DIVERSITY OF PHYTOPHAGOUS MITES AND THEIR NATURAL ENEMIES IN VEGETABLES

By

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DECLARATION

I, hereby declare that this thesis entitled **"Diversity of phytophagous mites and their natural enemies in vegetables"** 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.

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CERTIFICATE

Certified that this thesis, entitled **“Diversity of phytophagous mites and their natural enemies in vegetables”** is a record of research work done independently by **Ms. Binisha K.V.** 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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CERTIFICATE

We, the undersigned members of the Advisory Committee of **Ms.Binisha K.V.**, a candidate for the degree of Master of Science in Agriculture, agree that this thesis entitled **'Diversity of phytophagous mites and their natural enemies in vegetables'** may be submitted by **Ms.Binisha K.V**., in partial fulfillment of the requirement for the degree

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Nirvighnam Kuru Mey Deva, Sarva Kaaryeshu Sarvada"

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Introduction

1. INTRODUCTION

Mites are microscopic creatures belonging to the class Arachnida and subclass Acari. They are biologically the most diverse and dominant group which is world wide in distribution and inhabit all types of terrestrial and aquatic habitats. Mites may be classified as phytophagous, predatory, parasitic and stored product mites on the basis of their feeding behaviour. Around 7000 species of phytophagous mites are known worldwide occurring in five families namely Tetranychidae, Tenuipalpidae, Tarsonemidae, Eriophyidae and Tuckerellidae (Chillar *et al.,* 2007).

Vegetable crops are subjected to attack by a number of mite species leading to heavy economic loss. The average yield losses in vegetable crops due to mite pests in India were estimated to be around 25 per cent (Gupta, 1991a). Some phytophagous mites, mainly spider mites, false spider mites and eriophyoid mites, with their specialized mouthparts feed on the vascular tissues of higher plants and can cause losses to field and protected crops also (Evans,1992), thus becoming major pests of economic importance.

Two spotted spider mite (TSSM) is the most notorious mite pest responsible for significant yield losses in many horticultural, ornamental and agronomic crops worldwide (James and Price, 2002) which is due to its feeding habits on the underside of leaves, removing vital chlorophyll and causing a reduction in photosynthetic activity. The high reproductive potential and extreme short life cycle, combined with frequent acaricide applications, facilitates resistance build-up in most of the acarines. (Stumpf and Nauen, 2002; Van Leeuwen *et al*., 2005).

Mites in the family Tetranychidae are the major crop pests worldwide. The subfamily Tetranychinae includes a number of economically significant species, of which *Tetranychus urticae* Koch and *Tetranychus ludeni* Zacher are the most important species on many vegetable crops (McKinlay *et al.,* 1992). *T. ludeni* is widespread in the tropics and has been recorded from over 300 plant species worldwide (Bolland *et al.,* 1998). In India, *T. ludeni* commonly occurs on many cultivated crops, especially on vegetable crops, causing substantial losses, with the highest damage on egg plant and okra (Reddy, 2001).

The plant inhabiting predatory mites mostly belong to the family Phytoseiidae which has great economic importance as several phytoseiid mites are used for biological control of mite pests (Moraes, 2002). Other predatory mite families which are common on plants include Bdellidae, Cheyletidae, Cunaxidae, Stigmaeidae and Tydeidae. Some plant inhabiting mites show varied feeding habits such as mycophagy, saprophagy etc which are mostly represented by species of Acaridae, Ascidae and Tydeidae (Gerson *et al.,* 2003)

In India, occurrence of 2350 species of mites belonging to 725 genera under 190 families were reported (Gupta and Gupta, 1999). This forms only a small percentage of the world known biodiversity. However, information on the diversity of phytophagous mites affecting major vegetable crops in Kerala is limited. In this background, the proposed study is undertaken to provide a database on the important acarine species associated with major vegetable crops grown in Thrissur district, Kerala.

To evolve effective management practices against this destructive and dreaded group of pests, knowledge on their identity, host plants, distribution, seasonal population fluctuation and natural enemy complex are essential pre-requisites. Also, it is important to monitor the population build up of mite as influenced by weather factors, so that suitable management strategy could be taken up when such a favourable climatic condition occur and also would help to forecast the occurrence of mite incidence. In view of these facts and scarcity of related information on mite fauna associated with vegetables in Kerala, the research project entitled “Diversity of phytophagous mites and their natural enemies in vegetables” was carried out with the following objectives:

- To study the species composition and diversity of phytophagous mites infesting major vegetable crops namely, brinjal, okra, amaranthus, cowpea, bitter gourd and chilli.

- To document the natural enemy fauna associated with the phytophagous mites in these vegetables.

- To investigate the spatial and temporal dynamics of population of phytophagous mites and natural enemy fauna in these vegetable crops.

Review of Literature

2. REVIEW OF LITERATURE

Phytophagous mites are becoming a worldwide problem in agriculture. The scenario of mites as pests has been established on many crops. The misuse and overuse of pesticides in agriculture with the introduction of high yielding varieties has lead to problems of pesticide resistance, resurgence and contamination of different components of the environment and also, crop losses have consistently shown an increasing trend (Dhaliwal *et al.*, 2010). All these resulted in the regular occurrence of many mite species which were never seen earlier and hence knowledge of spatial distribution patterns of plant feeding mites and their natural enemies is essential for understanding their interactions and developing appropriate measures to manage them.

Intensive research work on mites has been carried out all over the world including India. Various literature on the diversity and seasonal incidence of phytophagous, predatory mites and also the impact of weather parameters on their population are presented here.

2.1. DIVERSITY OF PHYTOPHAGOUS MITES AND THEIR NATURAL ENEMIES IN VEGETABLES

Survey conducted in eight districts of West Bengal for mites associated with vegetable crops in 1985 had revealed a total of 22 species of both phytophagous and predatory mites. The phytophagous mite fauna included *Tetranychus cinnabarinus* (Boisd.) on cucumber, okra, bitter gourd, brinjal and beans; *Tetranychus neocalidonicus* Andre on brinjal, bottle gourd, okra, ridge gourd pumpkin and bitter gourd, *Tetranychus macferlanei* Baker and Pritchard on sponge gourd and pumpkin. Predatory mites recorded in the study were *Amblyseius largoensis* (Muma), *A. ovalis*

(Evans), *A. alstoniae* Gupta, A. *longispinosus* (Evans), *Cunaxa* sp., *C. setirostris* (Hermann), *Agistemus* sp., *Spinibdella* sp., *Rhizoglyphus* sp., and *Tyrophagus putrescentiae* (Gupta and Gupta, 1985).

Gerson and Smiley (1990) provided key and an introduction to the families of mites with potential for use in the biological control of pests. Gerson *et al.,* (2003) discussed in detail 34 acarine families of mites useful for the control of insects, mites, weeds, and nematodes pests.

According to Gupta (1991b), six species of mites *viz*., *T. cinnabarinus, T. neocaledonicus, Tetranychus ludeni* Zacher*, T. macfarlanei, Aceria lycopersici* (Wolffenstein) and *Polyphagotarsonemus latus* (Banks) were found to be serious pests of vegetables like brinjal, okra, cucurbits, chilli, and potato in major parts of India. Out of 17 predators, five species *viz*., *Amblyseius multidentatus* Swirski and Shechter, *A. alstoniae* Gupta, *A. delhiensis* (Narayanan and Kaur)*, A. finlandicus* (Oudemans) and *A. tetranychivorus* Gupta were reported to be the major predators.

The phytophagous mites namely *T. cinnabarinus, Brevipalpus californicus* (Banks) and *Brevipalpus phoenicis* (Geij.) and the predatory mites viz., *Amblyseius alstoniae, A. finlandicus* (Oudemans)*, A. multidentatus* Swirski and Shechter, *Phytoseius roseus* Gupta*, P. minutus* Narayanan and Ghai*, Typhlodromus gopali* Gupta*, Agistemus industani and Pronematus sp.* were reported to be associated with brinjal in Punjab (Grewal,1992).

Vora (1994) gave an account of the phytophagous and predatory mite fauna on brinjal in Navasari, Gujarat. *Tetranychus urticae* Koch, *Polyphagotarsonemus latus* (Banks), *Aceria lycopersici* (Wolffenstein) and *Brevipalpus phoenicis* (Geij.)

were reported as the phytophagous species and *Phytoseius* sp. and *Pronematus flaschneri* as the predatory mites.

Arbabi *et al*. (1994) reported *T. macferlanei* as a severe pest of brinjal from Varanasi, UP and minor incidence of *Brevipalpus rugulosus* Chaudhri and Rasool*, Aceria lycopersici* (Wolffenstein) and *Polyphagotarsonemus latus* (Banks).

A survey conducted in Thiruvananthapuram district, Kerala during 1996 recorded five species of phytophagous mites belonging to the families Tetranychidae, Tenuipalpidae and Tarsonemidae in different vegetables. The Tetranychid mite *T. cinnabarinus* was observed on *Amaranthus bicolor* and *A. dubius, T. ludeni* was associated with *Abelmoschus esculentus* (L.) and *Vigna unguiculata* sub sp. *sesquipedalis* L. (Verdecourt) and *T. neocalidonicus* was found to infest *Cucurbita pepo* L.*, Moringa oleifera* Lam. and *Solanum melongena* L. The only tenuipalpid mite found infesting with vegetables was *B. phoenicis* and it was recorded from *S. melongena.* The tarsonemid mite *P. latus* was found to infest the vegetable crops *Momordica charantia* L.*, Capsicum annum* L.*, C. pepo, Luffa acutangula* L.*, V. unguiculata* sub sp.*sesquipedalis* (Sudharma, 1996).

Abd-El-Rahman (1996) reported the occurrence of 42 species of mites belonging to 17 genera and two families (Tetranychidae and Tenuipalpidae) from different vegetables, fruits, ornamental and medicinal plants as well as weeds. According to him, *T. cucurbitacearum* (Sayed), was found in most economic plants while *T. urticae* was found in all kinds of sampled plants.

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

The predatory mite, *Amblyseius* sp. and the green lace wing, *Chrysoperla carnea* (Stephens) were reported to be the potential predators of *Tetranychus ludeni* Zacher on cowpea and of *P. latus* on chilli (Abhilash, 2001).

Zacarias and Moraes (2002) conducted a study on the diversity of mite species on euphorbiaceous plants in three regions of the State of São Paulo, Brazil. They reported a total of 31,603 mites belonging to 105 species in 74 genera and 16 families among which 21 species belonged to phytophagous families and 43 to families of predators.

Gulati (2004) reported the distribution and abundance of two spotted mite *Tetranychus urticae* Koch from the vegetable growing tracts of Punjab and Haryana. He also reported the incidence of *T. cinnabarinus* on different varieties of okra.

Zhovnerchuk (2006) made investigations on the tetranychoid mites inhabiting green plantings in Kyiv metropolis, Ukraine for the first time and recorded nine species of mites belonging to six genera of the families Tetranychidae and Bryobiidae.

Adango *et al.* (2006) reported *Tetranychus ludeni* Zacher as a pest of two leafy vegetables *Amaranthus cruentus* L. (Caryophyllales: Amaranthaceae) and nightshade, *Solanum macrocarpon* L. (Solanales: Solanaceae) in West Africa.

The results of the study made by Prasad (2006) to explore the mite pests associated with common vegetables in Hazaribagh district of Jharkhand revealed that four groups of mites viz. Tetranychid, Tenuipalpid, Tarsonemid and Eriophyid mites were found to infest vegetable crops throughout the year. During hot summer months, *T. urticae* emerged as extremely severe pest of brinjal, okra and cucumber. *T. ludeni* affected cowpea and French bean; *T. macferlanei* appeared as extremely severe pest on sponge gourd, ridge gourd, bottle gourd and pumpkin. Chillies were found to be badly affected by *P. latus*. Three species of tenuipalpid mites were also reported as pests of vegetables in this tract. *Brevipalpus phoenicis* (Geij) was found to infest okra and brinjal, *B. californicus* Banks, on okra and *B. rugulosus* on brinjal were reported as minor pest. The eriophyid mite *Aceria lycopersicae* (Wolffenstein) was found to occur on brinjal and tomato.

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 Ramani, 2006).

A study on the diversity of mites associated with crop plants of Kerala revealed 37 species of mites belonging to 24 genera and 9 families. The maximum species diversity of mite was recorded on *Manihot esculenta* L. and *Cocos nucifera* L. and also the population density of the members of *Tetranychus* was reported to be high among the various genera attacking vegetable crops (Sobha and Haq, 2007).

The red spider mite *Tetranychus evansi* Baker and Pritchard was reported for the first time in Greece on *Solanum nigrum* L. by Tsagkarakou *et al*. (2007). *T. evansi* was a serious pest of tomatoes and other Solanaceae crops (aubergine, potato, tobacco) and also recorded on several other vegetables and ornamental crops as well as on many weeds.

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)

Amelia *et al*. (2007) reported four species of phytophagous mites on different host plants in Mozambique, namely *Tetranychus evansi, T. urticae, T. ludeni* Zacher and *Polyphagotarsonemus latus*. They also reported 76 alternative host plants with varied spider mite densities, suggesting preference of mites for some species. The most frequent plant genera found as alternate hosts were tomato, cucurbits, *Datura, Sida, Solanum* and *Vigna.*

Phytophagous mites from natural vegetation in Venezuela was studied by Vásquez *et al*. (2009) and they reported two tenuipalpid and eight tetranychid mite species.

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 mite groups namely Eriophyidae, Tetranychidae, Bdellidae, Anystidae, Cheyletidae, Erythraeidae, Phytoseiidae, Stigmaeidae, Ascidae, Parasitidae, Ameroseiidae, Acaridae, Tydeidae, Tarsonemidae and Oribatidae. Among a total of 40 species, the plant parasitic mites *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% of the mite specimens collected. Most mite species was found on black nightshade (23 species), followed by tomato (17), climbing nightshade (16), pepper (16), eggplant (15) and thorn apple (13). *T. urticae* was mostly present on all plants especially egg plant (Cobanoglu, *et al.,* 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.

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 were already known, five assigned near to the already known species and remaining 17 were new to science (Gowda and Mallik, 2010)

The survey conducted in Varanasi and Azamgarh districts of eastern Uttar Pradesh revealed that tetranychid mites, *Tetranychus urticae*, *T. neocalidonicus* Andre, *T. ludeni* Zacher and *T. macfarlanei* Baker and Pritchard were found infesting many vegetables like okra, brinjal, cowpea, chilli, pumpkin, bitter gourd, cucumber, bottle gourd, sponge gourd, tomato, water melon etc. *Eutetranychus orientalis* Klein was recorded on hyacinth bean. Tenuipalpid mites, *Tenuipalpus phoenicis* Geij and *Brevipalpus californicus* Banks were also recorded on okra, brinjal, sponge gourd and bottle gourd. Eriophyid mite, *Aceria lycopersici* (Wolffenstein) was observed on brinjal only in months of September and October. Tarsonemid mite, *Polyphagotarsonemus latus* was recorded on different varieties of chilli only (Rai and Indrajeet, 2011)

Study conducted to investigate 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). Phytophagous mites, *Tetranychus turkestani* (Ugarov and Nikolski) and *T. cinnabarinus* were obtained from egg plant, bean, and cucumber. Predatory mites *Phytoseius finitimus* Ribaga and *Amblyseius andersoni* (Chant) (Acari: Phytoseiidae) were identified from eggplant and cucumber, respectively.

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)

2.2 POPULATION DYNAMICS OF PHYTOPHAGOUS AND PREDATORY MITES

The incidence of *T. neocaledonicus* on brinjal at Udaipur was low from October to January. Thereafter, with increase in temperature the pest population also showed increasing trend and reached its peak in May. Besides temperature and relative humidity, plant vigor and availability of more matured leaves also played a significant role in population build up of mites (Pande and Sharma, 1985).

In West Bengal, the population of *T. cinnabarinus* was found on vegetable crops throughout the year but the infestation was in severe form on brinjal during May to middle of July and again during November -December (Gupta and Gupta, 1985).

Mishra *et al.* (1990) reported that various accessions of brinjal were attacked by *T. cinnabarinus* throughout the crop period with maximum population during May when the mean temperature was 30 to 45^0C.

The tetranychid mites *T. cinnabarinus, T. neocalidonicus, T. ludeni* and *T. macferlanei* were found to severely infest brinjal and bhindi throughout the country and the mite population became more severe during summer. Population of mite in brinjal remained in peak during April – May, least during December – February whereas in bhindi the mite population was in peak during May-June (Gupta, 1991b).

Rai *et al.* (1991) reported the seasonal incidence of *T. macfarlanei* (Baker and Pritchard) on okra, in Navasari (Gujrat) during summer season. Incidence of mite started in the month of April and reached its peak during middle of May and gradually declined following the onset of monsoon.

In Ludhiana (Punjab), *T. cinnabarinus* population in brinjal was less in December - January, began to buildup in May and reached peak in September (Grewal, 1992).

Ho and Chen (1992) made survey in Taiwan and observed that population of *T. cinnabarinus* on brinjal reached peak twice. The first peak occurred in May - July and second in September - October.

The findings of Singh *et al.* (1993) indicated that the population of *T.ludeni* on cowpea in Varanasi attained its peak incidence during May-June and lower peak incidence during September – October.

According to Kumar and Sharma (1993), population of *T. ludeni* on okra appeared in first week of April, with 27 mites/10 cm^2 leaf area. Thereafter, the population increased gradually and reached to a maximum of 126 mites/10 cm^2 leaf area in the second week of June. An abrupt decrease in mite population was observed during first week of July (106 mites/10 cm^2 leaf area). Thereafter, a gradual decrease was observed. Mites disappeared completely during first fortnight of September.

Shaw and Devroy (1995) reported that May was the most suitable month for rapid development of *T. neocalidonicus* in brinjal at Jorhat, Assam.

Kapoor *et al*. (1997) noticed high population of *T. cinnabarinus in* brinjal from May to November, except July while phytoseiids peaked in September.

Lingeri *et al.* (1998) studied the seasonal incidence of chilli mite, *P. latus* and indicated that the activity of *P. latus* was noticed throughout the cropping period on all five dates of transplanting. The peak activity of chilli mite was noticed in the months of November and February and the mite population was favoured by higher temperature, lower humidity and lesser intensity of rainfall

Ram *et al.* (1998) studied the population fluctuation of *P. latus* on chilli under the agro-climatic conditions of Semiliguda (Orissa) and concluded that the yellow mite was the major destructive pest at flowering stage causing yield reduction and deterioration of quality. The yellow mite was available throughout the period of study. The population of the mite gradually increased from 32nd standard week with a sharp rise from 41st standard week. The maximum population of 17 mites per 10 twigs was recorded during 46th standard week. Thereafter, the mite population sharply declined and reached low during the seventh standard week of subsequent year.

