DIVERSITY OF PREDATORY MITE FAUNA IN VEGETABLE ECOSYSTEM

By

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THESIS

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DECLARATION

I, Maheswary J (2013 – 11 – 131) hereby declare that this thesis entitled **"Diversity of predatory mite fauna in vegetable ecosystem"** is a bonafide record of research done by me during the course of research and that the thesis has not previously formed the basis for the award of any degree, diploma, fellowship or other similar title, of any other University or Society

Vellanikkara

19/11/2015

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CERTIFICATE

Certified that this thesis, entitled **"Diversity of predatory mite fauna in vegetable ecosystem"** is a record of research work done independently by **Ms. Maheswary J.** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her

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CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

Introduction

1. INTRODUCTION

Mites belong to the subclass Acari under the class Arachnida of the sub-phylum Chelicerata They are minute in size, with body length ranging from 300 to 500 µm in the adult stage They are also ubiquitous, being found in all major terrestrial and aquatic habitats with 50,000 described species worldwide (Zhang, 2003) This highly diverse group comprising of minute phytophagous, predaceous, mycophagous, phoretic and parasitic acarines is unfortnately much less known than other groups in the Arthropoda, the most diverse phylum of living organisms

Mites constitute the most important group of non-insect pests in agriculture They attack virtually every plant of economic importance Vegetable crops in particular, are subjected to infestation by a number of mite species, leading to heavy economic loss The average yield loss in vegetable crops due to mite pests in India has been estimated to be around 25 per cent (Gupta, 1991)

Farmers depend mostly on synthetic pesticides for managing the mite problems because of instant spectacular knock down effect Over the last two decades, indiscriminate application of broad spectrum pesticides for contol of vegetable pests have led to many of the mite pests, which were either innocuous or of very little importance, assume major pest status Besides, due to repeated use of organophosphorous compounds and many a times at their sublethal doses, the mites have developed resistance/ cross resistance making mite control a more difficult task (Gupta, 2002)

The above situation calls for development of integrated pest management strategies with biocontrol as a corner stone Efforts are afast to explore, identify evaluate and utilise potential natural enemies for effective mite management

Predatory mites assume signifance in this context as they play a major role in reducing the populations of phytophagous mites and are able to feed on alternate sources of food and can survive even in the absence of prey mites Predatory mites mostly belong to the family Phytoseiidae under order Mesostigmata with several members being successfully employed in control of mite pests (Moraes, 2002) Other families which are common on plants include Bdellidae, Cheyletidae, Cunaxidae, Stigmaeidae and Tydeidae, coming under the order Prostigmata

Knowledge about the prevailing native predatory mite fauna in vegetable ecosystems is important for the identification of prospective species which can be used in biological control programmes However, information on the faunal composition of predatory mites associated with phytophagous mites infesting vegetable crops in Kerala is very much limited

In cognizance of the above fact, a research project entitled "Diversity of predatory mite fauna in vegetable ecosystem" was carried out to generate database on important predatory acarine species associated with major vegetable crops in Thrissur district of Kerala The objectives of the study were as follows

- To document the species diversity of predatory mites associated with phytophagous mites in vegetable ecosystems in Thrissur .

- To develop a taxonomic key for the identification of predatory mite fauna in vegetable ecosystems

Review of Literature

2. REVIEW OF LITERATURE

Infestation by phytophagous mites on vegetable crops has become a huge menace nowadays The widespread use of synthetic organic compounds against insects as target pests has toxic effects on other non target organisms in both lower and higher trophic levels (Dejan *et al*, 2011) Predatory mites are now valued by growers worldwide as natural enemies that provide effective pest control in greenhouses and on agricultural crops (Bjorson, 2008) Thus, knowledge about the prevailing predatory mite fauna on crops is becoming more important, for the identification of prospective species to be used in biological control programmes

The diversity of Acari is extraordinary and several taxonomic schemes have been proposed for their classification Intensive research work on mites has been carried out all over the world including India Various literature on the diversity of predatory mites associated with vegetable ecosystem are presented here

The foundation for a classification was laid down by Kramer (1877) and was modified by subsequent authors The book '*Introduction to Acarology* by Baker and Wharton (1952) classified mites to the family level and provided a list of known genera in each family This classification considered 'Acarina' as an order under phylum Arthropoda, subphylum Chelicerata and class Arachnida The order Acarina was further divided into suborder Onychopalpida, Mesostigmata, Ixodides, Trombidiformes and Sarcoptiformes Baker *et al* (1958) further identified supercohort, cohort and superfamily as well as provided keys and decriptions of mite groups within these categories Savory (1964) divided class Arachnida, on the basis of abdominal segmentation, into eleven subclasses, namely, Scorpiones, Palpigradi, Uropygi, Pseudoscorpiones, Ricinulei, Schizomida, Amblypygi, Opiliones,

Solifugae, Araneae and Acari Subclass Araneae consists of spiders while mites and ticks were included in the subclass Acari

2.1. Classification of subclass Acari

Acari has been considered either as order Acarina or as subclass of the class Arachnida Most Acarologists now recognize Acari as a subclass, but the ordinal level classification is not settled (Zhang, 2003)

Krantz (1970) proposed the system of higher classification of subclass Acari, which is accepted widely by Acarologists across the world and being followed till date This classification is based on the position of stigmata which included three orders and seven suborders The detailed scheme of classification is given below -

2.1.1. Order Opilioacariformes

This order is considered to be the most primitive acarine group since they possess a number of characteristics which are peculiar to unspecialized arachnid forms Only one suborder, namely Notostigmata is present under the order Opilioacariformes The suborder is characterized by the presence of four pairs of dorsolateral stigmata on hypostome, one or two terminal claws on palp tarsus and the absence of peritremes

2.1.2. Order Parasitiformes

The order parasitiformes is characterized with one or two pairs of hysterosomal stigmata, palp tarsal apotele is never terminal, with or without

peritremes This order is divided into three suborders, namely, Tetrastigmata, Mesostigmata and Metastigmata

2.1.2.1. Suborder Tetrastigmata

Suborder Tetrastigmata is characterized with more than three pairs of acessory setae on hypostome, apotele sometimes divided, anal valves strongly setate and the presence of peritremes

2 1.2.2. Suborder Mesostigmata

Suborder Mesostigmata is characterized with a maximum of three pairs of setae on hypostome, with a two, three or four tined apotele near the inner basal angle of the palpal tarsus, tritosternum is usually present with one or two lacinia and peritremes are generally present

2.1.2.3. Suborder Metastigmata

Suborder Metastigmata is characterized with the absence of apotele on palp tarsus and hypostome modified into a piercing organ with retrose teeth The dorsum of tarsus I possess a distinct sensory pit (Haller's organ) Stigmata is present behind coxae IV without elongate peritremes

2.1.3. Order Acariformes

The order Acariformes is characterized by the absence of hysterosomal stigmata Propodosomal sensory organs are modified into trichobothria or more

specialized structures in distinctive insertions This order is divided into three suborders, namely, Prostigmata, Astigmata and Cryptostigmata

2.1.3.1. Suborder Prostigmata

This is the most diverse group with great variation in body length (100-16,000 µm) They are found in a diverse range of habitats as predators, parasites, phytophagus, and fungivores There are 17,170 described species in the world which are placed under 1,348 genera and 131 families (Walter and Proctor, 1999)

2.1.3.2. Suborder Astigmata

These are usually weakly sclerotized, medium-sized mites (200- 1,200 µm) found in a diverse range of habitats Members of the suborder Acaridia are free-living or parasites, associated with insects or Crustacea, and only rarely parasites of mammals, whereas those of the other suborder Psoroptidia are parasites of birds and mammals, rarely of insects, or free-living There are 4,500 described species of Astigmata in the world which are placed under 627 genera and 70 families (Walter and Proctor, 1999)

2.1.3.3. Suborder Cryptostigmata

They are generally strongly sclerotized species, almost always with a pair of setate, clavate or club shaped sensory organs (pseudostigmatic organs) inserted in pseudostigmata on the propodosoma Hypostome with a pair of prominent terminal lutella and true claws are generally present

Zhang (2003) used the traditional system of classification adapted from Johnston (1982) and Evans (1992), in which the orders mentioned above were elevated to super orders and the suborders to orders, thus he recognized three super orders and seven orders as given below -

Superorder Opilioacariformes

This superorder consists of only one order namely, Opilioacarida (=Notostigmata) which include mites feeding on pollen and fungi They are found in dark places and under stones

Superorder Parasitiformes

The superorder Parasitiformes is divided into three orders namely, Holothyrida (=Tetrastigmata), Mesostigmata and Ixodida (=Metastigmata)

Superorder Acariformes

The superorder Acariformes is divided into three orders namely, Prostigmata, Astigmata and Oribatida (=Cryptostigmata)

Krantz and Walter (2009) revised the higher classification in which the order Opilioacarida is grouped with the orders Holothryrida, Mesostigmata (Gamasida) and Ixodida under the superorder Parasitiformes, and the orders Trombidiformes and Sarcoptiformes were proposed as orders under the superorder Acariformes The order Trombidiformes was further grouped into two suborders, Sphaerolichida and Prostigmata, thus degrading Prostigmata from order level to suborder level The order

Astigmata was degraded as cohort Astigmatina and grouped under the supercohort Desmonomatides of the suborder Oribatida in the order Sarcoptiformes

2.2. Predatory mite families

Predatory mites are commonly encountered on aerial portions of plants, where they feed on small insects or on phytophagous and mycophagous mites and their eggs (Wallace and Walters, 1974) Prostigmatic predators are numerous on most plants and often are brightly coloured in hues of red, yellow, or green, often assuming the colour of the prey species on which they feed Most of these predators actively seek their prey on leaf and stem surfaces, but some phytophilous Cheyletidae are ambush predators that lie in wait until the prey is close enough to capture (Muma, 1975) Some of its member species are important in the control of spider mites (Tetranychidae) and eriophyoid mites in commercial orchard and vine crops The mesostigmatid family Phytoseiidae is probably the most widely studied and best known assemblage of phytophilous mite predators (McMurtry, 1983)

2.2.1. Phytoseiidae

Class Arachnida, Subclass Acari, Superorder Parasitiformes, Order Mesostigmata, Suborder Monogynaspida, Superfamily Phytoseioidea, Family Phytoseiidae

Berlese (1916) proposed the tribe *Phytoseius* Ribaga as the type genus of this family Nesbitt (1951) critically reviewed this group for the first time Chant (1959) had the first review of the world fauna of Phytoseiidae

Mites in the family Phytoseiidae are mainly predators of plant feeding mites and small soft bodied insects like scales, aphids, thrips, whiteflies and their eggs (Nesbitt,1951, Muma, 1955)

Muma (1961) gave a new concept of classification of Phytoseiidae, by recognizing four subfamilies Phytoseiinae, Amblyseiinae, Macroseiinae and Aceodrominae, and he subsequently transferred the Aceodrominae to Ascidae Wainstein (1962) recognized two subfamilies in the family Phytoseiidae Phytoseiinae and Macrosennae Muma *et al* (1970) later recognized three subfamilies Phytoseiinae, Amblysennae, Macrosennae

In 1972, Wainstein transferred some groups from the family Otopheidomenidae to the third subfamily,Treatinae, and later (Wainstein, 1973) recognized five subfamilies to include Evansoseiinae and Gigagnathinae

Arutunjan (1977) recognized seven tribes in Phytoseiidae Amblyseiini, Phytoseiini, Typhlodromini, Macroseiini, Gigagnathini, Iphiseiini and Seiulini Krantz (1978) placed Phytoseiidae in the super family Phytoseioidea along with Otopheidomenidae, Ameroseiidae, Podocinidae and Epicriidae

A catalogue of all known species of Phytoseiidae was prepared by Moraes *et al* (1986, 2004) Kostiainen and Hoy (1996) compiled a comprehensive bibliography (1960–1994) of the family

Chant and McMurtry (2007) gave illustrated keys and diagnoses for the genera and subgenera of Phytoseiidae of the world The taxonomic system of Chant and McMurtry's classification was based partly on dorsal chaetotaxy of the adult female,

cheliceral morphology and dentition, the shape and setation of female ventrianal shield, setation of legs I-III and relative length of certain dorsal setae *etc*

Wu *et al* (2009) conducted studies on phytoseiid mites from China and recorded three subfamilies, 15 genera and 307 species in total (including 36 new species) in the *Fauna Sinica* volume, among which 204 species were endemic to China Similarly, Wu *et al* (2010) reviewed the research on the systematics of the family Phytoseiidae in China, and provided an updated checklist encompassing 304 species Thus, over 2500 phytoseiid mites in about 70 genera had been described worldwide (Moraes *et al* 2004) and more than 20 per cent of these species had been found useful in the biological control of mites and insect pests of agriculturally important crops

The number of nominal species in Phytoseiidae in the world is 2,709 (2,436 valid species), in 91 genera and three subfamilies (Amblyseiinae, Phytoseiinae and Typhlodrominae) In India, 195 species are known, that belong to 20 genera under 3 subfamilies (Demite *et al* , 2014)

2 2.2 Ascidae

These mites are also important predators, common habitats of these mites are leaf litter, soil and stored products Although a large number of species in this family have been documented, majority are from the habitats other than plants

The authority of the family name has been bestowed upon Canestrini and Fanzago (1876) Evans (1958) revised the British Aceosejinae wherein he provided key to all species totalling 35 Hurlburtt (1963) dealt with North American *Asca*, containing 15 species

Chant (1963) dealt with Blattisocinae and treated 32 species (including Indian species) in addition to describing new species So far as plant association of ascid mites from India is concerned, mention may be made of Narayanan and Ghai (1964), Menon and Ghai (1968) and Gupta and Chatterjee (1988)

There are 281 described species in the world under 17 genera (Zhang, 2003) In India, nine species from five genera are known to be associated with plants (Gupta, 2003)

2.2.3. Stigmaeidae

Class Arachnida, Subclass Acari, Superorder Acariformes, Order Trombidiformes, Suborder Prostigmata, Superfamily Raphignathoidea, Family Stigmaeidae

Stigmaeids are yellowish mites, ovoid or elongated, very active and occupy varied habitats Like phytoseiid mites, these mites are important predators and have received considerable importance

Oudemans (1931) erected this family with *Stigmaeus* Koch, 1836 as its type genus Gonzalez-Rodriguez (1965) dealt with the genera *Zetzellia, Agistemus* and *Mediolata* of the world and provided description of new species besides giving keys to all the genera and species

Gupta (1985) in his handbook on plant mites of India reported three species of Stigmaeidae known till then from India You-Bisong and Tsai (1995) recorded *Agistemus exsertus* as a predator of citrus spider mites

Fan and Zhang (2005) recorded 64 species under 14 genera in New Zealand, out of which 14 species were described and illustrated to be new species, and a new genus, *Scutastigmaeus* was described They also shifted three species of *Stigmaeus* to this genus, namely *Scutastigmaeus confusus* (Wood), *Scutastigmaeus longisetis* (Wood) and *Scutastigmaeus montanus* (Wood)

2.2.4. Tydeidae

Class Arachnida, Subclass Acari, Superorder Acariformes, Order Trombidiformes, Suborder Prostigmata, Superfamily Tydeoidea, Family Tydeidae

Tydeidae is a family of acariformes mites These are small, soft bodied mites with needle like chelicerae which may be fused or contiguous at base, often with striations or reticulations and eyes present or absent Most species are fungivorous, some are predatory and some are phytophagous

Kramer (1877) erected this family and later Baker (1965), while reviewing this family for the world, re-diagnosed the family and recognized 15 genera, out of which six were new Besides, he described eight new species, proposed some new combination and provided keys to all the genera

Baker, through a series of papers contributed on the tydeid fauna of the world under different genera, *viz*, *Pronematus* (Baker, 1968d), Lorryia (Baker, 1968a), *Paralorryia* (Baker, 1968b), erected two new genera, *viz*, *Oriol* and *Meyerella* Baker (1968c), on *Tydeus* (Baker, 1970) and on *Naudea* (Baker and Delfinade, 1976) In all his papers, the species recognized by him were fully described, illustrated and keyed out

Momen and Lindqvist (1996a) revised new and unrecorded species of the genus *Tydeus* from Southern Sweden and provided keys to those species, of which four species were described and illustrated as new to science

Momen and Lindqvist (1996b) proposed taxonomy of non- *Tydeus* genera in Southern Sweden, five species of tydeid belonging to five genera were illustrated and described as new to science

Tydeidae contains over 300 species under more than 40 genera in the world In India, 21 species belonging to five genera were known on plants (Gupta, 2002)

2.2.5. Bdellidae

These are yellowish to reddish coloured large sized mites with long snout and hence the name "snout mites" Duges in 1834 erected this family Atyeo and Tuxen (1962) dealt with species belonging to five genera and provided keys to Bdellidae of Iceland Wallace and Mahon (1973) dealt with Australian Bdellidae and included therein subfamilies Bdellinae, Spinibdellinae and Cytinae, provided keys to genera and species and described five new species Wallace and Mahon (1976) dealt with subfamily Odontroscirinae, treated 28 species under two genera, of which eight were described as new and re-descriptions were provided for other 20 species

Worldwide, 139 species under 14 genera were known under the family Bdellidae In India 14 species belonging to six genera under four sub families were known to be associated with plants (Gupta, 2002)

2.2 6. Cunaxidae

Class Arachnida, Subclass Acari, Superorder Acariformes, Order Trombidiformes, Suborder Prostigmata, Superfamily Bdelloidea, Family Cunaxidae

