BIONOMICS AND ECOLOGICAL MANAGEMENT OF COCONUT ERIOPHYID MITE *Aceria (Eriophyes) guerreronis* (KEIFER)

By

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THESIS

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Kerala Agricultural University

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DECLARATION

I hereby declare that this thesis entitled "**Bionomics and ecological management of coconut eriophyid mite,** ***Aceria (Eriophyes) guerreronis*** (Keifer)" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, fellowship or other similar title, of any other University or Society.

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Introduction

1. INTRODUCTION

The coconut palm (*Cocos nucifera* L.), popularly known as 'Kalpavriksha', is one of the most useful tree crops grown in the world. Among the different coconut growing countries of the world, India ranks first with an area of 1897.4 m ha and production of 13088 m nuts. Of this, Kerala accounts for 53 per cent of area and 45 per cent of production (Markose, 2000). In Kerala coconut is grown in homestead gardens and has an integral role in the economic, social and cultural lives of the people of our state.

As many as 547 species of pests including insects and mites associated with coconut palm at different stages of crop growth were listed by Kurian *et al.* (1979). Sathiamma (1991) recorded thirty one acarine fauna on coconut palm, which comprised eighteen genera and thirty one species of mites, from thirty countries of the world. In Kerala, sixteen species of mites belonging to fourteen different families and four suborders have been recorded from coconut palm foliage (Sathiamma, 1996).

A number of mites belonging to different families were found to be infesting the buttons of coconut. It includes two eriophyid mites namely *Aceria guerreronis* (Keifer) (Ortega *et al.*, 1965) and *Colomerus novahebridensis* K. (Hall *et al.*, 1980); a tenuipalpid mite, *Dolichotetranychus vandergooti* (Oudemans) (Sathiamma, 1985) and a tarsonemid mite *Xenaster mahunka* (Mohanasundaram, 1994). Among these, *A. guerreronis* is currently threatening the coconut production in South India.

The coconut eriophyid mite, *A. guerreronis*, was first reported from Guerrero in Mexico in 1960 (Ortega *et al.*, 1965). Later, its occurrence was reported from several states in Africa and Central and South America (Hall and Espinosa, 1981). During 1998, presence of this mite was detected from Ernakulam district of Kerala (Sathiamma *et al.*, 1998). Subsequently, the devastating effects of these mites were described from Banglore in Karnataka, Udumalpet in Tamil Nadu (Sathiamma *et al.*, 1998), three islands of Lakshadweep (Haq, 1999b) and Chittor in Andra Pradesh (Reddy and Naik, 2000). Now the pest has spread far and wide in South India.

Of the total of 13.88 crores of coconut palms of Kerala, 42.23 per cent (5.89 crore palms) has been affected by this mite, of which 9.87 per cent is severely infested and 16.94 is moderately infested. The total yield loss estimated was at about 21.8 per cent of the total state production (CDB, 2000). Nair *et al.* (2000) estimated a production fall of 30-40 per cent in most affected districts of Kerala. Tentative estimates have indicated 200 to 250 crores of rupees annual loss in the state of Kerala alone due to this mite (Haq, 1999b).

A. guerreronis has a vermiform elongate body divided into a cephalothorax and a tapering abdomen, and has only two pairs of legs situated near the anterior end (Plate 1a). Large numbers of these mites (Plate 1b) colonize on the tender portion of the button covered by the perianth and suck sap from the meristematic tissue by remaining inside. As a result of feeding, whitish or yellowish patches are formed on the surface of the nuts, which later turn necrotic, hardened and crinkled. The quality and size of kernal and copra content are affected by the attack.

Since this is an introduced pest, the information about it under the tropical climatic conditions of Kerala is scanty. The population of mites varies with weather aberrations. But the exact relationship of mites with different weather conditions is not known. Similarly, detailed information on the bunch preference, symptoms of damage, population dynamics, distribution pattern and ecological management strategies is also not available.

Hence, the present study was under taken

i. To study the preference of mites to bunches of increasing maturity;

ii. to study the symptomatology of mite attack;

iii. to understand the population dynamics of mites and the relationship of mite population with different weather factors;

iv. to investigate the seasonal occurrence of predatory mites;

v. to evaluate the influence of plant morphology on the distribution pattern of mites; and

vi. to elucidate some ecological management strategies against coconut mites

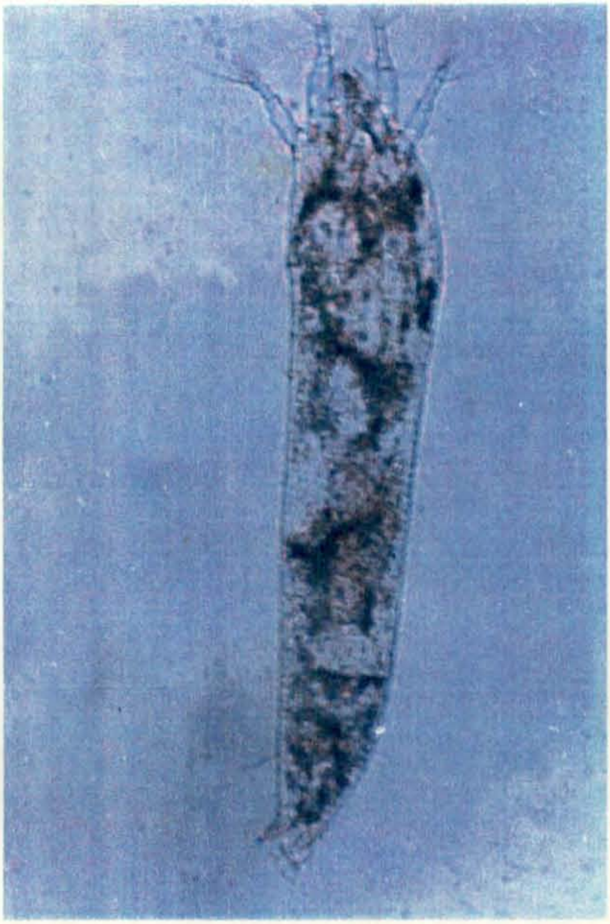


Plate 1a. A closer view of *Aceria guerreronis*

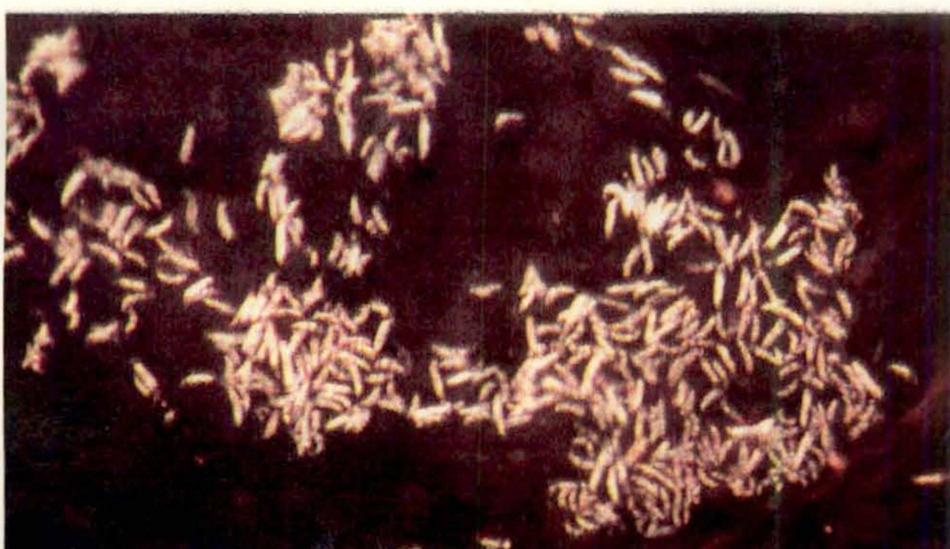


Plate 1b. Colony of *Aceria guerreronis*

Review of Literature

2. REVIEW OF LITERATURE

Aceria (Eriophyes) guerreronis (Keifer), the coconut eriophyid mite, has been a serious pest of coconut in Kerala for the last four years. This is an introduced pest and the information available on the biology and ecological management of the pest are scanty.

2.1 Description of the pest

Keifer (1965) described adult coconut mite to be between 36-52 µm in width and 205-255 µm in length. These mites are elongated and worm like in appearance and the body is finely ringed and beset with bristles. The mite is having two pairs of legs in the anterior portion and the head and thorax are combined to form cephalothorax. The abdominal portion is studded with microtubercles in a series of rings. The anal opening is terminal while the genital opening is anteriorly placed below the leg base (Mohanasundaram *et al.*, 1999).

2.2 Prevalence and spread of the pest

2.2.1 International prevalence

Coconut eriophyid mite *A. guerreronis* has been detected from different parts of the world. Damage symptoms of the mites were described from Colombia by Martyn (1949). The first incidence of *A. guerreronis* was reported from Guerrero in Mexico in 1960 (Ortega *et al.*,1965).

This mite has been described as a notorious pest in Caribbean islands, Africa and America by many workers. The pest was reported from Colombia in 1971 (Zuluaga and Sanchez, 1971). First report of damage caused to coconut by *A.*

guerreronis in a Caribbean island was from Cuba (Estrada, *et al.*, 1975). However, *A. guerreronis* was first discovered in Africa in 1967 on coconut in Benin, as reported by Mariau (1977). The author reported that the mites spread rapidly in that state and was also recorded in Togo, Cameroon, Sao Tome, Nigeria and Ivory Coast. Other reports of pest incidence were from Dominica (Moore and Alexander, 1985), Veracruz, Mexico (Olvera and Fonseca,1986) , Costa Rica (Schliesske, 1988) and Mozambique (Uaciquete *et al.*, 1998). Moore and Howard (1996) opined if the mites were to spread to Asia and Oceania where the coconut is of far greater importance, the consequences could be devastating.

2.2.2 National prevalence

Sathiamma (1981) studied the mite fauna associated with coconut palm in Kerala and reported that surveillance is being maintained in India, so as to check *A. guerreronis* at the point of entry itself. Even though there was an alarm on detection of these mites in North Kerala and though the area was combed for its occurrence, this mite could not be traced out then.

First report of the outbreak of nut infesting eriophyid mite was from Ernakulam district of Central Kerala (Sathiamma *et al.*,1998). Subsequently, the devastating effects of these mites were reported from Bangalore in Karnataka, Udumalpet in Tamil Nadu (Sathiamma *et al.*, 1998), three islands of Lakshadweep namely Minicoy, Kalpeni and Kavaratti (Haq,1999b) and Chittor in Andra Pradesh (Reddy and Naik, 2000). Now the pest has established in Kerala, Tamil Nadu and parts of Karnataka and Andra Pradesh.

2.2.3 State prevalence

Though the injurious effect of *A. guerreronis* was established in India only now, symptoms identical to the attack of the mite existed on nuts of coconut trees grown along the banks of the Anjengo lake in Kerala during 1960s (Haq, 1999a).

Even though this mite was reported first from coconut plantations of Ernakulam district, further survey revealed its occurrence in adjoining districts viz., Alleppey, Kottayam and Thrissur (Sathiamma *et al.*,1998). CDB (2000) revealed the occurrence of mites in all the fourteen districts of Kerala. But the intensity of infestation was high in districts of central region when compared to southern and northern districts.

2.3 Host plant of mites

Coconut eriophyid mite *A. guerreronis* was first reported in coconut from Guerrero in Mexico in 1960 (Ortega *et al.*,1965).

Flechtmann (1989) reported *Cocos weddelliana* (Palmae: Arecaceae) as new food plant for *Eriophyes guerreronis* (*A. guerreronis*) in Brazil.

2.4 Biology

Not much information is available on biology of *A. guerreronis*. They infest young buttons in the post fertilization period. Population of mites develop on the tender meristematic zone of the fruits which is covered by the perianth (Moore and Howard, 1996; Sathiamma *et al.*, 1998).

Nadarajan *et al.* (2000) reported that when the female flowers open up for pollination, the attachment between the perianth and nut become less tight giving a space for the entry of the minute sized mite into the inter space between perianth and button. They grow very fast inside the perianth and attain sexual maturity within a week. The female mite lay about 20-100 eggs during its life time. Eggs are globular and shining and hatch out within a few days into vermiform protonymphs. They further develop into deutonymphs and to adults. The life cycle of the mite is 8-10 days.

2.5 Symptoms of attack

The damage initially appears as a triangular patch at the level of perianth. Later, the feeding injury by large number of mites results in the brownish patches. As the nuts grow, the injury leads to warting and longitudinal fissures on the surface (Sathiamma *et al.*, 1998). Feeding of mites in the meristematic zone of nuts causes physical damage so that as the newly formed tissue expands, the surface become necrotic and suberized (Moore and Howard, 1996). Draining of the sap from young buttons causes reduction in the size of nuts (Estrada *et al.*, 1975; Mariau, 1986; Medina *et al.*, 1986; Sathiamma *et al.*, 1998) and leads to reduction in copra yield by 25 per cent (Mariau, 1977) and even upto 40 per cent (Muthiah and Bhaskaran, 2000).

Premature nut fall is also reported in some areas due to the attack of mites (Mariau, 1977; Medina *et al.*, 1986) and this was disputed by Mariau (1986). Seguni (2000) reported that losses due to premature nut fall were between 10-100 per cent in Tanzania. Besides the eriophyid mites, premature nut fall is influenced by damage by the coried bug, *Pseudotheraptus wayi* Brown, an indigenous and widespread pest.

Reduction in albumin content (Mariau, 1977), weight and quality of pulp (Medina *et al.*, 1986) kernal content and quality of husk (Sathiamma *et al.*, 1998) are also reported as symptoms of attack by the mite.

In many cases, when perianth is removed, a pinkish band can be seen on the inner side of button. At maturity the husk of infested nut is very tight and shrunken causing difficulty in dehusking (Nadarajan *et al.*, 2000).

In addition to damaging the fruit, *A. guerreronis* can kill coconut seedlings by feeding on their meristematic tissue (Arruda, 1974). Hypotheses that the coconut mite and other eriophyids on coconut can act as disease vectors have not been confirmed (Moore and Howard, 1996).

2.6 Natural enemies associated with mites

Some natural enemies are found associated with coconut mites, but are not considered as important as far as biological control is concerned.

Coconut mite, as with other mites, are not attacked by parasitoids, and their sheltered habitat and biology provide few opportunities for other natural enemies to be effective (Moore and Howard, 1996). Hall *et al.* (1979) found that a species of *Bdella*, two phytoseiids and a tarsonemid are predacious mites that have been found in association with *E. guerreronis* in the field but have little effect on populations. Two species of *Lupotarsonomus* was observed in the samples from Ivory Coast and New Guinea, but appeared to be of only minor significance in reducing populations (Hall *et al.*, 1980). Other predacious mites observed in the meristematic zone of coconut fruits are *B. distincta* Baker and Balock, *Amblyseius largoensis* Muma, *Neoseiulus mumai* Denmark and *N. paspalivorus* Deleon (Howard *et al.*, 1990).

Entomopathogenic fungi which are reported to be pathogenic to coconut mites are *Verticillium lecanii* (Hall *et al.*, 1979), *Hirsutella thompsoni* (Hall *et al.*, 1980; Beevi *et al.*, 2000) and *H. nodulosa* (Cabrera and Dominguez, 1987).

2.7 Distribution pattern of mites

2.7.1 Bunch preference

Preference for colonization by the mites was reported to vary with the age of the nuts. Moore and Alexander (1987) found that mites were not seen in unfertilized flowers but were present within a few weeks of fertilization. Infestation was very low in the first month after fertilization, but build up rapidly to a peak on buttons of third bunch from top and then dropped. The population tended to be low from ninth bunch. It appeared that bunches one to four were the most susceptible to colonization and mites were present on nuts up to 13 months but the population was low.

Sathiamma *et al.* (1998) observed that nuts upto nine months of age harboured the mite, but fully mature nuts never contained any stage of mites.

Colonies of mite comprising of eggs, first nymph, second nymph, males and females were detected on nuts of six weeks age and the mite population showed a rapid increase during this period. This trend continued during progressive development of nuts upto the age of twelve weeks, followed a steep reduction during subsequent weeks and the population receded to a minimum level on nuts of the age of 22 to 24 weeks. Such difference in the duration of infestation may be due to varietal or age difference of palms or other ecological factors (Haq, 1999a).

Ramaraju *et al.* (2000) reported that the population was very high in two to six month old buttons. He observed two to one forty mites along with large number of eggs in an area of four sq. mm on infested nuts.

There were no mites in male flowers and also in female flowers before pollination. In some nuts, which had very soft husk with a lot of moisture, heavy attack was seen even on seven month old tender nuts. Otherwise, maximum population of mites were seen on the third, fourth and fifth bunches from the fully opened flower bunches (Ranjith *et al.*, 2000).