Sugeetha (1998) observed that the incidence of *T. macferlanei* on okra started from middle of November to end of December in *kharif* crop. There was a decline in mite population at the end of December. Spider mite appeared on the summer okra crop much earlier as compared to the *kharif* crop (mid April) and reached its peak at the end of April to end of May.

Sobha and Haq (1999) reported the incidence, population fluctuation and distribution pattern of *T. neocalidonicus* on *Dolichos lablab.* They observed three peaks in population during September, November and March.

The study made by Sugeetha and Srinivasa (1999) on the seasonal abundance of *T.macferlanei* on different okra varieties in Bangalore revealed that the mite attack was more in summer crop than kharif crop.

Mohammed *et al.* (1999) observed that the yellow mite incidence in chilli started from the last week of October or first week of November but remained at low intensity throughout November followed by a progressive increase in population during December and January.

The population of *Eotetranychus broodryki* started building up on the kharif sown pigeonpea from September I fortnight and continued till crop maturity showing the highest peak during January I fortnight in Gujarat. The phytoseiid predators

(*Amblyseius* sp.) also appeared from September I fortnight and continued till crop end (Desai *et al*., 1999).

Prasad and Singh (2003) reported that the population of *T. macferlanei* on pumpkin started building up from second fortnight of March and continued until the first fortnight of July.

Gulati (2004) reported that in summer crop, mites appeared in the month of April, showed an increasing trend in May and then attained a peak in the month of June. In Kharif crop, mite population was maximum in the month of October, after that there was a gradual decline.

The study on the seasonal incidence of phytophagous mites on some common vegetables of Jharkhand showed that the mite species started began to attain larger population from middle of February and the population build-up gradually increased upto hot months of summer season with the highest peak incidence of mite pests observed during middle of April to middle of June. During rainy season the population of mites was found to be much declined and the mite population attained its second peak incidence during September and October (Prasad, 2006).

Patil and Nandihalli (2009) recorded the seasonal incidence of *T. macfarlanei* Baker and Pritchard on brinjal which attained its peak in mid July. The activity of phytoseiids also reached its peak in mid July coinciding with peak population of prey mite. During Rabi, spider mite population attained two peaks on brinjal during November and January.

In chilli, *Polyphagtar*so*nemus latus* occurred throughout the period of plant growth during summer. Peak mite population and activity of predatory mite was noticed between April and May. During Kharif, maximum mite population was noticed in October and Rabi crop attained peak population during second week of November (Patil and Nandihalli, 2009).

Rachana *et al*. (2009) reported the seasonal incidence of red spider mite *Tetranychus neocalidonicus* Andre and its natural enemies on okra in Shimoga, Karnataka. High mite population was observed from March first fortnight and this trend continued up to second fortnight of April and low population was recorded from June to February.

The seasonal incidence of Tetranychid mites in okra at Dharwad, Karnataka was studied by Varadaraju and Nandihalli (2010). In *Kharif* crop, the okra mites, *Tetranychus* spp. reached peak during the first fortnight of November and in Rabi crop the peak was noticed during the second fortnight of March. In summer, the peak was recorded during second fortnight of May.

Vichitbandha and Chandrapatya (2011) reported that the Broad mite, *P. latus* was found to be the most common pest collected from young shoots of chilli. Mite populations started to increase from the end of September and reached their peak after mid October.

2.3. INFLUENCE OF ABIOTIC FACTORS ON MITE POPULATION DYNAMICS

Mishra *et al.* (1990) found positive correlation between population of *T. cinnabarinus* on brinjal and temperature.

The correlation studies on the influence of weather parameters and population of *T. ludeni* on okra revealed a significant correlation between the mite population and temperature. As the minimum temperature started increasing from April, the mite population also showed an increasing trend. The correlation between minimum temperature and mite population was positive but non-significant. Relative humidity and rainfall had significant positive correlation with mite population (Kumar and Sharma, 1993).

Results of Rai *et al.* (1995) revealed that temperature, relative humidity and wind velocity were positively correlated with *T. urticae* population in brinjal while rainfall adversely affected the mite population. But, sunshine hours did not show any effect.

According to Sudharma (1996) there was no significant correlation between population of *T. ludeni* and weather parameters in bhindi and vegetable cowpea. However, *P.latus* had significant positive correlation with maximum and minimum temperature and negative correlation with humidity and rainfall in chillies.

The correlation between the population of *P. latus* on chilli and weather parameters was negative with maximum and mean temperature (-0.744 and -0.409) whereas, sunshine (0.460) was positively correlated. Also high rainfall received during July to September had washing effect on mites (Ram *et al.,* 1998).

Lingeri *et al.* (1998) observed that the population of *P. latus* in chilli was favoured by higher temperature coupled with lower humidity having lesser intensity of rainfall. Heavy rains washed out *P. latus* thereby reducing its population completely.

Bhagat and Singh (1999) confirmed that the population of *T. cinnabarinus* remained high during August to February on brinjal due to prevalence of congenial weather factors.

Studies made by Desai *et al*. (1999) regarding the influence of abiotic factors on the incidence of *Eotetranychus broodryki* on pigeonpea showed significant positive correlation between sunshine hours and population build up of the mite while rainy days, relative humidity and minimum and average temperature adversely affected the mite population.

Prevalence of prolonged maximum temperature and minimum temperature coupled with cloudiness, high humidity and absence of rainfall coincided with peak activity of yellow mite on chilli either during December or in January depending upon the fluctuation in maximum temperature. The sharp decline in mite activity leading to its disappearance during February was due to the rise in maximum temperature and fall in relative humidity. The maximum temperature and minimum temperature were found to have significant negative influence on the build up of mite (Mohammed *et al.,* 1999).

The population of *T. urticae* on okra showed a significant positive correlation with temperature, while relative humidity showed significant but negative correlation (Dhar *et al.,* 2004).

Praslicka and Huszár (2004) reported that high temperature favours the population increase of *T. urticae* on *Phaseolus vulgaris, Cucumis sativus* and *Capsicum annuum*.

Mandal *et al.* (2006) reported that the activity of *T. telarius* in okra at Pusa showed non-significant negative correlation with maximum temperature and positive correlation with minimum temperature. Morning and evening relative humidity showed a significant positive association with mite activity.

Choudhury *et al.* (2006) studied the effect of ecological factors on the population dynamics of red spider mite *Oligonychus coffeae* (Nietner), in India. The pest population was found to be seasonally variable and dependent on the prevailing agroclimatic conditions including maximum and minimum temperature as well as rainfall. The results indicated high population build up in high temperature and low rainfall.

Investigation on the influence of weather parameters on the population dynamics of *T. urticae* Koch on okra revealed that the mite population had significant positive correlation with maximum temperature and negative correlation with low temperature, relative humidity and rainfall (Chinniah *et al*., 2007).

Rolania and Sharma (2007) confirmed that the population of *T. urticae* on Ashwagandha peaked in the third week of December due to fairly high temperature, the population declined from the last week of December to negligible level in the third week of January due to the prevalence of high RH and rainfall.

Hosamani *et al*. (2007) reported that the population of *P. latus* on chilli showed a negative significant correlation with maximum and minimum temperature. Rainfall was negatively correlated with mite population. Morning relative humidity was positively correlated with mite population while, evening relative humidity showed negative and non-significant correlation.

A study conducted on the influence of certain abiotic factors on the population dynamics of two spotted spider mite, *T. urticae* in brinjal ecosystem revealed that maximum temperature had a significant positive correlation with mite population whereas relative humidity and rainfall had a significant negative correlation (Chinniah *et al.*, 2009).

The studies made by Patil and Nandihalli (2009) indicated that morning and evening relative humidity had a significant negative correlation with population of *P. latus* in chilli and also rainfall was highly detrimental and showed highly significant negative correlation with mite population. Predators established a highly significant positive correlation with mite activity.

2.1.4 SPATIAL DISTRIBUTION OF MITES ON HOST PLANTS

In brinjal, tetranychids were abundant on the middle and bottom leaves. But more number of mites were seen on leaves of upper canopy in June to August raised crop. Whereas, during September to December period, middle canopy leaves harbored more number of mites (Anon., 1994).

According to Rai *et al.* (1995), *T.urticae* on brinjal preferred bottom canopy leaves than middle and top canopy leaves.

The population of *E.broodyrki* on pigeonpea was found to be comparatively higher on lower leaves than middle and top canopy leaves (Desai *et al*., 1999).

In brinjal, among three different canopy levels, middle canopy harboured maximum mite density (50.75/4 cm^2 leaf area) followed by bottom (49.00/4 cm^2 leaf area) and top canopy (23.65/4cm^2 leaf area). There was significant variation in the population of immature and adults of red spider mites of top canopy with middle and bottom canopies while the population between middle and bottom canopies was non significant. In chilli, *P. latus* preferred apical young leaves for their feeding, shelter and oviposition (Patil, 2005).

Studies of Srinivasa *et al*. (2007a) on the distribution of two spotted spider mite on tomato reported that the middle canopy leaves harboured significantly more number of mites followed by leaves in the bottom canopy.

The population of *P. latus* on potato comprising eggs as well as active stages was more abundant on compound leaves in the top canopy. Also terminal leaflet in a compound leaf at the top canopy harboured maximum number of eggs as well as active stages compared to the corresponding terminal leaflet in the compound leaf of the bottom canopy and irrespective of the canopy level the terminal leaflet of the compound leaf was more preferred by the mite compared to lateral leaflets (Srinivasa *et al.*, 2007 b).

Materials & Methods

3. MATERIALS AND METHODS

The present study was undertaken at the Department of Agricultural Entomology, College of Horticulture, Vellanikkara during 2011-2012 to explore the faunal composition of phytophagous and predatory mites associated with six major vegetable crops in Thrissur district. The thrust areas of the investigation were the conduct of surveys in three major vegetable growing tracts of Thrissur to collect mite infested leaf samples from selected host plants and to identify the mite fauna up to generic / species level. The population dynamics of the mites and the influence of weather parameters on the mite population were also studied. In addition, the population parameters of species richness and species diversity indices were also worked out.

The methodologies and techniques adopted for conducting the experiment based on the objectives set forth in the studies are presented hereunder.

3.1. DIVERSITY OF PHYTOPHAGOUS MITES AND THEIR NATURAL ENEMIES IN VEGETABLES

Random roving surveys were carried out in the farmers fields from three vegetable growing tracts namely, Pazhayannur, Kannara and Vellanikkara of Thrissur district at fortnightly intervals during February, 2011 to January, 2012 to collect phytophagous and predatory mites associated with six vegetable crops *viz*., brinjal, bhindi, amaranthus, cowpea, bitter gourd and chilli at various growth stages.

3.1.1. Sampling and collection of mites

Mite infested leaf samples (3 leaves per plant) were collected from ten randomly selected plants each of brinjal, bhindi, amaranthus, cowpea, bitter gourd and chilli (Plate 1) separately in polythene bags from each locality and brought to the laboratory. In the laboratory, the leaves were observed under stereomicroscope

Plate1.Symptoms of mite infestation in vegetables

Plate1a.Red spider mite webbing in brinjal

Plate1b.Red spider mites on the under surface of leaves

Plate1.Symptoms of mite infestation in vegetables Contd...

Plate 1c. Red spider mite webbing in bhindi

Plate 1d. White speckles on bhindi leaves

Plate1.Symptoms of mite infestation in vegetables Contd...

Plate 1e. Mite damage symptoms in cowpea

Plate 1f. White speckles in amaranthus

Plate 1. Symptoms of mite infestation in vegetables Contd...

Plate 1g. Downward curling of leaves in chilli

Plate 1h. Broad mites in chilli (10X)

and mite specimens were collected using camel hair brush and preserved in 70 per cent ethyl alcohol with a few drops of glycerol taken in glass vials of 1.5ml capacity.

3.1.2. Preparation and identification of mite specimens

Permanent slides of the mites collected in the survey were prepared in Hoyer's media (Plate 2 and Appendix I). Single specimen representing both male and female mites of the same species was mounted separately on different slides. The specimens were placed on a drop of media on the glass slide in the dorsal view and pressed to the bottom of the slide to spread out the legs and a cover glass was placed on the top of the specimen without any air bubbles. The male tetranychid mites were mounted in the lateral position also to ensure the better orientation of the genital structures which were very important for species determination. The mounted specimens were kept in an oven at 40^{o}C for seven to ten days to get cleared and dried specimens. The slides were then labelled and numbered serially for identification. Details of host, locality, date of collection, collector's name and accession number were given on the label. The edges of the cover glass were sealed with nail polish to avoid damage of the specimen due to excessive moisture after the specimens were properly cleared and dried. The permanent slides were used for taxonomic studies using a Leica DM 500 phase contrast microscope (Plate 3).

The permanent slides prepared were observed under phase contrast microscope (Leica DM 500) which has an image analyzer software to study the taxonomic characters. Identification of the slide mounted mite specimens was made using appropriate literature and also with the help of mite taxonomists at the University of Agricultural Science Bangalore. A taxonomic key for the identification of mite fauna associated with vegetables obtained in the survey was prepared.

Plate 2.Hoyers media

Plate 3.Phase contrast microscope (Leica DM 500) with image analyser

3.2. DIVERSITY INDICES OF MITES IN DIFFERENT VEGETABLE CROPS

Roving field surveys were carried out in the farmers fields of Pazhayannur, Kannara and Vellanikkara tracts of Thrissur district at fortnightly intervals during February, 2011 to January, 2012 to collect phytophagous and predatory mites associated with the six vegetable crops at various growth stages. Three mite infested leaf samples per plant from randomly selected 10 plants of the six vegetable crops were plucked and put in separate polythene bags for subsequent identification of phytophagous and predatory mites. In the laboratory, individual leaf was thoroughly examined under a stereo microscope to collect mites.

The data on the proportion of different species of mites occurring in a crop is essential to calculate the species diversity indices in different ecosystems. As the identity of the species could not be established on observing live mites under stereo binocular microscope, the number of permanent slides prepared for each species/genus was used to work out the species diversity indices. The number of slides to be made for each taxa was standardized as follows. For predominant phytophagous mites in each crop, 10 slides were prepared per leaf sample collected during the survey. Whereas, for less abundant mites, all the mites observed on a leaf were used for slide preparation.

After establishing the identity of mites, the data on the total number of slides prepared per taxa in each crop were used to work out the various population parameters *viz*., genus richness and species diversity indices such as Simpson-Yule Diversity index (D), Shannon-Weaver Diversity Index (H), Evenness Index (E), and Berger-Parker Dominance Index (d).

a. Genus richness is the total number of genera present in the community, where the value ranges from o - ∞.

b. Simpson - Yule Diversity Index (D): Simplest measure of the character of a community that takes into account both the abundance pattern and the species richness. This is proposed by Simpson (1949) to describe the probability that a second individual drawn from a population should be of the same species as the first (Southwood and Henderson, 2000).Its value ranges from one to the total number of species.

$$D = 1 \Big/ \sum_{i=1}^{S} pi^2 \qquad \text{(Range = 1 to S)}$$

Where, S = total number of species present in the community

pi = proportion of individuals belonging to the i^{th} species

An index of one indicates that all individuals in the area belong to a single species and when D = S every individual belong to different species.

c. Shannon - Weaver Diversity Index (H): This index is a unique indicator of environmental stress as the sensitive species gradually shift or get eliminated from a habitat with the increase in magnitude of environmental stress. A decrease in the value of this index indicates an increase in the magnitude of environmental stress on the species (Cairns and Dickson, 1971).This is the most commonly used diversity index in ecological studies owing to the fact that it is dimensionless, independent of sample size and expresses the worth of each species (Kochsieck *et al*., 1971).

$$H = -\sum_{i=1}^{S} pi \ln pi \qquad \text{(Range = 0 to ln S)}$$

Where, pi = proportion of individuals belonging to the i^{th} species

ln = natural logarithm

d. Evenness Index (E): Ratio of the observed diversity to the maximum possible for the observed species number (Southwood and Henderson, 2000). It is a measure of the uniformity of different species in a community and the value increases as the environment becomes favourable for a number of species (Mitra, 2000).

$$E = H / \ln S \quad \text{(Range = 0 to 1)}$$

Where H = Shannon – Weaver Diversity Index

S = total number of species in the community

ln = natural logarithm

e. Berger – Parker Dominance Index (d) is a simple dominance measure .it refers to the proportion of total catch, N_T, that is due to the dominant species, N_{max} (Southwood and Henderson, 2000).

$$d = N_{max} / N_T \qquad \text{(Range = 0 to 1)}$$

Where N_{max} = number of individuals in the most abundant species

N_T = total catch of all the individuals

3.3. POPULATION DYNAMICS OF PHYTOPHAGOUS MITES AND THEIR NATURAL ENEMIES

Random surveys were conducted at fortnightly intervals during February, 2011 to January, 2012 in the vegetable fields of Vellanikkara tract to study spatial and temporal dynamics of population of phytophagous and predatory mites associated with brinjal, okra, amaranthus, cowpea, bitter gourd and chilli at various growth stages.

3.3.1. Spatial and temporal dynamics of mite population

During the survey, three leaves from top, middle and bottom canopy of ten randomly selected plants of brinjal, bhindi, amaranthus, cowpea and bitter gourd and from top canopy alone of chilli were collected separately in polythene bags (40cm × 30 cm and 50 µ). Thus 10 leaves from each canopy and 30 leaves from each crop formed the sample. The leaves were brought to the laboratory and observed under stereo binocular microscope for different stages of mites and population counts were recorded. The mite stages were counted from three loci of 1cm^2 window (Plate 4) in each leaf in all crops except chilli in which the counts were taken per leaf. The data on the mite count were compiled separately for different canopy levels and the mean number of mites per cm^2 leaf area was worked out over a period of 24 fortnights from first fortnight of February, 2011 to second fortnight of January, 2012. The data so obtained were analysed using t–test to compare the significant difference in the distribution of mites on different canopy levels.

3.4. INFLUENCE OF WEATHER FACTORS ON THE MITE POPULATION DYNAMICS

The role of various weather parameters *viz*., maximum and minimum temperature, morning and evening relative humidity and total rainfall on the population dynamics of the phytophagous and predatory mites was worked out. The weakly weather data for the period February 2011 to January 2012 were collected from the meteorology observatory of College of Horticulture, Vellanikkara (Appendix II). The observations were subjected to simple correlation analysis to determine their influence on the mite population dynamics. Correlation between the mite population and the weather factors were also worked out.