Cunaxids are cosmopolitan in their occurrence and are recorded in soil, leaf litter, compost, mosses, plants and stored products These are generalist predators of small arthropods and nematodes

This family was erected by Thor (1902) to include those mites having four palpal segments, previously included under Bdellidae *Scirus setirostris* Hermann (1804) was the first species assigned to this family Thor and Willmann (1941) made the first comprehensive study of this family and they recognized seven genera and 30 species Baker and Hoffmann (1948) in their monographic study retained only three genera, *Cunaxa, Bonzia* and *Scirula* and proposed replacement name *Cunaxoides* for *Eupalus*

Atyeo (1958) showed the relationship of Cunaxidae with Bdellidae and suggested its placement in super family Bdelloidea Smiley (1975) dealt with this family in detail and revised the generic classification According to him, the important taxonomic characters were number of palpal segments and number of setae on them, location of dorsal shields and their setal pattern, presence of any tarsal flanges, *etc* He recognized nine genera, of which, four were proposed as new Sepasgosarian (1984) discussed the past work done by various workers, introduced a new taxonomic concept and recognized six tribes, 15 genera and 124 species under this family

Smiley (1992) brought out a monograph on this family, wherein he treated 166 species distributed over nine subfamilies and 17 genera, three of which were erected as new Besides, he gave description and illustration of all the species, provided keys to all the taxa, discussed morphological characters of taxonomic importance and provided many new synonyms and new combinations The number of palpal segments, kinds of palpal setae, kinds of setae on interior region of hypostome (ventral side) *etc* served as characters for separating subfamilies, genera and species

In India 21 species belonging to five genera under two subfamilies have been known on plants (Gupta, 2002) Heyer (2011) reported that there are about 329 species under 27 genera all over the world

2.2.7. Acaridae

Class Arachnida, Subclass Acari, Superorder Acariformes, Order Sarcoptiformes, Suborder Oribatida, Superfamily Acaroidea, Family Acaridae

Mites belonging to the family Acaridae are economically the most important owing to their pest status Their habitat ranges from house dust, fungal moulds to being pathogens of human body

Generally, the Acaridae (Astigmata or Acaridida) appear to be pests of stored products, initiators of allergies, and pests of agricultural products However, a few are predators as well In greenhouses, *Rhizoglyphus robini* and *R echinopus* are pests of bulbs (Ascerno *et al* 1981, Gencsoylu *et al* 1998) Others may feed on vegetables, as well, especially when the soil contains large amounts of organic matter (Santos *et al* 1981) *Tyrophagus putrescentiae* was reported to be an important predator of

southern corn rootworm (*Diabrotica undecimpunctata howardi*) in peanut and cornfields in North Carolina (Brust and House, 1988)

2.3. Brief history of faunal studies on plant associated mites.

The earliest record of a mite in India dates back to middle of the 19th century when Peal (1868) discovered a mite on tea in Assam Wood-Mason (1884) reported (*Tetranychus bimaculatus* Wood-Mason) for the first time a fully named species of mite on tea in India

Narayanan *et al* (1960) studied the importance of characters like the number, the arrangement, the nature, the position and the relative length of setae together with some anatomical characters in the taxonomy of Phytoseiid mites They have recorded notes on six species of Phytosendae

According to Ghai (1964), in India, there are only only 65 species of mites known under 29 genera and 11 families Channa Basavanna (1966) published a list of eriophyid mites in his book "A Contributions to Knowledge of Indian Eriophyid Mites" which included 70 species under 21 genera on 59 host plants from different plants family

Channa Basavanna (1971) provided a list of mites associated with plants in India which included 111 species The first Catalogue on Indian mites (all habitats) was prepared by Prasad (1974) which included 769 species under 279 genera and 102 families

Nineteen species of Phytoseiid mites under four genera were reported from vegetable crops and other host plants by Shahid (1984) in his study of the taxonomy of predatory mites of the family Phytoseiidae (Acari) of Peshawar region

Gupta (1985) published a "Handbook on Indian Plant Mites", in which he included 557 species under 131 genera and 18 families The number of species under different families included Tetranychidae - 82 species, Tenuipalpidae - 54 species, Tuckerellidae - three species, Nalepellidae - three species, Eriophyoidea - 236 species, Rhyncaphytoptidae - eigtht species, Tarsonemidae - four species, Cheyletidae - three species, Stigmaeidae - three species, Tydeidae - five species, Bdellidae - one species, Cunaxidae - seven species, Erythraeidae - seven species, Amerosendae-2 species, Ascidae - three species, Phytoseiidae - 172 species, Acaridae - two species and Oribatulidae - one species

A review of literature on taxonomy of Indian mites up to the end of 20th centuary revealed the occurrence of 2350 species belonging to 725 genera under 190 families The number of species/genera/families in Astigmata, Mesostigmata, Prostigmata and Cryptostigmata were 155/75/35, 475/125/35, 1275/340/60 and 435/190/60, respectively In Prostigmata, Eriophyoidea is known by the largest number of species (448 spp /96genera) followed by Trombiculidae (112/24), Tetranychidae (106/20), Tenuipalpidae (98/20), Cheyletidae (40/20), Erythraeidae (28/10), Stigmaeidae (26/7), Cunaxidae (23/4) In Astigmata the maximum number of species were known was in Acaridae (28/8) In Mesostigmata the highest number of species were known was in Phytosendae (189/14) followed by Macrochelidae (61/5), Ascidae (44/12), Laelapidae (36/11) and Macronyssidae (21/7) So far as mite fauna associated with plants is concerned, the known species/ genera/ families in plants are 968/98/20 respectively (Gupta and Gupta, 1999)

The tetranychid mites *Tetranychus neocalidonicus* on brinjal and *Tetranychus ludeni* on bhindi were reported to be the major prey mites of *Cunaxa* sp and *Amblyseius longispinosus* (Evans) (Sudharma and Nair, 1999)

Faunistic studies on predatory mites associated with vegetable crops in Orissa revealed twenty six species belonging to Prostigmata (5 species) and Mesostigmata (21 species) (Kumar and Singh, 2000)

The predatory mite, *Amblyseius* sp was reported to be a potential predator of *Tetranychus ludeni* Zacher on cowpea and of *P latus* on chilli (Abhilash, 2001)

Gupta (2002) published "A monograph on plant inhabiting predatory mites of India- part I" which included predatory mites belonging to three orders, Prostigmata, Astigmata and Cryptostigmata This included 134 species under 52 genera and 15 families The book "A Monograph on Plant Inhabiting Predatory Mites of India- part II" included predatory mites belonging to order Mesostigmata described 185 species under 18 genera belonging to four families (Gupta, 2003)

A survey on the predatory mite fauna of the family Phytoseiidae harbouring on various species of economically important plants in northern Kerala revealed 40 species under nine genera (Sadanandan and Ramam, 2006)

A survey was conducted to estimate the mite diversity on plants of different families found in the Brazilian Atlantic forest by de Castro and de Moraes in 2007 A total of 2,887 mites belonging to 163 morpho - species of 16 families were collected Mite diversity was high, especially of predatory mites, these corresponded to 1,562 specimens of 92 morpho – species Within this group, Phytoseiidae comprised 71 per cent of the specimens and 62 per cent of the morpho – species

Survey on the diversity of mites in brinjal ecosystem in Dharwad revealed three tetranychid mite species *viz* , *T macfarlanei, T urticae* and *Tetranychus* sp of which *T macfarlanei* was the major one Predatory mite species encountered were *A longispinosus* and *Phytoseius minutes* (Prasanna, 2007)

A survey conducted in Turkey to evaluate the diversity and abundance of acarines on six solanaceous plants reported 40 plant parasitic, predatory and neutral mite species belonging to 15 families namely Eriophyidae, Tetranychidae, Bdellidae, Anystidae, Cheyletidae, Erythraeidae, Phytoseiidae, Stigmaeidae, Ascidae, Parasitidae, Ameroseiidae, Acaridae, Tydeidae, Tarsonemidae and Oribatidae Among these, the plant parasitic mites, namely*Tetranychus urticae* and *Aculops lycopersici* (Massee) (Eriophyidae), the predators *Pronematus ubiquitus* McGregor (Tydeidae), *Neoseiulus bicaudus* (Wain) and *Typhlodromus* (*Anthoseius*) *recki* Wain (Phytoseiidae) and the neutrals *Tydeus kochi* (Banks) and *Tydeus* sp (Tydeidae) were predominant species and corresponded to more than 88 per cent of the mite specimens collected Most mite species were found on black nightshade (23 species), followed by tomato (17), climbing nightshade (16), pepper (16), eggplant (15) and thorn apple (13) *T urticae* was common on all plants especially egg plant (Cobanoglu, *et al* 2010)

A study undertaken to record the phytoseiid mites on different host plants in four agro-climatic regions of southern Karnataka, India, reported fifty one species of phytoseiid mites belonging to 14 genera under three sub families Of the 51 species collected, 29 known species, five were assigned names near to the already known species and remaining 17 were new to science (Gowda and Mallik, 2010)

Karmakar and Gupta (2010) reported 31 species of predatory mites belonging to nine genera, seven families and two orders from different agri-horticultural crops

and weeds in Gangetic plains of West Bengal It was observed that four species, *viz* , *Amblyseius longispinosus* (Evans) and *A largoensis* (Muma), *Agistemus* sp and *Walzia indiana* were the dominant species and were proved to be effective for having good feeding potential

Zeiti (2011) studied the diversity of mites associated with selected plants species in Bangalore which revealed the presence of 71 species of mites under 38 genera and 17 families Phytoseiidae was represented by the maximum number of species/genera (20/7), followed by Tenuipalpidae (9/4), Tetranychidae (8/5), Iolmidae (6/2), Eriophyidae (4/3), Stigmaeidae (4/2), Tydeidae (4/3), Cunaxidae (4/2), Ascidae (3/1) and Tarsonemidae (2/2)

Study on phytophagous and predatory mites associated with vegetable plants in Riyadh, Saudi Arabia reported eight phytophagous and 10 predacious mites from 14 species of vegetable crops covering five major production localities Out of these 18 mite species, 13 species were new to the mite fauna of Saudi Arabia In addition, the two species, *Tenuipalpus punicae* Pritchard & Baker and *Agistemus exsertus* were reported for the first time on vegetable crops in Saudi Arabia (Al-Atawi, 2011)

Phytophagous and predatory mite species on vegetables and fruit trees in Kahramanmara, Turkey were reported by Ozisli and Çobanoglu (2011) Predatory mites *Phytoseius finitimus* Ribaga and *Amblyseius andersoni* (Chant) (Acari Phytoseiidae) were identified from eggplant and cucumber, respectively

A detailed study was conducted by Heyer (2011) on some statistics on the taxonomy of the family Cunaxidae (Acari Prostigmata) to prepare a database for providing complete information on Cunaxid taxonomy The cunaxids are presently arranged in five subfamilies, six tribes, 27 genera and 329 species The three largest

subfamilies are Cunaxinae, Coleoscirinae and Cunaxoidinae, with 133, 91 and 90 species, respectively Each of these subfamilies is divided into two tribes, whereas the remaining two subfamilies (Bonziinae, Scirulinae) were not divided into tribes

Extensive surveys were carried out to identify phytoseiid mites co-occurring with spider mites on crops throughout the islands of Okinawa, southwestern Japan Of the 19 species found, three were new to Japan and eight were new to Okinawa *Neoseiulus womersleyi* (Schicha) was the most common species with respect to the distribution range followed by *Amblyseius eharai* Amitai and Swirski (Ohno *et al*, 2012)

The results of a survey conducted on the predatory mite fauna associated with 32 species of economically important plants belonging to 27 genera and 21 families grown in three districts of North Kerala yielded 15 species of predatory mites belonging to six genera viz, *Amblyseius, Typhlodromips, Euseius, Neoseiulus, Phytoseius* and *Paraphytoseius* which comes under the sub order Mesostigmata (Haneef and Sadanandan, 2013)

Ten species of predatory mites belonging to five families were reported associated with phytophagous mites infesting major vegetable crops of Thrissur District, Kerala (Binisha *et al* 2013)

A survey was conducted in mid-hills of Himachal Pradesh during 2011-2012 to study the mite diversity in 16 different vegetables and ornamental crops A total of 32 species in 15 genera and seven families were observed during this study, out of which six species were of phytophagous mites belonging to two genera and two families, whereas 26 species were of the predatory mites belonging to 13 genera and five families Among phytophagous mites, three species *viz Tetranychus urticae*

Koch, *T ludeni* Zacher, *T hypogeae* Gupta were most commonly found and recorded on different crops Among predatory mites, four genera *viz Amblyseius*, *Euseius*, *Neoseiulus* and *Amblydromella* were most common Maximum numbers of predatory mite species were recorded on rose, cucumber and brinjal (Singh and Chauhan, 2014)

Materials & Methods

3. MATERIALS AND METHODS

The present study was undertaken at the Acarology Laboratory, Department of Agricultural Entomology, College of Horticulture, Vellanikkara during 2014 – 2015 to explore the diversity of predatory mite fauna in the vegetable ecosystems of Thrissur district, Kerala The objectives of the investigation were to document the species diversity of predatory mites associated with phytophagous mites in vegetable ecosystems in Thrissur and to identify the predatory mite fauna associated with the phytophagous mites upto the generic / species level The morphometric studies of the identified predominant predatory mite species were carried out and a character table was also prepared Finally a dichotomous taxonomic key was prepared based on the taxonomic characters

The methodology and techniques adopted for conducting experiments based on the objectives set forth in the studies are presented hereunder

3.1. Species diversity of predatory mite fauna associated with phytophagous mites in vegetable ecosystem

3.1.1. Field Survey

Extensive surveys were carried out in the vegetable fields of different locations of Thrissur district namely, Vellanikkara, Elanadu, Pazhayannur, Anthikkad, Chelakkara, Mala, Thanniyam, Mannuthy and Vadakkanchery

Surveys were conducted from August 2014 to May 2015 to collect the predatory mites and also to record the associated phytophagous mites on the vegetable crops *viz* , amaranthus, brinjal, bhindi, bittergourd, cowpea, coccinia, chilli, cucumber, snap melon and snakegourd at various growth stages during different seasons

Each locality was surveyed two to three times during the crop period for the collection of mites

3.1.2. Sampling and collection of mites

Intensive collection of predatory mites was made from the vegetable fields Mite infested leaf samples were collected at random from amaranthus, brinjal, bhindi, bittergourd, cowpea, coccinia, chilli, cucumber, snap melon and snakegourd separately from each locality in polythene covers, which were subsequently sealed The covers were labeled properly giving details of crop, locality, date of collection etc and brought to the laboratory for further examination and extraction of the mites In order to prevent water accumulation in the covers, precautions were taken not to expose them directly to the sun

Each sample collected was assigned an accession number, and the details such as place of collection, date of collection, host plant, age/ stage of the plant, method of cultivation of the crops, season of collection, presence of other mites etc In most of the cases, the samples were processed immediately When they could not be processed on the same day, they were stored in a refrigerator at 5 – 15 °C and such samples were processed within four days

In the laboratory, the leaves were observed under stereo binocular microscope with a magnification ranging from 10 to 35X The mites were picked with fine syringe needles moistened with media and mounted on glass slides

3.1.3. Processing and preparation of permanent slides

Permanent slides of the mites collected during the survey were prepared for further taxonomic study Hoyer's medium was used for mounting mites and the ingredients of the medium is given below -

Distilled water - 50 ml

Gum Arabic - 30 g

Chloral hydrate - 200 g

Glycerol - 20 ml

The mite was mounted on a drop of Hoyer's medium on a clean dry glass slide The specimen was pushed down the media to rest on the surface of the glass slide and then oriented in such a way that the gnathosoma was facing towards the observer and the legs and gnathosoma of the specimen were stretched properly A zero number glass cover slip of 12 mm diameter was placed gently on the media in such a way that no air bubble appeared between the glass slide and the cover slip A single specimen was mounted on each slide and up to 20 such slides were prepared for each sample The slides of the prey mites were also prepared wherever available

The slides were labeled on the right side with the locality label furnishing the following details *viz* , place of collection, date of collection, habitat, host plant, name of the collector and the accession number Identity label was pasted on the left side of the slide The slides were serially numbered under each accession number

The slides so prepared were kept in a hot air oven at 40° C temperature for seven to ten days to obtain digested, cleared and dried specimens After drying, the mounted slides were ringed, i e , the cover slips were sealed with a clear nail polish

using a fine brush to avoid shrinkage of the medium All mounted slides were stored in slide storage boxes in a cool place

3.1.4. Morphological characters

The permanent slides prepared were observed under phase contrast microscope (Leica DM 500) and the morphological characters were studied with the help of image analyser software The following morphological characters were used for the classification of the predatory mite fauna -

A Chelicerae
B Pedipalps
C Peritreme
D Apotele / leg pretarsus
E Propodosomal setae
F Idiosomal setae
G Chaetotaxy (Fig 1, 2, 3 and 4)
H Dorsal idiosomal shield
I Ventral idiosomal shield
J Male genitalia
K Female genitalia

3.1.5. Morphometry

The measurements of all dorsal setae, dimensions of the dorsal shield, length and width of the body, length of macrosetae in Phytoseiidae, length of the dorsal setae and ratio between the length and the distance between the dorsal setae in

Stigmaeidae and Tydeidae were taken using image analyzer software (Leica DM 500 phase contrast microscope) All the measurements were recorded in microns