2.7.2 Climate

It was suggested that coconut mite attack is more severe in relatively dry climates or during the dry season of wetter climates (Zuluaga and Sanchez, 1971). However, in other localities there is no clear relationship between coconut mite populations and wet and dry weather, or, if such relationship exists, it is obscured by other factors (Mariau, 1977; Howard *et al.*, 1990; Ramaraju *et al.*, 2000).

Hall *et al.* (1979) reported that in young bunches, the percentage of nuts attacked is greater during wet than in dry periods. Howard *et al.* (1990) found that the coconut mite is seen in tropical and subtropical climates, but populations can survive both short periods of frost and periods of temperatures just above zero more prolonged than those normally encountered where coconut palms are grown.

Haq (1999a) studied the correlation between temperature and rainfall with the population of mite and found that the population density of the mite was positively correlated with temperature and negatively correlated with rainfall. The population is reported to be maximum during summer or dry periods, even though the pest is present in the garden throughout the year (Nair and Koshy, 2000; Reddy and Naik, 2000; Vidyasagar, 2000).

2.7.3 Spread

The principal way in which coconut mites spread and colonize new plants, particularly over long distance, is probably through aerial dispersal of inseminated female mites. Wind appeared to be the main factor in spreading mites from one region to another. They could not be transported with the nuts since these ceased to be attractive to the pest (owing to lack of young growing tissues) two to three months before harvest (Mariau, 1977). In St. Lucia, major problems occurred in the early 1980s after a serious hurricane and the belief arose that the mite had been transported to the island by hurricane (Moore, 2000).

There is also debate as to what causes mite to leave the protection of the bracts, with population pressure being considered important (Griffith, 1984). But there was no clear evidence of migration being due to population pressure even though there were significant positive relationship between the number of mites on nut surface and the numbers under the bracts. Coconut mite can walk between touching inflorescences and being negatively geo- tactic tend to move from older to younger inflorescence (Moore and Alexander, 1987).

Griffith (1984) found adult mites on several bees visiting the female flower. His view was that the source of mite would have to be a infested flower and as such the significance of the bee dispersal was small. Schliesske (1990) reported that mites are spread over large distances by wind, and within plantations by rain and phoresis.

Moore and Howard (1996) opined that some dispersal may take place by phoresy, either on animals directly attracted to the inflorescence (e.g. pollinating agents such as bees; rodents which feed on fruits), or on those attracted by such animals (e.g. predatory lizards, birds, predaceous insects)

2.7.4 Height of tree

No information is available showing the relationship between height of tree and mite infestation.

2.7.5 Crown shape

The shape of the crown and the arrangement of nuts in the bunches influence the extent of attack by the mites. An open canopy of the coconut crown had a lower attack than a semi open crown and a closed canopy with thick set leaves and closely packed bunches showed heavy attack (Ranjith *et al.*, 2000).

2.7.6 Perianth arrangement

Mariau (1977) examined varietal differences and highlighted a Cambodian variety which was immune, probably because the floral parts adhered firmly to the nut, allowing no space for access to the nut surface by the mite.

Moore (1986) showed that the arrangement of bracts of growing coconut influenced the pattern of attack by the mite *E. guerreronis*. Mite attack was worst where the bract was less tightly adpressed and where bracts overlapped each other. This suggests that the bract act as a physical barrier to mite entry.

Moore and Alexander (1987) demonstrated that the perianth of round nuts adhered more tightly to the nut than with the elongated nuts and hence round nuts were less susceptible to attack than more elongated ones.

Tightness of the perianth to the coconut was identified as a key factor in determining susceptibility or resistance to attack due to *A. guerreronis*. (Howard and Rodriguez, 1991).

The tepals are tightly adpressed to the fruit during its first month of development and within about a month, the space between the coconut surface and the perianth are sufficiently large to permit the entry of coconut mites (Moore and Howard, 1996).

2.7.7 Nut shape

Moore and Alexander (1990) studied the responses to attack by *E.(A.) guerreronis* and found that reduced attack was associated with rounded nut shape. Similarly, oblong shaped nuts were infested to a higher degree than the round and oval nuts (Ranjith *et al.*, 2000)

2.7.8 Nut colour

Moore and Alexander (1990) reported that reduced attack was associated with green nut colour. This seems to be contradictory to the statement that there was a general preference by mite for green coloured nuts than orange or yellow coloured nuts (Muthiah and Bhaskaran, 2000; Ranjith *et al.*, 2000)

2.7.9 Varietal response to the attack of mites

There are reports that cultivars varied in their susceptibility to coconut mite infestation. The incidence of attack on Yellow Dwarf was greater than West African

Tall and a Cambodian variety was immune because the floral parts adhered firmly to the nut (Mariau, 1977; 1986).

A study of the susceptibility of ten varieties by Hall *et al.* (1979) showed that West African Tall and Malayan Yellow Dwarf were very susceptible, whereas the hybrid between these two, as well as other varieties such as Malayan Tall, Tahiti Tall and Cameroon Red Dwarf performed better.

Taffin *et al.* (1991) reported that hybrids are found more tolerant to *E. guerreronis*.

Even though all the coconut genotypes/ germplasm were found infested by the mite, the cultivar Kenthali was least susceptible to mite attack (Ramaraju *et al.*, 2000)

2.8 Ecological management

2.8.1 Water availability

In Benin, it was observed that a hybrid plantation which was irrigated after a period of water shortage, had aggravation of mites due to drought (Mariau, 1986). This was because the nuts developed more slowly and then remained susceptible to the mite for a longer period. But Alencar *et al* (1999) suggests avoidance of excessive irrigation as a cultural control method.

2.8.2 Fertilizers and micronutrients

Better cultivated trees, with appropriate fertilizer application suffer less coconut mite attack (Mariau, 1977).

A study by leaf analysis of the nutritional level present in coconuts in St. Lucia showed that less than 2.5 per cent of trees had adequate levels of all three major nutrients, namely, N,P and K. There was some association between nutrient status and levels of damage by the coconut mite. Damage generally increased with increasing levels of N and at one site K was associated with decreasing mite damage (Moore *et al.*, 1991). But avoidance of excessive use of fertilizers is suggested by Alencar *et al.* (1999) as a method of cultural control.

Moore (2000) reported that fertilizer regimes were designed to optimise the yield, not to control the pest. In Jamaica, during 1980s in well maintained coconuts the symptoms of mite damage were present, but the plants were tolerant and showed little yield loss.

Potassium is reported to impart resistance potential in coconut towards insect and non insect pests like mites. On the other hand, the usage of excess nitrogen either as organic or inorganic forms was reported to result in heavy incidence of pest and in particular, mite population on the palms (Mandal, 1991).

Ramarethinam and Marimuthu (1998) demonstrated that lack of potassium, leading to poor water retention, lead to poor insect and mite resistance. This caused exposure to mite and fungal infection and ultimately death of palm.

Use of micronutrients along with other practices will help in controlling mites for longer periods (Ramarethinam and Marimuthu, 1998).

Spot application of Borax, Gypsum and magnesium sulphate was suggested as specific recommendation for the management of coconut eriophyid mite by TNAU (2000).

The implementation of IPM (Integrated Pest Management) along with INM (Integrated Nutrient Management) and IWM (Integrated Water Management) is necessary to prevent and control mite infestation (Ramarethinam and Marimuthu, 1998).

2.8.3 Crown cleaning

Removal of infected plant parts is recommended as cultural control method (Alencar *et al*,1999).

Materials and Methods

3. MATERIALS AND METHODS

The experiment conducted in the year 1999-2001 under the Department of Entomology, College of Horticulture, Vellanikkara was intended to understand the following components.

1. Population of mites in bunches of increasing maturity
2. Symptoms of damage
3. Population dynamics
4. Population of predatory mites
5. Influence of plant morphology on the distribution pattern of mites
6. Ecological management strategies

3.1 Population of mites in bunches of increasing maturity

Population of mites is supposed to vary with the age of the nuts. In order to fix bunches having maximum number of mites, a field experiment was conducted in the coconut garden of Instruction Farm, Vellanikkara having uniform management practices. The experiment was laid out as a completely randomised design. Ten palms of West Coast Tall (WCT) of 24 years age were selected at random from a block. From each palm, buttons or nuts were collected randomly from the first nine bunches at a rate of two buttons per bunch, taking the youngest bunch with fertilized nutlets as bunch one. The flower bunch before this, was numbered as bunch zero. From this, both male and female flowers were collected to check the presence of mites.

Collected nuts were brought to the lab and population of mites were determined by slightly modifying the rapid method to assess the population of coconut mite by Ranjith *et al.* (2000). The perianth was removed from the button mechanically. Both the inside of the perianth and the portion of the button covered by the perianth were washed with a 0.2 per cent solution of Teepol. The outside of the button and the perianth was also washed with this solution to collect the mites dispersing outside. Directing a feeble jet of Teepol solution using a wash bottle helped to dislodge all the mites and their eggs. Buttons were washed directly to a counting dish with minimum quantity (two ml) of Teepol solution. All the mites were killed immediately and settled at the bottom of the counting dish within seconds. Mites were counted by keeping the dish under a stereomicroscope at 20X magnification. Counting was done using a hand tally counter, while viewing through the microscope. All the mites that got settled in the counting dish were counted, to arrive at the total population of mites in the button. This technique was used in all the ensuing experiments where counting of the mites was done.

These observations were taken four times at fortnightly intervals from May 2000 to June 2000. Based on this, buttons having maximum number of mites were determined and further counting for population dynamics was restricted to these bunches.

3.2 Symptoms of damage

Infested nuts in the field were closely observed at various stages and nature and symptoms of attack elucidated.

The visible surface damage that developed on the nuts of differing maturity was taken. For this, initially, the volume of buttons and nuts were taken using water displacement method and the volume was converted into surface area. Area of damage was measured using a graph paper xeroxed on a transparent sheet and it was kept over the damaged area. The number of squares was counted to get the area of damage. Area of the necrotic and whitish patch was also taken in the same manner.

Percentage of surface damage to total surface area of nuts was calculated using the formula given below.

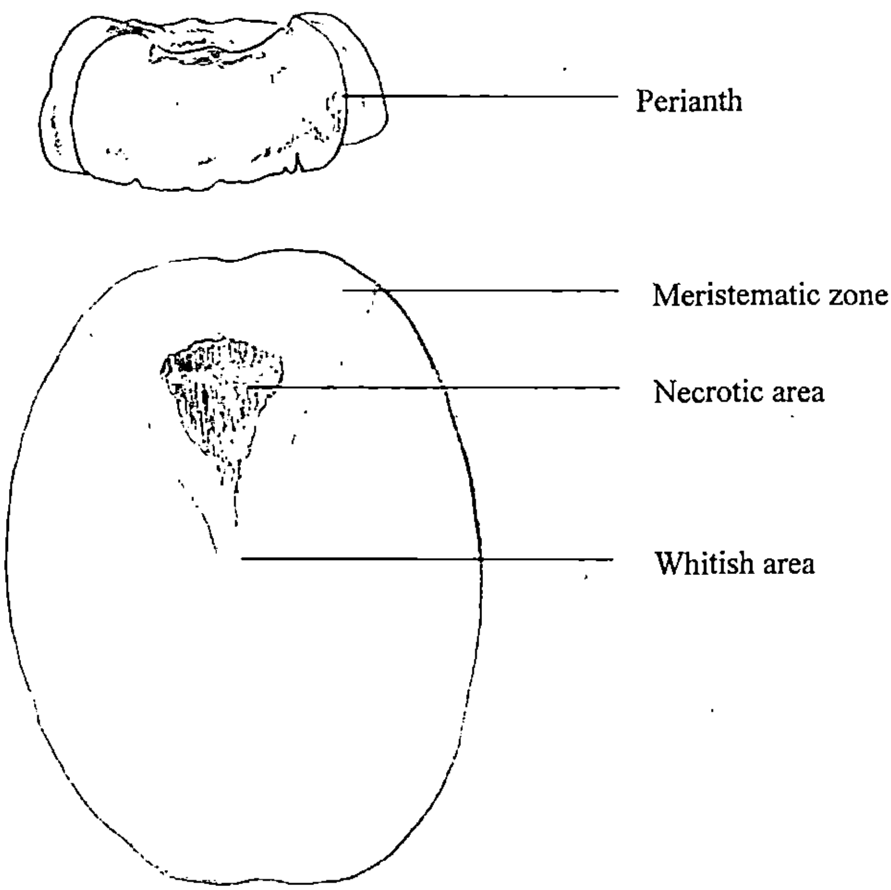
$$\text{Percentage of visible necrotic area} = \frac{\text{Visible necrotic area in cm}^2}{\text{Total surface area of button in cm}^2} \times 100$$

$$\text{Percentage of visible whitish area} = \frac{\text{Visible whitish area in cm}^2}{\text{Total surface area of button in cm}^2} \times 100$$

It was also possible that there was some relationship between the surface damage of button and the number of mites in the perianth. To study this, buttons collected from third and fourth bunches were used. This was due to the fact that initial studies indicated that maximum population was on these bunches. Mite population declined on the later bunches (Table 4). Total area of the damaged surface, area of the necrotic patch and area of whitish or yellowish streak was measured in cm^2. Each patch on the surface of button was measured separately (Fig.1). Area of damage was measured using a graph paper xeroxed on transparent sheet and it was kept over the damaged area. The number of squares was counted to get the area of apparent damage. Area of the necrotic and whitish patches was also taken in the same manner. Percentage necrosis/white patch can be expressed using the formula

$$\text{Percentage of necrotic area} = \frac{\text{Necrotic area in cm}^2}{\text{Total damaged area in cm}^2} \times 100$$

Fig. 1. Necrotic and whitish area of damage on buttons



$$\text{Percentage of whitish/yellowish area} = \frac{\text{Whitish/yellowish area in cm}^2}{\text{Total damaged area in cm}^2} \times 100$$

One set of observations was taken with the perianth intact. Later on, it was seen that heavy damage occurred inside the perianth before the same was visible outside. Hence, a second set of the above observations was taken with the perinath removed.

The number of mites inside the perianth was counted for each patch. The corresponding actual surface damage (exposed + concealed) was also measured. This was repeated for all the patches in the same button. For this, the necrotic areas along with perianth were cut out separately and washed to assess the mite population.

However, it was found that the size of the nuts varies with the palms. Sometimes, the buttons of third bunch of one tree will be larger than that of the fourth bunch of another. In such cases, it is better to take the surface damage in relation to the total surface area of buttons and then assess the mite population in each button. For taking the surface area of buttons, first the volume was taken by water displacement method and later related with the surface area. Area of the surface damage was measured using a transparent graph paper as described earlier. Thus the surface damage can be expressed as percentage of total surface area of the button

$$\text{Percentage of visible surface damage} = \frac{\text{Total surface damage of button in cm}^2}{\text{Total surface area of button in cm}^2} \times 100$$

Similarly, the area of necrotic patch and white/yellowish patch was also expressed as percentage of total surface area of the button

$$\text{Percentage of visible necrotic patch} = \frac{\text{Visible necrotic patch in cm}^2}{\text{Total surface area of button in cm}^2} \times 100$$

$$\text{Percentage of visible whitish patch} = \frac{\text{Visible area of white patch in cm}^2}{\text{Total surface area of button in cm}^2} \times 100$$

Population of mites of the entire button was counted and then related to the percentage of surface damage.

3.3 Population dynamics

Population of mites may vary with weather aberrations. To study the seasonal variation of mites in buttons, ten palms of 24 years age were selected at random from a group of West Coast Tall having uniform management practices. The design of the experiment was CRD.

Based on the results of the earlier experiment, sampling was restricted to third and fourth bunches. Buttons were collected randomly from third and fourth bunches at a rate of two buttons per bunch. Percentage infestation of buttons was calculated using the following formula.

$$\text{Percentage of button infestation} = \frac{\text{Number of infested buttons per bunch}}{\text{Total number of buttons per bunch}} \times 100$$

While taking observations, buttons even with a small scar were denoted as infested. This, however, does not consider the degree of damage in the buttons. The assessment of extent of damage of the collected buttons was done in the lab. The total number of patches in each sample button and percentage of necrosis in each patch were recorded.

After this the population of mites in each button was determined as explained earlier (Section 3.1).

Population of mites was taken for a period of one year i.e. from May 2000 to May 2001. Meteorological observations like temperature, rainfall, humidity, wind speed and sunshine hours were also taken during this period. Weather parameters are given in Appendix I and II

The correlation between weather factors and population of mites was worked out. Mite population was correlated with weather factors of corresponding week and different fortnights. The corresponding week was represented as current week and fortnights as current fortnight, -1 fortnight (one week lead time) and -2 fortnight (two weeks lead time) as the case may be (Table 1). Current week, current fortnight and other fortnights are represented as a calendar in Fig. 2a, 2b, 2c and 2d.