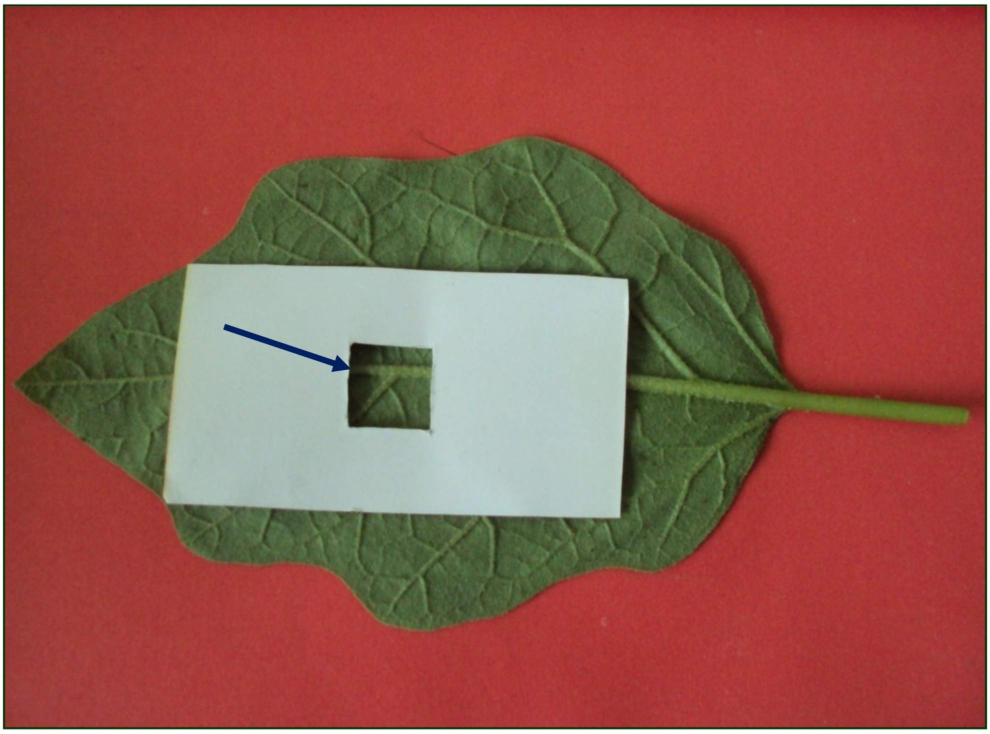

Plate 4. 1cm^2 window for observing mites under microscope

Plate 5. Adults and eggs of red spider mite (30X)

Results

4. RESULTS

4.1. DIVERSITY OF PHYTOPHAGOUS MITES AND THEIR NATURAL ENEMIES ASSOCIATED WITH VEGETABLES

A periodic survey was undertaken to explore the mite fauna associated with brinjal, bhindi, amaranthus, cowpea, chilli and bitter gourd from major vegetable growing tracts of Thrissur district. The phytophagous and predatory mite fauna in vegetables observed in the survey are presented in Table 1. A total of 19 species of phytophagous and predatory mites belonging to eight families were encountered. The phytophagous mite families recorded were Tetranychidae, Tenuipalpidae and Tarsonemidae represented by the genera *Tetranychus, Eutetranychus, Brevipalpus* and *Polyphagotarsonemus.* The predatory mite families include Phytoseiidae, Stigmaeidae, Cunaxidae, Bdellidae and Tydeidae. The acarine faunal diversity in different vegetable crop environments is mentioned below.

4.1.1. Faunal diversity of phytophagous and predatory mites associated with vegetables

4.1.1.1 Mite fauna in brinjal

A total of 10 species of mites belonging to three phytophagous and seven predatory mites were observed in brinjal. *Tetranychus urticae* Koch of the family Tetranychidae*, Polyphagotarsonemus latus* (Banks) of Tarsonemidae and *Brevipalpus phoenicis* (Geij.) belonging to family Tenuipalpidae were the phytophagous species among which *T. urticae* was the dominant one while the other two species occurred in very minor form. The predatory mites identified upto species level include *Neoseiulus longispinosus* Evans, *Paraphytoseius orientalis* Narayanan of the family Phytoseiidae and *Agistemus gamblei* Gupta of family Stigmaeidae. The other predatory mites identified upto generic level were *Amblyseius* sp., *Phytoseius* sp., *Typhlodromips* sp. and *Euseius* sp. all belonging to family Phytoseiidae.

4.1.1.2. Mite fauna in bhindi

Four different types of mite were observed from bhindi which included one phytophagous and three predatory mites. *T. urticae* was the only phytophagous mite recorded from this crop and the predatory mites include *N. longispinosus*, *Typhlodromips* sp., *Amblyseius* sp., of the family Phytoseiidae and *Agistemus* sp. belonging to family Stigmaeidae.

4.1.1.3. Mite fauna in amaranthus

In amaranthus, two species of phytophagous mites recorded were *Tetranychus* sp. and *B. phoenicis* of which *Tetranychus* was the predominant one. Predatory mites included *N. longispinosus*, *Amblyseius* sp., *Euseius* sp., *Scapulaseius* sp. and *Typhlodromips* sp. all belonging to the family Phytoseiidae.

4.1.1.4. Mite fauna in cowpea

In cowpea, three phytophagous mites and three predatory mites were collected. The phytophagous mites included *Tetranychus* sp., *Eutetranychus* sp., both belonging to family Tetranychidae and *P. latus* of family Tarsonemidae. Predatory mites were *N. longispinosus*, *Typhlodromips* sp. and *Amblyseius* sp.

4.1.1.5. Mite fauna in chilli

P. latus was the only phytophagous mite recorded from chilli. However, seven different species of predatory mites were collected during the study which included *Amblyseius paraaerialis* Muma, *Euseius* sp., *Typhlodromips* sp. of family Phytoseiidae, Tydeus sp. of family Tydeidae, *Agistemus* sp. of Stigmaeidae, *Cunaxa* sp. belonging to Cunaxidae and *Bdella* sp. of Bdellidae.

4.1.1.6. Mite fauna in bitter gourd

One species of phytophagous mite, *P. latus* and two predatory mites were recorded in bitter gourd. The predatory mites included *Euseius macrospatulatus* Gupta and *Typhlodromips* sp. of the family Phytoseiidae.

Table 1. Phytophagous and predatory mites associated with vegetable crops in Thrissur district

Host plant	Phytophagous mites			Predatory mites		
	Mite genus/species	Suborder	Family	Mite genus/species	Suborder	Family
Brinjal *(Solanum melongena* L.)	*Tetranychus urticae* Koch	Prostigmata	Tetranychidae	*Paraphytoseius orientalis* Narayanan	Mesostigmata	Phytoseiidae
	Polyphagotarsonemus latus (Banks)	Prostigmata	Tarsonemidae	*Neoseiulus longispinosus* (Evans)	Mesostigmata	Phytoseiidae
	Brevipalpus phoenicis (Geij.)	Prostigmata	Tenuipalpidae	*Amblyseius* sp.	Mesostigmata	Phytoseiidae
				Euseius sp.	Mesostigmata	Phytoseiidae
				Phytoseius sp.	Mesostigmata	Phytoseiidae
				Typhlodromips sp.	Mesostigmata	Phytoseiidae
				Agistemus gamblei Gupta	Prostigmata	Stigmaeidae
Bhindi *(Abelmosches esculentus* L.)	*T.urticae*	Prostigmata	Tetranychidae	*N.longispinosus*	Mesostigmata	Phytoseiidae
				Typhlodromips sp.	Mesostigmata	Phytoseiidae
				Amblyseius sp.	Mesostigmata	Phytoseiidae
				Agistemus sp.	Prostigmata	Stigmaeidae

Table 1. contd…

Host plant	Phytophagous mites			Predatory mites		
	Mite genus/species	Suborder	Family	Mite genus/species	Suborder	Family
Amaranthus *(Amaranthus* sp.	*Tetranychus sp.* *B. phoenicis*	Prostigmata Prostigmata	Tetranychidae Tenuipalpidae	*N. longispinosus* *Amblyseius* sp. *Euseius* sp. *Scapulaseius* sp. *Typhlodromips* sp.	Mesostigmata Mesostigmata Mesostigmata Mesostigmata Mesostigmata	Phytoseiidae Phytoseiidae Phytoseiidae Phytoseiidae Phytoseiidae
Cowpea (*Vigna unguiculata* L.)	*Tetranychus* sp. *Eutetranychus* sp. *P.latus*	Prostigmata Prostigmata Prostigmata	Tetranychidae Tetranychidae Tarsonemidae	*N. longispinosus* *Typhlodromips* sp. *Amblyseius* sp.	Mesostigmata Mesostigmata Mesostigmata	Phytoseiidae Phytoseiidae Phytoseiidae
Bitter gourd (*Momordica charantia* L.)	*P.latus*	Prostigmata	Tarsonemidae	*Typhlodromips* sp. *Euseius macrospatulatus* Gupta	Mesostigmata Mesostigmata	Phytoseiidae Phytoseiidae

Table 1. contd…

Host plant	Phytophagous mites			Predatory mites		
	Mite genus/species	Suborder	Family	Mite genus/species	Suborder	Family
Chilli (*Capsicum annum* L.)	*P.latus*	Prostigmata	Tarsonemidae	*Amblyseius paraaerialis* Muma	Mesostigmata	Phytoseiidae
				Euseius sp.	Mesostigmata	Phytoseiidae
				Typhlodromips sp.	Mesostigmata	Phytoseiidae
				Tydeus sp.	Prostigmata	Tydeidae
				Agistemus sp.	Prostigmata	Stigmaeidae
				Cunaxa sp.	Prostigmata	Cunaxidae
				Bdella sp.	Prostigmata	Bdellidae

4.1.2. Identification of Mites

The mites were identified upto genus /species level by using appropriate literature. The mites collected in the study belonged to two sub orders namely Prostigmata and Mesostigmata. A dichotomous key for the identification of mite genera collected during the study was prepared and presented here.

4.1.2.1. Key to the genera of mites associated with vegetables in Thrissur district

1. Stigmata opening at or between the bases of the chelicerae, at the base of the gnathosoma or in the anterior propodosomal shoulders (Plate 6); coxa fused to body wall; tritosternum absent ………. Sub order **Prostigmata** …………2

— Stgmata present between coxae III and IV laterally (Plate7); coxa free; tritosternum usually present (Plate 7a.) …. Suborder **Mesostigmata** ……. 9

2. Gnathosoma circular in outline, palpi lying closely appressed together; chelicerae tiny, stylet-like …………………………... family **Tarsonemidae;** empodia of tarsus II – III a broad membraneous pad; leg IV of male with a terminal claw, leg IV of female with two terminal whip-like setae (Plate 8) ……..
…………………………………………………..….. ***Polyphagotarsonemus***

— Gnathosoma variously shaped; palpi well developed, not lying closely appressed together; chelicerae distinct …………………………...………………...…… 3

3. Pedipalp with a distinct thumb-claw process …………………………….…….. 4
Pedipalp without a thumb claw process or thumb-claw process indistinct ………...………………………………………………………………………….. 6
4. Chelicerae long, recurved and whip-like and arising from a stylophore; genital aperture transverse ………….. family **Tetranychidae** …………….… 5

— Chelicerae short and needle - like, not arising from a stylophore; genital aperture longitudinal …………………………………... family **Stigmaeidae**; idiosoma broadly oval; propodosoaml plate with three pairs of setae; dorsal median plate carries five pairs of setae (Plate 9) ……………………………… ***Agistemus***

5. Tarsus I dorsally with two pairs of closely associated duplex setae and tarsus II with one pair of duplex setae; empodium splits distally into three pairs; dorsal setae simple (Plate 10) …………..………..…………….. ***Tetranychus***

— Tarsus I with single pair of closely associated duplex seta and tarsus II without duplex setae; empodium claw-like; dorsal setae sub-spatulate (Plate 11) …………………………...……...……………….……… ***Eutetranychus***

6. Chelicera whip-like and long, arising from an eversible stylophore; tarsal claws with tenent hairs …….…………………….…… family **Tenuipalpidae**; propodosoma without reticulations on the dorsomedian region; hysterosoma without dorso sublateral setae (Plate 12)…………………….... ***Brevipalpus***

— Chelicerae short and needle or scissors-like, not arising from stylophore; tarsal claws without tenent hairs ………………………………………… 7

7. Gnathosoma normal; cheliceral bases fused; chelicerae needle-like; propodosoma with one pair of sensory setae …………..….. family **Tydeidae**; transverse striation between second pair of hysterosomal dorsocental setae; genu II with two setae; tarsus I with one solenidion and eight setae; femur II and IV with one setae; femur I with three setae (Plate 13)……………………………………………………………...… ***Tydeus***

— Gnathosoma produced into a long snout anteriorly; chelicerae scissors-like, cheliceral bases not fused; propodosoma with two pairs of long sensory setae ……………………...…………………………………………………….. 8

8. Palpi long and turned inwards; distal segment of palpi raptorial; genital suckers two pairs (Plate 14) …… family **Cunaxidae** …..………..... ***Cunaxa***

— Palp long and elbowed with distal setae; distal segment of palpi not raptorial; genital suckers three pairs (Plate 15) …..…family **Bdellidae**...……… ***Bdella***

9. Seta z3 and s6 absent, with 4 pairs of prolateral setae ……………………….. ……………………………………. subfamily **Amblyseiinae** ……..…... 10

— Seta z3 and s6 present, with 6 pairs of prolateral setae …………………….…………….…………..…...… subfamily **Phytoseiinae**; seta Z1, S2, S3 and S4 absent; genu II with 7 setae; genu III with 6 setae; r3 present on dorsal shield ……………………….……………..…. ***Phytoseius***

Sternal shield with median posterior projection; forward migration of preanal setae JV2 and ZV2 (Plate 16 b); preanal setae in males arranged in a tangential row(Plate 16c); peritreme not extending beyond j3; deutosternal groove wider, more than 5µ wide………...……………………..… ***Euseius***

— Sternal shield without median posterior projection; preanal setae JV2 and ZV2 normally placed; preanal setae in males arranged in a triangular pattern; peritreme extending beyond j3; deutosternal groove narrow, less than 5 µ wide ……………………...………………………………………………...… 11

10. Seta S4 absent; dorsal setae thickened and strongly serrated; female ventrianal shield long and narrow; distinct notch in lateral margin of dorsal shield at level of seta s4 (Plate 17)…………………………. ***Paraphytoseius***

— 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…………………………………………………… 12

11. Seta s4:Z1 > 3.0:1.0; setae s4, Z4 and Z5 markedly longer than other setae; seta J2 present/absent; leg IV with three macrosetae (Plate 18) ……………. ***Amblyseius***

—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 ……………..………..… 13

12. 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 19) …... ***Neoseiulus***

— 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 ……………………………………………………………….…………14

13. 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 20) …..……………..… ***Scapulaseius***

— 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 21) …..……………..……………………………... ***Typhlodromips***

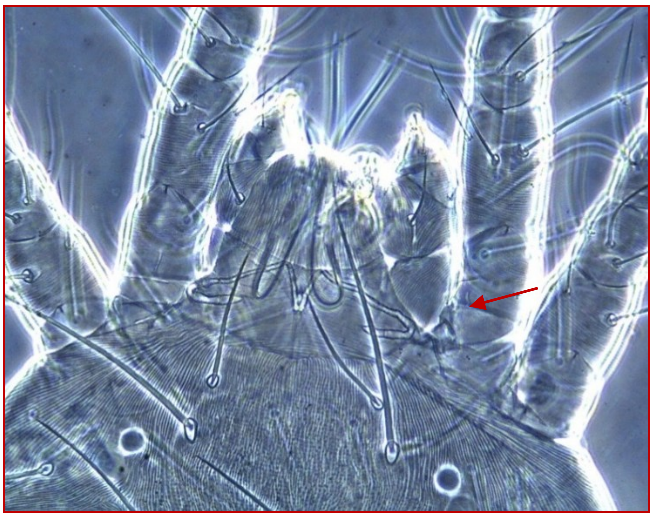

Plate 6. Peritreme in Prostigmata (40X)

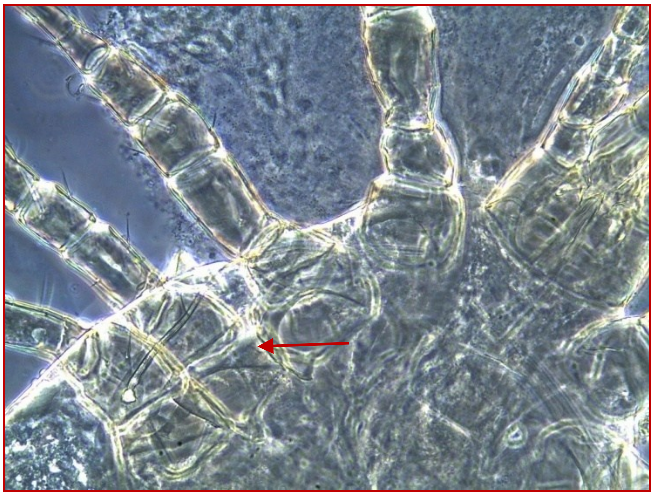

Plate 7. Peritreme in Mesostigmata (40X)

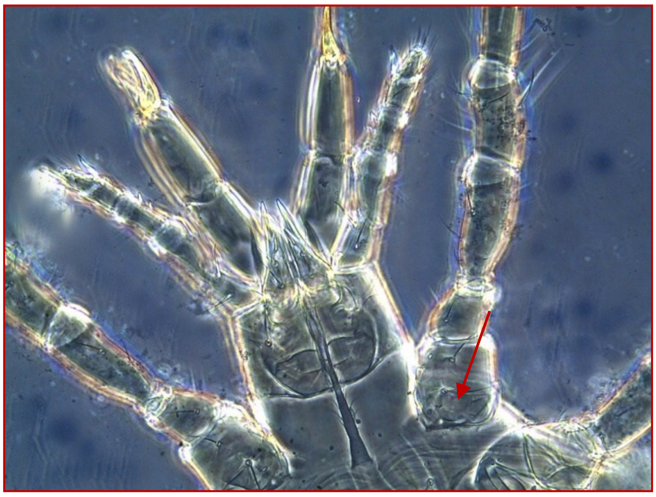

Plate 7a. Tritosternum (40X)

Plate 8. ***Polyphagotarsonemus latus***

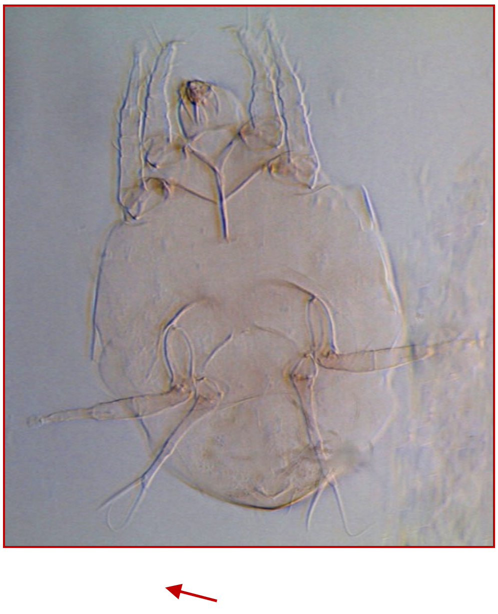

Plate 8a. whip-like seta on leg IV in female (40X)

