (Walter, 1999) on the rich and diverse fauna of mites inhabiting on the invasive weed, *L. camara.* The above weed was found to host more than 50 species of mites, comprising two species of host specific eriophyid mites *viz.* the leaf vagrant form,

Rhynacus kraussi and the lantana flower mite *Proctolaelaps lobatus;* three species of exotic pest mites with broad host ranges *viz. B. obovatus;* the passionvine mite, *B. phoenicis;* and the prickly pear spider mite, *T. desertorum* and 37 species of predatory mites. The results of the present study also agree with the earlier record on the diverse fauna of mites associated with 20 species of weeds grown among the physic nut crops in Brazil (Rezendo and Lofego, 2012) . The authors recorded 38 species under 16 families belonging to three major acarine taxa such as Mesostigmata, Prostigmata and Astigmata and reported that three species of weed plants *viz. Glycine wightii*, *Sida santaremnensis* and *Tridax procumbens* appeared remarkable by hosting the maximum diversity of mites, such as 18 species, 16 species and 17 species respectively. The species collected during the present study also represented the above taxonomic categories thereby giving further support to the earlier observation on their occurrence on weeds. The total 124 species recovered during the study were found to belong to three orders *viz.* Mesostigmata, Trombidiformes and Sarcoptiformes, representing two superorders, Parasitiformes and Acariformes. Of these, 53 species were categorized under a single order Mesostigmata and were assigned to the superorder Parasitiformes, and the remaining 71 species were recognized as representatives of the superorder Acariformes. The latter taxon was found to comprise species belonging to two orders *viz.* Trombidiformes and Sarcoiptiformes. Thus, 42.7% of the total mite fauna harbouring the invasive plants of Kerala were found to be the members of the superorder Parasitiformes and 57.3% of mites represented the superorder Acariformes.

The diversity of predatory mites was found very high on the invasive plants screened during the study, when compared to that of the phytophagous mites, thereby supporting the earlier finding from Egypt (Metwally *et al*. 2018) on the mite fauna associated with weeds, who observed dominance of predatory mites over phytophagous mites on weed

plants. The population density of predatory mites recorded by the authors was 77.92% whereas that of phytophagous mites was 74.72%. A similar dominance of predatory mites on weed plants was highlighted through the studies in Brazil (Rezendo and Lofego, 2012) where the phytoseiid mites showed the maximum density, though other mesostigmatid families like Ascidae and Blattisociidae and prostigmatid predatory families like Bdellidae, Cunaxidae, Stigmaneidae etc. were also recorded. The present study also disclosed similar results by collecting members of all the above families on the invasive plants including invasive weeds growing in various localities of Kerala. Thus the study helps to confirm that these plants would serve as good reservoirs and alternative hosts for predatory mites which serve as the natural biocontrol agents of harmful mites and insects, thereby ensuring protection to the agricultural crops. Based on the present as well as earlier studies, it is reliable to point out that proper handling of weeds and other invasive plants may often become useful to the farmers as these plants would serve as beneficial tools by acting as alternative hosts/reservoirs of efficient natural predators (Landis *et al.* 2000; Altieri *et al.* 2003), with high potential to suppress field populations of pest mites/insects, thereby ensuring better crop production. The predatory mite populations in the natural habitat might be influenced by the prevailing abiotic and biotic factors (Sathe and Bhosale, 2001) and which could be listed as the availability and abundance of prey population, phenology of the host plants of the prey mites, season, climate, as well as the ethology of both the predator and the prey (David, 1993).

The major families of predatory mites collected during the study were Phytoseiidae, Asciidae, Blattisociidae, Cheyletidae, Bdellidae, Cunaxidae, Eupodidae, Erythraeidae, Eupalopsellidae Stigmaeidae and Tydeidae. Of these, the former three families *viz.* Phytoseiidae, Asciidae and Blattisociidae were the mesostigmatid families and all the remaining families were categorized under the suborder Prostigmata of the order Trombidiformes. The

predatory habit of the members of Phytoseiidae has been well established globally and their dominance over the other groups of predatory mites collected during the study confirm the earlier reports (Jeppson *et al*, 1975; Walter, 1999; Rezendo and Lofego, 2012). The predatory family Ascidae collected during the study included five species under three genera *viz. Asca*, *Arctoseius* and *Lasioseius*, all of which formed new reports from the host plants and thus the present study helped to extend the host range of these species. Predatory habit of Ascidae and Blattisociidae has also been well documented (Krantz, 2009; Lindquist *et al.*, 2009), but some of the members of the former family might be saprophages (De Leon 1967). The prostigmatid families, Bdellidae and Cunaxidae also have been well known for their predatory mode of life style (Gerson, 2003; Walter *et al*., 2009), showing distribution in edaphic, arboreal and other ecosystems, feeding on different types of pests and there by regulating the prey populations (Muma, 1960). Results of the present study were in conformity with the above findings, by disclosing the presence of two species under Bdellidae and five species under Cunaxidae on the foliage of invasive plants, especially on the lower surface of middle aged leaves, where they were found wandering in search of prey and quite often feeding on the phytophagous mites also. In the present study, Tydeoidea was found represented by members of a single family, Tydeidae under which mites belonging to four genera *viz. Tydeus, Brachtydeus, Lorryia* and *Pronematus* were recovered, with the latter being the species rich genus. Tydeoid mites, have been reported to serve as prey for several groups of predatory mites including the phytoseiid mites as observed in citrus plantation (Momen, 2011). Hence, presence of species of this family appears to be very important to agroecosystems, through their dual roles such as the predators of phytophagous mites as well as prey of predatory mites. Tydeoidea has also been designated as a dominant group of predatory mites, showing worldwide distribution, generally colonizing a wide range of habitats, from soil to even

in the nasal cavities of mammals (Andre and Fain, 2000). The present study enabled to recover 11 species of Tydeidae, thereby supporting the earlier findings on their distribution on weed plants in Brazil (Rezendo and Lofego, 2012).

All the mesostigmatid mites collected during the study were recognized as members of important predatory families which showed distribution on the lower surface of leaf lamina of various species of invasive plants and were seen to wander in search of prey mites/insects. In the current study, the Mesostigmata was found represented by 48 species belonging to nine genera of Phytoseiidae and the rest shared by members of Ascidae and Blattisociidae. Thus the study confirmed Phytoseiidae as dominant group of Mesostigmata by constituting 90.6% of the total mesostigmatid mites collected. Phytoseiid mites are efficient predators with high potential to suppress populations of pest mites and also small insect pests like aphids, scale insects, thrips, white flies and so on (McMurtry and Croft, 1997; Gerson *et al*., 2003). The family Phytoseiidae comprises over 2,400 species worldwide (Demite *et al*., 2018). Extensive studies were carried out on Indian phytoseiids also since 1960 (Prasad, 1974; Gupta, 1986; 1987; Chatterjee and Gupta, 1996; Gupta and Chatterjee, 2007, Gupta *et al*., 2007; Sadanandan and Ramani, 2009; Gupta and Karmakar, 2011) and a total of 211 species belonging to 21 genera, and three subfamilies of phytoseiids are known from India (Gupta and Karmakar, 2015). These mites, based on their feeding attributes have been grouped into different categories like specialized feeders, selective feeders, generalist feeders and pollen feeders (McMurtry *et al.* 2013). Majority of these mites, being generalist predators, capable of feeding on several preys and can also survive on other substances like pollen, nectar, fungi etc. With their natural presence in agro-ecosystems, both on crops and adjacent natural vegetation (Tixier, 2018) they serve as promising candidates to perform ecosystem services like pest control, thereby

aiding in limited application of pesticides (Prischmann *et al.*, 2006; Mc Murtry *et al.*, 2015 ; Tixier, 2018). The phytoseiid genera recovered during the study were *Amblyseius, Euseius, Neoseiulus, Typhlodromus, Typhlodromips, Paraphytoseius, Phytoseius, Scapulaseius* and *Platyseiella* with a predominance of the genus *Amblyseius.* Results of field sampling enabled to record the association of all the life stages of various species of Phytoseiidae, Various life stages of members of the above genera were found associated with phytophagous mites belonging to the families, Tetranychidae, Tenuipalpidae, Eriophyidae etc. and also other insect pests like aphids, scale insects, thrips etc. All the life stages of these mites were found actively wandering on the abaxial surface of leaf lamina of respective host plants, in search of prey. These mites are known for their superior prey searching ability and preference to feed on mite pests and which raised their importance to serve as alternative to acaricides (Rondon *et al*. 2004). However, owing to their generalist feeding habit, phytoseiids are not always depending on a given prey species (McMurtry *et al*., 2013, 2015) and instead, their populations are greatly impacted by the phylloplan structure of host plants (Karban *et al*., 1995) rather than the availability of the prey (Duso, 1992; Duso *et al.*, 2004). The diverse populations of phytoseiid mites observed during the study would also be a reflection of the favourable phenotypic features of leaves of invasive plants such as the domatia and leaf hairiness (Schmidt, 2014) which would help these mites to get escaped from cannibalism and predation, by maintaining favoured humidity conditions for the survival of eggs and retaining pollen and other alternative food stuffs.

Of the total 124 species collected from invasive plants screened during the study, 71 species were identified as representatives of the superorder Acariformes, thereby constituting 57.3% of the acarine fauna. Under this superorder, members of two orders *viz.* Trombidiformes and Sarcoptiformes were recovered, with 65 species in the former and six species in the latter

taxa. Thus the study helped to record an overall predominance of Trombidiformes mites on the invasive plants of Kerala by disclosing 51%. The order Mesostigmata was constituted by 43% and the remaining 6% of mites were the members of the order Sarcoptiformes. The Trombidiformes collected during the study were found to belong to a single suborder *viz.* the Prostigmata. This finding is in agreement with an earlier report from Florida (Wiggers *et al.* 2005), which recorded a predominance of prostigmatid mites on an invasive exotic plant, *viz.* the Brazilian pepper tree, *Schinus terebinthifolius* . The authors reported that greatest species diversity of Prostigmata was followed by that of Mesostigmata, Astigmata, and Cryptostigmata, respectively on the weed. Despite this, in the present study astigmatid (acarid) diversity was the lowest, being represented by a single species *viz. T. putrescentiae.* Information on the mite fauna associated with invasive plants of India is practically meager, though several reports exist on the mite fauna of medicinal plants, ornamental plants, vegetable plants, agricultural crops etc. The association of 267 species of mites under 93 genera and 18 families with the medicinal and aromatic plants of India was elucidated in West Bengal (Gupta and Karmakar, 2011). Extensive surveys carried out in South Bengal revealed the association of 32 species representing both phytophagous and predatory feeding categories of mites with the ornamental and fruit plants (Karmakar, 2019). A total of 32 species of mites belonging to 15 genera and 7 families were reported from vegetables and ornamental plants in Himachal Pradesh (Vijay and Usha, 2014), of which 6 species represented the phytophagous category and 23 species represented the predatory category.

Among the prostigmatid mites recovered during the study, the family Eriophyidae showed the maximum generic representation, revealing the presence of 12 species under eight genera *viz. Eriophyes, Aceria, Acalitus, Calacarus, Aculus, Tegolophus, Diptilomiopus* and *Phyllocoptruta.* Eriophyid

mites are exclusively phytophagous in habit, with around 4,000 species described globally, and around 80% of which extremely high host specificity, seen in association with a single host plant species (Skoracka *et al.*, 2010, Vasquez *et al*., 2015). This leads to the possible occurrence of a large number of eriophyid mites in association with the diverse flora in nature, which await their detection and description. Most of the species were proved to be highly host specific, being confined to a single host plant each. The results of the present study also support this as it revealed the association of 12 species of eriophyid mites with eight species of invasive plants, of which two species appeared to be new to science. The noval species discovered during the study were *E. antigonus* sp. nov. and *P. merremiae* sp.nov. recovered from the host plants, *A. leptopus* and *M. vitifolia*. Eriophyoids with their high host specificity (Skoracka, 2010), high rates of reproduction and ability to enjoy wind dispersal have rated as excellent agents in weed control (Rosen and Huffaker , 1983; Lindquist *et al.*, 1996; Rosenthal, 1996; Cullen and Briese 2001; Smith *et al.*, 2010) . Through their exclusively phytophagous habit, these mites induce substantial damage to the vegetative and reproductive parts of their hosts, thereby leading to a decline in the vigor and fitness of their host weeds(Vasquez *et al*., 2015). However, only very few species of eriophyid mites have been introduced for biological control so far (Smith *et al*., 2010). Presently, species belonging to *Aceria* have been made use of weed control programmes all around the world, and the genus together another genus *Eriophyes* constitute one-third of the eriophyoid mites described so far, thereby indicating the rich species diversity of the above genera (Vasquez *et al.*, 2015). Some well known examples of weed control with the eriophyid mites as the biocontrol agents are those of *Aceria chondrillae A. malherbae* and *Aculus hyperici* , for the control of *C. juncea* (Cullen and Briese , 2001; Piper *et al*., 2004), *Convolvulus arvensis* (Littlefield, 2004; McClay and De Clerck-Floate, 2002; Craemer, 1995) and

Hypericum perforatum (Briese and Cullen 2001; Mahr *et. al*., 1997). Another case of successful introduction of biocontrol agent was that of *A. lantanae* which was introduced in various countries , for the management of *L.camara* (Creamer, 1996). The species caused gall induction and vegetative stunting, leading to 90% reduction in seed production. Similarly, another eriophyid mite, *Floracarus perrepae* was also reported as a potential natural enemy of the aggressive invasive weed of moist habitats of Southern Florida, *viz. Lygodium microphyllum* (Van Driesche *et. al.*,2007; Vasquez *et al.*, 2015). Feeding activity of the mite resulted in curling of the leaf margins of the weed, formation of black streaking and necrosis and leading to defoliation. Additionally, the mite was found to involve in the transmission of pathogenic diseases in *L. microphyllum*. The possibilities of using a species of *Aceria viz. A. artemisiae* for the control of the weed, *Artemisia vulgaris* were also evaluated by observing the bionomics of the species (Boczek and Maciejczyk, 1995) . The eriophyid mites collected during the study displayed high host specificity, limiting their distribution to a single species of invasive plant each. Results of the study enabled to collect 12 species of eriophyid mites from 8 different host plants. *E. camarae* sp.nov., *E. antigonus* sp. nov., *A. adoratus, C. lantanae, C. kalyaniensis, C. carinatus, P. merremiae* sp. nov., *T. calotropi, A. mikaniae, A. cassia, A. indicus* and *D. camerae* were the species recovered during the study from eight species of host plants. Though most of the species with biocontrol potential have been identified under the two genera, *Aceria* and *Eriophyes*, the present study encountered an eriophyid species belonging to another genus *viz. Acalitus* which also was designated as a species with weed control potential (McFadyen, 1995). The species identified was *A. adoratus* from the leaves of the Siam weed, *C. odorata* and it was found producing large number of erineal patches on the leaves of *C. odorata*. The latter plant was designated as a major invasive weed which spread very rapidly throughout the tropics,

(McFadyen, 1995; Muniappan *et al*., 2005 Zachariades *et al*., 2009). The mite was believed to be accidentally introduced and rapidly spread throughout Asia (Waterhouse 1994; McFadyen 1995; Muniappan and Bamba 2000; Orapa *et al.*,2002). The presence of the mite was reported thoughout Kerala (Ramani, 1998) and its developmental biology was also traced on the host weed *C. odorata* (Ramani, 2007). In the present study, the mite was found to infest the foliar surface, especially the abaxial surface of the leaves of *C. odorata* where it developed erineal patches of varying size and during severe infestation, erineal patches could be observed on both surfaces of the leaves of the weed, thereby supporting the earlier findings (Ramani, 2007). Being highly host specific as evidenced through the studies carried out in Trinidad (Mc Fadyen, 1977; Cock 1984), the mite would be a promising candidate with high potential to suppress the weed population under field condition.

In the present study, the family Tetranychidae showed the second position in terms of generic diversity by including species belonging to five genera. The association of species belonging to the tetranychid genera *viz. Tetranychus* and *Eutetranychus* with the invasive weed, *Bidens sulphurea* was already reported in Kerala (Saritha and Ramani, 2015) and the results of the present study strongly agree with the above finding by revealing infestation by members of five genera of Tetranychid mites *viz. Tetranychus*, *Oligonychus*, *Eutetranychus*, *Schizotetranychus* and *Bryobia* with the invasive plants of Kerala. The number of species collected under the above five genera of Tetranychidae were five, three, two, on and one respectively, thereby accounting to a total number of 12 species. Over 1275 tetranychid species were described worldwide under 71 genera from 3938 host plants of varied economic categories (Migeon and Dorkeld 2006-2017), of which 106 species under 20 genera belonging to two subfamilies, Bryobiinae and Tetranychinae were described from India, (Gupta and Gupta, 1999). Tetranychid mites constitute an extremely phytophagous group , showing

wide distribution and wide host range and all the species collected during the study were reported in various countries including India. Tetranychids have also been identified as an alternative tool for the control of weed plants (Vásquez *et al.,* 2015) as encountered through the studies on the gorse spider mite, *T. lintearius* in Tasmania, which induced severe damage to the aggressive invading species of gorse *viz. Ulex europaeus*, resulting in 36% reduction in shoot growth. However, their presence on invasive hosts has not been reported so far and hence the present recovery of these mites from new hosts, would help to extend the host range of these mites further.

The invasive plants screened during the study revealed infestation by false spider mites belonging to the family Tenuipalpidae also and a total of 6 species under 3 genera could be recovered. *Brevipalpus* was recognized as the species rich genus followed by *Tenuipalpus* and *Raoiella*. *B.phoenicis* was identified as the species with wide host range, showing infestation on 11 species of invasive plants out of the 25 species surveyed, thereby supporting earlier finding (Saritha and Ramani, 2015). Being a cosmopolitan species, *B. phoenicis* has the potential to colonise on a variety of economic crops comprising vegetables, fruit crops, medicinal plants, spices and so on (Jeppson *et al*., 1975; Kumari and Sadana 1990; Chiavegato and Kharfan 1993; Childers *et al.,* 2003a, Prabheena and Ramani, 2013; Saritha and Ramani, 2018). Detailed population studies carried out on *B. phoenicis* enabled to record the peak population of the mite in the dry season on the invasive host, *B. sulphurea* (Saritha and Ramani, 2015) and *M. micrantha* (Karmakar and Saha 2005; Saritha and Ramani, 2018).

The association of six species of Sarcoptiformes mites was also evident during the study through the recovery of members of the superorder Acariformes on three species of invasive plants *viz. C. odorata, M. micrantha* and *S. trilobata.* All the six species were representatives of the suborder

Oribatida and were included in families *viz.* Trhypochthoniidae , Oribatellidae, Mochlozetidae, Caloppiidae and Acaridae. The respective genera collected under the above families were *Allonothrus, Lamellobates (Paralamellobates), Uracrobates (Uracrobates), Zetorchella* and *Tyrophagus.* The respective species collected under the above genera were *A. russeolus russeolus, L. (P.) misella, L. (P.) bengalensis, U. (U.) indicus, Z. sejugata* and *T. putrescentiae.* Oribatid mites constitute the dominant inhabitants of soil ecosystem where they perform multitude of roles such as biodegradation and nutrient cycling (Harding and Stuttard, 1974; Haq, 1996, 2007, 2016, 2019; Haq and Konikkara, 1988; Haq and Xavier, 2005; Ramani and Haq, 2001; Lebrun and van Straalen, 1995), bioindication (Norton and Behan Pelletier, 1991; Skubala and Kafel ,2004; Lindo and Winchester, 2006; Gulvik, 2007; Gergocs and Hufnagel, 2009), biological control (Rockett and Woodring, 1966; Rockett, 1980; McClure, 1995; Cheah and McClure, 1996; Nithinya and Ramani, 2019), forensic science and so on. However, despite their prominent roles in soil ecosystem, many species of oribatid mites have colonized arboreal ecosystem (Jacot, 1930; Aoki, 1960, Ramani and Haq, 1988) and display phytophagous feeding mode (Ramani and Haq, 1987). Such phytophagous species have been reported to serve promising roles in the control of noxious weeds . Species like *Orthogalumna terebrantis* has been established in various countries as an excellent biocontrol agent of the aquatic weed, *Eichhornia crassipes* (Gordon and Coulson, 1969; Delfosse, 1978 ; Cordo and De Loach ,1975, 1976; Sankaran, 1971; Sumangala and Haq, 1990, 1992; 1995; Haq and Sumangala, 2003). Adult females of *O. terebrantis* cut circular holes on the laminar surface/petiole of the weed and oviposit within these, and the emerging larvae feed on the green matter and form feeding galleries and tunnels between the parallel veins of the lamina, leading to discoloration and desiccation of leaves. Oribatid species like *Scheloribates decarinatus* was reported to display a phytophagous habit on

the leaves of the Siam weed, *C. odorata* (Ramani and Haq, 1987) in Kerala. Diverse taxa of oribatid mites are known to colonise the foliage of invasive weeds like *E. crassipes* and *C. odorata* (Haq and Ramani, 1987) . Among the five genera of oribatid mites collected during the study, association of species belonging to genera like *Lamellobates (Paralamellobates), Uracrobates (Uracrobates)* and *Zetorchella* with plants of varied economic categories like plantation crops and weeds has been reported earlier (Ramani and Haq, 1988; Haq and Ramani, 1987).Results of the present study support the above findings and thereby confirm the arboreal habit of oribatid mites by recording the presence of these mites on three species of invasive plants screened during the study *viz. C. odorata, M.micrantha* and *S. trilobata* .

The diversity of Acarid/Astigmatid mites was comparatively very low on invasive plants as evidenced through the results of the present study. A single species of acarid mite *viz. T. putrescentiae* was recovered and it showed association with a single host plant *viz. M. micranthae* . *T. putrescentiae* is a ubiquitous species, exploiting varied natural habitats like the soil containing decomposing plant matter, nests of vertebrates, ecosystems containing varied commodities, laboratory cultures of fungi, plants and insects etc. (Hubert *et al*., 2018). The pest status of *Tyrophagus* on ornamental plants has been elucidated by many (Ciampolini *et al.*,1985; Czajkowska *et al.* 1988).) Nematophagy in *Tyrophagus* mites has also been reported (Walter *et al*., 1986; Abou El-Atta and Osman, 2016) and their potential to disseminate spores of pathogenic fungi has also been elucidated (Griffiths *et al*., 1959). *T. putrescentiae* was reported as the second most important species (after pyroglyphid house dust mites) among house dust mites which induce allergic diseases in man and domestic animals (Arlian *et al*., 1984). Many species of *Tyrophagus* were reported to induce aerial damage to several crop plants in different parts of the world and species like *T. similis, T. perniciosus,* and *T. putrescentiae* were known to cause damage in

cucurbitaceous and solanaceous crops in Japan (Ehara and Gotoh, 2000. During the present study, the presence of *T. putrescentiae* in moderate population density was observed on the leaves of *M. micranthae* and its functional role on the weed needs to be investigated further.

Thus, the present investigation revealed the association of 124 species belonging to three suborders, three orders and two superorders of the subclass Acari thereby disclosing the great diversity of mites harboured by the invasive plants of Kerala. Of these, two species belonging to the family Eriophyidae of the suborder Prostigmata were found new to science. The noval species collected and described during the study were *E. antigonus* sp.nov. and *P. merremiae* sp.nov. from respective host plants, *A. leptopus* and *M. vitifolia*. Further, results of field surveys carried out during the present investigation helped to record six species, *viz. C. reticulatus, T. kenyensis, H. biconvex, A. magnanalis, A. pristinus* and *L. parberlesei* as new reports from India. Further, the study also helped to record 51 species as new reports from Kerala and 111 species as new reports from respective invasive host plants.

Among the 25 species of invasive plants screened during the study, mite infestation could be evidenced on 24 species, and *M. diplotricha* revealed a total absence of mites. *M.* diplotricha, the so called giant sensitive plant is a fast growing invasive perennial shrub which is considered as a huge threat to the natural ecosystems by its adverse impact on agricultural crops, livestock production, biodiversity conservation and livelihoods *(*Ekhator *et al.,* 2013; Uyi, 2020). This weed is reported to smother and establish over other invasive plants like *C. odorata* and *M. micrantha* in India (Sankaran, 2001) and hamper the movement of wild animals in the National Park of Northern India (APFISN,2007). The plant is known to harbor quite a good number of insect associates and over 70 species of insects and 2 species of fungi have been identified to be associated with

this weed (Waterhouse, 1994; Ekhator *et al*., 2013), of which three species have been recognized as promising candidates for the control of the weed (Uyi, 2020). Despite the above finding, no insect /mite associates could be observed on the leaflets/stem of the weed, even after repeated examination of samples from the various collection localities surveyed during the study. Thus the results of the present study could not bring any possible chance for the biological suppression of the weed, to be initiated in Kerala, thereby demanding the need for cultural/mechanical management tactics for its regulation in the field.

In the present study, *L.camara* was identified as the invasive weed which supported the maximum diversity of mites, being infested with 35 species of mites representing 22 genera, 11 families, two suborders and two orders. *L. camara* is a notorious weed, invading all terrestrial ecosystems and imposing great threat to the natural flora and thereby leading to depletion of biodiversity. The weed is known to host a large number of insect and mite associates under natural conditions, all over the world (Palmer and Pullen, 1995; Craemer, 1996; Bolland *et al*., 1998; Walter, 1999; Held *et al*., 2001; Embarak and El-Saad, 2010). The species recovered from *L. camara* during the present study represented varied feeding groups such as predatory mites dominated by phytoseiidae, phytophagous mites dominated by eriophyid species like *E. camarae* sp.nov., Tenuipalpid species like *B.phoenicis*, Tarsonemid species like *P.latus* and also high populations of species representing undetermined feeding categories such as species of *Lorryia, Pronematus* etc. Thus the results of the present study seem to be in agreement with those of earlier workers (Flechtmann and Harley, 1974) who recorded the presence of injurious and vagrant species of eriophyid mites like *E. lantanae* and *R. kraussi* respectively apart from other phytophagous mites belonging to Tetranychidae (*T. desertorum, T. armipennis*) and Tenuipalpidae (*B. obovatus, B. trinidadensis*). Of the various injurious taxa

of mites recorded so far from *L. camara,* only the eriophyid species, *E. lantanae*, the so called lanatana flower gall mite has been successfully designated and established as the biocontrol agent of the weed (Craemer, 1996), based on its potential to induce flower galls and leading to up to 90% reduction in seed production in susceptible varieties (Vasquez *et al*., 2015).

Another notorious species of invasive terrestrial weed *viz.* the Siam weed, *C. odorata* also revealed great diversity of mites. *C. odorata,* is a weed of neotropical origin which spread throughout the tropics, and has been identified to have more than 200 arthropod natural enemies (McFadyen, 1988; Muniappan and Bamba, 2000). The present study disclosed infestation by 32 species representing 21 genera12 families three suborder and three order on the leaves of the weed. The above species were found to represent feeding categories like the predatory mites, phytophagous mites as well as nonspecialist feeders which survive on varied diet. The predatory mites were found to include species belonging to Phytoseiidae, Ascidae, Cunaxidae, Stigmaeidae, Tydeidae, Cheyletidae etc. which showed moderate to high population density on this weed. Phytophagous mites included the families of Eriophyidae, Tetranychidae and Tenuipalpidae, of which the former taxon appeared to be highly host specific, comprised of species like *A. adoratus* and *C. kalyaniensis. A. adoratus* was found to induce erineal patches of varying dimensions on the leaves of *C. odorata* thereby supporting the earlier findings (Mc Fadyen,1995; Muniappan *et al.,* 2005; Ramani, 2007). The present study also disclosed the occurrence of a single species of oribatid mite *viz. L. (P.) bengalensis* also on the foliage of the weed, thereby confirming the earlier observations on oribatid association with *C. odorata* in Kerala (Ramani and Haq, 1984; Haq and Ramani, 1987). Invasive plants like *M. vitifolia* and *A. leptopus* also supported good numbers of mite species, being infested with 24 species, and 15 species respectively, The remaining species of invasive plants screened showed either moderate or low levels of infestation by

different species of mites, without any striking species diversity and population density. Moderate/low population density by a single mite species each was observed on species like *P. chrysophylla, C. hirta, C. corymbosa, E. heterophylla, P. aquilinum* and *L. leucocephala,* thereby indicating the chances for exploitation of mites as possible regulators of Siam weed in future.

Increase in the species diversity and richness of an ecosystem is a clear reflection of the community stability (Andow, 1991). This was found confirmed during the present investigation also. The results gathered on the diversity indices on mites collected from the selected sampling sites distributed in the three districts of Kerala *viz.* Kozhikode, Malappuram and Palakkad districts revealed the maximum Shannon diversity index in the Malappuram district (H′-2.94906) followed by Palakkad (H′-2.90259) and Kozhikode districts (H′-1.52363).

Species richness also followed a similar trend with the maximum in the Malappuram Dt. (10.0002) followed by Palakkad (7.1953) and Kozhikode (4.155752) districts. However, species evenness was found high in the Palakkad Dt. (0.73108) followed by Malappuram (0.6769) and Kozhikode (0.44367) districts. In all the three districts studied, the sampling sites included undisturbed areas, agricultural lands, areas of human intervention etc. The maximum diversity of vegetation was observed in the Malappuram district followed by Palakkad and the minimum was in the Kozhikode district. Moreover, the sampling sites surveyed in the Kozhikode district were mostly located adjacent to the Kozhikode town, thereby experiencing more chances of getting exposed to pollution from various sources, especially from the automobiles and urban population. As a result, the values recorded for species diversity, richness and evenness were found the minimum in the Kozhikode district when compared to those of the Malappuram district where the

vegetation appeared relatively diverse, rich and with the maximum number of invasive flora to support the associated mite fauna.

The current study enabled to gather data on molecular barcoding and phylogeny analysis of a new species under the genus *Eriophyes viz. E. camarae* sp.nov. and the result supported the taxonomic findings made with the help of morphological characters. This mite showed a close relationship with *E. tiliae* reported from Australia. The phylogenetic tree constructed in the current study with similar species data obtained from the BLAST results showed considerable variation from the related species. DNA-based studies have been initiated as a tool in eriophyid mites about 15 years ago and the first publications dated from 1995 (Navajas and Navia 2010). The mitochondrial marker COI, which is widely used as a DNA barcode (Hebert *et al*., 2003), DNA barcoding has been used as an effective tool in species discrimination studies in taxonomy but is not a replacement for conventional taxonomy (Waugh, 2007).

The present investigation is the first report of molecular barcoding of eriophyid mites from Kerala. Classical taxonomy is considered as the foundation of taxonomy even though this DNA-based method can remove some of the unreliability associated with morphological-based taxonomy and thus contribute to the identification of deutogyne and protogyne forms of eriophyoid mites. The DNA barcoding is able to provide fast, accurate, and automatable species identifications by using short, standardized regions of gene as internal species tags (Guo *et al*, 2015). Molecular sequence data recently used to explain the taxonomy, systematics, evolutionary trends and population genetics of many acarine groups, including members of the Eriophyoidea (Navajas and Navia 2010; Skoracka *et al*., 2012; Lewandowski *et al*.,.2014). Molecular data helps to provide a sound taxonomic platform is now well established, being widely used to differentiate between species

accurately (Caterino *et al*., 2000; Tautz *et al*., 2003). DNA barcoding methods cannot replace the morphology for identification and classification of the species but those together should be collectively used (Tautz *et al*., 2003; DeSalle *et al*., 2005). The inaccessibility of a reference data is considered as one of the major causes that create a challenge in identification based on DNA barcode (Virgilio *et al*., 2010). The current study enabled to identify the morphological as well as molecular features of the new species *viz. E. camarae* sp. nov. inhabiting on the weed, *L. camara.* The results of morphological studies enabled to recognize it as a new species and it was further supported through molecular data , thereby confirming the novelty of the taxonomic status of the species. Identification and description of species could be done in a better way if the diverse types of information like morphological, ecological, physiological and molecular features of a species are integrated (Waugh, 2007; Padial *et al.*, 2010).

The population density and distribution of mites on the foliar surface of plants have been reported to be under the regulation of various physical factors operating in the environment (Sudo and Osakabe, 2011). The texture and structural features of leaves such as the density and shape of hairs, thickness of wax and cuticle and density of stomata etc. exert a great influence on the microclimates and which in turn would induce variations in temperature and humidity on the adaxial and abaxial surfaces of leaves (Price, 1980; O'Dowd and Willson, 1989; Chien and Sussex, 1996; Gutschick, 1999; Nishida, 2004; Weintraub *et al.*, 2007). Preference shown by mites to the abaxial surface of leaves could also be explained as an adaptation to escape from the adversely affecting 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). In the present study, majority of the mites showed a preference to mature leaves for feeding and their infestation was found confined to the abaxial surface. However, when the mite population got

increased, infestation was found to extend the adaxial surface also thereby infesting both surfaces of host leaves. This observation seems to be in agreement with the earlier report on the purple mite, *C. carinatus* on the mature tea leaves, where the mite population appeared higher on the lower surface initially and extended to both surfaces when the population attained peak levels (Das and Sengupta, 1962). Similarly, the citrus bud mite, *P. oleivora* preferred to infest the lower surface of citrus leaves initially, and then extended its distribution to the upper surface also, and the mite further preferred to feed on the exterior leaves than the interior ones, and also the fruits on the higher branches than those on the lower ones (Swirski, 1962). The populations of *Acaphylla parindiae* on tea plants were mostly found distributed on the mature foliage at the bottom 45 cm of tea bushes (Muraleedharan and Ambalatharasu, 1983). Similarly, the population density of *Epitrimerus pyri* on pear appeared to be greater on fruits of the upper branches than those on the lower branches (Westigard, 1975).

Detailed studies on eriophyid mites revealed their preference to occupy the unshaded areas for feeding. Intensity of shade exerts a major role in determining eriophyid mite populations, as observed in the case of tea mites. Incidence of the pink mite, *A. a theae* in tea plantation was reported to be more in unshaded areas (Banerjee, 1969). Similarly, in Tripura, *A. theae* was reported to show preference to unshaded bushes (Pande and Nandi 1983). During the present study also, shade preference by eriophyid mites was observed thereby supporting of earlier findings on *A. theae* (Banerjee, 1969) and *C. carinatus* (Danthanarayana and Ranaweera, 1974), both the species developed into high populations in unshaded areas of tea plantations when compared to those of shaded areas. This clearly shows that shade intensity would play a significant role in determining the population density of eriophyoid mites. During the present study, the eriophyid mites were found to prefer the small cracks and crevices present on lower leaf surfaces and also

both sides of the veins for deposition of eggs. Such ovipositional preference shown by mites would be an adaptation to ensure a kind of firm grip and protection to the eggs laid (Banu and Channabasavanna, 1972; Dhooria, 1982). Like other animal groups, eriophyid mite population also depends on temperature and humidity conditions of the local habitat of the host plants and among these, the impact of temperature is considered to be the most significant (Das and Sengupta 1958, Kozlowski and Boczek, 1989). In the present study the impact of major climatic factors like temperature, relative humidity, rainfall and wind velocity on the population density of selected species of eriophyid mites *viz. A. adoratus, E. camarae* sp.nov., *E. antigonus* sp. nov. and *P. merremiae* sp. nov. was also analysed and the results of the study revealed the attainment of peak populations by all the species during the summer months and a population decline during monsoon season. This observation is in support of the earlier studies on the apple russet mite, *A. schlechtendali* (Hoyt, 1969) held in Washington and which revealed that the number of mites increased during summer months and the population density reached as high as 2,000 mites per leaf during May. Similar results were recorded in another species of eriophyid mite *viz. A. litchii* (Sharma *et al.*, 1986) which displayed the maximum population density during the months of April to May with the minimum density being in the November to December period in Bihar.

In the mango bud mite, *E. mangiferae*, population density was reported to be highest in February and this was followed by a second peak beyond July with very few mites being present in October to December (Bindra and Bakhetia, 1969). Like other animal groups, eriophyid mite population also depends on temperature and humidity conditions of the local habitat of the host plants and among these, the impact of temperature is considered to be the most significant (Das and Sengupta 1958, Kozlowski and Boczek, 1989). Statistical analysis of the data obtained during the present

study on the population distribution of eriophyid mites enabled to establish a significant positive correlation between mite density and temperature, thereby confirming that temperature favours the multiplication and population build up of all the four species studied. This finding seems to support the earlier report on the positive correlation between temperature and population density of *A. litchi* on litchi (Sharma *et al*., 1986), *A. cajjani*, a vector of sterility mosaic disease in pigeon pea (Dipshikha *et al*., 2013) and the gall mite, *A. doctersi* on *Cinnamomum verum* (Nasareen and Ramani, 2015). Wind velocity also showed significant positive correlation with the population density of all the four species of eriophyids studied, thereby pointing out that wind favours mite dispersal, thereby supporting earlier observations on *A. cajani* (Reddy *et al*., 1990; Dipshikha *et al*., 2013) which developed into on high populations during months where the wind velocity was high, thereby confirming that wind velocity could assist dispersal of mites. Contrary to the above observation, a negative correlation could be established between population density of all the four species, and factors like relative humidity as well as rainfall. Humidity often served as a most important factor, affecting the population density of eriophyid mites (Proeseler, 1972) and the present study serves to confirm the negative impact of relative humidity on mite population. Despite this, a positive correlation was recorded between the population of the gall mite, *A. doctersi* on its host plant *C. verum* and the prevailing relative humidity (Nasareen and Ramani, 2015). However, the population density of the above species was found drastically affected by rain fall, thereby establishing a negative correlation between mite density and rainfall. The present study supports the above observation and also the findings on the significant negative impact of rainfall on the population density of the purple mite, *C.carinatus* (Danthanarayana and Ranaweera, 1974; Shiao, 1976). The adverse effect of rainfall on mite population could be due to the washing effect of rainfall on the adults and nymphal stages

(Kumar *et al.*, 2015). However, in the present study, all the selected species of eriophyid mites were not found completely washed out by rain fall from their respective host plants, but some were found to get retained on the host plants even after rainfall, and they were seen hiding inside the cracks and crevices on the lower surface of leaves and also on stems. With the onset of favourable conditions, these mites were found to move back to the leaves within a short period of time (Zhang *et al.*, 2003). These mites could be seen to restart multiplication after an initial decrease in numbers during the monsoon and post-monsoon seasons. Similar findings were reported in scarlet mites where the mortality rate decreased when the rain became less frequent (Oomen, 1982).

CHAPTER VII
INTRODUCTION

The second part of the thesis deals with biological observations made on four species of eriophyid mites, which showed very close association with their invasive host plants, causing significant damage through their feeding activity. Eriophyoid mites represent a unique and exclusively plant parasitic group, inducing diverse types of malformations like blistering, leaf curling, bud, leaf, flower and fruit deformation, stunted growth, witches broom effect, erineal growth, gall formation, etc. on their host plants. Almost all plant species show infestation by one or more species of eriophyid mites and most species of these mites show high degree of host specificity, being mostly monophagous and rarely oligophagous extending their feeding activity to host plants of related taxa. Invasive plants and weeds also harbor a good number of eriophyid species and over 80% of these mites occurring on weeds are reported to be monophagous, thereby necessitating their consideration as candidates for detailed explorations on their biocontrol potential of respective hosts (Bozcek and Petanovic, 1996). The association of these mites with the invasive plants screened during the present study and their dominance on respective hosts over other phytophagous mites prompted to undertake detailed studies on the feeding damage and post-embryonic development of four most common species on their respective host plants under four combinations of temperature-humidity conditions. This enabled to procure data on the extent of damage induced by these species on their concerned invasive hosts and to understand the ideal conditions which could support the maximum population build up of these mites

Around 4,000 species of eriophyid mites have been described so far and a large number of species await their detection and description (de Lillo

and Skoracka, 2010; Smith *et al.*, 2010). These mites are known to possess high reproductive rates, ability to get dispersed through wind and have high potential to damage the vegetative and reproductive parts of respective host plants, and all of which elevate their status to be considered as successful biocontrol agents (Rosen and Huffaker, 1983; Briese and Cullen, 2001). Despite the favourable features of these mites mentioned above, only very few species have been evaluated for introduction as biocontrol agents against weeds and invasive plants. As per the available reports, only 29 species have been enlisted as efficient biocontrol agents (Rosenthal, 1996; Briese and Cullen, 2001; Smith *et al*., 2010) and still, a lower number of species have been officially approved as classical biocontrol agents of invasive plants and weeds (Smith *et al.*, 2010). As 80% of the total described species of eriophyids have been reported to exhibit a monophagous feeding trend, and all plant species exhibit one or more species of these mites, the possibility of the occurrence of large number of eriophyid mites in association with the rich diversity of the flora, whether they are indigenous or invasive is very high under natural conditions. This warrants the urgent need to undertake more elaborate surveys covering extensive geographical localities so as to unravel the hidden species of eriophyid mites associated with these plants and the subsequent evaluation of their bicontrol potential on the most dreadful species of invasive plants and weed. Among the eriophyid species described so far, members widely used in weed control programmes have been found assigned to the genus *Aceria*, the probable reason for which is that the above genus together with another genus *Eriophyes* constitute nearly one-third of the known species of eriophyoid mites, thereby reflecting the high species diversity of the above genera (Vasquez *et al*., 2015).

Suppression of weeds and invasive plants by exploiting the phytophagous mites would help to control infestations and reduce their spread in time, in a safe way, without causing any adverse impact on the existing

biodiversity or the environment. Among the phytophagous mites, Eriophyoidea is the important group which has been proved successfully as biological agents for weed control (Lindquist *et al*., 1996) by inducing direct feeding damage on their hosts as well as by serving as vectors of various phytopathogenic agents and thereby transmitting serious plant diseases. For successful elucidation of biocontrol potential of eriophyids on invasive plants and weeds, mass rearing of the species is required in the laboratory, under optimum physical conditions and subsequently releasing them onto target plants in adequate numbers. It is infact a very difficult task to gather information on the host specificity of a particular biocontrol agent and its potential host range and for which elaborate studies are needed in the native range of the potential agent, on both the target plant as well as nontarget plants (Baudoin *et al.,* 1993). Invasive plants usually exhibit wide spread in natural conditions, encroaching vast geographical ranges, making their complete eradicaton using biological enemies practically impossible. Even then their population can be maintained at the desired levels, without imposing much harm to the environment or existing biodiversity, through the judicial use of natural enemies.

Apart from eriophyids, several other taxa of mites have been proved to be beneficial to agriculture, environment as well as ecosystem. At present, only five species of mites have been officially used for control of invasive plants, on a global level (Briese and Cullen, 2001). Of these, four species belong to Prostigmata and one species is a member of Oribatida. Among the prostigmatid candidates, one species belong to the family Tetranychidae while the remaining three species belong to Eriophyidae. The oribatid representative is a member of the family Galumnidae. Of these, the eriophyids have been proved to have high potential as classical biological control agents because of their high host plant specificity (Navia *et al*., 2010; Smith *et al.,* 2010;

Skoracka *et al.,* 2010). Apart from host-specificity, they often weaken the host plant by affecting plant growth and reproduction.

There are various limiting factors which reduce the potential of eriophyid mites as the biocontrol agents of weeds under natural habitats and which can be highlighted as the chances of predation, parasitism, host plant resistance, prevailing adverse climatic conditions etc. (Smith *et al.,* 2010). The most vital distribution modes of these mites, especially for covering short and medium distances include wind, pollinators and water (Lindquist *et al.,* 1996). Despite the active involvement of these agents in promoting the dispersal of these mites, the chances of their random and free deposition throughout the environment are great (Bergh, 2001). All these parameters necessitate the need for undertaking detailed studies to confirm the actual contribution expected from these mites to bring out the expectable population reduction of target weeds/invasive plants. Climatic factors exert a great impact on these mites which often would adversely affect their distribution and efficiency in the invaded range, so as to limit their control potential. This can be compensated now-a-days, by using climate matching techniques which are known to be effective in aligning climatically appropriate regions in the invasive habitat for the release of biocontrol agents (Robertson, 2008).

In the present study , attention has been focused to study the biological parameters particularly, the feeding and breeding attributes of four selected host specific and injurious species of eriophyid mites including two new species such as *Acalitus adoratus*, *Eriophyes camarae* sp.nov., *E. antigonus* sp. nov. and *Phyllocoptruta merremiae* sp. nov. on their respective host invasive plants *viz. Chromolaena odorata*, *Lantana camara*, *Antigonon leptopus* and *Merremia vitifolia*. All the above species of invasive plants have been included under the category of highly notorious weeds, based on their

adverse impact on the environment and the diversity of indigenous flora. Biological observations of the above species were carried out by adopting qualitative and quantitative methods with an intention to gather understand the nature and extent of damage induced on their respective invasive hosts. Visible symptoms of feeding damage induced by the above species of mites on their respective hosts were recorded and the anatomical injuries on leaves were assessed through histological studies of stained leaf sections. Further, the feeding impact of the above four species on the photosynthetic activity of respective host plants was studied by estimating the concentrations of photosynthetic pigments and measuring chlorophyll fluorescence of mite infested and uninfested host leaves. Alterations in the concentrations of primary and secondary metabolites in the host plants resulted through the feeding activity of the above species of eriophyid mites on their respective host plants were also analysed through biochemical estimation of total carbohydrate, total protein, total phenol, proline, moisture content etc. so as to generate data on the biotic stress induced by these mites on their target weeds. Fourier Transform Infrared Spectrophotometer (FTIR) analysis was also done to identify the structural deviations in the organic, inorganic, and polymeric materials based on the alterations in the characteristic pattern of absorption bands, so as to understand the change in the material composition.

Currently, very little information is available on the post-embryonic development of eriophyoid mites, from South India, especially from Kerala. As far as the mites infesting invasive plants are concerned, information on the biological attributes of these mites is practically paltry. Hence in the present work, data were incorporated on the developmental parameters of the above four species by rearing the species on their respective host plants, at four temperature-humidity combinations such as 20 ± 2^0C and 90±5%RH, 25 ± 2^0C and 80±5%RH, 30 ± 2^0C and 70±5%RH and 35 ± 2^0C and 60±5%RH, in order to find out the most optimum condition which could support the maximum

population build up of these mites. Precise knowledge on the optimum climatic conditions is highly essential as these would serve as the ideal conditions for mass rearing of the species under laboratory conditions, for evaluation of their biocontrol potential in future.

CHAPTER VIII
REVIEW OF LITERATURE

In the present review, earlier reports concerning the feeding attributes, injurious status as well as developmental biology of mites belonging to the various families of the superfamily Eriophyoidea have been cited. Data recorded by various workers on the diverse types of feeding damages induced by these mites on their respective host plants, including the physiological, anatomical, histological and biochemical changes, have also been included . Further, research works published by earlier workers on the life history and developmental attributes of eriophyids as well as the potential of these mites as promising candidates for the control of weeds and invasive plants have also discussed in this section.

In the pre-Linnean period itself, the occurrence of eriophyid galls and erinea was mentioned by de Reaumur (1737) who in his publication entitled "History of Insects" speculated the white tiny worm like organisms in the galls as maggots of small flies, and not as mites. He designated the linden galls induced by *Phytoptus tiliae* as "nail gall" and the erinea as "mold galls". Years later, Fee (1834) observed that the erinea contained worm like creatures, which induced the hairy masses and suggested to transfer these organisms to the animal kingdom. It was Green (1890) who first recorded an eriophyid mite on tea from India, and the species recorded by him was *Calacarus carinatus*, the commonly called purple mite of tea. Misra (1912) made the first report on an erinea forming mite from India, by observing the growth of chocolate coloured hairs on the leaves of litchi, produced by *A. litchi*. Life history parameters of a serious mite pest *viz. E. pyri,* infesting fruit crops like apple, pear etc. in various countries were studied by Hawley (1926). Massee (1927) conducted biological studies of the black currant gall

mite, *E. ribis.* Hassan (1928) while studying the host range of the species, *E. essigi reported the ability of the species to i*nfest on fruits of blackberry, loganberry and raspberry in California. The same author (1928) supplemented data on the life history and seasonal distribution of the walnut gall mite, *A .tristriatus* from California. The same author (1934) carried out elaborate studies on injuries caused by eriophyid mites to economic plants in Egypt. He observed the incidence of *E. ficus* on the younger leaves of *Ficus* in the Giza province, and *Phyllocoptes* sp. on olive trees and serious infestation of tomato in different regions of Egypt by the eriophyid mite, *E. cladophthirus.*

Putman (1939) made biological observations on the plum rust mite, *A. fockeui* and recorded that both males and females of the species were developed from the eggs laid by over wintering females. The author reported that the over wintering females (deutogynes) might be fertilized before hibernation, and only males were produced by the ordinary unfertilized females. Developmental studies carried out by Boyce and Korsmier (1941) on the citrus bud mite, *A.sheldoni* revealed that the development of the species could be completed within 7 days in the laboratory at a temperature of 24ºC. The presence of deutogynes in eriophyid mites was reported by Keifer (1942) when he conducted rearing experiments of the California buckeye rust mite, *Tegonotus aesculigoliae.* Life history studies of *A. lycopercisi* infesting tomato were performed by Bailey and Keifer (1943) and the authors observed the ability of the species to breed throughout the year except during very low temperature.

The tomato russet mite, *Vasates lycopersici* was found to induce bronzing on the leaves and stems of solanaceous plants like tomato, petunia, potato, Chinese thorn apple, various varieties of Solanum plants, as reported by Lamb (1953) and Anderson (1954). While studying the host range of *A.tulipae,* Connin (1956) recorded several plants like corn, maize, sorghum,

different kinds of grasses, wheat etc. as hosts for the species, among which wheat and barley formed the best host plants. The nature of damage induced by *A. sheldoni* was studied in detail by Fahmy (1958) on the host plants like sweet lime and lemon. Das and Sengupta (1958) conducted developmental studies of the pink mite of tea, *A. theae* and the authors recorded eight days as the mean duration required by the species to complete its life cycle. Studies were undertaken by Swirski and Amitai (1958) on the development and longevity of the citrus rust mite, *P. oleivora* and the authors recorded 28-30 annual generations for the species in Israel.

Keifer (1959) conducted studies on the morphological, functional as well as mobility aspects of the gnathosoma of eriophyid mites. Puttarudriah and ChannaBasavanna (1961) provided information on the potential of eriophyid mites in inducing viral diseases like the mango bunchytop disease in India. Boczeck (1961) from Poland performed detailed observations on the developmental attributes and overwintering habits of 12 gall forming and 11 free living species of eriophyid mites. He reported viviparity in two species *viz. A. uleae* and *R. ulmivagrans.* Slykuis (1963) attributed high host specificity to eriophyid mites and pointed out that these mites possessed an intimate relationship with their host plants. Certain species showed infestation on plants belonging to the same genus, while some others could infest on host plants belonging to several genera, but their infestation on plants belonging to more than one family was of very rare occurrence. The females of the wheat curl mite, *A. tulipae* were found to lay 3-25 eggs within 10 days as revealed through the studies of Maria *et al*., (1964). Hall (1967) conducted studies on the life cycles of two species of eriophyids like *Vasates cericides* and *Oxypleurites aesculifoliae.* The author mentioned that the eriophyids possessed two types of life cycles like the simple type with one type of female as seen in *V. cericides* and the complex type having the primary and secondary females (protogyne and deutogyne) as seen in

O. aesculifoliae. The author also provided information on the hatched larvae within the body of the protogyne of another species, *V. quadripeded* and stated that two species of eriophyids were found to produce live young ones, thereby supporting the occurrence of a third type of life cycle in which both primary and secondary females present, and the former being ovoviviparous. Oldfield (1969) reported that the chockecherry finger gall mite, *P. emarginatae* possessed only the deutogynes and the protogynes were found totally excluded from the life stages of the mite. Quack grass was recorded to be the most favoured host plant for species like *Abacarus hystrix* and *Aculodes mchenziei* while the sole host for *A. dubius* was timothy as recorded by Nault and Styer (1969). Population studies of the mango bud mite, *A. mangiferae* were carried by Bindra Bakhetia (1969) from India.

Most species of eriophyid mites were known to complete their life cycle on a single host while in certain species the females (deutogynes) spent several months without feeding and without leaving the host plants, as revealed through the studies of Oldfield (1970). The males of vagrant forms of eriophyids laid numerous spermatophores which were aggregated along the mid-vein and near the junction of lateral veins as reported by Oldfield *et al.*, (1970). Baker and Neunzig (1970) carried out biological observations on the blue berry bud mite, *A. vaccini*. Sternlicht and Golderberg (1971) made observations on fertilization, sex ratio and life stages of the citrus bud mite, *A. sheldoni*. Natcheff (1973) conducted studies on the damage caused by eriophyid mites on their respective host plants in Bulgaria. Infestation by *A. esculenti* was found to induce erinea formation on the leaves of the host, *Hibiscus esculentus* in Brazil as evidenced through the studies of Robbs and Peracchi (1972). Several strategies for classical weed biological control programmes in the Pacific region were proposed by Cochereau (1972). Extensive works carried out by Evert and Valing (1972), revealed that the eriophyid species *Nalepella halourga* induced damage to the black spruce,

Norway spruce, and New Brunswick. Structural details of sperm cells in *A. cornutus* were studied by Oldfield *et al.*, (1972) and they collected data on the process of insemination of protogynes of the species. Occurrence of deutogyne as an overwintering stage in the life history of the filbert rust mite, *A. comatus* was reported by Krantz (1973). From India, Mani (1973) provided information on some families of phytophagus mites and described a special type of gall induced by a new species of *Eriophyes*. Shevtchenko *et al*.,(1973) provided information on the occurrence of parthenogenetic mode of reproduction in the sophora gall mite, *V. semenovi,* and recommended the mite for controlling the poisonous fox tail sophora. Information on the import and establishment of the eriophyid biocontrol agent, *A. chondrillae* was provided by Careshe and Wapshere (1974) in Australia and the United States for the control of the weed, *Chondrilla juncea.* Studies on the developmental parameters of the apple rust mite, *A.schlechtendali* were carried out by Herbert (1974) and they also made observations on the population density of the mite on different cultivars of apple. Biological observations were made by Lall and Rahman (1975) on the erinose mite, *E. litchi.* Jeppson *et al.*, (1975) reported that the citrus bud mite, *A. sheldoni* apart from bud deformation could also alter the structure of leaves and fruits, and lead to the development of abnormality. Thomsen (1976) provided data on the initiation of galls, development of larvae, dispersal and overwintering of the gall mite, *E. tiliae*

Easterbrook (1978) conducted biological observations of *Epitrimerus pyri* and they traced the life history of the species under different temperatures. The morphology and life history of *A. schlechtendali* infesting apple in South-east England were also studied by the same author (1979) and he established a negative correlation between temperature and duration of development. Data on the duration of the different life stages of *E. datura* were collected by Abou-Awad (1980) by rearing the species in the laboratory

at 26±1^{0}C and 70% RH. The same author (1981) made biological studies on the mango bud mite, *E. mangiferae* and found that the mite required a minimum of 15 days for the completion of its life cycle when reared on mango seedlings in the laboratory at 26 ± 1^{0}C and 70 %R.H.

Keifer (1982) conducted studies on the various injurious symptoms caused by eriophyid mites on the buds, shoots, stems, twigs, flowers and fruits of their respective host plants. Schliesske (1984) assessed the impact of temperature and photoperiod on the development of the gall mite, *A. fockeui*. An elaborate account on the biological parameters of gall mites was provided by ChannaBasavanna and Nangia (1989). Studies on the duration of development of the raspberry leaf mite, *P. gracilis* were carried out by Dobrivojevic and Radmila (1985) and they observed that the species required around 14 days for completion of one generation. Sheela *et al*., (1988) conducted studies on the biology of the gall mite, *A. pongamiae* infesting *Pongamia pinnata* in Kerala and recorded duration of individual instars of the species. Nazacl *et al*., (1988) reported that *A. malherbae caused* damage to the leaves and buds of *Convolvulus* in Italy. Ives and Wong (1988) mentioned that mites of microscopic size induced galls on the flowers of ash and poplar trees, leaves of various plants like maple, linden, cherries etc., and the species of mites showed high host specificity. The authors observed that the flower galls and bud galls remained on the plants for several years and the leaf galls often showed discoloration and distortion and dropped, but the mites returned and showed reinfestation. The authors also pointed out that the mites injected some chemicals into the plant tissues during feeding and which caused the abnormal growth, leading to gall formation. Studies on the morphology and biology of *Neotegonotus indicus* were made by Ghosh and Chakrabarti (1988) from North India and the authors provided descriptions of the various developmental instars of the species. Royalty and Perring (1988) reported that the leaf vagrant eriophyid mite, *A.lycopersici* induced

hypersensitive reactions in the epidermal cells while piercing these for feeding and which in turn caused the accumulation of lignin like compounds in the walls of the adjacent intact cells. The same authors (1989) recorded a 50% decrease in the photosynthetic rate of tomato leaves, infested with *A.lycopersici.* The abnormalities induced by some species of gall forming mites were analysed by Baker and Chandrapatya (1989) in Thailand. Wilson and O'Dowd (1990) recorded 38 % reduction in the photosynthetic area in *P. americana* due to infestation by *Phytoptus emarginatae*. A direct correlation was observed between the level of infestation and population density of the mango leaf coating eriophyid mite, *Cisaberoptus kenyae* and mango varieties, as recorded by Ramani and Haq, 1989) in Kerala. Gerson and Smiley (1990) made a review on the potential use of eriophyid mites in biological control and the authors pointed out that these mites appeared relatively slow acting as well as highly host -specific. Life history studies of *C. kenyae* were carried out by Ramani and Haq (1991) under laboratory conditions.

The extent of damage caused by the gall and erinea forming species of eriophyid mites infesting on some medicinal plants of North Kerala were made by Sheela and Haq (1992). Rai *et al.,* (1993) conducted studies on the monthly fluctuations in population density of *C. kenyae* in North India and they provided information on the susceptibility of common mango varieties to the attack of this mite as well as percent of leaf area covered by the leaf coating on different varieties of mango trees. Crane and Hiratsuka (1994) studied the Perennial stem galls of aspen caused by the popular budgall mite, *Aceria parapopuli*.

Boczek and Maciejczyk (1995) carried out biological observations of the mite, *A. artemisiae* infesting the weed, *Artemesia vulgaris* in Poland. The authors reported that the mite exhibited wide distribution range covering the southern to the northern parts of Europe. Within the galls, the mite completed

two generations and the secondary female underwent overwintering on roots in the upper layer of soil. Based on the wide distribution and easy transfer of the mite, the authors suggested that the mite would get easily established in different habitats. McFadyen (1995) observed the formation of erinea by the eriophyid mite, *A. adoratus* on the leaves of the terrestrial weed of neotropical origin *viz. C.odorata.* Smith Meyer (1996) reported that *A. lantanae* induced vegetative deformations in the notorious terrestrial weed, *L. camara,* and which was evident as masses of very small leaves. Lindquist and Oldfield (1996) reported that feeding by eriophyid mites would result in reduction of nutrients and reduction in photosynthesis and gas exchange, and thereby destruction of the epidermal cells and reduced growth. Boczek and Petanovic (1996) provided information on the occurrence of 93 species of eriophyid mites on 103 species of weeds in Poland and Yugoslavia and the authors reported that many of the mite species inflicted considerable levels of damage on their respective host plants. The authors also provided data on the biological aspects and host relationships of a good number of these species and further reported that over 80% of eriophyid mites inhabiting on weeds, being monophagous, would be the ideal biological weed control agents. The feeding effects of mites on their host plants were studied by Westphal and Manson (1996) and they reported that eriophyid mites would attack all plant parts except the roots. The authors noticed the presence of dead cells in almost all mite galls resulted through the feeding activity of mites. The mites, after perforation withdrew their cheliceral stylets from the cell wall and then fixed their labrum to the hole in the cell wall to actively uptake the cell contents. The short term feeding activity of *A.lycopersici* was found to induce production of several enzymatic proteins in the leaves of tomato plants, as reported by Stout *et al*., (1996). Easterbrook (1996) observed various damage symptoms on the leaves, flowers and fruits of apple such as colour changes, cracking and russetting as a result of feeding by *A. schlechtendali.*

Cytological studies carried out by Kozlowski and Zielinska (1997) revealed the collapsing lower epidermal cells, rupture of cell walls and plasma lemma and damage of spongy parenchyma on the lower surface of apple leaves, which showed infestation by *A. schlechtendali.* Depending upon the extent of feeding and population density of the mite, a reduction in chlorophyll content and decrease in photosynthesis coupled with changes in the micro and macro nutrient concentration in the infested Apple leaves as observed by Kozlowski (1998). Spieser *et al.,* (1998) traced the feeding impact of *A. schlechtendali* on the field grown apple leaves in Switzerland and found a reduction in gas exchange within the spongy parenchyma, due to the damage of stomata. The eriophyid mites, after hatching out from the eggs were found to pass through two instars to become adults and the females (protogynes) resembled the males as evidenced through the studies of Nielsen (1998). The author further stated that certain species, particularly those which infested deciduous hosts had a secondary female/deutogyne which represented the overwintering stage and in some species, the deutogynes also moved out to undergo aestivation before overwintering.