3.1.6. Illustrations

The photographs of the mite specimens illustrating their morphological characters were made using Leica DM 500 phase contrast microscope with image analyzer software The photographs on morphological characters in females and males were prepared

3.1.7. Identification

Based on the taxonomic features, identification of the mite specimens was done upto the species level using standard taxonomic keys (Krantz, 1975, Gupta,1985, Gupta, 2002, Chant and McMurtry, 2006 and Chant and McMurtry, 2007) Based on the species level identification, the total number of species recorded under different predatory families were arrived The species composition (per cent) of each family was worked out as follows -

Number of species recorded in each family/ Total number of species recorded from all families* 100

3.2. Taxonomic key to the identification of predatory mite fauna

On the basis of the characters studied and identity obtained, all the specimens were grouped and character tables were prepared Based on the character tables and specimen descriptions, detailed dichotomous key to the identification of the predatory mites studied was prepared

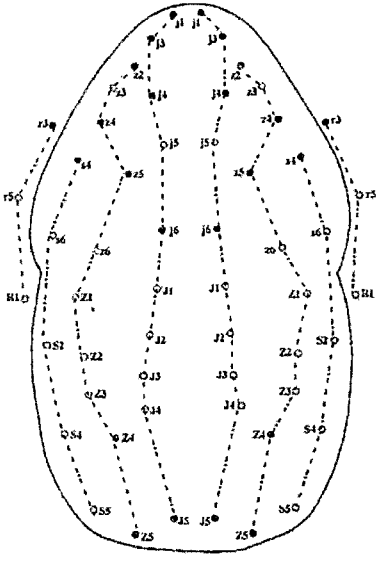


Fig 1 Hypothetical holotrichous setation on the dorsal idiosoma of Phytoseiidae (Chant and Yoshida – Shaul, 1992)

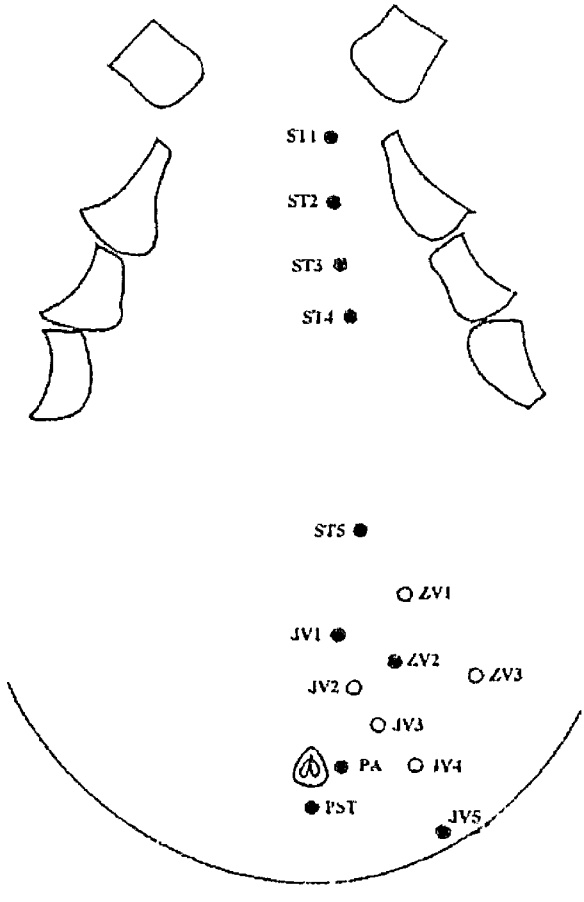


Fig 2 Hypothetical holotrichous ventral idiosomal chaetotaxy of Phytoseiidae (Chant and Yoshida – Shaul, 1992)

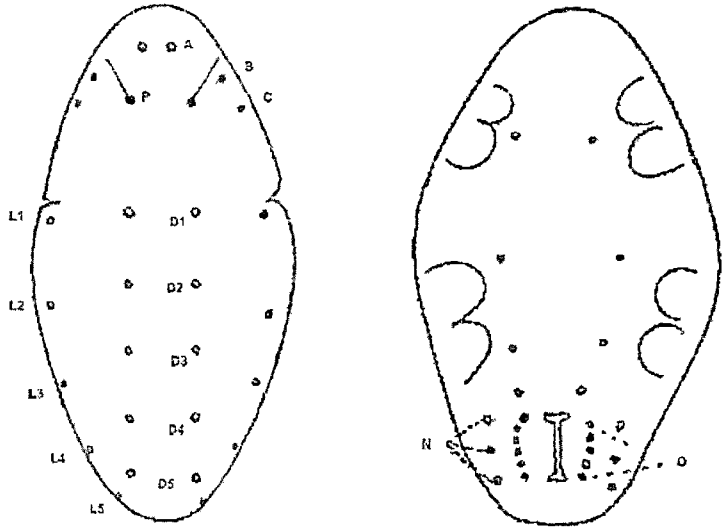


Fig 3 Tydeidae (a) Dorsum of a tydeid mite showing setal bases and (b) Ventral side of a tydeid mite showing setal bases (Gupta, 1985)

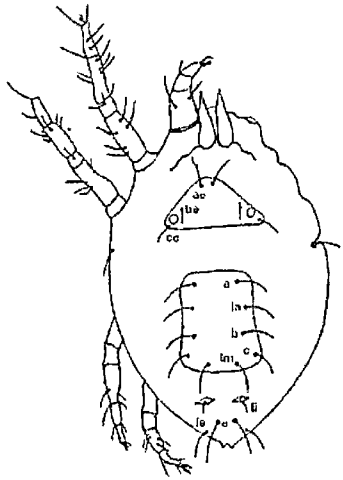


Fig 4 Dorsum of a stigmaeid mite showing setal bases (Gupta, 1985)

Results

4 RESULTS

The study on diversity of predatory mite fauna in vegetable ecosystem was conducted at the Acarology Laboratory, Department of Agricultural Entomology, College of Horticulture, Vellanikkara during 2014 – 2015 The results on various aspects of the study are presented below -

4 1 DIVERSITY OF PREDATORY MITES ASSOCIATED WITH VEGETABLES

An extensive survey was undertaken to explore the mite fauna associated with the vegetable crops *viz* amaranthus, brinjal, bhindi, bittergourd, chilli, cowpea, coccinia, cucumber, snakegourd and snap melon from major vegetable growing tracts of Thrissur district, Kerala The phytophagous and predatory mite fauna collected and identified from various vegetable crops during the survey are presented in Table 1 A total of 18 species of predatory mites belonging to six families were encountered The predatory mite families included Phytoseiidae, Stigmaeidae, Cunaxidae, Bdellidae, Tydeidae, and Acaridae represented by the genera *Neoseiulus Amblyseius, Typhlodromips Euseius, Paraphytoseius, Phytoseius Scapulaseius, Agistemus Cunaxa, Bdella, Tydeus* and *Pronematus* The associated phytophagous prey mite families recorded were Tetranychidae, Tenuipalpidae and Tarsonemidae represented by the genera *Tetranychus, Eutetranychus, Brevipalpus* and *Polyphagotarsonemus* The acarine faunal diversity in different vegetable crops is detailed below

4.1.1. Predatory mite fauna on amaranthus

A total of nine species of predatory mites, belonging to two families were observed in amaranthus These were *Neoseiulus longispinosus* Evans, *Paraphytoseius orientalis* Narayanan, *Amblyseius paraaerialis* Muma, *Amblyseius largoensis* (Muma), *Euseius macrospatulatus* Gupta, *Euseius* sp nr *prasadi*, *Typhlodromips syzygii* Gupta and *Scapulaseius* sp , all belonging to family Phytosendae and *Pronematus anconai* Baker belonging to family Tydeidae The associated phytophagous mites identified were *Tetranychus truncatus* Ehara and *Brevipalpus phoenicis* Geijskes of which *T truncatus* was the predominant one

4 1 2. Predatory mite fauna in bhindi

In bhindi, ten different species of predatory mites belonging to three families were recorded They were *N longispinosus*, *A paraaerialis*, *E macrospatulatus* and *Euseius* sp nr *prasadi* of the family Phytoseiidae, *Tydeus gossabaensis* Gupta and *P anconai* of the family Tydeidae, *Agistemus gamblei* Gupta, *Agistemus macrommatus* Gonzalez *Agistemus fleschneri* Summers and *Agistemus garrulus* Chaudhri of the family Stigmaeidae The prey mites observed were *Tetranychus tiliae* Koch *Tetranychus macfarlanei* Baker *and Eutetranychus orientalis* Klein

4.1 3 Predatory mite fauna in bitter gourd

In bitter gourd, a total of five species of predatory mites belonging to two families were recorded in association with *T truncatus* They were *N longispinosus*, *E macrospatulatus*, *T syzygii* and *A paraaerialis* of the family Phytosendae and *A gamblei* of the family Stigmaeidae

4.1.4. Predatory mite fauna in brinjal

The species richness of predatory mite fauna was found to be highest in brinjal , comprising of eighteen species belonging to five different families They were *N longispinosus*, *A paraaerialis A largoensis*, *E macrospatulatus*, *Euseius*

sp nr *prasadi*, *T syzygii*, *P orientalis*, *Phytoseius intermedius* Evans and *Scaplaseius* sp of the family Phytoseiidae, *T gossabaensis* and *P anconai* of the family Tydeidae, *A gamblei*, *A macrommatus*, *A fleschneri* and *A garrulus* of the family Stigmaeidae, *Cunaxa* sp of Cunaxidae, *Bdella khasyana* Gupta of Bdellidae and one unidentified astigmatid mite from Acaridae The major prey mites were *Tetranychus* spp among which *T macfarlanei* was the predominant one

4.1.5. Predatory mite fauna in chilli

Nine species of predatory mites belonging to five different families were observed in chilli during the survey They were *N longispinosus*, *A paraaerialis*, *E macrospatulatus* and *T syzygii* of the family Phytoseiidae, *T gossabaensis*, and *P anconai* of the family Tydeidae, *A gamblei* of the family Stigmaeidae, *Cunaxa* sp of Cunaxidae and *B khasyana* of Bdellidae These predatory mite species were associated with the phytophagous mite *Polyphagotarsonemus latus* (Banks)

4.1.6. Predatory mite fauna in cowpea

In cowpea, a total of eleven species of predatory mites belonging to five different families were recorded They were *N longispinosus*, *A paraaerialis*, *A largoensis* *E macrospatulatus*, *Euseius* sp nr *prasadi* and *T syzygii* of the family Phytoseiidae, *T gossabaensis* and *P anconai* of the family Tydeidae, *Cunaxa* sp of Cunaxidae and *B khasyana* of Bdellidae One species of astigmatid mite belonging to the family Acaridae was also observed The associated prey mites were *T truncatus*, *T macfarlanei* of the family Tetranychidae and *P latus* of the family Tarsonemidae

4.1.7. Predatory mite fauna in coccinia

Phytoseiid mites were the predominant predators in coccinia associated with the prey mite *Tetranychus* sp They were *N longispinosus*, *A paraaeralis*, *A largoensis* *E macrospatulatus* and *T syzygii*

4.1.8. Predatory mite fauna in cucumber

Four species of mesostigmatid predators belonging to the family Phytoseiidae and one species of astigmatid predator belonging to the family Acaridae were recorded from cucumber predating on *T truncatus* The phytoseiid predators were *N longispinosus*, *A paraaeralis*, *E macrospatulatus* and *T syzygii*

4.1.9. Predatory mite fauna in snakegourd

A total of seven species of predatory mites belonging to three different families were obtained from snakegourd during the study They were *N longispinosus*, *A paraaeralis*, *E macrospatulatus* and *T syzygii* of the family Phytoseiidae, *T gossabaensis* of the family Tydeidae as well as and *A macrommatus* and *A fleschneri* of the family Stigmaeidae The associated prey mites included *T truncatus* and *T macfarlanei*

4.1.10. Predatory mite fauna in snap melon

Four species of Phytoseiid predators were recorded on snap melon They were *N longispinosus*, *A paraaeralis* *E macrospatulatus* and *T syzygii* *Cunaxa* sp belonging to the family Cunaxidae was also observed *T truncatus* was the associated prey mite

Highest number of predatory mite species were observed on brinjal with a total of 18 species, followed by cowpea (11), bhindi (10), amaranthus (9), chilli (9), snakegourd (7), bittergourd (5), coccinia (5), cucumber (5) and snakegourd (4) (Table 2)

4.2. Faunal composition of predatory mite families

The predatory mites belonging to the family Phytoseiidae was found to be the most common predators on all the vegetable crops surveyed, comprising of nine species, followed by Stigmaeidae (4), Tydeidae (2), Bdellidae (1), Cunaxidae (1) and Acaridae (1) (Table 3) *Neoseiulus longispinosus* was found to be the predominant predatory mite species in all the crops

Table 1. Predatory and phytophagous mites associated with vegetable crops in Thrissur district

Host plant	Predatory mites			Phytophagous mites		
	Mite genus/species	Order	Family	Mite genus/species	Order	Family
Amaranthus (*Amaranthus* sp)	*Neoseiulus longispinosus*	Mesostigmata	Phytoseiidae	*Tetranychus truncatus* Ehara	Prostigmata	Tetranychidae
	Paraphytoseius orientalis	Mesostigmata	Phytoseiidae	*Brevipalpus phoenicis* Geijskes	Prostigmata	Tenuipalpidae
	Amblyseius largoensis	Mesostigmata	Phytoseiidae			
	Amblyseius paraaberrialis	Mesostigmata	Phytoseiidae			
	Euseius macrospatulatus	Mesostigmata	Phytoseiidae			
	Euseius sp *nr prasadi*	Mesostigmata	Phytoseiidae			
	Typhlodromips syzygii	Mesostigmata	Phytoseiidae			
	Scapulaseius sp	Mesostigmata	Phytoseiidae			
	Pronematus anconai	Prostigmata	Tydeidae			

Table 1 contd

Host plant	Predatory mites			Phytophagous mites		
	Mite genus/species	Order	Family	Mite genus/species	Order	Family
Bhindi	*Neoseiulus longispinosus*	Mesostigmata	Phytoseiidae	*Tetranychus urticae* Koch	Prostigmata	Tetranychidae
	Amblyseius paraaeralis	Mesostigmata	Phytoseiidae			
	Eusenus macrospatulatus	Mesostigmata	Phytoseiidae	*Tetranychus macfiularei* Baker	Prostigmata	Tetranychidae
	Eusenus sp nr *piasadi*	Mesostigmata	Phytoseiidae			
	Tydeus gossabaensis	Prostigmata	Tydeidae	*Eutetranychus orientalis* Klein	Prostigmata	Tetranychidae
	Agistemus gamblei	Prostigmata	Stigmaeidae			
	Agistemus macrommatus	Prostigmata	Stigmaeidae			
	Agistemus fleschneri	Prostigmata	Stigmaeidae			
	Agistemus garrulus	Prostigmata	Stigmaeidae			

Table 1 contd

Host plant	Predatory mites			Phytophagous mites		
	Mite genus/species	Order	Family	Mite genus/species	Order	Family
Bitter gourd	*Neoseiulus longispinosus*	Mesostigmata	Phytoseiidae	*Tetranychus truncatus*	Prostigmata	Tetranychidae
	Euseius macrospatulatus	Mesostigmata	Phytoseiidae			
	Typhlodromips syzygii	Mesostigmata	Phytoseiidae			
	Amblyseius paraaerialis	Mesostigmata	Phytoseiidae			
	Agistemus gamblei	Prostigmata	Stigmaeidae			
Brinjal	*Neoseiulus longispinosus*	Mesostigmata	Phytoseiidae	*Tetranychus macfarlanei*	Prostigmata	Tetranychidae
	Amblyseius paraaerialis	Mesostigmata	Phytoseiidae			
	Amblyseius largoensis	Mesostigmata	Phytoseiidae			
	Euseius macrospatulatus	Mesostigmata	Phytoseiidae			
	Euseius sp nr *prasadi*	Mesostigmata	Phytoseiidae			
	Typhlodromips syzygii	Mesostigmata	Phytoseiidae			
	Paraphytoseius orientalis	Mesostigmata	Phytoseiidae			
	Phytoseius intermedius Evans	Mesostigmata	Phytoseiidae			
	Scapulaseius sp	Mesostigmata	Phytoseiidae			

Table 1 contd

Host plant	Predatory mites			Phytophagous mites		
	Mite genus/species	Order	Family	Mite genus/species	Order	Family
	Pronematus anconai	Prostigmata	Tydeidae	*Tetranychus* spp	Prostigmata	Tetranychidae
	Agistemus gamblei	Prostigmata	Stigmaeidae			
	Agistemus macronmatus	Prostigmata	Stigmaeidae			
	Agistemus fleschneri	Prostigmata	Stigmaeidae			
	Agistemus garrulous	Prostigmata	Stigmaeidae			
	Cunaxa sp	Prostigmata	Cunaxidae			
	Bdella khasyana Gupta	Prostigmata	Bdellidae			
	Acarid mite	Astigmata	Acaridae			
Chilli	*Neoseiulus longispinosus*	Mesostigmata	Phytoseiidae	*Polyphagotarsonemus latus* (Baker)	Prostigmata	Tarsonemidae
	Amblyseius paraaerialis	Mesostigmata	Phytoseiidae			
	Euseius macrospatulatus	Mesostigmata	Phytoseiidae			
	Typhlodromips syzygii	Mesostigmata	Phytoseiidae			
	Tydeus gossabaensis	Prostigmata	Tydeidae			
	Pronematus anconai	Prostigmata	Tydeidae			