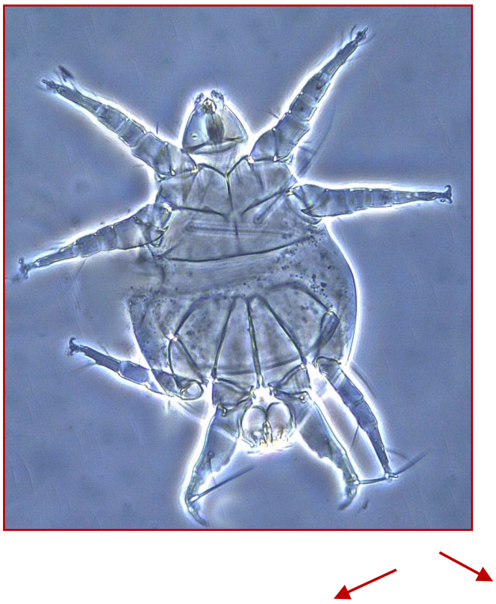

Plate 8b. Terminal claw on leg IV in male (40X)

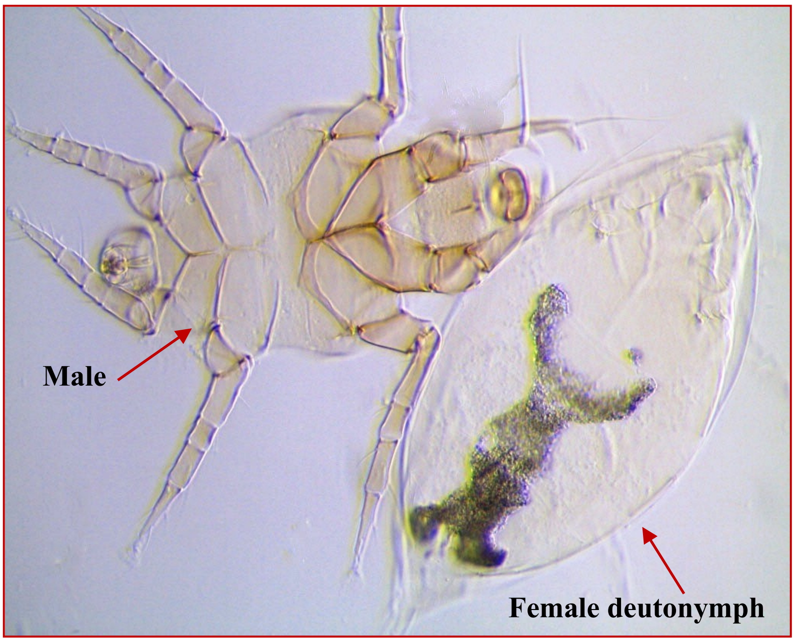

Plate 8c. Male carrying female deutonymph (40 X)

Plate 9. *Agistemus gamblei*

Plate 9a. *Agistemus gamblei* (10X)

Plate 9b. Needle like chelicerae (40X)

Plate 9c. Thumb-claw process (40X)

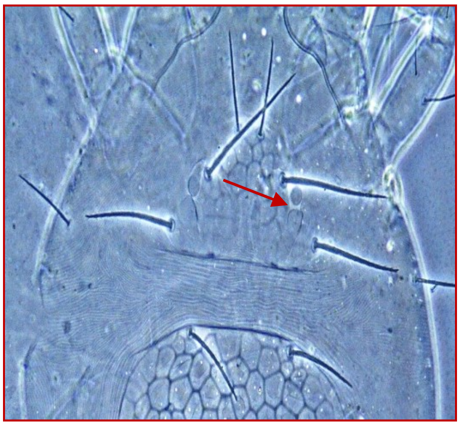

Plate 9d. Propodosomal shield (40X)

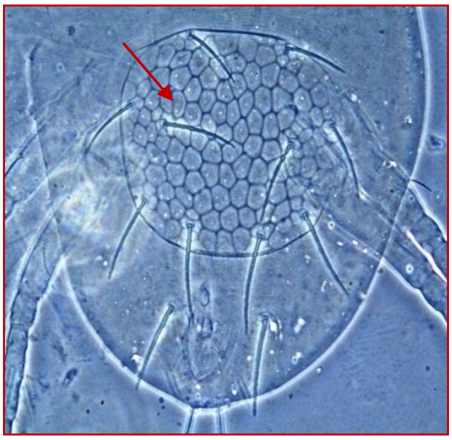

Plate 9e. Female hysterosomal shield (40 X)

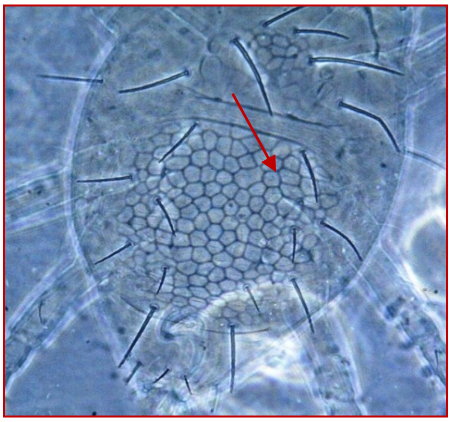

Plate 9f. Male hysterosomal shield (40 X)

Plate 10.*Tetranychus urticae*

Plate 10a. *Tetarnychus urticae*

Female (10 X)

Plate 10b. Male (10X)

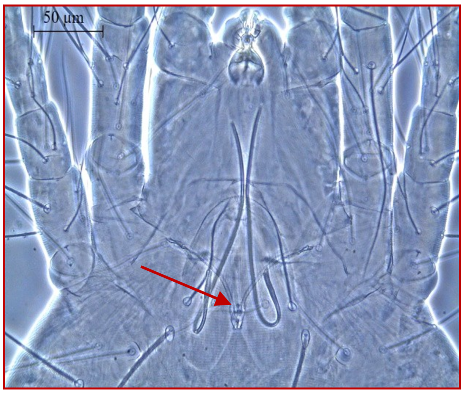

Plate 10c. Whip – like chelicerae (40X)

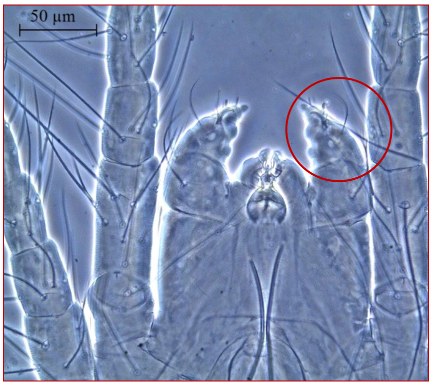

Plate 10d. Thumb-claw process (40X)

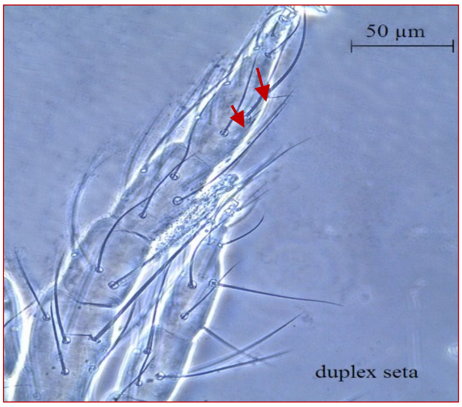

Plate 10e. Duplex seta on leg I (40X)

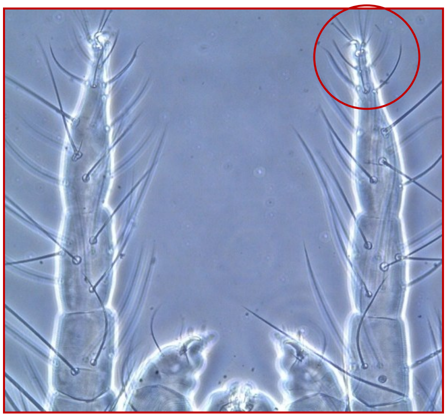

Plate 10f. Empodium (40X)

Plate 11. *Eutetranychus* sp.

Plate 11a. *Eutetranychus* Female (10 X)

Plate 11b. Stylet – like chelicerae (40X)

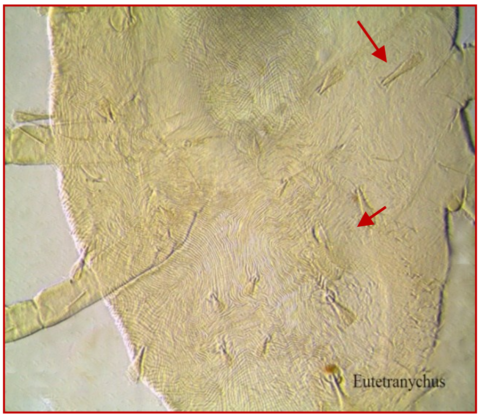

Plate 11c. Dorsal seta on idiosoma (40X)

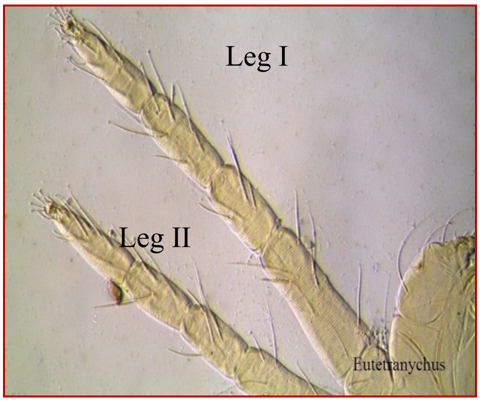

Plate 11d. Legs I and II (40X)

Plate 12. ***Brevipalpus phoenicis***

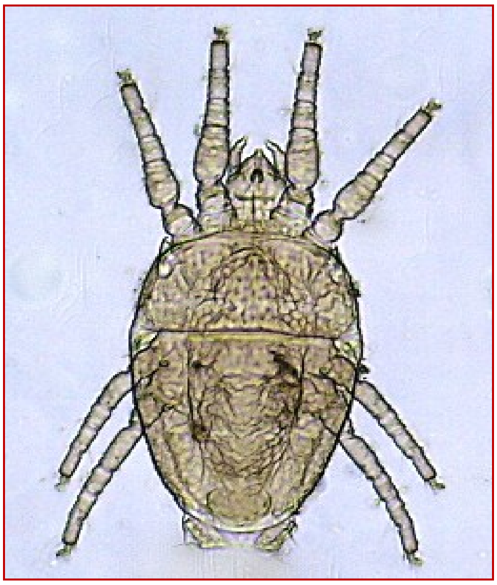

Plate 12a. ***Brevipalpus phoenicis*** **(10 X)**

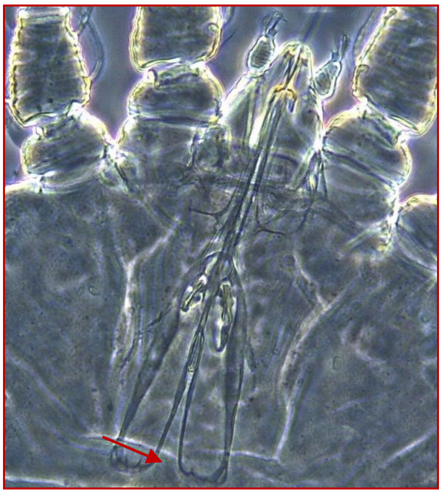

Plate 12b. Stylophore (40 X)

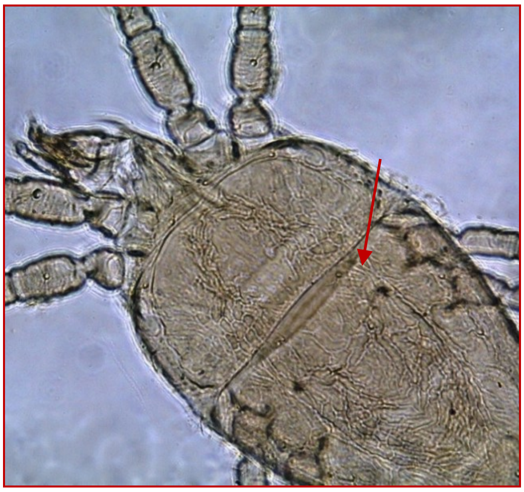

Plate 12c. Propodosoma (40 X)

Plate 13a. ***Tydeus*** **sp. (10X)**

Plate 13b. ***Tydeu*****s sp. – dorsum of adult mite (40X)**

Plate 14. ***Cunaxa*** **sp. (10X)**

Plate 14a. ***Cunaxa*** **sp. (10X) After drying**

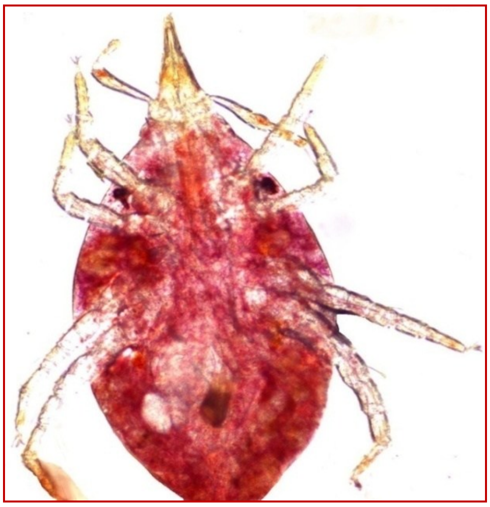

Plate 15. ***Bdella*** **sp. (10X)**

Plate 15a. Gnathosoma (40X)

Plate 15b. Palp elbowed with distal seta (40X)

Plate 16. *Euseius* sp. (10X)

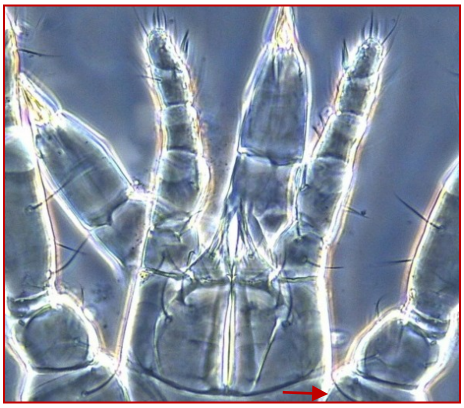

Plate 16a. Deutosternal groove (40X)

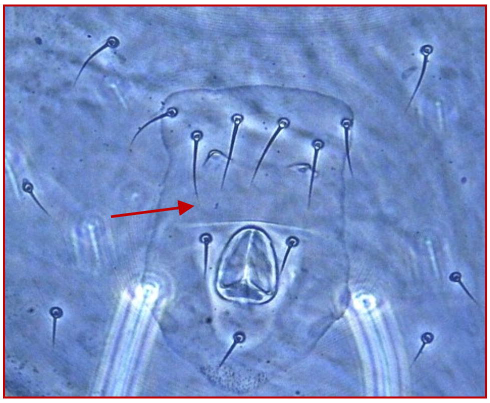

Plate 16b. Female ventrianal shield (40X)

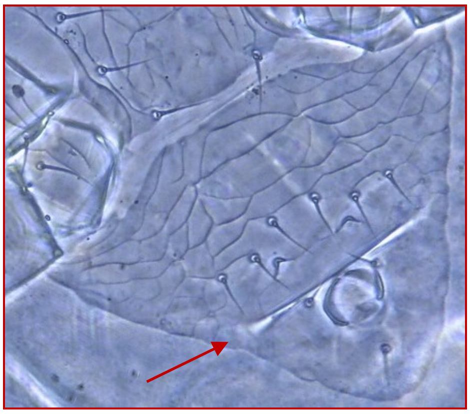

Plate 16c. Male ventrianal shield (40X)

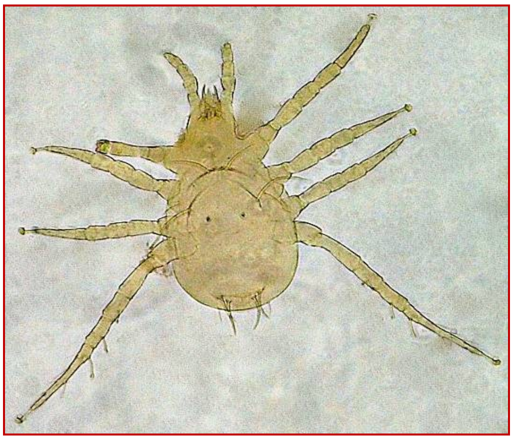

Plate 17. *Paraphytoseius* sp. (10X)

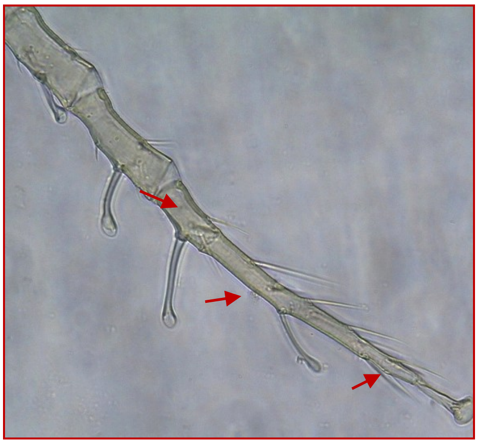

Plate 17a. Leg IV showing macrosetae (40X)

Plate 18. *Amblyseius* sp.