Infestation by *A.fockeui* on peach leaves resulted in a significant reduction in photosynthesis as recorded by Kondo and Hiramatsu (1999). Umapathy and Rajendran (1999) studied the seasonal incidence and control measures of *C. kenyae* on different mango varieties through the application of chemical and botanical acaricides. Ramaraju *et al.,* (1999) conducted studies on the management and control of coconut eriophyid mite, *A. guerreronis* in Tamil Nadu. It was observed by Cranshaw (1999) that most of the eriopyid mites would feed on perennial plants and their mouth parts being very small, could penetrate plant cells without killing the cells. The author also pointed out that some species would inject chemicals similar to weed killers into plant tissues while feeding thereby inducing distortion of leaves, buds and flowers. The same author (1999) reported that the development from egg to adult stage

in eriophyid mites could be completed in 10 days or two weeks under optimal conditions. Haq (1999) conducted elaborate studies on the invasion, spread and distribution of the coconut mite, *A. guerreronis* in India and neighbouring islands. Mohanasundaram *et al*., (1999) devised measures for the management and control of *A. guerreronis* in Tamil Nadu. Elaborate studies were undertaken by Haq *et al*., (2000) in Kerala on the invasion, distribution and injurious status of *A. guerreronis.*

Haq (2001) provided data on the culturing and rearing technique of the coconut mite, *A. guerreronis* and its predators. Detailed studies by Rancic and Petanovic (2002) on the morphological and anatomical alterations in the leaves of the weed, *Gallium mollugo* induced by the feeding activity of *A. anthobius* revealed leaf rolling of the host plant. The upper and lower epidermal cells of mite infested leaves were found destroyed. The results of their study enabled to understand the potential use of *A. anthobius* as a promising candidate for biological control of the weed. The feeding symptoms induced by *P. tetratrichus* on different host plants were traced by Soika and Kielkiewicz (2004). Martina *et al.*, (2005) recorded the effect of feeding by *Calepitrimerus vitis* on *Vitis vinefera* in Australia and they observed that mite feeding would lead to the incidence of Restricted Spring Growth Syndrome characterized by leaf and shoot distortion and retarded shoot growth. Ghoshal and Mukherjee., (2005) made a preliminary study on the feeding impact of different species of mites causing changes in the biochemical components of leaves of different host plants like bani, guava, jute and pumpkin. Their study revealed a reduction in the organic compounds *viz.* chlorophyll, total protein and total carbohydrate. Feeding by eriophyid mite, *Vasates quadripedes* caused leaf galls in *Acer sacharinum* as reported by Agnese *et al*., (2005), and the authors recorded a decrease in chlorophyll a, chlorophyll b, and total carotenoid pigments due to mite feeding. Abou-Awad *et al.,* (2005) conducted detailed studies on environmental management and

biological aspects of two species of olive infesting eriophyid mites *viz. Aceria oleae* and *Tegolophus hassani* in Egypt. Ozman and Goolsby (2005) carried out observations on the biology and phenology of the eriophyid mite, *F. perrepae*, a potential biocontrol agent of the invasive weed, *Lygodium microphyllum* in the native range of the host plant, Queensland, Australia. The damage potential was also studied by the authors and reported that *F. perrepae* caused consistent damage to *L. microphyllum* in all the field sites over the entire two years of their study. Goolsby *et al.,* (2005) reported that infestation by F. perrepae was specific to L. microphyllum, without causing any risk to other native or cultivated ferns in North and South America and based on their observations, the authors recommended for the release of the mite in Florida as a potential biocontrol agent against L. microphyllum .

Rancic *et al*., (2006) conducted detailed studies on the morphological and anatomical injuries induced by the eriophyid mite, *A. anthocoptes* on the leaves of the invasive plant, *Cirsium arvense* and the authors observed that the mite induced visible symptoms of russeting and bronzing on the leaves, folding and distortion of leaf blade , leaf edge curling and gradual drying up of leaves. The anatomical injury of field infested leaves was limited to the lower epidermis whereas experimentally infested plants showed injuries in the upper and lower epidermal cells, cells of the deeper mesophyll layers and even the phloem of the vascular bundles. Developmental studies of the erineal mite, *A. adoratus* were carried out by Ramani (2007) on the notorious terrestrial weed, *C. odorata* in Kerala. Structural malformations in the leaves of *Dipsacus laciniatus* induced by *Leipothrix dipsacivagus* were studied by Pecinar *et al.,* (2007) and the results of which revealed that the mesophyll tissue of infested leaves consisted of 2-3 layered palisade parenchyma and several layers of undifferentiated spongy parenchyma. Where as in uninfested leaves, the mesophyll is differentiated into several layers of palisade tissue and 1-3 layers of spongy tissue.

Le Bourgeois *et al* (2008) made a review on the opportunities for classical biological control of weeds in European overseas territories, some of the most threatening species for which classical biological control could be achieved through regional or international collaboration. Skoracka *et al*., (2010) carried out studies on the host-plant specificity and specialization in eriophyid mites and they mentioned the importance of these factors for the use of these mites as biocontrol agents of weeds. The results of the above studies showed that 80% of eriophyids infested only on one host species, 95% on one host genus, and 99% on one host family. Smith *et al*., (2010) evaluated the effectiveness of eriophyid mites for biological control of weedy plants and they identified critical areas like life history, foraging and dispersal behavior, mechanisms controlling host plant specificity, and evolutionary stability of these mites for future research. This knowledge was critical and essential for designing and interpreting laboratory and field experiments to measure host plant specificity and potential impact on target and nontarget plants, before their release in the field. An economic assessment of the role of biological control agents for the management of invasive alien plants and also to the protection of ecosystem services in South Africa was assessed by De Lange and Wilgen (2010). Petanovic and Kielkiewicz (2010) conducted studies related to both specific and unspecific morphological alterations of plant organs caused by eriophyoid mites. The authors analysed the diversity of plant malformations, such as galls, non-distortive feeding effects and complex symptoms induced by eriophyid mites and/or pathogens vectored by them, based on old and new case studies, and reported that rate of photosynthesis was reduced due to erineum formation induced by *A. tristriatus* on leaves of walnuts.

Smith *et al*., (2010) made a review of the available works on the effectiveness of eriophyid mites as agents in weed control and the authors made a detailed discussion on the challenging areas for future research. Duso

et al.,(2010) observed that the tomato russet mite, *A. lycopersici* was capable of tolerating and completing several generations under varied climatic conditions on different parts of its host plant until the desiccation of the latter**.** Observations made by Sheela and Haq (2010) on the breeding biology of *A. vitifoliae* infesting *H. vitifolius* revealed that the species could complete its development within 13 – 16 days at a temperature of 28-30^{0}C. Sholesadi *et al.*, (2010) studied the leaf damage induced by *A. oleae* on seven varieties of olive plants in green house condition and recorded a significant difference in damage depending on varietal difference.

Patankar *et al*., (2011) reported that the presence of galls on a leaf could reduce leaf photosynthesis by 30 to 60% and that the presence of only a few galls could compromise gas exchange across the entire leaf. The biochemical analysis of leaf galls of *H.vitifolius* induced by *A. hibisci* carried out by Chakrabarti *et al* (2011) revealed an increase in soluble sugar, polyphenol, free proline and rise in activation of oxidative enzymes etc. Their study also revealed that the increase in activation of enzymes in gall tissues was almost two folds when compared to that of the normal healthy tissue at the onset of gall formation. Studies were carried out by Abou-Awad *et al* (2011) with regard to environmental management and biological aspects of two species of eriophyid mango mites *viz. A. mangiferae* and *M. mangiferae* in Egypt. Detailed studies on the postembryonic development of *A. guerreronis* infesting coconut plants in Kerala were made by Sobha and Haq (2011). A review on the biology, recognition and impact of eriophyid mites associated with trees and shrubs was made by Grasswitz (2012). A case study of a leaf-curling eriophyid mite, *Aceria* sp. infesting on *Forestiera pubescens* was done to illustrate the control strategies for eriophyids in native plant nurseries Grasswitz (2012). Infestation by the mango leaf coating mite, *C. kenyae* was found to result in high decrease in all minerals and various macro and micronutrients in mango leaves as evidenced through the studies of

Abou-Awad *et al*., (2012). Daud *et al* (2012) studied the feeding impact of *C. heveae* on physiological processes of two varieties of rubber clones and revealed a reduction in the productivity of rubber trees due to significant reductions in the rates of transpiration, photosynthesis, stomatal conductance etc. Mite-induced damages, *viz.* chlorosis, bud malformation, shoot deformity, leaf crinkling and reduction of leaf size in the medicinal plants of Kerala were discussed by Sheela and Ramani (2012). While analyzing various biochemical parameters in the leaf galls of *P. pinnata* induced by *A. pongamiae,* Nasareen *et al.,* (2013) recorded an increase in concentration of phenols, especially that of o-dihydroxy phenols accompanied by an increase in Indol Acetic Acid. Patnaker *et al*., (2013), conducted studies on the impacts of galling by two species of eriophyoid mites on the leaves of two species of willows (*Salix pulchra* and *Salix glauca*) in Alaskan arctic tundra and found that galled leaves showed significant reduction in maximum photosynthetic capacity (Amax), photosystem II efficiency (FV/FM) and stomatal conductance and thereby affecting the whole-plant functioning in arctic willows.

The major type of injury caused by infestation of *A. tosichella* in wheat was found resulting from the transmission of severe pathogenic viruses such as the wheat streak mosaic virus and wheat mosaic virus yield-reducing pathogens, which could lead to drastic reduction in yield as revealed through the studies of Dumon *et al*., (2013). Studies conducted by Navia *et al*., (2013) proved that the mite could transmit other viruses also such as the brome streak mosaic virus and triticum mosaic virus. Van Wilgen *et al*., (2013) published a work entitled “Some Perspectives on the Risks and Benefits of Biological Control of Invasive Alien Plants in the Management of Natural Ecosystems” which provided a perspective on the risks and benefits of classical weed biological control, and it was aimed at assisting environmental managers in their deliberations on whether or not to use this strategy in preference, or as a supplement to other alien invasive plant control

practices. Lee *et al*., (2014) reported the incidence of *A. theae* on tea in Korea, and the species was detected as a vagrant on the lower leaf surface and it remained under floral bud scales and caused leaf rust. Mukwevho *et al.*, (2014) conducted seasonal surveys on the establishment and spread of *A. lantanae* on the invasive weed, *L. camara*, and infestation rate of which was recorded within 100 km radius from the original release points. The study revealed the relationship between establishment/infestation levels by the flower-galling mite as a biocontrol agent. The variety of *L. camara* exerted a significant impact in determining the establishment and infestation levels. Feeding impact of *A. doctersi* on cinnamon, *C. verum* was analysed by Nasareen *et al.,* (2014) and the study revealed a significant reduction in the amounts of chlorophyll a, b, total chlorophyll and carotenoid pigments, and thereby reducing the photosynthetic efficiency of the host plant. The ability of the wheat curl mite, *A. tosichella* to infest on a wide range of cultivated and wild grasses was reported by Skoracka *et al*., (2014). A comparative evaluation of the carbohydrate contents in the galled and ungalled leaf tissues of *C. verum* induced by *A. doctersi* was made by Nasareen and Ramani (2015). A significant increase in carbohydrate contents was observed in both the young and mature gall tissue when compared to the uninfested leaf tissues. Chetverikov *et al.,* (2015) reported that eriophyid mites could synthesize and secrete chemicals which would cause changes in the metabolism of plant hormones, as well as trigger biochemical chain reactions responsible for induction and growth of plant abnormalities. Biological studies made by Navik *et al.,* (2015) on *Calepitrimerus azadirachtae* infesting neem in Karnataka revealed that the mite completed its life cycle from egg to adult within 8.03 ± 0.81 days. Malagnini *et al.,* (2016) pointed out the possibility of transmitting around two dozens of severe viral diseases to the herbs and woody plants by eriophyid mites. The relationship between the damage and population density of *Aceria guerreronis* at different fruit ages

collected from green dwarf variety of coconut plantation was investigated in Brazil to improve monitoring techniques by Guimarães-Sousa *et al.,* (2017).

Marini *et al.,* (2017) provided information on two species of eriophyid mites which could be considered as promising candidates for the control of two species of invasive alien plants *viz. Ailanthus altissima* (Tree of Heaven) and *Ambrosia artemisiifolia* (Common Ragweed). Sarada *et al.,* (2018) made a detailed review on the nature of damage, biology, ecology, integrated management programme etc. of the citrus rust mite, *P. oleivora*. However, regular monitoring and resistance management were emphasized as the prime aspects for programming a sound integrated pest management program as a future perspective. de Lillo *et al*., (2018) made a review of eriophyoid-host plant interactions, the author also made studies on the susceptibility within selected crops and main host plant tolerance, resistance mechanisms and the role of species belonging to the family Eriophyidae as vectors of plant viruses etc. Al-Azzazy and Alhewairini (2018) conducted studies on the biology of the tomato russet mite, *A. lycopersici* on tomato at various temperatures ranging from 8°C to 39°C, all at 55 ± 5% R.H. and photoperiod 12/12 h light/dark, under laboratory conditions. Ramani (2019) conducted detailed observation on the feeding impact of the mango leaf coating eriophyid mite, *C. kenyae* on the photosynthetic efficiency as well biochemical constituents of its host plant, *M. indica* in Kerala and recorded significant reduction in the chlorophyll, carotenoid and total carbohydrate contents, decline in the functioning of photosystem II as well as significant increase in stress factors like proline and total phenol. While conducting studies on the population parameters of *A. guerreronis* infesting coconut plants in Kerala, Sobha and Haq (2019) recorded a seasonal fluctuation in the population density of the mite, with the maximum population being in the January to May period and minimum population during the months of June to August.

By quantifying the rate of growth of individual rachises of the invasive vine, *Lygodium microphyllum*, under varied light conditions and seasons, David and Lake (2020) determined the damage potential of the biological control mite, *F. perrepae*. The authors observed that the mite caused a reduction in the climbing ability of its invasive host and caused 85% of rachise damage through its feeding and the damaged rachises did not attain normal growth rate.

CHAPTER IX
MATERIALS AND METHODS

Mite species and respective invasive host plants selected:

Selection of the materials required for the present investigation was made considering various factors such as the wide occurrence, luxurious growth, notorious nature and adverse impact of the invasive host plants. Among the varied mite fauna associated with the invasive plants screened during the study, eriophyid mites alone were considered for detailed biological observations, considering their relatively high specificity and monophagous habit on their respective host plants. Further, the potential of these mites to induce considerable symptoms of feeding damage on respective invasive host plants was also taken into account while making their selection. Accordingly, four species of highly noxious invasive weeds which showed wide distribution range in all/most of the sampling localities surveyed during the study *viz. Chromolaena odorata, Lantana camara, Antigonon leptopus* and *Merremia vitifolia* and the respective eriophyid mite species associated with these weeds *viz. Acalitus adoratus, Eriophyes camarae* sp.nov., *E.antigonus* sp. nov. and *Phyllocoptruta merremiae* sp. nov. respectively were considered for the study.

1. *Acalitus adoratus vs. Chromolaena odorata*:

C. odorata, the commonly called Siam weed has been as a notorious terrestrial weed and included in the list of the top 100 of the world's worst invaders in the Global Invasive Species Database (GISD). Having the ability to spread very fast, the plant got introduced into various parts of the world, and successfully colonized all available habitats, exerting a lot of adverse impact on the environment. Though the plant was found to host 32 species of

mites on its foliage, the eriophyid species, *A. adoratus* exhibited high host specificity to confine its distribution mainly on the lower surface of leaves of *C. odorata*, in all collection localities. The visible symptoms of mite infestation were clearly visible in the form of varying number of dense hair growths developed as patches, the so called "erineal patches "which covered the entire laminar surface in extreme cases of infestation.

2. *Eriophyes camarae* sp.nov. vs. *Lantana camara*

L. camara has been rated as a notorious weed and included in the top 100 of the world's worst invaders in the Global Invasive Species Database (GISD). This plant was introduced as a popular ornamental garden plant, having medicinal values too. It got introduced in to various parts of the world and has got diverse geographical distribution. Despite its horticultural and medicinal benefits, this plant is known to cause a large scale biodiversity depletion, thereby necessitating its suppression at affordable levels. Apart from the various insect natural enemies, an eriophyid species *viz. A. lantanae* has already been listed as a promising biocontrol agent of the weed, based on its ability to induce formation of flower galls and stunting of vegetative growth. The present new eriophyid species, *E. camarae* sp.nov. is a leaf vagrant mainly infesting the lower laminar surface of *L. camara* and inducing feeding symptoms like chlorotic spots, stiplings, bronziness, yellowing and finally leaf drop. Considering the high population density of the mite on the weed and its significant feeding damage on the leaves the species was selected for detailed biological studies to evaluate its damage potential on the weed, the duration of life cycle as well as the optimum temperature-humidity combinations which support the maximum rate of development and the shortest developmental duration. Such a knowledge would be highly useful for mass rearing of the species for future studies on its biocontrol potential against the notorious weed.

3. ***Eriophyes antigonus* sp.nov. *vs. Antigonon leptopus***

A. leptopus is an invasive, fast growing perennial evergreen vine in the tropics, which climbs easily on palms, trees and electric lines, with the thick foliage quickly covering the walls, buildings etc. A new species of eriophyid mite *viz. E. antigonus* sp.nov. was found infesting the foliage of this weed, as a leaf vagrant form. This vagrant species was found to wander all over the laminar surface, mostly confining to areas adjacent to the midrib or other veins, inducing feeding symptoms like stipplings, yellowing, bronziness and finally dropping of leaves. Based on its host specificity and significant damage induced on the host plant, this species was selected for detailed biological studies.

4. ***Phyllocoptruta merremiae* sp.nov. *vs. Merremia vitifolia***

M.vitifolia is a widely distributed invasive species of climber, which easily invades the natural habitats by its twining habit. It is found flourishing at forest edges, along roadsides, railway tracks, vacant areas, agricultural zones, urban areas, electric lines etc. as thick foliage and which rapidly replaces the native flora. The foliage of this plant shows infestation by a new species of leaf vagrant form of eriophyid mite *viz. P. merremiae* sp. nov. All life stages of this species colonised on the lower leaf surface and during heavy infestation mites showed their distribution on both surfaces of the leaves, producing damage symptoms like feeding punctures, chlorotic spots, and stipplings. Mite infested areas were easily recognizable under field conditions based on the yellowish tinge followed by bronzing, shrinkage and ultimately leading to leaf drop. Considering the host specificity and the damage symptoms on infested leaves, the species was selected for detailed studies on its feeding attributes and postembryonic development under different temperature -humidity combinations to evaluate its damage potential on the invasive host plant, *M. vitifolia.*

I) STUDIES ON THE FEEDING BIOLOGY OF SELECTED SPECIES OF ERIOPHYID MITES

I) Assessment of feeding damage

The feeding biology of the above four species of eriophyid mites on their respective host plants was studied by adopting both qualitative and quantitative measures as described below:

1) **Qualitative assessment of feeding damage:**

a) Assessment of feeding damage based on visible symptoms of infestation:

i) Under field conditions: The mite infested leaves collected from the four species of invasive plants mentioned above were brought to the laboratory and specific feeding symptoms were analyzed under a stereozoom microscope (model KSz0850). The visible signs of feeding damage induced by the selected species of eriophyid mites on respective host plants mentioned above were noted. Photographs of the visible feeding symptoms induced by individual species on its host plant were taken using a Magvision 10 MP (Cat Cam), 48 MP camera with Sony IMX586 camera sensor and included in the thesis.

ii) Under laboratory conditions: Rearing of the four species of eriophyid mites selected for biological studies was carried out in the laboratory at ambient temperature-humidity conditions on the leaves of respective host plants by following leaf disc method. For this, the active life stages of the selected eriophyid species were introduced on to the fresh leaf discs, cut from the leaves of respective host plants. The leaf discs containing the active life stages were kept in petriplates (90 mm diameter and 10 mm height) lined with cotton pads and rearing was carried out under laboratory conditions. Regular

observation was made on the feeding activity of the various life stages of each species and the damage symptoms induced by them on the leaves of respective host plants. Photographs of the life stages of the various species and the damage symptoms induced by their feeding activity were taken with the help of Magvision 10 MP (Cat Cam) and 48 MP camera with Sony IMX586 camera sensor.

b) Assessment of anatomical damage:

Anatomical levels of leaf damage induced by the selected eriophyid species were studied by preparing thin sections of both uninfested and infested leaves of respective host plants. Both the uninfested and mite infested leaf samples collected from the respective host plants were brought to the laboratory in polythene bags and were subjected to thorough washing in order to remove the life stages, moulting skins etc. of the mites and also the dust/debris particles adhered to the laminar surface. After thorough cleaning and subsequent drying, thin sections of the leaves were cut using a sharp blade. Finely cut sections were stained with safranine for three minutes. Excess stain was removed through destaining and properly stained sections were mounted in DPX. The slide mounted sections were examined under a research microscope for making a comparative evaluation of the cellular features and anatomical alterations resulted through the feeding activity of the life stages of the selected species of eriophyid mites. Photographs of the slide mounts of stained leaf sections were taken with the help of Leica DFC 295 attached to Leica S8APO microscope, Magvision 10 MP (Cat Cam) and 48 MP camera with Sony IMX586 camera sensor.

c) Attenuated Total Reflectance Fourier Transform Infrared Spectrophotometer (ATR-FTIR) based analysis of alterations in functional groups:

Being one of the most powerful tool for identifying the types of chemical bonds (functional groups) present in compounds, Attenuated Total Reflectance Fourier Transform Infrared Spectrophotometer (ATR-FTIR) analysis was carried out to find out the alterations in the functional groups in the leaves as a result of feeding activity of the selected species of eriophyid mites. In the current study, Fourier Transform Infrared Spectrometer (Jasco FT/IR- 4700) was used for analysis. Placed each sample on top of surface of the crystal, then kept the gripper plate above to the sample. Adjusted the pressure applied to the gripper plate to ensure the consistent contact achieved between the crystal and the sample. The detector recorded the attenuated IR beam as an interferogram signal, which could be used to generate an IR spectrum.

2) Quantitative assessment of leaf damage:

Feeding damage induced by the various life stages of the selected species of eriophyid mites on their respective host plants was assessed quantitatively by measuring the photosynthetic efficiency of uninfested and mite infested leaves as well as through comparative estimation of concentrations of various biochemical parameters like the photosynthetic pigments, primary and secondary metabolites like the total carbohydrate, total protein, stress factors like proline, total phenol and moisture content etc. Apart from the above, alterations induced by the feeding activity of mites in the functional groups of the leaves of respective host plants were also studied using Fourier Transform Infrared Spectrophotometer (FTIR). The above lines of studies were carried out by collecting leaf samples from the respective host plants growing in localities lying in and adjacent areas of the Calicut

University Campus. The leaves collected from each host plant were kept in zip lock covers and brought to the laboratory for the various biochemical studies mentioned above. Prior to initiation of biochemical analysis, the leaves were thoroughly cleaned to remove adhered mites/life stages. Each experiment was repeated ten times to get a consistent result, and the data were analyzed statistically using IBM SPSS Statistics (Version 23) and were presented through graphs and tables.

i) Analysis of Photosynthetic Efficiency :

The photosynthetic efficiency of both the control (uninfested) and experimental (mite infested) leaves was measured using a Handy Photosynthetic Efficiency Analyzer instrument (Handy PEA, Hansatech Instrument Pvt. Ltd., Norfolk, UK (Plate 20, Fig. e). Chlorophyll fluorescence of the control and experimental leaves of the four species of invasive host plants was measured at room temperature on the fully expanded leaves. Prior to the measurement of chlorophyll fluorescence, leaf samples were dark adapted for 15 minutes, using dark adaptation clips (Plate 20, Fig. a – d). The fluorescence signal received by the sensor was recorded and digitalized by the control unit. Data on general parameters like F_0 (minimum fluorescence), Fm (maximum fluorescence), Fv (variable fluorescence) and PI (performance index) etc. were recorded separately for infested and uninfested leaves. Values for Fv/Fm (where Fv = Fm-F_0), a parameter commonly known as the "Maximum quantum yield of primary photochemistry" or "Maximal electron transport rate (ETR)" of PS II of both mite infested and uninfested leaves were recorded separately for calculating the reduction in photosynthetic efficiency owing to mite feeding.

ii) Estimation of photosynthetic pigments:

In order to evaluate the feeding impact of mites on the photosynthetic pigments of the invasive host plants, comparative biochemical estimation of chlorophyll a, chlorophyll b, total chlorophyll and carotenoids was carried out separately for mite infested and uninfested leaf samples of the four species of invasive plants, following the method of Arnon (1949).

Procedure:

One gram each of uninfested and mite infested leaf tissues of the four species of invasive host plants, were weighed separately and ground well using a mortar and pestle in 20 ml of 80% acetone. Four categories of leaves such as uninfested, lightly infested, moderately infested and heavily infested, were considered for the study from each of the four species of host invasive plants. This was done to get a more precise data on the extent of damage owing to the increasing levels of mite infestation. The leaf extract was then centrifuged at 5000 rpm for 5 minutes and transferred the supernatant to a volumetric flask. The procedure was repeated until the residue became colorless and made up to 100 ml with 80% acetone. The absorbance of each sample was measured at different nanometers like 450, 645, 663 and 670 in a UV-VIS Spectrophotometer (UV 1800 SHIMADZU) against a solvent blank. The experiment was repeated for 10 times for the confirmation of values. The calculations were made by using the following formula and the concentration of each photosynthetic pigment was represented in mg/g of fresh weight of leaf tissue.

Chlorophyll *a* = [12.69 (A663- A750) - 2.69(A645- A750)] × V/ W

Chlorophyll *b* = [22.9 (A645- A750) - 4.68(A663- A750)] × V/ W

Total Chlorophyll = [20.12 (A645- A750) + 8.02(A663- A750)] × V/ W

Carotenoid = [1000(A470) + 3.27{(chlorophyll a) – (chlorophyll b)}] ×V/ (W×229)

Where A is the absorbance at specific wavelengths, V is the final volume of chlorophyll extract in 80% acetone (supernatant) and W is the fresh weight of tissue extracted.

The results were subjected to statistical analysis following Oneway- ANOVA.

iii) Estimation of Total Carbohydrate

Total carbohydrate contents in the leaf extracts of both mite infested and uninfested leaves of the four species of invasive plants considered for the study were estimated by following Anthrone method (Hedge and Hofreiter, 1962).

Procedure:

Both the uninfested and mite infested leaf samples were weighed (500mg each) and homogenized with 5ml of 2.5 N HCl. These samples were kept in a hot water bath for 3 hours, then cooled to room temperature and added solid sodium carbonate until the effervescence ceased. Made up the solution to 25 ml and centrifuged for 20 minutes at 5000 rpm. The supernatant was saved and from which 0.1 ml was taken and added distilled water to make up the volume to 1 ml. Then added 4 ml of anthrone reagent and heated for 8 minutes in a boiling water bath and cooled rapidly to room temperature. Read the green colour at 630 nm in a UV-VIS Spectrophotometer (UV 1800 SHIMADZU) against a reagent blank. The calculations were made following the formula:

Concentration of carbohydrate present in 100 mg of the sample

$$= \frac{\text{mg of Glucose}}{\text{Volume of test sample}} \text{ X } 100$$

iv) Estimation of Total Nitrogen:

Estimation of total nitrogen content in the uninfested and mite infested leaf samples of selected species of invasive plants was made by following Kjeldahl method (1883). For that, the leaf samples were digested with 10 ml of NaOH for one hour. Then, added 20 ml of sodium thiosulphate. Each 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 in each sample was calculated following the equation:

$$\text{Mg } NH_3\text{- Nitrogen/ Kg} = \frac{A-B}{\text{g of dry weight of the sample}} \text{ X } 280$$

Where:

A - Volume of H_2SO_4 titrated with sample

B - Volume of H_2SO_4 titrated with blank

The results were statistically analysed following One way -ANOVA.

v) Estimation of Total Protein:

The total protein content was calculated by using the data recorded on the total nitrogen content in each sample of uninfested and infested leaves of invasive plants through Kjeldahl method (1883). To calculate the protein content, values obtained for total nitrogen content in each of the leaf samples were multiplied by 6.25 (AOAC, 1990).

vi) Estimation of Proline

The concentration of proline present in the leaf samples was estimated following the method of Bates *et al.,* (1973).

Procedure:

Weighed 0.5g of the samples of both uninfested and infested leaf tissue, were homogenized in 10 ml of 3% aqueous sulphosalicylic acid. Filtered the homogenate through Whatman No.2 filter paper. Then 2ml of filtrate was taken in a test tube and added 2 ml of glacial acetic acid and 2 ml of acid- ninhydrin. Heated the solution in a boiling water bath for 1 hour and kept the test tubes in an ice bath for 5 minutes to terminate the reaction. To each test tube, added 4 ml toluene and stirred well for 20-30 seconds. The toluene layer was taken out and read the absorbance at 520 nm against the reagent blank in a UV-VIS Spectrophotometer (UV 1800 SHIMADZU). A standard curve for proline was prepared by running a series of pure proline solutions and using the standard curve, the concentration of proline in each sample was determined and the calculation was made following the formula given below:

$$\mu g \text{ moles per g tissue} = \frac{\mu g \text{ Proline/ml x ml Toluene}}{115.5} \text{ X } \frac{5}{\text{g Sample}}$$

Where, 115.5 is the molecular weight of Proline.

The results were analyzed statistically following One way- ANOVA .

vii) Estimation of Total Phenol

In order to find out the concentration of total phenol in both uninfested and mite infested leaf samples of selected species of invasive plants, Malick and Singh (1980) method was followed, as described below.

Procedure:

Exactly 1 g of each leaf tissue was weighed and homogenized in 10 ml of 80% ethanol. The homogenate was centrifuged at 10,000 rpm for 20 minutes and saved the supernatant. Re-extracted the residue with 5 ml of 80

% ethanol, centrifuged and pooled the supernatants. Evaporated the supernatant to dryness, and added 5 ml of distilled water to the dried residue and mixed well. From the above solution, 1 ml was pipetted out and to that added 2ml of distilled water, 0.5 ml of Folin- Ciocalteu reagent and 20% of sodium carbonate. The sample was kept in a boiling water bath for 1 minute, cooled to room temperature and read the absorbance at 650 nm in a UV-VIS Spectrophotometer (UV 1800 SHIMADZU) against a reagent blank. Tannic acid was used as the standard for the experiment and graphs were plotted. The concentration of phenol was calculated based on the following formula expressed in mg phenol/ g tissue:

$$\text{Concentration of sample} = \frac{\text{Concentration of Standard X OD of sample}}{\text{OD of Standard}} \text{X } \frac{5}{1g} \text{X } 1$$

viii) Estimation of Moisture content

The moisture content in the mite infested and uninfested leaf samples of selected species of invasive plants was analyzed as described below:

Procedure:

Fresh weight and oven dried weight of leaf samples (N=6) were taken and recorded separately. The percentage of moisture content in each sample was analyzed based on the following formula:

% of moisture content = Fresh weight- Dry weight/ Fresh weight x 100

II BREEDING BIOLOGY

Studies on the postembryonic development of selected species of eriophyid mites under selected temperature-humidity combinations

Developmental studies were carried out on four species of host specific eriophyid mites *viz. A. adoratus, E. camarae* sp.nov. , *Eriophyes antigonus* sp. nov. and *Phyllocoptruta merremiae* sp. nov. on their respective invasive

host plants *viz. C. odorata*, *L. camara*, *A. leptopus* and *M. vitifolia* in the laboratory at different temperature-humidity combinations.

1) Raising of laboratory stock cultures of mites

Raising of stock cultures was found highly essential for ensuring uninterrupted supply of the active life stages in sufficient numbers for the completion of biological studies of each of the above four species of eriophyid mites. Stock cultures of eriophyid mites were maintained in the laboratory throughout the period of study in order to ensure constant supply of pure strains, without any contamination. For raising stock cultures of individual species, random sampling of leaves of the host plants growing in various localities of distributed over two districts of Kerala *viz.* Kozhikode and Malappuram was carried out. The collected leaves were put in separate Zip lock covers and brought to the laboratory for subsequent examination under a stereozoom microscope. In the laboratory, the various life stages of the selected species of mites were sorted out and the segregated mites were transferred species-wise to separate leaf discs cut out of their respective host plant leaves. Rearing of the mites in the laboratory and raising of stock cultures of individual species were done by adopting leaf flotation technique (Zhang *et.al.*, 1999). For this, fresh leaf discs of 2 x 2cm diameter were cut out from the leaves of the host plants and kept separately in petridishes lined with moistened cotton pads (Plate 21, Fig. a – d). Individual culture sets were prepared for each species by keeping sufficient numbers of the different life stages. Each culture set was covered with a fine mesh and kept separately as a precaution to avoid contamination. The leaf discs were maintained in fresh condition by frequent wetting of cotton pads with water. When the older leaf discs showed symptoms of decay, they were replaced with new ones.

2) Studies on postembryonic development under selected combinations of temperature-humidity conditions:

Developmental studies were performed in a BOD incubator at four combinations of temperature- humidity conditions such as 20±2°C and 90±5%RH, 25±2°C & 80±5%RH, 30±2°C & 70±5%RH and 35±2°C & 60±5%RH. The constant temperature and humidity conditions were maintained by keeping saturated salt solutions of Ammonium sulphate, equal concentration of potassium chloride and sodium chloride solution and potassium nitrate etc. For initiating studies on postembryonic development, the gravid females of each of the four species of eriophyid mites mentioned above were sorted out from the stock cultures and transferred to fresh leaf discs prepared from the leaves of respective host plants. Regular observation was made to record data on initiation of oviposition. When sufficient numbers of eggs were laid by the females, the adult mites were removed from the leaf discs and the eggs were kept in the BOD, set with the selected temperature-humidity conditions and subsequent rearing was carried out. Observation was made, thrice daily for recording the durations of incubation, hatching, nymphal stages, quiescenct stages, moulting, durations of various instars, total duration of development etc. The experiment was repeated and confirmed by maintaining 10 numbers of culture sets under the above mentioned constant temperature-humidity conditions. The data were subjected to statistical analysis using IBM SPSS Statistics (version 23).

3) Preparation of saturated salt solutions for maintenance of constant temperature-humidity conditions:

Various chemicals were used during the study for preparation of salt solutions to maintain constant relative humidity condition for the completion of biological studies. The salts used were Ammonium sulphate, Potassium chloride, Sodium chloride, Potassium nitrate, Lithium chloride and

Magnesium nitrate which were prepared as saturated solutions by adding warm water. Saturated solutions of the above salts were kept in the incubator at specific temperature set constantly, so as to ensure the required combination of constant temperature-relative humidity condition in the incubator (Winston and Bates, 1960).

Constant temperature-humidity conditions mentioned above were maintained in the BOD incubator by keeping saturated solutions of the following salts:

$(NH_4)_2 SO_4$ - for maintaining 20 ± 2^0 C & 90 ± 5% RH.

Nacl - for 25 ± 2^0 C & 80 ± 5% RH.

Mixing equal volumes of NaCl and KCl - for 30 ± 2^0 C &70 ± 5% RH.

Mixing equal volumes of LiCl and $Mg (NO_3)_{2-}$ for 35 ± 2^0 C and 60 ± 5% RH.

4) Studies on the morphological characters of the life stages of selected species of Eriophyid mites

The drawings of the morphological features of the various life stages of the four species of eriophyid mites infesting the invasive plants were also made and included in the thesis. Slide mounts of the various life stages such as the I nymph, II nymph and adult (female) of each species were prepared in Hoyer's medium and kept in an oven for 3-4 days for subsequent clearing and drying. Drawings of properly cleared specimens were made with the help of a drawing tube attached to the research microscope (Nikon Eclipse-80i). Morphological descriptions of the various instars were prepared and included along with the drawings. Measurements of all the life stages were taken with the stage and ocular micrometers attached to the research microscope and photographs were also taken using a camera (Leica DFC295) attached to Leica -S8APO microscope.

CHAPTER X
OBSERVATION

During the present investigation, detailed studies were undertaken on the feeding attributes of four species, including two new species of eriophyid mites belonging to three genera *Acalitus, Eriophyes* and *Phyllocoptruta,* infesting four species of notorious invasive plants. The species selected were *A. adoratus*, *E. camarae* sp.nov., *E. antigonus* sp. nov. and *P. merremiae* sp. nov. and their respective invasive hosts were *C. odorata, L. camara, A. leptopus* and *M. vitifolia* . Of these, the first species, *A. adorata* was recognized as an erineum inducer while the remaining three were leaf vagrants. Details of the feeding attributes of the above species have been discussed below.

Feeding activity of the selected species of eriophyid mites:

The selected four species of eriophyid mites mentioned above were found distributed on the abaxial leaf surface of their repective host plants, and during heavy infestation large numbers of these mites were seen on both surfaces of the leaves . The vagrant species *viz. E. camarae* sp.nov., *E. antigonus* sp. nov. and *P. merremiae* sp. nov. were found wandering on the entire leaf surface, except during their feeding and breeding time during which these mites appeared sedentary. The various life stages of the erineum inducing mite, *A. adoratus* were found confined to the erineal patches, in large numbers. All the species exhibited a general preference to inhabit on the young or middle aged leaves rather than the mature and older leaves, with a particular preference to occupy the adaxial surface, adhering to the midrib or other veins on the laminar surface. Life stages of *A. adoratus* quite often were

found distributed on the tender stems of *C. odorata*, apart from the young leaves.

The life stages of all the species initiated their feeding activity after getting firmly adhered to the abaxial leaf surface, so as to ensure a firm grip on the laminar surface. Subsequent to this, the active instars initiated feeding by inserting their cheliceral stylets in to the lower epidermis for sucking out the cell contents. While sucking the plant sap, the cheliceral stylets showed back and forth movement in a rhythmic fashion. The feeding activity at a particular point lasted for a short period of 2 to 4 minutes and subsequently, the stylets were retracted and the individuals moved to adjacent spots in search of new feeding sites on the leaf.

A) ASSESSMENT OF FEEDING DAMAGE INDUCED BY ERIOPHYID MITES

In the current study, attempts were made to trace the injurious symptoms and extent of damage induced on the leaves of respective host plants owing to the feeding activity of the selected species of eriophyid mites mentioned above, by adopting qualitative and quantitative measures.

1) Qualitative assessment of leaf damage induced by *Acalitus adoratus* on *Chromolaena odorata*

a) Visual assessment of damage symptoms

Physical assessment of feeding impact of *A. adoratus* on its host plant was made based on the visible symptoms of mite infestation under field cum laboratory conditions. During the initial stage of infestation, the various life stages of the species were found wandering on the foliar surface in search of feeding sites. Feeding activity of the various life stages in groups induced the development of abnormal growth of epidermal hairs, especially on the young

leaves and tender stem of the host plant. Such dense growth of glandular hairs was seen as isolated patches and which constituted the so called “erinea” on the foliar surface. Such white erineal patches were mainly confined to the lower surface of the leaves of *C. odorata* and all developmental stages of the mite were found to live amongst the dense growth of hairs. The size as well as number of erineal patches showed variation depending upon the size of the leaves and severity of infestation. Usually the number of erineal patches measured 1-3 mm in diameter and their number appeared in the range of 2-16. During heavy infestation, erineal patches were observed on the upper surface of the leaves also and in extreme cases, the upper surface and often the entire leaf lamina was found covered by the erineal patches (Plate 15, Fig. d - h) .

b) Assessment of anatomical damage

The cellular levels of feeding injury induced by *A. adoratus* were assessed by making histological studies of stained sections of both uninfested and infested leaf samples of *C. odorata*. The results of the study revealed the anatomical damage in mite infested leaves. In the control leaf, the parenchyma cells lying around the vascular bundles appeared as thin walled, and with collenchymas cells on the upper and lower portions of the midrib. Both the upper and lower epidermal cells were clearly visible, with the lower epidermal cells being curved, having trichomes and the mesophyll tissue consisting of closely arranged spongy cells. The palisade tissue was found packed with many chloroplast cells (Plate 16, Fig. a,b,c).

The stained leaf sections of mite infested samples on the other hand disclosed disrupted cuticular layer and punctured lower epidermal cells. The upper epidermis of mite infested leaf presented numerous abnormal hair growths (plate, fig.). The palisade tissue also appeared broken with damaged chloroplast. A number of chloroplast cells in the palisade tissue were found

reduced in the section of mite infested leaf when compared to that of the control leaf (Plate 16, Fig. d,e & f).

c) Studies on leaf functional group alterations through Attenuated Total Reflectance Fourier Transform Infrared Spectrophotometer (ATR-FTIR) analysis

Attenuated Total Reflectance Fourier Transform Infrared Spectrophotometer (ATR-FTIR) analysis was made to identify the functional groups present in the control leaves and the alterations of these groups in mite infested leaves. A total of 28 functional groups could be observed in the uninfested leaves of *C. odorata*, between the wavelength of 500-4000 cm^{-1} whereas in case of mite infested leaf samples, the total number of functional groups recorded was 13, between the wavelengths of 500-4000 cm^{-1}. The peak size showed variation with respect to difference in functional groups and some of them had highest peak range. Functional groups recorded during the study included amine groups, alkane groups, alkyl halide and alcohol groups. The characteristic strong peaks appeared to be different in the mite infested and uninfested leaves and were at 1210-1150 cm–1 due to the presence of S=O stretching vibration and 1720-1680 cm–1 due to the presence of C=O stretching conjugation (Table 18 & 19; Fig. 26).

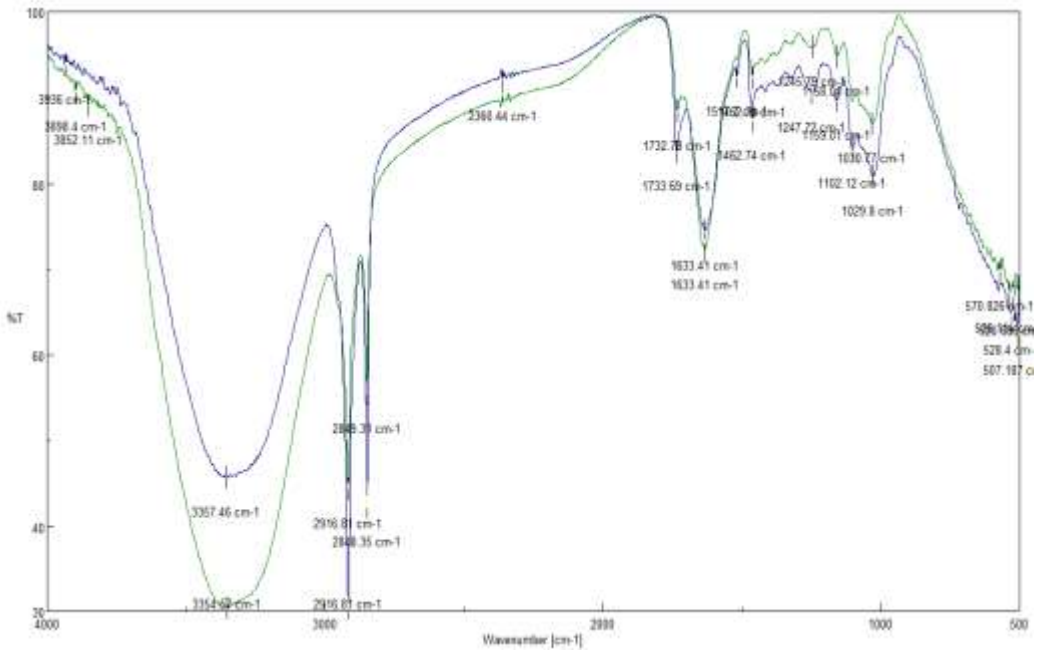
Table 18 : ATR-FTIR Analysis data of *Chromolaena odorata* Leaf (UnInfested)

Sl. No	Vibration	Start WN	End WN	Threshold
1.	Skeletal	650	500	Variable
2.	NO2 Def	650	600	Variable
3.	Si-OH Deformation	1040	1020	Medium
4.	Si-O-C stretch, asym	1100	1070	Variable
5.	C-O Stretch	1150	1070	Variable
6.	C-F stretch	1200	1105	Variable
7.	C-F stretch	1280	1175	Variable
8.	N=C=S Stretch, sym	1240	1100	Variable
9.	S=O stretch, Sym	1210	1150	Strong
10	C-H wag, Halogen Substituted	1245	1225	Variable
11	C-F Stretch	1375	1260	Variable
12	C-H Bend, CH3	1380	1370	Variable
13	C-H Wag	1375	1315	Variable
14	C-H Bend, CH2/CH3	1420	1375	Variable
15	C-H bend	1465	1430	Variable
16	C=C stretch	1520	1460	Variable
17	C=C stretch, Alkene	1665	1635	Variable
18	N-H bend	1625	1590	Variable
19	C=O stretch, conjugated	1720	1680	Strong
20	C=O Stretch	1740	1715	Strong
21	O-H Bonded, Acid	2710	2580	Variable
22	C≡N Stretch, Nitrile	2250	2200	Variable
23	C-H Stretch, Alkyl	2975	2845	Variable
24	C-H stretch, CH2	2975	2840	Variable
25	C-H Stretch, CH2	2965	2915	Variable
26	O-H Stretch	3450	3300	Variable
27	N-H stretch	3400	3300	Variable
28	O-H stretch, 2-Hydroxy	3500	3380	Variable

Table 19: ATR-FTIR Analysis data of *Chromolaena odorata* Leaf (Infested)

Sl. No	Vibration	Start WN	End WN	Threshold
1.	NO2 Def	650	600	Variable
2.	Si-O-C stretch, asym	1100	1070	Variable
3.	C-F stretch	1280	1175	Variable
4.	N=C=S Stretch, sym	1240	1100	Variable
5.	C-H wag, Halogen Substituted	1245	1225	Variable
6.	C-H bend	1465	1430	Variable
7.	C=C stretch, Alkene	1665	1635	Variable
8.	C=O Stretch	1740	1715	Strong
9.	C-H stretch, CH2	2975	2840	Variable
10.	C-H Stretch, CH2	2965	2915	Variable
11.	O-H Stretch	3450	3300	Variable
12.	N-H stretch	3400	3300	Variable
13.	O-H stretch, 2-Hydroxy	3500	3380	Variable

Fig. 26: Analysis of functional groups- Attenuated Total Reflectance Fourier Transform Infrared Spectrophotometer (ATR-FTIR)- *Chromolaena odorata* (Uninfested) + *Chromolaena odorata*(Infested)



2) Quantitative assessment of leaf damage induced by *A. adoratus* on *C. odorata*

The quantitative assessment of feeding injury induced by *A adoratus* was made by measuring the photosynthetic efficiency and by determining the concentrations of various biochemical constituents such as the photosynthetic pigments, total carbohydrate, nitrogen, moisture content, total protein, proline and phenol and by analyzing functional group dispositions in the mite infested leaves based on Fourier Transform Infrared Spectrophotometer (FTIR) analysis. Results of the various biochemical procedures followed during the quantitative assessment have been included below.

i) Photosynthetic Efficiency Analysis:

A comparative assessment of the photosynthetic efficiency of the mite infested and uninfested leaves of *C.odorata* was made by measuring their

fluorescence emission values, using a Handy PEA. The mean and standard error mean values of fluorescence emission (Fv/Fm) were 0.818 ± 0.004 for uninfested leaves and 0.672 ± 0.015 for infested leaves (Table 20; Fig. 36) The results of the study revealed a significant reduction ($p<0.05$) in the values of Fv/Fm, thereby recording a significant decline in the maximal electron transport rate of PSII in mite infested leaves, thereby recording a percentage reduction of 17.8% in the photosynthetic efficiency in the leaves of the invasive weed, *C. odorata* owing to infestation by *A. adorata.*

Table 20: Photosynthetic efficiency (Fv/Fm) of uninfested and *Acalitus adoratus* infested leaf of *Chromolaena odorata*

	UNINFESTED LEAVES				INFESTED LEAVES			
SL.NO	F0	Fm	Fv/Fm	Pindex	F0	Fm	Fv/Fm	Pindex
1	277	1708	0.838	3.427	263	1092	0.695	2.087
2	283	1534	0.816	2.137	360	1380	0.739	2.369
3	285	1476	0.807	2.121	392	1201	0.673	2.608
4	280	1482	0.811	2.045	281	1072	0.737	1.972
5	274	1579	0.826	2.802	410	1091	0.624	1.653
6	279	1693	0.842	3.187	421	1138	0.63	2.103
7	284	1570	0.801	2.128	397	1164	0.658	2.031
8	288	1541	0.804	2.018	417	1068	0.609	2.054
9	271	1602	0.827	3.543	431	1228	0.649	1.993
10	281	1493	0.809	2.103	288	1034	0.711	2.586
MEAN	275.2	1567.8	0.818	2.5511	367	1146	0.6725*	2.14456
SEM	5.59	25.79	0.0045	0.9706	19.97	32.48	0.0147	0.0931
SD	17.67	81.56	0.0143	0.6231	63.16	102.7	0.0465	0.2945

* - Statistically significant using one way – ANOVA with $P<0.05$

ii) Estimation of photosynthetic pigments:

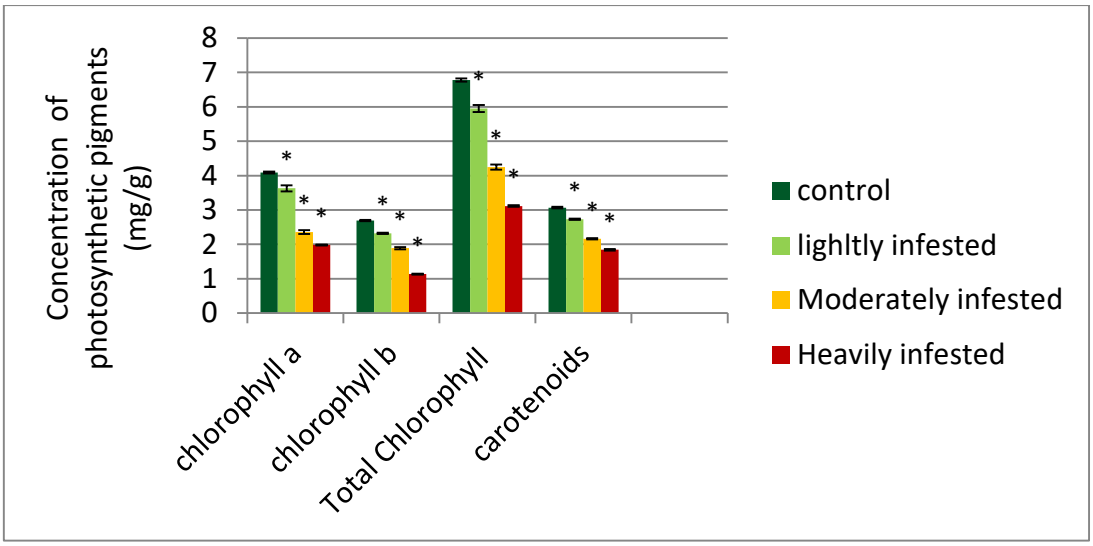
Comparative estimation of photosynthetic pigments in the uninfested and mite infested leaves of *C. odorata* was performed in order to measure the extent of damage induced by *A. adoratus.* A remarkable reduction was observed in the concentration of photosynthetic pigments like chlorophyll a, chlorophyll b, total chlorophyll and carotenoids. The values recorded for concentration of chlorophyll 'a' in uninfested leaf samples were 4.09 ± 0.029 mg/g, lightly infested leaf samples were 3.63 ± 0.09 (11.15± 2.12%), moderately infested leaf samples were 2.36 ± 0.05(42.36± 1.11%) and heavily infested leaf samples were 1.98 ± 0.01 mg/g (51.5±0.35%) (Table 21; Fig. 27 & 28). The values presented in parentheses show the percentage reduction of respective pigments. The mean values recorded for the concentration of chlorophyll 'b' in uninfested leaf samples were 2.69± 0.02 mg/g , lightly infested leaf samples were 2.32± 0.02 (13.9±0.66%), moderately infested leaf samples were 1.89± 0.03(29.81±1.32%) and heavily infested leaf samples were 1.13± 0.01mg/g (57.87±0.47%) respectively (Table 21; Fig.27 & 28). Similarly, the values recorded for total chlorophyll content of uninfested leaf samples were 6.78 ±0.04 mg/g while those of lightly infested, moderately infested and heavily infested leaf samples were 5.95 ± 0.10 (12.25±1.4%), 4.24 ± 0.07 (37.38±0.99%) 3.11±0.02 mg/g (54.03±0.36%) respectively (Table 21; Fig.27 & 28). The carotenoid content in uninfested leaf sample was recorded as 3.07±0.02 mg/g while those of lightly infested, moderately infested and heavily infested leaf samples were 2.73 ±0.02 (10.96±1.02%), 2.16 ±0.02 (29.45±0.66%) and 1.84 ±0.02 mg/g (39.9±1.04%) respectively (Table 21; Fig.27 & 28). The data recorded for the photosynthetic pigments when analyzed statistically following One way –ANOVA were found highly significant ($p<0.05$).

Table 21: Concentration (mg/g) and Percentage reduction(%) of Photosynthetic pigments (Chlorophyll a, b, Total Chlorophyll and Carotenoids)in *Chromolaena odorata* infested by *Acalitus adoratus* (mg/g)

Photosynthetic pigments	Control	Lighltly infested	Percentage reduction	Moderately infested	Percentage reduction	Heavily infested	Percentage reduction
Chlorophyll a	4.0861±0.03	3.6304±0.09*	14.87±0.39*	2.3563±0.06*	27.52±0.48*	1.9811±0.01*	50.94±1.16*
Chlorophyll b	2.6925±0.02	2.3175±0.02*	12.52±0.26*	1.8886±0.03*	25.23±0.93*	1.1339±0.01*	47.12±0.97*
Total Chlorophyll	6.7786±0.04	5.9479±0.1*	13.83±0.26*	4.2449±0.07*	26.52±0.46*	3.115±0.02*	49.26±0.47*
Carotenoids	3.0673±0.02	2.7297±0.02*	13.43±0.56*	2.1633±0.02*	28.86±0.82*	1.8419±0.02*	48.10±0.28*

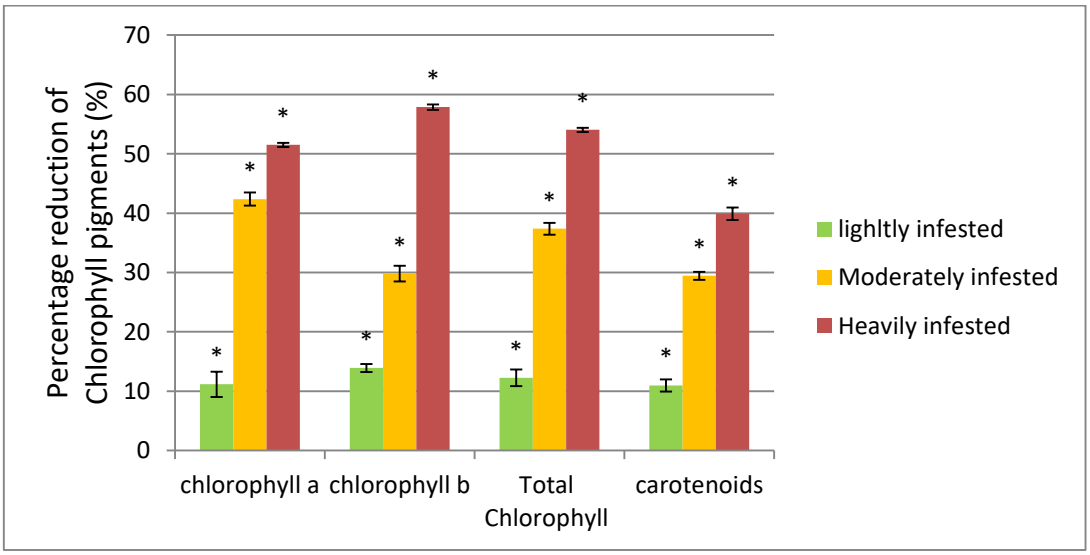
* - Statistically significant using one way – ANOVA with $P<0.05$

Fig. 27: Concentration of photosynthetic pigments (Chlorophyll a, b, Total Chlorophyll and Carotenoids) in *Chromolaena odorata* infested by *Acalitus adoratus* (mg/g)



* - Statistically significant using one way – ANOVA with P<0.05

Fig.28: Percentage reduction of photosynthetic pigments (Chlorophyll a, b, Total Chlorophyll and Carotenoids) in *Chromolaena odorata* infested by *Acalitus adoratus* (%)



* - Statistically significant using one way – ANOVA with P<0.05

iii) Estimation of Total Carbohydrate

The feeding impact of *A. adoratus* on the concentration of the primary metabolites of its invasive weed host, *C. odorata* was analyzed by determining the concentration of total carbohydrate in mite infested and uninfested leaf samples . The results of the study revealed a drastic reduction in the total carbohydrate concentration in the mite infested leaf samples when compared to that of the uninfested leaf samples. The percentage reduction in total carbohydrate content in the leaf samples have been presented in parenthesis along with the respective data. The mean concentration of carbohydrate in uninfested leaf sample was 63.75 ± 0.91mg/g. Due to the feeding activity of *A. adoratus,* the total carbohydrate concentration got reduced to 50.66 ± 1.33 (20.64±1.17%), 34.55±0.79 (45.84±0.69%) and 25.71±0.43mg/g (59.64±0.70%) in lightly infested, moderately infested and heavily infested leaf samples respectively (Table 22 & Fig. 39 - 40). Upon statistical analysis using One way –ANOVA, the data were found highly significant ($p<0.05$).

Table 22 : Concentration (mg/g) and Percentage reduction (%) of Carbohydrate in *Chromolaena odorata* infested by *Acalitus adoratus*

SL.NO.	CONTROL	LIGHTLY INFESTED	PERCENTAGE REDUCTION	MODERATELY INFESTED	PERCENTAGE REDUCTION	HEAVILY INFESTED	PERCENTAGE REDUCTION
1	59.64	43.98	26.257	32.89	44.852	27.41	54.040
2	67.81	54.16	20.129	38.64	43.017	28.13	58.516
3	63.67	52.43	17.653	33.71	47.055	26.03	59.117
4	64.38	52.93	17.785	32.15	50.062	25.19	60.872
5	64.91	51.87	20.089	36.27	44.122	25.91	60.083
6	67.64	54.4	19.574	37.93	43.923	26.19	61.280
7	63.87	52.71	17.472	33.86	46.986	25.4	60.231
8	59.93	45.13	24.695	32.18	46.304	24.38	59.319
9	60.89	44.97	26.145	31.69	47.955	23.67	61.126
10	64.73	54.01	16.561	36.16	44.137	24.74	61.779
Mean	63.747	50.659*	20.636*	34.548*	45.841*	25.705*	59.636*
Standard deviation	2.867	4.203	3.708	2.520	2.205	1.348	2.224
Standard error mean	0.906	1.329	1.172	0.797	0.697	0.426	0.703

* - Statistically significant using one way – ANOVA with $P<0.05$

iv) Estimation of Total Nitrogen

The results of the present study revealed a significant reduction in the total nitrogen content of host plant leaves as a result of mite infestation. The total nitrogen content in uninfested leaf sample was recorded as 2.82±0.05 mg/g. The mean values recorded for the concentration of total nitrogen in the mite infested leaves were 2.36 ±0.04 mg/g (16.04±0.77%) for lightly infested, 2.14 ±0.04 mg/g (23.99±1.41%) for moderately infested and 1.45±0.02 mg/g (48.59 ± 0.96%) for heavily infested leaf samples, and the values given in parenthesis represent the percentage reduction in the samples tested (Table 23 & Fig. 41 & 42). The data were found highly significant ($p<0.05$) when analyzed statistically using One way-ANOVA.

Table 23: Concentration (mg/g) and Percentage reduction (%) of Nitrogen in *Chromolaena odorata* infested by *Acalitus adoratus*

ESTIMATION OF TOTAL NITROGEN- *CHROMOLAENA ODORATA*							
SL.NO.	CONTROL	LIGHTLY INFESTED	PERCENTAGE REDUCTION	MODERATELY INFESTED	PERCENTAGE REDUCTION	HEAVILY INFESTED	PERCENTAGE REDUCTION
1	2.7056	2.2896	15.375	2.134	21.111	1.5056	44.352
2	2.9456	2.5024	15.046	2.387	18.957	1.4432	51.004
3	3.0416	2.5616	15.781	2.2256	26.827	1.5056	50.499
4	2.9504	2.4208	17.950	2.2736	22.939	1.5328	48.047
5	2.8688	2.384	16.899	2.1264	25.878	1.4608	49.079
6	3.0256	2.3984	20.729	2.0656	31.729	1.4256	52.882
7	2.6096	2.2208	14.898	1.9808	24.095	1.4288	45.248
8	2.7088	2.3872	11.872	2.2096	18.428	1.4448	46.662
9	2.6112	2.2448	14.031	2.0752	20.526	1.4176	45.710
10	2.7216	2.2368	17.813	1.92	29.453	1.296	52.380
Mean	2.8188	2.364*	16.039*	2.13984*	23.994*	1.446*	48.586*
Standard deviation	0.1665	0.115	2.443	0.1393	4.4598	0.0657	3.0538
Standard error mean	0.0526	0.036	0.772615	0.0440	1.4103	0.0207	0.9657

* - Statistically significant using one way – ANOVA with $P<0.05$

v) Estimation of Total Protein

The total protein contents of uninfested and mite infested leaf samples of *C. odorata* were estimated using AOAC (1990) and the results showed a significant reduction. The values showing percentage reduction of total protein have been given in parenthesis along with the mean values recorded for protein concentration in different leaf samples. The total protein content of uninfested leaves could be encountered as 17.62±0.33 mg/g whereas the values recorded for mite infested samples like the lightly infested, moderately infested and heavily infested leaves were 14.78 ±0.23 (16.04±0.77%), 13.37 ±0.27 (23.99± 1.4%) and 9.04 ±0.13 mg/g (48.59 ±0.96%) respectively (Table 24 & Fig. 43 & 44). The data recorded were found highly significant ($p<0.05$) when analyzed statistically following One way-ANOVA.