Table 1 contd

Host plant	Predatory mites			Phytophagous mites		
	Mite genus/species	Order	Family	Mite genus/species	Order	Family
	Agistemus gamblei	Prostigmata	Stigmaeidae			
	Cunaxa sp	Prostigmata	Cunaxidae			
	Bdella khasyana	Prostigmata	Bdellidae			
Cowpea	*Neoseiulus longispinosus*	Mesostigmata	Phytoseiidae	*Tetranychus truncatus*	Prostigmata	Tetranychidae
	Amblyseius paraaerialis	Mesostigmata	Phytoseiidae	*Tetranychus*		
	Amblyseius largoensis	Mesostigmata	Phytoseiidae	*macfarlanei*	Prostigmata	Tetranychidae
	Euseius macrospatulatus	Mesostigmata	Phytoseiidae			
	Euseius sp nr *pirasadi*	Mesostigmata	Phytoseiidae			
	Typhlodromips syzygii	Mesostigmata	Phytoseiidae			
	Tydeus gossabaensis	Prostigmata	Tydeidae			
	Pronematus anconai	Prostigmata	Tydeidae			
	Cunaxa sp	Prostigmata	Cunaxidae	*Polyphagotarsonemus latus*	Prostigmata	Tarsonemidae
	Bdella khasyana	Prostigmata	Bdellidae			
	Acarid mite	Astigmata	Acaridae			

Table 1 contd

Host plant	Predatory mites			Phytophagous mites		
	Mite genus/species	Order	Family	Mite genus/species	Order	Family
Coccima	*Neoseiulus longispinosus*	Mesostigmata	Phytoseiidae	*Tetranychus* sp	Prostigmata	Tetranychidae
	Amblyseius paraaerialis	Mesostigmata	Phytoseiidae			
	Euseius macrospatulatus	Mesostigmata	Phytoseiidae			
	Typhlodromips syzygu	Mesostigmata	Phytoseiidae			
Cucumber	*Neoseiulus longispinosus*	Mesostigmata	Phytoseiidae	*Tetranychus truncatus*	Prostigmata	Tetranychidae
	Amblyseius paraaerialis	Mesostigmata	Phytoseiidae			
	Euseius macrospatulatus	Mesostigmata	Phytoseiidae			
	Typhlodromips syzygu	Mesostigmata	Phytoseiidae			
	Acarid mite	Astigmata	Acaridae			
Snake gourd	*Neoseiulus longispinosus*	Mesostigmata	Phytoseiidae	*Tetranychus truncatus*	Prostigmata	Tetranychidae
	Amblyseius paraaerialis	Mesostigmata	Phytoseiidae			
	Euseius macrospatulatus	Mesostigmata	Phytoseiidae			

Table 1 contd

Host plant	Predatory mites			Phytophagous mites		
	Mite genus/species	Order	Family	Mite genus/species	Order	Family
	Typhlodromips syzygii	Mesostigmata	Phytoseiidae	*T macfarlanei*	Prostigmata	Tetranychidae
	Tydeus gossabaensis	Prostigmata	Tydeidae			
	Agistemus macrommatus	Prostigmata	Stigmaeidae			
	Agistemus fleschneri	Prostigmata	Stigmaeidae			
Snap melon	*Neoseiulus longispinosus*	Mesostigmata	Phytoseiidae	*T truncatus*	Prostigmata	Tetranychidae
	Amblyseius paraaberrialis	Mesostigmata	Phytoseiidae			
	Euseius macrospatulatus	Mesostigmata	Phytoseiidae			
	Typhlodromips syzygii	Mesostigmata	Phytoseiidae			
	Cunaxa sp	Prostigmata	Cunaxidae			

Table 2: Diversity of predatory mite species in vegetables

Sl no	Host plant	Number of predatory mite species
1	Amaranthus	9
2	Bhindi	10
3	Bittergourd	5
4	Brinjal	18
5	Chilli	9
6	Cowpea	11
7	Coccinia	5
8	Cucumber	5
9	Snakegourd	7
10	Snap melon	4

Table 3 : Faunal composition of predatory mite families

Sl no	Family	Number of species	Per cent (%) = Number of species in family/Total number of species recorded * 100
1	Phytoseiidae	9	50 00
2	Stigmaeidae	4	22 22
3	Tydeidae	2	11 11
4	Bdellidae	1	5 55
5	Cunaxidae	1	5 55
6	Acaridae	1	5 55
Total		18	100

4 2 TAXONOMY OF PREDATORY MITES ASSOCIATED WITH MAJOR VEGETABLE CROPS OF THRISSUR DISTRICT, KERALA

Eighteen species of predatory mites belonging to twelve genera under three orders *viz* Astigmata, Prostigmata and Mesostigmata representing six families namely Acaridae (one species), Tydeidae (two species), Stigmaeidae (four species), Cunaxidae (one species), Bdellidae (one species) and Phytoseiidae (nine species) were encountered from the vegetable fields during the study period The mites were identified upto genus /species level by using appropriate literature A synoptic description of these species along with keys from order level for identification are given Photographs of morphological characters are also provided wherever relevant

Key to the orders of predatory mites collected during the study

1 Stigmata present, trichobothria present on idiosoma, pedipalp with apotele 2

1'Stigmata absent, trichobothria never present on idiosoma, apotele completely absent on pedipalp (Plate 19) Order **Astigmata**

2 Stigmata opening at or between the bases of the chelicerae, at the base of the gnathosoma or in the anterior propodosomal shoulders (Plate 17c), coxa fused to body wall, tritosternum absent Order **Prostigmata**

2'Stigmata present between coxae III and IV laterally (Plate 7), coxa free, tritosternum usually present (Plate 4a) Order **Mesostigmata**

4.2.1. Order Mesostigmata

Mesostigmatid mites collected during the study ranged in size from 200µm to 400µm with a number of distinctive sclerotized shields or plates on the idiosomatic dorsum and venter They were characterised as follows a discrete sternal shield present, a pair of lateroventral stigmatal openings between coxae II – IV, associated with elongate peritremes, an inner basal palpal apotele with two, three or four tines, terminus of palpal tarsus equipped with several sensory setae, a pair of horn like corniculi at the terminus of hypostome, hypostome with three pairs of setae arranged in a triangle, or in a virtually straight line, a tritosternum ventrally behind the gnathosoma, with 1-3 laciniae, a transverse genital aperture in the intercoxal region covered with one, three or four shields in the female and by one or two shields in the male, males lack an aedeagus, male genital aperture located either at the anterior edge of, or within the sternogenital region

Two families of mesostigmatid mites were reported to be predaceous on phytophagous mites In the present study, predatory mites belonging to only one family under Mesostigmata, namely **Phytoseiidae** were collected from the vegetable crops

4.2.1.1. Family Phytoseiidae Berlese
Type genus- *Phytoseius* Ribaga, 1904

The adult phytoseiid mites were characterised as follows 200-400µm in length, idiosoma of adult female with 25-38 pairs of setae, dorsal shield with maximum of 23 pairs of setae, males with setae in the r – R series inserted on the dorsal shield, palpal claw with two tines, corniculi slender, proximal, parallel and

blade – like, tritosternum well developed with two lacinia, chelicerae chelate – dentate with both digits well developed, peritremal shield fused anteriorly with dorsal shield, female genital shield truncate posteriorly, with straight posterior margin, most adult females with ventral and anal shield fused to form ventrianal shield, males with sternogenital and ventrianal shields, all legs with claws and with reduced setation, genu II never with more than nine setae, tibia II with only seven setae, spermatheca well developed with atrium, calyx and major duct sclerotized, males with setae r3, r5 and R1 inserted on the lateral margin of dorsal shield

In India, 195 species of Phytoseiids are known, that belong to 20 genera under 3 subfamilies (Demite *et al*, 2014) About 42 species of Phytoseiid mites have been reported from Kerala so far (Sadanandan and Ramani, 2006) Nine species of phytosend mites were collected during the present study belonging to seven genera in two subfamilies namely, Amblyseiinae and Phytoseiinae

Key to subfamilies and genera of Phytoseiidae collected during the present study

1 Setae z3 and s6 absent (only 4 pairs of prolateral setae)
Amblyseiinae 2

1' Either seta z3 or seta s6 or both present (prolateral setae 5 or 6 pairs) Setae Z1, S2, S3 and S4 absent (Plate 2a) **Phytoseiinae** genus ***Phytoseius***
leg IV without any macrosetae (Plate 2d) ***intermedius***

2 Sternal shield with median posterior projection, deutosternal groove wider (> 5 µm in width), some forward migration of preanal setae JV2 and ZV2 (Plate 3c), preanal setae on the male usually arranged in a tangential row rather than in a triangular pattern (Plate 3d) genus ***Euseius*** 3

2' Sternal shield without posterior projection, deutosternal groove narrower (< 5 μm in width), without forward migration of preanal setae JV2 and ZV2, preanal setae on the male usually arranged in a triangular pattern rather than in a tangential row 4

3 Dorsal shield reticulated with anterolateral striations (Plate 3a) sp. nr. ***prasadi***

3' Dorsal shield smooth with no reticulations (Plate 4) ***macrospatulatus***

4 Seta S4 absent, dorsal setae thickened and strongly serrated (Plate 5a), female ventrianal shield long and narrow, distinct notch in lateral margin of dorsal shield at level of seta s4 genus ***Paraphytoseius***

genital shield wider than ventrianal shield width, leg IV with 4 stout macrosetae with tips swollen (Plate 5e) ***orientalis***

4' Seta S4 present, dorsal setae normal and without serrations, female ventrianal shield variable in shape, without distinct notch in lateral margin of dorsal shield at level of seta s4 5

5 Seta s4 Z1 > 3 1, setae s4, Z4 and Z5 markedly longer than other setae, seta J2 present/absent, leg IV with three macrosetae (Plate 6g) ***Amblyseius*** 6

5' Seta s4 Z1 < 3 0 1 0, setae s4, Z4 and Z5 not greatly longer than other setae, seta J2 always present, leg IV with either 1 or 3 macrosetae 7

6 Cervix of spermatheca looped (Plate 6f) ***paraaerialis***

6' Cervix of spermatheca elongate with the parallel sides (Plate 7c) ***largoensis***

7 Genu II without macroseta, fixed digit of chelicerae with fewer than six teeth, female ventrianal shield variable in shape, never vase-shaped, leg IV with one macroseta (Plate 8f) ***Neoseiulus***

ventrianal shield triangular, fixed digit of chelicera with 3 teeth, movable digit with 2 sharp teeth, peritreme extends anteriorly upto j1 (Plate 8a) ***longispinosus***

7' Genu II with macroseta, fixed digit of chelicera with more than six teeth, female ventrianal shield smooth and vase-shaped, leg IV with 3 macrosetae 8

8 Dorsal shield without prominent waist at level of seta R1, dorsal shield with distinct longitudinal striations on antero-lateral margin, seta R1 inserted on edge of dorsal shield in female (Plate 9) ***Scapulaseius***

8' Dorsal shield with a waist at level of seta R1, dorsal shield reticulate, with scale - like marking on antero-lateral margin, seta R1 never inserted on dorsal shield in female (Plate 10) ***Typhlodromips***

Z5 longer than all, thick and serrated, setae Z4 shorter than Z5 setae but thick, serrated, fixed digit of chelicera with six teeth, movable digit toothless (Plate 10b), leg IV with three strong macrosetae, which are smooth, setiform (Plate 10e) ***syzygii***

4.2.1 1.1 *Phytoseuis* Ribaga

Phytoseius Ribaga, 1904 177

Dorsal shield rugose with 15 pairs of setae and 1 pair of sublateral setae, R1 absent, setae j1, j3, z3, s4, s6, Z4, Z5, mostly long, thick and serrate, ventrianal shield

longer than wide with 3 pairs of preanal setae, macrosetae usually present on genu, tibia and basitarsus of leg IV

4.2.1.1.1.1. *Phytoseius intermedius* Evans and Macfarlane (Plate 2)

Phytoseius intermedius Evans and Macfarlane, 1962

Female: Dorsal shield length 255 67(250-260) µm, 148 23(145-150) wide at widest point (s6 level), with 15 pairs of dorsal setae s4, s6, Z4, Z5, very long, serrated, r3 inserted on dorsal shield, R1and J2 absent, sternal shield length (ST1-ST3) 52(50-54), width (ST3-ST3) 68(65-70), with 3 pairs of sternal setae, genital shield width (ST5-ST5) 63(60-65), ventrianal shield 80(83-77) long, 43(40-45) wide at widest point (anal opening) with 3 pairs of preanal setae, leg IV without any macrosetae

Male: Chaetotaxy of male is similar to that present in female, R1 inserted on the lateral margin of dorsal shield

Materials examined : 4 ♀, 2 ♂, Kerala Pazhayannur, ex brinjal, 18 ix 2014

4.2.1.1.2. *Euseius* Wainstein

Type species- *Seius finlandicus* Oudemans

All species had female dorsal setal pattern 10A 9B and most have caudoventral setal pattern JV-3 ZV, for total of 33 pairs of setae, dorsal setae short/medium in length, setiform, at most sparsely serrated, never greatly elongate or whip like, setae s4 and Z5 rarely but sometimes much longer than other dorsal setae Setae r3 and R1 inserted on the lateral margin of the dorsal shield of females of some

species, ventrianal shield reduced, either vase shaped or ovoid, never rectangular or pentangonal with three pairs of preanal setae

4.2.1.1.2.1. ***Euseius*** sp nr ***prasadi*** (Plate 3)

Female: Dorsal shield similar to *Euseius prasadi* but *R*1 not inserted laterally on dorsal shield, dorsal shield reticulated with anterolateral striations, constricted at the level of *R*1, 348 43(345-350) µm long, 268 32(265-270) wide (below s4), sternal shield smooth, length (ST1-ST3) 63(60-65), width (ST3-ST3) 75, with 3 pairs of preanal setae (ST1-3), genital shield smooth, with 1 pair of setae, width 78(75-80) (ST5-ST5), ventrianal shield vase shaped with 3 pairs of preanal setae, three pairs of macrosetae present on leg IV, measurements of macrosetae - genu 45, tibia 35(32-35), basitarsus 57(55-58)

Male: Chaetotaxy of male similar to that present in female, R1 and r3 inserted on the lateral margin of the dorsal shield, ventrianal shield reticulated with three pairs of preanal setae arranged in tangential row

Materials examined : 3♀, 1♂, Kerala Pazhayannur, Vellanikkara, Mathilakam, ex cowpea, 14 ix 2014, 09 x 2014, 19 x 2014, 7♀, 2♂, Kerala Chelakkara, Vellanikkara, ex bhindi, 06 viii 2014, 12 ii 2015, 8♀, 3♂, Kerala Pazhayannur, Mala , ex brinjal, 13 xi 2014, 15 in 2015, 12♀, 3♂, Kerala Pazhayannur, Anthikad, Vellanikkara, ex amaranthus, 06 ii 2015, 03 in 2015, 02 iv 2015

4.2.1.1.2.2. ***Euseius macrospatulatus*** (Gupta) (Plate 4)

Female: Dorsal shield smooth, broad but longer than wide with some sort of ornamentation, constricted at the level of R1, posterior margin broad and truncate, length 314 38(303-330), width at the widest point (between s4 and Z1 level) 221 54 (218-223), idiosoma with 33 pairs of setae, 19 pairs inserted on the dorsal side and 14 pairs on the ventral side, dorsal idiosomal setal pattern 10A 9B with 19 pairs of setae, 17 pairs inserted on the dorsal shield and two pairs inserted on the lateral integument of the dorsal shield (r- R series), dorsal shield with seven pairs of setae of j – J series, six pairs of z – Z series and four pairs of s – S series, dorsal setae smooth, setiform, short to medium in length, seta j1 and Z5 prominent, longer than others, later on thick and spine like and the remaining setae shorter in length J4, j5 and J5 minute, peritremes extending upto the level between j3 and z2

Sternal shield smooth, about as long as wide, posterior margin projected, length (ST1- ST3) 58 (56- 59), width (ST3- ST3) 65 (62-69) with three pairs of sterenal setae (ST1, ST2 and ST3), fourth pair of sternal setae ST4 inserted free on the integument, posterior to sternal shield, genital shield smooth, elongated, wider than ventrianal shield with (ST5-ST5) 62 (60-66) with a pair of genital setae (ST5), ventrianal shield smooth, vase shaped, lateral margins concave, wider than anal level, length 98 (95-103), width at ZV2 level 54 (49-59), width at the widest point (anal level 67 (65-68) with three pairs of pre anal setae arranged in a triangular pattern, spermatheca with long narrow calyx, chelicera reduced in size, small stubby, fixed digit with four small teeth, movable digit strongly recurved with one tooth, legs I and II with no macrosetae, leg III with macrosetae on genu and tibia and leg IV with three macrosetae, which are smooth, rod shaped, uniform girth throughout their length with rounded tip

Male Dorsal chaetotaxy similar to that of female except that the sublateral setae (setae of r- R series) are inserted on the lateral margins of the dorsal shield, ventrianal shield triangular, reticulate, with three pairs of preanal setae arranged in a tangential row