Fig. 2a. Calendar showing current week

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	**30***

*Date of taking observation

Fig. 2b. Calendar showing current fortnight

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	**30***

*Date of taking observation

Fig. 2c. Calendar showing -1 fortnight (one week lead time)

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	**30***

*Date of taking observation

Fig. 2d. Calendar showing -2 fortnight (two weeks lead time)

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	**30***

*Date of taking observation

Table 1. Description of the names of week and fortnights

Name of the week/ fortnights	Description of week/ fortnights
Current week	The week which is ending on the day of observation
Current fortnight	The fortnight which is ending on the day of observation
-1 fortnight (one week lead time)	The fortnight which is ending one week prior to the day of observation
-2 fortnight (two weeks lead time)	The fortnight which is ending two weeks prior to the day of observation

3.4 Population of predatory mites

Population of predatory mites were recorded at monthly intervals from sample buttons of second to sixth bunches

3.5 Influence of plant morphology on the distribution pattern of mites

Mite infestation varies with different palm and nut characters. To study this, an experiment was carried out during December 2000 to May 2001 as a completely randomised design (CRD).

3.5.1 Height of tree

Palms having different height were selected for taking observations. The trees were classified into three groups- < 6 m, 6 – 12 m and > 12 m height. Five palms were observed at random from each group. Total number of buttons and the number of infested buttons in third and fourth bunches from top were taken from the field itself. Percentage of buttons damaged was later calculated as

$$\text{Percentage of button infestation} = \frac{\text{Number of infested buttons per bunch}}{\text{Total number of buttons per bunch}} \times 100$$

Buttons having maximum damage were collected from third and fourth bunches at a rate of one button per bunch. They were brought to lab and population of mites was counted. These observations were taken at monthly intervals.

3.5.2 Crown shape

Shape of the crown varies with the palm. There are mainly three types of crown viz., spherical (Plate 2a), semi spherical (Plate 2b) and closed (Plate 2c). Orientation of leaves in the crown or the sunlight reaching directly on the button may be important as far as the coconut mite is concerned. So it is better to express the spherical, semi spherical and closed crown shapes as open, semi open and closed respectively. Palms with open crown shape are those in which there is enough gap between the fronds so that incidence of sunlight on buttons is more, whereas in closed crown the fronds are closely packed and direct sunlight falling on buttons is less. The arrangement of fronds in the crown and the incidence of sunlight are in between these two in case of semi open crown. To check whether there is any difference in the incidence of mites with different crown shapes, five palms were selected at random under each type. Total number of buttons and the infested buttons from third and fourth bunches were taken to calculate the percentage of infestation. Buttons with maximum mite infestation was collected from these bunches and population was counted in the lab as described earlier.

Plate 2. Palms showing different crown shapes

2a. Spherical

2b. Semi spherical

2c. Closed

Plate 3. Nuts showing different perianth arrangements

3a. Perianth less adpressed

3b. Perianth tightly adpressed

3.5.3 Perianth arrangement

Two types of perianth arrangement were considered

1. Perianth less adpressed
2. Perianth tightly adpressed (overlapping perianth)

Both these types are available within the same tree, and even within the same bunch. Since this is a nut character, grouping can be done only after collecting the buttons. Hence, classification of buttons into the above classes was done after the buttons were harvested. Grouping was done based on the arrangement of the three inner tepals. Tepal arrangement I is called as perianth less adpressed and tepal arrangement II is described as perianth tightly adpressed. In both types, the outer bracts are not considered.

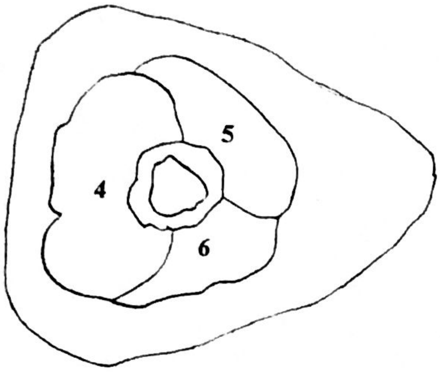
a. Tepal arrangement I (Perianth less adpressed) (Fig.3a)

In the inner ring, tepal four overlaps at both ends, tepal five overlaps at one end and overlapped at other end and tepal six is overlapped at both ends. Since the gap between fourth tepal and the button is more, this type of perianth arrangement was considered as less adpressed type (Plate 3a).

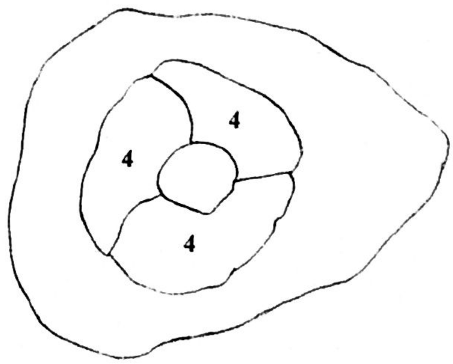
b. Tepal arrangement II (Perianth tightly adpressed) (Fig.3b)

This is otherwise called as overlapping perianth. In the inner ring, each tepal overlaps at one end and overlapped at the other end. Hence any or all of them can be tepal four. Since the gap between all the tepals and the button is less, it is considered as tightly adpressed type (Plate 3b).

Fig. 3. Arrangement of inner tepals on the button

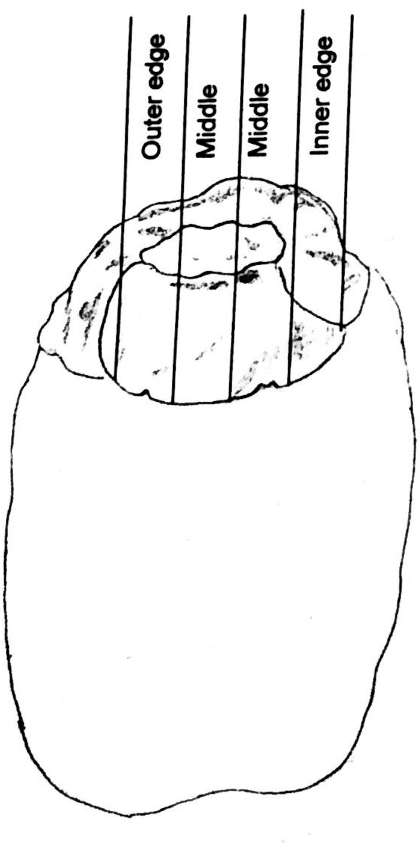


3a. Tepal arrangement I
Perianth less adpressed



3b. Tepal arrangement II
Perianth tightly adpressed

Fig. 4. Diagram showing different areas of inner tepal



In nuts with less adpressed perianth, the severity of damage under each inner tepal (four, five and six) was measured using a one to five scale. The area of infestation just below the length of inner tepal was observed to arrive at the scale as described below (Table 2).

Table 2. Scoring details of button damage just below the inner tepal

Score	Percentage of infested area	Severity of damage
0	0	No damage
1	<25 per cent infestation	Less damage
2	25 – 50 per cent infestation	Moderate damage
3	50 – 75 per cent infestation	Severe damage
4	>75 per cent infestation	Most severe damage

Another observation was taken to find the entry point of mite to the inner tepal. Here, each inner tepal was divided into four quarters. The quarters where bracts overlap the adjacent tepal were termed as 'outer edge', the quarters where the tepal is overlapped by the adjacent tepal were termed as 'inner edge' and the remaining two quarters at the centre were termed the 'middle' (Fig. 4). By recording where the mite damage extended farthest down the button it could be surmised where the initial colonization had occurred (Moore, 1986).

3.5.4 Nut shape

To study the difference in mite population due to nut shape, palms having different shaped nuts like round, oval and oblong were considered. Five palms were selected at random from each group. Percentage of button damage was obtained by taking the total number of buttons and the number of infested buttons in third and fourth bunch. Buttons having maximum damage were collected from these bunches at a rate of one button per bunch. Observations on population of mites were counted as described earlier, at monthly intervals.

3.5.5 Nut colour

To find out the preference of mites due to variations in nut colour, palms having different coloured nuts like green, greenish yellow and orange were selected. Five palms were observed at random under each group. Percentage of button damage was assessed by taking the total number of buttons and the number of infested buttons in third and fourth bunch. Buttons having maximum infestation were collected from these bunches at a rate of one button per bunch. Observations on population of mites were made at monthly intervals.

3.6 Ecological management

Some ecological methods were tried to understand whether such methods might be useful in managing the mite population. The ecological management practices were

3.6.1. Water availability

There were three treatments under this

i. Rainfed
ii. Channel irrigated
iii. Drip irrigated

Observations were taken from plots of Coconut Development Board, Vellanikkara, where palms are either rainfed or irrigated. Irrigated plots were of two types viz., channel irrigated and drip irrigated. Five palms were selected at random from these three plots. Observations were taken from the last bunches (nuts ready for harvest) at four months intervals (thrice in a year). Damage was assessed using scoring technique (NARP, 1990) (Table 3).

Table 3. Scoring details for nut damage

Score	Percentage of infested area
0	No visible symptom
1	<25 per cent damage on husk
2	26 – 50 per cent damage on husk
3	51 – 75 per cent damage on husk
4	>76 per cent damage on husk

3.6.2 Fertilizer treatments

Fertilizer treatments were done in a garden having uniform management practices in Instruction Farm, College of Horticulture, Vellanikkara. There were three treatments and a control and for each treatment five palms were selected at random from a block of WCT. All the palms used were of 24 years age.

3.6.2.1 Average management

Fertilizers were applied as per package recommendations for average management (KAU, 1996). Quantity of fertilizer used was 0.34:0.17:0.68 kg NPK/palm.

3.6.2.2 Good management

Fertilizers were applied as per package of practice recommendations for good management (KAU, 1996). Quantity of fertilizer used was 0.5:0.32:1.2 kg NPK/palm.

3.6.2.3 Applying less nitrogen

There were arguments that excessive nitrogen application caused increased mite infestation. Hence, in one treatment, the quantity of nitrogen was reduced to half. The quantity of fertilizer used was 0.25:0.32:1.2 kg NPK/palm.

3.6.2.4 Control

Control was also maintained in the same plot where, no fertilizer was applied.

Damage to nuts by mites was taken before the fertilizer application and two times after that at four months interval in all the cases. Nuts from the last bunches were used for taking observations. Damage was assessed using the scoring technique (NARP, 1999).

3.6.3 Micronutrients

To study the effects of micronutrients in managing the mite population, an experiment was carried out in a garden having uniform management practices. There were five treatments and a control and for each treatment five palms were selected at random from a block of WCT. Palms used were of 24 years age. Average management practices were followed in all the palms (0.34:0.17:0.68 kg NPK/palm) The additional treatment imposed was

i. $MgSO_4$ – 500g/palm/year

ii. $ZnSO_4$ – 200g/palm/year

iii. $MnSO_4$ – 200 g/palm/year

iv. Borax – 100g/palm/year

v. Micronutrient mixture (S, Mg, Mn, B, Zn, Cu, Fe, Cu, Mo) – 200 g/palm/year (Manufacturers: T. Stanes and Company Limited, Coimbatore)

All the above were applied as a single application during June 2000. Control was maintained without applying any micronutrient in the same block. Observations were taken before the application of micronutrients and two times after that at four months intervals. Nuts from last bunches were used for taking observations and damage was assessed using the scoring technique (NARP, 1999).

3.6.4 Crown cleaning

Effect of crown cleaning in managing mite population was studied. Two treatments and a control were maintained and for each treatment five palms of WCT of 24 years age were selected at random from a garden having uniform management practices. Design of the experiment was CRD. Treatments were

3.6.4.1 Two cleanings per year

Crown cleaning was done in five palms selected at random, twice in a year. First cleaning was during June 2000 and second was during October 2000.

3.6.4.2 One cleaning per year

Crown cleaning was done in five palms selected at random once in an year. Cleaning was done before the onset of South West monsoon, during June.

3.6.4.3 No cleaning

Five palms were left in the same field without cleaning.

Observations were taken from the last bunches before cleaning and at four months intervals. Damage was assessed using the scoring technique (NARP, 1999).

3.7 Statistical analysis of the data

Statistical analysis was done using MSTATC package.

Results

4. RESULTS

The experiments conducted in the year 1999 -2001 under the Department of Entomology, College of Horticulture, Vellanikkara revealed the following results.

4.1 Population of mites in bunches of increasing maturity

The population of *Aceria guerreronis* was counted from bunches of different maturity in the palms from unfertilized flower up to the ninth bunch. The results are given in Table 4.

Significant difference was noticed between the number of mites in each bunch. There were no mites in male flowers and unfertilized female flowers of all the inflorescence. Female flowers after pollination were found to show the incidence of mites. The initiation of infestation was found to be from second bunch onwards. Number of mites per nut was less in buttons of second bunches and the population built up rapidly to a peak on buttons of third or fourth bunch. Gradual reduction in mite population was noticed from fifth bunch onwards. Live mites were present even on nuts of ninth bunch, even though they were very negligible. Mean number of mites in buttons and nuts of second, third, fourth, fifth, sixth, seventh, eighth and ninth bunches were 496.2, 3021.8, 4415.2, 994.6, 509.2, 240.9, 92.8 and 37.7 respectively. Mite population on third bunch was not significantly different with that of fourth bunch. But these two bunches showed significant difference with that of fifth, sixth, seventh, eighth and ninth bunches.

4.2 Symptoms of damage

Mites inhabit the tender portion of nuts inside the perianth as colonies. They feed by lacerating and sucking the tender meristematic tissue covered by perianth.

Table 4. Population of mites in bunches of different maturity

Bunch number	Mite population
Unfertilized female flower	0 (0)
1	0 (0)
2	496.2 (1.381)
3	3021.8 (3.429)
4	4415.2 (3.602)
5	994.6 (2.822)
6	509.2 (2.597)
7	240.9 (2.134)
8	92.8 (1.471)
9	37.7 (1.024)

Figures in the parenthesis are log (X+1) transformed values

CD (0.05) = 0.6125

Mites can be seen on the inner side of inner bracts corresponding to the mite colony inside the perianth when the population is high. Substantial number of mites is seen on the bracts covering the area of attack inside the button. When the population exceeds further and goes beyond ten thousand they even migrate to the area in between the two rows of bracts. Colonies of mites comprise all life stages from egg to adults.

As a result of feeding of mite inside the perianth, a whitish triangular patch develops, extending from the lower edge of perianth. These symptoms can occur on any or all the three faces of the nuts. When the multiplication inside the perianth is at a slower rate, instead of the triangular patch, a whitish streak can be seen on small buttons. Further increase in mite population resulted in the extension of the patches and the length, width and appearance of these patches can be well differentiated from the newly formed fresh patches (Plate 4a). On removal of perianth, a light yellow or brown marking can be seen which is formed by the feeding of mites on the meristematic tissue inside the perianth (Plate 4b). In many cases when the perianth is removed, a pinkish streak can be seen inside. Prolonged feeding of mites result in the extension of the white patch and later it turns lightly brownish. The brownish patch was formed inside the perianth well before it was visible to outside and it appears outside from the base of the perianth. Later the patch increases in its length and width and the entire area appears as a dry necrotic patch. At this stage, the husk develops cracks, deep cuts and gummosis. As the nut grows, these necrotic areas enlarge and almost cover the entire area of nuts. The husk turns very hard and thin and hence dehusking becomes a problem. Affected nuts never attain normal size and shape and nuts will be very much deformed in appearance.

Initial white coloured symptoms were found on second, third and fourth bunches which indicate the initiation of infestation. Buttons of second bunches had only one or two white coloured patches. Third bunches carry three or four patches,

Plate 4a. Progressive development of symptom

Plate 4b. Onset of necrosis beneath the perianth

which are white or one fourth or half-necrotic. However, the number of white patches was more when compared to other types. Five or six patches were present on fourth bunches, most of which were one fourth or half-necrotic. White patches with initiation of necrosis were noticed commonly in fourth bunches. These buttons where necrosis has begun, carried maximum population of mites. Very rarely fully necrotic patches can be seen on buttons of third or fourth bunches. From fifth bunch onwards the number of three fourth necrotic or fully necrotic patches were very high when compared to third and fourth bunches. If the infestation had started from second bunch itself, by the time they reach fifth or sixth bunch, the nuts become almost fully necrotic. Fully white patches were very negligible in number from fifth bunch onwards. However, in a few palms, which have very tender husk, new colonies were formed even on sixth or seventh bunch.