Table 24: Concentration(mg/g) and Percentage reduction(%) of Total Protein in *Chromolaena odorata* infested by *Acalitus adoratus*

SL. NO.	CONTROL	LIGHTLY INFESTED	PERCENTAGE REDUCTION	MODERATELY INFESTED	PERCENTAGE REDUCTION	HEAVILY INFESTED	PERCENTAGE REDUCTION
1	16.91	14.31	15.375	13.34	21.111	9.41	44.352
2	18.41	15.64	15.046	14.92	18.957	9.02	51.004
3	19.01	16.01	15.781	13.91	26.827	9.41	50.499
4	18.44	15.13	17.950	14.21	22.939	9.58	48.047
5	17.93	14.9	16.899	13.29	25.878	9.13	49.079
6	18.91	14.99	20.729	12.91	31.729	8.91	52.882
7	16.31	13.88	14.898	12.38	24.095	8.93	45.248
8	16.93	14.92	11.872	13.81	18.428	9.03	46.662
9	16.32	14.03	14.031	12.97	20.526	8.86	45.710
10	17.01	13.98	17.813	12	29.453	8.1	52.380
Mean	17.618	14.779*	16.039*	13.374*	23.994*	9.038*	48.586*
Standard deviation	1.040	0.721	2.443	0.871	4.459	0.410	3.0538
standard error mean	0.329	0.228	0.772	0.275	1.410	0.129	0.965

* - Statistically significant using one way – ANOVA with $P<0.05$

vi) Estimation of Proline

The proline contents of mite infested and uninfested leaf samples were estimated separately to assess the extent of biotic stress induced by *A. adoratus* on the weed, *C. odorata*. Mite infested leaf samples presented an increase in proline content and the percentage increase in the proline contents of mite infested samples have been given in parenthesis, along with the values showing concentration. The mean concentration of proline in uninfested leaf sample was 4.19 ± 0.02 µmol/g where as those of lightly infested, moderately infested and heavily infested leaf samples were 5.84 ± 0.01 (28.32 ±0.29%), 7.94 ± 0.009 (47.23 ± 0.26 %) and 10.73 ± 0.009 µmol/g (60.93 ± 0.17%) respectively (Table 25 & Fig. 45 & 46). The data appeared highly significant ($p<0.05$) upon statistical analysis using One way –ANOVA.

Table 25: Concentration (mg/g) and Percentage increase (%) of Proline in *Chromolaena odorata* infested by *Acalitus adoratus*

SL. NO.	CONTROL	LIGHTLY INFESTED	PERCENTAGE INCREASE	MODERATELY INFESTED	PERCENTAGE INCREASE	HEAVILY INFESTED	PERCENTAGE INCREASE
1	4.15	5.89	29.541	7.96	47.864	10.73	61.323
2	4.19	5.8	27.758	7.91	47.029	10.7	60.841
3	4.29	5.91	27.411	7.9	45.696	10.71	59.943
4	4.23	5.79	26.943	7.96	46.859	10.73	60.577
5	4.17	5.81	28.227	7.99	47.809	10.7	61.028
6	4.09	5.83	29.845	7.93	48.423	10.73	61.882
7	4.26	5.9	27.796	7.94	46.347	10.75	60.372
8	4.19	5.88	28.74	7.96	47.361	10.76	61.059
9	4.15	5.84	28.938	7.96	47.864	10.7	61.214
10	4.2	5.83	27.958	7.93	47.036	10.79	61.075
Mean	4.192	5.848*	28.316*	7.944*	47.229*	10.73*	60.931*
Standard deviation	0.057	0.043	0.932	0.027	0.811	0.029	0.538
Standard error mean	0.018	0.013	0.294	0.008	0.256	0.009	0.170

* - Statistically significant using one way – ANOVA with $P<0.05$

vii) Estimation of Total Phenol

The total phenolic content of mite infested leaves of *C. odorata* showed an increase when compared to that of the uninfested (control) leaves. The values showing percentage increase in the concentration of total phenol in mite infested leaf samples have been given in parenthesis along with data on concentration. The uninfested leaves showed 34.37± 0.33mg/g of total phenol while the mite infested leaves showed an increase by recording 42.58 ± 0.32 (19.26 ±0.56%), 71.73 ± 0.19 (52.08 ± 0.43%), 116.28 ±0.64 mg/g (70.44 ±0.21%) for lightly infested, moderately infested and heavily infested samples respectively (Table 26 & Fig. 47 & 48). The differences in the mean values recorded for total phenol in uninfested and mite infested leaves when subjected to One way-ANOVA were found highly significant ($p<0.05$).

Table 26: Concentration(mg/g) and Percentage increase (%) of Total Phenol in *Chromolaena odorata* infested by *Acalitus adoratus*

SL. NO.	CONTROL	LIGHTLY INFESTED	PERCENTAGE INCREASE	MODERATELY INFESTED	PERCENTAGE INCREASE	HEAVILY INFESTED	PERCENTAGE INCREASE
1	35.61	43.24	17.645	72.36	50.787	118.41	69.926
2	34.76	42.31	17.844	71.26	51.220	115.32	69.857
3	34.82	42.43	17.935	71.33	51.184	114.31	69.538
4	32.73	40.74	19.661	70.32	53.455	113.31	71.114
5	32.79	41.08	20.180	72.1	54.521	113.39	71.082
6	34.71	44.03	21.167	71.94	51.751	116.7	70.257
7	35.09	42.71	17.841	71.79	51.121	118.31	70.340
8	33.16	43.1	23.062	72.17	54.052	117.34	71.740
9	35.17	43.18	18.550	72.14	51.247	118.31	70.273
10	34.91	42.94	18.700	71.93	51.466	117.44	70.274
Mean	34.375	42.576*	19.258*	71.734*	52.081*	116.284*	70.440*
Standard deviation	1.059	1.002	1.773	0.610	1.376	2.0385	0.6725
Standard error mean	0.335	0.317	0.560	0.192	0.435	0.6446	0.2126

* - Statistically significant using one way – ANOVA with $P<0.05$

viii) Estimation of Moisture content

Results of comparative estimation of moisture content of mite infested and uninfested leaf samples of *C. odorata* enabled to record a reduction in the moisture content in mite infested leaves. The mean percentage of moisture content in uninfested leaf samples was 79.82 ± 0.49% where as a progressive decrease was noticed due to increasing levels of mite infestation. Thus, the mean percentage of moisture content of lightly infested leaf samples was recorded as 73.19 ± 0.14 % while that of moderately infested and heavily infested leaf samples were 67.87 ± 0.28 % and 62.73 ± 0.43% respectively (Table 27 & Fig. 49 & 50). The data on moisture content analysis were found highly significant ($p<0.05$) when analyzed statistically, using One way-ANOVA.

Table 27: Amount of Moisture content (%) and Percentage reduction(%) in *Chromolaena odorata* infested by *Acalitus adoratus*

SL .NO.	CONTROL	LIGHTLY INFESTED	PERCENTAGE REDUCTION	MODERATELY INFESTED	PERCENTAGE REDUCTION	HEAVILY INFESTED	PERCENTAGE REDUCTION
1	79.15	73.45	7.2015	68.32	13.682	61.22	22.653
2	79.09	72.98	7.7253	67.91	14.135	61.91	21.722
3	78.34	73.63	6.0122	68.32	12.790	63.13	19.415
4	81.67	73.29	10.260	68.13	16.578	64.24	21.341
5	80.67	72.65	9.9417	66.51	17.552	63.13	21.742
6	79.98	73.19	8.4896	68.02	14.953	62.72	21.580
Mean	79.816	73.198*	8.2718*	67.868*	14.949*	62.725*	21.409*
Standard deviation	1.2118	0.3482	1.6335	0.685	1.808	1.053	1.073
Standard error mean	0.494	0.1421	0.666	0.279	0.738	0.430	0.438

* - Statistically significant using one way – ANOVA with $P<0.05$

3). Qualitative assessment of leaf damage induced by *Eriophyes camarae* sp.nov.infesting the terrestrial invasive weed, *Lantana camara*

a) Visual assessment of damage symptoms

Results of laboratory observation on the feeding activity *E. camarae* sp. nov. enabled to identify the mite as a leaf vagrant , exhibiting random feeding on the lower surface of the leaves of *L. camara.* The various life stages of the mite were found aggregated to form small groups on the foliar surfaces, adjacent to the midrib or other veins, where they located particular feeding spots and initiated feeding activity at the spots for some time and moved to new spots in adjacent areas. Several such groups of mites could be located on the laminar surface when examined under a stereomicroscope. Such prolonged feeding activity by the active life stages of the mite in groups on the foliage of the weed, *L. camara* induced the development of damage symptoms such as minute dots or stippling. Such feeding spots/punctures were found prevalent on the lower laminar surface of mite infested leaves and during heavy infestation, were found extending to the upper surface also. Progressive feeding activity of the different life stages intensified the formation of feeding punctures, and in response to the sap sucking activity of the life stages, the foliar surface developed a bronzed appearance, and subsequent rolling of the leaves (Plate14, Fig. b & h).

b) Assessment of anatomical damage

Anatomical alterations induced by the feeding activity of *E. camarae* sp.nov.on the leaves of *L. camara* were studied by comparative examination of transverse sections of mite infested and uninfested leaf samples. The stained section of uninfested leaf consisted of upper and lower epidermal cells, the former being larger in size and appeared bulbous. The mesophyll tissue was found to comprise closely arranged palisade cells and a few spongy

cells with air space and were found rich in chloroplast. The vascular bundles were bordered by the parenchymatous cells, as a boundary. On the upper and lower portions of the vascular bundles, 2-3 layers of collenchymatous cells were observed (Plate 17, Fig. a & c).

The stained section of mite infested leaf revealed the presence of disrupted cuticular layer and initial disruptions of the lower epidermal cells. The upper and lower epidermis were found punctured owing to the feeding activity of the different life stages of the mite. Punctures were seen in the lower collenchyma cells also. The chloroplast cells of the palisade layer also were found damaged (Table; Plate, Fig). In the palisade cells, the number of chloroplast cells was found reduced and appeared yellowish, when compared to the uninfested leaf tissue (Plate 17, Fig. d, e, f).

c) Attenuated Total Reflectance Fourier Transform Infrared Spectrophotometer (ATR-FTIR) analysis

Attenuated Total Reflectance Fourier Transform Infrared Spectrophotometer (ATR-FTIR) analysis was carried out separately for the uninfested and mite infested leaf samples of *L. camara* A total of 27 vibrations could be observed in uninfested leaves, between the wavelength of 500-4000 cm^{-1} whereas in the mite infested leaf samples, the total number of vibrations recorded were 19, between the wavelengths of 500-4000 cm^{-1}. The peak sizes were found different for different functional groups and some of them had a highest peak range. Functional groups recorded were amine groups, alkane groups, alkene groups, alkyl halide, aromatic groups, carbonyl groups, acid groups and alcohol groups. Eight extra vibrations were found in the uninfested leaf sample when compared to the infested leaf sample (Table 28 & 29, Fig. 29).

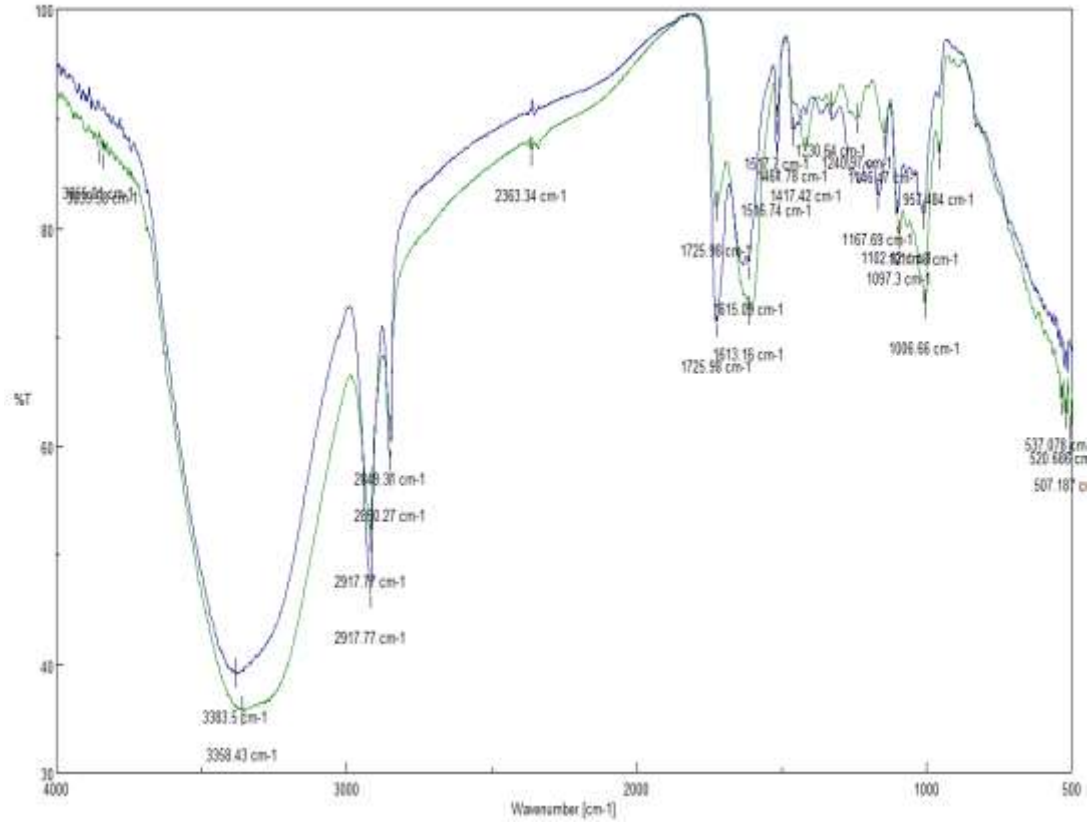
Table 28: ATR-FTIR Analysis data of *Lantana camara* Leaf (UnInfested)

Sl. No	Vibration	Start WN	End WN	Threshold
1.	Skeletal	650	500	Variable
2.	NO2 Def	650	600	Variable
3.	C-H bend, Alkene, OOP	975	950	Variable
4.	C-O Stretch	1150	1070	Variable
5.	C-F stretch	1200	1105	Variable
6.	C-F stretch	1280	1175	Variable
7.	N=C=S Stretch, sym	1240	1100	Variable
8.	S=O stretch, Sym	1210	1150	Strong
9.	C-H wag, Halogen Substituted	1245	1225	Variable
10.	C-F Stretch	1375	1260	Variable
11.	C-H Bend, CH3	1380	1370	Variable
12.	C-H Wag	1375	1315	Variable
13.	C-H Bend, CH2/CH3	1420	1375	Variable
14.	C-H bend	1465	1430	Variable
15.	C=C stretch	1520	1460	Variable
16.	C=C stretch, Alkene	1665	1635	Variable
17.	N-H bend	1625	1590	Variable
18.	C=O stretch, conjugated	1720	1680	Strong
19.	C=O Stretch	1740	1715	Strong
20.	O-H Bonded, Acid	2710	2580	Variable
21.	C≡N Stretch, Nitrile	2250	2200	Variable
22.	C-H Stretch, Alkyl	2975	2845	Variable
23.	C-H stretch, CH2	2975	2840	Variable
24.	C-H Stretch, CH2	2965	2915	Variable
25.	O-H Stretch	3450	3300	Variable
26.	N-H stretch	3400	3300	Variable
27.	O-H stretch, 2-Hydroxy	3500	3380	Variable

Table 29: ATR-FTIR Analysis data of *Lantana camara* Leaf (Infested)

Sl. No	Vibration	Start WN	End WN	Threshold
1.	C-F stretch	1200	1105	Variable
2.	N=C=S Stretch, sym	1240	1100	Variable
3.	S=O stretch, Sym	1210	1150	Strong
4.	C-H wag, Halogen Substituted	1245	1225	Variable
5.	C-F Stretch	1375	1260	Variable
6.	C-H Bend, CH3	1380	1370	Variable
7.	C-H Wag	1375	1315	Variable
8.	C-H Bend, CH2/CH3	1420	1375	Variable
9.	C-H bend	1465	1430	Variable
10.	C=C stretch	1520	1460	Variable
11.	C=C stretch, Alkene	1665	1635	Variable
12.	N-H bend	1625	1590	Variable
13.	C=O stretch, conjugated	1720	1680	Strong
14.	C=O Stretch	1740	1715	Strong
15.	C-H Stretch, Alkyl	2975	2845	Variable
16.	C-H stretch, CH2	2975	2840	Variable
17.	C-H Stretch, CH2	2965	2915	Variable
18.	O-H Stretch	3450	3300	Variable
19.	N-H stretch	3400	3300	Variable

Fig. 29: Analysis of functional groups- Attenuated Total Reflectance Fourier Transform Infrared Spectrophotometer (ATR-FTIR)-*Lantana camara* (Uninfested) + *Lantana camara* (Infested)



4. Quantitative assessment of leaf damage induced by *E. camarae* sp.nov. on *L. camara*

As in the earlier species, the feeding injury was assessed quantitatively by adopting same procedures described above such as : by measuring the photosynthetic efficiency as well as by determining the amounts of photosynthetic pigments, total carbohydrate, nitrogen, moisture content, total protein, proline, phenols and by studying the functional group dispositions in mite infested leaves through ATR-FTIR Spectrophotometric analysis.

i) Photosynthetic Efficiency Analysis:

Results of quantitative assessment of leaf damage induced by *E. camarae* sp.nov. based on measurement of fluorescence emission of

uninfested and mite infested leaves of *L. camara* enabled to record the mean and standard error mean values of Fv/Fm as 0.832 ± 0.003 for uninfested leaves and 0.658 ± 0.004 for mite infested leaves. The result showed that feeding activity of the species induced significant reduction in the photosynthetic efficiency (Table 13, Fig. 36). The percentage reduction recorded on the photosynthetic efficiency induced by the species was 21.5%, based on the reduction in values of Fv/Fm. Data on fluorescence emission parameters were found highly significant ($p<0.05$) when analysed statistically using One way-ANOVA.

Table 30 : Photosynthetic efficiency (Fv/Fm) of uninfested and *Eriophyes camarae* sp.nov. infested leaf of *Lantana camara*

SL.NO	UNINFESTED LEAVES				INFESTED LEAVES			
	F0	Fm	Fv/Fm	Pindex	F0	Fm	Fv/Fm	Pindex
1	260	1650	0.842	2.069	420	1250	0.664	0.599
2	272	1573	0.827	1.668	423	1209	0.65	0.807
3	280	1673	0.832	1.912	407	1139	0.642	0.038
4	246	1549	0.841	1.561	392	1120	0.65	0.789
5	269	1587	0.83	0.998	442	1308	0.662	0.747
6	299	1708	0.824	1.136	384	1098	0.65	0.763
7	283	1532	0.815	1.911	398	1207	0.67	0.533
8	231	1581	0.853	1.498	439	1341	0.672	0.713
9	284	1692	0.832	1.573	422	1290	0.672	0.831
10	292	1627	0.82	1.632	414	1171	0.646	0.93
MEAN	271.6	1617.2	0.8316	1.598	414.1	1213.3	0.6578*	0.7748
SEM	6.64	19.5	0.0035	0.1059	6.04	26.22	0.0036	0.0462
SD	20.99	61.65	0.0112	0.3349	19.09	82.91	0.0114	0.1459

* - Statistically significant using one way – ANOVA with $P<0.05$

ii) Estimation of photosynthetic pigments:

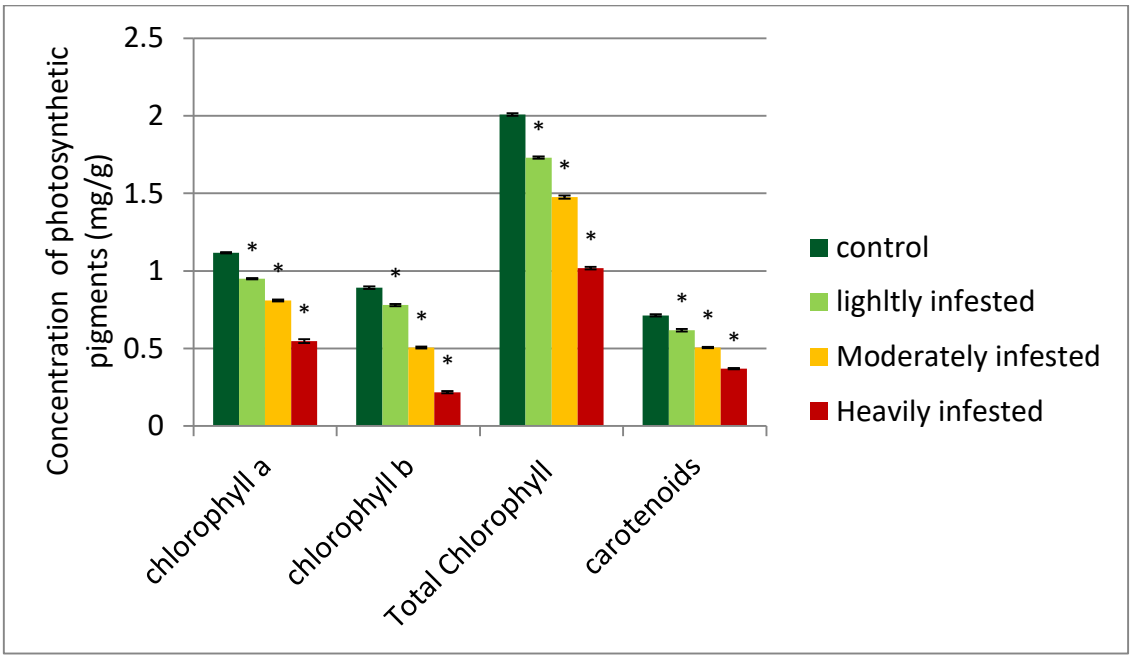
The concentrations of photosynthetic pigments like the chlorophyll a & b, total chlorophyll and carotenoid in the uninfested and mite infested leaves of *L.camara* when estimated quantitatively following Arnon's (1949) method, revealed a noticeable reduction . The values given in parenthesis indicate the percentage reduction. The concentration of chlorophyll 'a' recorded in the uninfested leaf sample was 1.12± 0.004mg/g while that of lightly infested leaf sample was 0.95± 0.004 (14.87± 0.39%), moderately infested sample was 0.81± 0.006 (27.52± 0.48%) and heavily infested sample was 0.55± 0.01mg/g (50.94±1.17%) respectively (Table 31, Fig. 30 & 31). The concentration of chlorophyll 'b' recorded in uninfested leaf sample was 0.89± 0.008mg/g, lightly infested sample was 0.78± 0.006 (12.52±0.26%), moderately infested sample was 0.67± 0.006 (25.23±0.93%) and heavily infested sample was 0.47± 0.007mg/g (47.13±0.97%) respectively (Table 31, Fig. 30 & 31). Total chlorophyll content of uninfested leaf sample was 2.008±0.008mg/g while that of lightly infested leaf sample was 1.73± 0.007 (13.83±0.26%), moderately infested leaf sample was 1.47± 0.01 (26.52±0.46%) and heavily infested leaf sample was 1.02±0.008mg/g (49.26±0.47%) respectively (Table 31, Fig. 30 & 31). The carotenoid concentration in uninfested leaf sample was 0.71 ± 0.007 mg/g and that of lightly infested, moderately infested and heavily infested leaf samples were 0.62 ± 0.008 (13.43 ± 0.56 %), 0.51 ± 0.004 (28.86 ± 0.82 %) and 0.37 ± 0.003 mg/g (48.1 ± 0.28 %) respectively (Table 31, Fig. 30 & 31). The data procured on the variations in the concentration of photosynthetic pigments when analyzed statistically using One way –ANOVA were found highly significant ($p<0.05$).

Table 31: Concentration (mg/g) and Percentage reduction(%) of Photosynthetic pigments (Chlorophyll a, b, Total Chlorophyll and Carotenoids)in *Lantana camara* infested by *Eriophyes camarae* sp.nov.

Photosynthetic pigments	Control	Lighltly infested	Percentage REDUCTION	Moderately infested	Percentage REDUCTION	Heavily infested	Percentage REDUCTION
Chlorophyll a	1.115±0.004	0.951±0.004*	14.87±0.39*	0.809±0.006*	27.52±0.48*	0.547±0.01*	50.94±1.16*
Chlorophyll b	0.892±0.007	0.779±0.006*	12.52±0.26*	0.505±0.006*	25.23±0.93*	0.218±0.007*	47.12±0.97*
Total Chlorophyll	2.008±0.008	1.73±0.007*	13.83±0.26*	1.476±0.01*	26.52±0.46*	1.018±0.008*	49.26±0.47*
Carotenoids	0.713±0.007	0.617±0.008*	13.43±0.56*	0.506±0.004*	28.86±0.82*	0.37±0.003*	48.10±0.28*

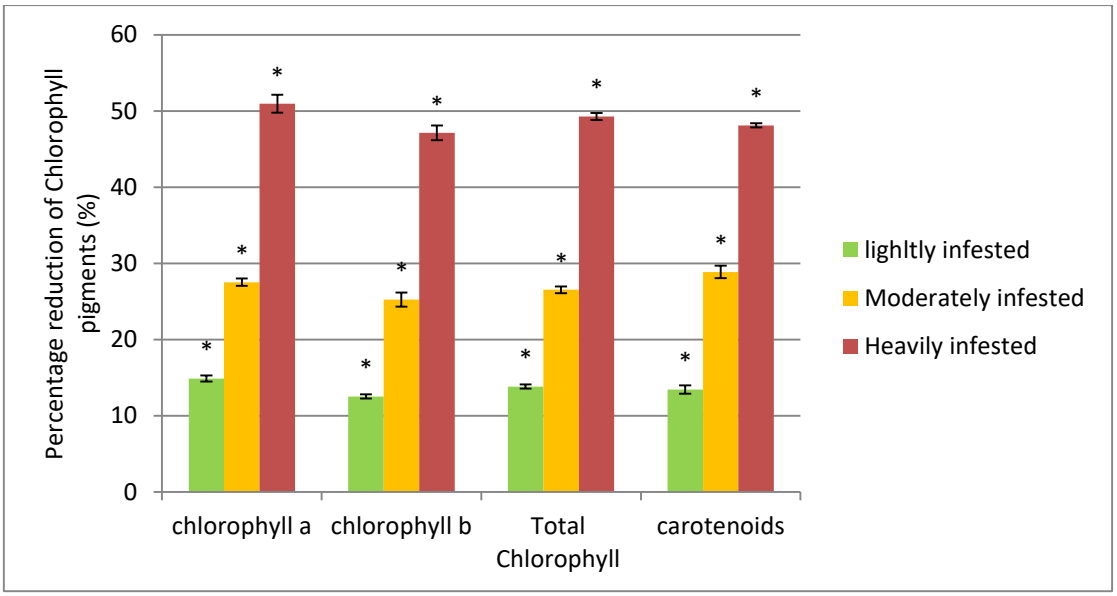
* - Statistically significant using one way – ANOVA with P<0.05

Fig. 30: Concentration of photosynthetic pigments (Chlorophyll a, b, Total Chlorophyll and Carotenoids) in *Lantana camara* infested by *Eriophyes camarae* sp.nov. (mg/g)



* - Statistically significant using one way – ANOVA with P<0.05

Fig. 31: Percentage reduction of photosynthetic pigments (Chlorophyll a, b, Total Chlorophyll and Carotenoids) in *Lantana camara* infested by *Eriophyes camarae* sp.nov. (%)



* - Statistically significant using one way – ANOVA with P<0.05

iii) Estimation of Total Carbohydrate

In order to understand the extent of damage induced by *E. camarae* sp.nov. on its host plant, *L. camara*, comparative estimation of the concentration of total carbohydrate was carried out separately for mite infested and uninfested leaf samples. The results showed a significant reduction in the total carbohydrate concentration in mite infested leaf samples when compared to that of uninfested samples. The percentage reduction in total carbohydrate content in the leaf samples have been presented in parenthesis. The mean concentration of total carbohydrate in uninfested leaf sample was 70.66 ± 0.21 mg/g. Due to the feeding activity of the mite, the concentration of total carbohydrate got reduced to 56.29 ± 0.43 (20.33±0.52%), 41.42 ± 0.21(41.38±0.18%) and 31.96 ± 0.29 mg/g(54.77 ±0.34%) in lightly infested, moderately infested and heavily infested leaf samples respectively (Table 32; Fig. 39 & 40). The results were analyzed

statistically using One way –ANOVA and were found highly significant ($p<0.05$).

Table 32: Concentration (mg/g) and Percentage reduction (%) of Carbohydrate in *Lantana camara* infested by *Eriophyes camarae* sp.nov.

SL.NO.	CONTROL	LIGHTLY INFESTED	PERCENTAGE REDUCTION	MODERATELY INFESTED	PERCENTAGE REDUCTION	HEAVILY INFESTED	PERCENTAGE REDUCTION
1	69.64	56.81	18.423	40.64	41.642	31.1	55.341
2	71.43	58.94	17.485	42.32	40.753	33.81	52.666
3	71.18	57.68	18.966	41.43	41.795	32.94	53.722
4	70.89	56.86	19.791	41.18	41.91	31.94	54.944
5	70.93	56.43	20.442	41.61	41.336	31.63	55.406
6	70.64	55.94	20.809	40.83	42.199	31.19	55.846
7	70.39	55.61	20.997	41.64	40.843	32.68	53.572
8	69.98	54.86	21.606	40.94	41.497	31.02	55.673
9	69.92	54.17	22.525	40.91	41.490	31.4	55.091
10	71.63	55.66	22.295	42.73	40.346	31.94	55.409
Mean	70.663	56.296*	20.334*	41.423*	41.381*	31.965*	54.767*
Standard deviation	0.671	1.378	1.662	0.676	0.574	0.915	1.064
Standard error mean	0.212	0.435	0.525	0.213	0.181	0.289	0.336

* - Statistically significant using one way – ANOVA with P<0.05

iv) Estimation of Total Nitrogen

The result of the study revealed a reduction in the concentration of total nitrogen due to the feeding activity of *E. camarae* sp.nov. The percentage reduction in total nitrogen was estimated and given in parenthesis. The total nitrogen content in uninfested leaf sample was 3.19 ± 0.03mg/g. The concentration of total nitrogen got reduced in mite infested samples and it could be recorded as 2.75 ±0.02 mg/g (13.59±1.07%) in lightly infested, 2.14±0.04 mg/g (32.76±1.69%) in moderately infested and 1.62± 0.02 mg/g (49.11±0.96%) in heavily infested leaf samples (Table 33; Fig. 41 & 42). The results were analyzed statistically using One way-ANOVA and were found highly significant ($p<0.05$).

Table 33: Concentration (mg/g) and Percentage reduction (%) of Nitrogen in *Lantana camara* infested by *Eriophyes camarae* sp.nov.

SL.NO.	CONTROL	LIGHTLY INFESTED	PERCENTAGE REDUCTION	MODERATELY INFESTED	PERCENTAGE REDUCTION	HEAVILY INFESTED	PERCENTAGE REDUCTION
1	3.2048	2.7888	12.980	2.339	27.009	1.665	48.027
2	3.2208	2.6112	18.926	2.092	35.022	1.619	49.726
3	3.0464	2.832	7.037	2.369	22.216	1.708	43.907
4	3.0976	2.7408	11.518	2.222	28.254	1.668	46.126
5	3.0352	2.7056	10.859	2.083	31.365	1.604	47.127
6	3.2544	2.7904	14.257	2.067	36.479	1.508	53.638
7	3.2992	2.8656	13.142	2.060	37.536	1.542	53.249
8	3.2112	2.7008	15.894	2.086	35.027	1.6	50.174
9	3.3696	2.7872	17.283	2.097	37.749	1.664	50.617
10	3.1504	2.708	14.017	1.985	36.973	1.620	48.552
Mean	3.188	2.753*	13.591*	2.140*	32.763*	1.620*	49.114*
Standard deviation	0.107	0.074	3.388	0.126	5.333	0.060	3.033
Standard error mean	0.034	0.023	1.071	0.040	1.686	0.019	0.959

* - Statistically significant using one way – ANOVA with $P<0.05$

v) Estimation of Total Protein

The total protein content of uninfested and mite infested leaf samples of *L.camara* when estimated following AOAC (1990) showed a significant reduction in the mite infested samples. The percentage reduction of total protein in mite infested samples are given in parenthesis. In the uninfested leaves, the total protein content was 19.93±0.21mg/g whereas reduced values like 17.21±0.15 (13.59±1.07%), 13.38 ±0.25 (32.76±1.69) and 10.13 ±0.12 mg/g (49.11±0.96%) could be recorded for lightly infested, moderately infested and heavily infested leaf samples respectively (Table 34; Fig. 43 & 44). The results were found highly significant ($p<0.05$) when analyzed statistically using One way-ANOVA.

Table 34: Concentration (mg/g) and Percentage reduction (%) of Total Protein in *Lantana camara* infested by *Eriophyes camarae* sp.nov.

SL.NO.	CONTROL	LIGHTLY INFESTED	PERCENTAGE REDUCTION	MODERATELY INFESTED	PERCENTAGE REDUCTION	HEAVILY INFESTED	PERCENTAGE REDUCTION
1	20.03	17.43	12.980	14.62	27.009	10.41	48.027
2	20.13	16.32	18.926	13.08	35.022	10.12	49.726
3	19.04	17.7	7.037	14.81	22.216	10.68	43.907
4	19.36	17.13	11.518	13.89	28.254	10.43	46.126
5	18.97	16.91	10.859	13.02	31.365	10.03	47.127
6	20.34	17.44	14.257	12.92	36.479	9.43	53.638
7	20.62	17.91	13.142	12.88	37.536	9.64	53.249
8	20.07	16.88	15.894	13.04	35.027	10	50.174
9	21.06	17.42	17.283	13.11	37.749	10.4	50.617
10	19.69	16.93	14.017	12.41	36.973	10.13	48.552
Mean	19.931	17.207*	13.591*	13.378*	32.763*	10.127*	49.114*
Standard deviation	0.673	0.465	3.388	0.792	5.333	0.380	3.033
Standard error mean	0.213	0.147	1.071	0.250	1.686	0.120	0.959

* - Statistically significant using one way – ANOVA with $P<0.05$

vi) Estimation of Proline

The injurious status of the mite on its host invasive plant was assessed based on the production of stress factors. In the current study, the concentration of proline content was estimated separately for uninfested and mite infested leaf samples and compared to evaluate the extent of the biotic stress induced by the mite. An increase in the proline content was recorded in mite infested leaves when compared to that of the uninfested leaf sample. The percentage increase in proline content in the leaf samples of varying levels of mite infestation are presented in parenthesis. The proline content of uninfested leaf sample was recorded as 5.46 ± 0.06 µmol/g and that of mite infested leaves was 11.48 ± 0.09 (52.35±0.78%), 16.53 ± 0.07 (66.93±0.37%) and 19.13 ± 0.04 µmol/g (71.41±0.34%) respectively for lightly infested, moderately infested and heavily infested leaf samples (Table

35; Fig. 45 & 46). The results when analyzed statistically using One way – ANOVA were found highly significant ($p<0.05$).

Table 35: Concentration(mg/g) and Percentage increase (%) of Proline in *Lantana camara* infested by *Eriophyes camarae* sp.nov.

SL. NO.	CONTROL	LIGHTLY INFESTED	PERCENTAGE INCREASE	MODERATELY INFESTED	PERCENTAGE INCREASE	HEAVILY INFESTED	PERCENTAGE INCREASE
1	5.37	11.6	53.706	16.45	67.355	19.04	71.796
2	5.87	11.09	47.069	16.8	65.059	19.2	69.427
3	5.38	11.61	53.660	16.84	68.052	19.5	72.410
4	5.36	11.07	51.580	16.4	67.317	19.08	71.907
5	5.39	11.03	51.133	16.87	68.049	19.07	71.735
6	5.37	11.42	52.977	16.46	67.375	19.11	71.899
7	5.82	11.62	49.913	16.44	64.598	19.02	69.400
8	5.31	11.82	55.076	16.43	67.681	19.09	72.184
9	5.39	11.87	54.591	16.43	67.194	19.07	71.735
10	5.41	11.71	53.800	16.23	66.666	19.09	71.660
Mean	5.467	11.484*	52.351*	16.535*	66.935*	19.127*	71.415*
Standard deviation	0.201	0.3158	2.458	0.218	1.186	0.139	1.079
Standard error mean	0.063	0.099	0.777	0.069	0.375	0.044	0.341

* - Statistically significant using one way – ANOVA with $P<0.05$

vii)Estimation of Total Phenol

The total phenolic content of the leaves of *L. camara* showed an increasing trend owing to infestation by *E. camarae* sp.nov. as observed during the study. The percentage increase in total phenol in the different samples are given in parenthesis. The mean values recorded for the total phenol in the uninfested leaf samples were 42.84 ± 0.37 mg/g . The data recorded for mite infested leaves were 82.92 ± 0.72 mg/g (48.31±0.58%), 114.51 ± 0.79 mg/g (62.57±0.47%), 151.64 ±0.74mg/g (71.74 ± 0.28%) for lightly infested, moderately infested and heavily infested leaf samples respectively (Table 36; Fig. 47 & 48) The data procured on the differences in the mean values of total phenol in uninfested and mite infested leaves when subjected to One way-ANOVA were found highly significant ($p<0.05$).

Table 36: Concentration(mg/g) and Percentage increase (%) of Total Phenol in *Lantana camara* infested by *Eriophyes camarae* sp.nov.

SL.NO.	CONTROL	LIGHTLY INFESTED	PERCENTAGE INCREASE	MODERATELY INFESTED	PERCENTAGE INCREASE	HEAVILY INFESTED	PERCENTAGE INCREASE
1	43.2	87.21	50.4644	118.41	63.51659	154.44	72.02797
2	45.31	81.34	44.29555	113.24	59.98764	153.12	70.40883
3	42.81	80.32	46.7007	114.25	62.52954	149.3	71.32619
4	43.23	82.34	47.49818	110.59	60.90967	146.73	70.53772
5	43.3	86.41	49.89006	115.1	62.38054	150.2	71.17177
6	42.73	83.4	48.76499	116.71	63.38788	152.7	72.01703
7	40.74	81.32	49.90162	114.71	64.48435	152.41	73.26947
8	43.12	82.79	47.91642	110.74	61.06195	154.12	72.0218
9	41.79	80.91	48.35002	116.7	64.19023	152.15	72.53368
10	42.14	83.17	49.33269	114.7	63.26068	151.2	72.12963
Mean	42.837	82.921*	48.311*	114.515*	62.570*	151.637*	71.744*
Standard Deviation	1.187	2.287	1.839	2.506	1.493	2.357	0.886
Standard error Mean	0.375	0.723	0.581	0.792	0.472	0.745	0.280

* - Statistically significant using one way – ANOVA with P<0.05

viii) Estimation of Moisture content

The moisture content of mite infested leaf samples showed a decrease as observed during the present study. The mean moisture contents recorded for uninfested leaf samples were 84.06 ± 0. 0.55 % whereas those of lightly infested, moderately infested and heavily infested leaf samples were 79.87 ± 0.48 % , 73.23 ± 0.29 % and 67.81 ± 0.41% respectively (Table 37; Fig. 49 & 50). The results when subjected to statistical analysis using One way ANOVA were found highly significant ($p<0.05$).

Table 37: Amount of Moisture content (%) and Percentage reduction (%) in *Lantana camara* infested by *Eriophyes camarae* sp.nov.

SL .NO.	CONTROL	LIGHTLY INFESTED	PERCENTAGE REDUCTION	MODERATELY INFESTED	PERCENTAGE REDUCTION	HEAVILY INFESTED	PERCENTAGE REDUCTION
1	82.45	79.13	4.026683	73.12	11.31595	68.21	17.27107
2	83.67	79.32	5.198996	72.43	13.43373	67.09	19.81594
3	83.98	78.37	6.680162	73.87	12.03858	68.41	18.54013
4	86.34	81.54	5.559416	73.98	14.3155	68.21	20.99838
5	84.67	80.89	4.464391	72.32	14.58604	66.14	21.88497
6	83.24	79.97	3.9284	73.64	11.53292	68.8	17.34743
Mean	84.058	79.87*	4.976*	73.226*	12.870*	67.81*	19.309*
Standard deviation	1.341	1.178	1.054	0.723	1.431	0.996	1.915
Standard error mean	0.547	0.480	0.430	0.295	0.584	0.406	0.781

* - Statistically significant using one way – ANOVA with P<0.05

5) Qualitative assessment of leaf damage induced by *Eriophyes antigonus* sp. nov. on *Antigonon leptopus*

a) Visual assessment of damage symptoms

Under field cum laboratory conditions, *E. antigonus* sp.nov. could be identified as a leaf vagrant characterized by the wandering habit on the leaf surface. The various life stages of the mite were recognized as random feeders and resembling the earlier species, exhibited sap sucking behavior by forming small groups at various sites on the foliar surface, adjacent to the midrib or other veins and initiated their feeding at the selected spots for some time and then moved to adjacent spots. . Localised feeding by the active life stages in each group on selected areas of the laminar surface resulted in the formation of minute feeding punctures or stipplings. During heavy infestation, the stipplings were found developed on both surfaces of the leaves. Closely placed stipplings developed on the lower laminar surface imparted a bronzed appearance and quite often the leaves became yellow coloured and dropped off (Plate 40, Fig. d & e; Plate 16, Fig. c).

b) Assessment of anatomical damage

Anatomical injury induced by the feeding activity of the different life stages was assessed through comparison of stained sections of mite infested and uninfested leaves of the host plant, *A. leptopus* . The uninfested leaf was found to consist of upper and lower epidermal cells, the upper epidermal cells being larger in size and with trichomes. The mesophyll tissue was found to comprise closely arranged palisade cells , the latter being rich in chloroplast and appeared dark green in colour (Plate 18, Fig. a, b & c).

The histological sections of mite infested leaves on microscopic examination revealed the presence of disruptions in the cuticular layer and lower epidermal cells, due to the initial feeding activity of mites. Prolonged feeding of the various life stages of the mite led to the formation of feeding punctures in the upper and lower epidermal cells. The collenchymatous cells of the lower leaf surface were found destroyed. The cells of the initial raw of vascular bundles were also found destroyed. The chloroplast cells bearing the photosynthetic pigments, in the palisade tissues of infested leaves showed considerable reduction and their green colour was found lost and transformed to yellowish in colour, indicating the lack of chlorophyll (Plate 18, Fig. d, e & f).

c) Attenuated Total Reflectance Fourier Transform Infrared Spectrophotometer (ATR-FTIR) analysis

Attenuated Total Reflectance Fourier Transform Infrared Spectrophotometer (ATR-FTIR) analysis was performed to identify the functional groups present in both the control and mite infested leaves of *A.leptopus*. There were a total of 18 vibrations in uninfested leaf samples between the wavelength of 500-4000 cm^{-1} while in the case of mite infested leaf samples, the total number of functional groups recorded were 17

between the wavelength of 500-4000 cm^{-1}. The peak sizes were found different for different functional groups, and some of them showed a highest peak range and some of them had lowest peak range. The functional groups recorded were alkyl halide, alkane groups, amine groups, alkene groups, alkyl group, aldehyde, and alcohol groups. There was an SCN bend found at 510-460 cm–1 in uninfested leaf sample and it was found absent in mite infested leaf sample (Table 38 & 39; Fig. 32)

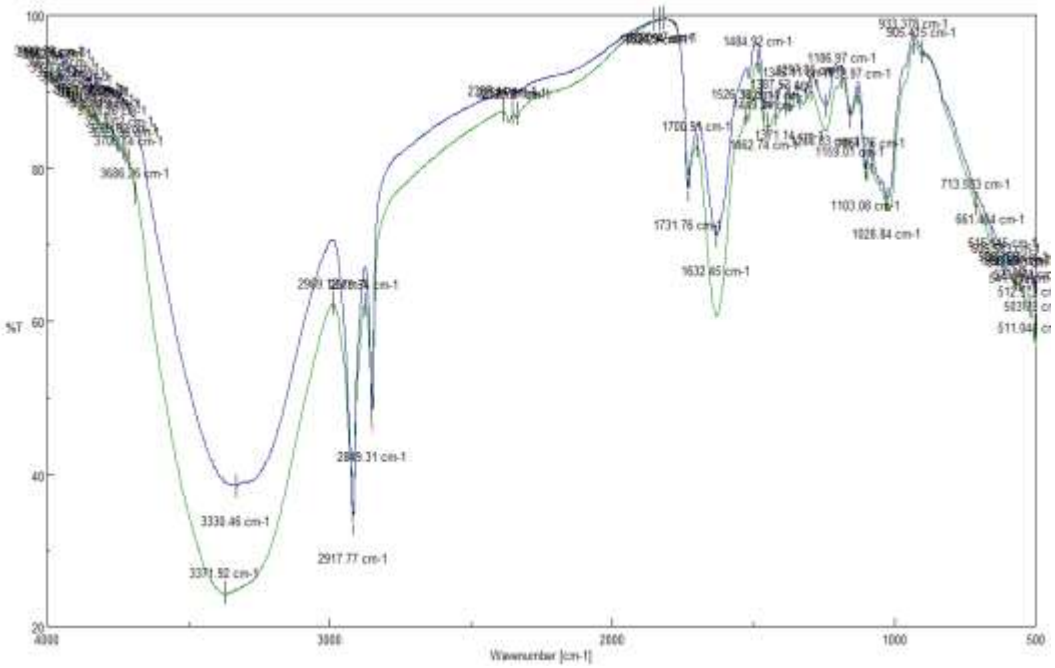
Table 38: ATR-FTIR Analysis data of *Antigonon leptopus* Leaf (Uninfested)

Sl. No	Vibration	Start WN	End WN	Threshold
1	SCN bend	510	460	Variable
2	Si-OH Deformation	1040	1020	Medium
3	C-F stretch	1200	1105	Variable
4	N=C=S Stretch, sym	1240	1100	Variable
5	S=O stretch, Sym	1210	1150	Strong
6	C-H wag, Halogen Substituted	1245	1225	Variable
7	C-F Stretch	1375	1260	Variable
8	C-H Bend, CH3	1380	1370	Variable
9	C-H Wag	1375	1315	Variable
10	C-H Bend, CH2/CH3	1420	1375	Variable
11	C-H bend	1465	1430	Variable
12	C=C stretch, Alkene	1665	1635	Variable
13	C=O Stretch	1740	1715	Strong
14	C-H Stretch, Alkyl	2975	2845	Variable
15	C-H stretch, CH2	2975	2840	Variable
16	C-H Stretch, CH2	2965	2915	Variable
17	O-H Stretch	3450	3300	Variable
18	N-H stretch	3400	3300	Variable

Table 39 : ATR-FTIR Analysis data of *Antigonon leptopus* Leaf (Infested)

Sl. No	Vibration	Start WN	End WN	Threshold
1.	Si-OH Deformation	1040	1020	Medium
2.	C-F stretch	1200	1105	Variable
3.	N=C=S Stretch, sym	1240	1100	Variable
4.	S=O stretch, Sym	1210	1150	Strong
5.	C-H wag, Halogen Substituted	1245	1225	Variable
6.	C-F Stretch	1375	1260	Variable
7.	C-H Bend, CH3	1380	1370	Variable
8.	C-H Wag	1375	1315	Variable
9.	C-H Bend, CH2/CH3	1420	1375	Variable
10.	C-H bend	1465	1430	Variable
11.	C=C stretch, Alkene	1665	1635	Variable
12.	C=O Stretch	1740	1715	Strong
13.	C-H Stretch, Alkyl	2975	2845	Variable
14.	C-H stretch, CH2	2975	2840	Variable
15.	C-H Stretch, CH2	2965	2915	Variable
16.	O-H Stretch	3450	3300	Variable
17.	N-H stretch	3400	3300	Variable

Fig. 32: Analysis of functional groups- Attenuated Total Reflectance Fourier Transform Infrared Spectrophotometer (ATR-FTIR)- *Antigonon leptopus* (Uninfested) + *Antigonon leptopus* (Infested)



6) Quantitative assessment of leaf damage induced by *E. antigonus* sp. nov. on *A. leptopus*

Quantitative assessment of feeding damage induced by *E. antigonus* sp. nov. on its host plant, *A. leptopus* was made during the present study by adopting the same procedures described above for the earlier two species.

i) Photosynthetic Efficiency Analysis:

Quantitative assessment of the photosynthetic efficiency of uninfested and mite infested leaves of *A. leptopus* was made by measuring their fluorescence emission. The results of fluorescence emission studies revealed the mean and standard error mean values of Fv/Fm as 0.836 ± 0.002 for uninfested leaves and 0.638 ± 0.012 for mite infested leaves (Table 40; Fig. 36). The percentage reduction in photosynthetic efficiency was calculated as 23.6% based on the reduction in the values of Fv/Fm. The results when analyzed statistically using One way –ANOVA were found highly significant ($p<0.05$).

Table 40: Photosynthetic efficiency (Fv/Fm) of uninfested and *Eriophyes antigonus* sp.nov. infested leaf of *Antigonon leptopus*

	UNINFESTED LEAVES				INFESTED LEAVES			
SL.NO	F0	Fm	Fv/Fm	Pindex	F0	Fm	Fv/Fm	Pindex
1	290	1749	0.834	2.282	410	1313	0.687	1.063
2	311	1846	0.832	2.135	462	1242	0.628	0.55
3	277	1729	0.84	3.142	491	1207	0.651	0.443
4	258	1717	0.85	3.882	423	1322	0.68	0.3
5	260	1581	0.836	3.372	420	1241	0.661	1.907
6	261	1603	0.829	3.343	362	1126	0.678	0.438
7	270	1709	0.841	3.139	454	1168	0.611	0.423
8	292	1752	0.839	2.098	481	1194	0.597	0.312
9	301	1830	0.829	2.16	488	1176	0.585	1.1
10	273	1730	0.832	3.228	467	1203	0.611	0.403
Mean	279.3	1724.6	0.8362	2.881	445.8	1219.2	0.6389*	0.6939
Sem	5.82	26.45	0.002	0.2027	13.05	19.6	0.0117	0.1626
SD	18.39	83.63	0.0064	0.6411	41.27	61.99	0.0372	0.5143

* - Statistically significant using one way – ANOVA with $P<0.05$

ii) Estimation of photosynthetic pigments:

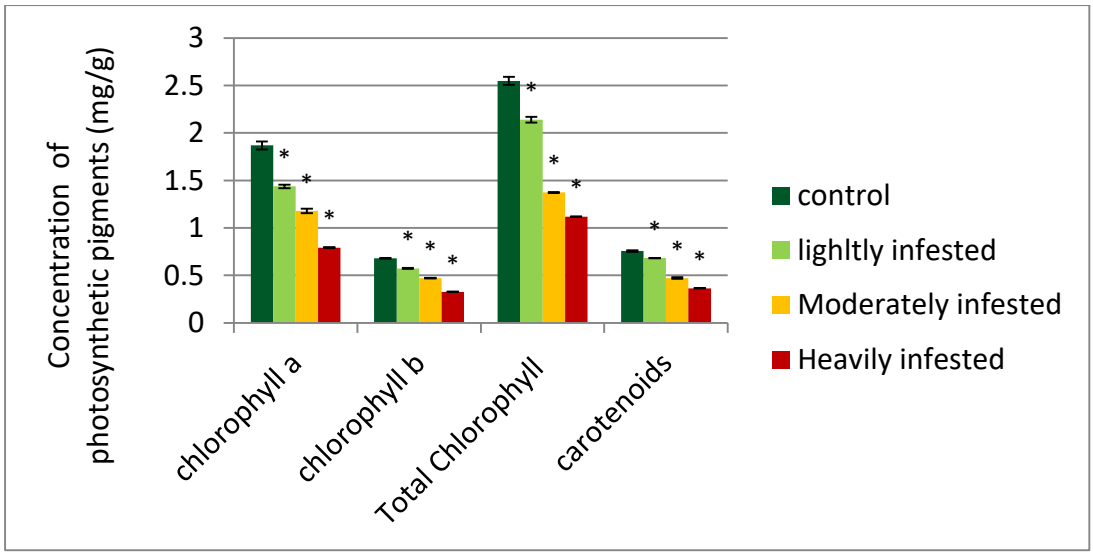
Results of quantitative analysis of the photosynthetic pigments *viz.* chlorophyll a, chlorophyll b, total chlorophyll and carotenoids of the uninfested and mite infested leaves of the invasive weed *A. leptopus* revealed that the mite induced significant reduction in the amounts of all the pigments mentioned above. The percentage reduction in photosynthetic pigments owing to mite feeding are presented in parenthesis. The values recorded for the concentration of chlorophyll 'a' in the uninfested leaf sample were 1.87 ± 0.04 mg/g and those of lightly infested, moderately infested and heavily infested leaf samples were 1.57 ± 0.03 (15.99 ± 0.73 %), 1.18 ± 0.02 (36.73 ± 1.04 %) and 0.79± 0.004 mg/g (57.35 ± 1.13 %) respectively (Table 41; Fig. 33 & 34). The chlorophyll 'b' content recorded for uninfested leaf sample was 0.68 ± 0.005 mg/g while that of lightly infested sample was 0.57 ± 0.005 (15.72 ± 0.89 %), moderately infested sample was 0.47 ± 0.003 (30.55 ± 0.6 %) and heavily infested sample was 0.33 ± 0.001mg/g (51.92 ± 0.38 %) respectively (Table 41; Fig. 33 & 34). The concentration of total chlorophyll pigment estimated during the study was 2.55 ± 0.043 mg/g in the uninfested leaf sample and the same for lightly infested leaf sample was 2.14 ± 0.03 (15.95 ± 0.52 %), moderately infested leaf was 1.37 ± 0.006 (45.98 ± 0.97 %) and heavily infested leaf sample was 1.12 ± 0.003 mg/g (55.95 ± 0.84 %) respectively (Table 41; Fig. 33 & 34). The carotenoid pigment present in the uninfested leaf sample was 0.76 ± 0.008 mg/g and that of lightly infested, moderately infested and heavily infested leaf samples could be recorded as 0.68 ± 0.002 (9.77 ± 1.04 %), 0.47 ± 0.007 (37.47 ± 1.24 %) and 0.36 ± 0.001 mg/g (51.75 ± 0.61 %) (Table 41; Fig. 33 & 34). The data were analyzed statistically using One way –ANOVA and were found highly significant ($p<0.05$).

Table 41: Concentration (mg/g) and Percentage reduction (%) of Photosynthetic pigments (Chlorophyll a, b, Total Chlorophyll and Carotenoids) in *Antigonon leptopus* infested by *Eriophyes antigonus* sp.nov.

Photosynthetic pigments	Control	lighltly infested	Percentage reduction	Moderately infested	Percentage reduction	Heavily infested	Percentage reduction
Chlorophyll a	1.868±0.042	1.436±0.019*	15.993±0.72*	1.180±0.02*	36.729±1.04*	0.792±0.004*	57.349±0.28*
Chlorophyll b	0.68±0.004	0.573±0.005*	15.718±0.89*	0.472±0.003*	30.548±0.60*	0.326±0.001*	51.92±0.38*
Total Chlorophyll	2.548±0.043	2.141±0.03*	15.955±0.52*	1.373±0.005*	45.984±0.97*	1.119±0.003*	55.948±0.83*
Carotenoids	0.756±0.008	0.681±0.002*	9.766±1.04*	0.472±0.007*	37.473±1.24*	0.364±0.001*	51.755±0.61*

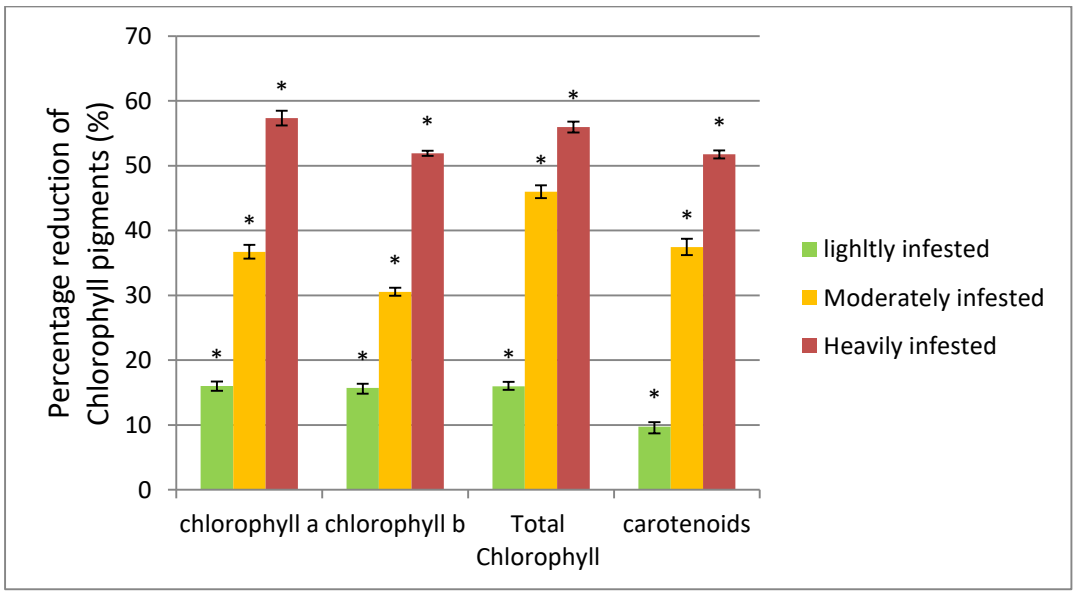
* - Statistically significant using one way – ANOVA with $P<0.05$

Fig. 33: Concentration of photosynthetic pigments (Chlorophyll a, b, Total Chlorophyll and Carotenoids) in *Antigonon leptopus* infested by *Eriophyes antigonus* sp.nov. (mg/g)



* - Statistically significant using one way – ANOVA with P<0.05

Fig. 34: Percentage reduction of photosynthetic pigments (Chlorophyll a, b, Total Chlorophyll and Carotenoids) in *Antigonon leptopus* infested by *Eriophyes antigonus* sp.nov. (%)



* - Statistically significant using one way – ANOVA with P<0.05

iii) Estimation of Total Carbohydrate

The results of quantitative studies revealed a remarkable reduction in the total carbohydrate concentration in mite infested leaf samples when compared to that of uninfested leaf samples. The values calculated for percentage reduction in total carbohydrate content are given in parenthesis. The total carbohydrate content in the uninfested leaf sample was 53.77 ± 0.24 mg/g. The feeding activity of *E. antigonus* sp.nov. induced a quantitative reduction in total carbohydrate content, by recording 46.09 ± 0.17(14.26±0.30%), 39.45 ± 0.18 (26.62±0.44%) and 32.96 ± 0.42 mg/g (38.71 ±0.68%) for lightly infested, moderately infested and heavily infested leaf samples respectively (Table 42; Fig. 39 & 40). The results were analyzed statistically using One way –ANOVA and were found highly significant ($p<0.05$).

Table 42: Concentration (mg/g) and Percentage reduction (%) of Carbohydrate in *Antigonon leptopus* infested by *Eriophyes antigonus* sp.nov.

SL.NO.	CONTROL	LIGHTLY INFESTED	PERCENTAGE REDUCTION	MODERATELY INFESTED	PERCENTAGE REDUCTION	HEAVILY INFESTED	PERCENTAGE REDUCTION
1	53.08	46.16	13.03693	39.18	26.18689	34.02	35.90806
2	54.44	47.02	13.62968	40.39	25.80823	35.81	34.22116
3	54.81	46.3	15.52636	39.26	28.37074	33.96	38.0405
4	54.95	46.81	14.81347	39.43	28.24386	33.28	39.43585
5	53.86	45.93	14.72336	38.56	28.40698	32.91	38.89714
6	53.19	45.1	15.20963	39.64	25.47471	32.18	39.49991
7	52.99	46.18	12.85148	39.38	25.68409	31.96	39.68673
8	53.17	45.87	13.72955	38.81	27.00771	32.17	39.49596
9	53.22	45.8	13.94213	40.25	24.37054	31.23	41.31905
10	54.01	45.82	15.16386	39.61	26.66173	32.1	40.56656
Mean	53.772	46.099*	14.262*	39.451*	26.621*	32.962*	38.707*
Standard deviation	0.750	0.542	0.948	0.567	1.380	1.346	2.146
Standard error mean	0.237	0.171	0.300	0.179	0.436	0.425	0.678

* - Statistically significant using one way – ANOVA with P<0.05

iv)Estimation of Total Nitrogen

The total nitrogen content calculated by following Kjeldal method (1883) indicated that the feeding activity of *E. antigonus* sp.nov. induced a remarkable reduction. The percentage reduction in total nitrogen are given in parenthesis. The amount of total nitrogen in the uninfested leaf sample of *A. leptopus* was 2.87 ± 0.02mg/g and the same was recorded as 2.54 ± 0.02 mg/g (11.65± 0.39%) in lightly infested 2.25 ± 0.02 mg/g (21.69±0.99%) in moderately infested and 1.92 ± 0.02 mg/g (33.07± 1.13%) in heavily infested leaf samples (Table 43; Fig. 41 & 42). The results were analyzed statistically using One way-ANOVA and were found highly significant ($p<0.05$).

Table 43: Concentration (mg/g) and Percentage reduction (%) of Total Nitrogen in *Antigonon leptopus* infested by *Eriophyes antigonus* sp.nov.