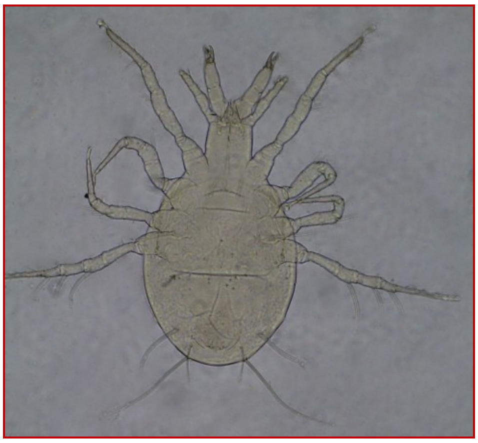

Plate 18a. *Amblyseius* sp. (10X)

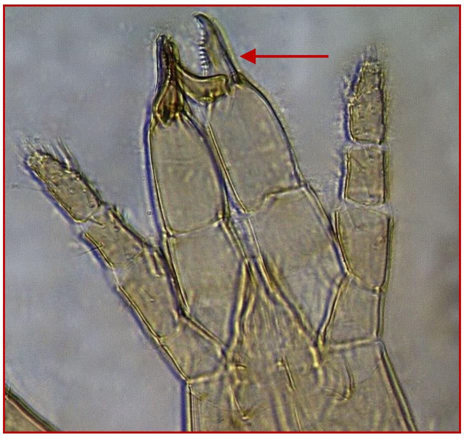

Plate 18b. Female chelicerae (40X)

Plate 18c. Spermadactyl (40X)

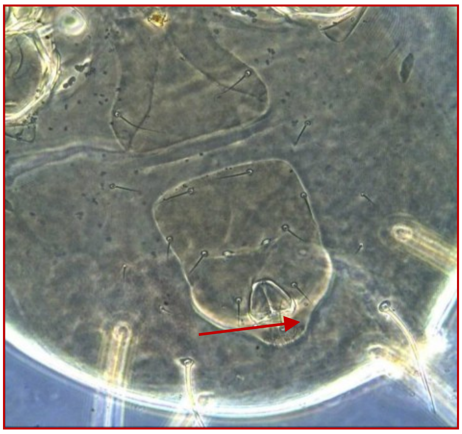

Plate 18d. Female ventrianal shield (40X)

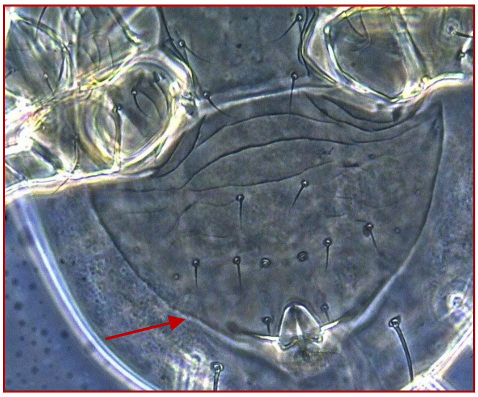

Plate 18e. Male ventrianal shield (40X)

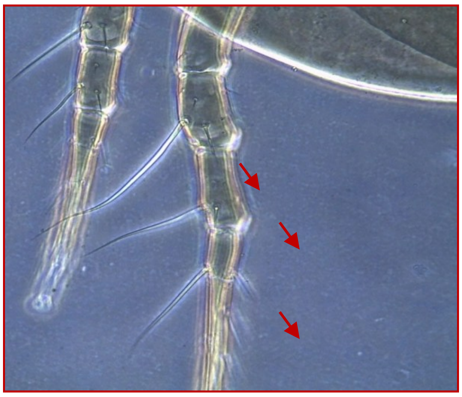

Plate 18f. Legs with macrosetae (40X)

Plate 19. ***Neoseiulus longispinosus*** **(10X)**

Plate 19a. ***N. longispinosus*** **(10X)**

Plate 19b. Spermadactyl (40X)

Plate 19c. Leg IV (40X)

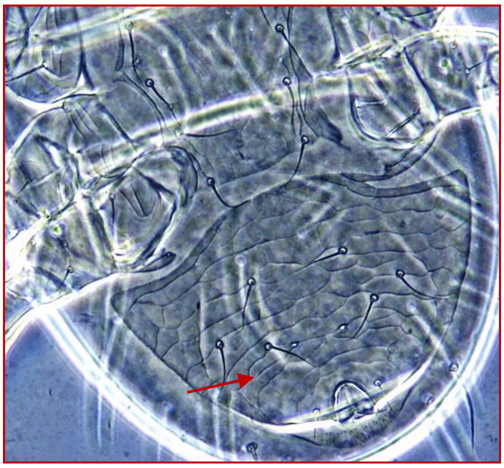

Plate 19d. Female ventrianal shield (40X)

Plate 19e. Male ventri anal shield (40 X)

Plate 20. *Scapulaseius* sp.

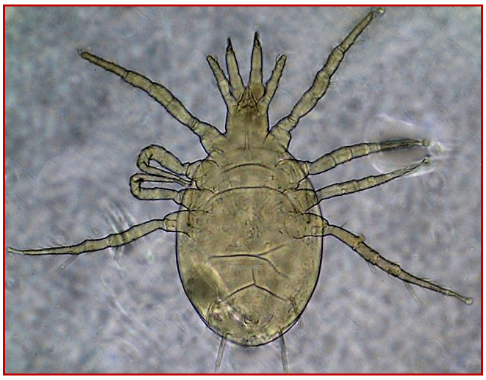

Plate 20a. *Scapulaseius* (10X)

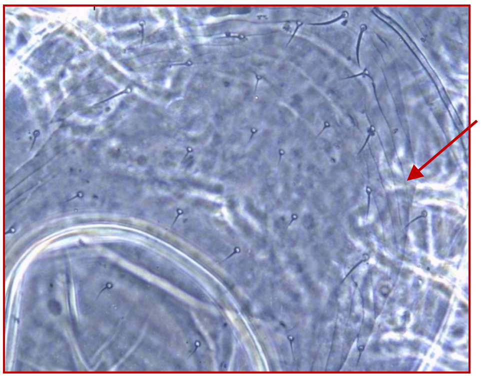

Plate 20b. Dorsal shield (40X)

Plate 20c. Female ventrianal shield (40X)

Plate 21. *Typhlodromips* sp. (10X)

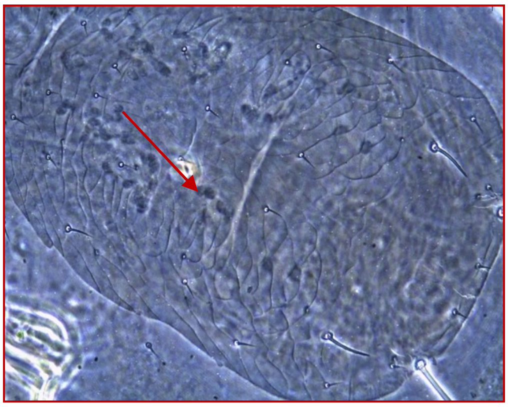

Plate 21a. Dorsal shield with scale like markings (40X)

Plate 21. ***Typhlodromips*** **sp. Contd…**

Plate 21c. Female chelicerae (40X)

Plate 21d. Spermadactyl (40X)

Plate 21e. Female ventrianal shield

4.2. DIVERSITY INDICES OF MITES IN DIFFERENT VEGETABLE CROPS

The diversity, richness and dominance of mites in different crop ecosystems were measured by means of various indices *viz*., Simpson-Yule Diversity index (D), Shannon-Weaver Diversity index (H), Evenness index (E) and Berger-Parker dominance index (d) and are given in Table 2.

The genus richness (S) was found to be highest in brinjal with a value of 10 which is followed by chilli with a value of 8, amaranthus (7), cowpea (6), bhindi (5) and the least value of 3 was observed in bitter gourd. The value of Simpson-Yule diversity index ranged from 1.96 to 2.92. The maximum value of Simpson-Yule diversity index was 2.92 in brinjal and the least value of 1.96 was found in bitter gourd while in cowpea it was 2.45, bhindi (2.18), chilli (2.3) and amaranthus (2.24).

The Shannon – Weaver Diversity index (H) was highest for brinjal (2.09) followed by amaranthus (1.68), 1.28 in cowpea, 1.25 in chilli,1.03 in bhindi and the least value of H was found to be in bitter gourd with a value of 0.85. The highest evenness index (E) value of 0.91 in brinjal was followed by amaranthus with a value of 0.86, chilli (0.77), cowpea (0.72), bhindi (0.64) and the least value of 0.60 was found in bitter gourd. The Berger – Parker dominance index (d) for the most dominant genus in the respective ecosystem was found to be 0.68 in brinjal, 0.57 in bhindi, 0.45 in cowpea, 0.64 in chilli , 0.61 in amaranthus and 0.51 in bitter gourd.

Table 2. Diversity indices of mite fauna in different vegetable crop ecosystems

Diversity indices	Range	Index values in vegetable crop ecosystems					
		Brinjal	Bhindi	Cowpea	Chilli	Bitter gourd	Amaranthus
Genus richness (S)	0 - ∞	10	5	6	8	3	7
Simpson – Yule diversity index (D)	1- S	2.92	2.18	2.45	2.30	1.96	2.24
Shannon – Weaver diversity index (H)	0 - ln* S	2.09	1.03	1.28	1.25	0.85	1.68
Evenness index(E)	0-1	0.91	0.64	0.72	0.60	0.77	0.86
Berger – Parker Dominance index** (d)	0-1	0.68	0.57	0.45	0.64	0.51	0.61

* ln is natural logarithm

**For the most dominant genus in the respective system

4.3. POPULATION DYNAMICS OF PHYTOPHAGOUS MITES AND THEIR NATURAL ENEMIES

The incidence of major phytophagous and predatory mite fauna associated with six vegetable crops at Vellanikkara was observed during February, 2011- January, 2012. The population of phytophagous mites was found to be highest during peak summer months of February to May and almost all the mites were washed off by heavy rains during monsoon season. The results on the population dynamics of mite pests in each vegetable crop are given below.

4.3.1. Spatial and temporal dynamics of mite population

4.3.1.1 *Brinjal*

The incidence of mite pests and predatory mites in brinjal was observed from first fortnight of February, 2011 to January, 2012. The crop initially recorded an average mite population of 1.48 per cm^2 leaf area which started increasing and reached a level of 2.47 per cm^2 leaf area in the second fortnight (Table 3). The population reached the highest level during first fortnight of April followed by a slight reduction in population in the second fortnight of April. A sharp decline in mite population was observed from June onwards and the population was nil till September first fortnight. Thereafter the population again started increasing and a fluctuating population was observed from October to January. Predatory mite population was generally found to be very low which ranged from 0.1 to 1.2 per leaf.

4.3.1.2. *Bhindi*

Data on the seasonal incidence of phytophagous and predatory mites in bhindi are presented in Table 4. The mite population was found to be increasing from February first fortnight onwards and this trend continued upto May reaching its peak population during second fortnight of March. The population followed a gradual increasing trend recording an average population of 1.52 per cm^2 leaf area in first

Table 3. Incidence of phytophagous and predatory mites on brinjal leaves in Vellanikkara during February 2011to January 2012

Month/ Fortnight	Top leaf			Middle leaf			Bottom leaf			Average
	*E	N+A	P	E	N+A	P	E	N+A	P	(N+A)
February I **2011**	0.93	0.50	0.10	3.13	2.44	0.00	5.00	1.50	0.00	1.48
February II	1.70	1.73	0.10	2.53	3.37	0.10	1.83	2.30	0.00	2.47
March I	0.33	2.87	0.40	1.50	4.86	0.17	0.60	3.66	0.60	3.80
March II	0.47	3.03	0.30	2.27	5.06	0.30	0.50	5.30	0.20	4.46
April I	1.15	3.50	0.00	2.83	6.10	1.20	0.50	5.20	0.10	4.93
April II	0.17	3.23	0.10	0.45	5.60	0.10	0.25	4.70	0.10	4.51
May I	1.57	3.57	0.60	2.65	5.20	0.70	1.53	4.67	0.10	4.48
May II	0.66	3.70	0.40	1.70	3.80	0.40	1.53	5.24	0.10	4.25
June I	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
June II	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
July I	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
July II	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
August I	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
August II	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
September I	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
September II	0.20	0.60	0.00	0.60	0.36	0.00	0.30	1.03	0.00	0.99
October I	0.73	0.90	0.10	0.43	1.70	0.10	0.90	1.30	0.40	1.30
October II	0.27	2.87	0.30	0.00	2.36	0.40	0.30	2.93	0.60	0.72
November I	0.20	2.53	0.20	0.33	1.05	0.80	0.00	0.00	0.80	1.19
November II	1.40	2.03	0.10	1.33	1.13	0.10	0.00	1.20	0.00	1.45
December I	0.90	2.33	0.20	2.40	1.46	0.60	1.80	2.63	0.20	2.14
December II	1.20	2.46	0.10	2.60	1.73	0.10	1.20	2.70	0.00	2.29
January I **2012**	1.50	2.53	0.10	2.70	2.73	0.10	0.47	1.67	0.40	2.38
January II	1.30	2.86	0.10	2.90	2.80	0.20	1.40	2.27	0.00	2.64

*E: mean number of eggs per cm^2 leaf area, P: mean number of predatory mites per leaf

N + A: mean number of active stages (nymph +adult) per cm^2 leaf area

Table 4. Incidence of phytophagous and predatory mites on bhindi leaves in Vellanikkara during February 2011to January 2012

Month/ Fortnight	Top leaf			Middle leaf			Bottom leaf			Average (N+A)
	*E	N+A	P	E	N+A	P	E	N+A	P	
February I **2011**	0.50	1.50	0.20	0.20	2.20	0.33	0.20	0.87	0.33	1.52
February II	0.60	0.96	0.13	0.70	3.40	0.50	0.20	2.84	0.60	2.40
March I	2.70	3.10	0.40	3.50	3.60	0.50	1.70	3.40	0.60	3.37
March II	3.05	4.40	0.60	2.80	4.60	0.80	2.40	3.30	0.40	3.43
April I	2.50	2.40	0.50	2.60	4.80	0.70	1.50	2.70	0.60	3.30
April II	0.70	2.50	0.20	1.50	3.10	0.20	2.10	3.67	0.40	3.09
May I	1.20	2.50	0.13	0.60	2.80	1.10	0.70	3.60	0.40	2.97
May II	1.60	3.10	0.70	1.13	4.70	0.90	0.90	3.60	0.70	3.13
June I	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
June II	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
July I	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
July II	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
August I	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
August II	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
September I	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
September II	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
October I	0.80	0.10	0.10	1.90	1.04	0.20	1.20	0.56	0.20	0.57
October II	0.43	0.54	0.70	0.90	0.30	0.10	0.90	0.67	0.00	0.50
November I	1.90	0.80	0.10	0.00	0.80	0.00	1.01	0.90	0.00	0.83
November II	1.10	2.10	0.40	0.70	1.10	0.40	1.70	1.10	0.40	1.43
December I	1.50	1.50	0.10	1.30	2.30	0.40	1.90	1.10	0.40	1.63
December II	1.40	2.00	0.10	1.70	1.90	0.60	1.50	1.70	0.00	1.87
January I **2012**	1.23	2.13	0.30	2.30	2.17	0.80	1.20	1.63	0.50	1.98
January II	1.50	3.20	0.40	2.70	2.40	0.70	2.30	3.60	0.70	1.93

*E: mean number of eggs per cm^2 leaf area, P: mean number of predatory mites per leaf

N + A: mean number of active stages (nymph +adult) per cm^2 leaf area

fortnight of February to 3.13 per cm^2 leaf area in second fortnight of May. The mite population was zero during June to September. After this, the population again started building up reaching a second peak incidence during December to January recording an average population of 1.6 to 1.9 per cm^2 leaf area. The predatory mite population was generally low with an average population of 0.3 to 0.5 per leaf.

4.3.1.3. *Amaranthus*

The incidence of phytophagous and predatory mites in amaranthus is presented in Table 5. During first fortnight of February, 2011 the initial population of mite was at a higher level with an average of 3.94 per cm^2 leaf area. The population of mite reached its peak incidence during second fortnight of March recording an average population of 4.6 per cm^2 leaf area. The mite population then declined steadily and became nil during June to September. Again the population started building up from October first fortnight onwards with an average population of 0.70 per cm^2 leaf area and reached second peak incidence level of 3.1 per cm^2 leaf area during January second fortnight. The predatory mite population was at a lower level throughout the period with an average population of 0.3 to 0.7 per leaf.

4.3.1.4. *Cowpea*

As compared to brinjal, bhindi and amaranthus, cowpea recorded high population of phytophagous mites throughout the period except the rainy season and reached peak levels of incidence during first and second fortnight of February,2011 with an average population of 6.11 and 5.10 per cm^2 leaf area (Table 6). Thereafter, slight reduction in population was noticed and it almost reached zero population level during June to September. The mite population again started increasing from October onwards and reached second peak incidence during second fortnight of January (3.33per cm^2 leaf area). The predatory mite population level ranges from 0.3 to 0.5 per leaf.

Table 5. Incidence of phytophagous and predatory mites on amaranthus leaves in Vellanikkara during February 2011to January 2012

Month/ Fortnight	Top leaf			Middle leaf			Bottom leaf			Average (N+A)
	*E	N+A	P	E	N+A	P	E	N+A	P	
February I **2011**	3.77	2.23	0.10	3.13	4.73	0.00	5.00	4.86	0.00	3.94
February II	4.56	4.70	0.10	2.53	3.49	0.10	1.83	4.26	0.00	4.15
March I	3.90	5.85	0.60	2.65	4.15	0.70	1.53	2.90	0.10	4.30
March II	1.33	3.80	0.40	0.66	4.60	0.40	1.53	5.40	0.10	4.60
April I	0.90	3.60	0.00	1.15	4.35	1.20	0.50	3.30	0.10	3.75
April II	0.20	3.20	0.10	0.45	3.85	0.10	0.25	2.80	0.10	3.28
May I	0.50	2.37	0.40	0.60	3.64	0.17	0.33	1.17	0.60	3.39
May II	0.80	2.90	0.30	0.50	3.90	0.30	0.47	2.90	0.20	3.23
June I	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
June II	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
July I	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
July II	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
August I	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
August II	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
September I	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
September II	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
October I	1.30	1.60	0.10	2.50	3.50	0.10	0.00	0.00	0.00	0.70
October II	0.00	0.00	0.00	0.20	1.53	0.10	0.20	1.20	0.00	0.91
November I	1.01	0.80	0.00	1.60	2.13	0.10	1.01	1.30	0.00	1.41
November II	1.25	1.77	0.10	6.5	3.23	0.40	0.80	1.90	0.10	2.30
December I	0.10	2.50	0.00	1.33	3.00	0.10	0.50	2.90	0.60	2.80
December II	0.30	2.90	0.40	0.90	4.07	0.00	0.70	2.70	0.00	2.87
January I **2012**	0.70	3.20	0.20	1.70	3.20	0.40	1.33	2.40	0.10	2.93
January II	1.30	3.10	0.40	0.80	3.44	1.20	1.67	3.67	0.40	3.10

*E: mean number of eggs per cm^2 leaf area, P: mean number of predatory mites per leaf

N + A: mean number of active stages (nymph + adult) per cm^2 leaf area

Table 6. Incidence of phytophagous and predatory mites on cowpea leaves in Vellanikkara during February 2011to January 2012

Month/ Fortnight	Top leaf			Middle leaf			Bottom leaf			Average
	*E	N+A	P	E	N+A	P	E	N+A	P	(N+A)
February I **2011**	0.33	1.86	0.60	1.67	4.20	0.13	3.7	12.26	0.17	6.11
February II	0.90	1.23	0.00	1.5	6.01	0.13	2.50	8.07	0.33	5.10
March I	0.57	2.04	0.33	1.73	5.33	0.00	1.43	6.26	0.10	4.22
March II	0.23	0.43	0.06	1.33	4.30	0.00	1.51	6.86	0.00	3.86
April I	0.45	0.08	0.10	0.80	4.36	0.20	1.33	5.76	0.13	3.72
April II	0.28	3.70	0.10	1.20	3.50	0.30	1.27	3.87	0.00	3.69
May I	0.80	1.63	0.06	1.30	3.80	0.33	1.95	5.96	0.00	3.80
May II	0.97	3.57	0.33	0.90	3.70	0.10	1.40	5.90	0.00	3.39
June I	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
June II	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
July I	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
July II	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
August I	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
August II	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
September I	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
September II	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
October I	0.00	0.00	0.00	0.93	1.13	0.00	0.36	1.57	0.70	0.70
October II	0.00	0.00	0.00	0.33	0.79	0.00	0.97	1.17	0.00	0.65
November I	0.00	0.00	0.00	0.46	1.30	0.10	1.10	2.01	0.00	1.10
November II	0.10	1.20	0.60	1.33	1.57	0.40	2.01	2.97	0.00	1.91
December I	0.40	2.10	0.70	1.80	2.65	0.00	0.70	2.73	0.00	2.49
December II	0.76	1.97	1.40	1.90	3.10	0.10	1.50	4.10	0.80	3.06
January I **2012**	1.47	2.73	0.90	1.97	2.80	0.10	1.80	3.90	0.10	3.14
January II	0.70	2.33	1.70	0.97	3.77	0.00	0.93	3.89	0.00	3.33

*E: mean number of eggs per cm^2 leaf area, P: mean number of predatory mites per leaf

N + A: mean number of active stages (nymph +adult) per cm^2 leaf area

4.3.1.5. *Bitter gourd*

Bitter gourd recorded a lower level of mite incidence throughout the period. (Table 7). The highest level of mite population was observed during first fortnight of February recording an average population of 3.30 mites per cm^2 leaf area which is followed by a declining trend from first fortnight of May recording zero level till September. Thereafter the population was generally very low recording a maximum of 1.4 per cm^2 leaf area. A low level of predatory mite population ranging from 0.1 to 0.4 per leaf was observed

4.3.1.6. *Chilli*

The mite *P.latus* occurred on chilli at high level during peak summer months. (Table 8).The peak mite population of 6.86 per leaf was noticed on first fortnight of February. The population became zero during rainy season from June to September. After the rain, the population build up was very slow and a low level of incidence was noticed from October, 2011 to January, 2012. The predatory mite population levels in chilli ranged from 0.1 to 0.5 per leaf.