4.2.1 Progressive development of symptoms due to mite attack

Visual observations of damage on buttons and nuts of different bunches were also taken. It was found that there was no surface damage on unfertilized female flowers and buttons just after pollination. The percentage of whitish area, necrotic area and total surface damage as a ratio of the total surface area of nuts was given in Table 5. Symptoms of surface damage were visible even from second bunch onwards. Visual damage on the surface of buttons was less when compared to matured nuts. On buttons of second bunch, there were only white coloured patches. Mean percentage of whitish area in the second bunch was 1.1 per cent. Necrosis started from third bunch onwards. But the necrotic area (0.6 per cent) was less compared to the whitish area (2.6 per cent) in third bunches. Necrotic (1.3 per cent) and whitish area (1.7 per cent) were found to be almost same in fourth bunch, whereas in fifth bunch the necrotic area (5.1 per cent) was more than the whitish area (1.4 per cent). The necrotic area gradually increases and from sixth bunch onwards normally there will not be any white patch at all. The mean of the total surface damage in the second, third, fourth,

Table 5. Percentage of surface damage due to mites on bunches of increasing maturity

Bunch number	Whitish area (%)	Necrotic area (%)	Total damage (%)
Unfertilized female flower	0.0 (0.707)	0.0 (0.707)	0.0 (0.707)
1	0 (0.707)	0 (0.707)	0.0 (0.707)
2	1.1 (1.174)	0.0 (0.707)	1.1 (1.174)
3	2.6 (1.716)	0.6 (0.954)	3.1 (1.88)
4	1.7 (1.464)	1.3 (1.251)	3.0 (1.699)
5	1.4 (1.364)	5.1 (2.041)	6.4 (2.420)
6	0.0 (0.707)	29.9 (5.379)	29.8 (5.379)
7	0.0 (0.707)	24.7 (4.931)	24.7 (4.931)
8	0.0 (0.707)	34.2 (5.883)	34.2 (5.883)
9	0.0 (0.707)	40.6 (6.411)	40.6 (6.411)
CD (0.05)	NS	1.326	1.352

Figures in the parenthesis are $\sqrt{x+0.5}$ transformed values
NS - Not significant at 5% level

fifth, sixth, seventh, eighth and ninth bunches were 1.1, 3.2,3.0, 6.5, 29.9, 24.7, 34.2 and 40.6 per cent respectively.

4.2.2 Relationship of mite population to surface damage

To find out the relationship of population of mites on the surface damage, first the surface damage was found out graphically by adopting the method as described earlier (Section 3.2).

The percentage of whitish and necrotic area before the removal of perianth (apparent surface damage) was calculated and the corresponding mite population was given in Table 6a.

The population of mite was 1014.5, 2848, 2414, 420, 153 and zero when the apparent surface damage was <1, 1-3, 3-6, 6-9, 9-12 and >12 cm^2 respectively. When the surface damage visible to outside was <1 cm^2, 98 per centwere found to be whitish with only 2 per cent of the area showing necrosis. When the total area of damage increased, the percentage of necrotic area also increased. Maximum mite population (2848) was noticed when the surface damage outside was 1-3 cm^2 with 82.6 per cent whitish area and 17.4 per cent necrosis and thereafter it showed a gradual reduction. 100 per cent necrosis was noticed when the surface damage was >12 cm^2 and the mite population became zero.

The percentage of whitish and necrotic area after the removal of perianth (actual surface damage) was calculated and the corresponding mite population was given in Table 6b.

The population of mite was 1638, 2763, 1844, 516, 83 and zero when the surface damage was 1-3, 3-6, 6-9, 9-12, 12-15 and >15 cm^2 respectively. Maximum

Table 6a. Relationship of mite population to apparent surface damage

Area of surface damage (cm^2)	Per cent whitish area	Per cent necrotic area	Mite population
<1	98.0	2.0	1014.5
1-3	82.6	17.4	2848.0
3-6	43.4	56.6	2414.0
6-9	22.6	77.4	420.0
9-12	2.0	98.0	153.0
>12	0.0	100.0	0.0

Table 6b. Relationship mite population to actual (exposed +concealed) surface damage

Area of surface damage (cm^2)	Per cent whitish area	Per cent necrotic area	Mite population
1-3	94.7	5.3	1638.0
3-6	73.6	26.4	2763.0
6-9	43.2	56.8	1844.0
9-12	13.3	86.7	516.0
12-15	4.0	96.0	83.0
>15	0.0	100.0	0.0

mite population (2763) was noticed when the surface damage was 3-6 cm^2, with percentage of whitish and necrotic area as 73.6 and 26.4 respectively. At a surface damage of 1-3 cm^2, the area was almost fully white (94.7 per cent), with only 5.3 per cent necrotic area. When the damage was >15 cm^2, the percentage of whitish area out of the total surface damage was zero.

4.2.3 Relationship of mite population to percentage of surface damage

The percentage of total surface damage, whitish area and necrotic area before and after the removal of the perianth was given in Table 7a and 7b respectively. Population of mite was 1500, 4927, 2501.5, 1036 and 140 and 72 when the apparent surface damage was <1, 1-3, 3-6, 6-9, 9-12 and >12 per cent respectively. Almost similar results were noticed after the removal of the perianth, where the mite population was 1357, 3432, 2019, 982, 124 and zero when the percentage of actual surface damage was <1, 1-3, 3-6, 6-9, 9-12 and >12 per cent respectively. At the lowest observed percentage of <1, the whitish area and the necrotic area was only 0.37 and 0.07 per cent before the removal of the perianth and it was 0.39 and 0.03 per cent after the removal of the perianth. The maximum whitish area was seen when the real percentage of surface damage was in between three and six in both cases. Then onwards the necrotic area increased and ended up at 20.3 and 17.6 per cent at >12 per cent surface damage before and after the removal of the perianth. The percentage of necrotic area was found to increase from fifth bunch onwards. From then onwards there was an increase in the necrotic area, which can go upto 100 per cent.

4.3 Population dynamics

Population of mites was taken for a period of one year at fortnightly interval from third and fourth bunches which were fixed as index bunches. Total rank score of third and fourth bunches for mite count by doing Kruskal walli's one way analysis of

Table 7a. Relationship of mite population to percentage of apparent surface damage

Per cent surface damage	Per cent whitish area	Per cent necrotic area	Mite population
<1	0.37	0.07	1500.0
1-3	2.03	0.32	4927.0
3-6	2.05	1.76	2501.5
6-9	1.75	4.90	1036.0
9-12	0.50	9.50	140.0
>12	0.21	20.30*	72.0

*This can go even upto 100% when the nuts grow further

Table 7b. Relationship of mite population to percentage of actual (exposed +concealed) surface damage

Per cent surface damage	Per cent whitish area	Per cent necrotic area	Mite population
<1	0.39	0.03	1357.0
1-3	2.20	0.43	3432.0
3-6	2.95	1.90	2019.0
6-9	1.80	5.60	982.0
9-12	0.70	9.60	124.0
>12	0.00	17.60*	0.0

*This can go even upto 100% when the nuts grow further variance and the mean of total score of third and fourth bunches were represented as Table 8. There was significant difference between the population of mites at different intervals. This indicates the change in population with time, which may be due to the variation in meteorological factors over a period of time. The difference in population is observed both in third and fourth bunches. Number of mites was more in fourth bunches than in third bunches.

Population of mite was high during May 2000 which was followed by a reduction during June and the population remained almost same without much noticeable change up to September. Further reduction was during September and population remained same up to February 2001. There was a steep rise in population during March and it remained same during April and May also. A maximum of about 22,853 and 19,161 mites per button was observed in a single button during May 2000 and March 2001 respectively.

Total rank score of third and fourth bunches for surface damage by doing Kruskal walli's one way analysis of variance and the mean of total score of third and fourth bunches were represented as Table 9. Significant difference in surface damage was also noted at different intervals of observations. This agrees with the change in number of mites on button with different weather factors. Surface damage was very high during July 2000 and first fortnight of August. A slight reduction was noted in September, which increased further in October. Visual damage was less from November to February 2001 but a steep increase occurred in March, which again decreased in June.

4.3.1 Correlation of mite population with weather parameters

The mite population in the third and fourth bunches over a period of one year was recorded. The population fluctuation was correlated with different weather

Table 8. Population of mites at fortnightly intervals (Total rank score by Kruskal Walii's one way analysis of variance)

Fortnights	Third bunch	Fourth bunch	Mean
I May 2000	1948.0	2410.0	2179.0
II May 2000	1938.0	2050.5	1994.3
I June 2000	1267.0	1742.5	1504.8
II June 2000	1409.5	1851.0	1630.3
I July 2000	2106.0	1204.0	1655.0
II July 2000	1442.0	1433.0	1437.5
I August 2000	1728.5	1457.0	1592.8
II August 2000	1505.0	1065.0	1285.0
I September 2000	1583	1029.5	1396.3
II September 2000	947.5	699.0	823.3
I October 2000	1231.0	1121.5	1176.3
II October 2000	864.5	853.0	858.8
I November 2000	865.0	789.0	827.0
II November 2000	649.5	1257.0	953.3
I December 2000	945.5	946.5	946.0
II December 2000	971.5	897.0	934.3
I January 2001	1172.0	688.5	930.3
II January 2001	835.5	900.5	868.0
I February 2001	926.0	873.0	899.5
II February 2001	792.0	902.5	847.3
I March 2001	1695.0	1659.0	1677.0
II March 2001	1910.0	2042.0	1976.0
I April 2001	1197.0	1506.0	1351.5
II April 2001	1728.5	1762.0	1745.3
I May 2001	1341.0	1748.0	1544.5
II May 2001	775.0	1231.0	1003.0

χ^2 of mean = 82.12**

** Significant at 1% level

Table 9. Percentage infestation of buttons at fortnightly intervals (Total rank score by Kruskal Walli's one way analysis of Variance)

Fortnights	Third bunch	Fourth bunch	Mean
II July 2000	1678.0	1786.5	1732.3
I August 2000	1755.0	1728.5	1741.8
II August 2000	1571.0	1119.5	1345.3
I September 2000	1501.5	936.5	1219.0
II September 2000	1024.0	783.0	903.5
I October 2000	1382.5	1030.5	1206.5
II October 2000	924.0	1412.5	1168.3
I November 2000	766.0	1054.0	910.0
II November 2000	713.0	1121.5	917.3
I December 2000	872.0	1057.0	964.5
II December 2000	838.5	979.5	909.0
I January 2001	1165.5	1032.5	1099.0
II January 2001	1047.0	778.0	912.5
I February 2001	1051.5	813.0	932.3
II February 2001	971.5	944.5	958.0
I March 2001	1775.0	1335.0	1555.0
II March 2001	1686.5	1852.0	1769.3
I April 2001	1279.0	1428.0	1353.5
II April 2001	1618.5	1353.0	1485.7
I May 2001	1409.0	1851.0	1630.0
II May 2001	919.5	1468.5	1194.0
I June 2001	971.5	1274.0	1122.8
II June 2001	979.5	961.0	970.3
I July 2001	1035.5	774.0	904.8

$\chi^2 = 42.01^{**}$
** Significant at 1% level

parameters like temperature, rainfall, relative humidity, wind speed and sunshine hours.

4.3.1.1 Population of mites and temperature

Population of mites was correlated with temperature (maximum and minimum) of current week (Table 10), current fortnight (Table 11), -1 fortnight (Table 12) and -2 fortnight (Table 13).

The relationship of the mite population with maximum and minimum temperature was studied separately. There was no significant relation between number of mites per button in third and fourth bunch and maximum temperature of current fortnight. But a positive significant relationship was noticed between the minimum temperature of current week, current fortnight, -1 and -2 fortnights. A positive relationship was noticed with maximum temperature of -2 fortnight.

4.3.1.2 Population of mites and rainfall

Rainfall of current week, current fortnight, -1 fortnight upto -3 fortnights was correlated with average mite population. There was no significant relation between the number of mites and rainfall of current week, current, -1, -2 and -3 fortnights. Thus the rainfall is not important in determining the population of mite. Number of rainy days of current week, current fortnight, -1,-2 and -3 fortnight were also correlated with the mite population. No significant relation was noticed in any case.

4.3.1.3 Population of mites and humidity

Population of mites was correlated with the relative humidity of current week, current fortnight, -1 fortnight upto -3 fortnights. The influence of morning

Table 10. Correlation of mite population with weather parameters of current week

	Maximum temperature	Minimum temperature	Morning humidity	Evening humidity	Wind speed	Sunshine hours	Rainfall	No. of rainy days	Mites on third bunch	Mites on fourth bunch	Mean population
Maximum temperature	1.000										
Minimum temperature	0.273	1.000									
Morning humidity	-0.168	-0.103	1.000								
Evening humidity	-0.436*	-0.204	0.767**	1.000							
Wind speed	0.049	-0.179	-0.910**	-0.648**	1.000						
Sunshine hours	0.409*	0.416*	-0.446*	-0.805**	0.309	1.000					
Rainfall	-0.431*	-0.413*	0.534**	0.732**	-0.351	-0.744**	1.000				
No. of rainy days	-0.470**	-0.324	0.619**	0.823**	-0.490**	-0.758**	0.825**	1.000			
Mites on third bunch	0.040	0.111	0.442*	0.229	-0.396*	0.083	0.191	0.151	1.000		
Mites on fourth bunch	0.216	0.577**	0.289	0.092	-0.408*	0.188	-0.087	0.031	0.688**	1.000	
Mean population	0.140	0.386*	0.397*	0.173	-0.442*	0.154	0.043	0.095	0.915**	0.921**	1.000

* Significant at 5% level
** Significant at 1% level

Table 11. Correlation of mite population with weather parameters of current fortnight

	Maximum temperature	Minimum temperature	Morning humidity	Evening humidity	Wind speed	Sunshine hours	Rainfall	No. of rainy days	Mites on third bunch	Mites on fourth bunch	Mean population
Maximum temperature	1.000										
Minimum temperature	0.513**	1.000									
Morning humidity	-0.308	0.094	1.000								
Evening humidity	-0.654**	-0.042	0.836**	1.000							
Wind speed	0.098	-0.282	-0.932**	-0.723**	1.000						
Sunshine hours	0.732**	0.246	-0.528**	-0.844**	0.388*	1.000					
Rainfall	-0.615**	-0.226	0.554**	0.753**	-0.413*	-0.804**	1.000				
No. of rainy days	-0.720**	-0.230	0.608**	0.824**	-0.472**	-0.872**	0.926**	1.000			
Mites on third bunch	-0.102	0.216	0.520**	0.361	-0.452*	-0.183	0.343	0.368	1.000		
Mites on fourth bunch	0.325	0.677**	0.333	0.118	-0.423*	0.114	0.011	0.036	0.688**	1.000	
Mean population	0.125	0.492**	0.466*	0.261	-0.479**	-0.033	0.183	0.214	0.915**	0.921**	1.000

* Significant at 5% level
** Significant at 1% level

Table 12. Correlation of mite population with weather parameters of -1 fortnight (one week lead time)

	Maximum temperature	Minimum temperature	Morning humidity	Evening humidity	Wind speed	Sunshine hours	Rainfall	No. of rainy days	Mites on third bunch	Mites on fourth bunch	Mean population
Maximum temperature	1.000										
Minimum temperature	0.291	1.000									
Morning humidity	0.067	0.079	1.000								
Evening humidity	-0.200	-0.131	0.831**	1.000							
Wind speed	-0.125	-0.274	-0.915**	-0.711**	1.000						
Sunshine hours	0.344	0.376*	-0.586**	-0.843**	0.422*	1.000					
Rainfall	-0.115	-0.256	0.614**	0.778**	-0.427*	-0.828**	1.000				
No. of rainy days	-0.289	-0.263	0.608**	0.819**	-0.440*	-0.860**	0.933**	1.000			
Mites on third bunch	0.213	0.286	0.480**	0.264	-0.403*	-0.131	0.232	0.189	1.000		
Mites on fourth bunch	0.345	0.670**	0.358	0.009	-0.445*	0.217	0.021	-0.073	0.688**	1.000	
Mean population	0.303	0.521**	0.461*	0.156	-0.465*	0.039	0.148	0.074	0.915**	0.921**	1.000

* Significant at 5% level
** Significant at 1% level

Table 13. Correlation of mite population with weather parameters of -2 fortnight (two weeks lead time)

	Maximum temperature	Minimum temperature	Morning humidity	Evening humidity	Wind speed	Sunshine hours	Rainfall	No. of rainy days	Mites on third bunch	Mites on fourth bunch	Mean population
Maximum temperature	1.000										
Minimum temperature	0.518**	1.000									
Morning humidity	-0.305	0.091	1.000								
Evening humidity	-0.665**	-0.069	0.831**	1.000							
Wind speed	0.078	-0.300	-0.927**	-0.703**	1.000						
Sunshine hours	0.734**	0.246	-0.525**	-0.853**	0.367	1.000					
Rainfall	-0.616**	-0.225	0.553**	0.761**	-0.397*	-0.804**	1.000				
No. of rainy days	-0.720**	-0.224	0.608**	0.836**	-0.454	-0.872**	0.927**	1.000			
Mites on third bunch	0.183	0.305	0.394*	0.139	-0.363	-0.057	0.108	0.124	1.000		
Mites on fourth bunch	0.603**	0.610**	0.320	-0.101	-0.464*	0.348	-0.147	-0.182	0.688**	1.000	
Mean population	0.447*	0.490**	0.398*	0.025	-0.458*	0.166	-0.016	-0.040	0.915**	0.921**	1.000

* Significant at 5% level
** Significant at 1% level

humidity and evening humidity on mite population was noted separately and it was seen that there was no significant relation between population of mite and evening humidity. A significant positive correlation was noted between the mite population and morning humidity of current week, current fortnight and other fortnights (Table10, 11,12 and 13). Population as well as humidity was minimum during the period between November 2000 and February 2001.