SL.NO.	CONTROL	LIGHTLY INFESTED	PERCENTAGE REDUCTION	MODERATELY INFESTED	PERCENTAGE REDUCTION	HEAVILY INFESTED	PERCENTAGE REDUCTION
1	2.9488	2.624	11.01465	2.2656	23.16875	1.8896	35.9197
2	2.9008	2.5808	11.03144	2.2432	22.66961	1.8176	37.34142
3	2.8304	2.5472	10.00565	2.2608	20.12436	1.8768	33.69135
4	2.9232	2.5904	11.38478	2.3312	20.25178	1.8912	35.30378
5	2.9456	2.5584	13.14503	2.2352	24.11733	1.9216	34.76372
6	2.9136	2.5472	12.57551	2.2128	24.05272	1.9168	34.21197
7	2.7984	2.4016	14.17953	2.1168	24.35678	1.904	31.96112
8	2.8624	2.5568	10.67636	2.1504	24.87423	1.9248	32.75573
9	2.8816	2.5616	11.10494	2.3872	17.15713	2.0176	29.98334
10	2.7424	2.4304	11.3769	2.3008	16.10268	2.0624	24.7958
Mean	2.874	2.539*	11.649*	2.250*	21.687*	1.922*	33.072*
Standard deviation	0.067	0.069	1.2636	0.080	3.129	0.070	3.578
Standard error mean	0.021	0.022	0.399	0.025	0.989	0.022	1.131

* - Statistically significant using one way – ANOVA with P<0.05

v) Estimation of Total Protein

Total protein content of uninfested and mite infested leaf samples of *A.leptopus* was estimated following AOAC (1990) and a significant

reduction was observed in the total protein concentration of mite infested leaf samples. The percentage reduction in total protein are indicated in parenthesis. In the uninfested leaf samples, the mean values recorded for total protein content were 17.97 ± 0.13 mg/g whereas those of lightly infested, moderately infested and heavily infested leaf samples were 15.87 ± 0.14 (11.65±0.39%), 14.06 ± 0.16 (21.69±0.99%) and 12.01 ± 0.14 mg/g (33.07±1.13%) respectively (Table 44; Fig. 43 & 44). The data were analyzed statistically using One way-ANOVA and were found highly significant ($p<0.05$).

Table 44: Concentration (mg/g) and Percentage reduction (%) of Total Protein in *Antigonon leptopus* infested by *Eriophyes antigonus* sp.nov.

SL. NO.	CONTROL	LIGHTLY INFESTED	PERCENT AGE REDUCTION	MODERATELY INFESTED	PERCENTAGE REDUCTION	HEAVILY INFESTED	PERCENTAGE REDUCTION
1	18.43	16.4	11.01465	14.16	23.16875	11.81	35.9197
2	18.13	16.13	11.03144	14.02	22.66961	11.36	37.34142
3	17.69	15.92	10.00565	14.13	20.12436	11.73	33.69135
4	18.27	16.19	11.38478	14.57	20.25178	11.82	35.30378
5	18.41	15.99	13.14503	13.97	24.11733	12.01	34.76372
6	18.21	15.92	12.57551	13.83	24.05272	11.98	34.21197
7	17.49	15.01	14.17953	13.23	24.35678	11.9	31.96112
8	17.89	15.98	10.67636	13.44	24.87423	12.03	32.75573
9	18.01	16.01	11.10494	14.92	17.15713	12.61	29.98334
10	17.14	15.19	11.3769	14.38	16.10268	12.89	24.7958
Mean	17.967	15.874*	11.649*	14.065*	21.687*	12.014*	33.072*
Standard deviation	0.419	0.435	1.263	0.500	3.129	0.437	3.578
Standard error mean	0.132	0.137	0.399	0.158	0.989	0.138	1.131

* - Statistically significant using one way – ANOVA with $P<0.05$

vi) Estimation of Proline

Estimation of the concentration of proline present in mite infested and uninfested leaf samples of *A. leptopus* disclosed a significant increase in proline in mite infested leaves when compared to that of uninfested leaves.

The values recorded for the percentage increase in proline are given in parenthesis. The mean concentration of proline in uninfested leaf sample was 7.13 ± 0.01 µmol/g and that of mite infested leaves could be recorded as 14.69 ± 0.06 µmol/g (51.43±0.06%), 17.37 ± 0.06 µmol/g (58.93 ±0.15%) and 18.22 ± 0.026 µmol/g (60.84 ±0.06%) respectively for lightly infested, moderately infested and heavily infested leaf samples (Table 45; Fig. 45 & 46). The data appeared highly significant ($p<0.05$), when analysed statistically using One way –ANOVA.

Table 45 : Concentration (mg/g) and Percentage increase (%) of Proline in *Antigonon leptopus* infested by *Eriophyes antigonus* sp.nov.

SL. NO.	CONTROL	LIGHTLY INFESTED	PERCENTAGE INCREASE	MODERATELY INFESTED	PERCENTAGE INCREASE	HEAVILY INFESTED	PERCENTAGE INCREASE
1	7.1	14.72	51.7663	17.49	59.40537	18.18	60.94609
2	7.08	14.19	50.10571	17.18	58.78929	18.21	61.12026
3	7.12	14.73	51.66327	17.41	59.10396	18.19	60.85761
4	7.18	14.81	51.51924	17.41	58.75933	18.3	60.76503
5	7.14	14.7	51.42857	17.13	58.31874	18.13	60.61776
6	7.15	14.7	51.36054	17.4	58.90805	18.13	60.5626
7	7.14	14.73	51.52749	17.41	58.98909	18.17	60.70446
8	7.11	14.73	51.73116	17.18	58.61467	18.3	61.14754
9	7.2	14.8	51.35135	17.31	58.40555	18.39	60.84829
10	7.13	14.81	51.85685	17.81	59.96631	18.19	60.80264
Mean	7.135	14.692*	51.431*	17.373*	58.926*	18.219*	60.837*
Standard deviation	0.035	0.181	0.496	0.196	0.486	0.084	0.193
Standard error mean	0.011	0.057	0.157	0.062	0.153	0.026	0.061

* - Statistically significant using one way – ANOVA with $P<0.05$

vii) Estimation of Total Phenol

The total phenolic content in the leaves of *A. leptopus* was found elevated due to infestation by *E. antigonus* sp.nov. as observed during the study. The percentage increase in total phenol for the lightly infested, moderately infested and heavily infested leaf samples are presented in parenthesis. The mean concentration of total phenol was 37.10 ± 0.44mg/g in

uninfested leaf samples of *A. leptopus*. The concentration of total phenol showed an increase in mite infesed samples and which could be recorded as 40.84 ± 0.14 mg/g (9.15± 0.92%) in lightly infestested, 103.24 ± 0.27 mg/g (64.06 ±0.38%) in moderately infested and 133.77 ± 0.50 mg/g (72.26 ± 0.31%) in heavily infested leaf samples of *A. leptopus* (Table 46; Fig. 47 & 48). The variations observed in the mean values on total phenol content in uninfested and mite infested leaves when subjected to One way-ANOVA were found highly significant ($p<0.05$).

Table 46: Concentration (mg/g) and Percentage increase (%) of Total Phenol in *Antigonon leptopus* infested by *Eriophyes antigonus* sp.nov.

SL.NO.	CONTROL	LIGHTLY INFESTED	PERCENTAGE INCREASE	MODERATELY INFESTED	PERCENTAGE INCREASE	HEAVILY INFESTED	PERCENTAGE INCREASE
1	39.61	41.28	4.045543	104.32	62.03029	136.41	70.96254
2	38.42	40.91	6.086531	103.26	62.79295	135.08	71.5576
3	38.21	41.12	7.076848	104.13	63.30548	131.97	71.04645
4	36.27	40.92	11.36364	102.74	64.69729	132.31	72.58711
5	36.97	41.14	10.13612	103.19	64.17288	134.73	72.55993
6	35.48	40.74	12.91114	102.18	65.27696	134.27	73.57563
7	38.13	41.13	7.293946	102.93	62.95541	132.73	71.27251
8	35.91	39.98	10.18009	101.74	64.70415	135.43	73.48446
9	36.12	40.12	9.97009	104.16	65.32258	132.54	72.74785
10	35.93	41.03	12.42993	103.72	65.35866	132.28	72.83792
Mean	37.105	40.837*	9.149*	103.237*	64.061*	133.775*	72.262*
Standard deviation	1.390	0.442	2.900	0.866	1.206	1.591	0.978
Standard error mean	0.439	0.139	0.917	0.274	0.381	0.503	0.309

* - Statistically significant using one way – ANOVA with $P<0.05$

viii) Estimation of Moisture content

The moisture content of mite infested leaves of *A. leptopus* showed a decrease as revealed through the results of the present study. The mean value recorded for the percentage of moisture content of uninfested leaf sample was 84.58 ± 0.91% and respective values recorded for lightly infested leaf samples were 79.32 ± 0.78% , moderately infested leaf samples were 75.17±

0.55% and heavily infested samples were 70.40± 0.94% (Table 47; Fig. 49 & 50).The mean differences in the moisture content of mite infested and uninfested leaf samples upon statistical analysis using One way ANOVA were found highly significant ($p<0.05$).

Table 47: Amount of Moisture content (%) and Percentage reduction (%) in *Antigonon leptopus* infested by *Eriophyes antigonus* sp.nov.

SL .NO.	CONTROL	LIGHTLY INFESTED	PERCENTAGE REDUCTION	MODERATELY INFESTED	PERCENTAGE REDUCTION	HEAVILY INFESTED	PERCENTAGE REDUCTION
1	80.6	76.16	5.508685	73.38	8.957816	68.19	15.39702
2	86.69	79.25	8.582305	75.05	13.42715	69.08	20.31376
3	83.76	78.09	6.769341	74.16	11.46132	68.38	18.36199
4	86.12	81.16	5.759405	77.09	10.48537	71.73	16.70924
5	84.64	80.89	4.430529	76.21	9.95983	74.13	12.4173
6	85.7	80.34	6.254376	75.14	12.32205	70.91	17.25788
Mean	84.585	79.315*	6.217*	75.171*	11.102*	70.403*	16.742*
Standard deviation	2.217	1.918	1.4002	1.342	1.631	2.308	2.689
Standard error mean	0.905	0.783	0.571	0.547	0.665	0.942	1.097

* - Statistically significant using one way – ANOVA with $P<0.05$

7) Qualitative assessment of leaf damage induced by *Phyllocoptruta merremiae* sp. nov. on *Merremia vitifolia*

a) Visual assessment of damage symptoms

Results of field cum laboratory observations disclosed that resembling the earlier two species described above, *P. merremiae* sp.nov. also was a leaf vagrant form of eriophyid mite showing randomized feeding habit on the leaves of its host invasive plant, *M. vitifolia*. Accordingly, the feeding habits and symptoms of injury induced by the species greatly resembled those of the earlier two species. The various life stages of *P. merremiae* sp.nov. formed small isolated groups on the lower surface and initiated feeding at random feeding spots. As a result, minute feeding spots/ and stipplings were developed at punctured spots on the lower leaf surface. During heavy infestation of the mite, damage symptoms were visible on both surfaces of the

host leaves. When the mite built up its population in very high density, the infested areas assumed an yellowish tinge and gradually developed bronzing, shrinking and ultimately leading to leaf drop (Plate 14, Fig. a, c, f & g; Plate 15, Fig. a & b).

b) Assessment of anatomical damage

Stained transverse sections of mite infested and uninfested leaves of *M. vitifolia* were examined under a research microscope to compare the cellular damages and alterations induced by the feeding activity of the various life stages of *P.merremiae* sp.nov. The stained section of uninfested leaf was found to consist of intact upper and lower epidermal cells, with the upper epidermal cells being larger and bulbous in appearance. Mesophyll tissue comprised of closely arranged palisade cells and a few loosely arranged spongy cells along with air space in between. The mesophyll tissue appeared rich in chloroplast as evidenced through the presence of densely packed, dark green coloured chlorophyll pigment (Plate 19, Fig. a, b & c).

In the mite infested leaf section, cuticular layer and lower epidermal cells were found disrupted. Feeding punctures were visible in both upper and lower epidermis. The parenchymatous and collenchymatous cells at the lower side of vascular bundle were found destroyed while the vascular bundles appeared intact. The palisade cells appeared damaged with comparatively lesser amount of photosynthetic pigments (Plate 19, Fig. d, e & f).

c) Attenuated Total Reflectance Fourier Transform Infrared Spectrophotometer (ATR-FTIR) analysis

The mite infested and uninfested leaves of *M. vitifolia* were subjected to Attenuated Total Reflectance Fourier Transform Infrared Spectrophotometer (ATR-FTIR) analysis to identify the functional groups present in the control leaves and the alterations of these groups in mite infested leaves. There were a total of 19 vibrations observed in uninfested

sample between the wavelength of 500-4000 cm^{-1} whereas in the case of mite infested leaf samples, the total number of vibrations recorded were 17 between the wavelength of 500-4000 cm^{-1}. The peak sizes were found different for different functional groups and some of them had a highest peak range. Functional groups recorded included alkane groups, alkene groups, amine groups, alkyl halide, aldehyde, amide group, and alcohol groups. The characteristic peaks at 1740-1715 cm–1 in the spectra of both the control and mite infested samples were found strong (Table 48 & 49; Fig. 35).

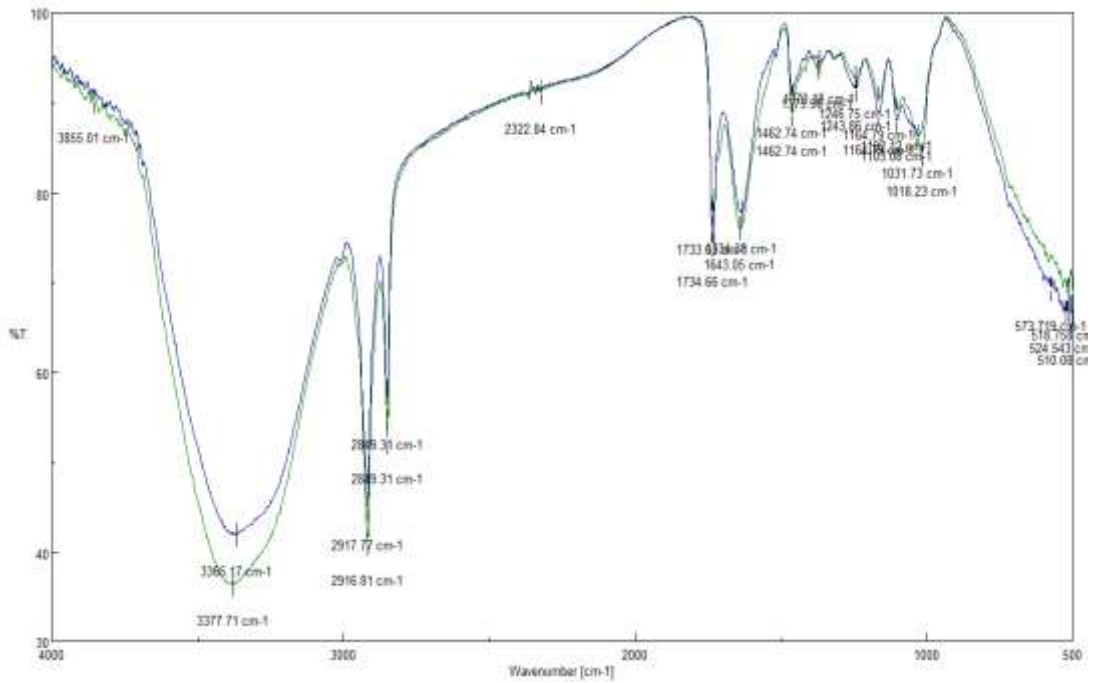
Table **48**: ATR-FTIR Analysis data of *Merremia vitifolia* Leaf (UnInfested)

Sl. No	**Vibration**	**Start WN**	**End WN**	**Threshold**
1.	Skeletal	650	500	Variable
2.	NO2 Def	650	600	Variable
3.	Si-OH Deformation	1040	1020	Medium
4.	Si-O-C stretch, asym	1100	1070	Variable
5.	C-O Stretch	1150	1070	Variable
6.	C-F stretch	1280	1175	Variable
7.	C-H wag, Halogen Substituted	1245	1225	Variable
8.	C-H Bend, CH3	1380	1370	Variable
9.	C-H Wag	1375	1315	Variable
10	C-H bend	1465	1430	Variable
11	C=C stretch, Alkene	1665	1635	Variable
12	N-H bend	1625	1590	Variable
13	C=O Stretch	1740	1715	Strong
14	C-H Stretch, Alkyl	2975	2845	Variable
15	C-H stretch, CH2	2975	2840	Variable
16	C-H Stretch, CH2	2965	2915	Variable
17	O-H Stretch	3450	3300	Variable
18	N-H stretch	3400	3300	Variable
19	O-H stretch, 2-Hydroxy	3500	3380	Variable

Table 49:ATR-FTIR Analysis data of *Merremia vitifolia* Leaf (Infested)

Sl. No	Vibration	Start WN	End WN	Threshold
1.	Skeletal	650	500	Variable
2.	Si-OH Deformation	1040	1020	Medium
3.	Si-O-C stretch, asym	1100	1070	Variable
4.	C-O Stretch	1150	1070	Variable
5.	C-F stretch	1200	1105	Variable
6.	C-H wag, Halogen Substituted	1245	1225	Variable
7.	C-F Stretch	1375	1260	Variable
8.	C-H Bend, CH3	1380	1370	Variable
9.	C-H Wag	1375	1315	Variable
10.	C-H bend	1465	1430	Variable
11.	C=C stretch, Alkene	1665	1635	Variable
12.	C=O Stretch	1740	1715	Strong
13.	C≡N Stretch, Nitrile	2250	2200	Variable
14.	C-H Stretch, Alkyl	2975	2845	Variable
15.	C-H stretch, CH2	2975	2840	Variable
16.	C-H Stretch, CH2	2965	2915	Variable
17.	O-H Stretch	3450	3300	Variable

Fig. 35: Analysis of functional groups- Attenuated Total Reflectance Fourier Transform Infrared Spectrophotometer (ATR-FTIR)- *Merremia vitifolia* (Uninfested) + *Merremia vitifolia* (Infested)



8**) Quantitative assessment of leaf damage induced by *P. merremiae* sp. nov. on *M.vitifolia***

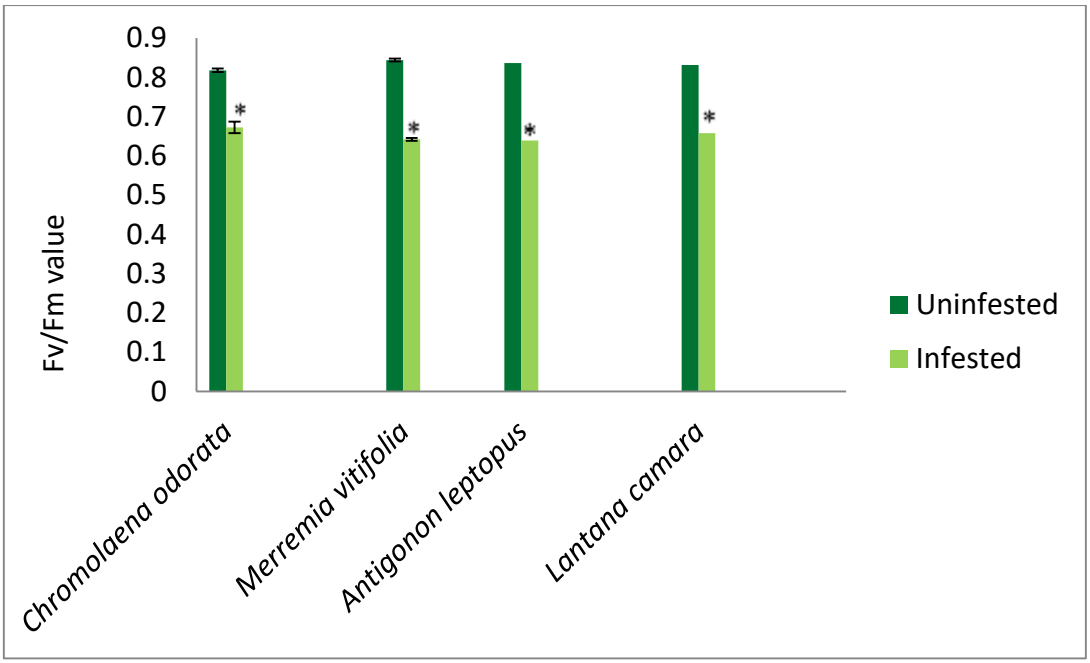
i) Photosynthetic Efficiency Analysis:

Comparative assessment of the photosynthetic efficiency of uninfested and mite infested leaves of *M.vitifolia* was made by measuring chlorophyll fluorescence emission using a Handy PEA. The values of the mean and standard error mean values of Fv/Fm were recorded as 0.844 ± 0.009 for uninfested leaves and 0.642± 0.005 for mite infested leaves, thereby accounting a significant reduction in the photosynthetic efficiency owing to infestation by *P. merremiae* sp.nov. (Table 50; Fig. 36). The percentage reduction in photosynthetic efficiency was recorded as 23.9%. Data on fluorescence emission were found statistically significant ($p<0.05$) when analysed following One way -ANOVA.

Table 50: Photosynthetic efficiency (Fv/Fm) of uninfested and *Phyllocoptruta merremiae* sp.nov. infested leaf of *Merremia vitifolia*

SL.NO	UNINFESTED LEAVES				INFESTED LEAVES			
	F0	Fm	Fv/Fm	Pindex	F0	Fm	Fv/Fm	Pindex
1	427	2736	0.844	3.964	439	1308	0.664	2.392
2	501	2680	0.813	3.323	516	1430	0.639	2.402
3	499	2529	0.802	3.419	551	1632	0.662	2.289
4	318	3094	0.897	3.997	484	1279	0.621	2.093
5	438	2694	0.837	3.642	511	1381	0.629	2.234
6	471	3210	0.853	3.871	488	1312	0.628	2.118
7	489	3041	0.839	3.712	528	1468	0.64	2.091
8	391	3012	0.87	3.813	492	1503	0.672	2.492
9	491	2605	0.811	3.301	474	1307	0.637	2.383
10	367	2942	0.875	3.832	518	1402	0.63	2.191
MEAN	439.2	2854.3	0.8441	3.6874	500.1	1402.2	0.6422*	2.2685
SEM	19.98	73.74	0.0096	0.08162	9.97	34.92	0.0055	0.04579
SD	63.2	233.2	0.0305	0.2581	31.53	110.44	0.0175	0.1448

Fig. 36: Photosynthetic efficiency (Fv/Fm) of selected species of invasive host plants infested by Eriophyid mites



* - Statistically significant using one way – ANOVA with P<0.05

ii) Estimation of photosynthetic pigments:

The concentration of photosynthetic pigments such as the chlorophylls and carotenoid was estimated separately for the uninfested and mite infested leaves of *M. vitifoliae* for assessing the damage induced by *P. merremiae* sp.nov. The data revealed a noticeable reduction in chlorophyll a, chlorophyll b, total chlorophyll and carotenoid concentrations in the mite infested leaf samples when compared to those of the control (uninfested) leaf samples. Data on the percentage reduction in photosynthetic pigments are presented in parenthesis. The concentration of chlorophyll 'a' recorded for uninfested leaf sample was 1.37± 0.01 mg/g while that of lightly infested sample was 0.98 ± 0.007 (28.90 ± 0.82 %), moderately infested sample was 0.76 ± 0.005 (44.94 ± 0.32%) and heavily infested one was 0.56 ± 0.006 mg/g (58.86 ± 0.42 %) respectively (Table 51; Fig. 37 & 38). The chlorophyll 'b' concentration recorded for uninfested leaf sample was 0.87 ± 0.005mg/g and the values for

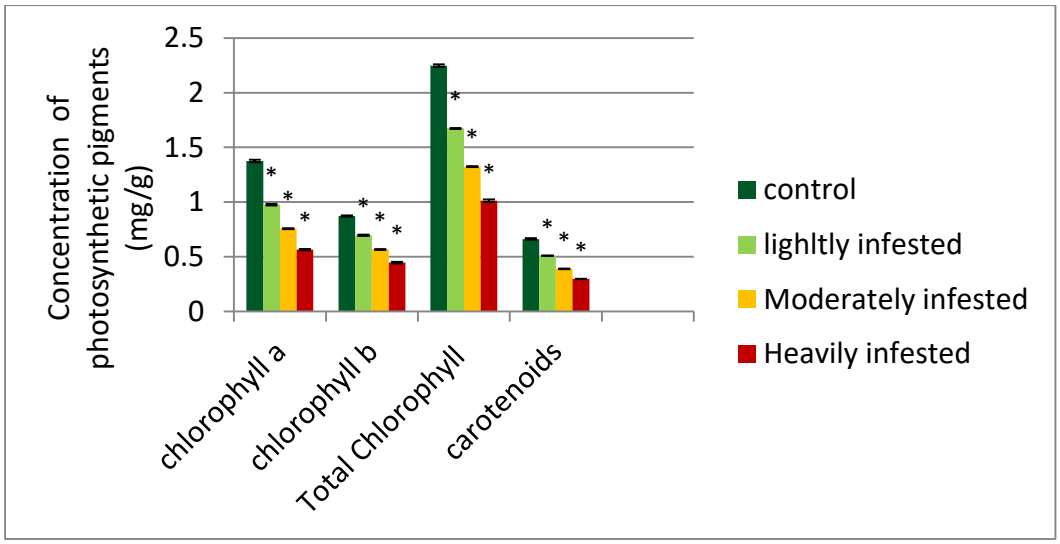
lightly infested, moderately infested and heavily infested leaf samples were 0.69± 0.004 (20.20 ± 0.53 %), 0.57± 0.001 (35.005 ± 0.33 %) and 0.45± 0.007mg/g (48.81 ± 0.76 %) respectively (Table 51; Fig. 37 & 38). Total chlorophyll content was recorded as 2.25±0.01mg/g for uninfested sample. The concentration of total chlorophyll recorded for lightly infested leaf sample was 1.67± 0.005 (25.54±0.38%), moderately infested leaf was 1.32± 0.005 (41.09±0.22%) and heavily infested leaf sample was 1.01±0.01mg/g (54.97±0. 0.43%) respectively (Table 51; Fig. 37 & 38). The carotenoid content recorded for uninfested leaf sample was 0.66 ± 0.008 mg/g and the values recorded for lightly infested, moderately infested and heavily infested leaf samples were 0.51± 0.003 (23.01± 0.83%), 0.39± 0.004 (41.20± 0.69%) and 0.29± 0.002mg/g (55.07± 0.73%) respectively (Table 51; Fig. 37 & 38). Statistical analysis of the results of photosynthetic pigment estimation using One way –ANOVA showed high significance at $p<0.05$.

Table 51 : Concentration (mg/g) and Percentage reduction (%) of Photosynthetic pigments (Chlorophyll a, b, Total Chlorophyll and Carotenoids) in *Merremia vitifolia* in infested by *Phyllocoptruta merremiae* sp.nov.

Photosynthetic pigments	Control	lighltly infested	Percentage REDUCTION	Moderately infested	Percentage REDUCTION	Heavily infested	Percentage REDUCTION
Chlorophyll a	1.374±0.011	0.976±0.007*	28.903±0.82*	0.756±0.004*	44.939±0.32*	0.565±0.005*	58.856±0.42*
Chlorophyll b	0.875±0.005	0.696±0.004*	20.204±0.53*	0.567±0.001*	35.006±0.33*	0.446±0.006*	48.811±0.76*
Total Chlorophyll	2.247±0.011	1.673±0.005*	25.543±0.37*	1.324±0.004*	41.090±0.21*	1.012±0.011*	54.970±0.43*
Carotenoids	0.662 ±0.007	0.509±0.002*	23.014±0.83*	0.388±0.004*	41.20±0.68*	0.296±0.001*	55.072±0.73*

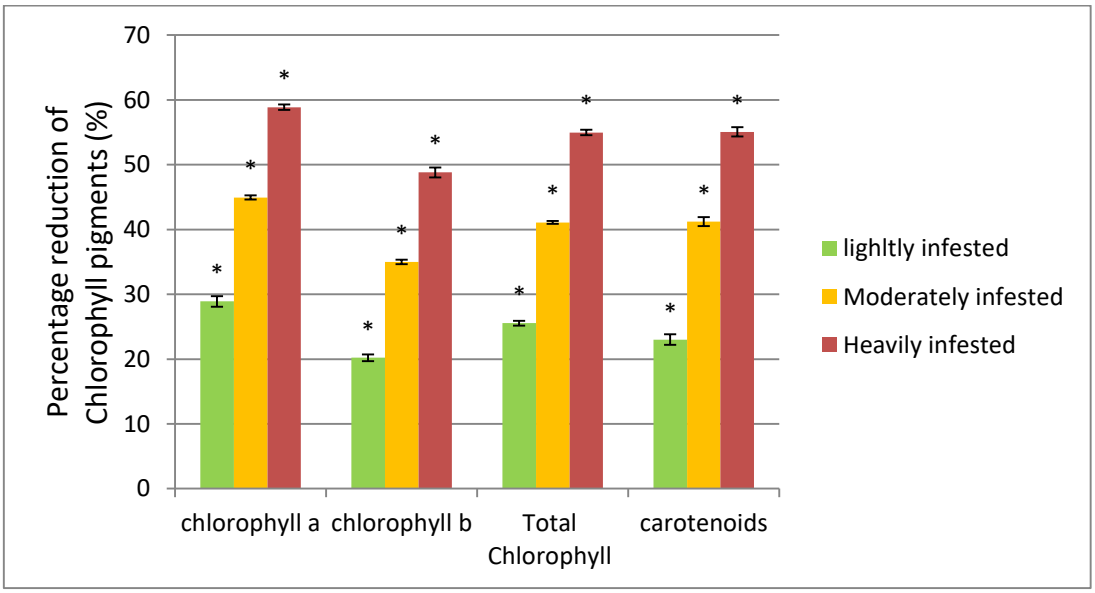
* - Statistically significant using one way – ANOVA with $P<0.05$

Fig. 37: Concentration of photosynthetic pigments (Chlorophyll a, b, Total Chlorophyll and Carotenoids) in *Merremia vitifolia* infested by *Phyllocoptruta merremiae* sp.nov. (mg/g)



* - Statistically significant using one way – ANOVA with P<0.05

Fig. 38: Percentage reduction of photosynthetic pigments (Chlorophyll a, b, Total Chlorophyll and Carotenoids) in *Merremia vitifolia* infested by *Phyllocoptruta merremiae* sp.nov. (%)



* - Statistically significant using one way – ANOVA with P<0.05

iii) Estimation of Total Carbohydrate

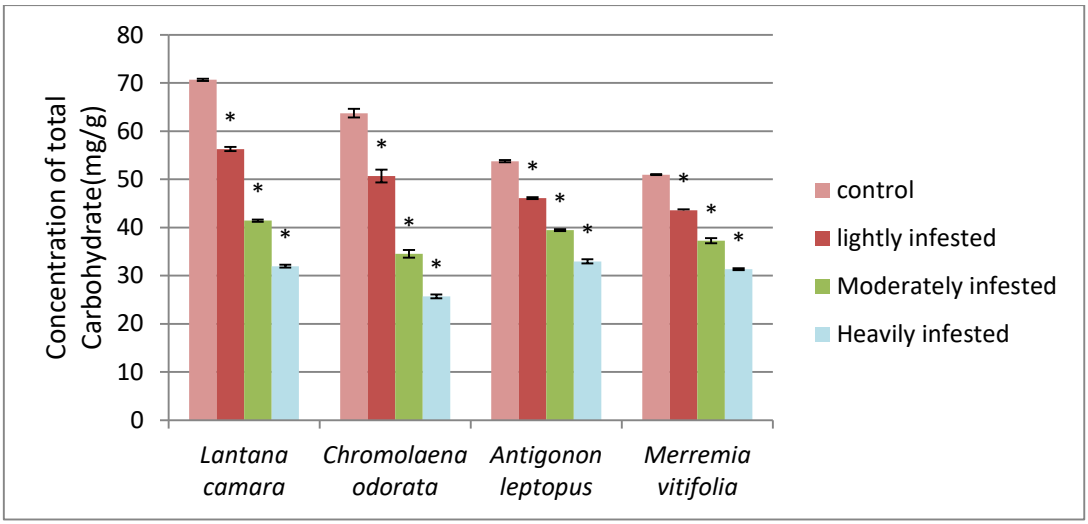
Comparative estimation of the concentration of total carbohydrate in the uninfested and mite infested leaf samples of *M. vitifolia* showed a drastic reduction in the mite infested samples. The values recorded for percentage reduction are given in parenthesis. The uninfested leaf sample showed a mean concentration of 50.97± 0.09 mg/g of total carbohydrate . The feeding activity of *P. merremiae* sp.nov. induced a reduction in the total carbohydrate content to the tune of 43.59 ± 0.18 (14.48±0.39%), 37.25 ±0.52 (26.92 ±1.02%) and 31.35 ±0.17 mg/g (38.49±0.32%) for lightly infested, moderately infested and heavily infested leaf samples respectively (Table 52; Fig. 39 & 40). The data were analyzed statistically using One way –ANOVA and were found highly significant ($p<0.05$).

Table 52 : Concentration (mg/g) and Percentage reduction (%) of Carbohydrate in *Merremia vitifolia* in infested by *Phyllocoptruta merremiae* sp.nov.

SL.NO.	CONTROL	LIGHTLY INFESTED	PERCENTAGE REDUCTION	MODERATELY INFESTED	PERCENTAGE REDUCTION	HEAVILY INFESTED	PERCENTAGE REDUCTION
1	50.82	44.12	13.18379	39.78	21.72373	31.93	37.17041
2	51.04	43.92	13.94984	38.91	23.76567	31.61	38.06818
3	50.93	44.03	13.54801	36.61	28.11702	30.93	39.26959
4	50.46	43.63	13.53547	36.84	26.99168	30.84	38.88228
5	50.71	43.3	14.6125	35.46	30.07296	30.87	39.12443
6	51.23	42.93	16.20144	34.91	31.85633	30.63	40.21081
7	51.28	42.96	16.22465	38.47	24.9805	31.98	37.63651
8	50.94	44.03	13.56498	38.72	23.98901	31.96	37.25952
9	51.36	44.3	13.74611	36.97	28.01791	31.81	38.06464
10	50.98	42.68	16.28089	35.84	29.69792	30.99	39.21146
Mean	50.975	43.59*	14.484*	37.251*	26.921*	31.355*	38.489*
standard deviation	0.273	0.579	1.263	1.637	3.231	0.547	0.999
standard error mean	0.086	0.183	0.399	0.517	1.021	0.173	0.316

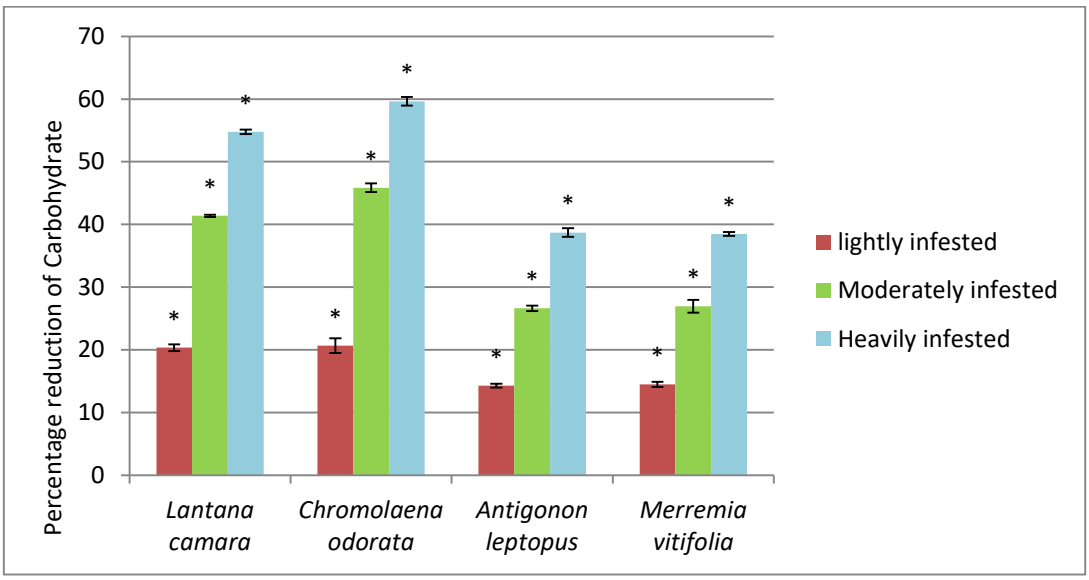
* - Statistically significant using one way – ANOVA with $P<0.05$

Fig. 39: Concentration of Total Carbohydrate (mg/g) in selected species of invasive host plants studied



* - Statistically significant using one way – ANOVA with P<0.05

Fig. 40: Total Carbohydrate reduction (%) due to feeding by eriophyid mites in selected species of invasive host plants studied



* - Statistically significant using one way – ANOVA with P<0.05

iv)Estimation of Total Nitrogen

The results of the study revealed a reduction in the concentration of total nitrogen owing to the feeding activity of *P. merremiae* sp.nov. The

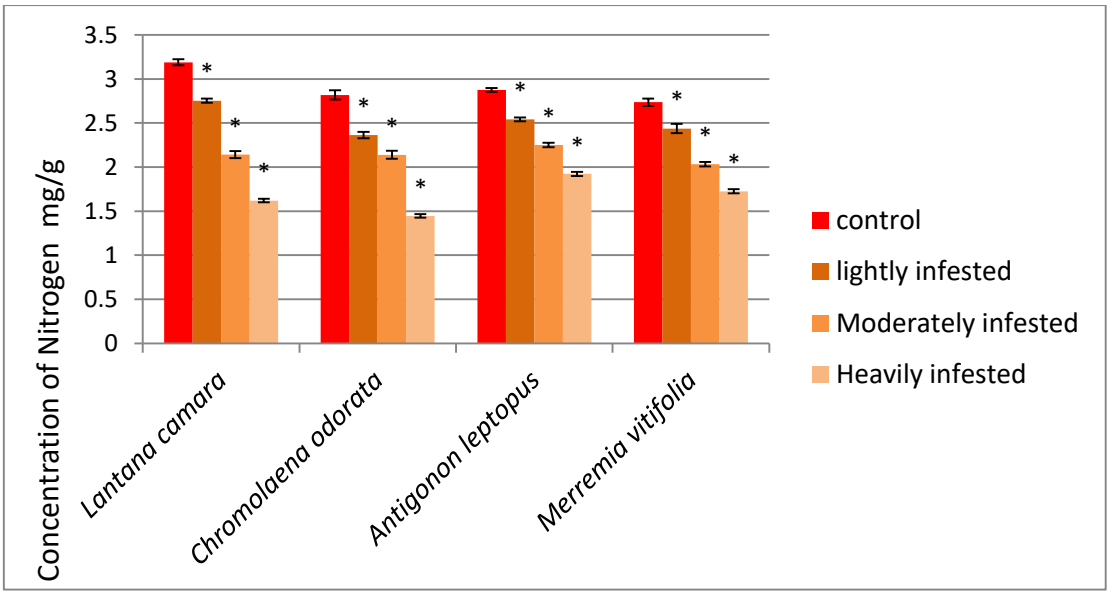
values on percentage reduction in total nitrogen content are given in parenthesis. The concentration of total nitrogen present in uninfested leaf sample was recorded as 2.73 ± 0.04 mg/g. The concentration of total nitrogen recorded for lightly infested leaf sample was 2.44 ± 0.05 mg/g (10.91 ±1.42%), moderately infested sample was 2.03 ± 0.02 mg/g (25.55± 1.19%) and heavily infested sample was 1.72 ± 0.02 mg/g (36.76±1.34%) (Table 53; Fig. 41 & 42). The results were found highly significant ($p<0.05$) when analyzed statistically using One way-ANOVA.

Table 53: Concentration (mg/g) and Percentage reduction (%) of Total Nitrogen in *Merremia vitifolia* infested by *Phyllocoptruta merremiae* sp.nov.

SL.NO.	CONTROL	LIGHTLY INFESTED	PERCENTAGE REDUCTION	MODERATELY INFESTED	PERCENTAGE REDUCTION	HEAVILY INFESTED	PERCENTAGE REDUCTION
1	2.6816	2.4208	9.725537	2.2224	17.12411	1.7648	34.18854
2	2.6096	2.3856	8.583691	1.9856	23.91171	1.7488	32.9859
3	2.9808	2.6944	9.608159	2.0688	30.59581	1.7568	41.0628
4	2.7424	2.5808	5.892649	2.0816	24.09568	1.8992	30.74679
5	2.7168	2.4176	11.01296	1.9888	26.79623	1.6432	39.51708
6	2.6288	2.4352	7.364577	1.9648	25.25867	1.7328	34.08399
7	2.6032	2.3952	7.990166	1.9248	26.06023	1.7184	33.98894
8	2.608	2.0176	22.63804	2.0176	22.63804	1.696	34.96933
9	2.8864	2.5168	12.80488	2.0272	29.76718	1.6512	42.79379
10	2.9008	2.5104	13.45836	2.0512	29.28847	1.6448	43.2984
Mean	2.735	2.437*	10.907*	2.033*	25.553*	1.725*	36.763*
standard deviation	0.132	0.167	4.499	0.077	3.786	0.072	4.246
standard error mean	0.041	0.052	1.422	0.024	1.197	0.023	1.342

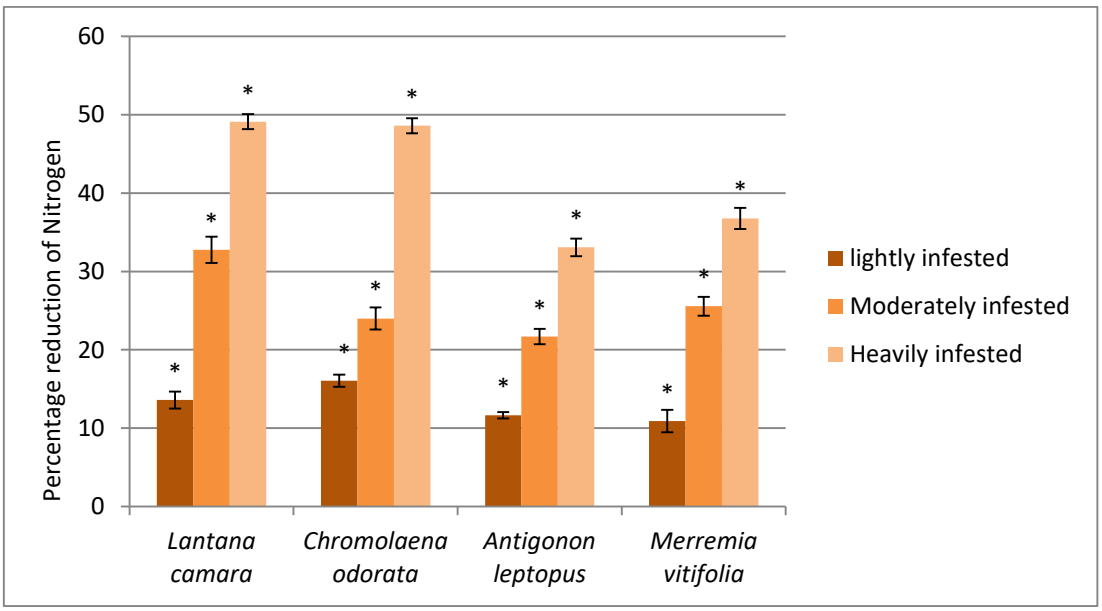
* - Statistically significant using one way – ANOVA with $P<0.05$

Fig. 41: Concentration of Nitrogen (mg/g) in selected species of invasive host plants studied



* - Statistically significant using one way – ANOVA with P<0.05

Fig. 42: Nitrogen reduction (%) in selected species of invasive host plants due to feeding by eriophyid mites



* - Statistically significant using one way – ANOVA with P<0.05

v) Estimation of Total Protein

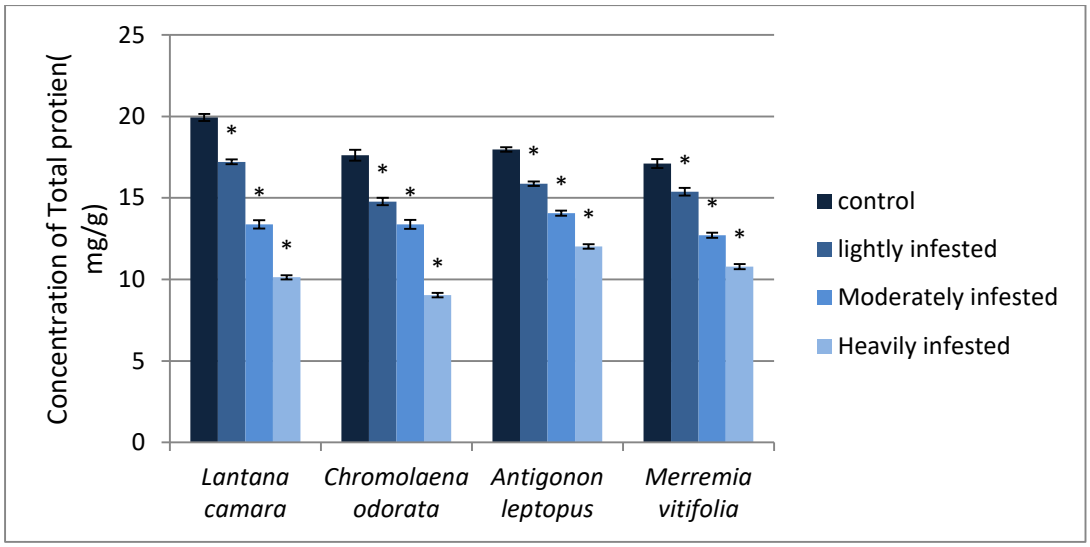
The concentration of total protein in the uninfested and mite infested leaf samples of *M. vitifolia* when estimated following AOAC (1990) showed a significant reduction in the mite infested samples. The data on percentage reduction in total protein are given in parenthesis. The total protein content of uninfested leaves could be recorded as 17.62±0.33 mg/g whereas the values were found reduced to 14.78 ±0.23 (10.04±0.86%), 13.37 ±0.27 (25.55±1.26%) and 9.04 ±0.13 mg/g (36.76±1.41%) in lightly infested, moderately infested and heavily infested leaf samples respectively (Table 54; Fig. 43 & 44). The results of the study were analyzed statistically using One way-ANOVA and were found highly significant ($p<0.05$).

Table 54: Concentration (mg/g) and Percentage reduction (%) of Total Protein in *Merremia vitifolia* infested by *Phyllocoptruta merremiae* sp.nov.

SL.NO.	CONTROL	LIGHTLY INFESTED	PERCENTAGE REDUCTION	MODERATELY INFESTED	PERCENTAGE REDUCTION	HEAVILY INFESTED	PERCENTAGE REDUCTION
1	16.76	15.13	9.725537	13.89	17.12411	11.03	34.18854
2	16.31	14.91	8.583691	12.41	23.91171	10.93	32.9859
3	18.63	16.84	9.608159	12.93	30.59581	10.98	41.0628
4	17.14	16.13	5.892649	13.01	24.09568	11.87	30.74679
5	16.98	15.11	11.01296	12.43	26.79623	10.27	39.51708
6	16.43	15.22	7.364577	12.28	25.25867	10.83	34.08399
7	16.27	14.97	7.990166	12.03	26.06023	10.74	33.98894
8	16.3	14.03	13.92638	12.61	22.63804	10.6	34.96933
9	18.04	15.73	12.80488	12.67	29.76718	10.32	42.79379
10	18.13	15.69	13.45836	12.82	29.28847	10.28	43.2984
Mean	17.099	15.376*	10.036*	12.708*	25.553*	10.785*	36.763*
standard deviation	0.870	0.766	2.715	0.513	3.991	0.479	4.476
standard error mean	0.275	0.242	0.858	0.162	1.262	0.151	1.415

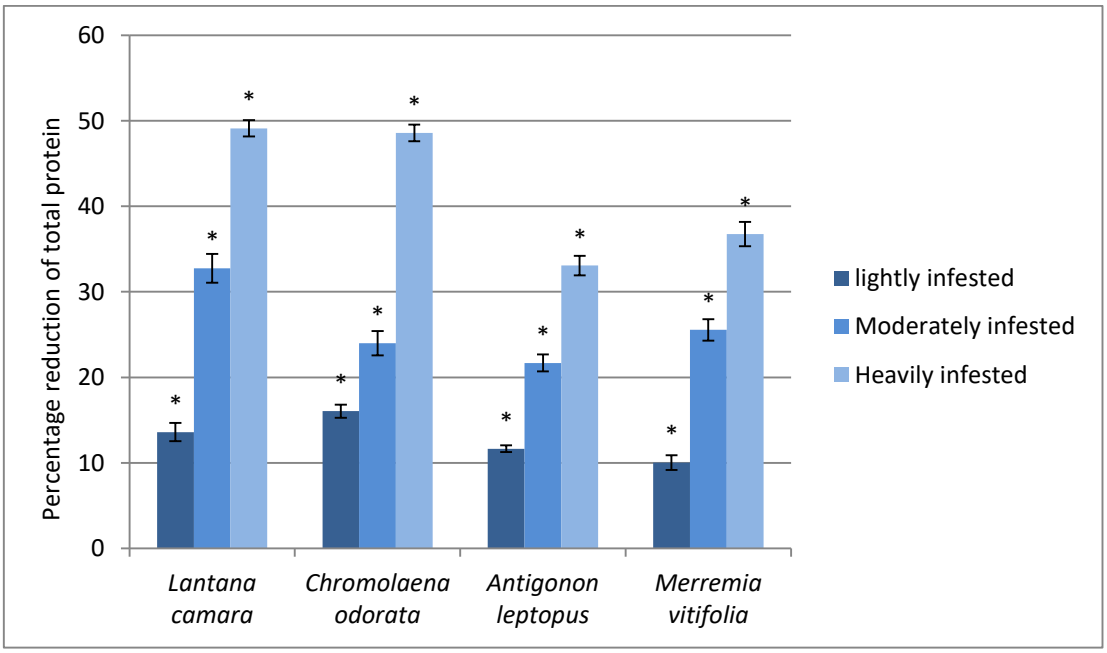
* - Statistically significant using one way – ANOVA with $P<0.05$

Fig. 43: Concentration of Total protein(mg/g) in selected species of invasive host plants studied



* - Statistically significant using one way – ANOVA with P<0.05

Fig. 44: Reduction of Total protein (%) in selected species of invasive host plants due to feeding by eriophyid mites



* - Statistically significant using one way – ANOVA with P<0.05

vi) Estimation of Proline

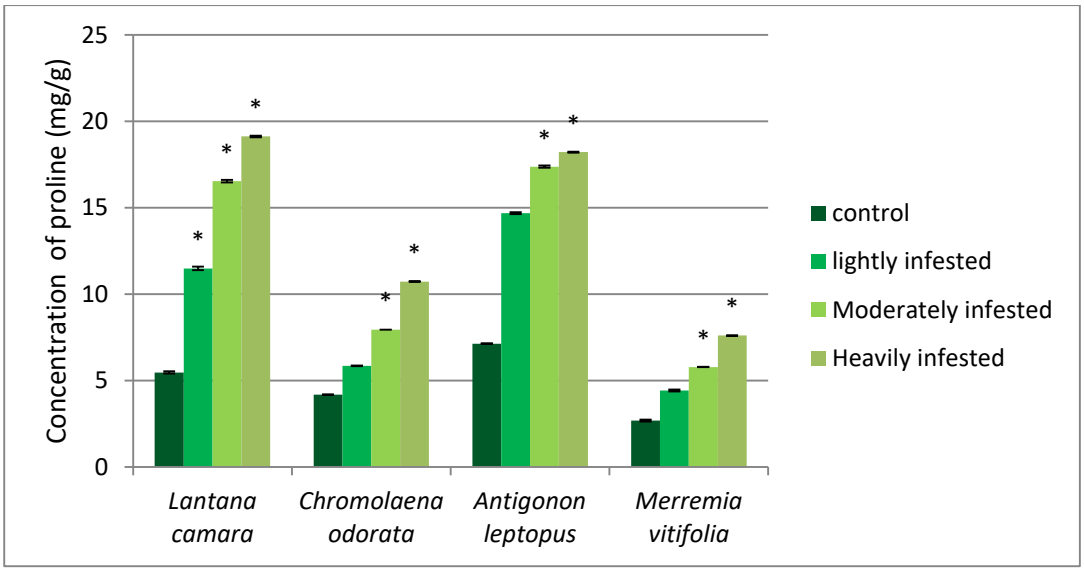
The concentration of proline was estimated separately for uninfested and mite infested leaf samples of *M. vitifolia* to assess the host response to the feeding activity of the vagrant mite, *P. merremiae* sp. nov. Mite infested leaf samples showed an increase in proline content and the percentage increase are shown in parenthesis. The proline concentration recorded for uninfested leaf sample was 2.68 ± 0.05 µmol/g and the values were found increased to 4.43 ± 0.06 µmol/g (39.42±1.11%), 5.78 ± 0.012 µmol/g (53.61 ±0.92%) and 7.60 ± 0.013µmol/g (64.73±0.71%) respectively in lightly infested, moderately infested and heavily infested leaf samples (Table 55; Fig. 45 & 46). The data on proline estimation were found highly significant when analyzed statistically using One way –ANOVA ($p<0.05$).

Table 55: Concentration (mg/g) and Percentage increase (%) of Proline in *Merremia vitifolia* infested by *Phyllocoptruta merremiae* sp.nov.

SL.NO.	CONTROL	LIGHTLY INFESTED	PERCENTAGE INCREASE	MODERATELY INFESTED	PERCENTAGE INCREASE	HEAVILY INFESTED	PERCENTAGE INCREASE
1	2.78	4.58	39.30131	5.8	52.06897	7.61	63.46912
2	2.19	4.23	48.22695	5.71	61.64623	7.53	70.91633
3	2.64	4.13	36.07748	5.74	54.00697	7.6	65.26316
4	2.71	4.53	40.1766	5.75	52.86957	7.6	64.34211
5	2.76	4.57	39.60613	5.79	52.33161	7.59	63.63636
6	2.79	4.58	39.08297	5.81	51.97935	7.63	63.43381
7	2.71	4.25	36.23529	5.84	53.59589	7.69	64.75943
8	2.73	4.28	36.21495	5.76	52.60417	7.58	63.98417
9	2.78	4.56	39.03509	5.81	52.15146	7.61	63.46912
10	2.73	4.57	40.26258	5.79	52.84974	7.59	64.03162
Mean	2.682	4.428*	39.421*	5.78*	53.610*	7.603*	64.730*
Standard deviation	0.178	0.181	3.507	0.039	2.899	0.040	2.256
Standard error mean	0.056	0.057	1.109	0.012	0.916	0.012	0.713

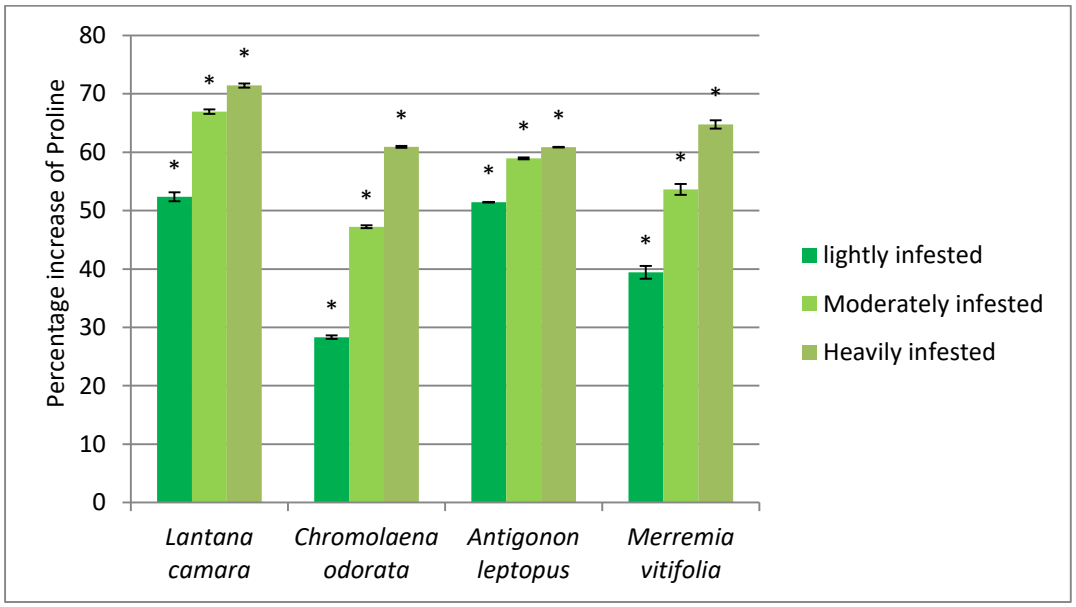
* - Statistically significant using one way – ANOVA with $P<0.05$

Fig. 45: Concentration of Proline (mg/g) in selected species of invasive host plants studied



* - Statistically significant using one way – ANOVA with P<0.05

Fig. 46: Increase of Proline (%) in selected species of invasive host plants studied due to feeding by eriophyid mites



* - Statistically significant using one way – ANOVA with P<0.05

vii) Estimation of Total Phenol

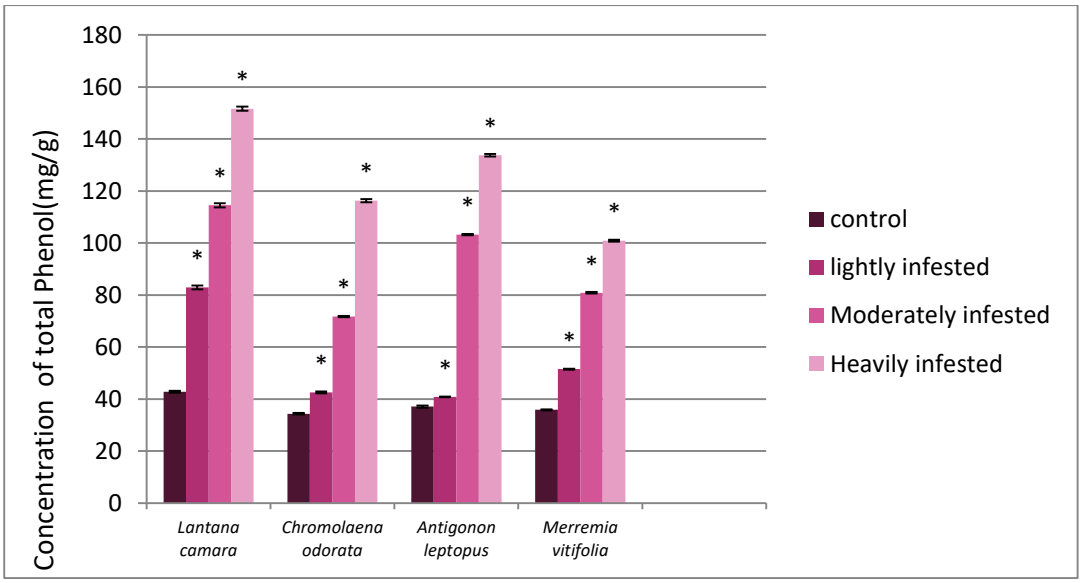
The data recorded for total phenolic content estimation revealed an increase in the total phenol in mite infested leaf samples when compared to that of the uninfested sample of *M. vitifolia*. The uninfested leaf sample showed 35.88 ± 0.18 mg/g of total phenol. The percentage increase recorded in total phenol are given in parenthesis. The mite infested leaves showed an increase in phenolic content and which could recoded as 51.49 ± 0.19 mg/g (30.32±0.33%), 80.87 ± 0.28 mg/g (55.63± 0.21%), and 100.92 ± 0.34 mg/g (64.44±0.27%) for lightly infested, moderately infested and heavily infested leaf respectively (Table 56; Fig. 47 & 48) The differences in the mean values recorded for total phenol in uninfested and mite infested leaf samples when subjected to One way-ANOVA were found highly significant ($p<0.05$).

Table 56: Concentration (mg/g) and Percentage increase (%) of Total Phenol in *Merremia vitifolia* infested by *Phyllocoptruta merremiae* sp.nov.