4.3.2. Vertical distribution of mites within plants

The results on distribution of phytophagous mites in each vegetable crop at three different canopy levels are given in Table 9. Among the three canopy levels, leaves of middle canopy harboured maximum mite density in all crops except cowpea where maximum mite density was observed in bottom canopy leaves. In chilli and bitter gourd the mites preferred only the top leaves and it was completely absent in middle and bottom canopy. The results of statistical analysis shows that there was significant variation in the population of egg and active stages of mites of top canopy with middle and bottom canopy in brinjal but non-significant variation in population of mites and eggs are obtained between middle and bottom canopy levels. In bhindi

Table 7. Incidence of phytophagous and predatory mites on bitter gourd in Vellanikkara during February 2011 to January 2012 (Mean number per cm^2 leaf area)

Month	Fortnight	Phytophagous mites		Predatory mites /leaf
		Egg	Nymph + Adult	
February, 2011	I	0.60	3.30	0.10
February	II	0.56	3.10	0.10
March	I	0.90	2.80	0.10
March	II	0.53	2.77	0.00
April	I	0.40	2.43	0.20
April	II	0.20	1.40	0.30
May	I	0.00	0.00	0.00
May	II	0.00	0.00	0.00
June	I	0.00	0.00	0.00
June	II	0.00	0.00	0.00
July	I	0.00	0.00	0.00
July	II	0.00	0.00	0.00
August	I	0.00	0.00	0.00
August	II	0.00	0.00	0.00
September	I	0.00	0.00	0.00
September	II	0.00	0.00	0.00
October	I	0.20	0.47	0.10
October	II	0.10	0.60	0.00
November	I	0.00	0.87	0.00
November	II	0.17	0.73	0.20
December	I	0.27	0.77	0.40
December	II	0.60	1.03	0.20
January, 2012	I	0.37	1.43	0.40
January, 2012	II	0.53	1.47	0.30

Table 8. Incidence of phytophagous and predatory mites on chilli in Vellanikkara during February 2011 to January 2012 (Mean number per leaf)

Month	Fortnight	Phytophagous mites		Predatory mites /leaf
		Egg	Nymph + Adult	
February, 2011	I	1.33	6.86	0.20
February	II	0.80	5.90	0.10
March	I	0.83	5.77	0.10
March	II	0.47	3.67	0.00
April	I	0.27	3.35	0.20
April	II	0.67	3.10	0.30
May	I	0.40	3.22	0.40
May	II	0.83	3.30	0.30
June	I	0.00	0.00	0.00
June	II	0.00	0.00	0.00
July	I	0.00	0.00	0.00
July	II	0.00	0.00	0.00
August	I	0.00	0.00	0.00
August	II	0.00	0.00	0.00
September	I	0.00	0.00	0.00
September	II	0.00	0.00	0.00
October	I	0.37	0.40	0.10
October	II	0.40	0.37	0.20
November	I	0.37	0.80	0.10
November	II	0.40	0.93	0.20
December	I	0.47	1.40	0.50
December	II	0.60	1.70	0.50
January, 2012	I	0.67	1.93	0.40
January, 2012	II	0.80	2.04	0.50

Crop	Canopy level	Mean number of mites/cm^2			Canopy level	Calculated t values for comparison	
		Egg	Active stages	Total		Egg	Active stages
Brinjal	Top	0.86	1.43	2.29	Top and middle	3.19**	3.25**
	Middle	1.76	3.04	4.80	Middle and bottom	1.86 NS	0.88 NS
	Bottom	1.06	2.84	3.90	Top and bottom	1.64**	1.34**
Bhindi	Top	1.42	1.05	2.47	Top and middle	0.11 NS	1.24 NS
	Middle	1.53	2.58	4.11	Middle and bottom	0.13 NS	0.92 NS
	Bottom	1.34	2.20	3.54	Top and bottom	0.02 NS	0.25 NS
Amaranthus	Top	0.37	1.87	2.24	Top and middle	1.63*	1.87*
	Middle	1.7	3.56	5.26	Middle and bottom	1.21 NS	1.98 NS
	Bottom	1.11	2.79	3.90	Top and bottom	1.57*	2.11*
Cowpea	Top	0.76	2.19	3.95	Top and middle	4.76**	4.60**
	Middle	1.63	3.97	5.60	Middle and bottom	0.46 NS	2.02 NS
	Bottom	1.78	5.43	7.21	Top and bottom	3.90**	4.95**

no significant difference in the population of eggs and active stages of mites were obtained between the three canopy levels. In amaranthus and cowpea the population levels of different mite stages showed significant variation between top and middle canopy and top and bottom canopy leaves. The population between middle and bottom canopy was non-significant in both cases. The distribution of eggs and active stages of mites in chilli and bitter gourd was restricted to the top canopy leaves only.

4.4. ROLE OF WEATHER FACTORS IN THE POPULATION FLUCTUATION OF MITES

The data pertaining to relationship between mite population and weather parameters is presented in Table 10.The results revealed that the maximum temperature had highly significant positive correlation with mite population in brinjal(r = 0.87), bhindi (r = 0.72), cowpea (r = 0.85), amaranthus (r = 0.87), bitter gourd (r = 0.81) and chilli (r = 0.77), whereas rainfall and evening relative humidity showed highly significant and negative effect on the population of mites in brinjal (r = -0.65 and -0.51), bhindi (r = -0.50 and -0.41), cowpea (r = -0.65 and -0.77), amaranthus (r = -0.66 and -0.69), bitter gourd (r = -0.57 and -0.61) and chilli (r = -0.51 and -0.54). The effect of minimum temperature was found to be non-significant in all case except brinjal and bhindi where it had a positive highly significant correlation with mite population. The factor morning relative humidity showed non-significant effect on mite population in the present study.

Table 10. Correlation coefficient (r) values of mites/cm^2 and weather parameters

Weather parameters	Mean mite population on different crops					
	Brinjal	Bhindi	Cowpea	Amaranthus	Bittergourd	Chilli
Maximum temperature	0.87**	0.72**	0.85**	0.87**	0.81**	0.77**
Minimum temperature	0.55**	0.58**	0.19 NS	0.20 NS	0.34 NS	0.28 NS
Rainfall	-0.65**	-0.50**	-0.65**	-0.66**	-0.57**	-0.51**
Morning relative humidity	-0.25 NS	-0.23 NS	-0.25 NS	-0.25 NS	-0.34 NS	-0.19 NS
Evening relative humidity	-0.51**	-0.41*	-0.77**	-0.69**	-0.61**	-0.54**

* Significant at 5% level

**Significant at1% level

NS: Non-significant

Discussion

5. DISCUSSION

The present study was undertaken to explore the diversity of mites associated with vegetables in Thrissur district, Kerala and also to study the spatial and temporal dynamics of population of mites in vegetables. The observations and the inferences based on the study are discussed below.

5.1. DIVERSITY OF PHYTOPHAGOUS MITES AND THEIR NATURAL ENEMIES ASSOCIATED WITH VEGETABLES

5.1.1. Faunal diversity of phytophagous and predatory mites associated with vegetables

The survey on the diversity of mite fauna in vegetables in Thrissur district revealed a total of 19 species of phytophagous and predatory mites belonging to eight families. The family Tetranychidae, Tenuipalpidae and Tarsonemidae were represented by the genera *Tetranychus, Eutetranychus, Brevipalpus* and *Polyphagotarsonemus.* Spider mites belonging to the genus *Tetranychus* were found to be the dominant phytophagous mite in brinjal, bhindi, amaranthus and cowpea whereas, in chilli and bitter gourd, the tarsonemid mite, *Polyphagotarsonemus latus* (Banks) was the predominant species. These mites were reported as important mite pests of vegetable crops from different parts of India (Gupta, 1991b; Gulati, 2004, Rai and Indrajeet, 2011).

Faunal studies of mites in six vegetable crops revealed highest diversity of mites in brinjal with three phytophagous and seven predatory mites and the least diversity in bitter gourd with one phytophagous and three predatory mites. *Tetranychus urticae* Koch was the predominant phytophagous mite in brinjal and bhindi. Tetranychid mites on amaranthus and cowpea were identified only upto generic level as *Tetranychus*. The tetranychid mites are considered as important pests of vegetables and can result in considerable yield loss (Prasad, 2006). The tarsonemid mite *Polyphagotarsonemus latus* (Banks) was found to be the predominant phytophagous species on chilli and bitter gourd. It was also recorded as minor pests in brinjal and cowpea. Karmakar (1997) reported the broad mite, *P. latus* as one of the most destructive pests and a major contributing agent of the devastating "Murda" complex in chilli. *Brevipalpus phoenicis* (Geij.) was the only tenuipalpid mite observed during the study and it was reported in amaranthus and brinjal. *B. phoenicis* was earlier reported feeding on brinjal from Kerala (Sudharma, 1996). This is the first report of *B. phoenicis* on amaranthus from Kerala.

The predatory mites found associated with vegetables in the present study belonged to five families *viz*., Phytoseiidae, Stigmaeidae, Tydeidae, Cunaxidae and Bdellidae and among which Phytoseiidae predominates. The important phytoseiid predators observed in the survey include *A. paraaerialis*, *P. orientalis, N. longispinosus, Phytoseius* sp., *E. macrospatulatus*, *Typhlodromips* sp. and *Scapulaseius* sp. Several species of phytoseiid mites were reported as effective predators of plant feeding mites all over the world in many diverse crop ecosystems (Abhilash, 2001; Sadanandan and Ramani, 2006 and Karmakar and Gupta, 2010).

Predatory mites belonging to the family Cunaxidae and Bdellidae were found in association with *P.latus* in chilli. Cunaxid mites were widely observed in field whereas only few species of mites of the family Bdellidae were found to feed on phytophagous mites (Gupta, 1989). The cunaxid and bdellid mites were reported to be well known predators of many phytophagous mites and small insects (Smiley, 1992).

The Stigmaeid mites of the genus *Agistemus* was found associated with phytophagous mites on brinjal, bhindi and chilli. The species in brinjal was identified as *A. gamblei.* *Agistemus* spp. has gained a great economic importance as biocontrol agent and play pivotal role in controlling phytophagous mites and soft bodied insects in different vegetables (Khan *et al*., 2008).

The predatory mite, *Tydeus* sp. of the family Tydeidae was found to be associated with *P. latus* in chilli. Tydeid mites were reported to be efficient predators of six spotted spider mites *Eotetranychus sexmaculatus* (Riley) on avocados (Tomkins, 2002).

5.1.2. Identification of mites

The mites were identified upto generic /species level by using appropriate literature by Krantz, 1975; Gupta,1985; Gupta, 2002; Chant and McMurthy, 2006 and Chant and McMurthy, 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 two suborders *viz.,* Prostigmata and Mesostigmata which are classified based on the position of stigmata. The prostigmatid mite families include Tetranychidae, Tenuipalpidae, Tarsonemidae, Stigmaeidae, Tydeidae, Cunaxidae and Bdellidae. The Phytoseiidae is the only Mesostigmatid mite family identified. The predatory mites were identified upto generic level and further taxonomic studies have to be taken to obtain the identity of the mite species.

The members of the family Tetranychidae are provided with distinct palpal thumb-claw process, long, recurved and whip-like chelicerae arising from a stylophore, peritremes confined to the anterior portion of propodosoma and empodium without tenant hairs.

The tarsonemid mites differ in their body shape with circular gnathosoma, and stylet-like chelicerae. Females have two terminal whip-like setae and males with a terminal claw on leg IV.

The key characters for identifying the tenuipalpid mite, *B.phoenicis* are: propodosoma without reticulations on the dorso-median region and dorso-sublaterals absent on the hysterosoma.

Tydeus sp. is characterized by the presence of needle-like stylet, solenidion on Tarsus I. The genus identification is based on the number of setae on genu and femur of legs II, III and IV.

Cunaxa and *Bdella* are characterised by the presence of genital suckers. The cunaxid mites have two pairs of genital suckers and long palpi with distal palpal segments raptorial, where as the bdellid mites have three pairs of genital suckers and palp is elbow-like with a distal setae.

The stigmaeid mite *Agistemus* have distinct palpal thumb-claw process and short and stylet-like chelicerae.

The key character for identifying the predatory mites of the family Phytoseiidae is the chaetotaxy ie. the arrangement of dorsal and ventral setae. Based on the presence or absence of setae z3 and s6, they can be classified into three subfamilies viz., Amblyseiinae, Phytoseiinae and Typhlodrominae. In the present study, phytoseid mites belonging to the subfamilies Amblyseiinae and Phytoseiinae were collected.

5.2. DIVERSITY INDICES OF MITES IN DIFFERENT VEGETABLE CROPS

Based on the comparison of different diversity indices, brinjal exhibited highest genus richness with a value of 10. The value of Simpson-Yule Diversity index (D) was highest for brinjal which indicated that brinjal supported maximum genera of mites. The minimum value of D was in bitter gourd suggesting that it was least favoured for mite diversity. The value of H was found to be highest for brinjal (2.09) indicating the suitability of the host plant to harbor a wide variety of mite fauna. The least value of the Shannon – Weaver Diversity index (H) in bitter gourd showed the less preference of this crop by the mite species. The Shannon – Weaver Diversity index (H) highlighted the influence of environmental stress on the survival of individuals in a given ecosystem .A decrease in the value of this index indicated an increase in the magnitude of environmental stress on the species (Cairns and Dickson, 1971).

The evenness index is a measure of the uniformity of different species in a community and the value increases as the environment becomes favourable for a number of species (Mitra, 2000). The highest evenness index value of 0.91 in brinjal was followed by amaranthus, chilli, cowpea, bhindi and the least value of 0.60 was found in bitter gourd. This shows that brinjal was more favoured for a large number of mite species whereas bitter gourd was least preferred by the mite species. The Berger – Parker dominance index (d) was worked out for the most dominant genus in the respective ecosystem and it was found that *Tetranychus* was the most dominant genus in brinjal, bhindi, cowpea and amaranthus where as *P.latus* was the dominant one in chilli and bitter gourd.

5.3. POPULATION DYNAMICS OF PHYTOPHAGOUS MITES AND THEIR NATURAL ENEMIES

5.3.1. Spatial and temporal dynamics of mite population

The incidence of phytophagous mites in vegetables from Vellanikkara tract during February 2011 to January 2012 is given in Fig.1 to 6. The observations on the population dynamics of mites in vegetables revealed that the population of mite species increased during hot summer months. The highest peak incidence of mite pests was during April to May in all cases. From June to September the population level of mite species was much declined and washed off due to heavy and consistent rainfall. After the cessation of rainfall, the mite pest incidence was found to be increased again and attained their second peak incidence during December to January. High temperature during summer months might have favoured the mite population by increasing the fecundity rate and shortening the duration of life stages. The study on the biology of *Oligonychus coffeae* revealed that the life cycle took shorter time with high fecundity at a temperature 33.2^{0}C and 79.85 per cent RH and longer duration with lowest fecundity at 26^{0}C and 71.6 per cent RH (Saha *et al*., 1999). This trend in population dynamics of mites reaching heavy population during peak summer months and absence of mites in rainy season is in accordance with results of Mishra, *et al*.,1990; Rai *et al*., 1991; Ho and Chen, 1992; Kumar and Sharma, 1993 and Gulati, 2004. The predatory mite population was generally low in all the crops throughout the period of study. Results of many works suggest that the predatory potential of different species of predatory mites is high enough to result in natural control of their prey mites even at low population densities (Reis *et al*., 2003; Sarwar *et al*., 2011).