4.3.1.4 Population of mites and wind speed

Mite population was correlated with wind speed of current week, current fortnight, -1 fortnight upto -3 fortnights. There was significant relation between mite population and wind speed. Population of mites was negatively correlated with the wind speed of current week and current fortnight and other fortnights (Table10, 11,12 and 13). Population was minimum while wind speed was maximum during the period between November 2000 and February 2001.

4.3.1.5 Population of mites and sunshine hours

Mite population was correlated with sunshine hours of current week, current fortnight, -1 fortnight upto -3 fortnights. Even though there is some negative relation between mite population and sunshine hours of current fortnight, it was found to be non-significant.

4.3.1.6. Multiple regression analysis for influence of weather factors on mite population

The influence of weather factors on the build up of mite population was correlated independently. Relationships were obtained for some, while some weather factors did not have any effect (Table 10, 11, 12 and 13). In order to apportion the influence of these factors and to arrive at the contribution in the final population build up, regression equation was worked out. The relationship with an R^2 of 0.527 is

$$Y = -9097.16 + 76.22X_1 + 117.49X_2 + 54.11X_3 + 133.02X_4$$

Y = Mite population

X_1 = Maximum temperature

X_2 = Minimum temperature

X_3 = Morning humidity

X_4 = Wind speed

Determinant matrix, ANOVA and other details are given as Appendix III.

4.4 Population of predatory mites

Predatory mites were also found along with eriophyid mites. The average population of the predatory mites from the different bunches at monthly intervals is given in Table 14.

Predatory mites are more active, lesser in number but larger in size compared to eriophyid mites. Eggs of these mites, which are much larger than that of eriophyid mites, were seen in the colonies of coconut mites. Predatory mites were more in fifth and sixth bunch compared to third and fourth bunches. The average population of predatory mites in third, fourth fifth and sixth bunches were 0.09, 0.91, 4.5 and 1.43 respectively. They were comparatively more during May 2000 to September 2000 and March 2001 to May 2001. Maximum population of predatory mites was noticed in May 2000 (3.7) and March 2001 (3.16). Predatory mites were almost absent during October 2000 to January 2001.

Table 14. Population of predatory mites at monthly intervals

Bunch / Month	Second	Third	Fourth	Fifth	Sixth	Mean
May 2000	0.2	0.1	1.3	10.6	6.3	3.7
June 2000				8.6	2.2	2.16
July 2000		0.5	2.0	5.2	1.8	1.9
August 2000		0.2	0.2	4.4		0.96
September 2000		0.4	2.6	5.6	1.3	1.98
October 2000						
November 2000				0.8		0.16
December 2000						
January 2001						
February 2001				3.3		0.66
March 2001			3.2	8.4	4.2	3.16
April 2001			1.6	6.9	1.7	2.04
May 2001			0.9	4.7	1.2	1.36
Mean	0.01	0.09	0.91	4.50	1.43	1.39

4.5 Influence of plant morphology on the distribution pattern of mites

Variation in the population of mite with different characters like height of the palm, crown shape, perianth arrangement, nut shape and nut colour were studied and the results obtained are given below.

4.5.1 Height of tree

Comparison of the number of mites present in the buttons of third (Table 15a) and fourth bunches (Table 15b) and their means (Table 15c) between palms having different heights viz., < 6m, 6-12m and >12m were given. There was no significant difference in the mite population on palms having different heights. Percentage of nut infestation on third (Table 16a) or fourth (Table 16b) bunches and their means (Table 16c) were also compared. The percentage incidence also did not show a significant difference with the height of palm. The infestation, nevertheless, changed with different months of observation. However, there was no variation in the amount of infestation at different intervals in accordance with the height of the palm i.e. within the same period of observation, the mite population did not differ significantly between different heights of the palm.

4.5.2 Crown shape

Population of mites and Percentage of nut infestation due to mite attack were compared for palms having different crown shapes viz., spherical, semi spherical and closed. Comparison of mite count and percentage of nut infestation of third and fourth bunches and their means were given in Table 17a, 17b, 17c, 18a, 18b and 18c respectively.

Table 15a. Fluctuations in mite population in the third bunch buttons on palms of different heights

Height / Month	<6m	6-12m	>12m	Mean
December 2000	1183.4 (0.754)	535.2 (1.653)	326.0 (1.096)	681.0 (1.168)
January 2001	257.0 (1.436)	146.2 (1.430)	567.0 (1.237)	323.6 (1.368)
February 2001	699.6 (1.830)	1267.6 (1.295)	547.0 (2.044)	838.1 (1.723)
March 2001	939.4 (2.884)	3142.8 (2.819)	1648.0 (2.578)	1910.1 (2.760)
April 2001	441.8 (2.155)	2818.6 (3.219)	579.6 (2.130)	1280.0 (2.502)
May 2001	0.0 (0.000)	204.2 (1.074)	428.6 (2.151)	210.9 (1.705)
Mean	586.9 (1.510)	1352.5 (1.915)	682.7 (1.873)	874.0 (1.766)

Figures in the parenthesis are log (X+1) transformed values

CD (0.05) Height = NS
Month = 0.9986
Months within heights = NS

Table 15b. Fluctuations in mite population in the fourth bunch buttons on palms of different heights

Height / Month	<6m	6-12m	>12m	Mean
December 2000	1919.8 (2.548)	826.0 (1.322)	68.6 (0.507)	938.1 (1.459)
January 2001	1074.2 (1.925)	2211.6 (2.712)	461.4 (2.168)	1249.1 (2.269)
February 2001	2566.0 (2.679)	2226.6 (3.118)	1566.8 (2.431)	2119.8 (2.743)
March 2001	2553.4 (3.388)	4389.4 (3.588)	4511.8 (3.566)	3818.2 (3.514)
April 2001	2679.2 (3.281)	4276.6 (3.281)	3434.8 (3.442)	3463.5 (3.335)
May 2001	810.4 (2.236)	908.2 (2.865)	1424.2 (2.960)	1047.6 (2.687)
Mean	1933.8 (2.676)	2473.1 (2.814)	1911.2 (2.513)	2106.1 (2.668)

Figures in the parenthesis are log (X+1) transformed values

CD (0.05) Height = NS
Month = 0.7963
Months within heights = NS

Table 15c. Fluctuations in mite population (mean of third and fourth bunches) on palms of different heights

Height / Month	<6m	6-12m	>12m	Mean
December 2000	1551.6 (2.467)	680.6 (2.156)	197.3 (1.423)	809.8 (2.015)
January 2001	665.7 (2.270)	1179.2 (2.505)	514.2 (2.581)	786.3 (2.452)
February 2001	1632.8 (2.513)	1747.1 (3.072)	1056.9 (2.962)	1478.9 (2.849)
March 2001	1746.4 (3.232)	3766.1 (3.557)	3079.9 (3.450)	2864.1 (3.413)
April 2001	1560.5 (3.054)	3547.6 (3.411)	2007.2 (3.228)	2371.7 (3.231)
May 2001	405.2 (1.996)	556.2 (2.618)	926.4 (2.884)	629.2 (2.499)
Mean	1260.3 (2.589)	1912.8 (2.886)	1296.9 (2.755)	1490.1 (2.743)

Figures in the parenthesis are log (X+1) transformed values

CD (0.05) Height = NS
Month = 0.6440
Month with height = NS

Table 16a. Fluctuations in percentage infestation in the third bunch buttons on palms of different heights

Height / Month	<6m	6-12m	>12m	Mean
December 2000	11.6 (0.532)	22.6 (0.865)	10.0 (0.577)	14.7 (0.652)
January 2001	20.6 (0.884)	17.2 (0.858)	10.6 (0.561)	16.1 (0.768)
February 2001	21.4 (0.906)	23.4 (0.906)	18.8 (0.792)	20.5 (0.868)
March 2001	58.6 (1.700)	54.4 (1.390)	26.6 (1.206)	46.5 (1.432)
April 2001	42.6 (1.325)	31.0 (1.446)	10.6 (0.865)	28.1 (1.212)
May 2001	0.00 (0.000)	3.8 (0.260)	21.5 (1.131)	8.4 (1.464)
Mean	25.8 (0.891)	25.4 (0.954)	16.0 (0.852)	22.4 (0.899)

Figures in the parenthesis are log (X+1) transformed values

CD (0.05) Height = NS
Month = 0.5128
Months within heights = NS

Table 16b. Fluctuations in percentage infestation in the fourth bunch buttons on palms of different heights

Height / Month	<6m	6-12m	>12m	Mean
December 2000	33.0 (1.248)	18.8 (0.672)	2.8 (0.235)	18.2 (0.731)
January 2001	47.2 (1.130)	51.6 (1.425)	21.8 (1.128)	4.2 (1.228)
February 2001	47.6 (1.396)	59.2 (1.690)	50.4 (1.407)	52.4 (1.498)
March 2001	72.6 (1.836)	85.0 (1.918)	62.0 (1.699)	73.2 (1.817)
April 2001	62.2 (1.701)	65.8 (1.738)	39.4 (1.522)	55.8 (1.653)
May 2001	52.0 (1.442)	25.2 (1.383)	63.2 (1.805)	46.8 (1.543)
Mean	52.4 (1.465)	50.9 (1.471)	39.9 (1.299)	47.7 (1.412)

Figures in the parenthesis are log (X+1) transformed values

CD (0.05) Height = NS
Month = 0.4363
Months within heights = NS

Table 16c. Fluctuations in percentage infestation (mean of third and fourth bunch) on palms of different heights

Height / Month	<6m	6-12m	>12m	Mean
December 2000	22.3 (1.120)	20.7 (1.015)	6.4 (0.473)	16.4 (0.87)
January 2001	33.9 (1.287)	34.4 (1.281)	16.23 (0.997)	28.1 (1.188)
February 2001	34.5 (1.299)	41.3 (1.598)	33.6 (1.498)	36.4 (1.465)
March 2001	65.6 (1.799)	49.7 (1.838)	44.3 (1.588)	59.8 (1.742)
April 2001	52.4 (1.639)	48.4 (1.654)	25.0 (1.325)	41.9 (1.539)
May 2001	26.0 (1.208)	14.5 (1.131)	42.37 (1.633)	27.6 (1.324)
Mean	39.1 (1.392)	38.1 (1.420)	27.9 (1.252)	35.1 (1.355)

Figures in the parenthesis are log (X+1) transformed values

CD (0.05) Height = NS
Month = 0.3585
Month with height = NS

Table 17a. Fluctuations in mite population in the third bunch buttons on palms of different crown shapes

Crown shape / Month	Spherical	Semispherical	Closed	Mean
December 2000	209.6 (1.055)	535.2 (1.653)	2640.6 (2.488)	1128.2 (1.732)
January 2001	325.6 (1.162)	146.8 (1.430)	1165.6 (1.347)	546.0 (1.313)
February 2001	351.8 (1.582)	1267.6 (1.295)	413.0 (1.608)	677.4 (1.495)
March 2001	1807.6 (2.607)	3142.8 (2.819)	1161.0 (2.969)	2037.1 (2.798)
April 2001	123.6 (1.692)	2818.6 (3.219)	1345.0 (2.347)	1428.8 (2.419)
May 2001	123.0 (1.692)	204.2 (1.074)	197.8 (1.503)	163.9 (1.036)
Mean	484.5 (1.438)	1352.5 (1.915)	1153.7 (2.044)	996.9 (1.799)

Figures in the parenthesis are log (X+1) transformed values

CD (0.05) Crown shape = NS
Month = 1.0315
Months within crown shape = NS

Table 17b. Fluctuations in mite population in the fourth bunch buttons on palms of different crown shapes

Crown shape / Month	Spherical	Semispherical	Closed	Mean
December 2000	715.6 (1.790)	1307.6 (2.429)	330.4 (1.616)	784.5 (1.945)
January 2001	936.6 (2.821)	2211.6 (2.712)	2960.8 (2.699)	2030.3 (2.744)
February 2001	1399.8 (2.560)	2226.6 (3.118)	1964.4 (3.093)	1863.6 (2.924)
March 2001	3382.8 (3.494)	4389.4 (3.588)	5782.0 (3.620)	4518.1 (3.591)
April 2001	2425.6 (3.106)	4276.6 (3.281)	4417.8 (3.621)	3706.6 (3.336)
May 2001	1007.2 (2.391)	908.2 (2.865)	2290.0 (3.271)	1401.8 (2.842)
Mean	1644.6 (2.694)	2553.3 (2.999)	2957.5 (2.998)	2385.1 (2.897)

Figures in the parenthesis are log (X+1) transformed values

CD (0.05) Crown shape = NS
Month = 0.7224
Months within crown shape = 1.0607

Table 17c. Fluctuations in mite population (mean of third and fourth bunch) on palms of different crown shapes

Crown shape / Month	Spherical	Semispherical	Closed	Mean
December 2000	462.6 (2.545)	921.4 (2.328)	1485.2 (2.342)	956.4 (2.405)
January 2001	631.1 (2.773)	1179.2 (2.505)	2063.2 (3.080)	1291.167 (2.786)
February 2001	875.8 (2.402)	1747.1 (3.072)	1188.7 (2.872)	1270.5 (2.782)
March 2001	2595.2 (3.336)	3766.1 (3.557)	3471.5 (3.483)	3277.6 (3.469)
April 2001	1274.3 (2.903)	3547.6 (3.411)	2881.4 (3.445)	2567.7 (3.253)
May 2001	548.5 (2.189)	556.2 (2.618)	1243.9 (3.021)	782.8 (2.609)
Mean	1064.5 (2.697)	1952.9 (2.915)	2055.6 (3.040)	1691.1 (2.884)

Figures in the parenthesis are log (X+1) transformed values

CD (0.05) Crown shape = NS
Month = 0.5718
Month with crown shape = NS

Table 18a. Fluctuations in percentage infestation in the third bunch buttons on palms of different crown shapes

Crown shape / Month	Spherical	Semispherical	Closed	Mean
December 2000	6.4 (0.489)	12.6 (0.787)	59.6 (1.492)	26.2 (0.923)
January 2001	12.0 (0.591)	35.8 (1.062)	36.6 (0.786)	28.1 (0.813)
February 2001	35.8 (1.259)	10.8 (0.545)	25.2 (0.977)	23.9 (0.927)
March 2001	48.6 (1.419)	28.4 (0.912)	44.8 (1.589)	40.6 (1.307)
April 2001	46.6 (1.579)	46.2 (1.503)	57.0 (1.476)	49.9 (1.519)
May 2001	7.0 (0.491)	8.4 (0.536)	29.2 (1.007)	14.8 (0.678)
Mean	26.067 (0.971)	23.7 (0.891)	42.067 (1.221)	30.6 (1.028)

Figures in the parenthesis are log (X+1) transformed values

CD (0.05) Crown shape = NS
Month = 0.5636
Months within crown shape = NS

Table. 18b. Fluctuations in percentage infestation in the fourth bunch buttons on palms of different crown shapes

Crown shape / Month	Spherical	Semispherical	Closed	Mean
December 2000	17.4 (0.874)	30.4 (1.261)	28.0 (0.971)	25.2 (1.035)
January 2001	40.2 (1.514)	58.8 (1.488)	68.4 (1.529)	55.8 (1.510)
February 2001	36.2 (1.326)	79.2 (1.865)	59.7 (1.748)	58.2 (1.646)
March 2001	61.6 (1.790)	74.0 (1.573)	83.4 (1.912)	73.0 (1.758)
April 2001	40.6 (1.540)	48.0 (1.642)	76.6 (1.859)	55.1 (1.680)
May 2001	38.6 (1.298)	56.6 (1.734)	63.0 (1.8)	52.7 (1.611)
Mean	39.1 (1.390)	57.8 (1.594)	63.1 (1.637)	53.3 (1.540)

Figures in the parenthesis are log (X+1) transformed values

CD (0.05) Crown shape = NS
Month = 0.4111
Months within crown shape = NS

Table 18c. Fluctuations in percentage infestation (mean of third and fourth bunch) on palms of different crown shapes

Crown shape / Month	Spherical	Semispherical	Closed	Mean
December 2000	11.9 (1.082)	21.5 (1.137)	43.8 (1.389)	25.7 (1.203)
January 2001	26.1 (1.384)	47.3 (1.402)	52.5 (1.678)	41.9 (1.488)
February 2001	36.0 (1.309)	45.0 (1.61)	42.2 (1.579)	41.1 (1.499)
March 2001	55.1 (1.714)	51.2 (1.444)	64.1 (1.793)	56.8 (1.650)
April 2001	43 (1.570)	47.1 (1.62)	66.8 (1.818)	52.5 (1.669)
May 2001	22.8 (1.146)	32.5 (1.519)	46.1 (1.642)	33.8 (1.436)
Mean	32.5 (1.367)	40.7 (1.455)	52.5 (1.650)	41.9 (1.491)

Figures in the parenthesis are log (X+1) transformed values.