SL.NO.	CONTROL	LIGHTLY INFESTED	PERCENTAGE INCREASE	MODERATELY INFESTED	PERCENTAGE INCREASE	HEAVILY INFESTED	PERCENTAGE INCREASE
1	36.08	51.24	29.58626	80.46	55.15784	101.01	64.28076
2	35.38	52.18	32.19624	81.21	56.43394	100.93	64.946
3	36.18	51.28	29.44618	80.32	54.95518	101.42	64.32656
4	36.32	52.04	30.20753	83.18	56.33566	101.97	64.38168
5	35.39	51.48	31.25486	80.87	56.23841	102.12	65.34469
6	36.81	52.73	30.19154	81.09	54.60599	98.94	62.79563
7	36.13	50.79	28.86395	80.52	55.12916	99.73	63.77218
8	36.17	51.23	29.39684	80.73	55.19633	99.83	63.76841
9	35.19	51.08	31.10807	80.13	56.08386	101.87	65.45597
10	35.15	50.93	30.9837	80.17	56.15567	101.39	65.33189
Mean	35.88	51.498*	30.323*	80.868*	55.629*	100.921*	64.440*
Standard deviation	0.561	0.620	1.041	0.891	0.680	1.077	0.852
Standard error mean	0.177	0.196	0.329	0.281	0.215	0.340	0.269

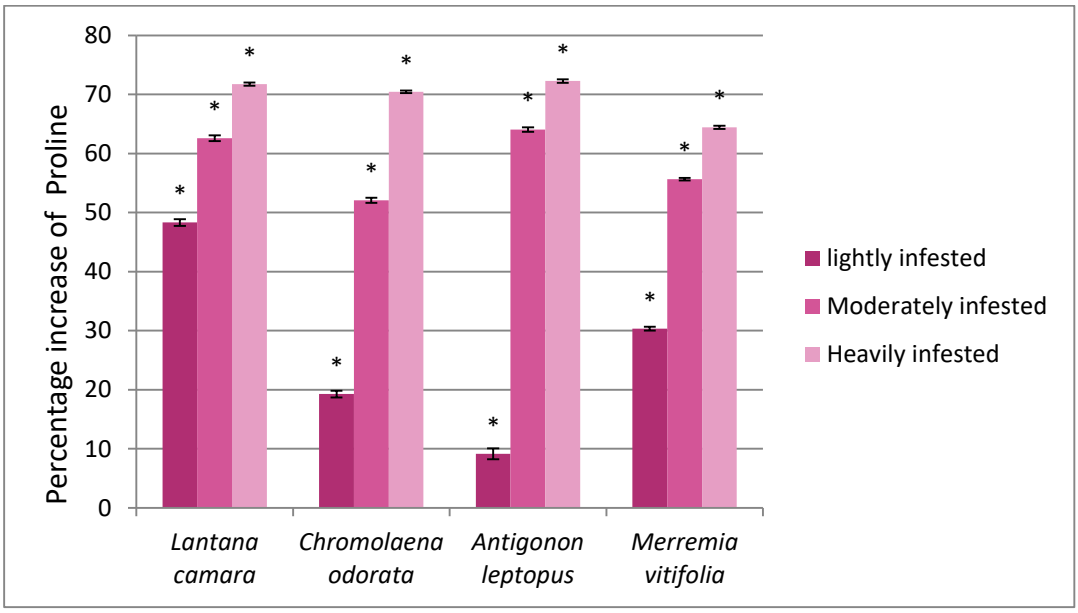
* - Statistically significant using one way – ANOVA with $P<0.05$

Fig. 47: Concentration of Total Phenol (mg/g) in selected species of invasive host plants studied



* - Statistically significant using one way – ANOVA with P<0.05

Fig. 48: Increase of Total Phenol (%) in selected species of invasive host plants due to feeding by eriophyid mites



* - Statistically significant using one way – ANOVA with P<0.05

viii) Estimation of Moisture content

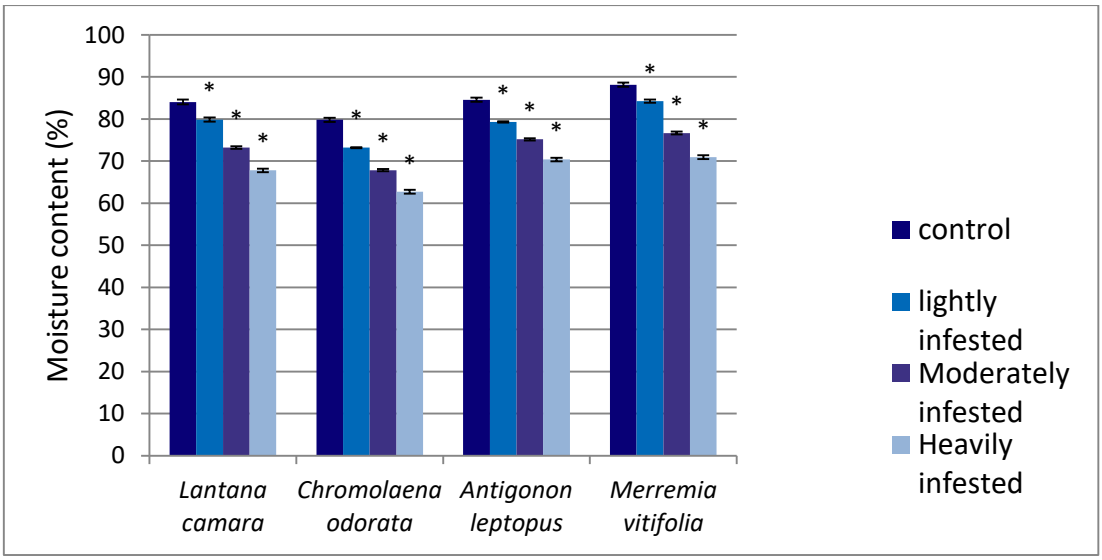
The moisture content of mite infested and uninfested leaves of *M.vitifolia* when estimated revealed reduced values in the case of mite infested samples. The mean moisture content recorded for uninfested leaf samples was 88.17 ± 0.48%. The mean moisture content recorded for lightly infested leaf sample was 84.28 ± 0.39% while that of moderately infested leaf sample was 76.69 ± 0.37 % and heavily infested sample was 70.96 ± 0.44% (Table 57; Fig. 49 & 50).The data when subjected to statistical analysis following One way-ANOVA were found highly significant ($p<0.05$).

Table 57: Amount of Moisture content (%) and Percentage reduction (%) in *Merremia vitifolia* infested by *Phyllocoptruta merremiae* sp.nov.

SL .NO.	CONTROL	LIGHTLY INFESTED	PERCENTAGE REDUCTION	MODERATELY INFESTED	PERCENTAGE REDUCTION	HEAVILY INFESTED	PERCENTAGE REDUCTION
1	89	86.02	3.348315	78.32	12	69.49	21.92135
2	88	84.14	4.386364	76.92	12.59091	71.22	19.06818
3	86	83.3	3.139535	76.42	11.13953	72.09	16.17442
4	89	84.08	5.52809	76.08	14.51685	72.25	18.82022
5	88	84.52	3.954545	75.76	13.90909	70.36	20.04545
6	89	83.61	6.05618	76.62	13.91011	70.34	20.96629
Mean	88.166	84.278*	4.402*	76.686*	13.011*	70.958*	19.499*
standard deviation	1.169	0.954	1.175	0.897	1.3102	1.087	2.000
standard error mean	0.477	0.389	0.479	0.366	0.534	0.443	0.816

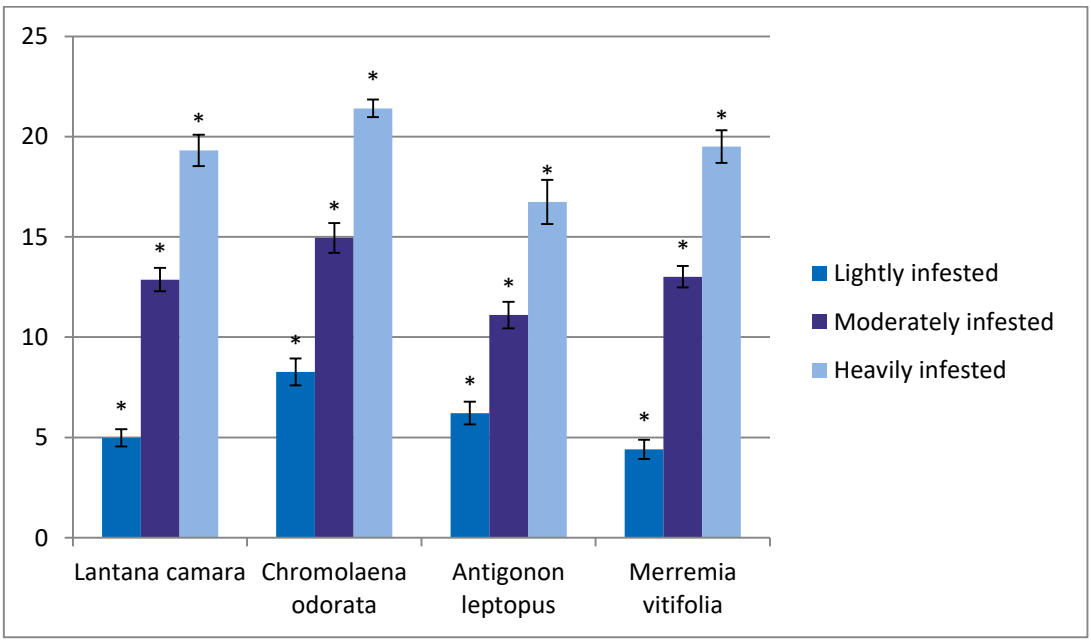
* - Statistically significant using one way – ANOVA with $P<0.05$

Fig. 49: Amount of Moisture content (%) in selected species of invasive host plants studied



* - Statistically significant using one way – ANOVA with P<0.05

Fig. 50: Reduction of Moisture content (%) in selected species of invasive host plants due to feeding by eriophyid mites



* - Statistically significant using one way – ANOVA with P<0.05

II) STUDIES ON POSTEMBRYONIC DEVELOPMENT OF SELECTED SPECIES OF ERIOPHYID MITES UNDER DIFFERENT TEMPERATURE-HUMIDITY COMBINATIONS

In the current study, attention was focused to trace the postembryonic development of the above mentioned four host specific species of eriophyid mites *viz. A. adoratus*, *E. camarae* sp.nov., *E. antigonus* sp. nov. and *P. merremiae* sp.nov. on their respective host plants *viz. C. odorata*, *L. camara*, *A. leptopus* and *M. vitifolia* in the laboratory, under four different sets of temperature- humidity combinations. The four sets of temperature - humidity combinations selected for biological studies were 20±2ºC and 90±5%RH, 25±2ºC and 80±5%RH, 30±2ºC and 70±5%RH and 35±2ºC and 60±5%RH. Data on the various developmental parameters such as pre-oviposition period, oviposition period, post-oviposition period, duration of development of the active and quiescent nymphal instars, total duration of development, adult longevity, fecundity etc. were recorded and were subjected to statistical analysis to know the level of significance. The details of biological observations of the four species under the various temperature-humidity combinations are discussed below:

1) Postembryonic development of *Acalitus adoratus* on *Chromolaena odorata*

The erineal patches of varying number and size developed on the leaf lamina of *C. odorata* were found to harbor dense populations of the erineum inducing species, *A. adoratus*. All stages of the mite were found dispersed among the thick, glandular erineal hairs. Resembling all other eriophyid mites studied so far, the life history of *A. adoratus* also was found to include various life stages such as the egg, first nymph, first quiescent instar, second nymph, second quiescent instar and the adult (male & female) stages.

Pre-oviposition period

The active adult females of *A. adoratus* were found to colonise the lower surface of the leaves of the noxious terrestrial weed, *C. odorata*, always seen in association with the erineal patches, showing specific preference to the newly formed erineal patches. The duration of pre-oviposion period of *A. adoratus* showed variation with respect to the variations in the temperature-humidity parameters selected for the conduct of biological studies. A decrease in the duration of pre-oviposition period was evident with an increase in temperature and decrease in relative humidity. The data recorded for the pre-oviposition period of the species were 5.09 ± 0.028 days at 20±2°C and 90±5%RH; 4.21±0.035 days at 25±2°C and 80±5%RH; 3.04±0.034 days at 30±2°C and70±5%RH and 3.82 ±0.029days at 35±2°C and 60±5%RH. The minimum duration for the pre-oviposition period was recorded at 30±2°C and70±5%RH (Table 58; Fig.51).

Oviposition period

Like the pre-oviposition period, the mean duration of oviposition period also was subjected to variation depending upon the variations in temperature humidity conditions. The oviposition periods recorded during the study were: 10.62±0.049 days at 20±2°C and 90±5%RH; 9.82±0.025 days at 25±2°C and 80±5%RH; 8.18±0.047 days at 30±2°C and 70±5%RH and 9 ±0.026 days at 35±2°C and 60±5%RH. The minimum duration was recorded for the oviposition period at temperature- humidity combination of 30±2°C and 70±5%RH and the maximum was recorded at 20±2°C and 90±5%RH (Table 58; Fig.51).

Post-oviposition period

During the post-oviposition period, the mites appeared sluggish with reduced feeding and their mobility was also found retarded. Later on the females became inactive. The mean durations of post-oviposition period recorded during the study were 3.99±0.028 days at 20±2°C and 90±5%RH; 3.27±0.037 days at 25±2°C and 80±5%RH; 3.29±0.035 days at 30±2°C and 70±5%RH and 3.59±0.066 days at 35±2°Cand 60±5%RH respectively. The minimum duration was observed at the temperature- humidity combination of 25±2°C and 80±5%RH while the maximum duration could be noted at 20±2°C and 90±5%RH (Table 58; Fig.51).

Adult Longevity

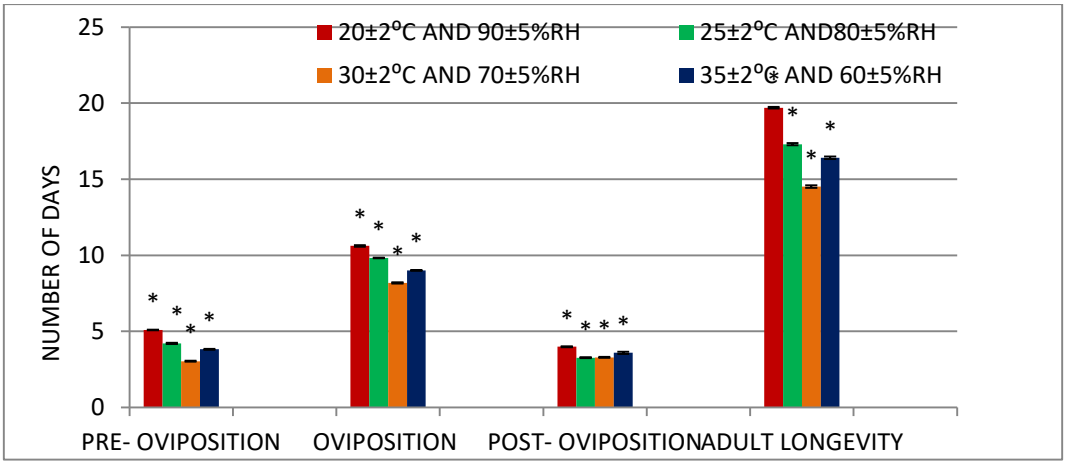
Adult longevity was also found influenced by the temperature-humidity variations. The minimum longevity was observed at 30±2°C and 70±5%RH, and the maximum could be recorded at 20±2°C and 90±5%RH. The adult longevity recorded at 20±2°C and 90±5%RH was 19.7±0.047days; at 25±2°C and 80±5%RH it was 17.3±0.068 days; at 30±2°C and 70±5%RH it was 14.51±0.082 days and at 35±2°Cand 60±5%RH, the longevity was recorded as 16.41±0.09 days (Table 58; Fig.51).

Table 58: Impact of selected Temperature –Humidity combinations on the duration of Pre- oviposition, Oviposition & Post- oviposition periods and Adult longevity in *Acalitus adoratus* on *Chromolaena odorata*

Developmental Period	Temperature and Relative Humidity combinations			
	20±2°C & 0±5%RH	**25±2°C &80±5%RH**	**30±2°C &70±5%RH**	**35±2°C & 60±5%RH**
Pre-Oviposition	5.09±0.03*	4.21±0.03*	3.04±0.03*	3.82±0.13*
Oviposition	10.62±0.05*	9.82±0.02*	8.18±0.05*	9±0.03*
Post- Oviposition	3.99±0.03*	3.27±0.03*	3.29±0.03*	3.59±0.06*
Adult Longevity	19.7±0.05*	17.3±0.06*	14.51±0.08*	16.41±0.14*

* - Statistically significant using one way – ANOVA with P<0.05

Fig. 51: Impact of different Temperature –Humidity conditions on the duration of Pre- oviposition, Oviposition & Post- oviposition periods and Adult longevity in *Acalitus adoratus* infesting on *Chromolaena odorata*



Oviposition and Fecundity

During the oviposition period, the gravid females initiated egg deposition by laying single eggs in the erineal patches, among the erineal hairs. The eggs were found firmly adhered to the base of the erineal hairs and placed very close to each other. Though the eggs were laid singly, the clumped erineal hairs and the very closely spaced eggs together imparted a more or less clustered appearance to the eggs. Freshly laid eggs were spherical, glistening, smooth and transparent .

The average number of eggs laid per female during her life span was also calculated at different temperature-humidity set ups during the study. The fecundity recorded was 15.4±0.635 at 20±2°C and 90±5%RH (Table 59); 20.3±0.803 at 25±2°C and 80±5%RH (Table 60); 23.5±1.014 at 30±2°C and 70±5%RH (Table 61) and 21.1±0.809 at 35±2°C and 60±5%RH (Table 62) respectively. The maximum fecundity was recorded at 30±2°C and 70±5%RH. The rate of oviposition was maximum on the 4th day of the oviposition period and the maximum number of eggs laid were found averaged to 6.4±0.221 at 30±2°C and 70±5%RH (Fig. 52).

Table 59: Fecundity of *Acalitus adoratus* on *Chromolaena odorata* at 20±2ºC and 90±5%RH

No .of eggs laid on different days of oviposition											
SL.NO.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Total no. of Eggs Laid**
1	1	1	2	4	3	2	1	1	0	1	16
2	1	1	2	3	2	2	2	0	1	1	15
3	1	0	2	3	4	1	2	1	0	1	15
4	1	1	2	4	2	2	0	1	1	1	15
5	1	1	2	4	3	2	2	1	0	1	17
6	1	0	1	3	2	0	2	0	1	1	11
7	1	1	2	4	3	2	1	1	0	1	16
8	1	1	2	4	3	2	3	1	1	1	19
9	1	1	2	3	2	2	2	0	1	1	15
10	1	0	1	3	3	2	2	2	0	1	15
Mean	1	0.7	1.8	3.5	2.7	1.7	1.7	0.8	0.5	1	15.4*
Standard Deviation	0	0.483	0.421	0.527	0.674	0.674	0.823	0.632	0.527	0	2.011
Standard Error Mean	0	0.152	0.133	0.166	0.213	0.213	0.260	0.2	0.166	0	0.635

* - Statistically significant using one way – ANOVA with P<0.05

Table 60: Fecundity of *Acalitus adoratus* on *Chromolaena odorata* at 25±2ºC and 80±5%RH

No. of eggs laid on different days of oviposition										
SL.NO.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**Total no.of Eggs Laid**
1	1	2	2	4	3	3	2	1	1	19
2	1	2	2	4	3	3	3	1	1	20
3	2	2	2	5	3	3	2	1	1	21
4	1	2	4	6	4	3	2	1	1	24
5	1	2	3	4	3	2	2	1	1	19
6	1	1	2	3	3	2	3	1	1	17
7	1	2	3	4	3	3	2	2	1	21
8	2	2	3	5	5	3	3	1	1	25
9	1	1	2	3	4	3	2	1	1	18
10	1	2	2	4	3	3	2	1	1	19
Mean	1.2	1.8	2.5	4.2	3.4	2.8	2.3	1.1	1	20.3*
Standard Deviation	0.421	0.421	0.707	0.918	0.699	0.421	0.483	0.316	0	2.540
Standard Error Mean	0.133	0.133	0.223	0.290	0.221	0.133	0.152	0.1	0	0.803

* - Statistically significant using one way – ANOVA with P<0.05

Table 61: Fecundity of *Acalitus adoratus* on *Chromolaena odorata* at 30±2ºC and 70±5%RH

No. of eggs laid on different days of oviposition									
SL.NO.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**Total no. of Eggs Laid**
1	1	3	3	7	5	3	2	1	25
2	1	3	3	7	4	2	1	1	22
3	1	2	5	6	5	3	2	2	26
4	2	3	4	5	4	3	1	1	23
5	1	1	5	7	5	4	2	1	26
6	1	2	4	6	4	2	2	1	22
7	2	1	3	6	3	2	0	1	18
8	1	2	4	7	5	5	3	2	29
9	1	2	3	6	3	3	1	1	20
10	1	2	2	7	5	4	2	1	24
Mean	1.2	2.1	3.6	6.4	4.3	3.1	1.6	1.2	23.5*
Standard Deviation	0.421637	0.737865	0.966092	0.699206	0.823273	0.994429	0.843274	0.421637	3.205897
Standard Error Mean	0.133333	0.233333	0.305505	0.221108	0.260342	0.314466	0.266667	0.133333	1.013794

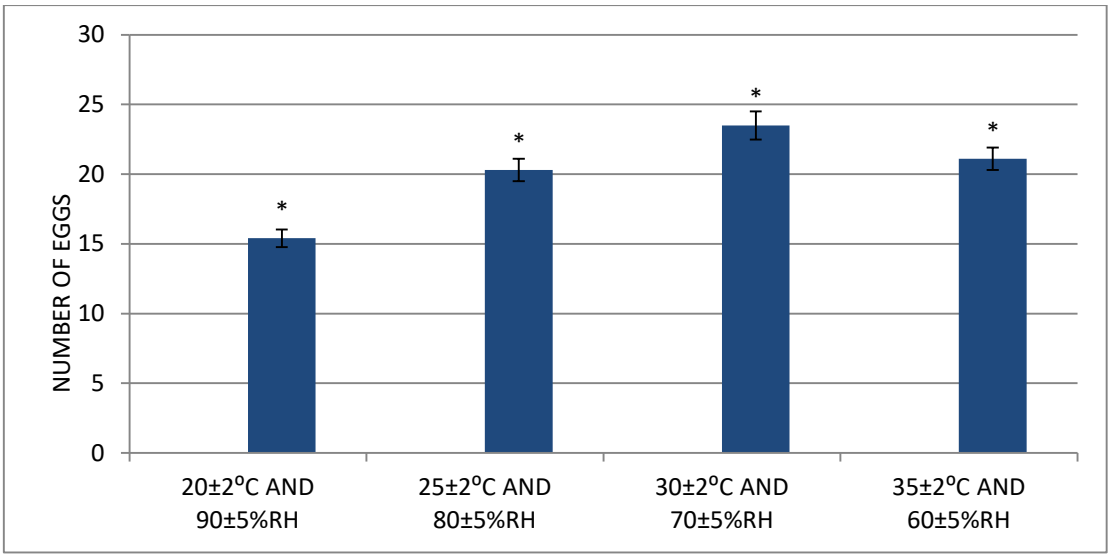
* - Statistically significant using one way – ANOVA with P<0.05

Table 62: Fecundity of *Acalitus adoratus* on *Chromolaena odorata* at 35±2ºC and 60±5%RH

No. of eggs laid on different days of oviposition										
SL.NO.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**Total no. of Eggs Laid**
1	1	2	2	4	3	3	2	1	0	18
2	1	2	2	4	5	3	3	1	0	21
3	2	2	2	5	4	3	2	1	1	22
4	1	2	4	6	4	3	2	1	1	24
5	1	2	3	4	4	4	2	2	0	22
6	1	3	2	3	3	2	3	2	1	20
7	1	2	3	4	3	3	2	2	1	21
8	2	3	3	5	5	3	3	1	1	26
9	1	1	2	3	4	3	2	1	1	18
10	1	2	2	4	3	3	2	1	1	19
Mean	1.2	2.1	2.5	4.2	3.8	3	2.3	1.3	0.7	21.1*
Standard Deviation	0.421	0.567	0.707	0.918	0.788	0.471	0.483	0.483	0.483	2.558
Standard Error Mean	0.133	0.179	0.223	0.290	0.249	0.149	0.152	0.152	0.152	0.808

* - Statistically significant using one way – ANOVA with P<0.05

Fig.52: Number of eggs laid by *Acalitus adoratus on Chromolaena odorata* at different temperature- humidity conditions



* - Statistically significant using one way – ANOVA with P<0.05

Duration of developmental stages

Incubation period

The incubation period also showed slight variation with respect to the variations in the temperature-humidity conditions. The incubation period was found averaged to 5.25±0.0401 days at 20±2°C and 90±5%RH; 4.54±0.081 days at 25±2°C and 80±5%RH; 3.82±0.025 days at 30±2°C and 70±5%RH and 4.47 ±0.058 days at 35±2°C and 60±5%RH. The maximum duration for the incubation period could be recorded at a temperature- humidity combination of 20±2°Cand 90±5%RH and the minimum was recorded at 30±2°C and 70±5%RH (Table 63; Fig. 53).

Hatching

Prior to hatching, the egg became highly transparent and its shape also was found altered. A conical protrusion appeared on the egg surface and a

longitudinal slit appeared at the protruded end. The slit got widened gradually and through which the legs of the first nymph were ptotruded. The process of hatching was found completed within 20-25 minutes.

First nymph

The first nymph appeared very minute, sluggish, transparent and slow moving. Immediately after emergence from the egg case, the first nymph appeared highly sensitive and could not withstand when exposed to the light at the time of microscopic observation. Slowly, it initiated feeding activity by sucking the plant sap. The duration the first nymphal period lasted for 3.41±0.069 days at 20±2°C and 90±5%RH; 3.21±0.048 days at 25±2°C and 80±5%RH; 2.88±0.033 days at 30±2°C and 70±5%RH and 3.29±0.052 days at 35±2°C and 60±5%RH (Table 63; Fig. 53). The first nymph after its active feeding period became sluggish, swollen and ceased feeding activity and entered into an inactive / quiescent phase of short duration.

First quiescent phase

The first quiescent stage or nymphochrysalis, was recognized as an inactive period between the first and second nymphal stages and which lasted for a very short period. The first quiescent phase recorded during the study at 20±2°C and 90±5%RH was 2.51 ±0.050 days; 2.2±0.059 days at 25±2°C and 80±5%RH; 1.85±0.017 days at 30±2°C and 70±5%RH and 2.39±0.035 days at 35±2°C and 60±5%RH (Table 63; Fig.53). The period of quiescence was minimum at 30±2°C and 70±5%RH. At the end of the first quiescent phase, the process of moulting took place and the second nymphal stage emerged out.

Second nymph

The second nymph was larger than the preceding stage and moved faster. It fed actively by sucking the plant sap, with in the erineal patch. The duration of the second nymph was recorded as 4.59±0.067 days at 20±2°C and 90±5%RH; 4.3±0.063 days at 25±2°C and 80±5%RH; 3.73±0.377 days at 30±2°C and 70±5%RH and 4.34±0.054 days at 35±2°C and 60±5%RH (Table 63; Fig. 53). At the end of the active feeding period, the second nymph became lethargic, its body became swollen and it entered into an inactive/quiescent phase.

Second quiescent phase

The second quiescent phase was also known as the imagochrysalis stage and the duration of which showed slight variation, depending upon the variations in temperature-humidity conditions. The duration of second quiescent phase recorded during the study was 2.54 ± 0.016 days at 20±2°C and 90±5%RH; 2.3± 0.087 days at 25±2°C and 80±5%RH; 1.73 ± 0.03 days at 30±2°C and 70±5%RH and 2.5 ± 0.033 days at 35±2°C and 60±5%RH (Table 63; Fig. 53). Finally it got moulted in to a very active adult.

Moulting

Moulting, the process of shedding the exuviae of the preceding instar was observed twice in the development of *A. adoratus*, the first moulting occurred between the first and second nymphal stages and the second between the second nymph and adult stages. During moulting, a clear, transparent skin was shed out from the quiescent instar and the newly emerged instar became active as and when it became free from the exuviae. The process of moulting lasted for 20-30 minutes and it was not affected much by the variations in temperature-humidity conditions.

Adult

The adult mites were comparatively larger than the second nymphal stage and appeared more active, fast moving and exhibited voracious feeding on the plant sap, within the erineal patch. With the increase in population density, many mites were found wandering outside the erineal patches also . The adult females were larger than the males.

Total duration of development

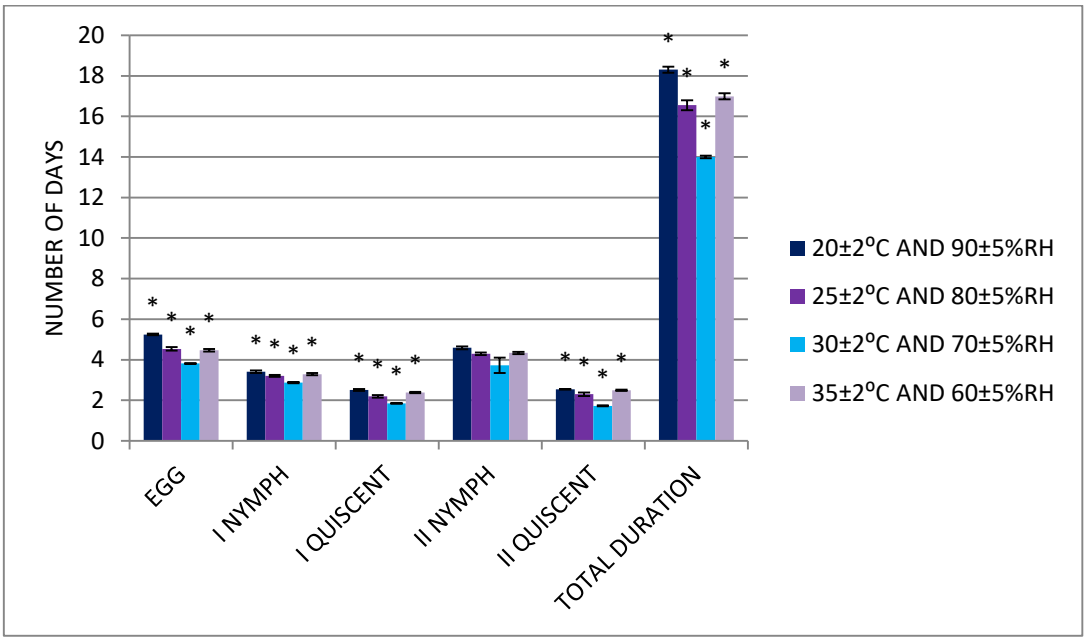
In *A. adoratus*, the development from egg to adult was found to complete within 18.3±0.153 days at 20±2°C and 90±5%RH; 16.55±0.248 days at 25±2°C and 80±5%RH; 14±0.058 days at 30±2°C and 70±5%RH and 16.99 ±0.144 days at 35±2°C and 60±5%RH. The minimum time taken for the completion of life cycle was recorded at 30±2°C and 70±5%RH and maximum was at 20±2°C and 90±5%RH (Table 63; Fig. 53).

Table 63: Impact of selected Temperature – Humidity combinations on the duration (in days) of life stages of *Acalitus adoratus* on *Chromolaena odorata*

Developmental stages	Temperature and Relative Humidity combinations			
	20±2°C & 90±5%RH	**25±2°C &80±5%RH**	**30±2°C & 70±5%RH**	**35±2°C &60±5%RH**
Egg	5.25±0.4*	4.54±0.08*	3.82±0.02*	4.47±0.06*
I Nymph	3.41±0.07*	3.21±0.05*	2.88±0.03*	3.29±0.05*
I Quiscent	2.51±0.05*	2.2±0.06*	1.85±0.02*	2.39±0.03*
II Nymph	4.59±0.07	4.3±0.06	3.73±0.38	4.34±0.05
II Quiscent	2.54±0.02*	2.3±0.09*	1.73±0.03*	2.5±0.03*
Total Duration	18.3±0.15*	16.55±0.25*	14±0.06*	16.99±0.14*

* - Statistically significant using one way – ANOVA with P<0.05

Fig. 53: Impact of different Temperature –Humidity conditions on the duration of life stages (in days) of *Acalitus adoratus on Chromolaena odorata*



* - Statistically significant using one way – ANOVA with P<0.05

Morphological description of life stages of *A. adoratus* (Table 64)

Egg

Diameter: 35.4±0.702 µm

The eggs appeared spherical, transparent, smooth and shiny. At the end of incubation period, just prior to hatching it became more transparent.

First nymph (Plate 22, Fig. a – g)

Length: 71.5±0.341µm

Width: 29.4±0.653 µm

Dorsal region: Gnathosoma 12.6 µm long and 11µm wide, rostrum facing downwards . Prodorsal shield without median lines, and with 4-5 minute

broken lines. Prodorsal setal tubercles set near rear margin, the scapular setae directed backward, 5.3 µm long. Opisthosoma vermiform, and with 39 Nos. of closely arranged dorsal annuli. Each annulus bears an average number of 9 very small microtubercles.

Ventral region: Ventral annuli 47 in number, each annulus bearing an average number of 9 very minute microtubercles. Genital cover flap absent, genital setae 2.5µm long. Lateral setae 9µm long and set on ring 4 , Ist ventral setae 16 µm long, set on 12th annulus, IInd ventral setae 7.6µm long on ring 25, IIIrd ventral setae 3 µm long, set on 5th ring from the rear, caudal setae 19µm long and accessory setae not present. Coxae smooth, I, II, III being 1.4, 8 and 13µm in length respectively. Forelegs 19 µm long and hindlegs 16µm long. Feather claw 3.2 µm long and 4 rayed.

Second nymph (Plate 23, Fig. a – g)

Length: 121.5±0.5µm

Width: 33.2±0.533µm

Dorsal region: Gnathosoma 19.2 µm long and 17. 7µm wide, rostrum facing downwards. Prodorsal shield with incomplete median lines, not connected each other. Prodorsal setal tubercles set near rear margin, the scapular setae directed backward, 11.5µm long. Opisthosoma vermiform with 71 closely arranged dorsal annuli , each bearing an average number of 13 small, round micro-tubercles.

Ventral region: The number of ventral annuli being 86 and each annulus carries an average number of 13 small, round microtubercles. Genital cover flap absent, genital setae 11.3 µm long. Lateral setae 12. 8µm long and inserted on 4th ring, Ist ventral setae 22 µm long, set on ring 17; IInd ventral setae 12.6µm long, set on ring 37; IIIrd ventral setae 9.7 µm long and inserted on77 th ring, caudal setae 29.7µm long, telosome with very minute accessory

setae. Coxa smooth, coxal setae I, II& III 3.6, 15.4 and 23.3µm long respectively. Forelegs 24.9 µm long and hindlegs 20.5µm long. Feather claw 3.2 µm long and 4 rayed.

Adult female (Plate 24, Fig. a – g)

Length: 186.1±0.795µm

Width: 44.4±0. 921 µm

Dorsal region: Gnathosoma 24 µm long and 20 µm wide, rostrum facing downwards. Prodorsal shield with a medium sized frontal lobe. Prodorsal shield bears short median line, long admedian and submedian lines connected together. Prodorsal setal tubercles set near rear margin, the scapular setae directed backward, 15.3 µm long and set 16 µm apart from each other. Opisthosoma vermiform, with 93 closely arranged dorsal annuli, each annulus with an average of 16 numbers of small, round micro-tubercles.

Ventral region: Ventral annuli 106 in number, each with an average number of 12 small microtubercles. Genital coverflap 16.5 µm long and 20µm wide, granulated anteriorly with 10 posterior longitudinal ribs. Genital setae 1 pair, 12 µm, set 14 µm apart. Lateral setae 16 µm long, set on ring 8; I^{st} ventral setae 26.1 µm long, set on ring 27, II^{nd} ventral setae 16.3 µm long, inserted on on ring 38, III^{rd} ventral setae 13.1 µm long and inserted on ring 98; caudal setae 36 µm long . Telosome with minute accessory setae. Coxae smooth, coxal setae I, II & III being 5.9, 18 and 28µm long respectively. Forelegs 29 µm long and hindlegs 26.4 µm long. Feather claw 6.3µm long and 4 rayed.

Adult male

Length: 162.7±1.044µm

Width: 38.2±0.8 µm

Males were smaller when compared to the females and showed great morphological similarity with females except in the nature of genitalia. Genitalia 12 long, 15 wide, eugenital setae 14 long and 12 apart.

Table 64: Measurements of life stages of *Acalitus adoratus*

Life stages									
Sl. No.	**Egg**	**I nymph**		**II nymph**		**Adult female**		**Adult male**	
	Diameter	legth	width	legth	width	legth	width	legth	Width
1	33	71	26	121	34	186	44	163	38
2	35	73	30	123	32	189	48	167	35
3	33	71	31	119	31	186	49	163	41
4	39	70	26	123	33	183	41	167	36
5	39	71	29	121	36	184	42	166	35
6	36	73	31	123	34	183	42	157	37
7	35	71	29	121	31	188	44	162	41
8	36	71	29	123	35	189	48	159	38
9	35	71	32	119	32	184	42	162	42
10	33	73	31	122	34	189	44	161	39
Mean	35.4	71.5	29.4	121.5	33.2	186.1	44.4	162.7	38.2
Standard Deviation	2.221	1.080	2.065	1.581	1.686	2.514	2.913	3.301	2.529
Standard Error mean	0.702	0.341	0.653	0.5	0.533	0.795	0.921	1.044	0.8

2) Postembryonic development of *Eriophyes camarae* sp.nov. on *Lantana camara*

Both in the field and laboratory conditions, infestation by *E. camarae* sp. nov. was found confined to the lower surface of the leaves of the invasive host weed, *L. camara*. The species appeared as a leaf vagrant, inducing feeding symptoms like the development of stiplings, bronziness and quite often yellowing of leaves and ultimately leading to leaf drop, during heavy infestation. In the present study, postembryonic development of the species was traced in the laboratory under four sets of temperature- humidity conditions like 20±2°C and 90±5%RH; 25±2°C and 80±5%RH; 30±2°C and

70±5%RH and 35±2°C and 60±5%RH. Details of the results of the studies are described below:

Pre-oviposition period

Duration of the pre-oviposition period of the females of *E. camarae* sp.nov. showed variation in accordance with the variations in the temperature-humidity conditions under which the biological observations were made. As recorded during the study, the mean duration of pre-oviposition period was 4.57 ± 0.1001 days at 20±2°C and 90±5%RH; 3.26±0.034 days at 25±2°C and 80±5%RH; 2.44±0.081 days at 30±2°C and 70±5%RH and 3.33 ± 0.104 days at 35±2°C and 60±5%RH. Thus the minimum duration for pre-oviposition period was recorded at 30±2°C and70±5% RH and the maximum duration was recorded at 20±2°C and 90±5%RH (Table 65; Fig. 54).

Oviposition period

The gravid females laid eggs singly on the abaxial surface of the host plant, near the leaf veins, adjacent to the midrib. The mean durations of oviposition period recorded during the study were 9.56± 0.194 days at 20±2°C and 90±5%RH; 7.75±0.076 days at 25±2°C and 80±5%RH; 6.87±0.056 days at 30±2°C and 70±5%RH and 8.61±0.086 days at 35±2°C and 60±5%RH. The minimum duration of oviposition period was observed at 30±2°C and 70±5%RH and the maximum was at 20±2°C and 90±5%RH (Table 65; Fig. 54).

Post-oviposition period

Post-oviposition period of *E. camarae* sp.nov. also showed variation depending upon the variations in the temperature-humidity combinations at which the biological studies were carried out. During the post-oviposition period, the mites became lethargic, and passive feeders and as the days

progressed, cessation of feeding and movement was observed and later on the mites were found dead. The mean durations of post-oviposition period recorded were 3.68 ± 0.057 days at 20±2°C and 90±5%RH; 3.17 ± 0.026 days at 25±2°C and 80±5%RH; 2.65 ± 0.052 days at 30±2°C and 70±5%RH and 3.12±0.044 days at 35±2°C and 60±5%RH respectively. The minimum duration for post-oviposition period was recorded at 30±2°C and 70±5%RH (Table 65; Fig. 54).

Adult Longevity

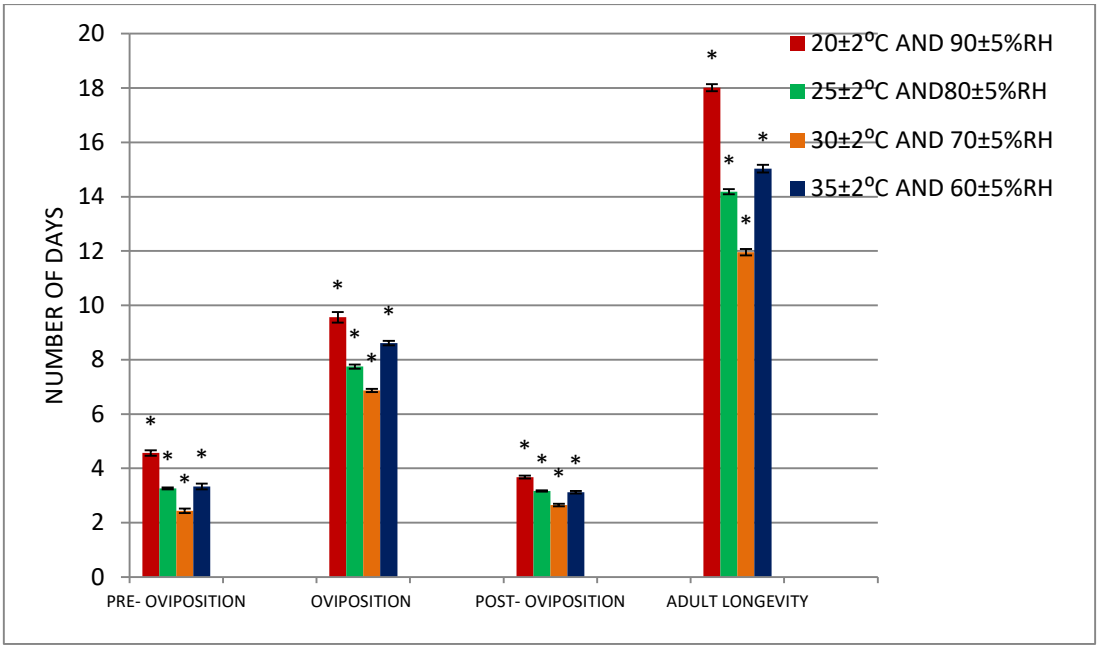
The maximum duration of longevity was recorded at 20±2°C and 90±5%RH and minimum was observed at 30±2°C and 70±5%RH. The data obtained for longevity of adults under different temperature- humidity conditions were 18.01 ±0.126 days at 20±2°C and 90±5%RH; 14.18±0.096 days at 25±2°C and 80±5%RH; 11.96± 0.118 days at 30±2°C and 70±5%RH and 15.03±0.141 days and at 35±2°Cand 60±5%RH it was 16.41±0.09 days (Table 65; Fig. 54).

Table 65: Impact of selected Temperature –Humidity combinations on the duration of Pre- oviposition, Oviposition &Post- oviposition periods and Adult longevity in *Eriophyes camarae* sp.nov. infesting on *Lantana camara*

Developmental Period	Temperature and Relative Humidity combinations			
	20±2°C &90±5%RH	**25±2°C &80±5%RH**	**30±2°C & 70±5%RH**	**35±2°C &60±5%RH**
Pre-Oviposition	4.57±0.1*	3.26±0.03*	2.44±0.08*	3.33±0.10*
Oviposition	9.76±0.19*	7.75±0.07*	6.87±0.06*	8.61±0.08*
Post-Oviposition	3.68±0.06*	3.17±0.03*	2.65±0.05*	3.12±0.04*
Adult Longevity	18.01±0.13*	14.18±0.09*	11.96±0.12*	15.03±0.14*

* - Statistically significant using one way – ANOVA with P<0.05

Fig. 54: Impact of different Temperature –Humidity conditions on the duration of Pre- oviposition, Oviposition &Post- oviposition periods and Adult longevity in *Eriophyes camarae* sp.nov. infesting on *Lantana camara*



* - Statistically significant using one way – ANOVA with P<0.05

Oviposition and Fecundity

The gravid females were found laying solitary eggs, on the lower surface of host leaves, mostly adjacent to the veins. Freshly laid eggs were spherical and transparent. The eggs appeared glistening and with smooth surface. The rate of oviposition was found influenced by the temperature-humidity conditions. The mean number of eggs laid per female during her life time was recorded as 17.5±0.734 at 20±2°C and 90±5%RH (Table 66); 18.2±0.533 at 25±2°C and 80±5%RH (Table 67); 19.3±0.817 at 30±2°C and 70±5%RH (Table 66) and 18.8±0.827 at 35±2°Cand 60±5%RH (Table 69) respectively. The maximum number of eggs laid per female was at 30±2°C and 70±5%RH. The maximum number of eggs laid by the female was on the 4th day of oviposition and the mean number of eggs laid was 5.1±0.378 at 30±2°C and 70±5%RH (Fig. 65).

Table 66: Fecundity of *Eriophyes camarae* sp.nov. on *Lantana camara* at 20±2°C and 90±5%RH

No. of eggs laid on different days of oviposition											
SL.NO.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Total no. of Eggs Laid**
1	1	2	2	4	3	2	2	1	1	0	18
2	1	1	2	3	3	3	2	0	1	0	16
3	1	2	2	3	4	2	2	1	1	0	18
4	1	1	2	4	2	3	2	1	1	1	18
5	1	1	3	4	3	2	2	2	1	0	19
6	1	1	2	3	2	0	2	0	1	0	12
7	1	1	2	4	3	3	1	2	1	0	18
8	1	2	3	4	3	3	3	1	1	0	21
9	1	1	2	3	4	2	2	0	1	1	17
10	1	0	2	4	3	3	2	2	1	0	18
Mean	1	1.2	2.2	3.6	3	2.3	2	1	1	0.2	17.5*
Standard Deviation	0	0.632	0.421	0.516	0.666	0.948	0.471	0.816	0	0.421	2.321
Standard Error Mean	0	0.2	0.133	0.163	0.210	0.3	0.149	0.258	0	0.133	0.734

* - Statistically significant using one way – ANOVA with P<0.05

Table 67: Fecundity of *Eriophyes camarae* sp.nov. on *Lantana camara* at 25±2°C and 80±5%RH

No. of eggs laid on different days of oviposition									
SL.NO.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**Total no. of Eggs Laid**
1	1	2	3	4	3	3	2	1	19
2	1	1	2	5	4	2	1	0	16
3	1	2	2	3	4	3	2	1	18
4	1	1	2	5	4	3	1	0	17
5	1	1	3	4	3	4	2	0	18
6	1	2	4	5	3	2	2	0	19
7	2	1	3	5	3	2	1	0	17
8	1	2	4	4	4	3	3	1	22
9	1	1	3	5	3	3	1	0	17
10	1	2	2	4	4	4	2	0	19
Mean	1.1	1.5	2.8	4.4	3.5	2.9	1.7	0.3	18.2*
Standard Deviation	0.316	0.527	0.788	0.699	0.527	0.737	0.674	0.483	1.686
Standard Error Mean	0.1	0.166	0.249	0.221	0.166	0.233	0.213	0.152	0.533

* - Statistically significant using one way – ANOVA with $P<0.05$

Table 68: Fecundity of *E riophyes camarae* sp.nov. on *Lantana camara* at 30±2°C and 70±5%RH

No. of eggs laid on different days of oviposition								
SL.NO.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Total no. of Eggs Laid**
1	1	2	2	6	3	1	0	15
2	2	3	3	5	4	3	2	22
3	1	2	4	6	4	3	1	21
4	1	3	4	5	4	2	0	19
5	2	3	3	6	4	3	0	21
6	1	2	2	4	4	2	1	16
7	2	3	4	4	3	3	1	20
8	1	2	3	5	4	3	0	18
9	1	3	4	3	4	3	0	18
10	2	2	3	7	5	4	0	23
Mean	1.4	2.5	3.2	5.1	3.9	2.7	0.5	19.3*
Standard deviation	0.516	0.527	0.788	1.197	0.567	0.823	0.707	2.584
Standard error mean	0.163	0.166	0.249	0.378	0.179	0.260	0.223	0.817

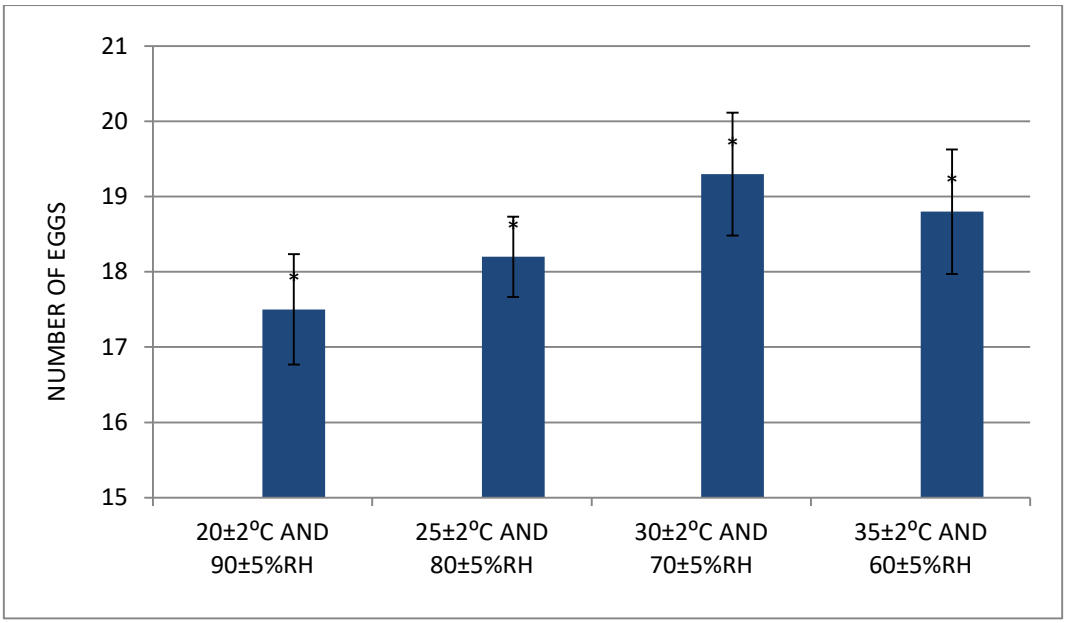
* - Statistically significant using one way – ANOVA with $P<0.05$

Table 69: Fecundity of *E riophyes camarae* sp.nov. on *Lantana camara* at 35±2°C and 60±5%RH

No. of eggs laid on different days of oviposition										
SL.NO.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**Total no. of Eggs Laid**
1	1	2	2	4	3	3	2	2	0	19
2	1	2	1	3	3	2	3	1	0	16
3	2	2	2	5	4	2	2	1	0	20
4	1	1	2	3	4	3	2	1	1	18
5	1	2	3	4	3	4	2	2	0	21
6	1	2	2	3	3	2	3	1	0	17
7	1	2	3	4	3	3	2	2	0	20
8	1	3	3	5	5	3	3	1	0	24
9	1	1	2	3	2	3	2	1	0	15
10	1	2	2	4	3	3	2	1	0	18
Mean	1.1	1.9	2.2	3.8	3.3	2.8	2.3	1.3	0.1	18.8*
Standard Seviation	0.316	0.567	0.632	0.788	0.823	0.632	0.483	0.483	0.316	2.616
Standard Error Mean	0.1	0.179	0.2	0.249	0.260	0.2	0.152	0.152	0.1	0.827

* - Statistically significant using one way – ANOVA with $P<0.05$

Fig. 55: Number of eggs laid by *Eriophyes camarae* sp. nov. on *Lantana camara* at different temperature- humidity conditions



* - Statistically significant using one way – ANOVA with P<0.05

Duration of developmental stages

Incubation period

The mean durations of incubation period were 5.69±0.121 days at 20±2°Cand 90±5%RH; 5.25 ± 0.060 days at 25±2°C and 80±5%RH; 4.13 ±0.03 days at 30±2°C and 70±5%RH and 4.78 ± 0.033 days at 35±2°C and 60±5%RH. The selected combination of temperature- humidity condition of 20±2°Cand 90±5%RH was found extending the incubation period whereas it was of minimum duration at 30±2°C and 70±5%RH (Table 70; Fig. 56).

Hatching

Prior to hatching, eggs became more rigid and transparent. The shape also got changed due to the development of a cone like projection on the egg surface. The commencement of hatching process was marked by the formation of a longitudinal slit on the egg surface at the protruded end and

which got widened gradually and through which the legs and gnathosoma of the emerging nymph protruded out. Hatching process completed within 20-25 minutes.

First nymph

The newly emerged first nymph was very minute, transparent to white in colour and slow moving. It slowly started active movement and wandered on the leaf surface and initiated feeding activity. The first nymph was found highly sensitive to the exposure of light during microscopic observation for a long duration. Depending upon the variations in the temperature and humidity conditions, the active period of the first nymph also got varied and the results of the present study revealed the duration of first nymphal period as 2.78 ± 0.068 days at 20±2°C and 90±5%RH; 2.5±0 days at 25±2°C and 80±5%RH; 2.03±0.015 days at 30±2°C and 70±5%RH and 2.3±0.039 days at 35±2°C and 60±5%RH (Table 70; Fig. 56). After the active feeding period, the first nymph ceased its feeding activity, became sluggish and subsequently immobile with swollen body and entered into an inactive period, the so called first quiescent phase or the nymphochrysalis stage.

First quiescent phase

The nymphochrysalis stage lasted only for a very short period and its duration was found subjected to variations depending upon the temperature-humidity conditions. The durations of first quiescent phase in *E. camarae* sp. nov. recorded at 20±2°C and 90±5%RH were 1.06± 0.027 days; 1±0 days at 25±2°C and 80±5%RH; 0.81±0.018 days at 30±2°C and 70±5%RH and 0.87±0.021days at 35±2°C and 60±5%RH (Table 70; Fig.56). The minimum duration of less than a day was recorded at 30±2°C and 70±5%RH and the maximum was observed at 20±2°C and 90±5%RH. The end of the first

quiescent phase was marked by the moulting process, leading to the emergence of the second nymph.

Second nymph

The second nymph was larger and fast moving active feeder when compared to the first nymph. The duration of active period of the second nymph could be recorded as 4.38±0.139 days at 20±2°C and 90±5%RH; 4± 0.015 days at 25±2°C and 80±5%RH; 3.53± 0.015 days at 30±2°C and 70±5%RH and 3.86 ± 0.022 days at 35±2°C and 60±5%RH (Table 70; Fig. 56) and subsequently it entered into the second quiescent phase or the imagochrysalis stage.

Second quiescent phase

The mean duration of the imagochrysalis stage lasted for 1.61 ± 0.031 days at 20±2°C and 90±5%RH; 1.52 ± 0.013 days at 25±2°C and 80±5%RH; 1.23 ± 0.015 days at 30±2°C and 70±5%RH and 1.44 ± 0.022 days at 35±2°C and 60±5%RH (Table 70; Fig. 56). The end of the imagochrysalis stage was marked by moulting, resulting in the emergence of the adult mite.

Moulting

Moulting was observed after each quiescent phase and during moulting, a clear transparent skin was found shed out from the quiescent stage and the newly emerged instar became active within a short time. The moulting process was found to last for 15-20 minutes and it was not influenced by the differences in the temperature-humidity conditions as observed during the study.

Adult

The adult mite was larger than the nymphal stages and was pale yellow coloured, fast moving and voraciously feeding on the lower leaf surface of the

host plant. The female was broader and larger than the male and showed infestation on the lower surface of the leaves of *L. camara*. However, when the population got increased, the species extended its distribution to the upper surface of the leaves also, thereby infesting on both surfaces of the host leaves.

Total duration of development

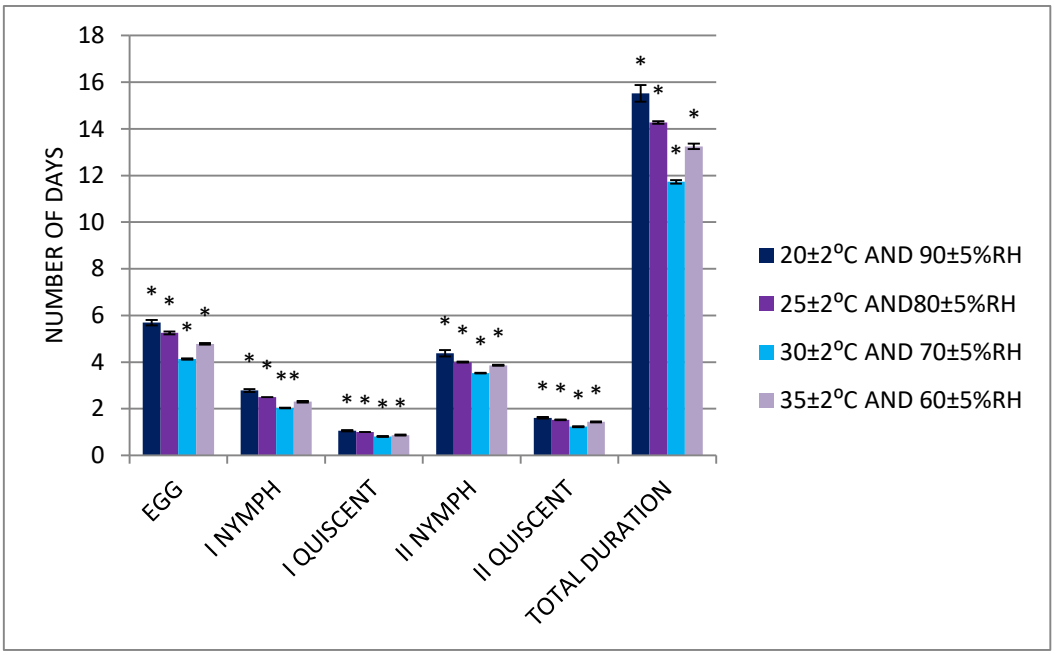
The total duration of development of *E. camarae* sp.nov. from egg to the adult stage was found to complete within 15.52±0.353 days at 20±2°C and 90±5%RH; 14.27±0.058days at 25±2°C and 80±5%RH; 11.73±0.071days at 30±2°C and 70±5%RH and 13.25±0.122 days at 35±2°C and 60±5%RH. Thus, postembryonic development of *E. camarae* sp.nov. was found completed with a minimum duration of 11.73±0.071days at 30±2°C and 70±5%RH on the leaves of its host plant, *L.camara.* An extended duration of 15.52±0.353 days was recorded during the study at 20±2°C and 90±5%RH (Table 70; Fig. 56).

Table 70: Impact of selected Temperature – Humidity combinations on the duration of life stages (in days) of *Eriophyes camarae* sp.nov. on *Lantana camara*

Developmental Periods	Temperature and Relative Humidity combinations			
	20±2°C & 90±5%RH	**25±2°C &80±5%RH**	**30±2°C &70±5%RH**	**35±2°C &60±5%RH**
Egg	5.69 ±0.12*	5.25±0.06*	4.13±0.03*	4.78±0.03*
I Nymph	2.78±0.07*	2.5±0*	2.03±0.01*	2.3±0.04*
I Quiscent	1.06±0.03*	1±0*	0.81±0.02*	0.87±0.02*
II Nymph	4.38±0.14*	4±0.01*	3.53±0.02*	3.86±0.02*
II Quiscent	1.61±0.03*	1.52±0.01*	1.23±0.01*	1.44±0.02*
Total Duration	15.52±0.35*	14.27±0.06*	11.73±0.07*	13.25±0.12*

* - Statistically significant using one way – ANOVA with P<0.05

Fig. 56: Impact of different Temperature –Humidity conditions on the duration of life stages (in days) of *Eriophyes camarae* sp.nov. on *Lantana camara*



* - Statistically significant using one way – ANOVA with P<0.05

Morphological description of life stages of *Eriophyes camarae* sp.nov. (Table 71)

Egg

Diameter: 40.3±0.538µm

Freshly laid eggs of *E. camarae* sp.nov. appeared spherical, transparent, smooth and shiny. Just prior to hatching, the eggs became more transparent and on cleavage pattern was clearly visible when the slide mounted eggs were examined under a research microscope.

First nymph (Plate 25, Fig. a – g)

Length: 74.5±0.833µm

Width: 35 ± 0.889µm

Dorsal region: Gnathosoma 11.2 µm long and 9.5µm wide, rostrum facing downwards. Prodorsal shield without median lines, but with granules. Prodorsal setal tubercles set near rear margin, the scapular setae 4.5µm long and directed forward. Opisthosoma vermiform with 49 numbers of closely set dorsal annuli, each annulus with an average number of 10 small, round microtubercles.

Ventral region: Ventral annuli 53 in number, each of which bears an average number of 10 minute microtubercles. Genital cover flap absent, genital setae being 4.1µm long. Lateral setae 8.9µm long and inserted on 7th ring ; Ist ventral setae 29.5µm long, set on ring 15; IInd ventral setae 13.7µm long, placed on ring 23; IIIrd ventral setae 9.6µm µm long and set on 6th ring, from the rear; caudal setae 21.4µm long . Accessory setae not present. Coxae smooth, coxal setae I, II, III being 1.9µm, 6.8 and 11.3µm long respectively. Forelegs 19.5µm long and hindlegs 17.4µm long. Feather claw 3 µm long and 4 rayed.

Second nymph (Plate 26, Fig. a – g)

Length: 137.5±1.579µm

Width: 51±1.074µm

Dorsal region: Gnathosoma 16.5 µm long and 16. 7 µm wide. Rostrum facing downwards. Prodorsal shield with incomplete median lines and 4 broken lines. Prodorsal setal tubercles set near rear margin, scapular setae 6.6µm long, directed antero- medially. Opisthosoma vermiform with 68 numbers of closely arranged dorsal annuli. Each annulus bears 12 numbers of small, round micro-tubercles.

Ventral region: Ventral annuli 73 in number, each with 14 small, round microtubercles. Genital cover flap absent, genital setae being 11.7 µm long. Lateral setae 12.4µm long and inserted on 9 th ring. Ist ventral setae 46.2 µm

long and inserted on 25th ring ; IInd ventral setae 20.1µm long and set on ring 40; IIIrd ventral setae 13.5 µm long, set on 5th ring, from the rear; caudal setae 36.7µm long. Telosome with very minute accessory setae. Coxae smooth, coxal setae I, II, III being 3. 4 µm, 11.6 µm and 16 µm long respectively. Forelegs 26.4 µm long and hindlegs 22.2µm long. Feather claw 4.2 µm long and 4 rayed.

Adult female (Plate 27, Fig. a – g)

Length: 194.5±2.286µm

Width: 63.5±1.249µm

Dorsal region: Gnathosoma 20 µm long and 18 µm wide; rostrum facing downwards. Prodorsal shield with median, admedian and submedian lines, all being incomplete; sides of prodorsal shield with short lines; prodorsal setal tubercles set near rear margin; scapular setae directed antero-medially and 8 µm long and 11 µm apart from each other. Opisthosoma vermiform with 71 numbers of closely arranged dorsal annuli. Each annulus with 19 small, round microtubercles.