Materials examined : 8♀, 2♂, Kerala Vellanikkara, Mathilakam, Mannuthy, ex amaranthus, 07 iii 2015, 23 ix 2014, 26 iii 2015, 4♀, 2♂, Kerala Pazhayannur, Elanad, Vellamkkara, 21 viii 2014, 19 i 2015, ex bhindi, 2♀, Kerala Vellanikkara, Anthikkad, 02 iii 2015, 18 xii 2014, ex chilli, 6♀, 3♂, Kerala Pazhayannur, Elanad, Vellanikkara, Vadakaanchery, Chelakkara, 14 vi 2014, 21 vi 2014, 15 vii 2014, 11 viii 2014, 17 viii 2014, 2♀, Kerala Vellanikkara, Pazhayannur, 16 x 2014, 10 ii 2015, 3♀, Kerala Pazhayannur, Elanad, 14 vi 2014, 21 vi 2014, ex cucumber, 2♀, Kerala Vellanikkara, Pazhayannur, 14 vi 2014, 21 vi 2014, ex snakegourd

4.2.1.1.3. ***Paraphytoseius*** Swirski and Schechter

Paraphytoseius Swirski and Schechter, 1961 113

Type species-*Typhlodromus (Amblyseius) orientalis* Narayanan, Kaur and Ghai, 1960 384

Dorsal setal pattern 10A 6E, with 16 pairs of setae, J2, S2 and *S*4 absent and seta S5 present/absent, dorsal setae variable in length and morphology, setae j3, s4, Z4 and Z5 elongate, very thick, strongly serrated arising from tubercles, setae Z4 and Z5 in unusually close proximity

4.2 1.1 3.1 ***Paraphytoseius orientalis*** (Narayanan, Kaur and Ghai) (Plate 5)

Typhlodromus (Amblyseius) orientalis, Narayanan, Kaur and Ghai, 1960 349

Paraphytoseius orientalis Chant and McMurtry 2003b 179

Female· Dorsal shield smooth much longer than wide, deeply notched at the level of s4, rounded posteriorly, with the waist at the level of setae R1, length 386 62(380-387) µm, width at the widest point (the level between s4 and Z1) 166 76(163-168), dorsal shield with 13 pairs of setae and 2 pairs of lateral setae (r3 and R1), setae j3, s4, Z4, and Z5 long, prominent, very thick and serrated, peritreme long and extending beyond the level of setae j1, sternal shield smooth slightly wider than long, length 67(65-68), width 76(75-76), with 2 pairs of sternal setae (ST1-2), 3th pair (ST3) inserted on the posterolateral margin of the sternal shield, genital shield wider than ventrianal shield width (ST5-ST5) 83(81-85), ventrianal shield length 104(103-105) width at the level of anal opening 59(58-60), with 3 pairs of preanal setae, leg IV with 4 stout macrosetae with tips swollen with length genu 27(25-28), tibia 34(33-35), basitarsus 45, distitarsus 37(35-39)

Male: Dorsal chaetotaxy similar to female

Materials examined : 4♀, 2♂, Kerala Vellanikkara, Pazhayannur, ex amaranthus, 13 vi 2014, 16 vii 2014, 13♀, 6♂, Kerala Vellanikkara, Pazhayannur, Elanad, ex brinjal, 14 viii 2014, 29 ix 2014, 14 iii 2015

4.2.1.1.4. *Amblyseius* Berlese

Amblyseius Berlese, 1914 143

Type species- *Zercon Obtusus* Koch

The genus *Amblyseius* is distinguished by the following characters setae S2 shorter with the ratio seta s4 S2> 3 0 1 0, all species have setae z2, z4, Z1, S2, S4 and *S5* short/minute, subequal, setae s4, Z4 and Z5 are usually greatly elongated

4.2.1.1.4.1. *Amblyseius largoensis* (Muma) (Plate 6)

Amblyseiopsis largoensis Muma, 1955 266.

Typhlodromus (Amblyseius) largoensis Chant, 1959a 1-146

Amblyseius (Amblyseius) largoensis Muma, 1961 267.

Amblyseius largoensis Chant and McMurtry, 2004 171

Female: Dorsal shield smooth, 349 62(347-352) µm long, 245 35(242-247) wide at S2 level, with 17 pairs of setae, setae j1, j3, s4 long, Z4 and Z5 long and whip like, sternal shield longer than wide, with 3 pairs of setae, metasternal plate distinct with one seta (ST4), genital shield 70 wide (ST5-ST5) with a pair of setae (ST5), ventrianal shield longer than wide, 119(118-120) long, 71(70-71) wide, vase shaped, lateral margins concave, with 3 pairs of preanal setae, 4 pairs of setae around ventrianal shield, spermatheca with tubular cervix, walls parallel, peritreme extends anteriorly up to j1, measurement of macrosetae on leg IV genu 131(130-132), tibia 109(110 107), basitarsus 74(73-75)

Male: Dorsal chaetotaxy similar to female

Materials examined : 4♀, 2♂, Kerala Vellanikkara, Pazhayannur, Elanad, ex amaranthus, 14 viii 2014, 29 ix 2014, 14 iii 2015, 7♀, 3♂, Kerala Vellamkkara, Pazhayannur, Elanad, ex brinjal, 14 viii 2014, 29 ix 2014, 14 iii 2015

4.2.1.1.4. 2. *Amblyseius paraaerialis* Muma (Plate 7)

Amblyseius paraaerialis Muma, 1967 270

Female: Dorsal shield smooth, broad much longer than wide, posterior region broader than anterior region, slightly constricted at the level of *R*1, length 372 37(365-375) µm, 255 28(250-260) wide at the widest point (*S*2 level), dorsal

shield with 17 pairs of setae and 2 setae inserted laterally (*r-R* series), peritreme very long and extending well beyond the level of setae *j*1, sternal shield smooth, wider than long, posterior margin straight, length (ST1-ST3) 63(62-63), width (ST3-ST3) 79(77-80), with 3 pairs of sternal setae (ST1-3), genital shield smooth, slightly narrower than ventrianal shield, width (ST5-ST5) 74(72-75) with one pair of genital setae (*ST5*), ventrianal shield pentagonal, smooth broader at the anterior end, lateral margins slightly concave, length 120 21(115-125), width 98(95-100) at the widest point (above ZV2), with 3 pairs of preanal setae, fixed digit of chelicera with 9 teeth and movable digit with 5, leg IV with 3 macrosetae

Male: Dorsal chaetotaxy similar to female

Materials examined : 11♀, 3♂, Kerala Vellanikkara, Pazhayannur, Elanad, ex amaranthus, 07 iii 2015, 23 ix 2014, 26 iii 2015 , 9♀, 2♂, Kerala Mathilakam, Vadakaanchery, Mala, ex bhindi, 14 vi 2014, 24 vii 2014, 16 i 2015 , 16♀, 6♂, Kerala Vellanikkara, Pazhayannur, Elanad, ex brinjal, 07 iii 2015, 23 ix 2014, 26 iii 2015, 3♀, Kerala Mathilakam, Vadakaanchery, Mala, ex chilli, 14 vi 2014, 24 vii 2014, 16 i 2015 , 12♀, 5♂, Kerala Vellanikkara, Pazhayannur, Elanad, ex cowpea, 07 iii 2015, 23 ix 2014, 26 iii 2015, 4♀, Kerala Mathilakam, Vadakaanchery, Mala, ex coccinia, 14 vi 2014, 24 vii 2014, 16 i 2015, 7♀, 3♂, Kerala Vellanikkara, Pazhayannur, Elanad, ex cucumber, 07 iii 2015, 23 ix 2014, 26 iii 2015, 5♀, Kerala Vellanikkara, ex snakegourd, 03 i 205, 3♀, Kerala Vellanikkara, ex snap melon, 26 iii 2015

4.2.1.1.5. *Neoseiulus* Hughes

Neoseiulus Hughes, 1948 141

Type species- *Neoseiulus barkeri*

Dorsal setal pattern 10A 10B, dorsal setae short to medium in length, setiform but occasionally strongly serrated, subequal except that Z5 and sometimes Z4 are longer in some species, peritreme usually extending to level of setae J1, ventrianal shield variable in shape, never vase shaped

4.2.1.1.5.1. ***Neoseiulus longispinosus*** (Evans) (Plate 8)

Typhlodromus longispinosus Evans, 1952 413

Amblyseius (Neoseiulus) longispinosus Gupta 1986 116

Neoseiulus longispinosus Chant and McMurtry, 2003a 3

Female: Dorsal shield 324 29(337-312) µm long, 193 57(200-188) wide at the point of S2, dorsal shield smooth with 17 pairs of setae, all setae on dorsal shield very long except j1, J5 and S5 which are shorter, sternal shield smooth with 3 pairs of setae ST1-3, ventrianal shield triangular, with 3 pairs of preanal setae, four pairs of setae present around ventrianal shield, fixed digit of chelicera with 3 teeth, movable digit with 2 sharp teeth, peritreme extends anteriorly upto j1

Male: Chaetotaxy of male is similar to that in female except that sublateral setae (r3, R1) inserted on lateral margin of dorsal shield, ventrianal shield reticulated with three pairs of preanal setae arranged in triangular pattern

Materials examined : 14♀, 6♂, Kerala Vellanikkara, Mala, Mathilakam, ex amaranthus, 23 v 2014, 06 i 2015, 18♀, 8♂, Kerala Vellanikkara, Pazhayannur, Chelakkara, ex bhindi, 26 vi 2014, 8♀, 3♂, Kerala Vadakaanchery, Mannuthy, ex bittergourd, 21 ix 2014, 31♀, 14♂, Kerala Vellanikkara, Pazhayannur, Chelakkara, Anthikad, ex brinjal 14 viii 2014, 9♀, 2♂, Kerala ex chilli, 29 xi 2014, 26♀, 10♂, Kerala Vellanikkara, Pazhayannur, Chelakkara, Anthikad, ex cowpea,

17 xii 2014, 7♀, 3♂, Kerala Pazhayannur, Elanad, ex coccinia, 12 ii 2015, 10♀, 4♂, Kerala Vellanikkara, Anthikad, Pazhayannur, ex cucumber, 14 ii 2015 , 6♀, 2♂, Kerala Vellanikkara, Chelakkara, ex snakegourd, 23 vi 2014, 5♀, 2♂, Kerala Mala, ex snapmelon, 06 i 2015

4.2.1.1.6. *Scapulaseius* sp. Karg and Oomen – Kalsbeck (Plate 9)

Female idiosomal setal pattern 10A 9B, with 33 pairs of setae, dorsal shield ovoid with anterolateral striations running parallel to the margin of the shield,dorsal setae setiform, with all setae short except seta Z5, sternal shield smooth, male ventrianal shield with 3 pairs of preanal setae arranged in a triangular pattern, peritreme extending to the level of j1, fixed digit of chelicera with 6 prominent teeth, movable digit 2 teeth, leg IV with 3 macrosetae

Materials examined : 1♀, Kerala Vellanikkara, ex amaranthus, 28 xii 2014, 2♀, Kerala Vellanikkara, ex brinjal, 12 i 2015

4.2.1.1.7. *Typhlodromips* De Leon

Typhlodromips De Leon, 1965 23

The genus *Typhlodromips* can be recognised by the following characters female idiosomal setal pattern 10A 9B, with 19 pairs of setae with setae J1 present, dorsal shield much longer than wide with strong reticulation, with a prominent waist at the level of setae R1, most dorsal setae setiform but setae Z4 and Z5 often stout, club like, serrated, other setae of medium length or short, setae S2, S4 and S5 short, setae r3 and R1 never inserted on the dorsal shield of the adult female, ratio seta s4

Z1 < 3 1 1 0, sternal shield about as long as wide, smooth, with posterior margin straight or concave, with setae ST1 – 3, genital shield smooth, about as wide as or narrower than ventrianal shield, female ventrianal shield pentagonal, smooth, with three pairs of preanal setae arranged in a triangular pattern, male with three pairs of preanal setae, peritreme extending to level of seta j1, fixed digit of chelicerae with 8 – 11 or more teeth, movable digit with three teeth, GeII and III, and often GeI with macrosetae, leg IV with three strong macrosetae with tips blunt or lobed

4 2.1.1.8.1. ***Typhlodromips syzygii*** (Gupta) (Plate 10)
Amblyseius syzygi Gupta, 1975 42
Amblyseius (Typhlodromips) syzygi Gupta, 1985b
Typhlodromips syzygi Chant and McMurtry 2005c 315

Female Dorsal and the ventral shields well sclerotised and clearly visible, dorsal shield reticulated with anterolateral striations, much longer than wide, broad at the posterior end, tapering anteriorly, considered at the level of R1, length 345 48 (338 – 358), width at widest point (between S2 and S4 level) – 227 37 (223 – 238), idiosoma with 33 pairs of setae, 19 pairs inserted on the dorsal side and 14 pairs on the ventral side, dorsal idiosomal setal pattern 10A 9B with 19 pairs of setae, 17 pairs inserted on the dorsal shield and two pairs inserted on the lateral integument of the dorsal shield (r – R series), dorsal shield with seven pairs of setae j – J series, six pairs of z – Z series and four pairs of s – S series, most of the dorsal setae short and setiform, Z5 longer than all, thick and serrated, setae Z4 shorter than Z5 setae but thick, serrated and spine like, peritremes long and extending to the level of setae j1

Sternal shield smooth, wider than long, posterior margin straight, length (ST1 – ST3) 58 (56-59), width (ST3 – ST3) 72 (70- 75) with three pairs of sternal setae

(ST1, ST2 and ST3), fourth pair of sternal seta (ST4) inserted on metasternal plates posterior to sternal shield, genital shield smooth, as wide as ventrianal shield, width (ST5 – ST5) 67 (64-70), with a pair of genital setae (ST5), ventrianal shield smooth, pentagonal, lateral margins concave, length 112 64 (108-115), width at anal level also 78 (75-80), with three pairs of preanal setae arranged in a triangular pattern, caudoventral region with nine pairs of setae, four JV series, three pairs of ZV series, one pair of preanal setae (PA) and a postanal seta (PST), five of the nine pairs of caudoventral setae inserted on the ventrianal shield (JV1, JV2, ZV2, PA and PST) and four pairs inserted on the integument around the ventrianal shield (ZV1, ZV3, JV4 and JV5) of which JV5 the longest, spermatheca with a long major duct, fixed digit of chelicera with six teeth, movable digit toothless, leg I, II and III with macrosetae on genu and leg IV with three strong macrosetae, which are smooth, setiform and with pointed tip

Male Dorsal chaetotaxy similar to that of female except that the sublateral setae (setae of r- R series) are inserted on the lateral margins of the dorsal shield, ventrianal shield reticulated with three pairs of preanal setae arranged in a triangular pattern

Materials examined : 5♀, 2♂, Kerala Pazhayannur, Vellanikkara, ex amaranthus, 25 viii 2014, 06 i 2015, 4♀, 2♂, Kerala Vellanikkara, ex bittergourd, 05 iii 2015, 13♀, 6♂, Kerala Vellanikara, Mala, Elanad, Chelakkara, ex brinjal, 17 vii 2014, 23 viii 2014, 15 ix 2014, 26 x 2014, 4♀, 2♂, Kerala Mala, Vellanikkara, ex chilli, 04 ii 2014, 06 iii 2014, 11♀, 5♂, Kerala Vellanikkara, Pazhayannur, Elanad, ex cowpea, 07 iii 2015, 23 ix 2014, 26 iii 2015 , 6♀, 1♂, Kerala Pazhayannur, Elanad, ex coccinia, 23 ix 2014, 26 iii 2015 , 9♀, 4♂, Kerala Vellanikkara, Pazhayannur, ex cucumber, 07 iii 2015, 23 ix 2014, , 4♀, 2♂, Kerala Vellanikkara, Chelakkara, ex snakegourd, 07 iii 2015, 16 iv 2015, 5♀, Kerala Mala, ex snap melon, 23 viii 2014

4.2.2. Order Prostigmata

Often sclerotized mites of normal shape or idiosoma vermiform with overlapping sclerites, chelicerae rarely chelate dentate, pedipalps of various forms, tibia and tarsus of pedipalp often form thumb claw process, paired stigmata present between the cheliceral bases or on dorsal surface of propodosoma

Predatory mites belonging to four families in this order namely **Tydeidae, Cunaxidae, Bdellidae** and **Stigmaeidae** were collected from the vegetable crops during the study

Key to the families of Order Prostigmata

1 Pedipalp with thumb claw complex, chelicerae generally independently movable but stylophore like, legs I and II directed anteriorly, III and IV directed posteriorly (Plate 17) **Stigmaeidae**

1' Pedipalp without thumb claw complex 2

2 Cheliceral bases fused, or if not fused, not capable of lateral scissors – like motion over gnathosoma (Plate 11) **Tydeidae**

2' Chelicerae free, attached at base and free to move scissors like laterally across gnathosoma 3

3 With 2 pairs of genital suckers, the relatively long palpi turned inward, distal segment usually claw like (Plate 3c) **Cunaxidae**

3' With 3 pairs of genital suckers, the relatively long palpi elbow like with distal setae (Plate 3b) **Bdellidae**

4.2.2.1. Family Tydeidae Kramer

Tydeidae Kramer, 1877, 232-246

Type genus- *Tydeus* Koch

Small soft bodied mites, weak or unsclerotized body, palp 4 segmented, palp tarsus with 5 setae and a solenidion, chehcera needle like, dorsal setae 3 pairs P1, P2, P3 along with a pair of sensillary setae on the propodosoma, hysterosomal setae in 5 transverse rows of 4 setae each, setae D1- D5 form dorsal series and L1-L5 form lateral series