CD (0.05) Crown shape = NS
Month = NS
Month with crown shape = NS

A significant change in the population of mite in the buttons of third and fourth bunch was not noticed with different shapes of crown. The percentage of nut infestation on nuts of third and fourth bunches also showed the same results. Generally there was comparatively less number of mites and less surface damage on buttons of spherical crowned palms, whereas palms with semi spherical and closed crown bears almost same number of mites, but visual damage was comparatively more for closed crown than semi spherical crown. But all these were not significant. This indicated that the infestation of mites was irrespective of crown shape. The infestation, however, was significantly different between different months of observation. In this case also, there was no variation in the amount of infestation as influenced by the crown shape of the palm.

4.5.3 Perianth arrangement

The difference in the incidence of mites with respect to the adpression of the perianth, arrangement of each tepal and variation on the population between various portions under each tepal were evaluated and the results were given below.

4.5.3.1 Variation in mite population with the adpression of perianth

Since the arrangement of inner tepals is important, nuts for taking observation were selected only after collection. There were two types of perianth arrangement

a) Less adpressed perianth
b) Tightly adpressed perianth

Both types of tepal arrangement could be found on nuts from same inflorescence. Observations from buttons having two types of perianth arrangement were given in Table 19. Mean of the number of mites from buttons of same inflorescence with less adpressed and tightly adpressed perianth were 1435.6 and 1347.7 respectively and there was no significant difference in the population of mites with this nut character.

4.5.3.2 Variation in mite population with the arrangement of each tepal

The three tepals in the inner side are arranged differently in less adpressed type of perianth arrangement. Based on the severity of damage, symptoms were grouped as explained in materials and methods. Analysis of score was done and given in Table 20. Sum of the scores which was an index of the intensity of damage at the level of fourth, fifth and sixth bracts were 2708, 1802 and 1097.5 respectively. There was significant difference in the surface damage at the level of these three tepals. This indicates the difference in the colonization of mites under each inner tepal. Maximum surface damage was noticed at the level of fourth tepal followed by fifth and then sixth tepal.

4.5.3.3 Variation in mite population with the regions under each tepal

The entry of mites inside the cap of buttons also varies with the arrangement of tepals (Table 21). Areas just below the tepals were divided into four as explained in materials and methods. Thus fourth tepal has two types of areas just below the tepal and named as 'outer edge' and 'middle' and the average score for these portions were 204 and 98.5 respectively. Fifth tepal has three parts viz., 'outer edge', 'middle' and 'inner edge' and the average score for these portions were 140, 120 and 80 respectively. Sixth tepal has two portions, 'middle' and 'inner edge' and the average score which was an index of entry of mites through this portions were 133.5 and 89 respectively. Maximum entry points were noted in the fourth tepal followed by fifth and sixth tepals. Within the tepal there was difference in selection of entry points by

Table 19. Population of mites based on perianth arrangement

No.	Tightly adpressed	Less adpressed
1	101	184
2	2042	2090
3	1024	5053
4	687	2229
5	6600	572
6	734	448
7	3984	3428
8	117	327
9	334	442
10	1463	5137
11	586	1216
12	704	1996
13	1259	661
14	399	1336
15	506	293
16	3295	323
17	704	123
18	986	394
19	331	1390
20	822	1284
Mean	1435.6	1347.7

t value = -0.2052^{NS}

Table 20. Index of apparent damage by mites in the tepals (Total rank score by Kruskal Walli's one way analysis of variance)

No.	Fourth tepal	Fifth tepal	Sixth tepal
1	97.0	79.0	11.0
2	54.5	54.5	11.0
3	97.0	54.5	54.5
4	79.0	54.5	54.5
5	79.0	54.5	31.5
6	54.5	54.5	31.5
7	97.0	79.0	79.0
8	97.0	54.5	31.5
9	79.0	97.0	54.5
10	79.0	54.5	31.5
11	97.0	79.0	11.0
12	97.0	97.0	79.0
13	97.0	79.0	31.5
14	97.0	11.0	11.0
15	79.0	54.5	11.0
16	79.0	54.5	31.5
17	54.5	31.5	11.0
18	79.0	54.5	11.0
19	54.5	11.0	11.0
20	97.0	54.5	31.5
21	79.0	31.5	11.0
22	97.0	54.5	54.5
23	79.0	31.5	11.0
24	97.0	54.5	31.5
25	31.5	11.0	11.0
26	54.5	11.0	11.0
27	79.0	31.5	31.5
28	31.5	11.0	11.0
29	54.5	31.5	11.0
30	79.0	54.5	31.5
31	97.0	79.0	54.5
32	97.0	97.0	97.0
33	54.5	31.5	11.0
34	79.0	54.5	79.0
35	54.5	54.5	11.0
Total rank score	2708	1802	1097.5

Kruskal Walli's one way analysis of variance H - static = 45.03**
** Significant at 1% level

Table 21. Index of apparent damage by mites through different regions of tepals (Total rank score by Kendal's co-efficient of concordance)

No	Fourth tepal		Fifth tepal			Sixth tepal	
	Outer edge	Middle	Outer edge	Middle	Inner edge	Middle	Inner edge
1	7.0	3.0	6.0	3.0	3.0	3.0	3.0
2	7.0	3.0	6.0	3.0	3.0	3.0	3.0
3	7.0	2.0	5.0	5.0	2.0	5.0	2.0
4	5.0	5.0	5.0	5.0	1.5	5.0	1.5
5	7.0	2.5	2.5	5.5	2.5	5.5	2.5
6	6.0	2.5	6.0	2.5	2.5	6.0	2.5
7	6.0	2.5	2.5	6.0	2.5	6.0	2.5
8	7.0	5.0	2.0	5.0	2.0	5.0	2.0
9	6.5	3.0	6.5	3.0	3.0	3.0	3.0
10	5.0	5.0	1.5	5.0	1.5	5.0	5.0
11	7.0	2.5	2.5	5.5	2.5	5.5	2.5
12	7.0	2.5	5.5	2.5	2.5	5.5	2.5
13	7.0	3.5	3.5	3.5	3.5	3.5	3.5
14	7.0	2.5	5.5	5.5	2.5	2.5	2.5
15	7.0	4.5	4.5	4.5	1.5	4.5	1.5
16	7.0	2.5	5.5	2.5	2.5	5.5	2.5
17	7.0	3.5	3.5	3.5	3.5	3.5	3.5
18	7.0	3.0	6.0	3.0	3.0	3.0	3.0
19	7.0	3.5	3.5	3.5	3.5	3.5	3.5
20	7.0	2.5	5.5	5.5	2.5	2.5	2.5
21	7.0	4.0	4.0	4.0	1.0	4.0	4.0
22	7.0	3.5	3.5	3.5	3.5	3.5	3.5
23	7.0	3.0	6.0	3.0	3.0	3.0	3.0
24	6.5	2.5	5.0	2.5	2.5	6.5	2.5
25	6.5	4.0	1.5	4.0	1.5	6.5	4.0
26	7.0	2.5	2.5	5.5	2.5	5.5	2.5
27	6.5	3.0	6.5	3.0	3.0	3.0	3.0
28	6.5	3.0	6.5	3.0	3.0	3.0	3.0
29	3.0	3.0	6.5	3.0	3.0	6.5	3.0
30	6.5	3.0	6.5	3.0	3.0	3.0	3.0
31	7.0	3.0	3.0	3.0	3.0	3.0	3.0
Total rank score	204	98.5	140	120	80	133.5	89

Kendal's co-efficient of concordance W = 0.443**

** Significant at 1% level

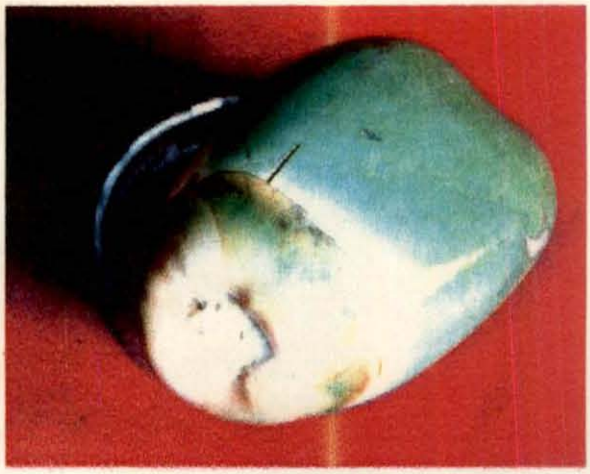
mites. Maximum entry of mites was through the 'outer edge' of fourth tepal (Plate 5a) followed by the 'outer edge' of fifth tepal (Plate 5b). In the sixth tepal, the 'middle' portion is preferred more (Plate 5c), which have no 'outer edge'. Among the 'middle' portions, the one of sixth tepal is preferred more followed by that of fifth and fourth tepal. Area of tepals that are overlapped by the edge of other tepals is least preferred by mites for their entry. The entry of mites through this area is more in sixth tepal when compared to that of fifth tepal.

4.5.4 Nut Shape

Palms bearing different shaped nuts viz., round, oval and oblong were selected to study the preference of mite to the shape of nuts. Comparison of mite population and percentage of nut infestation on third and fourth bunches and mean of third and fourth bunches with different shaped nuts were given in Table 22a, 22b, 22c, 23a, 23b and 23c respectively. Significant difference in the population of mites was noted with nut shape, both in third and fourth bunches. There was significant difference in the number of mites and percentage of infested nuts on third and fourth bunch of round and oblong shaped nuts. There was no significant difference between the mite population and percentage nut infestation between round and oval shaped nuts in the third bunch. But a variation in the population of mite and percentage of infestation was observed in fourth bunch. Even though the nut infestation in third bunch of oval and oblong shaped nuts vary, there was no significant difference in the number of mites in these bunches. Number of mites per button and the percentage of infested buttons of fourth bunch of oblong and oval shaped nuts were almost the same. Generally it was found that maximum number of mites were noticed in oblong shaped nuts with a mean of 2149.6 which was almost the same to that of oval shaped nuts with a mean of 1952.9. Percentage of nut infestation was also high in oblong shaped nuts than in oval shaped nuts where the means of damage were 52.5 percent and 40.7 percent respectively. But there was no significant difference in mite count and

Plate 5. Variation in mite population with the regions under each tepal

5a. Fourth tepal



5b. Fifth tepal

5c. Sixth tepal

Plate 6. Variation in damage symptom based on nut shape

Plate 7. Variation in damage symptom based on nut colour

Table 22a. Fluctuations in mite population in the third bunch buttons on palms of different nut shapes

Month \ Nut shape	Round	Oval	Oblong	Mean
December 2000	54.8 (1.137)	695.8 (1.288)	535.2 (1.653)	428.6 (1.359)
January 2001	66.4 (1.106)	338.2 (1.998)	146.8 (1.430)	183.8 (1.511)
February 2001	289.2 (2.125)	1182.2 (2.887)	1267.6 (1.295)	913.0 (2.102)
March 2001	791.2 (2.789)	2635.8 (3.399)	3142.8 (2.819)	2189.9 (3.002)
April 2001	79.4 (1.162)	2092.8 (3.122)	2818.6 (3.219)	1663.6 (2.501)
May 2001	0.0 (0.0)	371.6 (2.089)	204.2 (1.074)	191.9 (1.054)
Mean	213.5 (1.386)	1219.0 (2.464)	1352.5 (1.915)	928.4 (1.922)

Figures in the parenthesis are log (X+1) transformed values

CD (0.05) Nut shape = 0.5802
Month = 0.8208
Months within nut shape = NS

Table 22b. Fluctuations in mite population in the fourth bunch buttons on palms of different nut shapes

Nut shape / Month	Round	Oval	Oblong	Mean
December 2000	116.4 (0.926)	1307.6 (2.429)	1439.0 (2.008)	954.3 (1.787)
January 2001	405.4 (1.150)	2211.6 (2.712)	1282.4 (2.491)	1299.8 (2.118)
February 2001	501.6 (2.603)	2226.6 (3.118)	3692 (3.512)	2140.1 (3.078)
March 2001	1606.4 (3.118)	7489.4 (3.588)	7263.6 (3.809)	4419.8 (3.505)
April 2001	474.8 (2.550)	4276.6 (3.281)	2872.2 (3.23)	2541.2 (3.041)
May 2001	372.2 (2.548)	908.2 (2.865)	1929.8 (3.257)	1072.1 (2.891)
Mean	579.4 (2.149)	2553.3 (2.99)	3079.3 (3.062)	2070.8 (2.737)

Figures in the parenthesis are log (X+1) transformed values

CD (0.05) Nut shape = 0.4796
Month = 0.6783
Months within nut shape = NS

Table 22c. Fluctuations in mite population (mean of third and fourth bunch) on palms of different nut shapes

Nut shape / Month	Round	Oval	Oblong	Mean
December 2000	85.6 (1.165)	921.4 (2.328)	1067.4 (2.463)	691.4 (1.985)
January 2001	235.9 (1.32)	1179.2 (2.505)	810.3 (2.738)	741.8 (2.188)
February 2001	395.4 (2.498)	1747.1 (3.072)	2437.1 (3.343)	1526.5 (2.971)
March 2001	1198.8 (3.017)	3766.1 (3.557)	4949.7 (3.671)	3304.8 (3.415)
April 2001	277.1 (2.32)	3547.6 (3.411)	2482.5 (3.322)	2120.4 (3.018)
May 2001	186.1 (2.249)	556.2 (2.618)	1150.7 (3.028)	631.0 (2.632)
Mean	396.4 (2.095)	1952.9 (2.915)	2149.6 (3.192)	5162.5 (2.77)

Figures in the parenthesis are log (X+1) transformed values

CD (0.05) Nut shape = 0.3894
Month = 0.5510
Month with nut shape = NS

Table 23a. Fluctuations in percentage infestation in the third bunch buttons on palms of different nut shapes

Nut shape / Month	Round	Oval	Oblong	Mean
December 2000	13.4 (0.808)	12.6 (0.787)	14 (0.592)	13.6 (0.729)
January 2001	19.4 (0.883)	35.8 (1.062)	27.6 (1.234)	27.6 (1.060)
February 2001	28.2 (1.426)	10.8 (0.545)	30.6 (1.445)	23.2 (1.139)
March 2001	45.0 (1.625)	28.4 (0.912)	91.4 (1.956)	54.9 (1.498)
April 2001	16.4 (0.842)	46.2 (1.503)	66.2 (1.807)	42.9 (1.384)
May 2001	0.0 (0.0)	8.4 (0.536)	36.0 (1.294)	14.8 (0.610)
Mean	20.4 (0.931)	23.7 (0.891)	44.4 (1.388)	29.5 (1.070)

Figures in the parenthesis are log (X+1) transformed values

CD (0.05) Nut shape = 0.3313
Month = 0.4678
Months within nut shape = NS

Table 23b. Fluctuations in percentage infestation in the fourth bunch buttons on palms of different nut shapes

Nut shape / Month	Round	Oval	Oblong	Mean
December 2000	8.6 (0.531)	30.4 (1.261)	45.4 (1.380)	28.1 (1.058)
January 2001	12.0 (0.580)	58.8 (1.488)	41.8 (1.367)	37.5 (1.145)
February 2001	23.0 (1.360)	79.2 (1.865)	51.4 (1.65)	51.2 (1.625)
March 2001	50 (1.701)	74.0 (1.573)	100 (2.04)	74.6 (1.759)
April 2001	28 (1.433)	48.0 (1.642)	58.8 (1.708)	44.9 (1.594)
May 2001	21.1 (1.317)	56.6 (1.734)	66.2 (1.812)	48.1 (1.621)
Mean	23.8 (1.154)	57.8 (1.594)	60.6 (1.653)	47.4 (1.467)

Figures in the parenthesis are log (X+1) transformed values

CD (0.05) Nut shape = 0.2663
Month = 0.3768
Months within nut shape = NS

Table 23c. Fluctuations in percentage infestation (mean of third and fourth bunch) on palms of different nut shapes

Nut shape / Month	Round	Oval	Oblong	Mean
December 2000	11.0 (0.749)	21.5 (1.137)	30.1 (1.264)	20.8 (1.050)
January 2001	15.7 (0.860)	47.3 (1.402)	34.7 (1.534)	32.5 (1.265)
February 2001	25.6 (1.416)	45 (1.610)	41 (1.577)	37.2 (1.534)
March 2001	47.5 (1.673)	51.2 (1.444)	95.7 (1.984)	64.8 (1.7)
April 2001	22.2 (1.296)	47.1 (1.62)	62.5 (1.796)	43.9 (1.571)
May 2001	10.7 (1.038)	32.5 (1.519)	51.5 (1.706)	31.4 (1.421)
Mean	22.1 (1.172)	40.7 (1.455)	52.5 (1.643)	38.4 (1.446)

Figures in the parenthesis are log (X+1) transformed values

CD (0.05) Nut shape = 0.2335
Month = 0.3301
Month with Nut shape = NS

percentage of infestation between these two shaped nuts. Numbers of mites and percentage of infestation were comparatively very less in round nuts with a mean of 396.4 and 22.1 percent respectively. Mite population and percentage of nut infestation of round nuts was significantly different with that of oblong and oval shaped nuts (Plate 6).