Ventral region: Ventral annuli 89 in number, each with 19 small round microtubercles. Genital coverflap 12 µm long, and 19 µm wide, with 7 anterior longitudinal ribs, and slightly granulated posteriorly, genital seta 13 µm long. Lateral setae 14µm long , inserted on ring 11. Ist ventral setae 54.6µm long, placed on ring 23; IInd ventral setae 23.5 µm long, set on ring 49; IIIrd ventral setae 15.7 µm long and inserted on 7th ring from the rear. Caudal setae 42.1 µm long and telosome with minute accessory setae. Coxae smooth, coxal setae I, II, III being 7.1 µm, 13.2 µm and 19.1µm long respectively. Forelegs 31 µm long and hindlegs 27 µm long. Feather claw 5.1µm long and 4 rayed.

Adult male

Length: 170±1.639µm

Width: 48.1±1.741µm

Males were smaller in size when compared to the females and they greatly resembled the females morphologically, except in their genital features. Genitalia 10 long, 16 wide, eugenital setae 17 long and 13apart.

Table 71: Measurements of life stages of *Eriophyes camarae* sp.nov.

Life stages									
Sl. No.	**Egg**	**I nymph**		**II nymph**		**Adult female**		**Adult male**	
	Diameter	legth	width	legth	width	legth	width	legth	width
1	38	72	36	131	46	206	69	169	44
2	43	73	35	133	53	199	65	167	55
3	39	71	31	129	49	186	63	173	45
4	41	76	36	141	45	189	66	169	46
5	39	79	36	139	51	184	59	176	55
6	41	73	34	143	54	201	62	164	47
7	40	76	29	136	51	198	64	172	46
8	43	78	39	142	55	189	61	179	38
9	40	74	35	139	52	194	57	162	52
10	39	73	39	142	54	199	69	169	53
Mean	40.3	74.5	35	137.5	51	194.5	63.5	170	48.1
Standard Deviation	1.702	2.635	3.126	4.994	3.399	7.230	3.951	5.185	5.506
Standard Error Mean	0.538	0.833	0.988	1.579	1.074	2.286	1.249	1.639	1.741

3) Postembryonic development of *Eriophyes antigonus* sp. nov. on *Antigonon leptopus*

Results of field and laboratory studies revealed the distribution of *E. antigonus* sp. nov. on the lower surface of the leaves of the host plant, *A. leptopus.* Postembryonic development of the species was traced in the laboratory under four sets of temperature- humidity combinations such as 20±2°C and 90±5%RH; 25±2°C and 80±5%RH; 30±2°C and 70±5%RH and

35±2°C and 60±5%RH to gather information on the most preferred conditions which support the shorter duration of development and completion of more number of annual generations. The data procured on the above lines of study were analysed statistically and presented here.

Pre-oviposition period

The adult females of *E. antigonus* sp.nov. were recognized as vagrant forms, inhabiting on the lower surface of the leaves of its host invasive weed, *A. leptopus.* The mites were found wandering on the entire leaf surface and in cases of high population density, the life stages of the species were found to occupy the upper leaf surface also. Results of developmental studies revealed variations in the durations of life stages with respect to temperature-humidity conditions. As observed during the study, the mean durations of pre-oviposition period of *E. antigonus* were 3.5± 0.052 days at 20±2°C and 90±5%RH; 2.84± 0.022 days at 25±2°C and 80±5%RH; 2.01±0.023 days at 30±2°C and 70±5%RH and 3.01±0.023 days at 35±2°C and 60±5%RH. The lowest duration for pre-oviposition period was recorded at 30±2°C and70±5%RH and the maximum duration was at 20±2°C and 90±5%RH (Table 72; Fig. 57).

Oviposition period

The mean durations of the oviposition period recorded during the study were 9.74± 0.04 days at 20±2°C and 90±5%RH; 8.82±0.025 days at 25±2°C and 80±5%RH; 7.75± 0.043 days at 30±2°C and 70±5%RH and 9.06±0.022 days at 35±2°C and 60±5%RH. The oviposition period was of minimum duration at 30±2°C and 70±5%RH while it was the maximum at 20±2°C and 90±5%RH (Table 72; Fig. 57).

Post-oviposition period

Higher temperature reduced the duration of post-oviposition period of *E. antigonus* and the lower temperature extended the duration, as observed during the study. During post-oviposition period, the mites appeared slow moving, became passive with reduced feeding and later on died. The mean durations recorded for post-oviposition period were 2.84± 0.045 days at 20±2°C and 90±5%RH; 2.45± 0.043 days at 25±2°C and 80±5%RH; 2.18± 0.042 days at 30±2°C and 70±5%RH and 2.36±0.054 days at 35±2°C and 60±5%RH respectively (Table 72; Fig. 57).

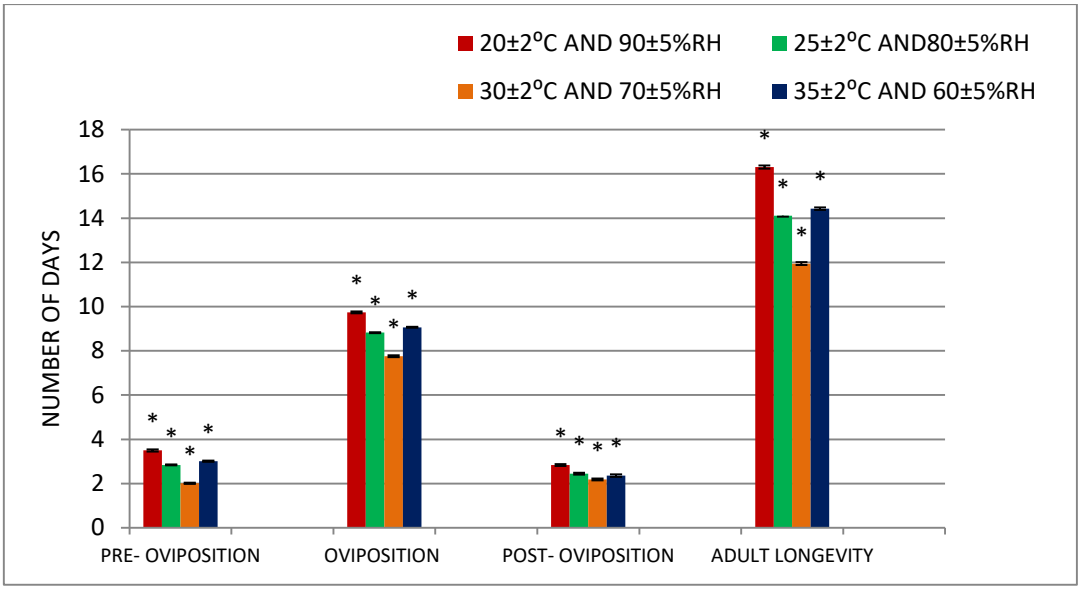
Adult Longevity

The results of the study revealed the maximum duration of adult longevity at 20±2°C and 90±5%RH and the minimum duration at 30±2°C and 70±5%RH. The data recorded for duration of longevity were 16.31±0.067 days at 20±2°C and 90±5%RH; 14.11±0.041 days at 25±2°C and 80±5%RH; 11.94± 0.065 days at 30±2°C and 70±5%RH and 14.43±0.062 days and at 35±2°Cand 60±5%RH (Table 72; Fig. 57).

Table 72: Impact of selected Temperature –Humidity combinations on the duration of Pre- oviposition, Oviposition & Post- oviposition periods and Adult longevity in *Eriophyes antigonus* sp.nov. on *Antigonon leptopus*

Developmental Periods	Temperature and Relative Humidity combinations			
	20±2°C &90±5%RH	25±2°C &80±5%RH	30±2°C & 70±5%RH	35±2°C &60±5%RH
Pre-Oviposition	3.5±0.05*	2.84±0.02*	2.01±0.02*	3.01±0.12*
Oviposition	9.74±0.04*	8.82±0.02*	7.75±0.04*	9.06±0.02*
Post- Oviposition	2.84±0.05*	2.45±0.04*	2.18±0.04*	2.36±0.05*
Adult Longevity	16.31±0.07*	14.11±0.04*	11.94±0.06*	14.43±0.06*

Fig. 57: Impact of different Temperature –Humidity conditions on the duration of Pre- oviposition, Oviposition & Post- oviposition periods and Adult longevity in *Eriophyes antigonus* sp.nov. infesting on *Antigonon leptopus*



* - Statistically significant using one way – ANOVA with P<0.05

Oviposition and Fecundity

The gravid females laid single eggs on the abaxial surface, closely apposed to the midrib and veins of the host leaves. Freshly laid eggs appeared spherical, snow white in colour, shiny and with a smooth chorion.

The mean number of eggs laid by the female of *E. antigonus* sp.nov. throughout her life cycle was recorded as 11.5±0.307 at 20±2°C and 90±5%RH (Table 73); 13±0.471 at 25±2°C and 80±5%RH (Table 74); 15.6±0.305 at 30±2°C and 70±5%RH (Table 75) and 12.1±0.407 at 35±2°Cand 60±5%RH (Table 76) respectively. The temperature-humidity combination of 30±2°C and 70±5%RH was found to promote high fecundity. The maximum number of eggs was laid on the 4th day of oviposition and the number was averaged to 4.2±0.2 at 30±2°C and 70±5%RH (Fig. 58).

Table 73: Fecundity of *Eriophyes antigonus* sp.nov. on *Antigonon leptopus* at 20±2°C and 90±5%RH

No. of eggs laid on different days of oviposition										
SL.NO.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**Total no. of Eggs Laid**
1	1	1	1	2	2	2	1	0	1	11
2	1	0	2	3	2	1	0	1	1	11
3	1	2	2	3	1	1	1	0	1	12
4	1	1	1	2	2	1	1	1	1	11
5	1	1	1	2	3	1	0	1	1	11
6	1	1	2	3	2	2	1	0	1	13
7	1	0	1	2	2	1	1	1	1	10
8	1	1	2	3	2	2	1	0	1	13
9	1	1	2	3	1	2	0	1	1	12
10	1	0	2	3	2	1	1	0	1	11
Mean	1	0.8	1.6	2.6	1.9	1.4	0.7	0.5	1	11.5*
Sstandard Deviation	0	0.632	0.516	0.516	0.567	0.516	0.483	0.527	0	0.971
Standard Error Mean	0	0.2	0.163	0.163	0.179	0.163	0.152	0.166	0	0.307

* - Statistically significant using one way – ANOVA with $P<0.05$

Table 74: Fecundity of *Eriophyes antigonus* sp.nov. on *Antigonon leptopus* at25±2°C and 80±5%RH

No. of eggs laid on different days of oviposition									
SL.NO.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**Total no. of Eggs Laid**
1	1	2	3	3	2	1	0	1	13
2	1	1	2	3	2	2	1	1	13
3	1	2	2	3	2	1	0	1	12
4	1	2	2	4	2	2	1	1	15
5	1	1	2	3	1	1	2	1	12
6	1	2	2	3	2	2	0	1	13
7	2	1	2	3	1	1	0	1	11
8	1	1	2	3	2	2	0	1	12
9	1	1	3	3	1	2	1	1	13
10	1	2	2	3	2	3	2	1	16
Mean	1.1	1.5	2.2	3.1	1.7	1.7	0.7	1	13*
Standard Deviation	0.316	0.527	0.421	0.316	0.483	0.674	0.823	0	1.490
Standard Error Mean	0.1	0.166	0.133	0.1	0.152	0.213	0.260	0	0.471

* - Statistically significant using one way – ANOVA with P<0.05

Table 75: Fecundity of *Eriophyes antigonus* sp.nov. on *Antigonon leptopus* at 30±2°C and 70±5%RH

No. of eggs laid on different days of oviposition								
SL.NO.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Total no. of Eggs Laid**
1	1	2	2	4	3	1	1	14
2	1	2	3	5	3	1	1	16
3	1	2	4	4	3	1	1	16
4	1	2	3	5	3	2	1	17
5	2	2	3	4	2	1	1	15
6	1	2	2	4	2	2	1	14
7	2	3	3	4	2	1	1	16
8	1	2	3	5	4	0	1	16
9	1	2	2	3	4	3	1	16
10	2	2	3	4	2	2	1	16
Mean	1.3	2.1	2.8	4.2	2.8	1.4	1	15.6*
Standard Deviation	0.483	0.316	0.632	0.632	0.788	0.843	0	0.966
Standard error Mean	0.152	0.1	0.2	0.2	0.249	0.266	0	0.305

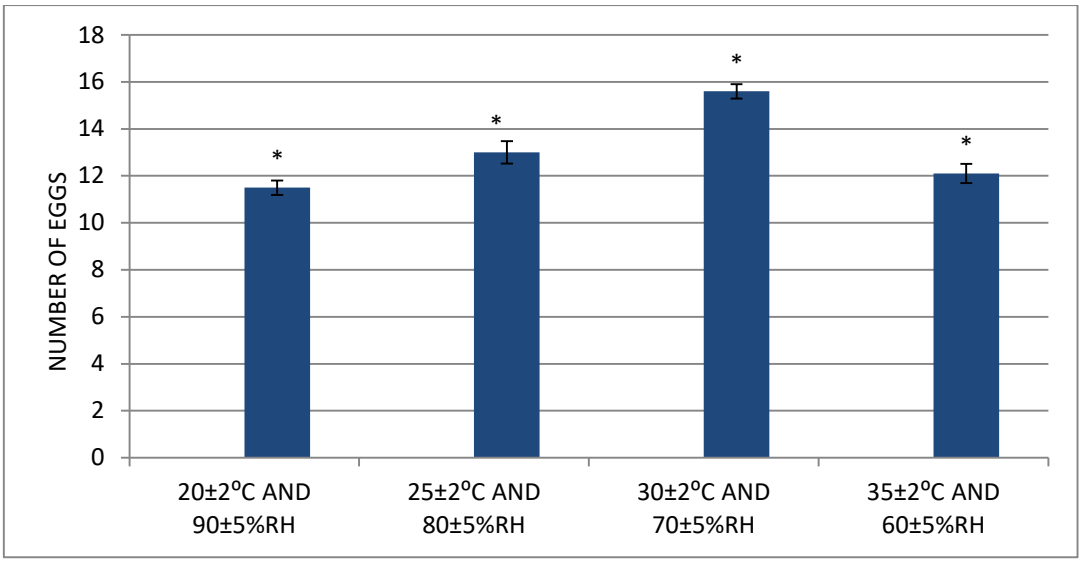
* - Statistically significant using one way – ANOVA with P<0.05

Table 76: Fecundity of *Eriophyes antigonus* sp.nov. on *Antigonon leptopus* at 35±2°C and 60±5%RH

No. of eggs laid on different days of oviposition										
SL.NO.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**Total no. of Eggs Laid**
1	1	1	1	2	2	2	1	0	1	11
2	1	0	2	3	2	1	0	1	1	11
3	1	1	1	3	1	2	1	0	1	11
4	1	1	1	2	2	1	1	1	1	11
5	1	1	1	2	3	2	2	1	1	14
6	1	2	2	3	2	2	1	0	1	14
7	1	0	1	3	2	2	1	1	1	12
8	1	1	2	3	2	2	1	0	1	13
9	1	1	2	3	1	2	1	1	1	13
10	1	0	2	3	2	1	1	0	1	11
Mean	1	0.8	1.5	2.7	1.9	1.7	1	0.5	1	12.1*
Standard Deviation	0	0.632	0.527	0.483	0.567	0.483	0.471	0.527	0	1.286
Standard Error Mean	0	0.2	0.166	0.152	0.179	0.152	0.149	0.166	0	0.406

* - Statistically significant using one way – ANOVA with P<0.05

Fig. 58: Number of eggs laid by *Eriophyes antigonus* sp. nov. on *Antigonon leptopus* at different temperature- humidity conditions



* - Statistically significant using one way – ANOVA with P<0.05

Duration of developmental stages

Incubation period

The gravid females laid solitary eggs on the abaxial surface in areas adjacent to the midrib and veins. The eggs hatched within 4.91±0.038 days at 20±2°C and 90±5%RH, 4.55± 0.027 days at 25±2°C and 80±5%RH, 3.48±0.042 days at 30±2°C and 70±5%RH and 4.13±0.015 days at 35±2°C and 60±5%RH. The duration of incubation period was extended at a temperature humidity condition of 20±2°Cand 90±5%RH and it was minimum at 30±2°C and 70±5%RH (Table 77; Fig.59).

Hatching

Prior to hatching, the eggs developed a white colouration and became much more rigid. Hatching was initiated by the appearance of a longitudinal slit and which got widened through which the legs and gnathosoma of the

nymph protruded. Hatching completed within 20-25 minutes and the first nymph escaped out of the egg case.

First nymph

The newly emerged first nymph was very minute, transparent in colour and slow moving. It appeared highly sensitive when exposed to light during microscopic observation. The first nymph initiated feeding activity a short time after hatching and its active period showed slight variation with respect to the differences in the temperature-humidity conditions studied. The active period of the first nymph lasted for an average of 2.92± 0.029 days at 20±2°C and 90±5%RH; 2.49±0.028 days at 25±2°C and 80±5%RH; 2.18±0.020 days at 30±2°C and 70±5%RH and 2.33±0.015 days at 35±2°C and 60±5%RH (Table 77; Fig. 59). At the end of its active period, the first nymph ceased its feeding and became immobile and its body turned to swollen and it entered into the first quiescent phase/nymphochrysalis stage for a very short time.

First quiescent phase

The first nymph after ceasing its feeding activity entered in to an inactive quiescent phase/nymphochrysalis stage , the mean duration of which was recorded as 1.14 ± 0.033 days at 20±2°C and 90±5%RH; 1.03 ±0.015 days at 25±2°C and 80±5%RH; 0.7 ±0.026 days at 30±2°C and 70±5%RH and 0.95 ±0.017 days at 35±2°C and 60±5%RH (Table 77; Fig. 59). The nymphochrysalis stage had a shortest duration of less than a day at 30±2ºC and 70±5%RH and a longest duration at 35±2°C and 60±5%RH. The nymphochrysalis further moulted in to the second nymph.

Second nymph

The second nymph was larger than the previous stage and more active in feeding and movement. The duration of active period of the second nymph was recorded as 4.36±0.054 days at 20±2°C and 90±5%RH; 4.02±0.025 days at 25±2°C and 80±5%RH; 3.18±0.029 days at 30±2°C and 70±5%RH and 3.75±0.027 days at 35±2°C and 60±5%RH (Table 77; Fig. 59). The culmination of the active period of the second nymph was marked by the initiation of the second quiescent phase/imagochrysalis, by becoming lethargic, swollen, non-feeding and immobile.

Second quiescent phase

The imagochrysalis stage also showed variation in its duration in response to the temperature- humidity differences selected for biological studies. The duration of second quiescence was recorded to be 2.04± 0.016 days at 20±2°C and 90±5%RH; 1.84±0.068 days at 25±2°C and 80±5%RH; 1.21±0.023 days at 30±2°C and 70±5%RH and 1.57±0.030 days at 35±2°C and 60±5%RH (Table 77; Fig. 59). The second quiescent stage subsequently moulted into a very active adult .

Moulting

Moulting, the process of shedding of the old cuticle was observed after the first and second quiescent phases. During moulting, the clear and transparent exuvium was found shed off from the quiescent instar and newly moulted individual resumed movement and subsequent feeding activity. The process of moulting required 25-30 minutes for completion and was not influenced by the temperature-humidity variations, as observed during the study.

Adult

The adult mites were larger in size, fast moving and voraciously feeding on the lower leaf surface of the host plant. The females were found to be broader than the males and were larger in size. When the population got increased, the mites were found distributed on both surfaces of the host leaves.

Total duration of development

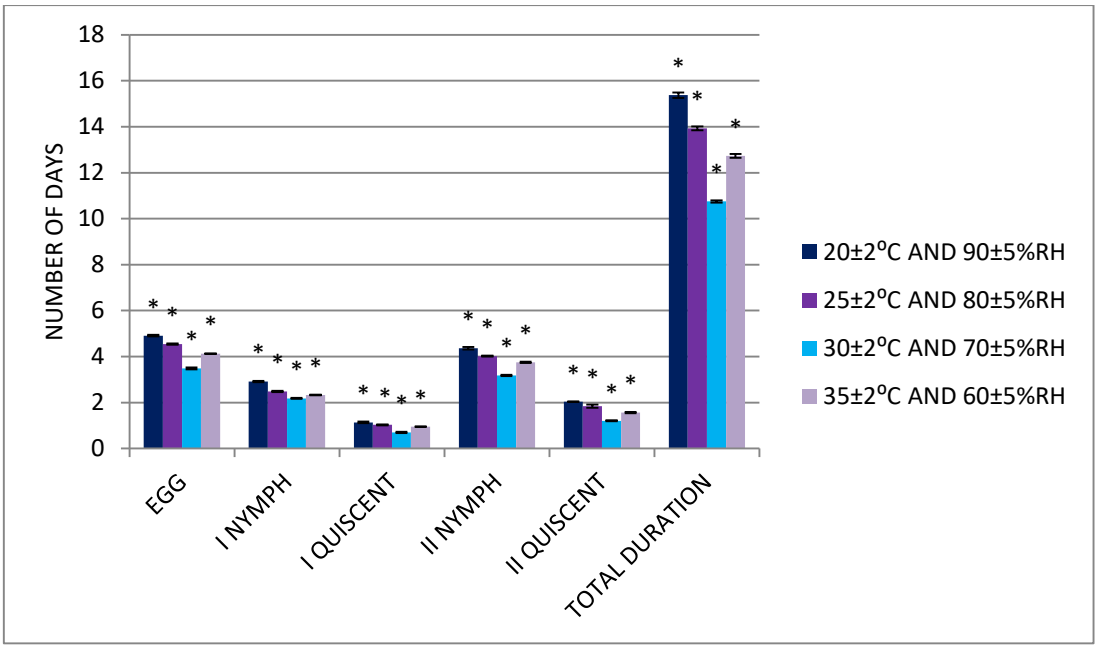
The total duration of development of *E. antigonus* sp.nov. from egg to adult was 15.37±0.114 at 20±2°C and 90±5%RH; 13.93±0.079 days at 25±2°C and 80±5%RH; 10.75±0.052 days at 30±2°C and 70±5%RH and 12.73±0.087 days at 35±2°C and 60±5%RH. The minimum time taken for completion of the life cycle of *E. antigonus* sp.nov. on *A.leptopus* was recorded at 30±2°C and 70±5%RH, and thereby could recognized as the most favoured and ideal condition ensuring faster development and rapid build up of mite population. The maximum duration was recorded at 20±2°C and 90±5%RH (Table 77; Fig.59).

Table 77: Impact of selected Temperature – Humidity combinations on the duration of life stages (in days) of *Eriophyes antigonus* sp.nov. on *Antigonon leptopus*

Developmental stages	Temperature and Relative Humidity combinations			
	20±2°C & 90±5%RH	**25±2°C &80±5%RH**	**30±2°C &70±5%RH**	**35±2°C &60±5%RH**
Egg	4.91±0.04*	4.55±0.03*	3.48±0.04*	4.13±0.02*
I Nymph	2.92±0.03*	2.49±0.03*	2.18±0.02*	2.33±0.01*
I Quiscent	1.14±0.03*	1.03±0.02*	0.7±0.02*	0.95±0.02*
II Nymph	4.36±0.05*	4.02±0.02*	3.18±0.03*	3.75±0.03*
II Quiscent	2.04±0.16*	1.84±0.06*	1.21±0.02*	1.57±0.03*
Total Duration	15.37±0.11*	13.93±0.08*	10.75±0.05*	12.73±0.09*

* - Statistically significant using one way – ANOVA with P<0.05

Fig. 59: Impact of different Temperature –Humidity conditions on the duration of life stages (in days) of *Eriophyes antigonus* sp.nov. on *Antigonon leptopus*



* - Statistically significant using one way – ANOVA with P<0.05

Morphological descriptions of life stages of *E. antigonus* sp. nov. (Table 78)

Egg

Diameter: 40.1±0.752µm

Eggs were spherical, transparent , smooth and shiny. At the end of incubation period just prior to hatching it became more transparent. In slide mounted eggs, cleavage patterns were well visible under a research microscope.

First nymph (Plate 28, Fig. a – g)

Length: 86.8±0.853µm

Width: 36.8±1.03µm

Dorsal region: Gnathosoma 10.7 µm long and 16.7µm wide, rostrum facing downwards. Prodorsal shield without median lines, but with 6-7minute broken lines. . The prodorsal setal tubercles set near rear margin, the scapular setae directed forward, 5.6µm long. Opisthosoma vermiform with 46 dorsal annuli, arranged very closely. Each annulus bears 10 numbers of small, spherical microtubercles .

Ventral region: Ventral annuli 52 in number and each with 10 numbers of very minute microtubercles. Genital cover flap absent; genital setae 7.1 µm long. Lateral setae 8.5µm long and inserted on 6th ring. Ist ventral setae 21 µm long, set on 13th ring; IInd ventral setae 7.8µm long, arranged on ring 21; IIIrd ventral setae 7.1 µm long, placed on 6th ring from the rear. Caudal setae 29.5µm long and accessory setae not present. Coxae smooth, coxal setae I, II and III measure 2.4 µm, 8.4 µm and 14.1µm long respectively. Forelegs 19.5 µm long and hindlegs 17.6µm long. Feather claw 4µm long and 4 rayed.

Second nymph (Plate 29, Fig a – g)

Length: 130.9±1.026µm

Width: 54±0.614µm

Dorsal region: Gnathosoma 16.8µm long and 19. 6 µm wide, rostrum facing downward. Prodorsal shield with incomplete median lines and other 4-5 small broken lines. Prodorsal setal tubercles set near rear margin, the scapular setae directed forward, 8.8µm long. Opisthosoma vermiform with 58 numbers of closely arranged dorsal annuli. Microtubercles small, round and 13 in number.

Ventral region: Ventral annuli 66 in number, each with an average of 13 small microtubercles. Genital cover flap absent, genital setae 14.3 µm long. Lateral setae 13.2µm long, placed on 8th ring. Ist ventral setae 48 µm long, placed on 17th ring; IInd ventral setae 11.6µm long, inserted on ring 30; IIIrd

ventral setae 11.4 µm long, set on 6th ring from rear. Caudal setae 30.7µm long. Telosome with very minute accessory setae. Coxae smooth, coxal setae I, II and III being 3.6 µm, 15.4 µm and 23.3µm in length respectively. Forelegs 23.4 µm long and hindlegs 21.5µm long. Feather claw 5. 7 µm long and 4 rayed.

Adult female (Plate 30, Fig. a – g)

Length: 162.7±1.044µm

Width: 63.4±1.231µm

Dorsal region: Gnathosoma 17 µm long and 22 µm wide, rostrum facing downward. Prodorsal shield with median, admedian and submedian lines, all incomplete. Apart from the major median lines, prodorsal shield bears other small broken lines. Prodorsal setal tubercles set near rear margin, the setae directed antero-medially and 11 µm long and 14 µm apart from each other. Opisthosoma worm-like with 65 numbers of closely arranged dorsal annuli. Micro-tubercles rounded and 15-17 in number on each annulus.

Ventral region: Ventral annuli 71 in number, and each with an average of 17 microtubercles. Genital coverflap 18 µm long and 21 µm wide, with 12 anterior longitudinal ribs, granulated posteriorly; genital setae 19 µm long. Lateral setae 14µm long , inserted on ring 9. Ist ventral setae 61µm long, placed on ring 23; IInd ventral setae 13.2 µm long, set on ring 32; IIIrd ventral setae 16.3 µm long and inserted on ring 61. Caudal setae 40 µm long and telosome with minute accessory setae. Coxae smooth, coxal setae I, II & III measure 6.8 µm, 16 µm and 21 µm in length respectively. Forelegs 27 µm long and hindlegs 24 µm long. Feather claw 7µm long and 4 rayed.

Adult male

Length: 149.6±1.384µm

Width: 45.2±0.94µm

Male smaller in size than that of the female. It shows great morphological resemblance to the female, except in the genital features. Genitalia 11 long, 15 wide, eugenital setae 13 long and 12 apart.

Table 78: Measurements of life stages of *Eriophyes antigonus* sp.nov.

Life stages									
Sl. No.	**Egg**	**I nymph**		**II nymph**		**Adult female**		**Adult male**	
	Diameter	legth	width	legth	width	legth	width	legth	Width
1	39	88	36	132	50	163	69	151	48
2	41	82	30	133	52	167	58	153	45
3	39	88	38	134	54	163	66	146	41
4	43	90	36	123	53	167	61	154	46
5	37	89	39	129	56	166	62	154	45
6	42	83	34	133	54	157	64	153	47
7	38	86	36	132	56	162	63	146	41
8	42	88	39	133	55	159	58	151	48
9	43	85	42	129	56	162	69	147	42
10	37	89	38	131	54	161	64	141	49
Mean	40.1	86.8	36.8	130.9	54	162.7	63.4	149.6	45.2
Standard Deviation	2.378	2.699	3.259	3.247	1.943	3.301	3.893	4.376	2.974
Standard Error Mean	0.752	0.853	1.030	1.026	0.614	1.044	1.231	1.384	0.940

4) Postembryonic development of *Phyllocoptruta merremiae* sp. nov. on *Merremia vitifolia*

Results of field cum laboratory studies enabled to detect *P. merremiae* sp. nov. as a leaf vagrant form showing a very close association with the invasive weed plant, *M.vitifolia*. All the life stages of the mite showed a preference to feed on the lower surface of the host leaves. However, when the population assumed peak levels, the mite showed infestation on both surfaces of the leaves, and induced leaf damage through feeding. In the present study, biological observations of the species were made by rearing it under four selected combinations of temperature-humidity conditions like 20±2°C and

90±5%RH; 25±2°C and 80±5%RH; 30±2°C and 70±5%RH and 35±2°C and 60±5%RH to record the durations of the various instars as well as the total duration of development. Results of biological studies also revealed the most favoured temperature-humidity conditions supporting faster development, leading to rapid population build up of the species. The results of the studies were subjected to statistical analysis following One way- ANOVA to confirm significance of the values.

Pre-oviposition period

Depending upon the temperature –humidity variations, the pre-oviposion period of *P. merremiae* sp.nov. also showed slight variations as observed during the present study. The durations of the pre-oviposition period recorded were 2.7 ± 0.049 days at 20±2°C and 90±5%RH; 2.27 ± 0.021 days at 25±2°C and 80±5%RH; 1.64 ± 0.037 days at 30±2°C and 70±5%RH and 2.37 ± 0.040 days at 35±2°C and 60±5%RH respectively (Table 79; Fig.60).

Oviposition period

The average durations of oviposition period of the adult females of the species recorded during the study were 7.73± 0.037 days at 20±2°C and 90±5%RH; 7.45±0.031 days at 25±2°C and 80±5%RH; 6.56± 0.037 days at 30±2°C and 70±5%RH and 7.49±0.059 days at 35±2°C and 60±5%RH respectively. The minimum duration was recorded for the oviposition period at the temperature- humidity conditions of 30±2°C and 70±5%RH and the maximum was recorded at 20±2°C and 90±5%RH (Table 79; Fig.60).

Post-oviposition period

Minimum duration for post-oviposition period was recorded in *P. merremiae* sp. nov. at higher temperature and the maximum duration could be recorded at lower temperature and respective humidity conditions. During

the post-oviposition period, the mites became slow moving, their feeding activity got reduced and gradually they were found dead. The mean durations of post-oviposition period recorded were 2.46 ± 0.045 days at 20±2°C and 90±5%RH; 2.09 ± 0.038 days at 25±2°C and 80±5%RH; 1.88± 0.033 days at 30±2°C and 70±5%RH and 2.2±0.036 days at 35±2°C and 60±5%RH respectively. The maximum post-oviposition period was recorded at 20±2°C and 90±5%RH (Table 79; Fig. 60).

Adult Longevity

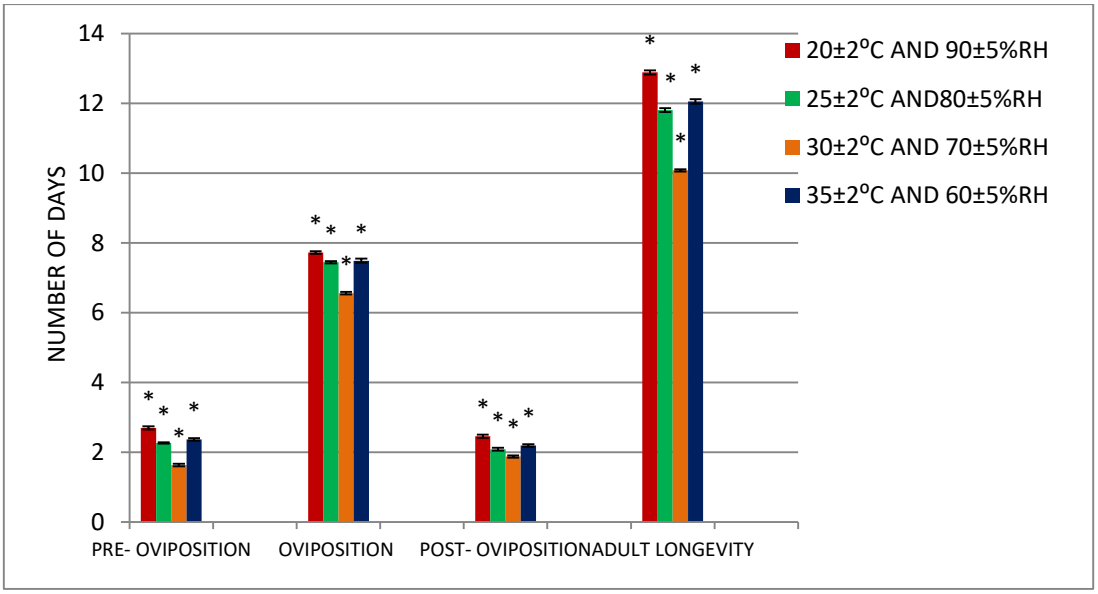
The maximum duration of adult longevity was recorded at 20±2°C and 90±5%RH and minimum at 30±2°C and 70±5%RH. The data recorded on adult longevity in *P. merremiae* at the selected temperature-humidity conditions were 12.89±0.06 days at 20±2°C and 90±5%RH; 11.81±0.057 days at 25±2°C and 80±5%RH; 10.08± 0.029 days at 30±2°C and 70±5%RH and 12.06±0.065 days and at 35±2°C and 60±5%RH (Table 79; Fig.60).

Table 79: Impact of selected Temperature –Humidity combinations on the duration of Pre- oviposition, Oviposition & Post- oviposition periods and Adult longevity in *Phyllocoptruta merremiae* sp.nov. on *Merremia vitifolia*

	Temperature and Relative Humidity combinations			
Developmental Periods	**20±2°C&90± 5%RH**	**25±2°C &80±5%RH**	**30±2°C &70±5%RH**	**35±2°C &60±5%RH**
Pre-Oviposition	2.7±0.05*	2.27±0.02*	1.64±0.04*	2.37±0.04*
Oviposition	7.73±0.03*	7.45±0.03*	6.56±0.04*	7.49±0.06*
Post-Oviposition	2.46±0.04*	2.09±0.04*	1.88±0.03*	2.2±0.04*
Adult Longevity	12.89±0.06*	11.81±0.06*	10.08±0.03*	12.06±0.06*

* - Statistically significant using one way – ANOVA with P<0.05

Fig. 60: Impact of different Temperature-Humidity conditions on the duration of Pre-Oviposition, Oviposition & Post- oviposition periods and Adult longevity in *Phyllocoptruta merremiae* sp.nov. infesting on *Merremia vitifolia*



* - Statistically significant using one way – ANOVA with P<0.05

Oviposition and Fecundity

The gravid females laid eggs singly on the entire leaf lamina , on the lower surface of the leaves of *M. vitifoliae* . The freshly laid eggs were spherical, white, smooth and shiny**.** The average number of eggs laid by a single female of *P. merremiae* during her lifespan was calculated to be 19±0.471 at 20±2°C and 90±5%RH (Table 80); 22±0.365 at 25±2°C and 80±5%RH (Table 82); 26.1±0.888 at 30±2°C and 70±5%RH (Table 82) and 19.4±0.427 at 35±2°C and 60±5%RH (Table 83) respectively. The rate of oviposition was found promoted by the temperature-humidity condition of 30±2°C and 70±5%RH and at which maximum number of eggs was laid by a single female of the species. The maximum number of eggs were found laid on the 3rd day of oviposition and it averaged to 7. 4± 0.30 at 30±2°C and 70±5%RH (Fig. 61).

Table 80: Fecundity of *Phyllocoptruta merremiae* sp.nov. on *Merremia vitifolia* at 20±2°C and 90±5%RH

No. of eggs laid on different days of oviposition								
SL.NO.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Total no. of Eggs Laid**
1	1	2	4	5	4	3	1	20
2	1	2	3	6	3	2	1	18
3	1	3	5	6	4	2	1	22
4	1	2	3	5	3	2	1	17
5	2	3	3	4	3	3	2	20
6	1	2	4	6	3	2	1	19
7	2	3	3	4	2	2	1	17
8	1	2	3	5	4	3	1	19
9	1	2	2	5	4	3	2	19
10	2	2	3	5	4	2	1	19
Mean	1.3	2.3	3.3	5.1	3.4	2.4	1.2	19*
Standard Deviation	0.483	0.483	0.823	0.737	0.699	0.516	0.421	1.490
Standard Error Mean	0.152	0.152	0.260	0.233	0.221	0.163	0.133	0.471

* - Statistically significant using one way – ANOVA with P<0.05

Table 81: Fecundity of *Phyllocoptruta merremiae* sp.nov. on *Merremia vitifolia* at 25±2°C and 80±5%RH

No. of eggs laid on different days of oviposition								
SL.NO.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Total no. of Eggs Laid**
1	2	3	4	5	4	2	1	21
2	1	3	5	6	3	2	1	21
3	2	4	5	6	3	3	1	24
4	1	3	4	6	4	2	2	22
5	2	3	4	5	4	2	1	21
6	1	3	3	6	5	2	1	21
7	2	3	4	7	2	3	1	22
8	1	4	4	6	4	2	1	22
9	2	3	4	6	4	3	2	24
10	2	2	4	6	4	3	1	22
Mean	1.6	3.1	4.1	5.9	3.7	2.4	1.2	22*
Standard Deviation	0.516	0.567	0.567	0.567	0.823	0.516	0.421	1.154
Standard Error Mean	0.163	0.179	0.179	0.179	0.260	0.163	0.133	0.365

* - Statistically significant using one way – ANOVA with $P<0.05$

Table 82: Fecundity of *Phyllocoptruta merremiae* sp.nov. on *Merremia vitifolia* at 30±2°C and 70±5%RH

No. of eggs laid on different days of oviposition							
SL.NO.	**1**	**2**	**3**	**4**	**5**	**6**	**Total no. of Eggs Laid**
1	2	4	9	6	5	2	28
2	3	5	8	5	4	3	28
3	3	4	7	6	5	4	29
4	2	3	8	5	4	2	24
5	2	3	8	7	5	3	28
6	3	4	6	5	4	2	24
7	2	3	7	4	3	3	22
8	2	2	6	5	4	3	22
9	3	5	7	6	5	3	29
10	2	4	8	6	4	3	27
Mean	2.4	3.7	7.4	5.5	4.3	2.8	26.1*
Standard Deviation	0.516	0.948	0.966	0.849	0.674	0.632	2.806
Standard Error Mean	0.163	0.3	0.305	0.268	0.213	0.2	0.887

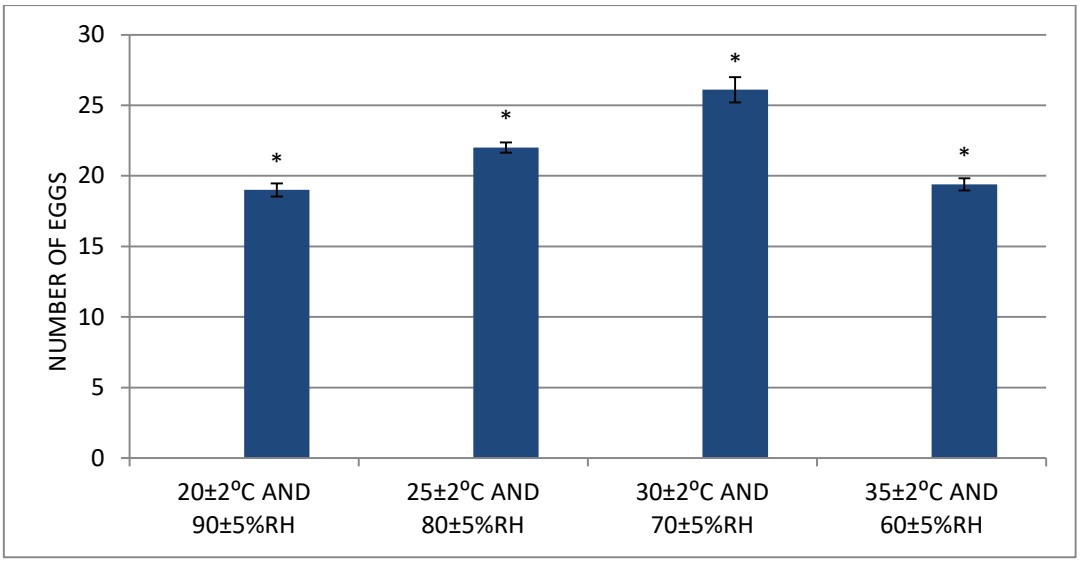
* - Statistically significant using one way – ANOVA with $P<0.05$

Table 83: Fecundity of *Phyllocoptruta merremiae* sp.nov. on *Merremia vitifolia* at 35±2°C and 60±5%RH

No. of eggs laid on different days of oviposition								
SL.NO.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Total no. of Eggs Laid**
1	1	2	3	5	3	2	2	18
2	2	4	4	5	4	1	1	21
3	1	2	4	6	3	3	2	21
4	1	2	3	5	4	2	1	18
5	2	3	4	5	2	2	1	19
6	1	4	4	5	4	2	1	21
7	2	3	5	4	3	2	1	20
8	1	2	4	6	3	3	1	20
9	1	2	2	4	4	3	2	18
10	2	2	3	5	3	2	1	18
Mean	1.4	2.6	3.6	5	3.3	2.2	1.3	19.4*
Standard Deviation	0.516	0.843	0.843	0.666	0.674	0.632	0.483	1.349
Standard Error Mean	0.163	0.266	0.266	0.210	0.213	0.2	0.152	0.426

* - Statistically significant using one way – ANOVA with $P<0.05$

Fig. 61: Number of eggs laid by *Phyllocoptruta merremiae* sp.nov. on *Merremia vitifolia* at different temperature- humidity conditions



* - Statistically significant using one way – ANOVA with P<0.05

Duration of developmental stages

Incubation period

The duration of incubation also differed with respect to the variations in temperature-humidity combinations selected for the study. The average durations of incubation period recorded were 3.87± 0.021 days at 20±2°C and 90±5%RH; 3.63± 0.015 days at 25±2°C and 80±5%RH; 2.84± 0.016 days at 30±2°C and 70±5%RH and 3.18± 0.013 days at 35±2°C and 60±5%RH. The maximum duration of incubation period was recorded at 20±2°Cand 90±5%RH while it was observed to be the minimum at 30±2°C and 70±5%RH (Table 84; Fig.62).

Hatching

Before hatching, the colour of the egg got changed to milky white and it became rigid. A cone like protrusion developed on the egg surface and a

longitudinal slit appeared at the protruded end. The slit got widened through which the first nymph protruded its legs and gnathosoma. Hatching was found completed within 20-25 minutes.

First nymph

The first nymph was very minute, slow moving and white in colour. Soon after hatching the first nymph resumed movement and initiated its feeding activity on the lower leaf surface. The active feeding period of the first nymph was found averaged to 2.06± 0.022 days at 20±2°C and 90±5%RH; 1.39±0.01 days at 25±2°C and 80±5%RH; 1.24±0.022 days at 30±2°C and 70±5%RH and 1.34± 0.026 days at 35±2°C and 60±5%RH (Table 84; Fig.62).

First quiescent phase

At the end of the active feeding period, the first nymph became lethargic with reduced feeding activity and soon it became immobile and its body assumed a swollen appearance and it entered in to the first quiescent phase/ nymphochrysalis stage for a very short time. The duration of first quiescent phase recorded at 20±2°C and 90±5%RH were 1.25±0.022 days; 0.85±0.017 days at 25±2°C and 80±5%RH; 0.61±0.010 days at 30±2°C and 70±5%RH and 0.75±0.017 days at 35±2°C and 60±5%RH (Table 84; Fig. 62). The mean duration of nymphochrysalis stage lasted for more than a day at 20±2°C and 90±5%RH and less than a day at the remaining three temperature-humidity conditions. The shortest duration was noted at 30±2°C and 70±5%RH, and it was longest at 20±2°C and 90±5%RH.

Second nymph

The second nymph was larger than the first nymph and moved fast and exhibited very active feeding on the leaf sap. The duration of development of

the second nymph could be recorded as 2.27±0.026 days at 20±2°C and 90±5%RH; 1.59±0.01 days at 25±2°C and 80±5%RH; 1.32± 0.013 days at 30±2°C and 70±5%RH and 1.54±0.016 days at 35±2°C and 60±5%RH (Table 84; Fig. 62).

Second quiescent phase

At the end of the active feeding period of the second nymph, an inactive, non feeding and immotile stage was observed which represented the second quiescent phase or imagochrysalis stage. The duration of second quiescent phase was recorded as 1.43± 0.03 days at 20±2°C and 90±5%RH; 0.66±0.016 days at 25±2°C and 80±5%RH; 0.63± 0.015 days at 30±2°C and 70±5%RH and 0.57± 0.015 days at 35±2°C and 60±5%RH (Table 84; Fig. 62). At the end of the second quiescent phase, moulting occurred, leading to the emergence of the active adult.

Moulting

Moulting process of *P.merremiae* sp.nov.resembled that of the earlier three species described above. During moulting the transparent exuvium of the quiescent instar was found shed out, resulting in the release of the succeeding instar. The total duration of moulting was observed to be 15-25 minutes and its duration was not affected by the temperature-humidity variations.

Adult

The adult mite was larger in size, yellowish white coloured, fast moving and voraciously feeding on the lower leaf surface of the host plant leaves. The female was broader and larger than the male. The adult mites showed a general preference to colonise the lower leaf surface, but when the

mite population became too high, their distribution was found extended to both surfaces of leaves.

Total duration of development

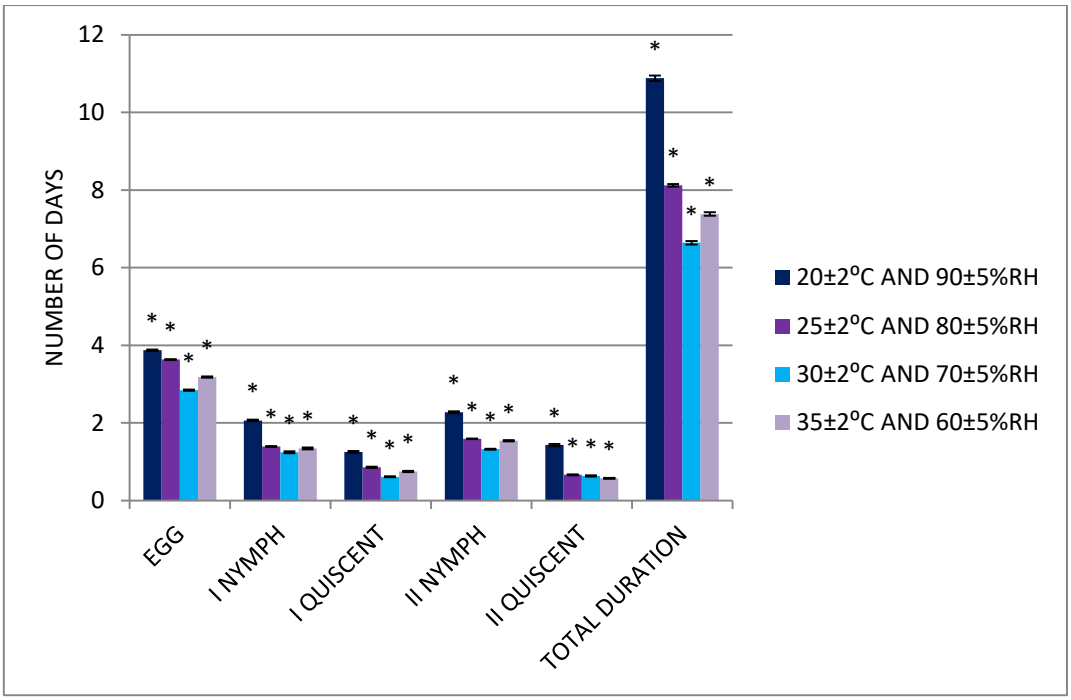
The total duration of development of *P.merremiae* sp.nov.on the invasive weed, *M. vitifolia* from egg to the adult stage was recorded as 10.88±0.069 days at 20±2°C and 90±5%RH; 8.12 ±0.033 days at 25±2°C and 80±5%RH; 6.64±0.043 days at 30±2°C and 70±5%RH and 7.38±0.044 days at 35±2°C and 60±5%RH. Thus the temperature-humidity combination of 30±2°C and 70±5%RH was recognized as the ideal condition to support the shortest development time where as 20±2°C and 90±5%RH caused a delay in the duration of development (Table 84; Fig.62).

Table 84: Impact of selected Temperature – Humidity combinations on the duration of life stages (in days) *Phyllocoptruta merremiae* sp.nov. on *Merremia vitifolia*

Developmental stages	Temperature and Relative Humidity combinations			
	20±2°C &90±5%RH	**25±2°C &80±5%RH**	**30±2°C &70±5%RH**	**35±2°C & 60±5%RH**
Egg	3.87±0.02*	3.63±0.02*	2.84±0.02*	3.18±0.01*
I Nymph	2.06±0.02*	1.39±01*	1.24±0.02*	1.34±0.03*
I Quiscent	1.25±0.02*	0.85±0.02*	0.61±0.01*	0.75±0.02*
II Nymph	2.27±0.03*	1.59±0.01*	1.32±0.01*	1.54±0.02*
II Quiscent	1.43±0.03*	0.66±0.02*	0.63±0.02*	0.57±0.02*
Total Duration	10.88±0.07*	8.12±0.03*	6.64±0.04*	7.38±0.04*

* - Statistically significant using one way – ANOVA with P<0.05

Fig. 62: Impact of different Temperature –Humidity conditions on the duration of life stages (in days) of *Phyllocoptruta merremiae* sp.nov. on *Merremia vitifolia*



* - Statistically significant using one way – ANOVA with P<0.05

Morphological descriptions of life stages of *P. merremiae* sp. nov. (Table 85)

Egg

Diameter: 41.6±0.371µm

Freshly laid eggs appeared spherical, white, smooth and shiny and later on, the colour changed to milky white and it became rigid prior to hatching. Slide mounted eggs clearly showed the cleavage pattern when examined under a research microscope.

First nymph (Plate 31, Fig. a – g)

Length: 110.7±1.116µm

Width: 57.1±0.721µm

Dorsal region: Gnathosoma 13 µm long and 20µm wide; rostrum facing downwards. Prodorsal shield with small admedian lines, the latter not prominent; 4-5 minute broken lines also present on the shield. The prodorsal setal tubercles set ahead of rear margin; scapular setae directed backwards, 6 µm long. Opisthosoma fusiform with 27 distantly arranged dorsal annuli. Microtubercles absent.

Ventral region: Ventral annuli 52 in number, and each with an average number of 8 very minute microtubercles. Genital cover flap absent, genital setae 2.6µm long. Lateral setae 6.8µm long, placed on 5^{th} ring. I^{st} ventral setae 12 µm long , set on 14^{th} ring; II^{nd} ventral setae 5.3µm long, inserted on 24^{th} ring; III^{rd} ventral setae 2.8 µm long, placed on 6^{th} ring, from the rear. Caudal setae 13µm long and accessory setae absent. Coxae smooth, coxal setae I, II & III being 1.9 µm, 7.5 µm and 11µm long respectively. Forelegs 19.7 µm long and hindlegs 17. 7µm long. Feather claw 4 µm long and 4 rayed.

Second nymph (Plate 32, Fig. a – g)

Length: 160.9±0.862µm

Width: 56.5±0.872µm

Dorsal region: Gnathosoma 17.6 µm long and 27µm wide, rostrum facing downwards. Prodorsal shield with clear admedian lines, small incomplete median and submedian lines. Prodorsal setal tubercles set ahead of rear margin; the scapular setae directed postero-medially, 6. 9 µm long.

Opisthosoma fusiform with 41 dorsal annuli and the latter without microtubercles.

Ventral region: Ventral annuli 67, each with an average number of 13 small microtubercles. Genital cover flap absent, genital setae 13.1 µm long. Lateral setae 18.2µm long and set on 5th ring. Ist ventral setae 30 µm long, inserted on 18th ring; IInd ventral setae 12.8µm long and set on 42nd ring; IIIrd ventral setae 10.4 µm long and placed on 6th ring from rear. Caudal setae 30.1µm long. Telosome with very minute accessory setae. Coxae smooth, coxal setae I, II & III being 5.6, 15. 9 and 19.9 µm long respectively. Forelegs 23.2 µm long and hindlegs 21.5µm long. Feather claw 5.4 µm long and 4 rayed.

Adult female (Plate 33, Fig. a – g)

Length: 212.3±1.414µm

Width: 82.4±0.897µm

Dorsal region: Gnathosoma 24 µm long and 32.4 µm wide, rostrum projecting downwards. Prodorsal shield with median, admedian and submedian lines, the latter complete and form an anterior triangular pattern. Prodorsal setal tubercles set ahead of rear margin, setae directed posteromedially, 9 µm long and 25.2 µm apart from each other. Opisthosoma fusiform with 48 numbers of broader dorsal annuli , the latter without any microtubercles .

Ventral region: Ventral annuli 83 in number, each with an average of 18 microtubercles. Genital coverflap granulated anteriorly and with 11 longitudinal lines posteriorly, Genital setae 18 µm long and 23 µm wide apart from each other. Lateral setae 32 µm long, and inserted on ring 12. Ist ventral setae 43 µm long, placed on ring 30; IInd ventral setae 18. 9 µm long and seen on ring 51; IIIrd ventral setae 14 µm long, set on the 7th ring from the rear. Caudal setae 40 µm long, placed on ring 78 . Telosome with minute

accessory setae. Coxae smooth, coxal setae I, II& III being 8.3 µm, 20µm and 26 µm long respectively. Forelegs 28 µm long and hindlegs 24 µm long. Feather claw 6.2 µm long and 4 rayed.

Adult male

Length: 184.5±1.231µm

Width: 73.2±1.093µm

Male comparatively smaller than the female but greatly resembles the latter in all morphological details except in the genital features. Genitalia 10 long, 17 wide, eugenital setae 15 long.

Table 85: Measurements of life stages *Phyllocoptruta merremiae* sp.nov.

Life stages									
Sl. No.	**Egg**	**I nymph**		**II nymph**		**Adult female**		**Adult male**	
	Diameter	legth	width	legth	width	Legth	width	legth	Width
1	43	116	56	161	54	209	84	182	78
2	42	113	54	157	57	214	88	183	75
3	43	111	58	164	58	211	79	189	71
4	41	114	56	163	53	204	81	189	76
5	41	105	59	161	56	210	82	183	75
6	40	111	53	163	54	216	82	179	77
7	42	110	60	156	61	219	84	188	71
8	41	108	59	163	60	215	78	183	68
9	40	106	58	159	58	209	82	180	72
10	43	113	58	162	54	216	84	189	69
Mean	41.6	110.7	57.1	160.9	56.5	212.3	82.4	184.5	73.2
Standard Deviation	1.173	3.529	2.282	2.726	2.758	4.473	2.836	3.894	3.457
Standard Error Mean	0.371	1.116	0.721	0.862	0.872	1.414	0.896	1.231	1.093

CHAPTER XI
DISCUSSION

The association of herbivorous arthropods with their host plants generally would lead to the development of highly complex and reciprocal types of interaction and which have been well studied in the case of native plant species whereas the invasive plants still represent a very poorly explored group. Such type of intimate association often leads to the development of extreme sort of host specificity and the intensity of which shows tremendous variation among the different groups of herbivorous arthropods. Accordingly, certain groups have developed extreme host specificity to feed on a single host species, some are adapted to feed on related taxa while the others show wide host range to thrive on varied food plants (Futuyma, 1983; Jaenike, 1990; Mitter and Farrell, 1991; R'Kha *et al*., 1991; Novotny *et al*., 2002a, b; Dyer *et al*., 2007). Among the plant feeding arthropod groups, mites, especially the eriophyoid mites represent a group with smallest size, exhibiting dynamic interactions with their host plants, and accordingly have been categorized variously as crop pests, vectors of phytopathogenic diseases and also more recently, as promising candidates in the biocontrol of weeds (Lindquist *et al*., 1996; Oldfield, 2005). Regarding the latter aspect, an increasing interest has been developed to exploit the potential of these mites in the control of weeds and other invasive harmful plants, primarily based on their supreme adaptive features like their highly restricted host range, ability for wind dispersal, ability to cause damage to the vegetative and reproductive parts of their hosts and thereby leading to a general weakening of the plant growth and retardation of vigor. Although there is much information on the adverse impact of these mites on their respective hosts, there is a considerable lacuna of knowledge on the biological aspects of these mites and their feeding

impact on the target weeds and this is especially true in Kerala as well as India which totally lacks any information on the above parameters. In this context, the present investigation was undertaken with an intention to gather information on the faunal composition and diversity of mites associated with the most harmful invasive plants of Kerala and to elucidate details of feeding and breeding parameters of a few selected species associated with the most troublesome weeds like *C. odorata, L. camara, A. leptopus* and *M. vitifolia*. Apart from the above, the study also helped to identify the optimum temperature-humidity combinations which could support the maximum fecundity and shortest developmental duration of the selected species of mites mentioned above, on their respective host plants. It is hoped that the findings gathered through the present study would serve as a platform to initiate further attempts involving the mass rearing of the species for subsequent field release against the noxious weeds, in future.

Results of the present study revealed the association of 124 species of mites belonging to 50 genera, 21 families and 3 orders with the 25 species of invasive plants screened, with the exception of *M. diplotricha* , the latter was found deprived of any faunal associates. The mite fauna associated with the invasive plants was found to include exclusively phytophagous prostigmatid mites representing two superfamilies *viz.* Tetranychoidea and Eriophyoidea. All the tetranychoid species were proved to be phytophages, inflicting varied types of injuries like chlorosis, yellowing, bronzing and so on. The damage symptoms induced by these mites were found much more pronounced than that of the eriophyoid mites, and even then they were not considered for detailed biological studies on the feeding and breeding parameters, considering their highly polyphagous nature, on a number of host plant species. Tetranychoid mites have already been ranked as highly polyphagous crop pests and species like *T. urticae, T. ludeni, T. neocaledonicus, B. phoenicis, R. indica* etc. were reported to enjoy a wide host range, on diverse

types of flora representing varied economic categories (Jeppson *et al*., 1975; Kumari and Sadana 1990; Chiavegato and Kharfan 1993; Bolland *et al*., 1998; Zhang, 2002; Childers *et al.,* 2003a; Dermauw *et al*., 2013). The results of the present study also provided ample evidence to prove the polyphagous nature of tetranychoid mites and thereby supporting the earlier findings.

The members of the superfamily Eriophyoidea collected during the study were found to comprise 12 species including three new species *viz. E. antigonus* sp. nov. *E.camarae* sp.nov. and *P. merremiae* sp. nov., recognized under eight genera. Irrespective of the variations in the genus or geographical locality screened, all the eriophyid species were found to exhibit high host specificity, restricting their association with a single species of invasive host plant. Eriophyoids, represent an obligatory plant feeding group and unlike other plant feeding mites, are specialized with several unusual morphological, biological and behavioural traits (Skoracka *et al*., 2010). With the possession of various desirable features like the high degree of host plant specificity, high reproductive potential coupled with shorter generation time, wide dispersal rate over wind, ability to cause potential damage to the vegetative and reproductive parts of respective host plants etc., these mites have been ranked as the most ideal candidates in the classical weed control programmes (Rosen and Huffaker, 1983; Rosenthal, 1983; Briese and Cullen, 2001; Skoracka *et al*., 2010; Smith *et al*., 2010). The exceeding level of host specificity of these mites is well evident as 80% of the total 4000 species of eriophyoids described so far, limit their association with a single species of host plant, 95% subsist on host plants belonging to a single genus, and 99% thrive on host plants belonging to a single family (Skoracka *et al*., 2010). Despite the above favourable features which could enhance their suitable application in weed control, only a very few species of eriophyids have been evaluated properly so far, for their successful introduction against target weeds (Smith *et al*., 2010) and much of the species are yet to be evaluated. In

the above context, giving priority to the host specificity shown by these mites and the lacuna of biological information on this group of mites infesting invasive plants and weeds, four species including three novel species were selected for detailed studies on their feeding damage as well as developmental durations on their respective species of very common and widely occurring notorious invasive hosts. Selection of these mites was done purely based on their high host specificity as well as the notorious nature of their respective host plants. Therefore in the present study, attention was focused to gather information on the feeding and breeding attributes of the selected species of eriophyid mites under selected combinations of temperature-humidity conditions.