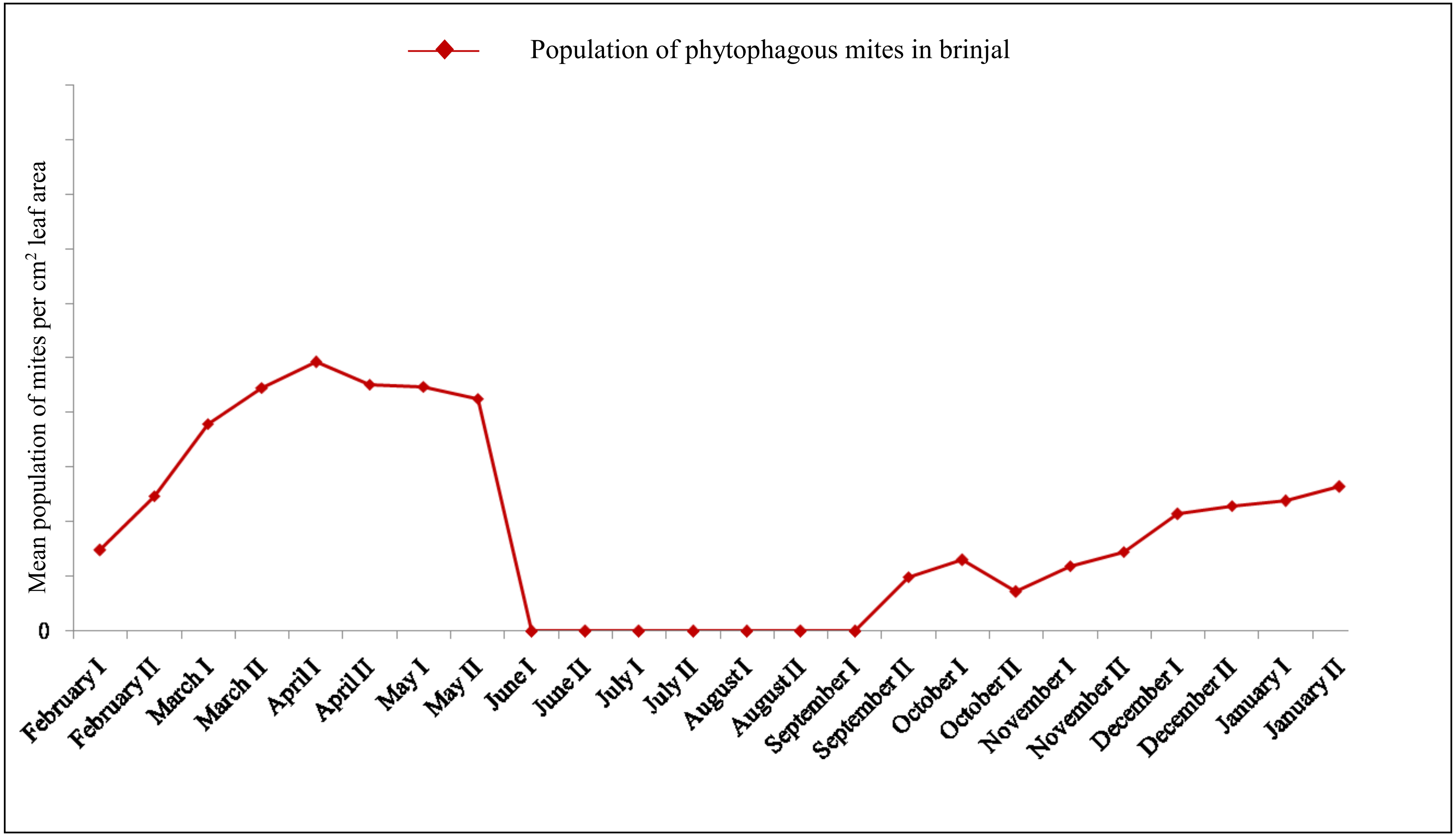

Figure 1. Seasonal incidence of phytophagous mites in brinjal during 2011- 2012 at Vellanikkara

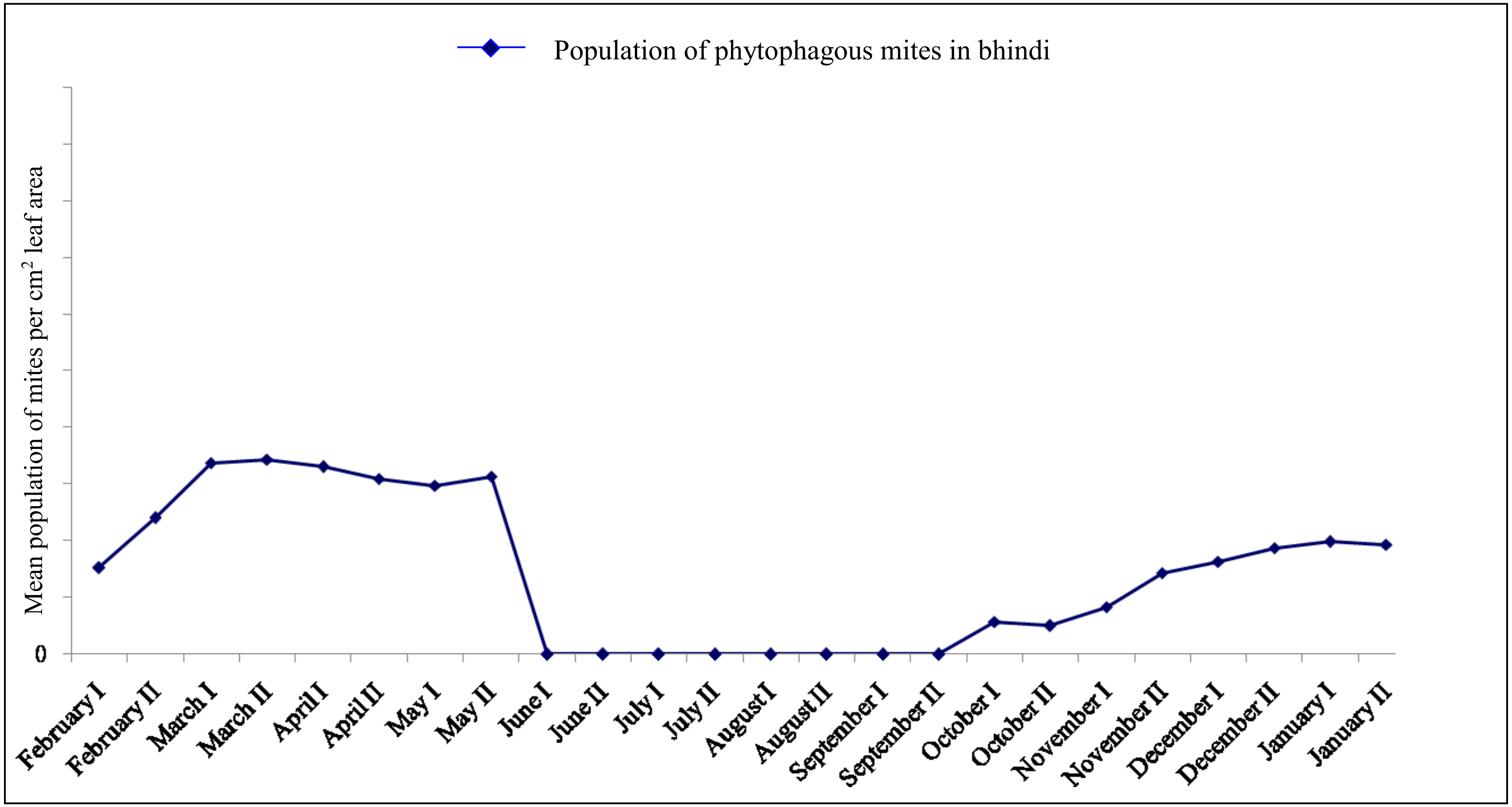

Figure 2. Seasonal incidence of phytophagous mites in bhindi during 2011- 2012 at Vellanikkara

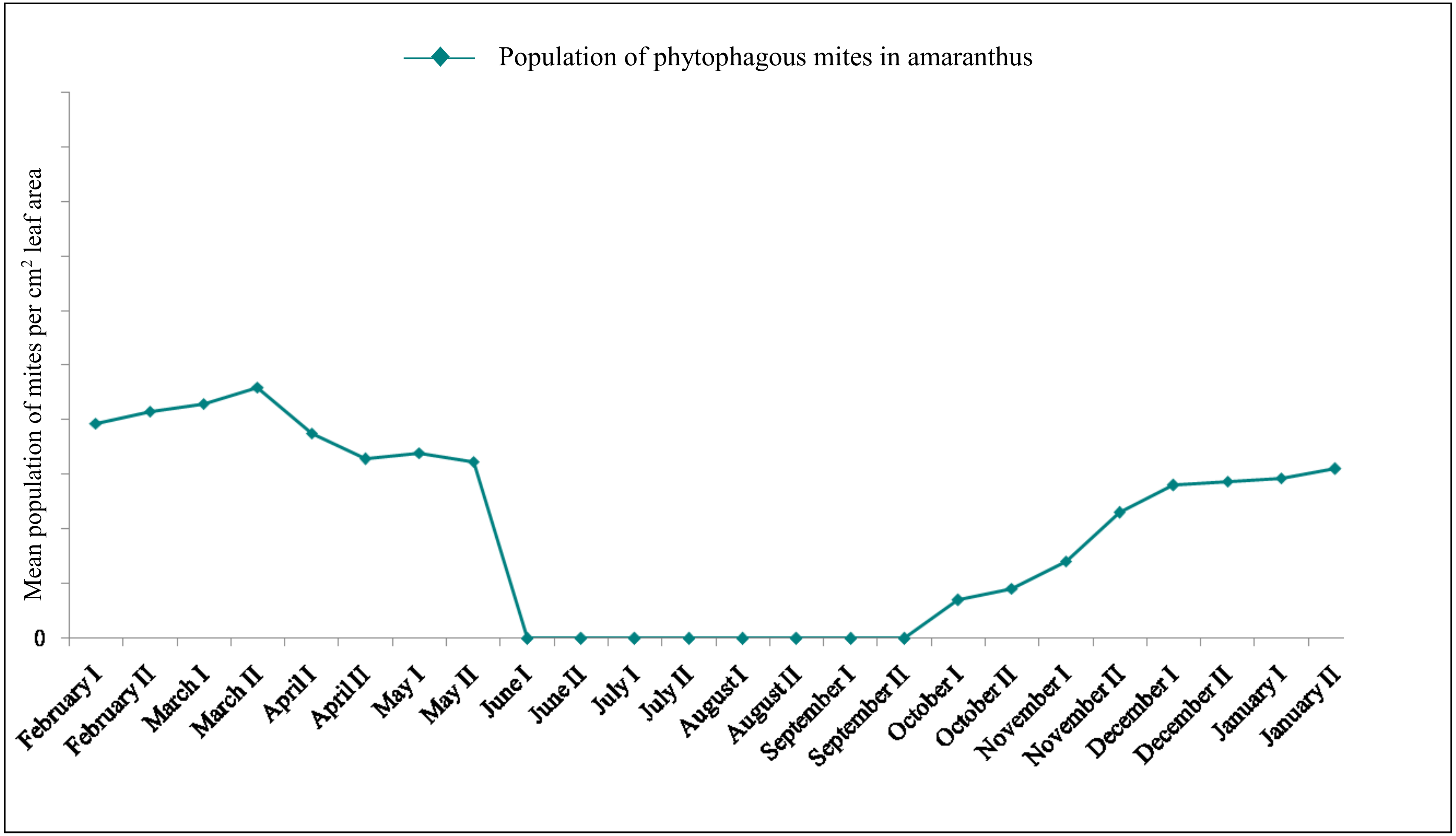

Figure 3. Seasonal incidence of phytophagous mites in amaranthus during 2011- 2012 at Vellanikkara

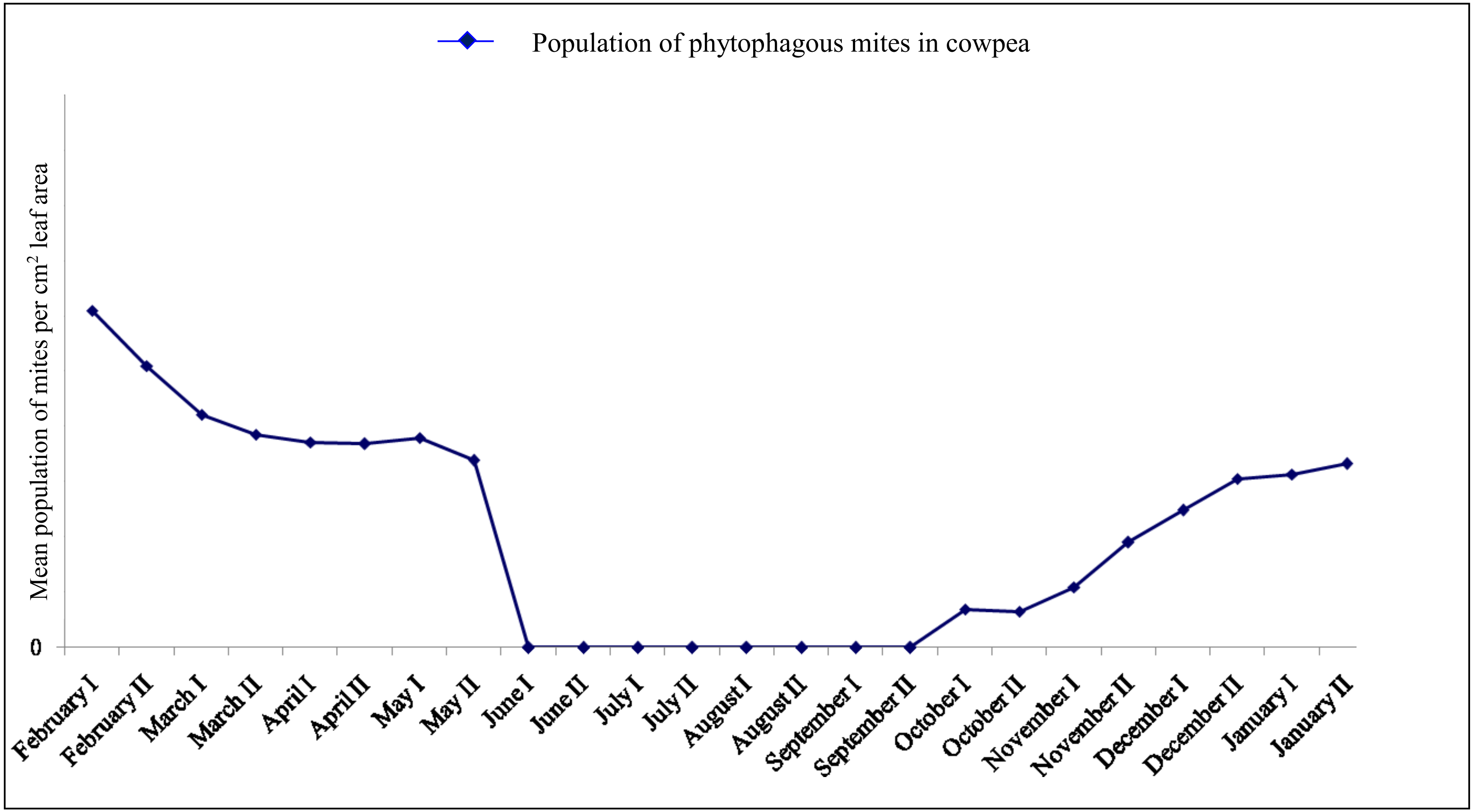

Figure 4. Seasonal incidence of phytophagous mites in cowpea during 2011- 2012 at Vellanikkara

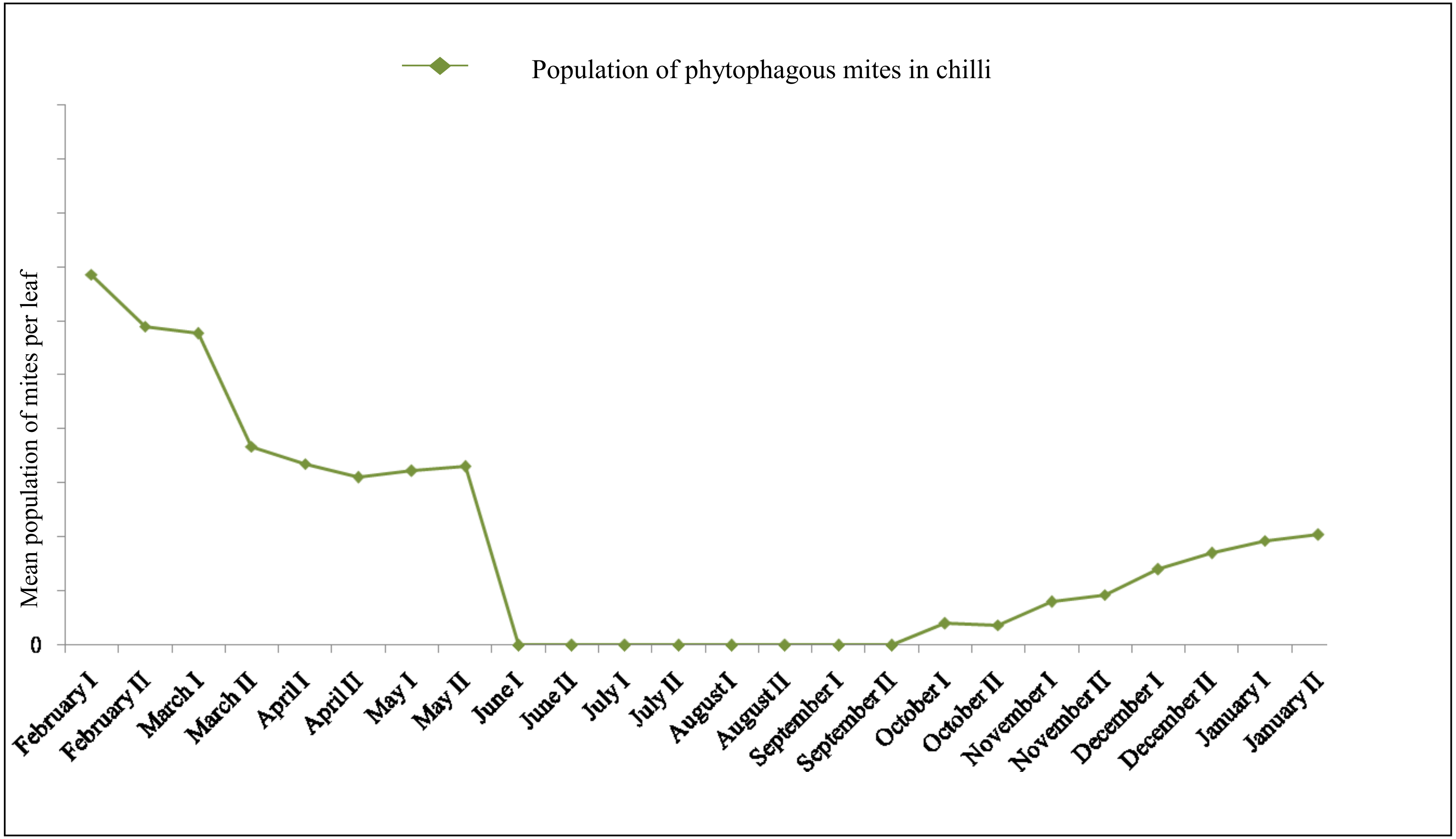

Figure 5. Seasonal incidence of phytophagous mites in chilli during 2011- 2012 at Vellanikkara