4.5.5 Nut Colour

Number of mites per button and percentage of nut infestation due to mites on different coloured nuts viz., green, greenish yellow and orange were compared separately for third (Table 24a, and Table 25a) and fourth (Table 24b and 25b) bunches. It was found that preference of mites was very much dependent on the colour of nuts. Significant difference was noted in the population of mites and percentage infestation on nuts in third and fourth bunches of different coloured nuts. Maximum population of mites and percentage of infestation was in green coloured bunches compared to greenish yellow nuts both in third and fourth bunches. Colonization and per cent damage was very negligible in orange coloured nuts. Comparison of mean of mite population (Table 24c) and percentage of infestation (Table 25c) of third and fourth bunches represented the general preference of mites to nut colour. There were practically no mites in orange coloured nuts and hence any surface damage. Mean number of mites and percentage of nut infestation in orange coloured nuts were 0.65 and 0.35 per cent respectively. Mean of mite population from third and fourth bunches of green and greenish yellow nuts were 1952.9 and 90.2 respectively. Mean of percentage of button infestation also showed difference with a percent of 40.7 and 11.5 for green and greenish yellow coloured nuts. Significant difference was noticed in the number of mites and percentage of infestation of green with greenish yellow nuts, greenish yellow with orange nuts and green with orange coloured nuts (Plate 7). There was some variation in the amount of infestation and

Table 24a. Fluctuations in mite population in the third bunch buttons on palms of different nut colours

Nut colour / Month	Green	Greenish yellow	Orange	Mean
December 2000	535.2 (1.653)	0.0 (0.0)	0.0 (0.0)	178.4 (0.551)
January 2001	146.8 (1.43)	0.0 (0.0)	0.0 (0.0)	48.9 (0.477)
February 2001	1271.6 (1.295)	83.4 (1.805)	0.0 (0.0)	451.6 (1.033)
March 2001	3142.8 (2.819)	291.0 (2.021)	0.0 (0.0)	1144.6 (1.613)
April 2001	2818.6 (3.219)	104.2 (1.281)	0.0 (0.0)	974.2 (1.5)
May 2001	204.2 (1.074)	0.0 (0.0)	0.0 (0.0)	68.1 (0.358)
Mean	1353.2 (1.915)	79.7 (0.851)	0.00 (0.00)	477.6 (0.922)

Figures in the parenthesis are log (X+1) transformed values

CD (0.05) Nut colour = 0.4762
Month = 0.6735
Months within nut colour = NS

Table 25a. Fluctuations in percentage infestation in the third bunch buttons on palms of different nut colours

Nut colour / Month	Green	Greenish yellow	Orange	Mean
December 2000	12.6 (0.787)	0.0 (0.0)	0.0 (0.0)	4.2 (0.262)
January 2001	35.8 (1.062)	0.0 (0.0)	0.0 (0.0)	11.9 (0.354)
February 2001	10.8 (0.545)	27.2 (1.341)	0.0 (0.0)	12.6 (0.629)
March 2001	28.14 (0.912)	22.4 (1.119)	0.0 (0.0)	16.9 (0.677)
April 2001	46.2 (1.503)	21.2 (0.889)	0.0 (0.0)	22.4 (0.797)
May 2001	8.14 (0.536)	0.0 (0.0)	0.0 (0.0)	2.8 (0.179)
Mean	23.7 (0.891)	11.8 (0.558)	0.0 (0.0)	11.8 (0.483)

Figures in the parenthesis are log (X+1) transformed values

CD (0.05) Nut colour = 0.2691
Month = 0.3807
Months within nut colour = 0.6595

Table 24b. Fluctuations in mite population in the fourth bunch buttons on palms of different nut colours

Nut colour / Month	Green	Greenish yellow	Orange	Mean
December 2000	1307.6 (2.429)	5.2 (0.286)	0.0 (0.0)	437.6 (0.905)
January 2001	2211.6 (2.712)	17.2 (0.388)	0.0 (0.0)	742.9 (1.033)
February 2001	2226.6 (3.118)	190 (1.394)	3.6 (0.256)	806.7 (1.589)
March 2001	4389.4 (3.588)	301 (2.436)	4.2 (0.268)	1564.9 (2.098)
April 2001	4276.6 (3.281)	69.2 (0.508)	0.0 (0.0)	1448.6 (1.263)
May 2001	908.2 (2.865)	21.8 (0.697)	0.0 (0.0)	310.0 (1.187)
Mean	2553.0 (2.999)	100.767 (0.952)	1.3 (0.087)	885.1 (1.346)

Figures in the parenthesis are log (X+1) transformed values

CD (0.05) Nut colour = 0.4054
Month = 0.5732
Months within nut colour = NS

Table 25b. Fluctuations in percentage infestation in the fourth bunch buttons on palms of different nut colours

Nut colour / Month	Green	Greenish yellow	Orange	Mean
December 2000	30.4 (1.261)	2.2 (0.216)	0.0 (0.0)	10.8 (0.492)
January 2001	58.8 (1.488)	2.6 (0.229)	0.0 (0.0)	20.4 (0.572)
February 2001	79.2 (1.865)	14.4 (0.812)	2.2 (0.216)	31.9 (0.964)
March 2001	74.0 (1.573)	43.4 (1.592)	2.0 (0.208)	39.8 (1.125)
April 2001	48.0 (1.642)	2.4 (0.223)	0.0 (0.0)	16.8 (0.621)
May 2001	56.6 (1.734)	0.371 (3.0)	0.0 (0.0)	19.8 (0.702)
Mean	57.8 (1.594)	11.3 (0.574)	0.7 (0.071)	23.2 (0.746)

Figures in the parenthesis are log (X+1) transformed values

CD (0.05) Nut colour = 0.2489
Month = 0.3520
Months within nut colour = NS

Table 24c. Fluctuations in mite population (mean of third and fourth bunch) on palms of different nut colours

Nut colour / Month	Green	Greenish yellow	Orange	Mean
December 2000	921.4 (2.328)	2.6 (0.299)	0.0 (0.0)	308.0 (0.852)
January 2001	1179.2 (2.505)	8.6 (0.329)	0.0 (0.0)	395.9 (0.945)
February 2001	1747.1 (3.072)	136.7 (1.863)	1.8 (0.2)	628.5 (1.712)
March 2001	3766.1 (3.557)	296.1 (2.458)	2.1 (0.212)	1354.7 (2.076)
April 2001	3547.6 (3.411)	86.7 (1.72)	0.0 (0.0)	1211.4 (1.528)
May 2001	556.2 (2.618)	10.9 (0.579)	0.0 (0.0)	189.0 (1.066)
Mean	1952.9 (2.915)	90.2 (1.105.)	0.65 (0.069)	681.2 (1.363)

Figures in the parenthesis are log (X+1) transformed values

CD (0.05)	Nut colour	= 0.3433
	Month	= 0.4855
	Month with Nut colour	= 0.8410

Table 25c. Fluctuations in percentage infestation (mean of third and fourth bunch) on palms of different nut colours

Nut colour / Month	Green	Greenish yellow	Orange	Mean
December 2000	21.5 (1.137)	1.1 (0.163)	0.0 (0.0)	7.5 (0.433)
January 2001	47.3 (1.402)	1.3 (0.175)	0.0 (0.0)	16.2 (0.526)
February 2001	45.0 (1.61)	20.8 (1.296)	1.1 (0.163)	22.3 (1.023)
March 2001	51 (1.444)	32.9 (1.457)	1.0 (0.156)	28.3 (1.019)
April 2001	47 (1.620)	11.8 (0.732)	0.0 (0.0)	19.6 (0.784)
May 2001	32.5 (1519)	1.5 (0.270)	0.0 (0.0)	11.3 (0.596)
Mean	40.7 (1.455)	11.5 (0.682)	0.35 (0.053)	17.5 (0.73)

Figures in the parenthesis are log (X+1) transformed values

CD (0.05) Nut colour = 0.2160
Month = 0.3054
Month with nut colour = 0.3056

percentage of nut infestation at different intervals in accordance with the colour of nuts.

4.6 Ecological management

The results of ecological management practices like different water regimes, fertilizer regimes, micronutrients and crown cleaning is given below.

4.6.1 Water availability

Symptoms of surface damage were taken from the last bunches at four months interval for a period of one year. Scoring of the severity of damage was done as explained in materials and methods. Average of the ranks of the scores was analyzed and given in Table 26. Apparent surface damage was almost same at different types of water availability. There was no significant difference in damage on nuts between the palms grown under rainfed and irrigated condition and also between channel irrigated and drip irrigated palms.

4.6.2 Fertilizer treatments

Three treatments of fertilizers were given to study the management practice for coconut eriophyid mites. Scoring of the severity of damage was done as explained in materials and methods. Average of the ranks of the scores was analyzed and given in Table 27. There was no significant difference in damage between different fertilizer treatments. Apparent surface damage was almost the same in conditions of average management, good management, applying less nitrogen and even in control. There was no difference in damage after the fertilizer application in all the three cases. Surface damage remained same before and after the fertilizer treatments.

Table 26. Mean damage score of apparent nut damage at different water regimes

Interval	Rainfed	Irrigated	
		Channel Irrigation	Drip Irrigation
I_1	3	2	1
I_2	3	1.5	1.5
I_3	2	3	1
Total rank score	8.5	6.5	3.5

χ^2value = 3.5 NS

Table 27. Mean damage score of apparent nut damage at different fertilizer regimes

Interval	Average management*	Good management**	Less nitrogen***	Control
I_1	4	2	3	1
I_2	4	1	3	2
I_3	3.5	3.5	1.5	1
Total rank score	11.5	6.5	8	4

*0.34:0.17:0.68kg NPK/ palm
**0.5:0.32:1.2kg NPK/ palm
***0.25:0.32:1.2kg NPK/ palm

χ^2value = 5.9 NS

4.6.3 Micronutrients

Application of different micronutrients viz., $MgSO_4$, Borax, $ZnSO_4$, $MnSO_4$ and Micronutrient mixture were done to study the effect of micronutrients in managing the coconut eriophyid mites. Scoring of apparent husk damage was done before and after the application as explained in materials and methods. Analysis of the rank of scores revealed that there was no significant difference in damage in any of the treatments (Table 28). In all the cases surface damage remained same before and after micronutrient application. No difference was noted in damage between different micronutrient treatments and even with control.

4.6.4 Crown cleaning

Two treatments viz., two cleanings and one cleaning per year were tried. Control was also maintained without any crown cleaning. Scoring of apparent husk damage was done before and after treatments and their analysis revealed that there was no significant difference between these two treatments (Table 29). Surface damage was almost same in both cases and in control. No significant difference in damage was noted before and after treatment in both the cases.

Table 28. Mean damage score of apparent nut damage at different micronutrient regimes

Interval	MgSO4	Borax	ZnSO4	MnSO4	Micronutrient Mixture	Control
I_1	3.5	3.5	3.5	1	3.5	6
I_2	1	4	2.5	2.5	5	6
I_3	5	1	4	2.5	25	6
Total rank score	9.5	8.5	10	6	11	18

χ^2value = 7.6 ^{NS}

Table 29. Mean damage score of apparent nut damage based on crown cleaning

Interval	Control	one cleaning/ year	Two cleanings/ year
I_1	3	1	2
I_2	2.5	1	2.5
I_3	1.5	1.5	3
Total rank score	7.0	3.5	7.5

χ^2value = 3.2 ^{NS}

Discussion

5. DISCUSSION

The experiment was conducted to study the population dynamics and distribution pattern and to find out ecological management strategies for the coconut eriophyid mite under the Department of Entomology in the year 1999-2001. The results obtained after statistical analysis are discussed below based on earlier literature and in the present context.

5.1 Population of mites in bunches of increasing maturity

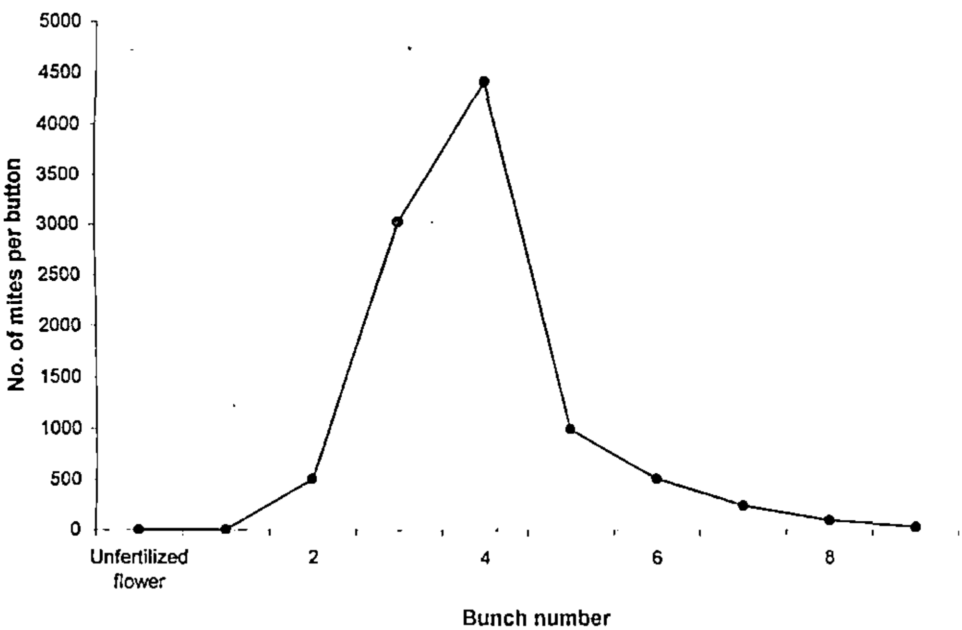
Graphical representation of the population of *Aceria guerreronis* in coconut bunches of different maturity is given Fig. 5.

Mites were not found in male flowers of any inflorescence. Results of Ranjith *et al.* (2000) also showed the absence of mites in male flowers. This may be because of the absence of soft tissue in the male flowers where mites can feed. Besides, the development cycle of mites lasts more than 10 days (Mariau, 1977) and by that time the male flowers fall off. Hence it is an unsuitable site for infestation.

There were no mites in unfertilized female flowers. Moore and Alexander (1987) and Ranjith *et al.* (2000) also reported the absence of mites in unfertilized female flowers. The absence of mites from the unfertilized female flower may reflect the tight adpression of bracts to the nut (Hall *et al*, 1979). In female flowers the meristematic tissue where the mites usually feed is well protected inside the perianth. Since the perianth is tightly adpressed, the gap between the perianth and the flower is very less and the mite cannot enter into the meristematic tissue.

When the female flowers, (which we normally denote as 'buttons') open up for pollination, the attachment between the perianth and the button becomes less tight

Fig. 5. Population of mites in coconut bunches of increasing maturity



giving entry of the minute sized mite into the interspace between the perianth and the button. There is also disproportionate growth between the perianth parts and nut proper, so that the entry of the mite is facilitated (Nadarajan *et al.*, 2000).