Of the 12 species of eriophyoid mites collected during the study, four species which induced considerable levels of damage symptoms such as erinea formation, russetting, feeding punctures, chlorotic spots, stipplings, yellowing, leaf rolling etc. on four species of highly notorious invasive weeds were selected for making detailed observations on their feeding and breeding attributes by adopting qualitative and quantitative measures. Three out of the four species selected represented new species *viz. E. antigonus* sp. nov., *E. camarae* sp.nov. and *P. merremiae* sp. nov. infesting the invasive plants, *A. leptopus, L. camara* and *M. vitifolia* respectively. The remaining one species was *A. adoratus,* which showed infestation on the most troublesome terrestrial weed, *C. odorata*. Results of field cum laboratory studies clearly revealed that among the four selected species of eriophyid mites mentioned above, three species with the exception of *A. adoratus* could be considered as leaf vagrants while the latter species was an erineum inducer (McFadyen, 1995; Muniappan and Bamba 2000; Muniappan *et al.,* 2005; Zachariades *et al*., 2009). The taxon Eriophyoidea was reported to comprise mostly vagrant forms of mites (Skoracka *et al*., 2009) and it was recorded that atleast half of all eriophyoid species would possess vagrant life strategy and another half

follow refuge creating or seeking strategy and both strategies might be advantageous to these mites (Petanovic´ and Kielkiewicz, 2010). This was found true in the present study also by revealing three leaf vagrant species out of the four species selected for biological studies. However, despite the general assumption that vagrant forms are less host specific and are generalists, parasitizing on a number of hosts as reported in species like *C. citrifolii, A. schlechtendali* etc. (Kozłowski and Boczek , 1987; Oldfield, 1996; Petanovic´ and Kielkiewicz, 2010), all the three species of leaf vagrants were found limiting their association with a single host species, and could not be recovered from any other host species screened, irrespective of seasonal or geographic variations. Thus the present finding seems to contradict the earlier reports on Eriophyoidea, warranting further investigation through more in-depth studies involving host specificity tests, for confirmation. *A. adoratus* selected for the present study was found to promote the development of glandular hairs, and thereby enabling its inclusion under the category of refuge inducing mite (Sabelis and Bruin, 1996; Westphal and Manson, 1996).

A general preference to colonize and suck sap from the lower surface of host plant leaves was reported among the plant feeding mites including the eriophyoid mites (Jeppson *et al.*, 1975). In the present study also, all the four species of eriophyid mites showed a preference to colonise mainly the lower surface of the respective host leaves, thereby supporting the earlier findings. The preference shown by these mites to the abaxial surface may be a behavioural adaptation to get protection from predators and also over exposure to the adverse climatic factors such as heavy rain, wind etc. Further, the lower laminar surface being rich in trichomes, would serve to provide a firm grip to the immobile life stages like the eggs, quiescent stages etc. of eriophyids, especially the vagrant forms, apart from affording protection from natural predators (Rancic *et al.*, 2006). Similar behavioural adaptations have

been reported earlier in vagrant eriophyid species like *Rhinophytoptus concinnus*, *A. comatus* *Macrotuberculatus bagdasariani* etc. the quiescent stages of which were found hiding in the shafts of leaf trichomes of their respective host plants (Krantz, 1973; Michalska, 2003).

During the present study, the feeding impact of the above four species of eriophyoid mites was assessed on the leaves of their respective host plants, both through qualitative and quantitative means. Of the four species, *A. adoratus* was recognized as an erineum inducer on the most notorious weed, *C. odorata* while the remaining three species were vagrant forms on their respective hosts. The feeding activity of *A. adoratus* was found to induce the development of dense patches of glandular hairs, the so called "erinea" at the sites of infestation, mainly on the lower laminar surface of the terrestrial weed, *C. odorata*. During heavy infestation, large number of erineal patches were found developed on both the surfaces of host leaves. Being an accidentally introduced species showing rapid spread in Asia (McFadyen, 1995, 2002), its infestation could be reported in Kerala also (Ramani, 1998). The mite was found to infest the foliar surface, especially the lower/abaxial surface of the leaves of *C. odorata* where it developed erineal patches of varying size and number and during severe infestation, erineal patches could be observed to extend the entire laminar surface covering both the abaxial and adaxial surfaces of the leaves, thereby supporting the earlier findings (Ramani, 2007). A more or less similar erineum inducing species was reported to be common in Asia and Europe, *viz. A. ilicis* which induced the formation of numerous erineal pockets on the leaves of *Quercus*. However, unlike *A. adoratus*, the erineal pockets produced by *A. ilicis* were found confined to the lower leaf blade of *Quercus* and which were characterized by papillae, the latter joined partially at the base and branched upwards (Keifer, 1969). The erineal pockets of *A. adoratus* appeared simple and the papillae were not joined. Being highly host specific as confirmed through studies at

Trinidad (Mc Fadyen, 1977; Cock 1984), the mite would be considered as a promising candidate to suppress the weed population under field condition.

The feeding activity of the three vagrant species *viz. E. camarae* sp.nov., *E. antigonus* sp. nov. and *P. merremiae* sp. nov. showed great resemblance irrespective of species variation or host plant variation. The life stages of the above three species were found aggregated to form small groups near the mid rib or veins on the lower foliar surface where they initiated feeding activity from selected sites. After feeding at a particular spot for some time, these mites were found moving to adjacent areas in search of new feeding spots. Several such feeding groups comprising the various life stages of individual species were detected on leaves of respective host plants. This observation seems to be in agreement with the earlier findings on the tendency of eriophyoid vagrants to form aggregates on host plants so as to enjoy the benefits of enhanced reproduction, exploitation of resources and escape from predators (Danchin *et al*., 2008; Michalska *et al.,* 2010). The prolonged feeding activity of these mites promoted the development of varied damage symptoms on host leaves such as formation of feeding spots/punctures, russetting, rolling of leaves, yellowing, bronziness and finally leaf drop, as observed during the study. Thus the results of the study served to confirm the earlier record (Rancic *et al*., 2006) on another leaf vagrant species *viz. A. anthocoptes* which induced russeting, bronzing, folding and distortion of the leaf blade and curling of leaf edge on it invasive host, *C. arvense*. Upon infestation on young plants, the above species was reported to induce leaf curling and the whole plant distortion in *C. arvense* (Petanovic´ *et al*., 1997; Ochoa *et al*., 2001).

Vagrant species of eriophyids when exist in low population density will not cause much damage on their host plant, but in high density they are known to induce different types of leaf injuries and malformations. Epidermal

cells injured by these mites often get collapsed and die and repeated attacks in adjacent portions of epidermal cells would lead to various changes on leaf surface like discolouration, bronzing, russeting etc. (Petanovi´c and Kielkiewicz, 2010). Results of comparative histological studies made during the present investigation disclosed disruptions in the cuticle and lower epidermal cells in mite infested leaf sections of all host plants and feeding punctures were seen in the epidermal cells. The present observation thereby confirms the earlier finding on another leaf vagrant species, *A. anthocoptes* infesting the invasive weed, *C. arvense* in which the field infested plants disclosed deformation and quite often complete destruction of the lower leaf epidermis, and epidermal cells were found displaced by scars due to callose deposits (Rancic *et al*., 2006). In the mite infested leaf section of *C. odorata,* the upper epidermis showed the presence of numerous abnormal hair growths, corresponding to the so called 'erinea'. Presence of dense hair growth on the lower epidermis of host leaves developed in response to infestation by vagrant forms of eriophyid mites have already been reported by several workers (Petanovic´ *et al*., 1997; Kozlowski 1998, Rancic *et al*., 2006) which would serve as protective habitat for the mites from natural predators. In the leaf sections infested by vagrant mite species, cuticular layer showed the presence of feeding punctures, both in the upper and lower epidermal cells. The palisade layers of the mesophyll tissue in the mite infested leaves of all the host plants studied were found damaged, presenting reduced number of chloroplast, imparting an yellowish tinge in contrast to the dark green colour of the uninfested leaves. Mite infested leaves showed an yellowish tinge and often appeared bronzed, as evidenced through the field cum laboratory studies, thereby confirming the earlier observation (Newcombe *et al*., 2018) that the sucking activity of leaf vagrants would destroy the spongy mesophyll cells thereby leading to discoloration and bronzing of leaves. The yellow colour is a clear indication of the reduced amount of photosynthetic pigments

and thereby supporting the earlier studies (Geijskes, 1939; Avery and Briggs, 1968) that the punctured cells would lose their potential to participate more in the metabolic processes of host plants, and which in turn would detrimentally affect the health and vigor of the plant. The feeding activity of mites would cause water stress in leaves and that might influence the chlorophyll metabolism of injured cells or due to cell disturbances and chloroplast removal as pointed out by earlier workers (Tomezynsk and Kropzynska, 1985). Many leaf vagrant species of eriophyids are known to induce damage through the hyperplasia of hypodermal and mesophyll cells underlying the damaged epidermis and the continued destruction of epidermal cells would result in desiccation and collapse of mesophyll cells (Royalty and Perring, 1998; Park and Lee, 2002). The results of the current study also seem to be in agreement with the above findings by recording similar cellular deformities like the disruption of cuticle, punctured/collapsed epidermal cells, and reduced number of spongy and palisade parenchyma cells in mite infested leaves. Similar sort of structural degeneration of chloroplast in the palisade and spongy layers of mesophyll tissue and neighbouring tissues was recorded in mango leaves also due to the sucking activity of *C. kenyae* and the mite feeding was found to induce significant reduction in photosynthetic pigments and photosynthetic efficiency of the host plant (Ramani, 2019).

Measurement of chlorophyll fluorescence has been widely used as a tool for many years as a probe to assess the photosynthetic efficiency of plants in vivo (Renger and Schreiber, 1986). The Fv/Fm values of healthy, uninfested leaves usually would fall in the range of 0.778 to 0.860 and reduced Fv/Fm values have been recorded for the leaves of plants which grow under conditions of biotic or abiotic stress (Kawashima and Nakatani, 1998; Schansker *et al*., 2005). The decreased Fv/Fm values recorded during the study in the mite infested leaves of all the four species of host plants, and the differences in the values were found significant upon statistical analysis,

thereby confirming that the mites could impose biotic stress upon their host plants, in turn affecting the normal functioning of the PSII system and thereby significantly reducing their photosynthetic efficiency (Bolhar-Nordenkampf *et al*., 1989; Iatrou *et al*., 1995). Thus the study enabled to provide further confirmation that the feeding activity of eriophyid mites could result in significant reduction in the values of chlorophyll fluorescence as observed in species like *C. kenyae* on *M. indica* (Ramani, 2019), often establishing an inverse relationship between values of chlorophyll fluorescence and increasing level of mite infestation as recorded in the case of spider mites species like *T. urticae* on apple cultivars (Warabieda and Borkowska, 2004) and *Jatropha curcas* (Hsu *et. al*., 2015).

Being the vital photosynthetic pigment in plants, chlorophyll plays a very important role in determining the photosynthetic efficiency and hence the growth of plants (Singsaas *et al*., 2004; Li *et al*., 2018). Quantitative reduction in chlorophyll would exert an adverse impact on the photosynthetic efficiency and a direct relationship exists between the chlorophyll concentration and photosynthetic efficiency of plants. A decrease in photosynthetic activity was recorded earlier in mite infested plants which revealed a reduction in the concentration of chlorophyll pigment (Sances *et al.,*1979; Bondada *et al.,* 1995; Haile and Higley, 2003). The decrease in chlorophyll content might be resulted from the mechanical damage of the chloroplast induced by the feeding of mites and also due to the effect of ROS-mediated lipid peroxidation (Khattab 2007; Sivritepe *et al*., 2009). During the current study, significant reduction of 50.94±1.16%, 47.12±0.97%, 49.26±0.47% and 48.10±0.28% could be recorded in the photosynthetic pigments like chlorophyll a, chlorophyll b, total chlorophyll and carotenoids respectively was induced by *A. adoratus* in *C. odorata*. A similar reduction of photosynthetic pigments (chlorophyll a, b, total chlorophyll and carotenoids) could be recorded in the remaining three species of invasive

plants also, which could be accounted to 50.94±1.16%, 47.12±0.97%, 49.26±0.47% and 48.10±0.28% respectively in *L. camara* infested by *E. camarae* sp.nov., 57.35 ±0.28%, 51.92±0.38%, 55.95 ±0.83% and 51.76±0.61% respectively in *A. leptopus* infested by *E. antigonus* sp.nov. and 58.86±0.42%, 48.81 ±0.76%, 54.97 ±0.43% and 55.07±0.73% respectively in *M. vitifolia* infested by *P. merremiae* sp.nov. This is in accordance with the earlier findings on *A. hibisci* infesting on *Hibiscus vitifolius* (Chakrabarti *et al*., 1999), which induced a percentage reduction of 18.05% and 39.01% in chlorophyll a and b respectively and on *C. kenyae* infesting mango leaves (Ramani, 2019), which induced a percentage reduction of 75.22±9.42%, 85.93 ±9.36%, 77.91 ±9.22% and 48.03 ±8.72% in chlorophyll a, chlorophyll b, total chlorophyll and carotenoids respectively.

Plants exposed to water stress conditions were known to exhibit decreased levels of soluble protein content (Sharma and Dubey, 2005) and the feeding activity of plant mites was shown to induce significant reduction in the total protein, carbohydrate, nitrate and nitrite contents as recorded in mango leaves infested by the eriophyid species like *A. jasmini* infesting jasmine (Vishnupriya *et al*., 2016) and the mango spider mite species like *O. mangiferus* (Ghoshal, *et al*., 2011). Feeding by the false spider mite species, *T. pernicis* was recorded to induce 5.56% protein reduction in guava leaves (Ghoshal and Barman, 2012). The results of the present study also strongly support the above findings by recording significant protein reduction in all the four species of invasive host plants studied in response to eriophyid mite infestation and which could be accounted to 48.58± 0.96 % in *C. adorata* induced by *A. adoratus*, 49.11 ± 0.96 % in *L. camara* induced by *E. camarae* sp.nov., 0.96 ± 1.13% in *A. leptopus* induced by *E. antigonus* sp. nov. and 36.76±1.42 % in *M. vitifoliae* induced by *P. merremiae* sp. nov.

Carbohydrates in plants serve multiple roles as important sources of energy, as skeletons for build up of organic compounds, as signaling molecules, antioxidants etc. and their formation takes place during photosynthesis (Smeekens *et al*., 2010; Keunen *et al*. 2013; Trouvelet *et al*., 2014). Thus they act very efficiently in the mediation of communication systems to co-ordinate metabolic processes associated with the growth and responses to environmental changes (Rolland *et al*., 2002, 2006). So, any factor which adversely affects the photosynthesis and carbohydrate synthesis would exert a negative impact on plant growth. In the present study, all the four species of invasive host plants displayed significant reduction in the total carbohydrate concentration which could be recorded as 59.6± 0.7 % in *C. adorata* induced by *A. adoratus*, 54.7 ± 0.3% in *L. camara* induced by *E. camarae* sp.nov, 38.7± 0.67% in *A. leptopus* induced by *E. antigonus* sp.nov. and 38.5± 0.31% in *M. vitifoliae* induced by *P. merremiae* sp. nov. This observation seems to support the earlier findings made on plants infested by spider mites like *S. chizopus* infesting thorny bamboo (Vibija and Ramani, 2021), false spider mites like *T. cordata* on *E. tiliae* (Boczek, 1974) and *T. pernicis* on guava (Ghoshal and Barman, 2012) and eriophyid mites like *C. kenyae* on *M. indica* (Ramani, 2019) . Thus, the results of the present study very clearly brought out the potential of four species of eriophyid mites including two new species in inducing drastic reduction in the protein and carbohydrate contents of their respective notorious invasive weeds, and thereby adversely affecting the metabolic processes and growth. This is infact encouraging to think in terms of the possible exploitation of these mites for suppression of the weed populations in the nearby future after conducting adequate field trials.

In response to the stress conditions induced by various biotic and abiotic factors, plants produce secondary plant products such as phenolic compounds, proline etc. as a part of their defense mechanism to overcome the

stress (Harborne, 1980). Accordingly, plants produce elevated levels of the amino acid proline , which plays a major role to resist the biotic or physical stress (Kuznetzov *et al*., 1999). In the present study, all the four species of host plants revealed increased quantities of secondary metabolites *viz.* proline and total phenol in response to the biotic stress resulted from the feeding activity of the four species of eriophyid mites. The quantitative increase in proline recorded during the study was 60.9±0.17% in *C. odorata*, 71.4±0.34% in *L. camara*, 60.8 ±0.06% in *A. leptopus* and 64.7±0.71% in .*M. vitifolia* thereby providing a clear evidence of biotic stress induced by respective species of eriophyid mites. The present study thus seems to be in support of the earlier findings on *A. olearius* and *A. oleae* (Çetin *et al*., 2011) and *Epitrimerus gibbosus* (Shi and Tomczyk, 2001). Further, the increased levels of secondary metabolites in eriophyid mite infested leaves were found to afford protection to these mites against parasites, predators and other competing plant feeders (Cornell, 1983; Taper *et al.*, 1986; Mound, 1994; Hartley 1998). A similar feeding impact leading to increased production of phenolic compounds was recorded in spider mite species like *O. mangiferus* on mango leaves (Ghoshal, *et. al*., 2011) and false spider mite species like *T. pernicis* on guava (Ghoshal and Barman, 2012) also thereby confirming the biotic stress induced by plant mites, irrespective of variations in taxa or host plants.

The feeding punctures produced by plant mites in the cuticular and epidermal layers of host plant leaves would permit water reduction, which in turn would impose heavy stress in host plants (Walsh, 2001). This was found true during the present study also as all the four species of host plants experienced significant reduction in moisture content and which could be recorded as 17.09 % in *C. odorata*, 16.25% in *L. camara*, 13.67% in *A. leptopus* and 17.21% in *M. vitifolia* due to the feeding by *A. adoratus*, *E. camarae* sp. nov., *A. leptopus* sp. nov. and *P. merremiae* sp. nov. respectively.

This seems to be in agreement with the earlier finding on the coconut infesting eriophyid mite, *A. guerreronis* which induced a percent reduction of 15.1% in the moisture content of coconut (Vishnupriya *et al*., 2017).

ATR-FTIR analysis has been used as a tool now-a-days to understand the alterations in the leaf functional groups as a result of infestation by herbivores. The spectral bands obtained from vibrational spectra are specific and would help in providing direct information about the biochemical composition (Movasaghi, 2007). The result of the ATR-FTIR analysis carried out during the study revealed the alterations in the functional groups of mite infested leaves of all the four species of invasive hosts studied, as revealed through the differences in the size of the peaks. The number of functional groups recorded between the wavelengths of 500-4000 cm^{-1} showed a reduction owing to mite infestation in all the four species of host plants studied. In the uninfested leaves of *C. odorata,* presence of 28 functional groups was recorded whereas mite infested leaves showed a much lesser number, like 13 between the wavelength of 500-4000 $cm^{-1.}$ Similarly, the uninfested leaf of *L. camara* showed the presence of 27 functional groups while only 19 functional groups could be recorded in mite infested leaves. In the remaining two species of plants, not much drastic changes in functional groups were recorded, though the mite infested leaves showed a reduced number of functional groups between the wavelength of 500-4000$cm^{-1.}$ The functional groups recorded in the leaves of the host plants included alkanes, alkenes, amines, alkyl halide, aldehyde, amides and alcohol groups. The peak size showed variation with respect to differences in functional groups and some of them had highest peak range. Strong peak characteristics also showed variation in the mite infested and uninfested leaves of all the host invasive weeds studied. The results of these studies were in confirmation with the earlier findings made on the gall mite, *A. pongamiae* infesting *Pongamia*

pinnata, the spectral analysis of which also presented some unique absorption peaks (Anand and Ramani, 2021).

During the current study, observations were also made on the developmental biology of the four species of eriophyid mites mentioned above to collect information on the duration of individual life stages as well as total duration of life cycle under four combinations of temperature and humidity conditions such as 20±2^{0}C & 90±5%RH, 25±2^{0}C & 80±5%RH, 30±2^{0}C & 70±5%RH and 35±2^{0}C & 60±5%RH. The above combinations of physical factors were selected for biological studies with an intention to find out the optimum conditions which could support the maximum fecundity, shortest duration of development and the maximum rate of development so as to explore the possibilities for their mass rearing in future, for evaluation of their biocontrol potential. Results of postembryonic developmental studies of the four species of eriophyid mites under four sets of temperature- humidity combinations revealed that 30±2^{0}C and 70±5%RH was the ideal temperature-humidity combination which supported faster development of all the species with enhanced fecundity and minimum durations of immature stages. A more or less similar result, but with a slightly lowered temperature was reported earlier in other eriophyid species such as the citrus rust mite, *P. oleivora* which attained optimum growth at 26^{0}C and 75%RH (Swirski and Amitai, 1957), the tomato russet mite, *V. lycopersici* which showed shortest life cycle at 27.6^{0}C and 30% RH (Rice and Strong, 1962) and *C. carinatus* with shortest life cycle at 29^{0}C (Das and Sengupta, 1962). The present result seems to be in complete agreement with the results of biological studies carried out in Egypt (Abou-Awad *et al*., 2005), on two eriophyid species infesting olive *viz. A.oleae* and *Tegolophus hassani* , the oviposition period of both the species was shortest at 20 ^{0}C and 50 % R.H, while it was the longest at 31^{0}C and 80 % R.H. The mean duration of pre-oviposition period was 04.60 ± 0.24, 03.00 ± 0.44 and 01.80 ± 0.20 days; oviposition period was 07.60 ± 0.50,

10.00 ± 0.31 and 10.40 ± 0.24 days; post-oviposition period was 03.40 ± 0.50, 02.20 ± 0.20 and 01.40 ± 0.24 days; total life span was 29.46 ± 0.19a 24.59 ± 0.43b 20.18 ± 0.37 days and total fecundity was 07.40 ± 0.81a 15.00 ± 1.30b 21.40 ± 1.40 days at 20 ± 1 & 50 % , 25 ± 1 & 70 % and 31 ± 1 & 80 % respectively. The average duration of the pre- oviposition period in *T. hassani* was 04.40 ± 0.40, 03.20 ± 0.02 and 02.00 ± 0.31 days; oviposition period was 07.40 ± 0.24, 09.80 ± 0.37 and 08.40 ± 0.50 days; post-oviposition period was 03.00 ± 0.01, 02.20 ± 0.20 and 02.00 ± 0.31days; total life span was 29.95 ± 0.20, 25.13 ± 0.56 and 19.72 ± 0.37 days and total fecundity was 05.60 ± 0.95, 11.20 ± 0.37 and 14.20 ± 1.06 days at 20 ± 1 & 50 % , 25 ± 1 & 70 % and 31 ± 1 & 80 % respectively. A more or less similar result as that of the present study was evident in the case of *F. perrepae*, a potential biocontrol agent of the invasive weed, *Lygodium microphyllum* which required 8.9 ± 0.1 and 7.0 ± 0.1 days for the development of immature and the adult longevity recorded was 30.6 ± 1.6 and 19.4 ± 1.2 days.

During the present study, the durations of the various developmental stages of the erineum inducing mite on *C. odorata viz. A. adoratus* such as the egg, I nymph, I quiescent phase, II nymph, II quiescent phase and total duration were recorded as 5.25±0.4, 3.41±0.07, 2.51±0.05, 4.59±0.07, 2.54±0.02 and 18.3±0.15 respectively at 20±2^{0}C and 90±5%RH; 4.54±0.08, 3.21±0.05, 2.2±0.06, 4.3±0.06, 2.3±0.09 and 16.55±0.25 respectively at 25±2^{0}C and 80±5%RH; 3.82±0.02, 2.88±0.03, 1.85±0.02, 3.73±0.38, 1.73±0.03 and 14±0.06 respectively at 30±2^{0}C and 70±5%RH; 4.47±0.06, 3.29±0.05, 2.39±0.03, 4.34±0.05, 2.5±0.03 and 16.99±0.14 respectively at 35±2^{0}C and 60±5%RH. Life cycle studies made on *A. adoratus* infesting the weed, *C. odorata* under laboratory conditions earlier at 23±2^{0}C and 70% in Kerala (Ramani, 2007) revealed the durations of the egg, I nymph, I quiescent phase, II nymph and II quiescent phase as 4-6, 3-4, 2-3, 4-5 and 2-3 days respectively and the total duration of F1 generation was recorded as 18- 22

days respectively. A temperature range of 28-30^{0}C was recorded as favourable for the development of *A.vitifoliae* also, as it completed development from egg to adult within 13-16 days on the leaves of the host plant, *H.vitifolius* (Sheela and Haq, 2010). Results of studies on the life cycle of the coconut mite, *A.guerreronis* carried out at three temperatures like 20^{0}C, 25^{0}C and 30^{0}C revealed that the species completed its life cycle with in 16, 11.5 and 8.1 days respectively with the optimum temperature being 33.6^{0}C and the maximum temperature being 40^{0}C (Ansaloni and Perring, 2004). This was found true in the present study also by proving 30±2^{0}C along with 70±5%RH as the ideal combination of temperature and relative humidity for all the four species of eriophyid mites. Biological parameters of two eriophyid species infesting mango trees *viz. A. mangiferae* and *Metaculus mangiferae* when studied in Egypt revealed that the female life-cycle lasted for a period of 6.29, 4.90 and 4.44 days at 25, 30 and 35 ^{0}C, respectively (Abou-Awad *et al*., 2011). In the current study the maximum number of eggs laid per female of *A. adoratus, E. camarae* sp.nov., *E. antigonus* sp.nov. and *P. merremiae* sp.nov. was at 30±2^{0}C and 70±5%RH, the rate of fecundity recorded being 23.5±1.014, 19.3±0.817, 15.6±0.305 and 26.1±0.888 respectively in *A. adoratus*, *E. camarae* sp.nov., *E. anigonus* sp. nov., and *P. meremiae* sp.nov. This is a clear evidence for the influence of temperature-humidity conditions on the biotic potential of plant mites as already reported in other species of eriophyid mites like the tomato russet mite, *V. lycopersici* which showed the fecundity rate in the range of 10 – 53 depending upon the prevailing environmental conditions (Rice and Strong, 1962) and *F. perrepae*, a biocontrol agent of the invasive weed, *L. microphyllum* in Australia in which the mean rate of fecundity was 54.5 ± 3.2 at 21^0 C and 38.5 ± 1.6 eggs at 26^0 C (Ozman and Goolsby 2005).

The life history of all eriophyid mites generally include five developmental stages such as the egg, I nymph, I quiescent phase, II nymph

and II quiescent phase before reaching the adulthood and each quiescent stage is terminated by moulting (Hassan, 1928; Keifer, 1952). This was found true in the present study also, as all the four species had two active nymphal instars and two quiescent instars before reaching the adult stages.

Thus the biological observations made during the present study by focusing on the feeding and breeding attributes of four species of eriophyid mites infesting four species of noxious terrestrial weeds like *C. odorata, L. camara, A. leptopus* and *M. vitifolia* provided encouraging results to think of their possible use in managing the invasive weeds after properly evaluating their host specificity under laboratory cum field conditions. It is well known that feeding activity of eriophyids would result in varied types of malformations such as stunting, gall formation, chlorosis, leaf curling and rolling, russeting, stippling, witches broom effect, reduced length of internodes, reduction in fruit and seed production and so on (Cullen and Briese, 2001) and thereby reducing the vigour and growth of their host plants. The above significant impact on host plants coupled with their very narrow host range make these mites as ideal candidates for biological control of weeds (Andres, 1982; Rosenthal, 1996; Cullen and Briese, 2001) and this potential has been taken up by many to undertake progressive research work to utilize them for the control of invasive plants and weeds. As a result, several species of eriophyid mites have been used currently in biological control programs against weeds which include species like *A. acroptiloni* (Kovalev, 1973); *A. chondrillae* (Sobhian and Andres, 1978; Cullen *et al*., 1982; Boldt and Sobhian, 1993); *A. malherbae* (McClay *et al*., 1999; Michels *et al.,* 2000); *A. hyperici* (Willis *et al.,* 1995; Mahr *et al*., 1997); *P. nevadensis* (Littlefield and Sobhian, 2000) and *Phyllocoptes fructiphilus* (Amrine, 1996).

Several critical areas have been identified by many workers to be addressed in future research programmes, giving priority to gather information on behavioural aspects, testing of host specificity, and evolutionary stability of eriophyid mites. As a very preliminary attempt on the above points, in the present investigation, life history studies of four species of eriophyid mites including three new species were carried out in order to contribute more on the critical areas identified by earlier workers for future research. Further, the impact of different combinations of temperature-relative humidity on the above four species was also assessed to identify the most optimum conditions which support highest fecundity, shortest life cycle and hence the maxium population density of each species. It is hoped that the above studies would be useful for future workers to conduct mass rearing of the species for exploring the possibilities of introducing them to suppress the populations of their respective invasive weed hosts. All possible efforts need to be undertaken to maintain the encroaching invasive weed populations in a manageable level, as this has become a major threat to the existing biodiversity, ecosystem processes, environment as well as animal health. Hence protection of biodiversity and ecosystem processes has become the need of the hour and the present work was undertaken to gather information on the basic aspects of faunal composition of mites associated with selected troublesome invasive plants, population studies of selected species of mites, their injurious status on respective weed hosts and developmental studies at different temperature-humidity conditions so as to provide data on the optimum conditions to conduct mass rearing of the species in future, for their exploitation in weed control programmes.

CHAPTER XII

SUMMARY

Invasive plants attracted global attention, due to their significant negative impact on the ecosystem processes, biodiversity, environment and animal health. In India, over 1500 species of invasive alien plants are known to be imported to meet various purposes and their introduction was either accidental or intentional. Like all other plants, invasive plants also harbor a rich diversity faunal ingredients dominated by Arthropods, playing multiple roles like pests, parasites, predators and so on. Among the arthropods, insects and mites constitute the major biodiversity component, serving a variety of roles. Of these, scattered informations are available related to the functional impacts of insects on these plants, but still remains as a very poorly explored aspect as far as the faunal diversity and roles of mites on them, especially in developing countries like India. In Kerala, practically no information is available on mites inhabiting the invasives, though many species have enough potential to induce significant damage to the most notorious weeds like *Eichhornia crassipes, Lantana cmara, Chromoaena odorata* etc. In this context, the present study was undertaken with an intention to gather information on the faunal diversity of mites, description of the total species recovered, molecular characterization of new species, impact of seasonal and geographical variations on population distribution of selected species, the injurious status of selected dominant and injurious species of eriophyid species through qualitative and quantitative studies on feeding damage induced by them on their respective host plants, postembryonic development of the injurious eriophyid species under varied temperature - humidity combinations etc. The present study forms the first attempt to reveal the faunistic composition of the diverse taxa of mites associated with weeds, and

its sheds light on the systematic position and description of all species with appropriate photographs and drawings along with data on the diversity indices, population fluctuation with respect to climatic factors, molecular barcoding and phylogenetic analysis of a selected new species of highly host specific species of eriophyid mite. All the above lines of studies are included in Part I of the thesis. Besides these, the thesis also sheds light on the feeding and breeding parameters of selected dominant species with potential to induce significant levels of injury on their respective notorious invasive weed hosts.

For studying the faunal diversity of mites associated with invasive plants, 25 species of noxious invasive plants belonging to 25 genera and 12 families were surveyed from 88 localities distributed over 12 districts of Kerala, for a period of five years from 2015-2019. The leaf samples from the above 25 species of invasive plants growing under field conditions and were brought to the laboratory for examination under a stereo zoom microscope to locate the associated mite species. The collected specimens were preserved in 70 % alcohol, processed and mounted in Hoyer's medium for taxonomic studies following identification keys and relevant literature. The measurements of the recovered species were taken using a research microscope (Zeiss-Scope.A1, based on Zen 2.5 lite software) and taxonomic descriptions were made. Drawings of morphological features of the new species collected during the study were made with the help of a drawing tube attached to the research microscope (Nikon Eclipse-80i).

Results of the taxonomic studies enabled to identify 124 species of mites belonging to 50 genera and 22 families categorized under three orders *viz.* Mesostigmata, Trombidiformes and Sarcoptiformes and two superorders *viz.* Parasitiformes and Acariformes. The dominant group of mites recovered during the study was from the order Trombidiformes with 65 species belonging to 33 genera, 14 families and eight superfamilies. Order

Mesostigmata was found to comprise 53 species belonging to 12 genera, three families and two superfamilies. Order Sarcoptiformes was the group with the lowest number of species, comprising six species belonging to five genera, five families and five superfamilies. The family Eriophyidae showed the maximum generic representation under the suborder Prostigmata of the order Trombidiformes, followed by Tetranychidae, Tenuipalpidae and Cheyletidae. The remaining families like Bdellidae, Stigmaeidae, Eupodidae, Suidasiidae, Erythraeidae and Eupalopsellidae showed the presence of members of a single genus each. Of the total 124 species of mites recovered during the study, three species of prostigmatid mites belonging to the family Eriophyidae were found new to science, *viz. E. antigonus* sp. nov., *E. camarae* sp. nov and *P. merremiae* sp.nov. The new species were found to inhabit the invasive plants *viz. A. leptopus, L.camarae* and *M. vitifolia* respectively. Six species of mites collected during the study *viz. C. reticulatus, T.kenyensis, H. biconvex, A. magnanalis, A. pristinus* and *L. parberlesei* formed new reports from India, 51 species formed new reports from Kerala and 111 species formed new reports from respective invasive host plants. The results of the study enabled to assign the tenuipalpid member, *B.phoenicis* as the species with maximum host range, enjoying distribution on 11 species of host plants *viz. L. camara, C. odorata, A. leptopus, M. vitifolia, S. trilobata, C. hirta, T. procumbens, M. micrantha, C. tora, C. procera* and *L. luecocephala.* The study also disclosed *L. camara* as the invasive plant which supported the maximum species diversity of mites, hosting 35 species of mites followed by *C. odorata* with 32 species. The maximum species diversity of mites could be recorded from invasive hosts growing in the Malappuram Dt. by revealing 78 species and the lowest mite diversity was recorded from host plants collected from the Kasaragod Dt., showing only five species. The mites showed a general tendency to get distributed on the lower or the adaxial surface of host leaves,

adjacent to the midrib and leaf veins. However, when the population of mites attained peak levels, they were found to colonise both surfaces of leaves.

Evaluation of the species diversity indices of mites collected from the various geograpgical localities distributed over three district of Kerala *viz.* Malappuram, Kozhikode and Palakkad were carried out based on different population parameters *viz.* species richness, evenness, Shannon-Wiener Diversity Index and Simpson's Index of Diversity (Magurran 2004).

A higher diversity index (H′) was observed in the Malappuram Dt. (H′-2.94906) followed by Palakkad Dt. (H′-2.90259) and Kozhikode (H′-1.52363). The maximum species richness was recorded in the Malappuram Dt. (10.0002) followed by Palakkad Dt. (7.1953) and the minimum richness was observed in the Kozhikode Dt. (4.155752). Species evenness was high in the Palakkad Dt. (0.73108) followed by Malappuram Dt. (0.6769) and it was minimum in the Kozhikode Dt. (0.44367).

Molecular phylogenetic analysis of the new species of eriophyid mite, *E.camarae* sp.nov. was carried out using Neighbor-Joining method and Maximum likelihood method. The nucleotide sequences of *E. camare* sp. nov. were found to be the first record and were deposited in Gen Bank and NCBI. The deposition was provided with an accession number MW748222. *E.camarae* sp.nov. showed variation in the total composition of nucleotides in each of the position of codons in comparison with other related species isolated from different geographical localities. Analyzing all the facts, this species appeared different from all the other related species and hence could be assigned as a new taxon.

During the study, four species of highly host specific eriophyid mites *viz. A. adoratus*, *E. camarae* sp. nov., *E. antigonus* sp. nov. and *P. merremiae* sp. nov. inhabiting on respective invasive host plants *viz. C. odorata*,

L. camara, *A. leptopus* and *M. vitifolia* were selected for a period of one year, from September 2016 to August 2017 for detailed studies on their population density in relation to climatic factors. Data procured on the population density of the above four species were correlated with the meteorological data such as temperature, relative humidity, rainfall and wind velocity procured from the Centre for Water Resources Development and Management (CWRDM), Kozhikode. Results of the study revealed a significant positive correlation between mite population and temperature as well as wind velocity, whereas a negative correlation was recorded between mite population and relative humidity as well as rainfall.

Detailed studies on the biological parameters of four species of host specific eriophyid mites *viz. A. adoratus, E.camarae* sp. nov., *E.antigonus* sp. nov. and *P. merremiae* sp. nov. infesting on respective invasive host plants *viz. C.odorata*, *L.camara*, *A. leptopus* and *M. vitifolia* were carried out and the details of which have been presented in Part II of the thesis. The feeding impact the above species of eriophyids on respective plants was assessed through qualitative as well as quantitative studies. Qualitative studies were based on the visual assessment of physical damage symptoms induced by individual species on the leaves of the host plants and also by comparative evaluation of the anatomical changes present in thin stained leaf sections prepared from mite infested and uninfested leaves of respective host plants. In addition the alterations induced in the functional groups of host leaves as a result of feeding activity of the above four eriophyid species on their respective host plants were also studied using Fourier Transform Infrared Spectrophotometer (FTIR). For quantifying the feeding damage, biochemical estimations of photosynthetic pigments like the chlorophyll a, chlorophyll b, total chlorophyll and carotenoids were carried out along with measurement of chlorophyll fluorescence of leaves so as to rate the photosynthetic efficiency of the respective host plants. Further, quantitative assessment of primary and

secondary metabolites of host plants like the concentrations of total carbohydrate, total protein, total nitrogen, total phenol, proline, moisture content etc. was also made during the study. Results of all the quantitative studies were subjected to statistical analysis in order confirm their significance.

Results of visual assessment of damage symptoms produced on respective host plants revealed that out of the four species of eriophyid mites studied currently, one species *viz. A. adoratus* was as an erineum inducer and the remaining three species were vagrant forms. *A. adoratus* induced dense growth of glandular hairs developed as patches, the so called "erinea" at the feeding sites on the leaves of the invasive weed, *C. odorata* , the number and size of erinea showed variation on individual leaves. The erineal patches were mainly confined to the lower laminar surface of *C. odorata* especially on young leaves and tender stems even, and during severe mite infestation, the upper laminar surface also showed mite infestation. In extreme caes, erineal patches were found covering the entire leaf lamina. Feeding activity of *A. adoratus* induced anatomical levels of damage also as evidenced through histological studies. The cuticular layer and lower epidermal cells of mite infested leaves were found punctured and the upper epidermis showed dense growth of abnormal hairs. The palisade tissue of mite infested leaves appeared disrupted broken with damaged chloroplast and reduced amount of chlorophyll. Result of FTIR analysis showed alterations in the functional groups of mite infested leaf samples when compared with those of uninfested samples. Measurement of chlorophyll fluorescence enabled to record a significant reduction in photosynthetic efficiency by recording 17.8% reduction in the value of Fv/Fm. The concentration of chlorophyll 'a', 'b', total chlorophyll and carotenoid pigments showed a significance decrease in the tune of 51.5±0.35%, 57.87±0.47%, 54.03±0.36% and 39.9±1.04% respectively. Mite infested samples leaf samples of *C. odorata* showed a

percent decrease in the total carbohydrate, total nitrogen, and total protein contents in the tune of 59.64±0.70%, 48.59 ± 0.96% and 48.59 ±0.96% respectively and a decrease in moisture content of up to 62.73 ± 0.43% . The concentration of secondary metabolites like proline and total phenol showed a significant increase of 60.93 ± 0.17 and 70.44 ±0.21 respectively in mite infested leaf samples

Feeding activity of *E. camarae* sp.nov. induced the appearance of damage symptoms like small feeding feeding spots and punctures, bronziness, rolling of leaves etc. in *L. camara*. Results of histological studies showed cellular disruptions, damaged chloroplast and reduced amount of chlorophyll. Results of FTIR analysis revealed eight extra vibrations in the mite infested leaf samples when compared with the uninfested samples, thereby confirming the alterations in the leaf functional, as result of mite infestation. The photosynthetic efficiency of mite infested leaves showed a significant reduction of 21.5%. The concentration of chlorophyll 'a', chlorophyll 'b', total chlorophyll and carotenoid showed a significant reduction of 50.94±1.17%, 47.13±0.97%, 49.26±0.47% and 48.1 ± 0.28 % respectively. The percent reduction recorded in the total carbohydrate, total nitrogen, total protein and moisture contents due to mite infestation was 54.77 ±0.34%, 49.11±0.96%, 49.11±0.96% and 67.81 ± 0.41% respectively. The proline and total phenol contents also showed significant reduction in mite infested leaf samples by recording 71.41±0.34 and 71.74 ± 0.28 respectively.

Prolonged feeding of *E. antigonus* sp.nov. induced major feeding damages like the development of small feeding punctures and feeding spots, stipplings, yellowing, bronziness and finally dropping of leaves. Examination of stained sections of mite infested leaves showed disrupted cuticle and lower epidermis, feeding punctures in the upper and lower epidermis, damages cells of vascular bundles, damaged chloroplast and reduced amount of chlorophyll.

FTIR analysis also revealed changes in the functional groups in the mite infested leaf samples of *A. leptopus*. The percentage reduction of photosynthetic efficiency due to mite infestation was 23.6%. The concentration of chlorophyll 'a', chlorophyll 'b', total chlorophyll and carotenoid pigments showed a reduction of 57.35 ± 1.13 %, 51.92 ± 0.38 %, 55.95 ± 0.84 and 51.75 ± 0.61 % respectively. The percentage reduction recorded in total carbohydrate, total nitrogen, total protein and moisture contents owing to mite infestation was 38.71 ±0.68%, 33.07± 1.13%, 33.07±1.13% and 60.84 ±0.06% respectively. The increase in the concentration of secondary metabolites like proline and total phenol recorded during the study owing to mite infestation was 60.84 ±0.06% and 72.26 ± 0.31% respectively.

P.merremiae sp.nov. also was found to induce the formation of small feeding punctures, feeding spots, stipplings, yellowing, bronzing, shrinking and finally dropping of leaves. Leaf sections of mite infested samples revealed the disrupted cuticle, epidermal layers, damaged palisade layer and reduced number of chloroplast cells. FTIR analysis revealed a change in the functional groups due to infestation by *P. merremiae* sp.nov. compared to that of the uninfested leaves. Mite infestation also induced a reduction in the photosynthetic efficiency of the leaves and which was recorded as 23.9%. The concentration of chlorophyll 'a', chlorophyll 'b', total chlorophyll and carotenoid igments also showed significant reduction by recording a reduction of 58.86 ± 0.42%, 48.81 ± 0.76 %, 54.97±0.43% and 55.07± 0.73% respectively. Feeding activity of *P. merremiae* sp.nov. resulted in significant reduction in the concentration of total carbohydrate, total nitrogen, total protein and moisture contents, recorded as 38.49±0.32%, 36.76±1.34%, 36.76±1.41% and 70.96 ± 0.44% respectively. A percentage increase was observed in the proline and total phenol contents , which could be recorded as 64.73±0.71 and 64.44±0.27 respectively.

Studies on the breeding biology of the above four species of host specific eriophyid mites on their respective host plants like *C. odorata, L. camara, A. leptopus* and *M. vitifolia* were also carried out in the laboratory by adopting leaf flotation technique, (Zhang *et.al.,* 1999) . Post embryonic development of each of the above species was conducted in a BOD at four combinations of constant temperature humidity conditions such as 20±2ºC and 90±5%RH, 25±2ºC and 80±5%RH, 30±2ºC and 70±5%RH and 35±2ºC and 60±5%RH. Data were collected on various developmental parameters like the oviposition, fecundity, hatching, moulting and durations various developmental stages such as the incubation peiod, nymphal instars, quiescent stages, pre-oviposition, oviposition and post oviposition periods, adult longevity etc. were recorded and presented in the thesis. The measurements of the various life instars were taken using sage and ocular micrometers. Drawings of the nymphal and adult stages were made with the help of a drawing tube attached to a research microscope (Nikon Eclipse-80i) and the morphological descriptions have been given in the thesis

Results of the postembryonic developmental studies clearly revealed the impact of the varied temperature-humidity combinations of on the durations of individual sages as well as total duration of development of all the species selected. Data recorded on the duration of pre-oviposition period of *A. adoratus* on the leaves of *C. odorata* were 5.09 ± 0.028 days at 20±2ºC and 90±5%RH; 4.21±0.035 days at 25±2ºC and 80±5%RH; 3.04±0.034 days at 30±2ºC and70±5%RH and 3.82 ±0.029days at 35±2ºC and 60±5%RH, with the minimum duration at 30±2ºC and 70±5%RH (3.04±0.034 days).The minimum duration of oviposition was also observed at 30±2ºC and 70±5%RH (8.18±0.047 days) and the maximum was at 20±2ºC and 90±5%RH (10.62±0.049 days). The minimum duration of post-oviposition period was observed at 25±2ºC 80±5%RH (3.27±0.037 days). The maximum number of eggs per female was on the 4th day of oviposition with the mean number being

6.4±0.221 at 30±2ºC and 70±5%RH. Adult longevity was minimum at 30±2ºC and 70±5% RH, and maximum at 20±2ºC and 90±5%RH. The minimum time taken for completion of life cycle of *A. adoratus* on *C. odorata* was at 30±2ºC and 70±5%RH (14±0.058 days) and the maximum was at 20±2ºC and 90±5%RH (18.3±0.153 days).

The minimum duration for pre-oviposition period in *E. camarae* sp. nov. on *L.camara* was also recorded at 30±2ºC and70±5%RH (2.44±0.081) and the maximum was at 20±2ºC and 90±5%RH (4.57 ± 0.1001 days). The oviposition period was of minimum duration at 30±2ºC and 70±5%RH (6.87±0.056 days) and the maximum was at 20±2ºC and 90±5%RH (9.56± 0.194 days). The post-oviposition period was also of the minimum duration at 30±2ºC and 70±5%RH (2.65 ± 0.052 days). The maximum number of eggs laid per female was on the 4th day of oviposition and the number averaged to 5.1±0.378 at 30±2ºC and 70±5%RH. Adult longevity was maximum at 20±2ºC and 90±5%RH (18.01 ±0.126 days) and the minimum was at 30±2ºC and 70±5%RH (11.96± 0.118days). The minimum time taken for the completion of life cycle of *E. camarae* sp. nov. on *L.camara* was at 30±2ºC and 70±5%RH (11.73±0.071days) and the maximum was at 20±2ºC and 90±5%RH (15.52±0.353days).

The minimum duration recorded for pre-oviposition period in *E. antigonus* sp.nov. on *A. leptopus* was at 30±2ºC and70±5%RH (3.01±0.023 days) and the maximum was at 20±2ºC and 90±5%RH (3.5± 0.052 days). The minimum duration for oviposition period was observed at 30±2ºC and 70±5%RH (7.75± 0.043 days) and the maximum was at 20±2ºC and 90±5%RH (9.74± 0.04 days). The duration of post-oviposition period of *E. antigonus* sp.nov.was minimum at higher temperature and maximum at lower temperature. The maximum number of eggs laid per female was on the 4th day of oviposition and the number of eggs averaged to 4.2±0.2 at 30±2ºC

and 70±5%RH. The adult longevity was maximum at 20±2ºC and 90±5%RH and minimum at 30±2ºC and 70±5%RH. The minimum time taken for completion of life cycle of *E. antigonus* sp.nov. on *A.leptopus* was at 30±2ºC and 70±5%RH (10.75±0.052 days) and maximum was at 20±2ºC and 90±5%RH(15.37±0.114 days).

The pre-oviposion period in *P. merremiae* sp.nov. was of minimum duration at 30±2ºC and 70±5%RH (1.64 ± 0.037 days) and the minimum was at 20±2ºC and 90±5%RH (2.7 ± 0.049 days). The oviposition period was minimum at 30±2ºC and 70±5%RH (6.56± 0.037 days) and maximum at 20±2ºC and 90±5%RH (7.73± 0.037 days). The maximum duration for post-oviposition period was recorded at 20±2ºC and 90±5%RH (2.46 ± 0.045 days). The maximum number of eggs laid per female was on the 3rd day of oviposition and the average number of eggs laid was 7.4± 0.30 at 30±2ºC and 70±5%RH. The adult longevity was maximum at 20±2ºC and 90±5%RH (12.89±0.06 days) and minimum at 30±2ºC and 70±5%RH (10.08± 0.029 days). The minimum time taken for completion of life cycle was at 30±2ºC and 70±5%RH (6.64±0.043 days) and maximum at 20±2ºC and 90±5%RH (10.88±0.069 days).

Thus the results of the present study revealed the rich faunal diversity of mites associated with selected species of most common invasive plants of Kerala, by revealing 124 species of mites representing 50 genera and 22 families. Of the collected species, two species of eriophyid mites were found new to science, six species were new reports from India, 51 species were new reports from Kerala and 11 species were new reports from invasive plants. Results of studies on the feeding attributes of four species of highly host specific eriophyid mites including the two new species clearly proved the potential of these mites in inducing significant levels of damage on their respective invasive hosts, thereby indicating the possibilities of exploiting the

potential of these mites as promising candidates for biological suppression of weed hosts, after the conduct of repeated field trials. Studies on the postembryonic development of the above four species of eriophyid mites under four combinations of temperature-humidity conditions enabled to identify the combination 30±2ºC and 70±5%RH as the ideal condition by supporting maximum fecundity and by minimizing the durations of various life instars and total duration of life cycle and thereby promoting the maximum number of annual generations of the mite species. Prior knowledge on the ideal condition for the maximum population build-up of species with high specificity on respective invasive host plants would be highly helpful for future workers to conduct mass rearing of the species for subsequent release in field against target weeds.

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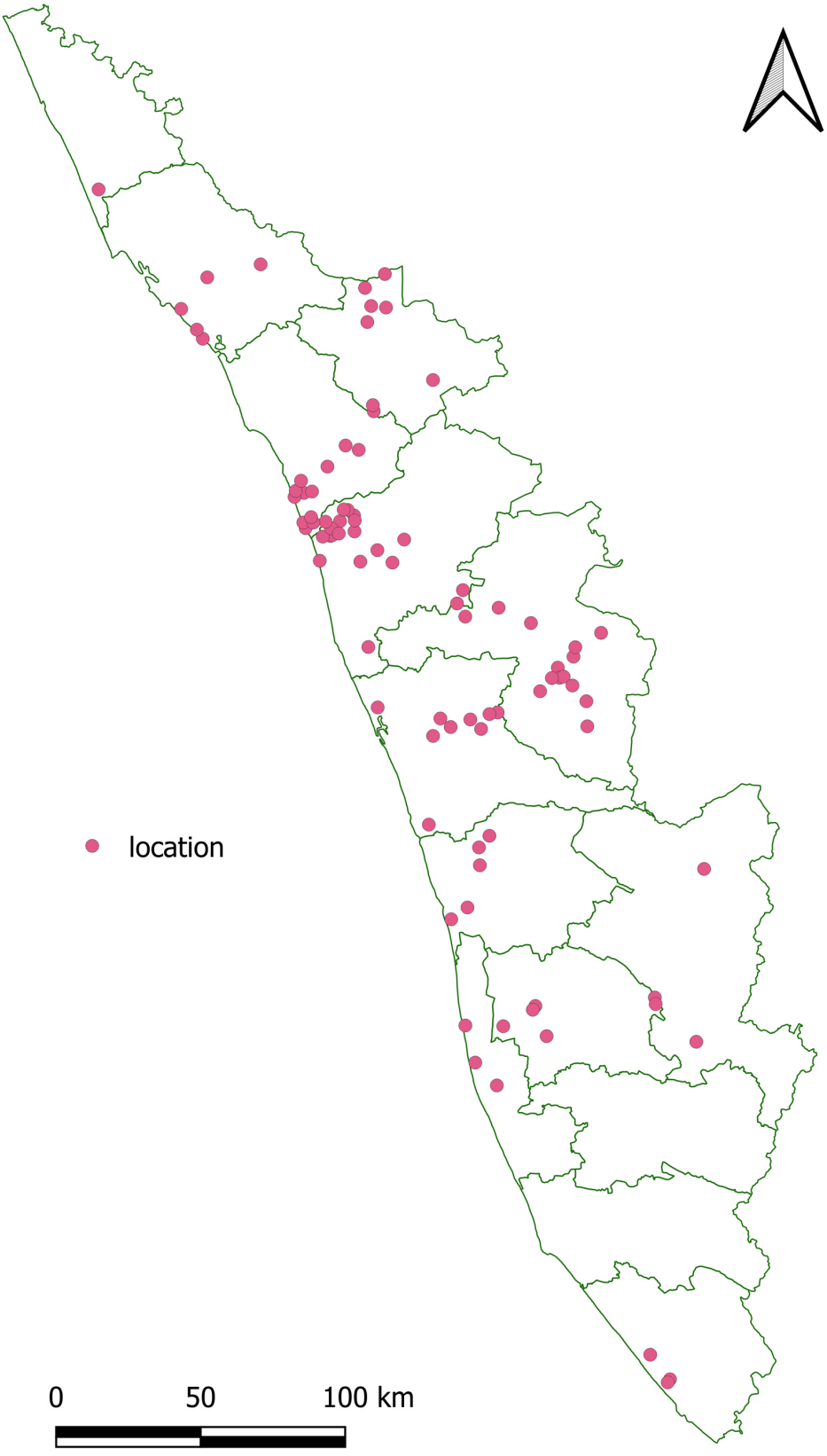


Plate 1: Map of Kerala showing sampling localities distributed over 12 districts

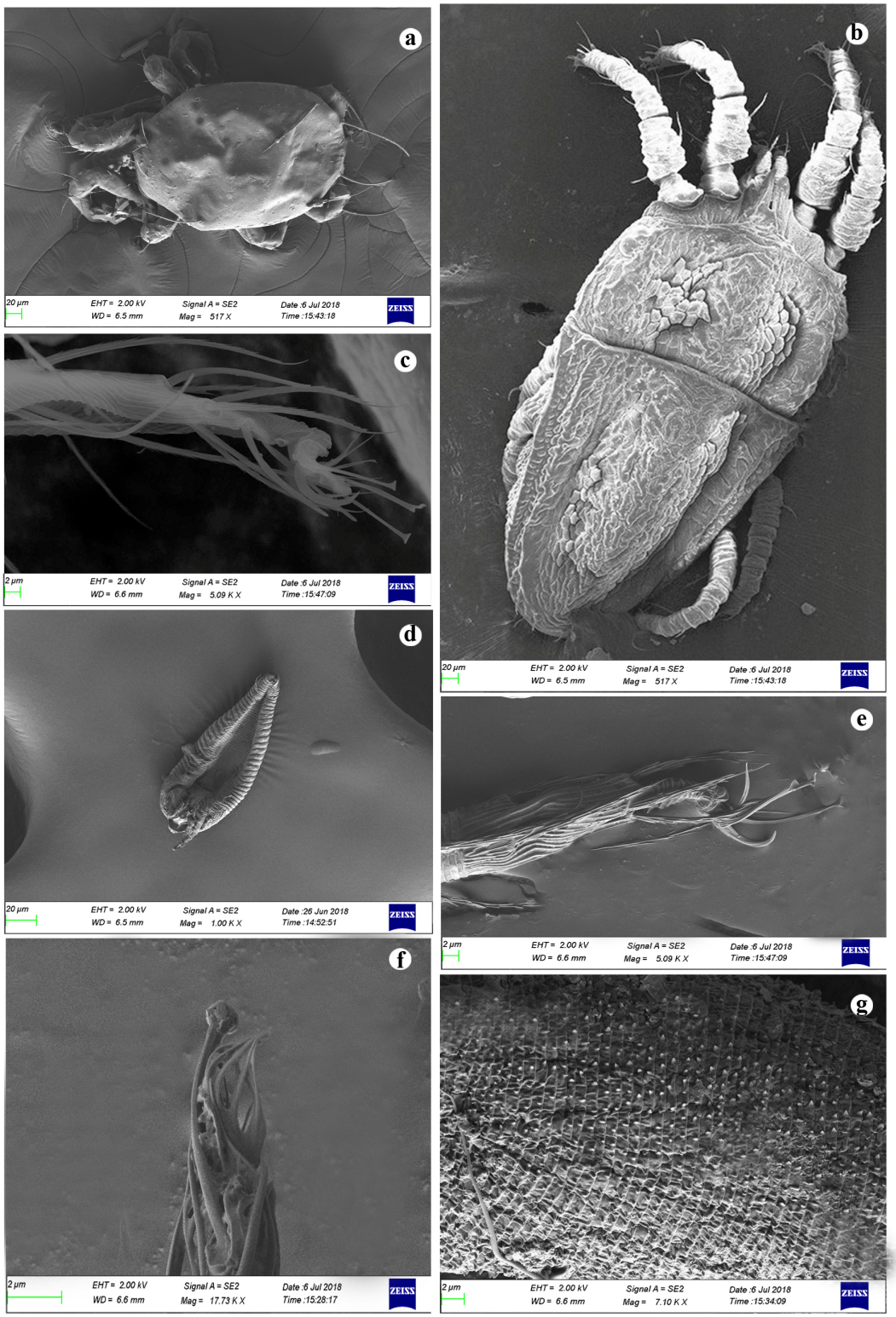
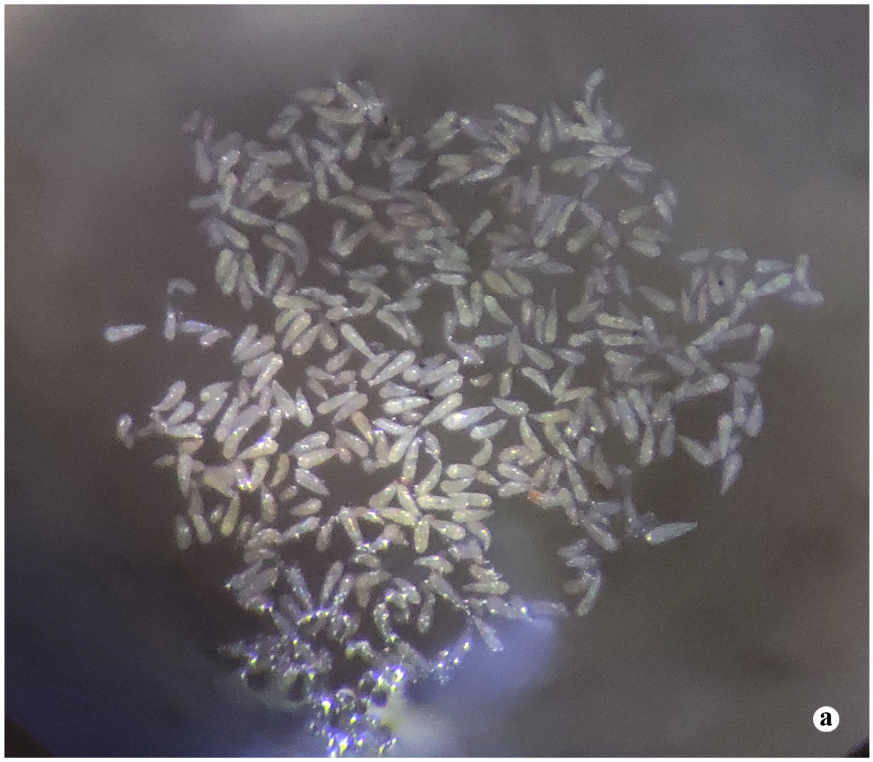


Plate12: SEM pictures of mite species. a. *Amblyseius largoensis* - Dorsal view; **b.** *Brevipalpus phoenicis* - Dorsal view; **c.** *Oligonychus biharensis*- Empodium with tenent hairs; **d.** *Tetranychus urticae* -Empodium with tenent hairs; **e.** *Phyllocoptruta merremiae* sp. nov.- ventral view; **f.** *Eriophyes camarae* sp. nov.- Empodium; **g.** *Eriophyes camarae* sp. nov.- Annuli with Microtubercles



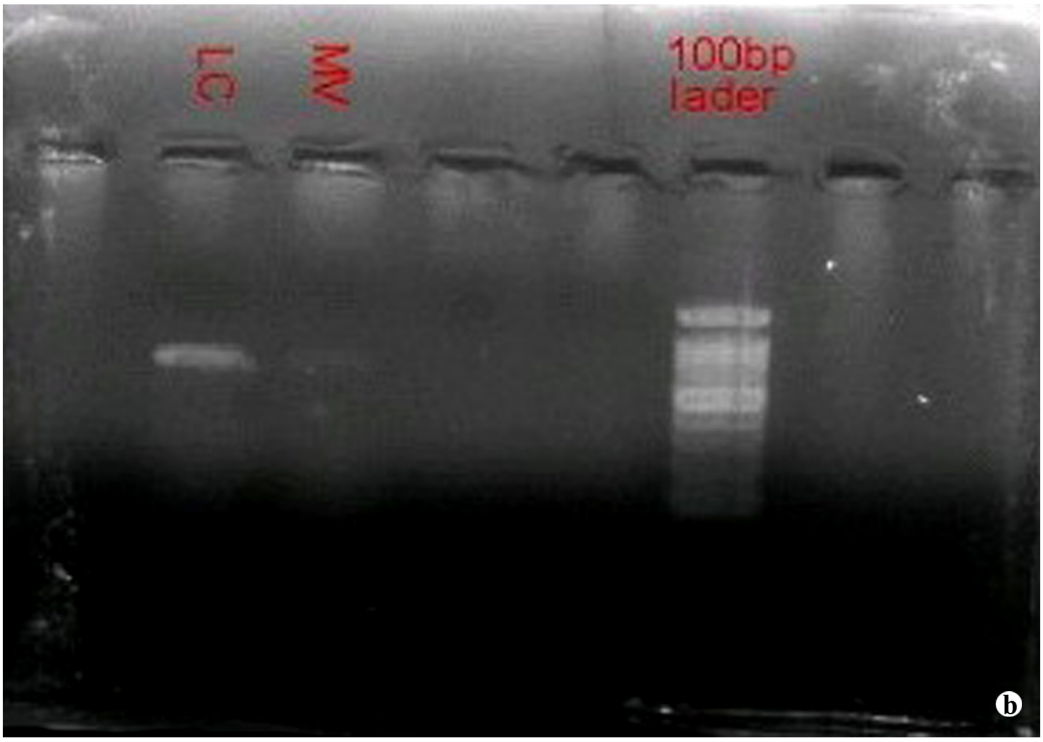


Plate13: Molecular phylogenetic analysis. a. *Eriophyes camarae* sp.nov. collected for Molecular phylogenetic analysis; **b.** Bands obtained in Gel electrophoresis

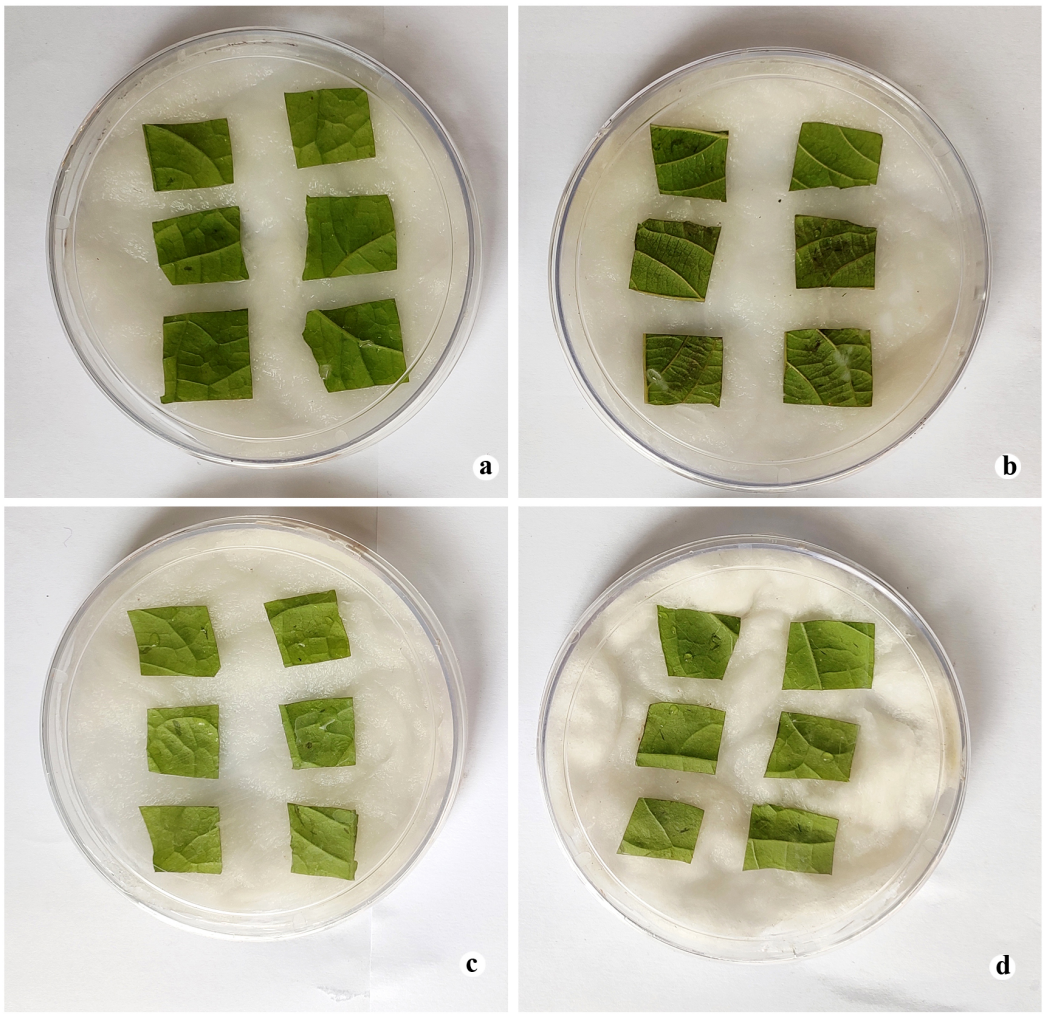


Plate 21: Laboratory rearing of live mites for breeding biology. a. Culture sets with different life stages of *Acalitus adoratus*; **b.** Culture sets with different life stages of *Eriophyes camarae* sp. nov.; **c.** Culture sets with different life stages of *Eriophyes antigonus* sp.nov.; **d.** Culture sets with different life stages of *Phyllocoptruta merremiae* sp.nov.