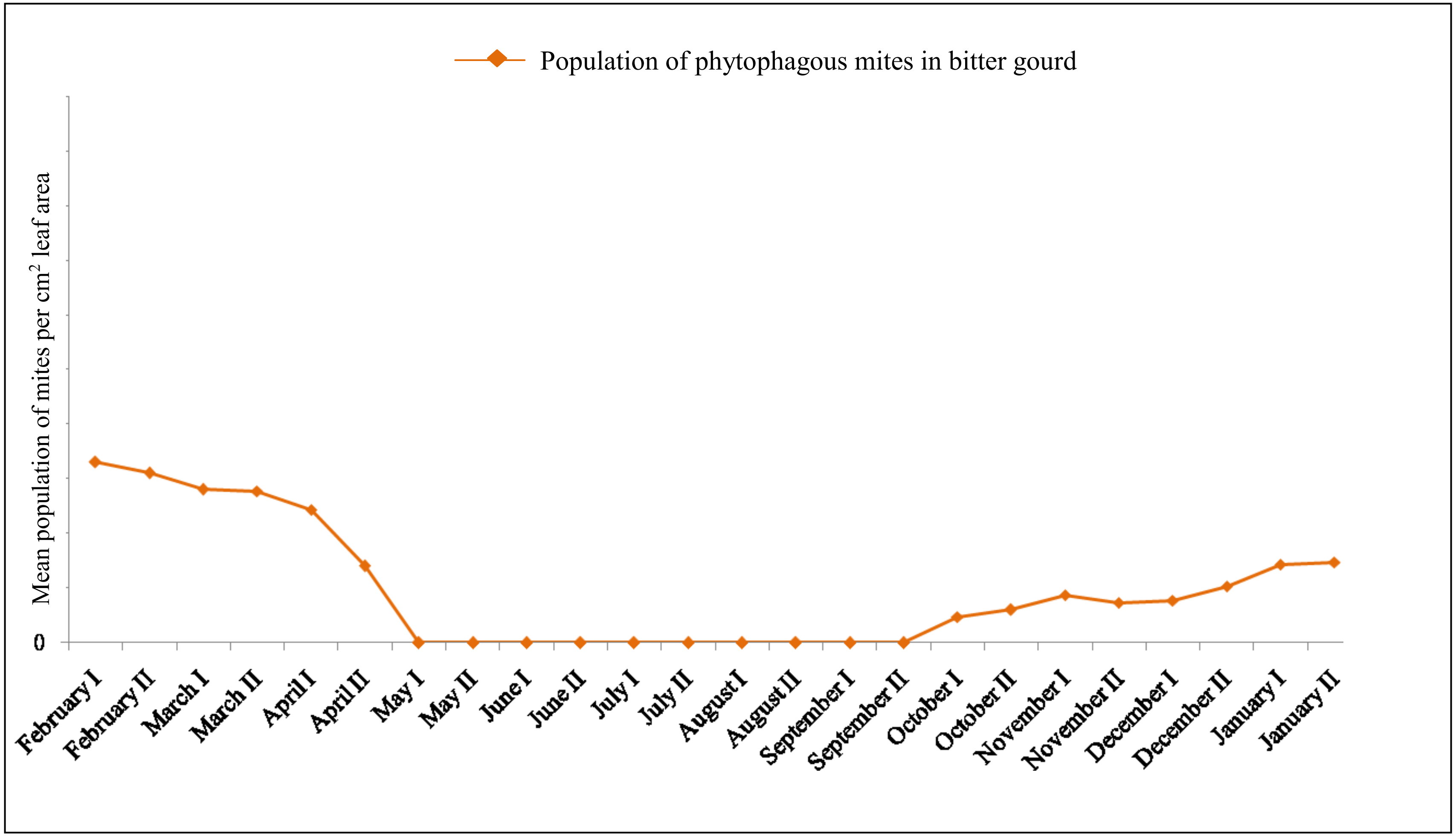

Figure 6. Seasonal incidence of phytophagous mites in bitter gourd during 2011- 2012 at Vellanikkara

5.3.2. Vertical distribution of mites within the plants

The distribution of mites on different crops varies with the canopy level (Fig.7). *Tetranychus* mites preferred leaves of middle canopy in brinjal and amaranthus where as leaves of bottom canopy recorded the maximum mite density in cowpea. The difference in the distribution of mites in different canopy levels may be due to the differences in the availability of nutrients in the leaves. Changes in nutrient concentrations within the canopy of a plant may have a role in feeding site selection and movement on the plant over time. A similar study on the distribution of spider mites on plants found positive correlations between within-plant distribution of mites and the corresponding tissue nitrogen and phosphorous concentrations in three foliage strata, suggesting that tissue nutrient content may influence mite selection of feeding sites (Chen *et al*., 2007). In bhindi, there was no significant difference in the distribution of mites on the three canopy levels. The distribution of *P.latus* in chilli and bitter gourd was restricted to the top canopy alone. This clearly confirms that yellow mites preferred young apical leaves for feeding, shelter and oviposition. These results are in line with the works of Rai *et al*., 1995 and Patil, 2005, who reported that the population of *P. latus* was distributed only on the top leaves of chilli.

5.4. INFLUENCE OF WEATHER FACTORS ON THE MITE POPULATION DYNAMICS

The weather parameters have greater influence on fluctuation of mite population. The results revealed that maximum temperature had highly significant positive correlation with mite population in all host plants, whereas rainfall and evening relative humidity showed highly significant negative effect on the population of mites. The effect of minimum temperature was found to be non-significant in all cases except brinjal and bhindi where it had a highly significant

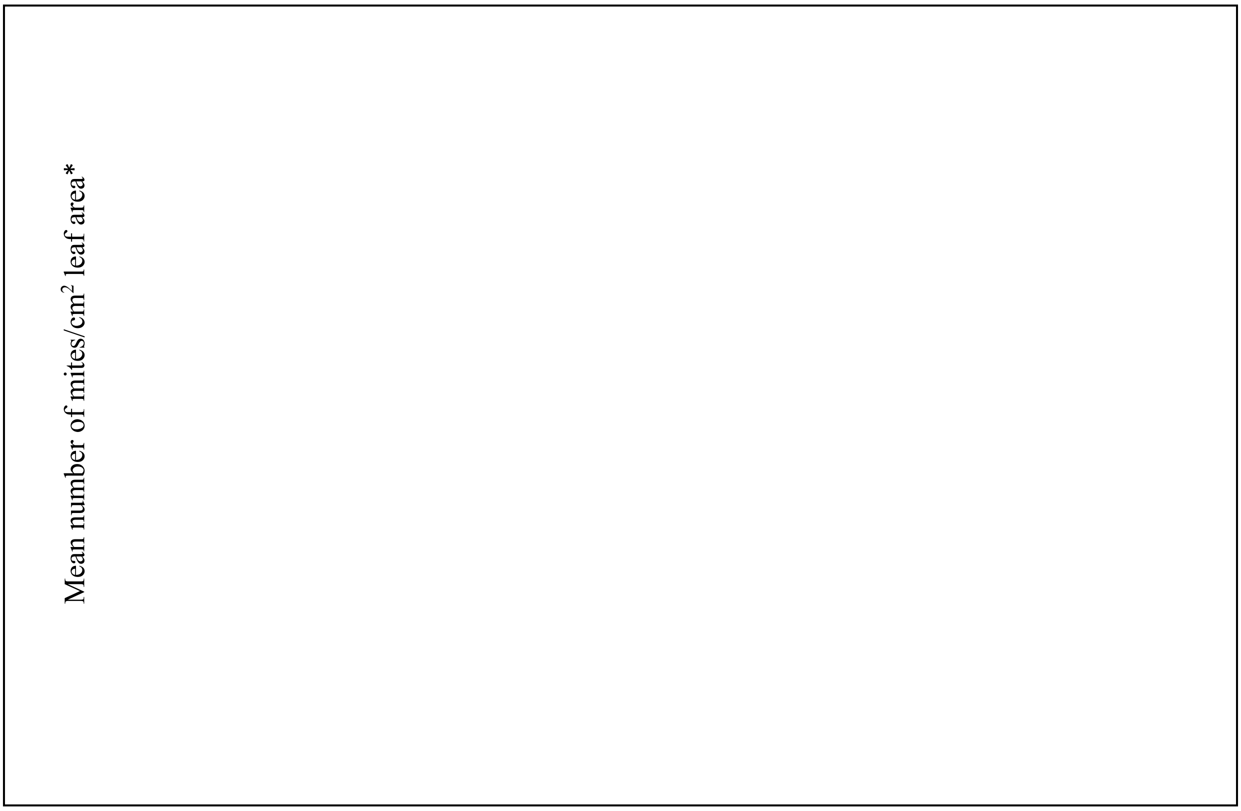

Figure 7.Vertical distribution of mites on different crop plants

*: Mean number of mites per leaf in chilli and bitter gourd.

positive correlation with mite population. The morning relative humidity showed non-significant effect on mite population in the present study. Temperature showed a significant role in the biology of mites which increased the fecundity and reduced the duration of life stages favouring their fast multiplication during hot summer periods. The rainfall directly influenced the mite population as the mites were easily washed off during heavy rains. The present findings are in confirmation with the works of Lingeri *et al*., 1998; Chinniah *et al*., 2007 and Patil and Nandihalli, 2009 who reported a significant positive correlation between mite population and maximum temperature and a significant negative correlation with rainfall. Contrary to this finding Mandal *et al*., (2006) reported that the activity of *T. telarius* in okra showed significant negative correlation with maximum temperature, positive correlation with minimum temperature and morning and evening relative humidity.

Summary

6. SUMMARY

The study entitled 'Diversity of phytophagous mites and their natural enemies in vegetables' was carried out at the Department of Agricultural Entomology, College of Horticulture, Vellanikkara during February 2011- January 2012 to explore the faunal composition of phytophagous and predatory mites associated with six vegetable crops *viz.,* brinjal, bhindi, cowpea, amaranthus, chilli and bitter gourd in Thrissur district. Regular fortnightly surveys were conducted in three major vegetable growing tracts of Thrissur namely Pazhayannur, Kannara and Vellanikkara to collect mite infested leaf samples from the selected host plants and to identify the mite fauna up to generic / species level. The population parameters of species richness and species diversity indices were worked out and also the population dynamics of the mites and the influence of weather parameters on the mite population were studied.

The salient findings of the study are summarized hereunder.

- A total of 19 species of phytophagous and predatory mites belonging to eight families were encountered. The phytophagous mite families recorded were Tetranychidae, Tenuipalpidae and Tarsonemidae and the predatory mite families include Phytoseiidae, Stigmaeidae, Cunaxidae, Bdellidae and Tydeidae.

- Brinjal recorded highest diversity of mites with three phytophagous and seven predatory mites and the least diversity was observed in bitter gourd with one phytophagous and three predatory mites.

- *Tetranychus urticae* Koch of the family Tetranychidae, *Polyphagotarsonemus latus* (Banks) of Tarsonemidae and *Brevipalpus phoenicis* (Geij.) of Tenuipalpidae were the phytophagous mites observed in brinjal among which

T.urticae was the dominant one while the other two species occurred in very minor form. The predatory mites were *Neoseiulus longispinosus* Evans, *Paraphytoseius orientalis* Narayanan, *Amblyseius* sp., *Phytoseius* sp., *Typhlodromips* sp. and *Euseius* sp. of the family Phytoseiidae and *Agistemus gamblei* Gupta of family Stigmaeidae.

- *T. urticae* was the only phytophagous mite observed in bhindi and the predatory mites included *N. longispinosus*, *Typhlodromips* sp., *Amblyseius* sp., of the family Phytoseiidae and *Agistemus* sp. belonging to family Stigmaeidae.

- Tetranychid mites on amaranthus and cowpea were identified as *Tetranychus* sp. The tenuipalpid mite *B.phoenici*s and the tetranyvhid mite *Eutetranychus* sp. were also observed in minor form in amaranthus and cowpea respectively.

- *P. latus* was the only phytophagous mite recorded from chilli and bitter gourd. Seven different species of predatory mites were collected in chilli which included *Amblyseius paraaerialis*, *Euseius* sp., *Typhlodromips* sp. of family Phytoseiidae, Tydeus sp. of family Tydeidae, *Agistemus* sp. of Stigmaeidae, *Cunaxa* sp. belonging to Cunaxidae and *Bdella* sp. of Bdellidae. *Euseius macrospatulatus* and *Typhlodromips* sp. of the family Phytoseiidae were the predatory mites identified in bitter gourd.

- The diversity, richness and dominance of mite species in the selected crop ecosystems when measured and compared showed that brinjal exhibited highest genus richness. The highest value of Simpson-Yule diversity index (D) in brinjal indicated that it supported maximum genera of mites. The minimum value of D was in bitter gourd suggesting that it was least favoured for mite diversity. The value of Shannon – Weaver diversity index (H) was also found to be highest in brinjal indicating the suitability of the host plant to harbor a wide variety of mite fauna and the least value of H in bitter gourd showed the less preference of this crop by the mite species. The Berger – Parker dominance index (d) was worked out for the most dominant genus in the respective ecosystems and it was found that *Tetranychus* was the most dominant genus in brinjal, bhindi, cowpea and amaranthus where as *P.latus* was the dominant one in chilli and bitter gourd.

- The study on the population dynamics of mites in vegetables revealed that the mite population increased during hot summer months. The mite population was at their lowest from June to September as they were washed off due to heavy and consistent rainfall. After the cessation of rainfall, the mite incidence increased again and attained a second peak during December to January.

- The vertical distribution pattern of mites within the plants was found to differ with the canopy level and it was observed that *Tetranychus* mites preferred leaves of middle canopy in brinjal and amaranthus where as leaves of bottom canopy recorded the maximum mite density in cowpea. In bhindi, there was no significant difference in the distribution of mites on the three canopy levels. The distribution of *P.latus* in chilli and bitter gourd was restricted to the top canopy leaves alone.

- The weather parameters showed greater influence on mite population dynamics and it was observed that maximum temperature had highly significant positive correlation with mite population. Whereas, rainfall and evening relative humidity showed highly significant negative effect on the population of mites. The effect of minimum temperature was found to be non-significant in all cases except brinjal and bhindi where it had a highly significant positive correlation with mite population.

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Appendices

Appendix I. Composition of Hoyer's medium

Sl.No.	Content	Quantity
1.	Chloral Hydrate	200 g
2.	Gum Arabic	30 g
3.	Glycerol	20 ml
4.	Distilled water	50 ml

Appendix II. Fortnightly meteorological data recorded at College of Horticulture, Vellanikkara during 2011- 2012

Month/ Fortnight	Temperature (° C)		Relative humidity (%)		Rainfall (mm)
	Maximum	Minimum	Morning	Evening	
2011					
February I	34.20	21.00	68	27	0.00
February II	33.50	22.70	90	52	11.60
March I	35.50	23.70	84	33	0.00
March II	34.10	25.00	89	58	0.00
April I	35.00	25.10	87	56	2.80
April II	33.80	24.60	89	*65*	145.55
May I	32.80	24.70	88	64	0.00
May II	33.70	25.60	91	61	118.8
June I	29.20	24.00	95	84	201.10
June II	30.00	23.40	96	76	122.55
July I	30.30	23.20	94	75	181.40
July II	28.30	22.40	96	83	152.35
August I	29.20	22.50	97	80	202.2
August II	29.60	22.80	94	73	142.25
September I	28.70	22.80	96	79	193.50
September II	31.50	23.10	91	63	24.10
October I	32.30	23.40	92	62	5.50
October II	31.90	23.30	89	71	153.60
November I	31.70	22.00	84	54	17.10
November II	31.50	23.90	63	54	7.70
December I	32.30	22.80	82	51	0.00
December II	31.00	23.50	61	44	1.20
2012					
January I	33.30	22.60	81	44	0.00
January II	32.60	20.80	67	34	0.00

DIVERSITY OF PHYTOPHAGOUS MITES AND THEIR NATURAL ENEMIES IN VEGETABLES

By

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ABSTRACT OF THE THESIS

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ABSTRACT

Vegetable crops are subjected to attack by a number of mite species leading to heavy economic loss. However, information on the diversity of phytophagous mites affecting major vegetable crops in Kerala is limited. Considering this, the proposed study entitled 'Diversity of phytophagous mites and their natural enemies in vegetables' was undertaken to develop a database on the important acarine species associated with major vegetable crops in Thrissur district, Kerala. The study was carried out in the Department of Agricultural Entomology, College of Horticulture, Vellanikkara during 2011-2012. The main objectives of the study were to identify the species composition of phytophagous and predatory mites associated with brinjal, okra, amaranthus, cowpea, chilli and bitter gourd from various localities of Thrissur district and also to study the spatial and temporal dynamics of population of phytophagous mites in these vegetable crops.

A total of 19 species of phytophagous and predatory mites belonging to eight families in two suborders were identified. Tetranychidae, Tenuipalpidae and Tarsonemidae were the major phytophagous mite families recorded in the study. *Tetranychus* was found to be the dominant phytophagous mite in brinjal, bhindi, amaranthus and cowpea, whereas in chilli and bitter gourd, the tarsonemid mite, *Polyphagotarsonemus latus* (Banks) was the predominant one.

The predatory mites associated with vegetables belonged to five families *viz*., Phytoseiidae, Stigmaeidae, Tydeidae, Cunaxidae and Bdellidae, among which Phytoseiidae predominated. The important phytoseiid predators observed in the survey included *Amblyseius paraaerialis* Muma, *Paraphytoseius orientalis* Narayanan, *Neoseiulus longispinosus* (Evans), *Phytoseius* sp., *Euseius macrospatulatus* Gupta, *Typhlodromips* sp. and *Scapulaseius* sp. The predatory mite *Tydeus* sp. of the family Tydeidae, *Cunaxa* sp. of the family Cunaxidae and *Bdella*

sp. of the family Bdellidae were found in chilli. The Stigmaeid mite of the genus *Agistemus* was found in brinjal, bhindi and chilli.

The comparison of different diversity indices in various crop ecosystems revealed that brinjal had highest genus richness. The value of Simpson-Yule Diversity index (D) was highest for brinjal which indicated that brinjal supported maximum genera of mites. The minimum value of D was in bitter gourd suggesting that it was least favoured by mites. Similarly the value of Shannon – Weaver Diversity index was found to be highest in brinjal and the least in bitter gourd. This shows that brinjal is favoured by a large number of mite species as compared to bitter gourd. The Berger – Parker dominance index (d) was worked out for the most dominant genus in the respective ecosystem and it was found that *Tetranychus* was the most dominant genus in brinjal, bhindi, cowpea and amaranthus where as *P.latus* was the dominant one in chilli and bitter gourd.

The study on the population dynamics of mites in vegetables revealed that the mite population increased during hot summer months. The mite population was at their lowest from June to September as they were washed off due to heavy and consistent rainfall. After the cessation of rainfall, the mite incidence increased again and attained a second peak during December to January.

The distribution pattern of mites on the plants varied with the canopy level and it was found that tetranychid mites preferred matured leaves of middle canopy in brinjal and amaranthus but bottom canopy in cowpea. In bhindi, there was no significant difference in the distribution of mites at the three canopy levels. The distribution of *P.latus* in chilli and bitter gourd was restricted to the top canopy leaves alone.

Weather factors such as rainfall and evening relative humidity showed highly significant negative correlation with mite population, whereas maximum temperature showed highly significant positive effect on the population of mites. Hence it is evident from the study that increase in temperature coupled with decrease in relative humidity favoured an increase of mite population.