Two species of tydeid mites were collected during the present study which belong to two genera namely ***Tydeus*** and ***Pronematus***

Key to the genera of Tydeidae collected during the study

1 Hysterosomal seta L2 in normal lateral position, striation transverse between second pair of hysterosomal dorsocentral setae(Plate 11c) ***Tydeus***

1' Hysterosomal seta L2 shifted to lie in the line of D series, striation between second pair of hysterosomal dorsocentral setae of varying pattern (Plate 12) ***Pronematus***

4.2.2.1.1. *Tydeus* Koch

Type species- *Tydeus kochi* Oudemans

The setae L2 located on normal lateral position, slightly behind and lateral to D2, propodosoma with fine longitudinal striation and hysterosoma with transverse striation on dorsomedian region, hysterosoma with 9 pairs of setae, L5 absent, genital setae 6 pairs, paragenital setae 4 pairs, anal setae one pair, setal formula of palp- 5, 2, 2, palp tarsus slender and elongate, all tarsi possess claws and empodium

4.2.2.1.1.1. *Tydeus gossabaensis* Gupta (Plate 11)

Tydeus gossabaensis Gupta, 1992 131

Female Dorsum 346 long 263 wide, propodosoma with longitudinal striation medially, transverse striation between D1 setae, v shaped posteriorly, all dorsal setae mostly thick with pointed tip, D3 and D4 of same length, L2 and L1 of same length, D4 over 20 microns

Male Not seen

Materials examined : 5♀, Kerala Vellanikkara, Elanad, Chelakkara, ex brinjal, 14 viii 2014, 29 ix 2014, 14 iii 2015, ex bhindi, , 8♀, Kerala Elanad, Chelakkara, Pazhayannur, ex brinjal, 16 vi 2014, 15 vii 2014, 26 viii 2015, 2♀, Kerala Vellanikkara, ex chilli, 05 ii 2015, 6♀, Kerala Vellanikkara, Elanad, Chelakkara, 14 viii 2014, 29 ix 2014, 14 in 2015, ex cowpea, , 4♀, Kerala Vellanikkara, ex snakegourd, 24 ii 2015

4.2.2.1.2. *Pronematus* Canestrini

Pronematus Canestrini 1886, 698

L2 setae on dorsal position, tarsus I lacks claws and empodium and it ends in four terminal setae, hysterosomal setae located in four and half rows, L5 missing, propodosoma with setae P1, P2, P3, S, anal setae 1 pair, 4 pairs of setae on the anterolateral side of genitalia, ventral setae 3 pairs

4.2.2.1.2. 1. *Pronematus anconai* Baker (Plate 12)

Pronematus anconai Baker, 1943 188

Female Tarsus I as long as or longer than tibia I, distal setae of tarsus I not serrate along entire length, dorsal body setae longer, half as long as distance between bases, distal segment of palp normal

Male Not seen

Materials examined : 4♀, Kerala Vellanikkara, Pazhayannur, ex amaranthus, 23 vi 2014, 14 i 2015, 5♀, Kerala Vellanikkara, ex bhindi, 24 vii 2015, 7♀, Kerala Vellanikkara, Elanad, Chelakkara, ex brinjal, 14 viii 2014, 29 ix 2014, 14 iii 2015, 2♀,Kerala Vellanikkara,ex chilli, 30 xii 2014, 6♀, Kerala Vellanikkara, ex cowpea, 16 x 2014

4.2 2.2. Family Cunaxidae Thor

Type genus- *Cunaxa* Heyden, 1826

Reddish/ brownish, fast moving mites, gnathosoma snout like, formed by elongate chelate chelicerae, palp 5 segmented, inner median surface of palp tarsus

with simple spine like setae, palp genu with setose apophysis, tibiotarsus terminates in a small claw, chelicera broad basally, narrow distally, propodosoma with shield, smooth, hysterosoma smooth, tarsus I – IV tapering distally

One species of female mite under the genus ***Cunaxa*** was collected during the study The species was not determined

4.2.2.2.1. *Cunaxa* Heyden (Plate 13)
Cunaxa Heyden, 1826
Type species- *Scirus setirostris* Hemann

Body strongly sclerotized covered by 2 dorsal shields, smooth, palp 5 segmented with spine-like setae, palpal genu without large subrectangular apophysis, tarsus I-IV tapering distally without lateral bilobed flanges

Materials examined : 1♀ Kerala Vellanikkara, ex brinjal, 15 vi 2014, 2♀, Kerala Vellanikkara, ex chilli, 28 xi 2014, 1♀, Kerala Pazhayannur, ex cowpea, 25 v 2014, 1♀, Kerala Mala, ex snap melon, 16 i 2015

4.2.2.3. Family Bdellidae Duges
Type genus - *Bdella* Latreille, 1795

Reddish, large sized mites with long snout and finely striated integument, subcutaneous shields present on propodosoma, gnathosoma snout like, formed by elongate chelate chelicerae, one or more setae present on chelicerae, palpi 6 segmented, tibiotarsus bearing apically two long tactile setae

One species of mite under the genus ***Bdella*** was collected during the present study

4.2.2.3.1. ***Bdella*** Latreille

Bdella Latreille, 1795 18

Palp tibiotarsus truncate, considerably shorter than palpal basifemur, subequal, end setae as long as or longer than palp femur, chelicera bearing 2 setae on proximal ¾ of their lengths, movable digit sickle shaped on small chela

4.2.2.3.1.1. ***Bdella khasyana*** Gupta (Plate 14)

Bdella khasyana Gupta, 1991, 221

Female: Suture between propodosoma and hysterosoma absent, two pairs of eyes present on each side of propodosoma, propodosoma with four pairs of setae, lateral propodosomal setae longer than median one, striation on propodosoma longitudinal, that on hysterosoma transverse in the region of dorsocentral setae and longitudinal laterally, hysterosoma with 9 pairs of setae, chelicera with longitudinal striation, chela dentate, movable digit sickle shaped, two setae on chelicera, palp with normal segmentation, tibiotarsus with 6 setae, the end setae distinct, genu with 4 setae, hypostome with 6 pairs of setae, each leg with claws and rayed empodium

Male: Not seen

Materials examined · 4♀, Kerala Vellanikkara, Mala, ex brinjal, 24 xii 2014, 23 i 2015, 2♀, Kerala Anthikad, ex chilli, 04 xii 2014, 2♀, Kerala Vellanikkara, ex cowpea, 17 iii 2015

4.2.2 4. Family Stigmaeidae Oudemans

Stigmaeidae Oudemans, 1931 252

Type genus- *Stigmaeus* Koch, 1836

Yellowish, ovoid, fast moving active mites, peritreme absent, dorsum of idiosoma completely covered by 2 shields, dorsal body setae vary from 13-14 pairs, palpal thumb claw complex present and consisting of tibial claw, with a seta like or claw like at the base and a palp tarsus

Four predatory mite species were collected under this family during the present study belonging to one genus ***Agistemus.***

4.2.2.4.1. ***Agistemus*** Summers

Agistemus Summers, 1960 234

The genus was diagnosed by the following characters presence of three unpaired plates, propodosomal, median and suranal, cover most of the dorsal region, two pairs of paired plates - humerals and intercalaries, main plates plain or reticulate, propodosomal plates carry setae ae, be, ce, median plate usually entire with five pairs of setae a, b, c, la, lm, two pairs of setae on suranal plate, a central e and lateral le, humeral and intercalary plates with one setae on each, one pair of eyes present, one pairs of ocular bodies situated between eyes and setae ce, palp tibia with long primary claw, longer than half the length of palp tarsus, accessory claws about half the length of palp tarsus, subcapitular setae two pairs, m and n, four pairs of setae present on anogenital plate, two pairs of paragenital setae on independent plates

Key to species of *Agistemus* collected from vegetable fields

1 Propodosomal plate reticulate 2

1' Propodosomal plate not reticulate 3

2 Ratio of setae ac/ae – ae less than 3, reticulation pattern of hysterosomal plate 2-14 cells in median longitudinal row (Plate 15) **fleschneri**

2' Ratio of setae ae/ae – ae more than 3, reticulation pattern of hysterosomal plate 2-14 cells not as above (Plate 16b) **gamblei**

3 Postocular body very large, almost touching be and ce (Plate 17c) **macrommatus**

3' Postocular body never so large, setae ae shorter than be, seta c longer than la (Plate 18) **garrulus**

4 2.2.4.1 1. ***Agistemus fleschneri*** Summers (Plate 15)

Agistemus fleschneri Summers, 1960 237

Female Body 352 long, 160 wide, dorsal propodosomal plate with polygonal reticulations, reticulation on median plate with not less than 12 cells between successive dorsocentral setae, the plate covers 2/3 of hysterosoma, ratio of setae ae/ae – ae 2 7

Male Dorsal chaetotaxy same as in females

Materials examined · 6♀, 2♂, Kerala Vellamkkara, Anthikad, Chelakkara,ex bhindi, 16 vi 2014, 21 ii 2015, 28 ix 2015, 8♀, 3♂, Kerala Vellanikkara ,

Mathılakam, Pazhayannur, ex brınjal, 21 ıı 2015, 15 ı 2015, 25 xıı 2015, 3♀, Keıala Vellanıkkara, ex snakegourd, 14 ıı 2015

4.2.2.4.1.2. *Agistemus gamblei* Gupta (Platc 16)

Agıstemus gamblei Gupta, 1991 218

Female Body length wıth gnathosoma 450 (438-462), wıdth 268 (260-275) at *c*l level, propodosomal and medıan plates dıstınct, retıculate, the former wıth 3 paırs of setae and the latter wıth 5 paırs of setae, ratıo of setae ae/ae – ae 3 2

Male Dorsal chactotaxy same as that of female, body sıze smaller than that of female

Materıals examıned : 5♀, 2♂, Kerala Vellamkkara , Mala, Pazhayannur, ex bhındı, 28 vıı 2014, 19 vıı 2014, 23 ıx 2014, 7♀, 3♂, Kerala Vellanıkkara ex brınjal, 08 ıı 2015, 2♀, Kerala ex chıllı, 15 ıı 2015

4.2.2.4.1.3. *Agistemus macrommatus* Gonzalez-Rodrıguez (Plate 17)

Agıstemus macromatus Gonzalez-Rodrıguez, 1965 38

Female: Body 420 (412-428) µm long wıth gnathosoma, 244 (238-250) wıde at *c*l level, propodosoma and medıan plates smooth, dorsal setae thıck, ındıstınctly barbed, ıntegument transversely strıated between propodosomal and medıan plates, ıntegument posterıor to ıt transversely strıated, dıameter of postocular body 30, two

pairs of parageniital setae present, anogenital setae 4 pairs, *g*1 extends up to middle of *g*2, palp tarsus and tibial claws of the same length

Male Chaetotaxy similar to that of female

Materials examined : 5♀, 2♂, Kerala Elanad, Vellanikkara, ex bhindi, 04 iii 2015, 14 iv 2015, 6♀, 3♂, Kerala Vellanikkara , Pazhayannur, Mannuthy, ex brinjal, 26 xi 2014, 18 xii 2014, 06 i 2015, 15 ii 2015, 2♀, Kerala Vellanikkara, ex snakegourd, 17 xii 2014

4.2.2.4.1.4. ***Agistemus garrulus*** Chaudhri, Akbar & Rasool (Plate 18)

Agistemus garrulus Chaudhri, Akbar & Rasool, 1974 197

Female· Body 278 long, 196 wide, palp tibial claw well developed, chelicera 91 long, stylet 30 long, dorsal propodosomal shield non – reticulated, integument striated, eyes one pair, postocular body never so large, parageniital setae one paired, anogenital setae 4 pairs, ratio of setae ac/ac – ae 1 9

Male Not seen

Materials examined : 4♀, Kerala Vellamkkara, ex bhindi, 26 xii 2014 , 5♀, Kerala Vellamkkara , Chelakkara, ex brinjal, 15 x 2014, 22 ii 2015

4.2.3 Order Astigmata

Body distinguishable into 2 regions by a transverse line into propodosoma and hysterosoma, stigmata and peritreme absent, trichobothria never present on idiosoma

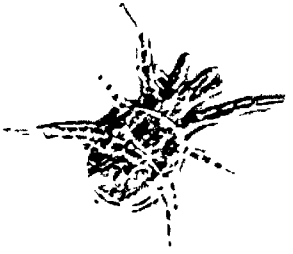
4.2.3.1. Family Acaridae

Soft bodied mites with prodorsal shield, sejugal furrow present, chelicerae chelate dentate, palpi simple, apotele with empodial claw on legs, 5 terminal spines at the end of tarsi

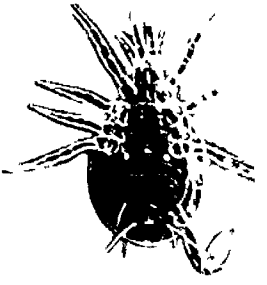
One species of female Acarid mite (Plate 19) was collected during the study The genus and species identity could not be established

Materials examined : 2♀, Kerala Vellanikkara, ex brinjal, 13 xi 2014 , 1♀, Kerala Pazhayannur, ex cowpea, 16 ix 2014, 1♀, Kerala Vellanikkara ex cucumber, 02 i 2015

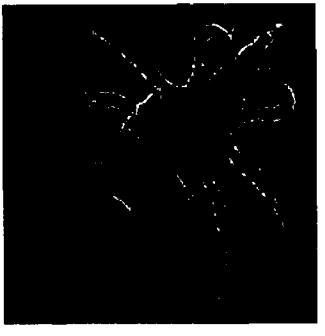
Plate 1 Phytoseiid mites



a *Neoseiulus longispinosus* (Evans)

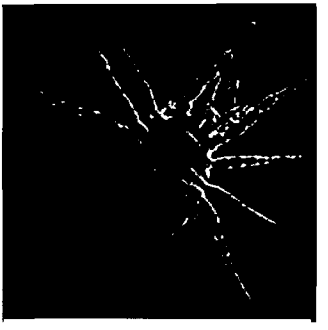


b *Amblyseius paraaerialis* Muma

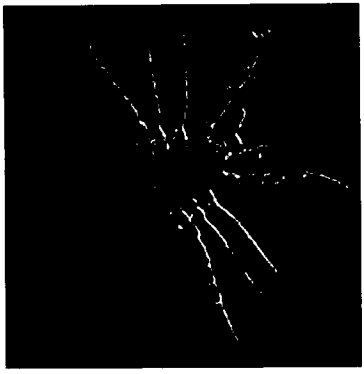


c *Amblyseius largoensis* (Muma)

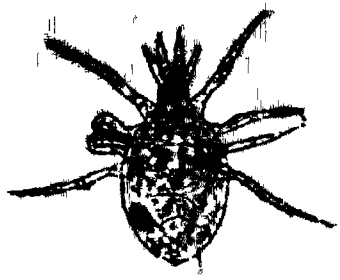
d *Typhlodromips swirskii* (Gupta)



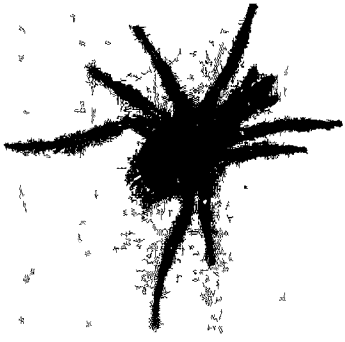
e *Euseius macrosquatulatus* (Gupta)



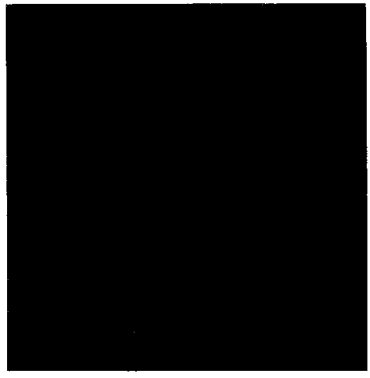
f *Fuscus* sp nr *prasadi*



g *Scapulfuscus* sp



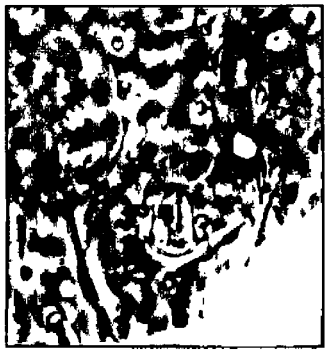
h *Paraphyfoscus orientalis* (Narayanan Kaur and Ghai)



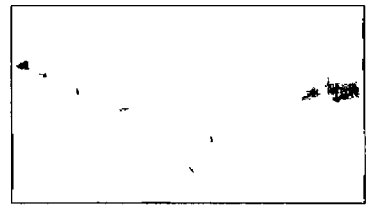
i *Phyf scus intermedius* Evans and Macfarlane