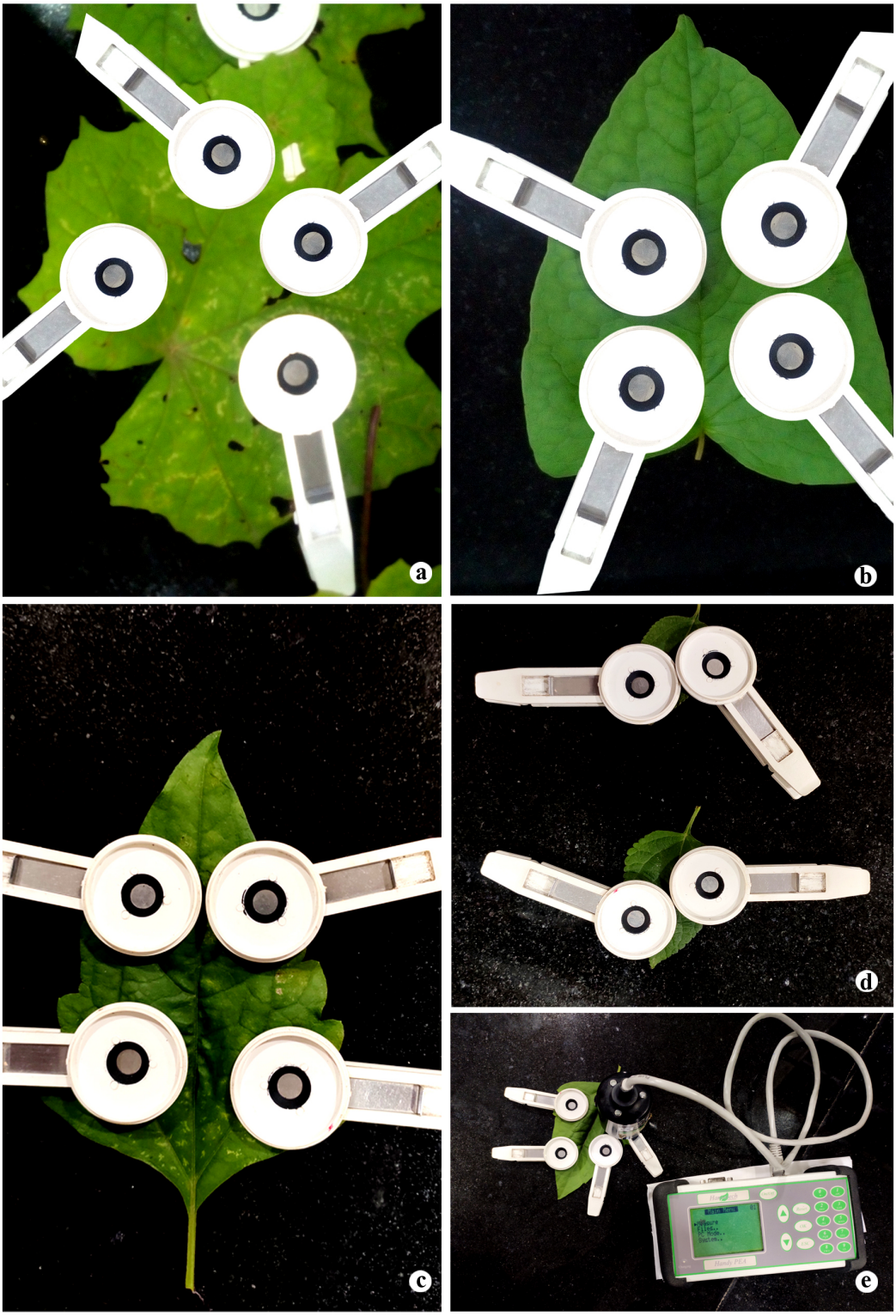


Plate 20: Photosynthetic Efficiency Analysis of leaf samples. a. Leaf clips put on leaf samples of *Merremia vitifolia*; **b.** Leaf clips put on leaf samples of *Antigonon leptopus*; **c.** Leaf clips put on leaf samples of *Chromolaena odorata*; **d.** Leaf clips put on leaf samples of *Lantana camara*; **e.** Experimental set up of Handy Photosynthetic Efficiency Analysis

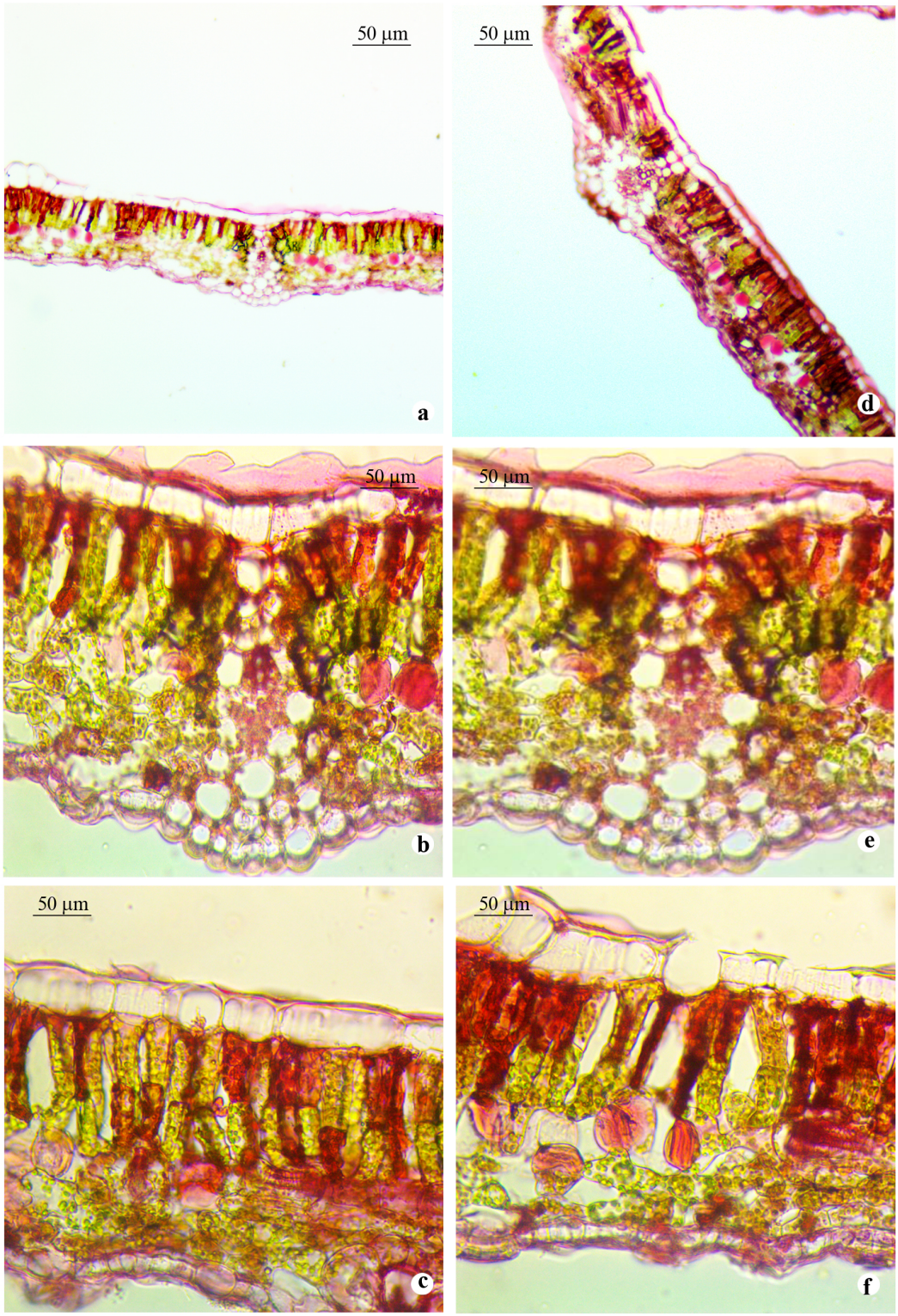


Plate17: Feeding damage – Mite induced anatomical changes in *Lantana camara* leaf: a, b, c- Stained sections of uninfested leaf sample; **d, e, f-**Stained sections of infested Leaf sample

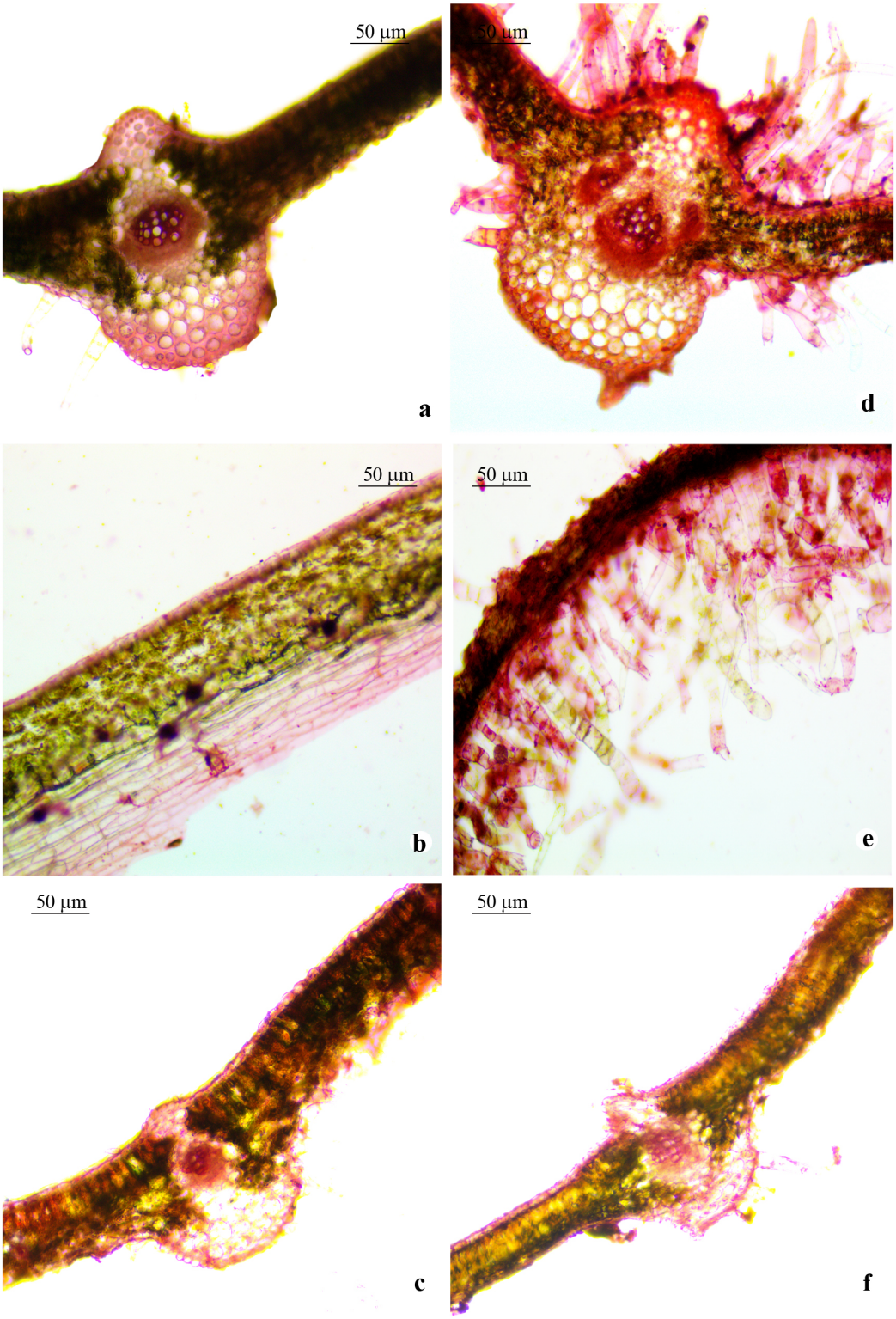


Plate 16: Feeding damage – Mite induced anatomical changes in *Chromolaena odorata* leaf: a, b, c- Stained sections of uninfested leaf sample; **d, e, f-**Stained sections of infested leaf sample

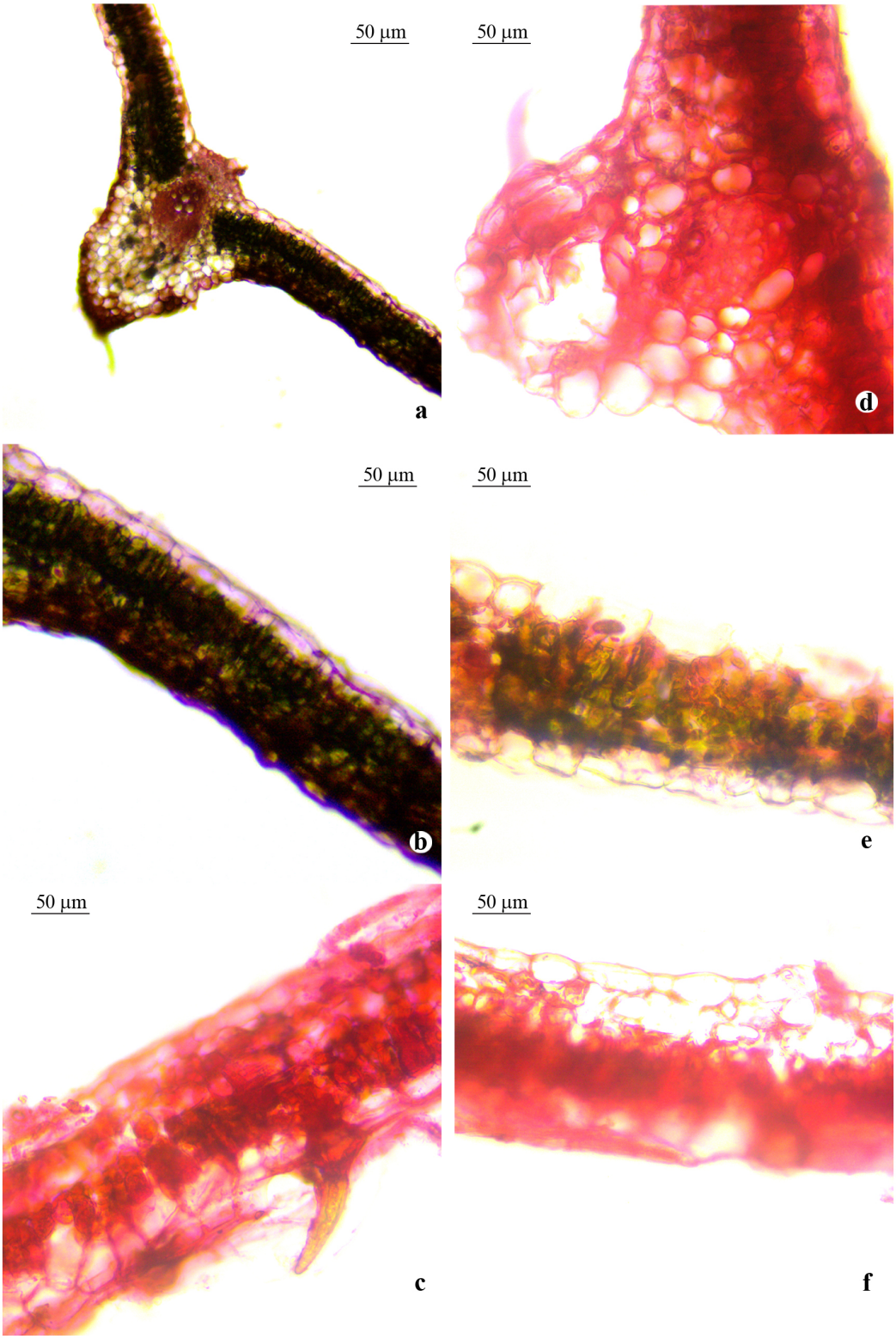


Plate 18: Feeding damage – Mite induced anatomical changes in *Antigonon leptopus* leaf; a, b, c- Stained sections of uninfested Leaf sample; **d, e, f-** Stained sections of infested Leaf sample

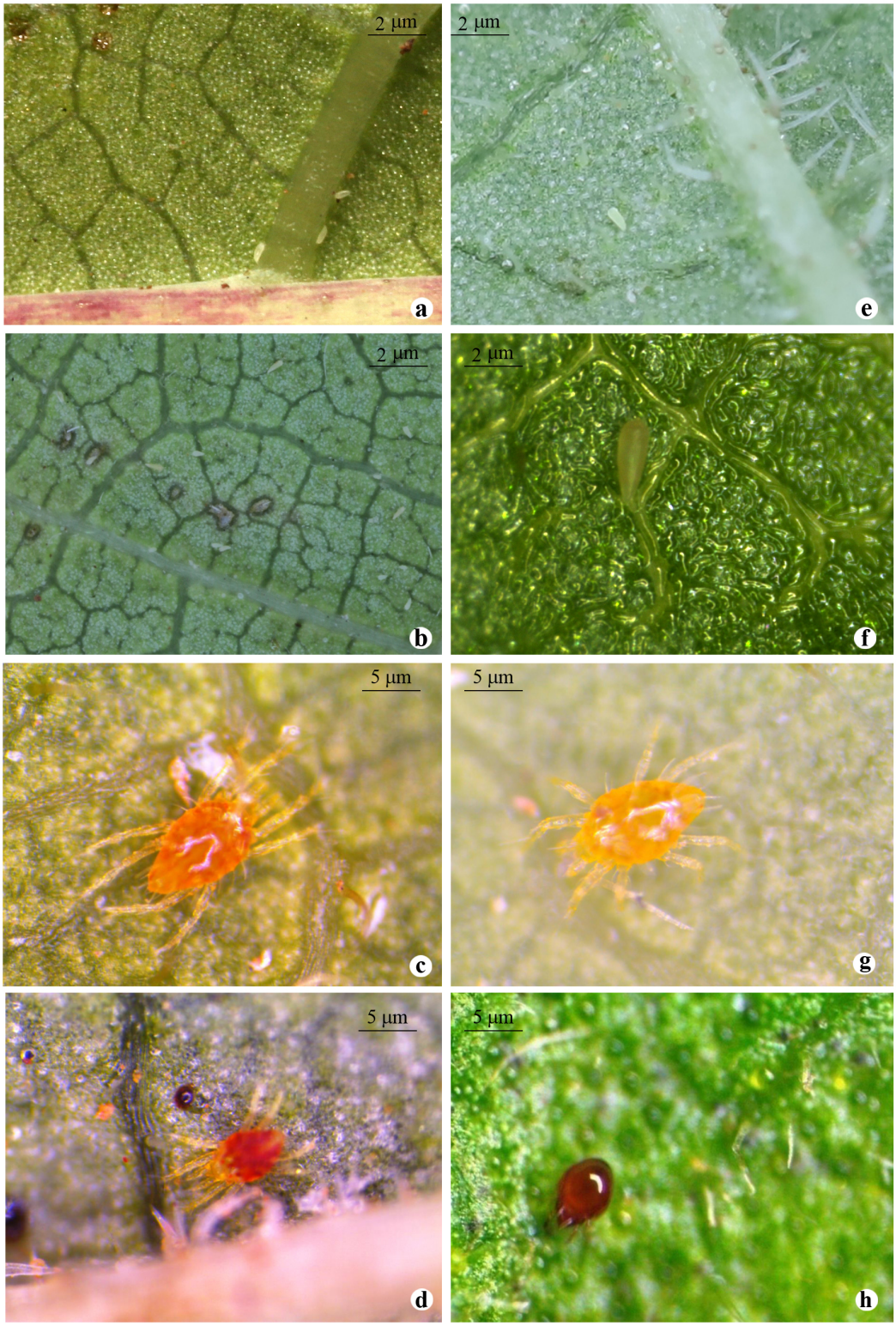


Plate11: Mite species recovered from selected species of invasive plants; **a.** *Aculus indicus* Channa Basavanna, 1966; **b.** *Phyllocoptruta merremiae* sp. nov.; **c.** *Agistemus fleschneri* Summers, 1960; **d.** *Agistemus floridanus* Gonzalez, 1965; **e.** *Eriophyes camarae* sp.nov.; **f.** *Eriophyes antigonus* sp.nov.; **g.** *Agistemus gamblei* Gupta, 199; **h.** *Lamellobates (Paralamellobates) bengalensis* Bhaduri and Raychaudhuri, 1968

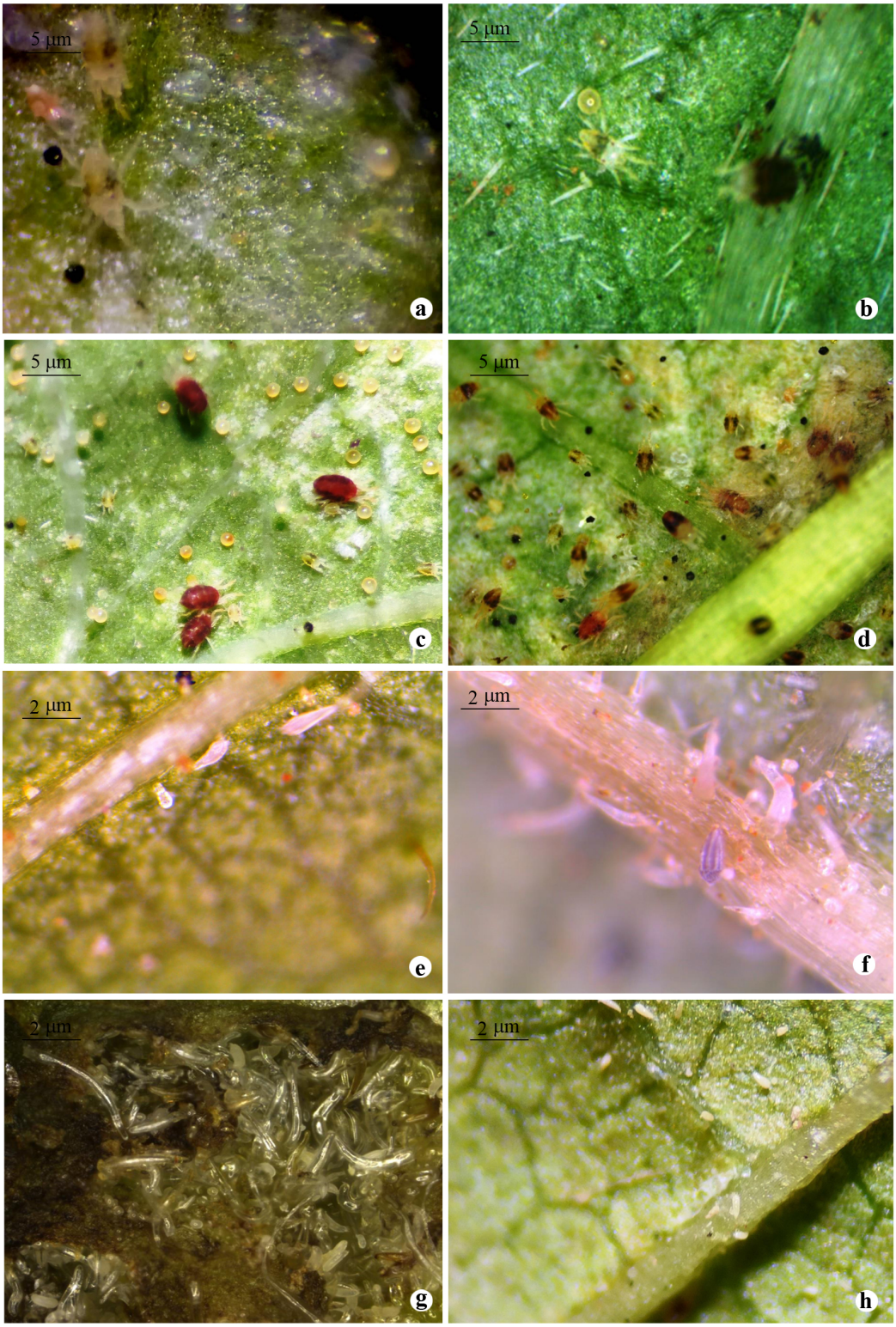


Plate 10: Mite species recovered from selected species of invasive plants. a) *Tetranychus urticae* -male; **b)** *Tetranychus ludeni* -male; **c)** *Oligonychus indicus* -colony; **d)** *Tetranychus urticae* -colony; **e)** *Aceria mikaniae Nalepa*, 1918; f) *Calacarus carinatus* Green, 1890; **g)** *Acalitus adoratus* Keifer, 1970; **h)** *Phyllocoptruta merremiae* sp. nov.

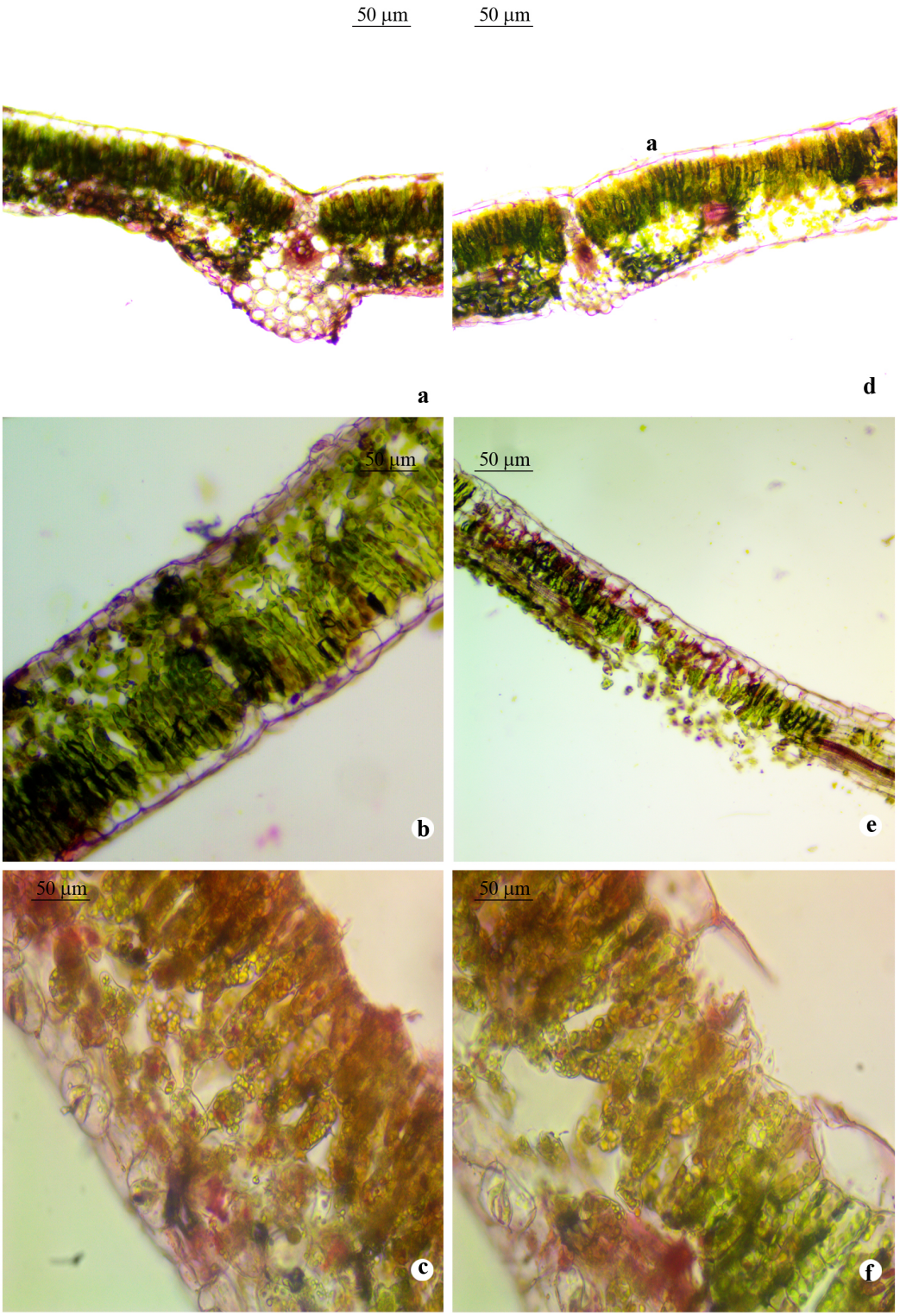


Plate 19: Feeding damage – Mite induced anatomical changes in *Merremia vitifolia* leaf. a, b, c. Stained sections of uninfested Leaf sample; **d, e, f.** Stained sections of infested Leaf sample

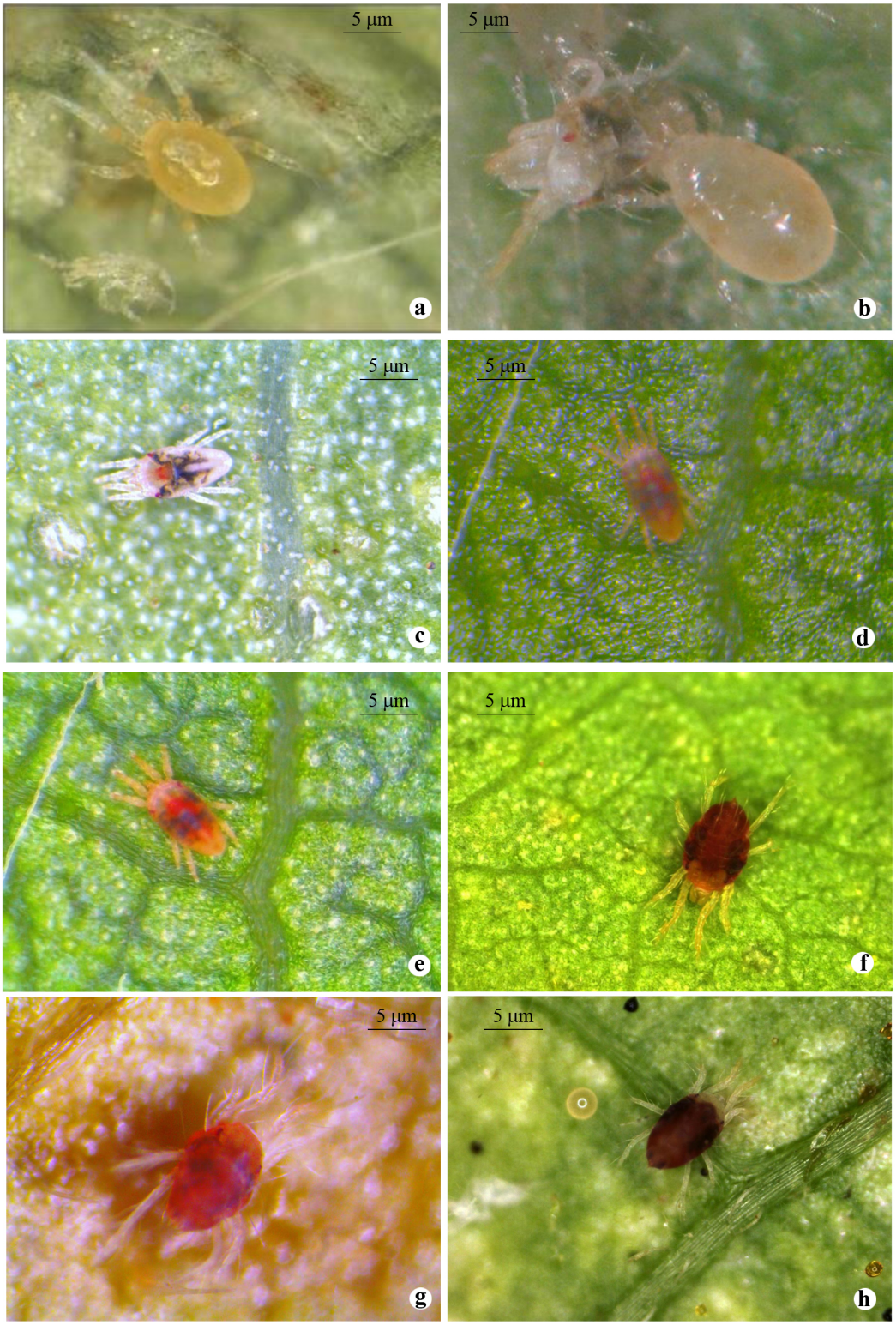


Plate 9: Mite species recovered from selected species of invasive plants; a) *Amblyseius neorykei* Gupta 1977; **b)** *Amblyseius muraleedharani* Gupta, 1986; **c)** *Brevipalpus californicus* Banks, 1904; **d)** *Brevipalpus obovatus* Donnadieu, 1875; **e)** *Brevipalpus phoenicis* Geijskes, 1939; **f)** *Tetranychus urticae* Koch, 1836; **g)** *Tetranychus neocaledonicus* Andre, 1933; **h)** *Oligonychus biharensis* Hirst, 1924



Plate 8: Mite species recovered from selected species of invasive plants; a) *Neoseiulus californicus* McGregor, 1954; **b)** *Typhlodromus (Typhlodromus) occidentalis* (Davis, 1970); **c)** *Typhlodromus (Typhlodromus) pyri* Scheuten, 1857; **d)** *Typhlodromips syzygii* Gupta, 1975; **e)** *Euseius finlandicus* Oudemans, 1915; **f)** *Neoseiulus cucumeris* (Oudemans, 1930); **g)** *Neoseiulus fallacis* (Garman, 1948); **h)** *Neoseiulus baraki* Athias-Henriot, 1966

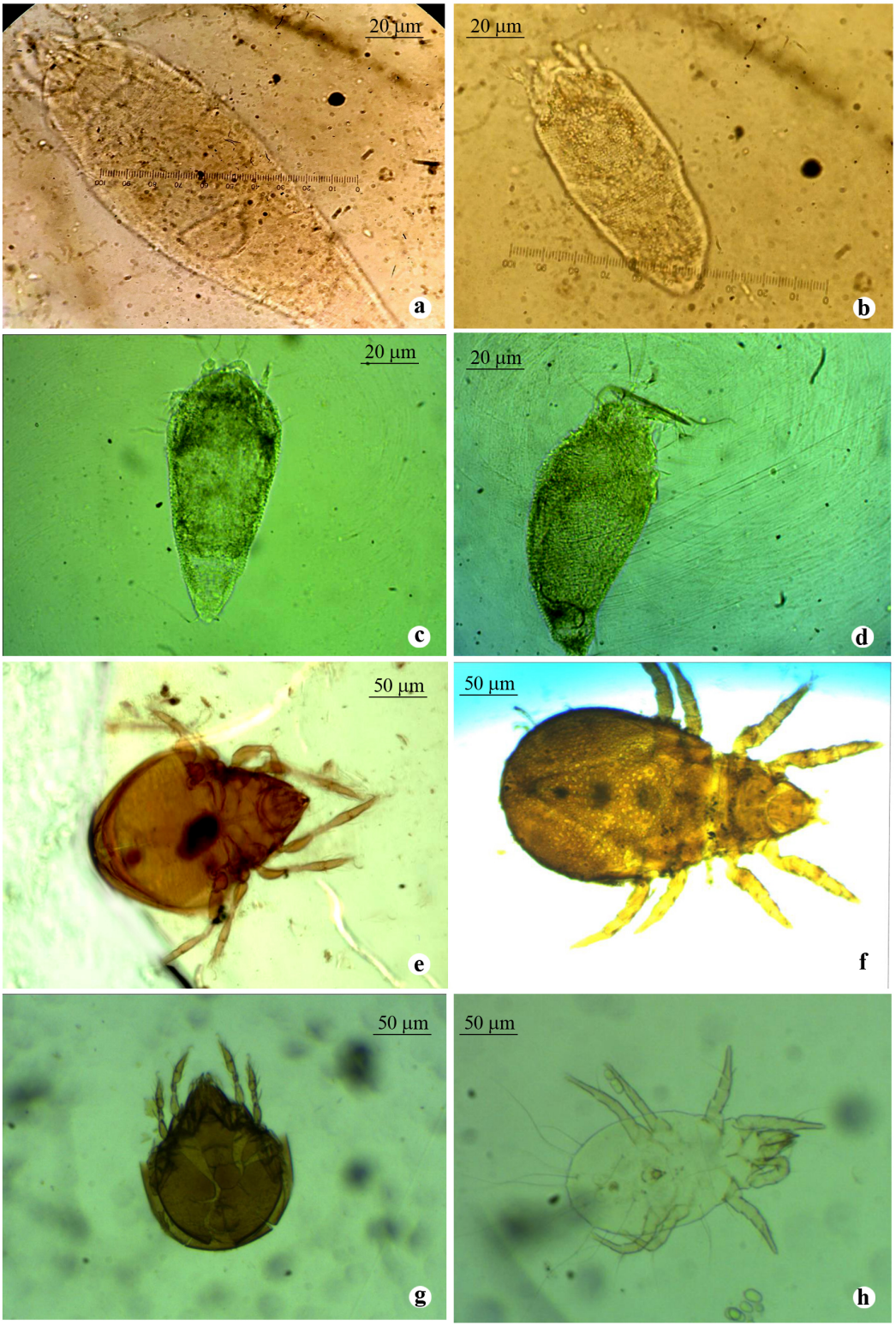


Plate 7: Mite species recovered from selected species of invasive plants; a) *Eriophyes camarae* sp.nov.; **b)** *Acalitus adoratus* Keifer, 1970; **c)** *Phyllocoptruta merremiae* sp. nov.; **d)** *Diptilomiopus* camerae Mohansundaram, 1981; **e)** *Uracrobates (Uracrobates) indicus* Ramani and Haq, 1990; **f)** *Allonothrus russeolus russeolus* Wallwork, 1960; **g)** *Lamellobates (Paralamellobates) misella* Berlese, 1910; **h)** *Tyrophagus putrescentiae* Schrank, 1781

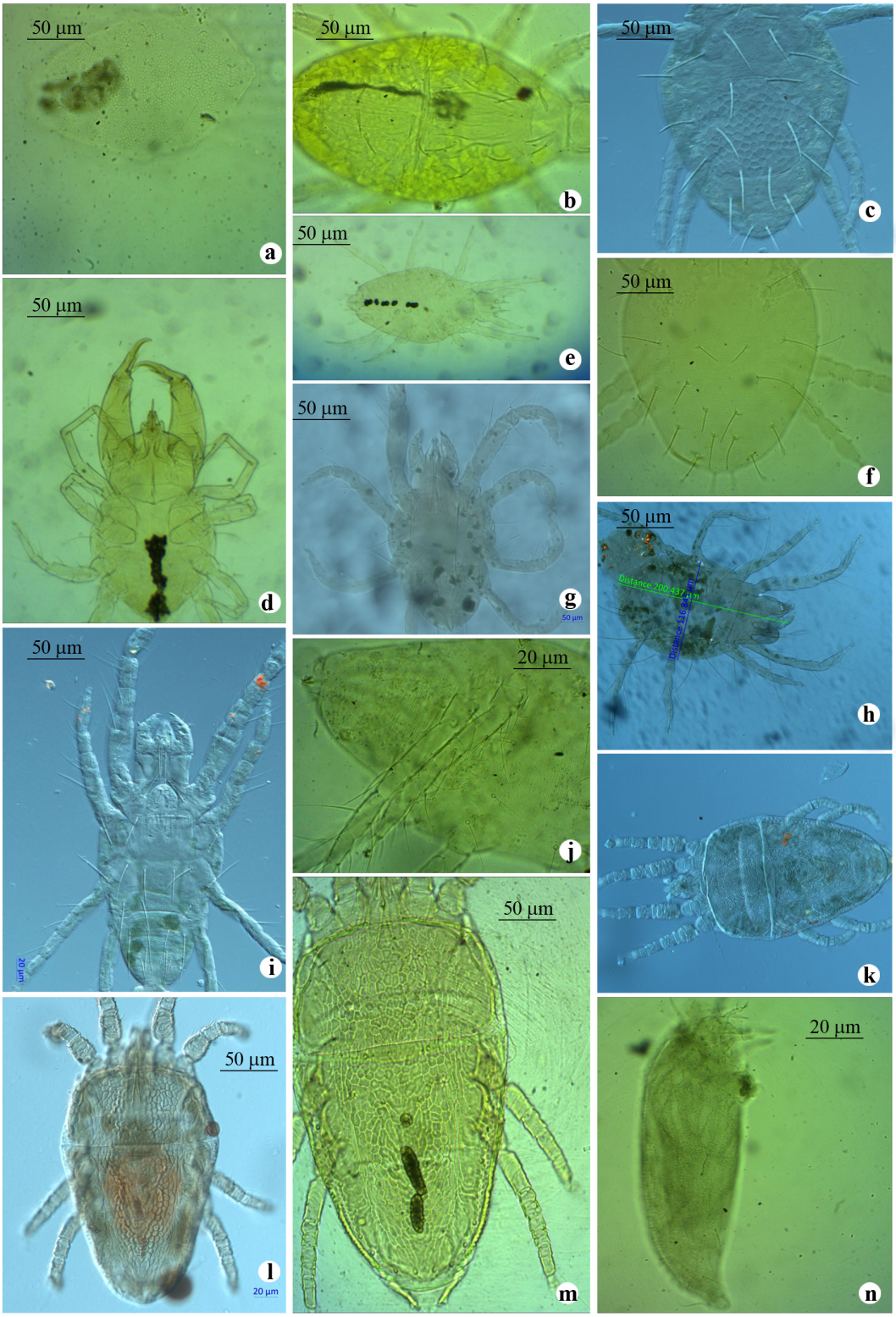


Plate 6: Mite species recovered from selected species of invasive plants: a) *Lorryia formosa* Cooreman,1958; **b)***Agistemus exsertus* Gonzalez, 1963; **c)** *Agistemus aimogastensis* Leiva et al.,2013; **d)***Cheyletus eruditus* Schrank, 178; **e)** *Cheyletus malaccensis* Oudemans, 1903; **f)** *Eutetranychus orientalis* Klein, 1936; **g)** *Tetranychus marianae* McGregor, 1950; **h)** *Oligonychus indicus* Hirst, 1923; **i)** *Schizotetranychus lespedezae* Beglyarov and Mitrofanov, 1973; **j)** *Tetranychus urticae* Koch, 1836; **k)** *Brevipalpus californicus* Banks, 1904; **l)** *Brevipalpus obovatus* Donnadieu, 1875; **m)** *Brevipalpus phoenicis* Geijskes,1936 **n)** *Aculus cassiae Mondal* and Chakrabarti, 1981

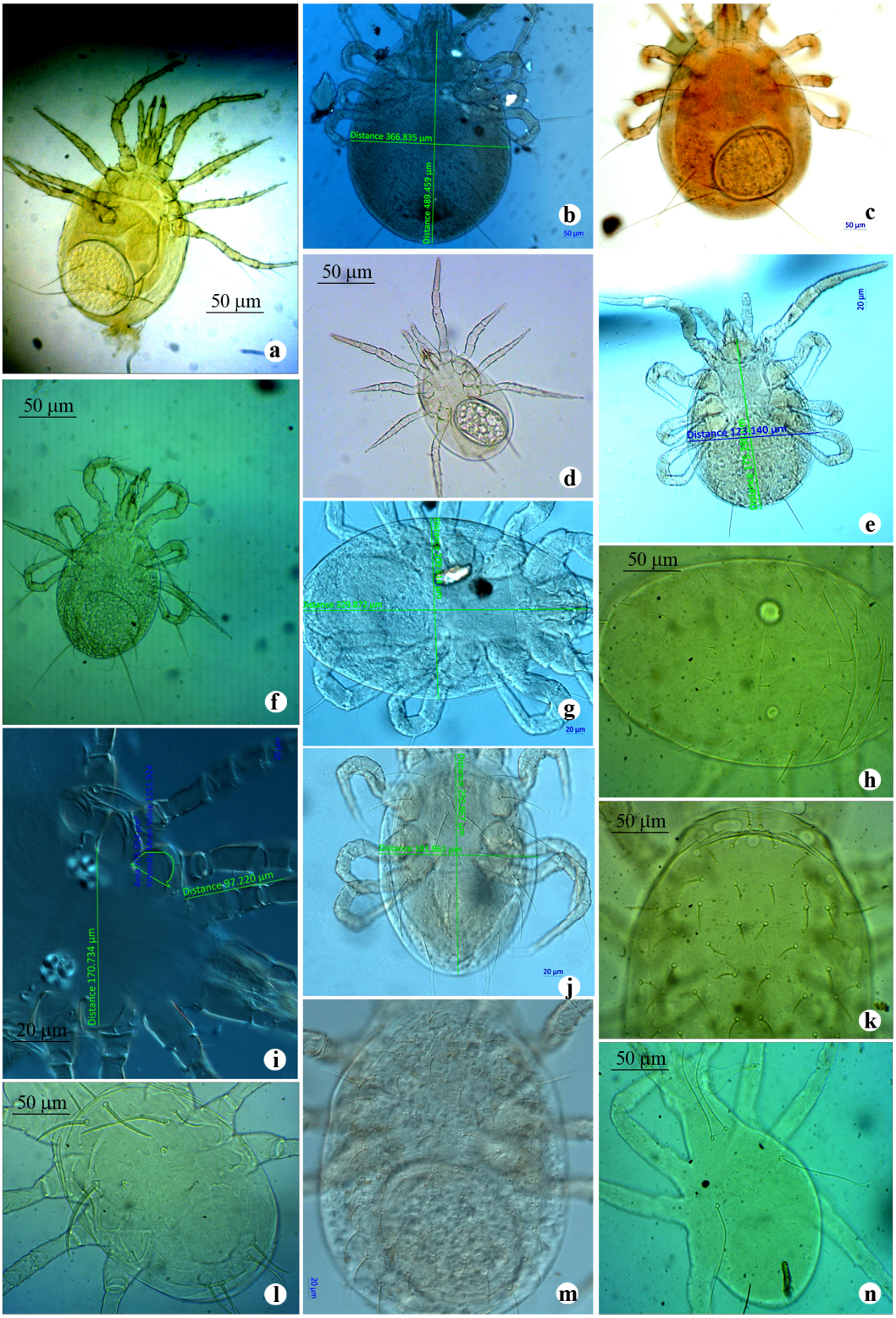


Plate 5: Mite species recovered from the selected species of invasive plants: a) *Amblyseius adhatodae* Muma, 1967; **b)** *Amblyseius largoensis* Muma,1955; **c)** *Amblyseius herbicolus* Chant,1959; **d)** *Amblyseius indirae* Gupta, 1985; **e)** *Amblyseius orientalis* Ehara,1959; **f)** *Euseius finlandicus* Oudemans, 1915; **g)** *Neoseiulus villoonniyensis* Anithalatha, 2006; **h)** *Scapulaseius suknaensis* Gupta, 1970; **i)** *Amblyseius paraaerialis* Muma, 1967; **j)** *Neoseiulus longispinosus* (Evans, 1952); **k)** *Asca evansi* Genis, Loots and Ryke, 1969; **l)** *Paraphytoseius multidentatus* Swirski and Shechter,1981; **m)** *Asca afroaphidiodes* Hurlbutt, 1971; **n)** *Cunaxa myabunderensis* Gupta & Ghosh, 1980

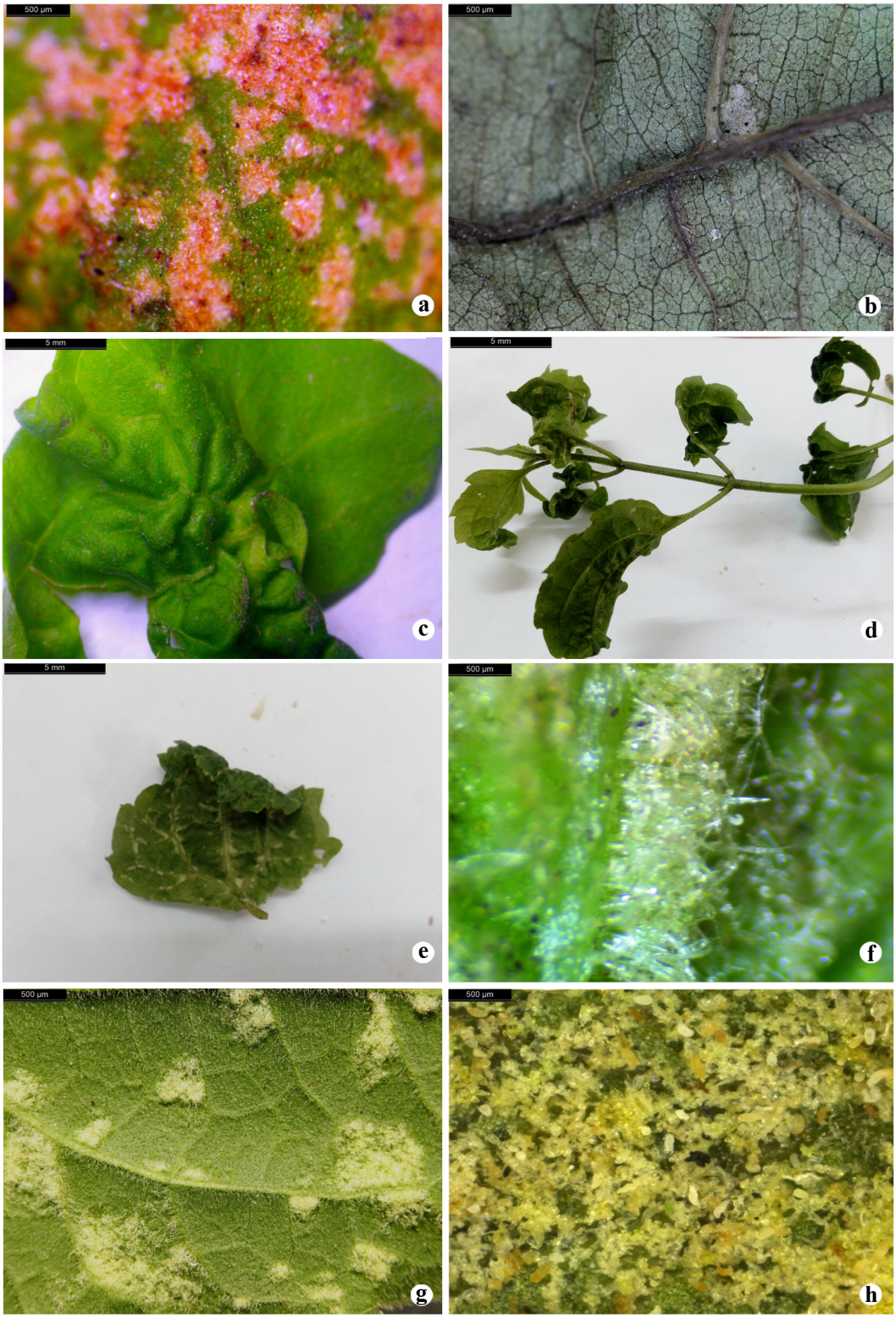


Plate15: Feeding damage – Visible symptoms; a) *Merremia vitifolia* - Necrotic (brown) spots; **b)** *Merremia vitifolia* - Bronzing; **c)** *Antigonon leptopus* - Curling of leaves; **d)** *Chromolaena odorata* - Curling of leaves; **e)** *Chromolaena odorata* -Rolling of leaf with erinea; **f)** *Chromolaena odorata* - Erinea; **g)** *Chromolaena odorata* -Erineal patches; **h)** *Chromolaena odorata* - Erinea with all life stages of *Acalitus adoratus*

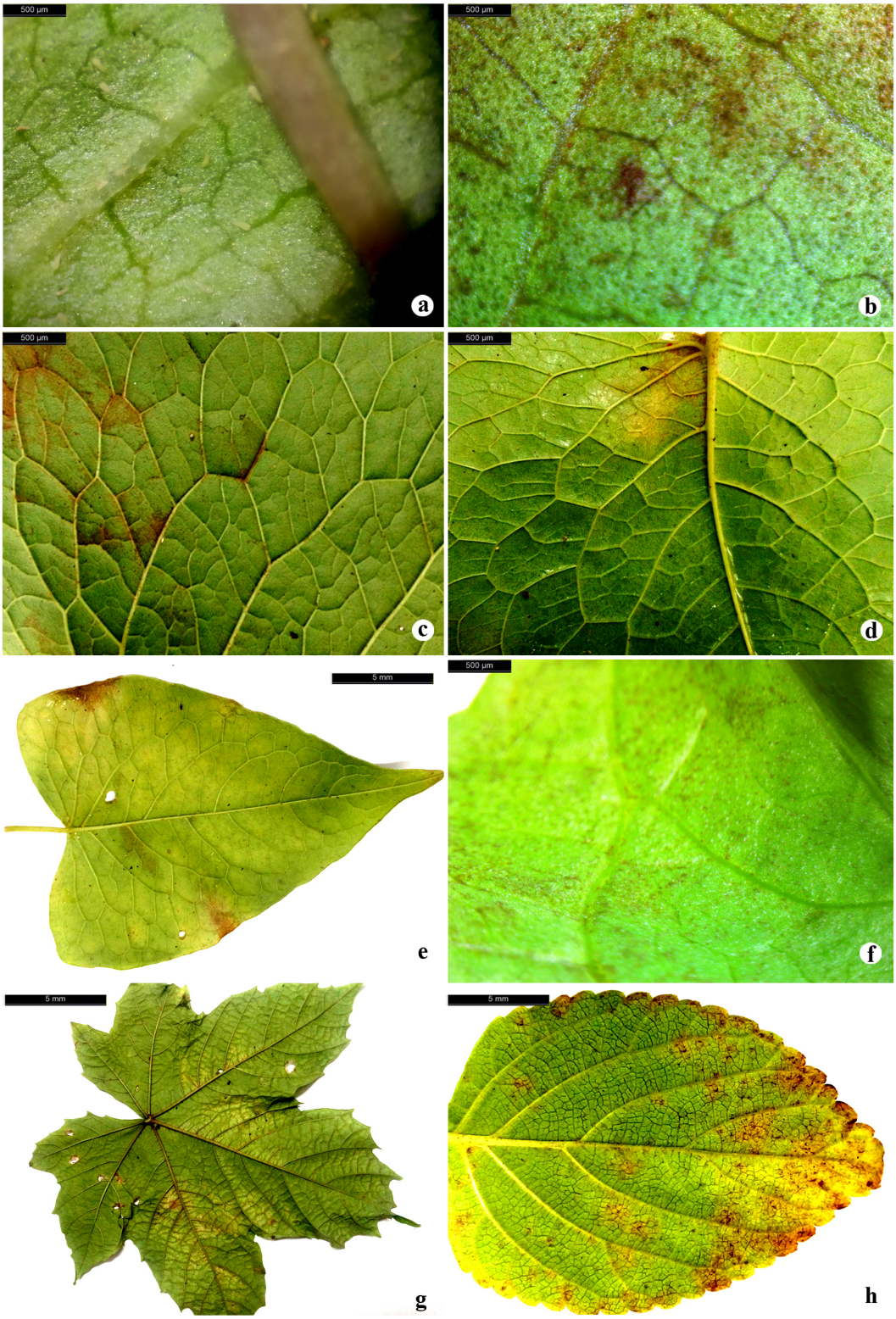


Plate14: Feeding damage -Visible symptoms; a) *Merremia vitifolia* - Chlorotic spots; **b)** *Lantana camara* - Chlorotic patches; **c)** *Merremia vitifolia* - Necrotic (brown) spots; **d)** *Antigonon leptopus* - Yellowing; **e)** *Antigonon leptopus* Distortion of leaves; **f)** *Merremia vitifolia* -Stippling; **g)** *Merremia vitifolia* - Yellowing; **h)** *Lantana camara* Bronzing



Plate 4: Invasive plants screened; a. *Senna tora* (L.) Roxb.; **b** *Alternanthera bettzickiana* (Regl.) G. Nicholson; **c.** *Stachytarpheta jamaicensis* (L.)Vahl; **d.** *Desmodium tortuosum* (SW.) DC.**; e.** *Cissampelopsis corymbosa* (Wallich ex DC.) C. Jeffrey and Y.L. Chen **f.** *Parthenium hysterophorus* L; **g.** *Euphorbia heterophylla* L. **h.** Collection of leaf sample



Plate 3: Invasive plants screened; a. *Clidemia hirta* (L.) D. Don; **b.** *Pueraria phaseoloides* (Roxb.) Benth; **c.** *Pityrogramma chrysophylla* (Sw.) Link; **d.** *Pteridium aquilinum* (L.) Kuhn. **e.** *Ageratina adenophora* R.M. King & H.Robinson**; f.** *Ipomoea carnea* Jacq ssp. fistulosa (Mart.ex. Choisy) Austin; **g.** *Calotropis procera* (Ait.) R. Br.; **h.** *Leucaena leucocephala* (Lam.) de Wit; **18** *Synedrella nodiflora* (L.) Gaertn



Plate 2: Invasive plants screened; a. *Lantana camara* L.; **b.** *Chromolaena odorata* (L.) R. M. King and H.Robinson; **c.** *Mikania micrantha* Kunth; **d.** *Antigonon leptopus* Hook &Arn.; **e.** *Mimosa diplotricha* var. *diplotricha* C.Wight ex Sauvalle; **f.** *Merremia vitifolia* (Burm.f.) Hallier **f**.; **g.** *Sphagneticola trilobata* (L.) Pruski; **h.** *Tridax procumbens* L. **i.** *Ageratum conizoides* L.