Plate 2 *Phytoseius intermedius*

(a) dorsal body



(b) female ventrianal shield



(c) leg IV

Plate 3 *Eucetus* sp. nr. *prasadi*

(a) dorsal shield with striations

(b) chelicerae with spermatophoral process

(c) female ventrianal shield

(d) male ventrianal shield

(e) leg IV with macrosetae

(f) Adult mite

Plate 4 *Eutetranychus macrospatulatus*

(a) body with peritreme

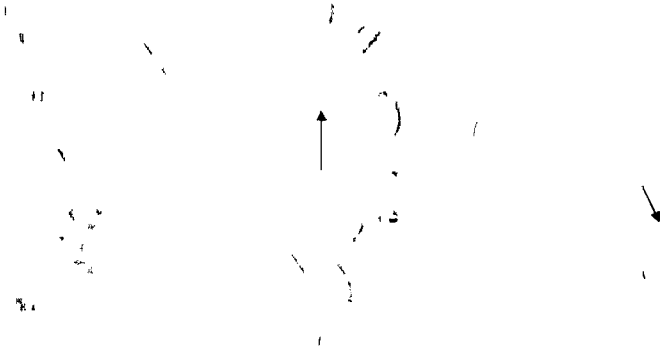
(b) chelicerae with spermatophoral process

(c) Adult mite

(c) male ventrianal shield

(d) leg IV with macrosetae

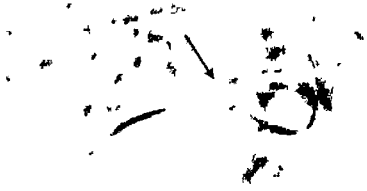
Plate 5 *Paraphytoseius orientalis*



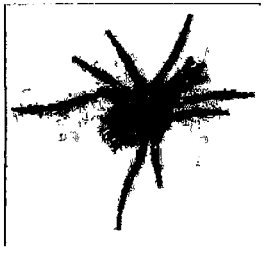
(a) dorsal shield

(b) chelicerae

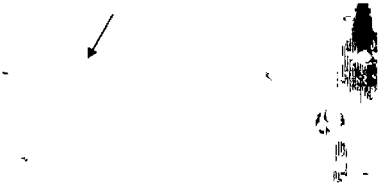
(c) female ventrianal shield



(d) spermatheca



Adult mite

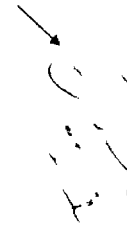


(e) leg IV with macroseta

Plate 6 *Amblyomma paramaculatum*

(a) body with peritreme

(b) spermadactyl

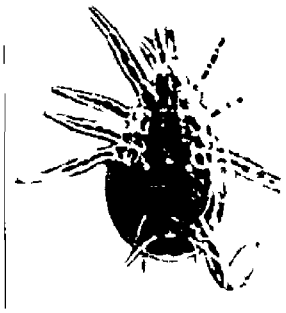


(c) female chelicera

(d) female ventral shield

(e) male ventral shield

Plate 6 Contd



Adult mite

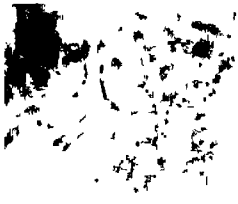
(f) spermatheca

(g) leg IV with microsetae

Plate 7 *Amblyseius largoensis*

(a) dorsal body

(b) male chelicerae



(c) spermatheca

(d) leg IV with macrosetae

(e) female ventrianal shield

(f) male ventrianal shield

Plate 8 *Neoseiulus longispinosus*

(a) dorsal shield

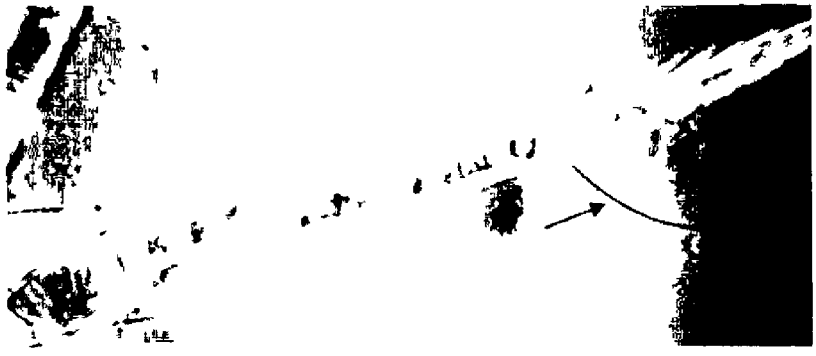
(b) spermatheca

(c) female chelicerae

(d) ventranal shield of female

(e) ventranal shield of male

(f) spermatheca



(g) leg IV with macrosetae

Plate 9 *Scapulaseius* sp

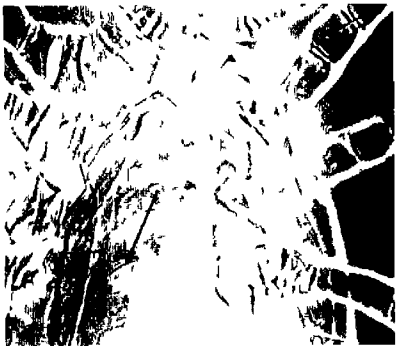
(a) dorsal surface

(b) female ventranal shield

(c) male ventranal shield

(d) leg IV with microsetae

Plate 10 *Typhlodromips swirskii*



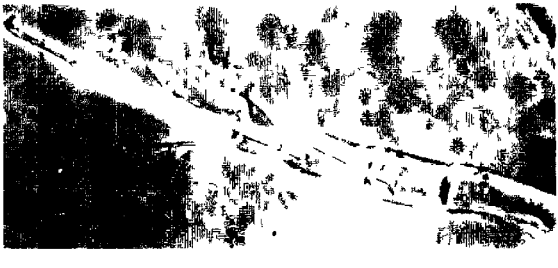
(a) dorsal body striations

(b) female chelicerae

(c) spermatheca

(d) spermadactyl

(e) female ventrianal shield



(f) leg IV with macrosetae

Plate 11 *Lydeus gossabaensis*

(a) *Lydeus gossabaensis*

(b) legs I and II

(c) dorsal body striations

Plate 12 *Pronematus anconai*

(a) dorsal surface

(b) tarsus I

Plate 13 *Cunaxa* sp

(a) *Cunaxa* sp

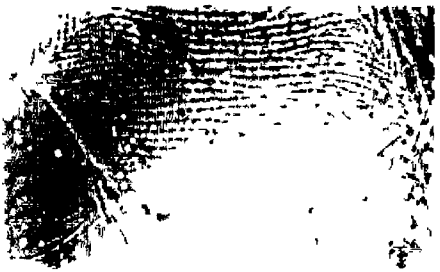
(b) dorsal shield

(c) gnathosoma

Plate 14 *Bdella Ihasvana* Gupta

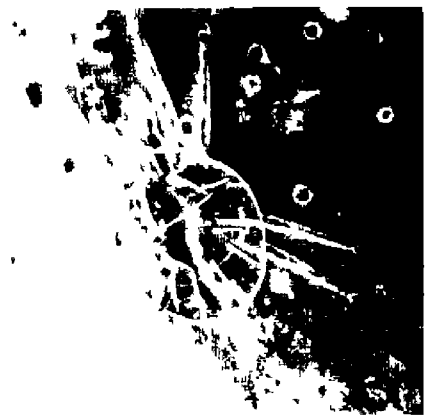
(a) chelicerae

(b) pedipalp with setae

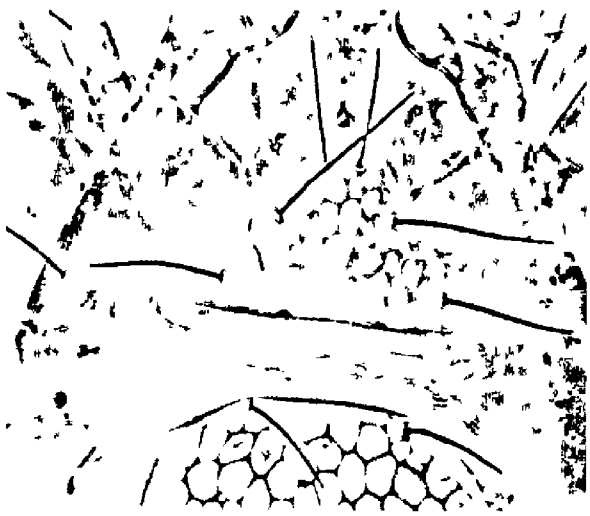


(c) body striations

Plate 15 *Agistemus fleschneri*

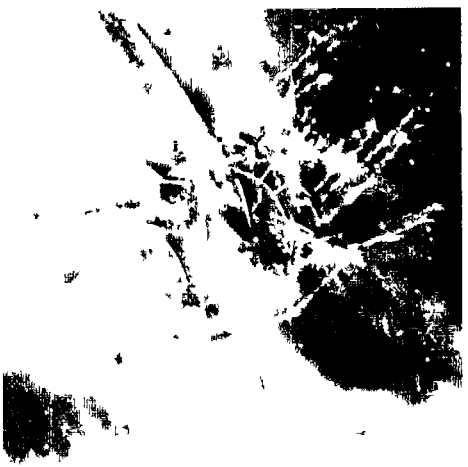


(a) Agistemus fleschneri

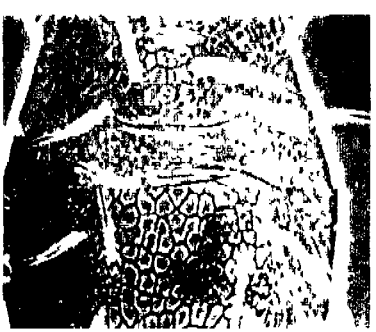


(b) dorsal body surface

Plate 16 *Lysichemus zambica*



(a) *Lysichemus zambica*



(b) dorsal reticulation

(c) pedipalp

Plate 17 *Agistemus macrommatus*

(a) *Agistemus macrommatus*

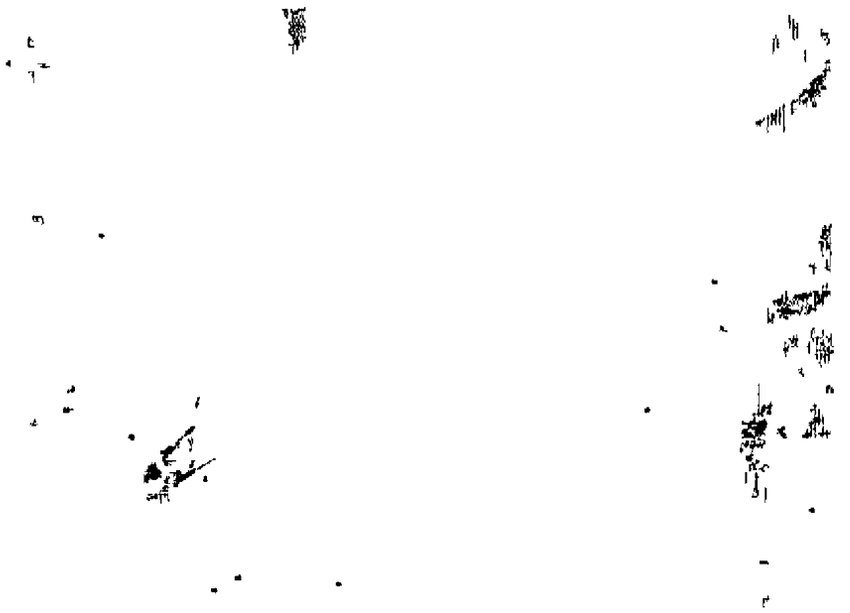
(b) gnathosoma

thumb claw process

post ocular body

(c) dorsal body

Plate 18 *Agistemus garrulus*

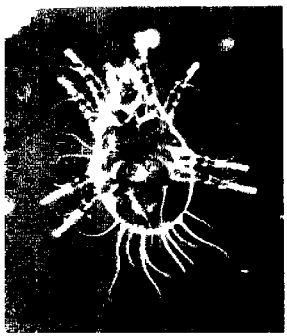


(a) *Agistemus garrulus*

(b) chelicera

(c) tarsus I

Plate 19 Acaridae



(a) adult mite

(b) chelicerae

(c) legs I and II with solenidon

(d) ventral body

Discussion

5. DISCUSSION

The present study was undertaken to explore the diversity of predatory mite fauna in the vegetable ecosystems of Thrissur district, Kerala and to identify the predatory mites associated with the phytophagous mites upto the generic / species level as well as to document the species diversity and develop a taxonomic key for the identification of predatory mite fauna in vegetable ecosystems The observations and the inferences based on the study are discussed below

5 1 FAUNAL DIVERSITY OF PREDATORY MITES ASSOCIATED WITH VEGETABLES

The survey on the diversity of predatory mite fauna in vegetable ecosystems in Thrissur district, Kerala revealed a total of 18 species of predatory mites under 12 genera belonging to six families namely Phytoseiidae, Stigmaeidae, Cunaxidae, Bdellidae, Tydeidae, Ameroseiidae and Acaridae These families were represented by the genera *Neoseiulus, Amblyseius, Typhlodromips Euseius, Paraphytoseius Phytoseius, Scapulaseius Agistemus Cunaxa, Bdella, Tydeus* and *Pronematus* The associated phytophagous prey mite families recorded were Tetranychidae, Tenuipalpidae and Tarsonemidae represented by the genera *Tetranychus, Eutetranychus, Brevipalpus* and *Polyphagotarsonemus* Predatory mites of the above mentioned families have been reported to be associated with phytophagous mites in different crops in India (Gupta, 2002, Chant and McMurtry, 2007, Gowda, 2009, Binisha and Bhaskar, 2013) and abroad (Cobanoglu *et al* , 2010)

The study of predatory mite fauna in the ten vegetable crops revealed highest diversity of mites in brinjal (Fig 5), with a total of 18 species belonging to five different families, of which nine species belonged to the family Phytoseiidae Survey on the diversity of mites in brinjal ecosystem in Dharwad also revealed

phytoseiid mites as the major predators (Prasanna, 2007) Faunal studies of mites in six vegetable crops in Thrissur district, Kerala had also recorded highest diversity of mites in brinjal with three phytophagous and seven predatory mites (Binisha and Bhaskar, 2013)

Phytoseiid mites were found to be the most common predators in the vegetable fields of Thrissur district, Kerala (Fig 6) Family Phytoseiidae have been generally considered to be the most promising predators of pest mites on different crops (Gerson *et al*, 2003) Among the phytoseiid mites, *Neoseiulus longispinosus* was the predominant species, recorded in association with phytophagous mites in all the vegetable fields surveyed A survey conducted in mid-hills of Himachal Pradesh during 2011-2012 to study the mite diversity in 16 different vegetables has also revealed that *N longispinosus* was one of the predominant predatory mite species associated with the phytophagous mites (Singh and Chauhan, 2014)

Other phytoseiids were *A paraaerialis, A largoensis, E macrospatulatus, Euseius* sp nr *prasadi, T syzygii, P orientalis, P intermedius* and *Scapulaseius* sp The associated prey mites were *T macfarlanei, E orientalis, B phoenicis* and *P latus* Binisha and Bhaskar (2013) also had reported seven species of phytoseiid mites from major vegetable crops in Thrissur, Kerala Several species of phytoseiid mites have been reported as effective predators of plant feeding mites across diverse crop ecosystems (Abhilash, 2001, Sadanandan and Ramani, 2006 and Karmakar and Gupta, 2010)

Predatory mites, *Cunaxa* sp of the family Cunaxidae and *Bdella khasyana* of the family Bdellidae were found in association with *P latus* in chilli and *Tetranychus* sp in cowpea and snap melon Cunaxid mites have been widely reported from vegetable fields whereas only few species of mites of the family Bdellidae have been reported to feed on phytophagous mites (Gupta, 1989)

Smiley(1992) observed that cunaxid and bdellid mites were well known predators of many phytophagous mites and small insects in different crops

Four species of stigmaeid mites under the genus *Agistemus* were found associated with phytophagous mites on bhindi, bitter gourd, brinjal, chilli and snake gourd They were identified as *A gamblei, A macrommatus, A fleschneri* and *A garrulus Agistemus* spp were reported as important biocontrol agents that play pivotal role in controlling phytophagous mites and soft bodied insects in different vegetables (Khan *et al*, 2008) *A gamblei* was reported as an imporant predator on brinjal associated with *B phoenicis* in Thrissur district, Kerala (Binisha *et al*, 2013)

The predatory mites *T' gossabaensis* and *P anconai* of the family Tydeidae were found to be associated with phytophagous mites, *T macfarlanei, B phoenicis* and *P latus* in amaranthus, bhindi, brinjal, chilli, cowpea and snake gourd Tydeid mites were reported to be efficient predators of six spotted spider mite *Eotetranychus sexmaculatus* (Riley) on avocados (Tomkins, 2002) *Tydeid* sp was also reported from Kerala on chilli plants preying on *P latus* in Thrissur district (Binisha *et al*, 2013)

One species of astigmatid mite belonging to the family Acaridae was found in association with phytophagous mites in brinjal and cowpea Brust and House (1988) reported the occurence of acarid predatory mites in vegetables

Figure 5 Diversity of predatory mite species in vegetables Thrissur district Kerala

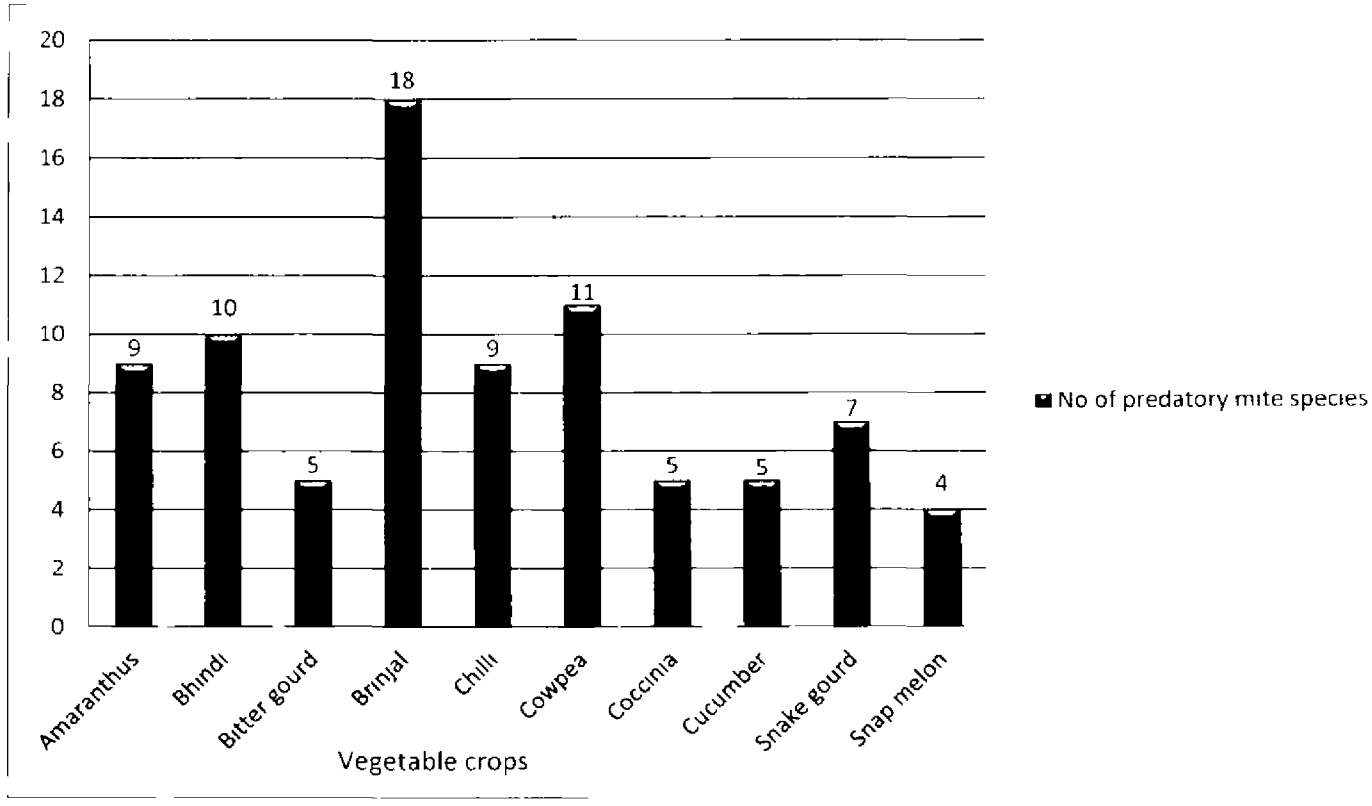
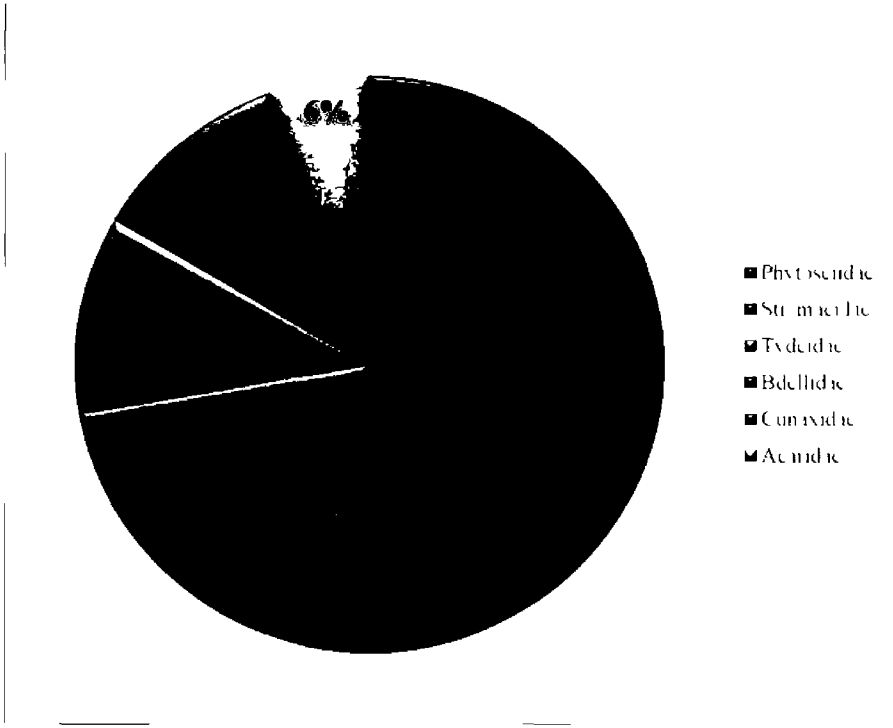


Figure 6 Faunal composition of predatory mite families in vegetables Thrissur district Kerala



5 2 TAXONOMY OF PREDATORY MITES ASSOCIATED WITH MAJOR VEGETABLE CROPS OF THRISSUR DISTRICT, KERALA

The predatory mites collected during the study were identified upto generic /species level by using appropriate literature (Krantz, 1970, 1975, Gupta,1985, Gupta, 2002 and Chant and McMurtry, 2007) A dichotomous key for the identification of the mite genera collected during the study was prepared and the important characters for the identification are discussed here

The mites identified in the present study belonged to three orders *viz* Mesostigmata, Prostigmata and Astigmata which were classified based on the position of stigmata The position of stigmata has been considered as the key character for the classification of sub class Acari into various orders (Krantz, 1975) The predatory mites were identified upto species level based on the taxonomic characters studied and illustrations made

During the present study, eighteen species of predatory mites under 12 genera and 6 families were found associated with ten major vegetable crops The mites collected during the present study are discussed hereunder in comparison with the earlier records of these mites in India and other countries

5.2.1. Order Mesostigmata

Mites belonging to mesostigmatid family namely Phytoseiidae alone was collected in the study

5.2.1 1. Family Phytoseiidae

The key character used for identifying the predatory mites of the family Phytoseiidae was the chaetotaxy *i e* the arrangement of dorsal and ventral setae The sub families were identified based on the presence or absence of setae z3 and s6 (Chant and McMurtry, 2007) In the present study, phytoseiid mites belonging to two subfamilies, namely, Amblyseiinae and Phytosciinae were collected Morphometric observations, size and shape of spermatheca and spermatophoral process, shape of the dorsal and ventral shields and teeth dentition were the major characters taken into account for species level identification

Nine species of phytoseiids were collected during the present study belonging to seven genera m the two subfamilies Highest number of mite species collected during the present study was from this family The species included *N longispinosus A paraaerialis A largoensis, E macrospatulatus, Euseius* sp nr *prasadi T syzygii, P orientalis, P intermedius* and *Scaplaseius* sp They were recorded on different host plants, namely amaranthus, brinjal, bhindi, bittergourd, cowpea, coccinia, chilli, cucumber, snap melon and snakegourd

All the species collected during the present study except *Euseius* sp nr *prasadi,* and *P intermedius* have been recorded from Kerala on different host plants by different workers Haneef and Sadanandan (2013), for instance, recorded the phytoseiid mites *A largoensis and T syzygii* from North Kerala *N longispinosus, A paraaerialis E macrospatulatus, T syzygii, P orientalis* and *Scapulaseius* sp were recorded earlier from Thrissur district by Binisha *et al* (2013) *Euseius* sp nr *prasadi* and *P intermedius* have been reported from Karnataka (Zeiti, 2011) However, they are new records for Kerala

5.2.2. Order Prostigmata

The prostigmatid predatory mite families encountered in the study included Tydeidae, Stigmaeidae, Cunaxidae and Bdellidae

5.2.2.1. Family Tydeidae

Tydeid mites are characterized by the presence of needle-like stylet and solenidion on tarsus I The genera were identified based on the number of setae on genu and femur of legs II, III and IV The position of the hysterosomal setae and striations on hysterosoma were mainly used for species identification Gupta (2002) described five genera and twenty one species of Tydeidae from crops based on these key characters

Two species of Tydeid mites under two genera *viz Tydeus gossabaensis* and *Pronematus anconai* were collected during the present study from amaranthus, bhindi, brinjal, chilli, cowpea and snakegourd *Pronematus anconai* was earlier recorded from India on different plant species (Pandey *et al* , 1979) However this is a new report for Kerala *Tydeus gossabaensis* was reported by Gupta (1992) from West Bengal on unidentified plant species This is also a new report for Kerala

5 2.2.2. Family Stigmaeidae

The stigmaeid mites have distinct palpal thumb-claw process and short and stylet-like chelicerae (Krantz, 1975) In this study, only one genus of stigmaeid mite namely *Agistemus* was collected from vegetable crops surveyed Reticulations on the propodosomal plate, size of the post ocular body, ratio of the length of setae

ae to ae – ae distance were the major characters used for the species level identificatm of *Agistemus*

Four species of stigmaeids *viz* , *Agistemus gamblei, A fleschneri, A garrulus* and *A macrommatus* were collected in the present study *A gamblei* was earlier recorded on brinjal *(Solanum melongena* L) from Thrissur, Kerala (Bimsha *et al* , 2013) *A macrommatus* though, recorded from different states in India on a number of plant species earlier (Gupta, 2002), is a new record for Kerala *A fleschneri* was earlier recorded on plants like citrus, litchi, mango, guava etc from Meghalaya and Arunachal Pradesh and vegetables and ornamental plants in Hissar, Haryana (Gupta, 2002, Tagore and Putatunda, 2003) However this is a new record for Kerala *A garrulus* is also a new record for Kerala It was earlier recorded (Chaudhri *et al* , 1974) on different plants in other states of the country

5.2.2.3. Family Cunaxidae

The cunaxid mites have two pairs of genital suckers and long palpi with distal palpal segments claw like and raptorial Only one species, *Cunaxa* sp was collected from brinjal, chilli and cowpea during the present study Of the 133 species of *Cunaxa* reported worldwide, 19 species were recorded from India (Heyer, 2011) However, the species of Cunaxa collected during the study could not be determined

5.2.2.4. Family Bdellidae

Bdellid mites differs from cunaxids mainly in that they have three pairs of genital suckers and palp is elbow-like with a distal setae (Gupta, 1985)

Only one species, *Bdella khasyana* was collected on chilli and cowpea in this family during the present study This species was first described on *Litsea khasyana* from Arunachal Pradesh, India (Gupta, 2002) It was also reported from ornamental plants from Bangalore (Zeiti, 2011) This is a new record for Kerala

5.2.3. Order Astigmata

Predatory mite in the family Acaridae was collected from brinjal and cowpea fields from the order Astigmata

5.2.3.1. Family Acaridae

The mite family was identified based on chelate dentate chelicerae and five terminal spines at the distal end of tarsi (Gupta, 2002) Only one species of acarid mite was collected in the present study Several species of astigmatid mites were reported to predate on phytophagous mites on mango, rose and other ornamental plants in Meghalaya, India (Gupta, 2002) However the species identity of acarid mite collected in the present study could not be established with the literature available

Summary

6. SUMMARY

The study entitled 'Diversity of predatory mite fauna in vegetable ecosystem' was undertaken at the Acarology Laboratory, Department of Agricultural Entomology, College of Horticulture, Vellanikkara during 2014 – 2015 to explore the faunal composition of predatory mites associated with the vegetable crops *viz* amaranthus, brinjal, bhindi, bittergourd, chilli, cowpea, coccinia, cucumber, snakegourd and snap melon of Thrissur district, Kerala An extensive survey was carried out in the major vegetable tracts of Thrissur to collect mite infested leaf samples from selected host plants and to identify the predatory mite fauna associated with the phytophagous mites upto the generic / species level The morphometric studies of the identified predatory mite species were carried out and a dichotomous taxonomic key for the identification of predatory mites collected during the study was prepared based on the characters identified

The salient findings of the study are summarized hereunder

- Eighteen species of predatory mites in twelve genera belonging to three orders *viz* Astigmata, Prostigmata and Mesostigmata representing six families namely Acaridae (one species), Tydeidae (two species), Stigmaeidae (four species), Cunaxidae (one species), Bdellidae (one species) and Phytoseiidae (nine species) were encountered from the vegetable fields

- Faunal studies revealed highest diversity of mites on brinjal comprising eighteen species of five different families, of which nine species belonged to

the family Phytoseiidae and the lowest diversity on coccinia, cucumber, snap melon and snakegourd with five species each

- Phytosend mites were found to be the most common predators in the vegetable fields of Thrissur district, Kerala Among the Phytoseiid mites, *Neoseiulus longispinosus* was the predominant species recorded in association with phytophagous mites in all vegetable fields Other species were *A paraaerialis, A largoensis, E macrospatulatus, Euseius* sp nr *prasadi, T syzygii, P orientalis, P intermedius* and *Scaplaseius* sp Occurence of *Euseius* sp nr *prasadi* and *P intermedius* are new reports for Kerala

- Predatory mites, *Cunaxa* sp of to the family Cunaxidae and *Bdella khasyana* of the family Bdellidae were found in association with *P latus* in chilli and *Tetranychus* sp in cowpea and snap melon *Bdella khasyana* is a new report for Kerala

- Four species of stigmaeids *viz* , *Agistemus gamblei, A fleschneri, A garrulus* and *A macrommatus* were recorded on bhindi, bitter gourd, brinjal, chilli and snake gourd Occurence of *A fleschneri, A garrulus* and *A macrommatus* are new reports for Kerala

- The predatory mites *T gossabaensis* and *P anconai* of the family Tydeidae were found to be associated with phytophagous mites *T macfarlanei, B*

phoenicis and *P latus* in amaranthus, bhindi, brinjal, chilli, cowpea and snake gourd Both the predatory mites are new reports for Kerala

- One species of astigmatid mite in the family Acaridae was collected from brinjal and cowpea during the study

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DIVERSITY OF PREDATORY MITE FAUNA IN VEGETABLE ECOSYSTEM

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ABSTRACT OF THE THESIS

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ABSTRACT

Mites constitute the most important group of non-insect pests in agriculture Vegetable crops in particular, are subjected to infestation by a number of mite species, leading to heavy economic loss The average yield loss in vegetable crops due to mite pests in India has been estimated to be around 25 per cent (Gupta, 1991). Predatory mites play a major role in reducing the populations of phytophagous mites and are able to feed on alternate sources of food and can survive in the absence of prey mites

The present study was undertaken at the Acarology Laboratory, Department of Agricultural Entomology, College of Horticulture, Vellanikkara during 2014 – 2015 to explore the diversity of predatory mite fauna in the vegetable ecosystems of Thrissur district, Kerala The objectives of the study were to document the species diversity of predatory mites associated with phytophagous mites in vegetable ecosystems in Thrissur and also to develop a taxonomic key for the identification of predatory mite fauna in vegetable ecosystems

A purposive survey was undertaken to explore the mite fauna associated with the vegetable crops *viz* amaranthus, brinjal, bhindi, bittergourd, chilli, cowpea, coccinia, cucumber, snakegourd and snap melon in major vegetable growing tracts of Thrissur district, Kerala The taxonomic characters of the collected mite specimens were studied and were classified upto species level Based on the characters studied and the species identity established, a detailed dichotomous key to the identification of the predatory mites studied was prepared

A total of 18 species of predatory mites belonging to six families were encountered in the study The predatory mite families included Phytoseiidae, Stigmaeidae, Cunaxidae, Bdellidae, Tydeidae, and Acaridae represented by the genera *Neoseiulus, Amblyseius, Typhlodromips, Euseius, Paraphytoseius, Phytoseius, Scapulaseius Agistemus, Cunaxa, Bdella, Tydeus* and *Pronematus* The associated

phytophagous prey mite families recorded were Tetranychidae, Tenuipalpidae and Tarsonemidae represented by the genera *Tetranychus, Eutetranychus, Brevipalpus* and *Polyphagotarsonemus*

Faunal studies in ten vegetable crops revealed highest species richness of predatory mites in brinjal, with a total of 18 species belonging to five different families Mites in the family Phytoseiidae were found to be the most common predators in the vegetable fields of Thrissur district Among the phytoseiid mites, *Neoseiulus longispinosus* was identified as the major species, associated with phytophagous mites in all the vegetable fields surveyed Other species were *Amblyseius paraaerialis, Amblyseius largoensis, Euseius macrospatulatus, Euseius* sp nr *prasadi, Typhlodromips syzygii, Paraphytoseius orientalis, Phytoseius intermedius* and *Scapulaseius* sp Occurence of *Euseius* sp nr *prasadi* and *Phytoseius intermedius* are new reports for Kerala

Predatory mites, *Cunaxa* sp of the family Cunaxidae and *Bdella khasyana* of the family Bdellidae were recorded in chilli, cowpea and snap melon *Bdella khasyana* is a new report for Kerala Four species of mites belonging to the family Stigmaeidae *viz* , *Agistemus gamblei A fleschneri, A garrulus* and *A macrommatus* were recorded on bhindi, bitter gourd, brinjal, chilli and snake gourd Occurence of *A fleschneri, A garrulus* and *A macrommatus* are new reports for Kerala

The predatory mites *Tydeus gossabaensis* and *Pronematus anconai* of the family Tydeidae recorded in amaranthus, bhindi, brinjal, chilli, cowpea and snake gourd are new reports from Kerala One species of astigmatid mite in the family Acaridae was also collected from brinjal and cowpea during the study