Moore and Alexander (1987) reported 20 per cent of bunch one nuts were found to contain mites. Our results, as also the results of Ranjith *et al.* (2001) failed to observe mites in the bunch one nuts. It is expected that the cultivars currently being grown in these areas may not be opening up their bracts sufficiently to allow the entry of mites. When the buttons grow further, cracks develop in the bracts or the rate of growth of the bract is higher than the nut proper, so that the entry of mites is facilitated. Further evidence to the development of space for the entry of mites through different regions under the tepal is provided in section 5.5.3.3.

The initiation of infestation is from the second bunch onwards. The number of mites gradually increases and reaches a peak on fourth bunches and thereafter it decreases. A few numbers of mites were noticed even on ninth bunch. Ranjith *et al.* (2000) observed maximum population of mites on the third, fourth and fifth bunches.

The meristematic tissue of the second, third and fourth bunches is very soft so that the mites can feed easily. Most probably the colonization starts either from the second or the third bunches. The inflorescence opens at the rate of one per month. So at every month the bunch number changes, i. e. bunch two in one month becomes bunch three in the next month. The mites take approximately 10 days for their development (Mariau, 1977). They develop at an average of two to three generations per month, inside the button. The number of mites that enter the buttons of second and third bunch may be only a few, but within one month, after uninterrupted multiplication, they become enormous. The population explodes in geometric proportions. Each adult is capable of 100 fold multiplication (Nadarajan *et al.*, 2000) and hence two generations itself would mean 100 X 100 mites within a single month.

So very high number of mites can be noticed in the third or fourth bunches depending on whether the initial colonization was on second or third bunches. When the buttons get older, the meristematic tissue gets harder and it will be difficult for the mites for feeding. So from fifth bunch onwards a reduction in the number of mites can be noticed. Even though there was no significant difference between the number of mites on second bunch with eighth and ninth bunches, they have to be considered separately. Mite count was found to be less in second bunch since it was at the initial stage of development, whereas in eighth and ninth bunches, it was the remnants of mite population of previous stages.

Generally it appeared that bunches two, three, four and five were more preferred by mites for colonization. But maximum number of mites were noticed in buttons of fourth bunches. Since there was no significant difference between population of mites of third and fourth bunch, these two bunches were fixed as index bunches and further observations were restricted to these bunches only. It is to be noted that the nomenclature as the third, fourth bunch etc. from the top is not entirely accurate. A good palm can produce 12-14 bunches per year, at an average of about one bunch per month. The period from flower opening till fertilization of female flower is about one month. It is only after this that the mites enter the button. Between a palm with a new flower just opened and another which have the last flower opened about a month before, the connotation as third bunch from the fully opened bunch may differ widely in physiological maturity. To overcome this, it suggested that population counts have to be taken from the third to fourth bunches and the average arrived at (Ranjith *et al.*, 2001).

5.2 Symptoms of damage

Mites live inside the perianth as colonies by lacerating and sucking the sap from the meristematic tissue. Even though they feed mainly on the meristematic tissue, when the number is enormous, they can be seen on the perianth also.

The first symptom to appear takes the form of a whitish triangular patch with the base at the level of the tepals. At this stage, when the floral parts are lifted up, a white area is perceived which is an accumulation of thousands of mites at all stages of their development. The triangular patch turns brown and the epidermis of the nuts becomes crackled (Mariau, 1977). Cuts, gummosis and freckles have also been reported due to the attack of mites. In many cases, when the perianth of the buttons are removed, a pinkish band can also be seen on its inner side (Nadarajan *et al.*, 2000).

Normally mite enter only on or after the second bunch and hence the first symptoms are visible from second bunch onwards only. Development of brownish patches inside the whitish area and further necrosis continues based on the population explosion of the mites. But after the fifth bunch normally there is no fresh colonization, so that development of whitish streak is rare after the fifth bunch. However, there is an exception to this phenomenon, in the case of cultivars with very soft husk. In such instances initial colonization and whitish streak can occur even upto the seventh bunch.

5.2.1 Progressive development of symptoms due to mite attack

There were no symptoms on unfertilized female flowers and also on buttons of first bunch because of the absence of mites in these bunches. Since the development of mite population just starts in the second bunches, the number of mites in these bunches will be less. Hence the damage on the second bunches will be very small as a white discolouration. When the population increases further, the surface damage on the buttons also increases and turns brown and later necrotic.

Fig. 6, which is a graphical expression of Table 5, expresses the progressive developments of symptoms on the buttons. It is seen that the whitish area starts from the second bunch. But it is interesting that the area of whitish triangular patch as a percentage of the total area of the button is the same through out. This is because after a few days of symptom initiation as a whitish patch, there is the development of necrotic area within the button. The development of necrotic area may be due to three reasons. One is the loss of cell sap due to laceration and feeding by the mites. Another cause could be the toxemia consequent to the release of toxic chemicals by the mites. A third reason is the plant reaction similar to hypersensitivity. This may be mediated by the release of phenolics or other biochemicals consequent to mite attack, so that the necrotic areas fail to sustain the population of the mites. However, the change in the composition of phenolics or biochemicals consequent to the infestation has not been attempted in the present study.

Development of necrotic patches proceeds slowly upto the fifth bunch. Percentage of total damage also behaves similarly. However, from the sixth bunch onwards there is substantial necrosis and remains in the same range until the ninth bunch. It is to be explained here that the husk damage, which is initiated in the sixth bunch remains through out the life of the nut without any remission even when the nut grows.

5.2.2 Relationship of mite population to surface damage

Mites feed within the meristematic tissue of the buttons and the symptoms develop after a few days. Substantial number of mites were noticed when the apparent surface damage before the removal of the perianth was <1 cm^2. During this time,

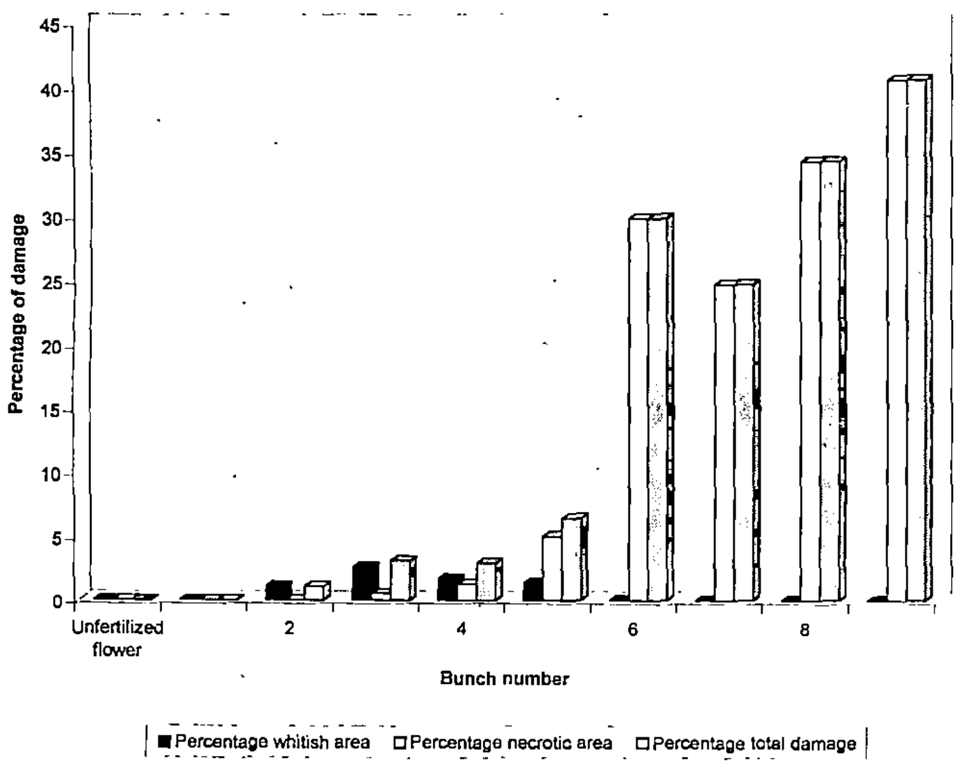


Fig. 6. Percentage of surface damage on bunches of increasing maturity

damaged area can be noticed inside the perianth also. Here the actual damage including the damage seen inside the perianth was 1-3 cm^2. When the apparent and actual surface damage was <1 and 1-3 cm^2 respectively, mite population was found to be almost same. This trend goes on and the apparent surface damage was 1-3, 3-6, 6-9, 9-12 and >12 cm^2 when the actual surface damage was 3-6, 6-9, 9-12 and 12-15 and >15 cm^2 respectively.

When the actual surface damage was 1-3 cm^2 the population is somewhat high (Fig. 7). At this point the whitish area was very much higher than the necrotic area. Within a few days the population increases. By that time the symptoms have increased to 3-6 cm^2. Here also the whitish area was found to be high, but the necrosis was found to be increasing. The necrotic area increases further and the mites find it difficult to feed from this necrotic area of meristematic tissue. Hence the population gradually decreases. Even though the necrotic area was higher than the whitish area, when the damage is 6-9 cm^2, the population of mites was appreciable, but has shown a downtrend. Further growth of the population will not occur because of the absence of feeding sites and the population shows a reduction in growth and finally becomes zero. However it is to be remembered that zero mite population was obtained when the necrotic area was 100 per cent and the surface damage was >15 cm^2. But in nature, during favourable periods of population multiplication further fresh colonization is possible which will be manifested outside as fresh yellowish streak. Under those situations there can be some mite population even beyond the fifth bunch. Nevertheless, we could still be reasonably sure that when the buttons have only necrotic patches towards outside there might not be any mites at all on button.

When surface damage increase beyond 15 cm^2, there will not be much change in the damaged area before and after the removal of perianth. This is an important observation. When the damage crosses >15 cm^2 and there is no fresh attack,

Fig.7. Relationship of actual surface damge with mite population

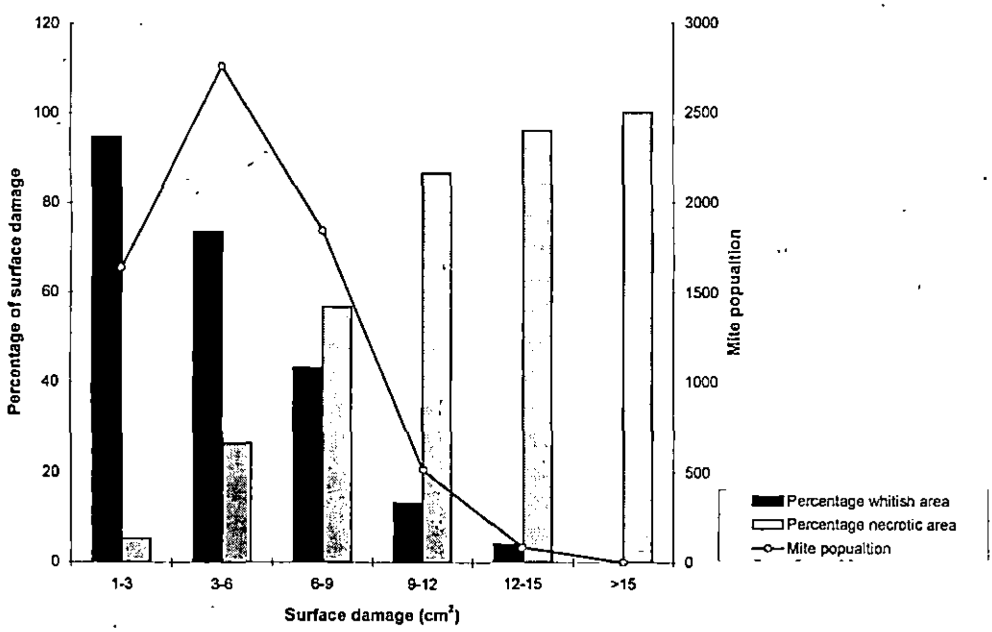
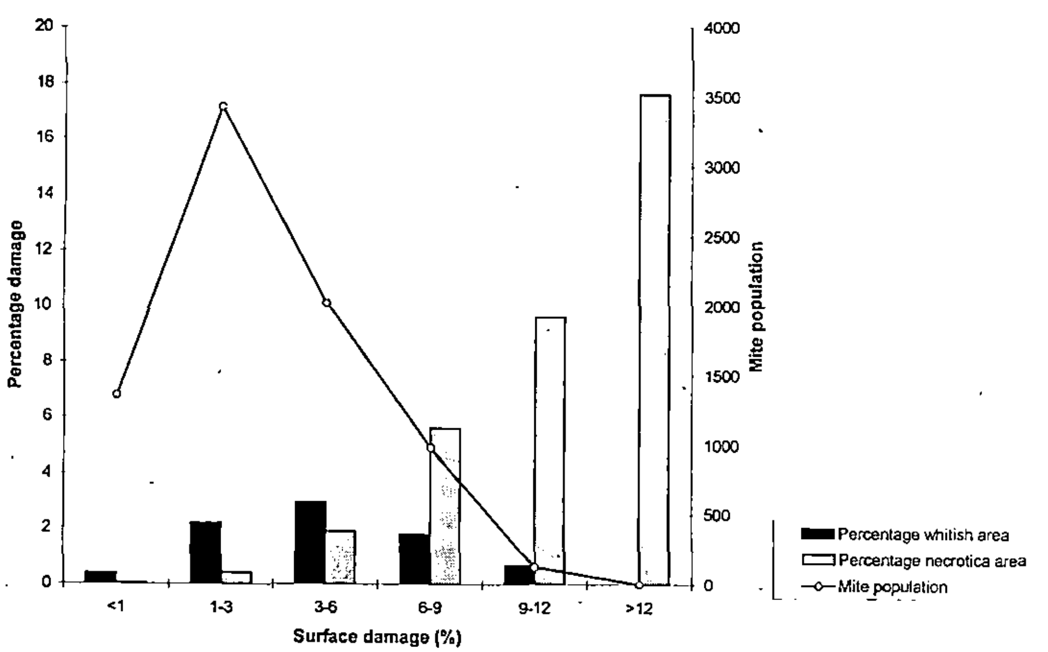


Fig.8. Relationship of percentage surface damage with mite population



there will be no yellow streak. At this stage, there is no further damage at the meristematic region inside the perianth and the mites have also left. Hence, there is no inside damage and only outside damage persist. However, the outside damages increases further, and can develop into a lot of necrosis, gummosis, freckles, cuts and lesion on the husk.

5.2.3 Relationship of mite population to percentage of surface damage

Mites attack inside the protected area of perianth on the meristematic tissue. The damage however is not visible outside. Even when the damage inside is appreciable, visible outside damage exterior to perianth may only be marginal. Moreover, the growth pattern, colour, rate of growth, shape and surface area of the buttons differs widely between palms. A reasonable estimate, which is comparable among the palms, can be obtained by finding out the relationship of the whitish or necrotic patches as a ratio of the total surface area of the buttons. The population of mites in these buttons can then be compared with percentage of damaged area.

The results represented as Fig. 8 indicate that when the coefficient was considered, maximum necrotic area of around 17.6 per cent itself shows zero population of mites. In other words, when roughly one fifth of the total surface is damaged by necrosis, mite population has ceased to exist. Before this stage (between 9-12 per cent) also, the percentage necrotic area is always below 10 per cent. An academician should hence view damages to the button in the third, fourth and fifth bunches alone to arrive at the menace by eriophyid mites. What is visible to lay men as a fast developing necrotic patch on the husk is only an expression of the plant reaction to an attack by the mites, long after they have left the bunch. In other words, when the symptom is very severe there are practically no mites and at low initial level of symptom development there is a substantial mite population.

The opinion expressed by Moore and Alexander (1987) is reproduced below. "The greatest population under the bract was found when nuts were showing between 5 and 15 per cent surface damage. Mite numbers declined as the levels of surface damage increased beyond 15 per cent. This suggests that the nuts become unsuitable for large population with increasing damage. Numbers may drop because of migration or death, but as the mite numbers on the surface appeared not to be proportionally greater with higher populations under the bracts, migration was not likely to be responsible for decline. Increased damage of the nut reduces food supply and the surface of damaged nut often becomes sticky, trapping mites. This plant response sometimes killed majority of the mites present on a nut." The present results authentically explain the situation in a clear way, with the backing of actual mite counts.

5.3 Population dynamics

Mite population showed a difference in their occurrence during different seasons (Fig. 9). This may be due to the difference in the weather conditions. The change in the temperature especially minimum temperature, morning humidity and wind speed have got definite influence in determining the development of mites and hence the population. The percentage of nut infestation also varied significantly with the season (Fig. 10), which indicates the importance of weather factors. Sometimes the effect of different factors acts either complementary or contradictory to bring about a variation in the population of mites.

5.3.1 Correlation of mite population with weather parameters

Differences were noticed in the mite population with season. To study the effect of different weather factors, correlation of mite population with weather parameters of different fortnights was done. The main weather parameters under

Fig. 9. Population of mites from May 2000 to May 2001

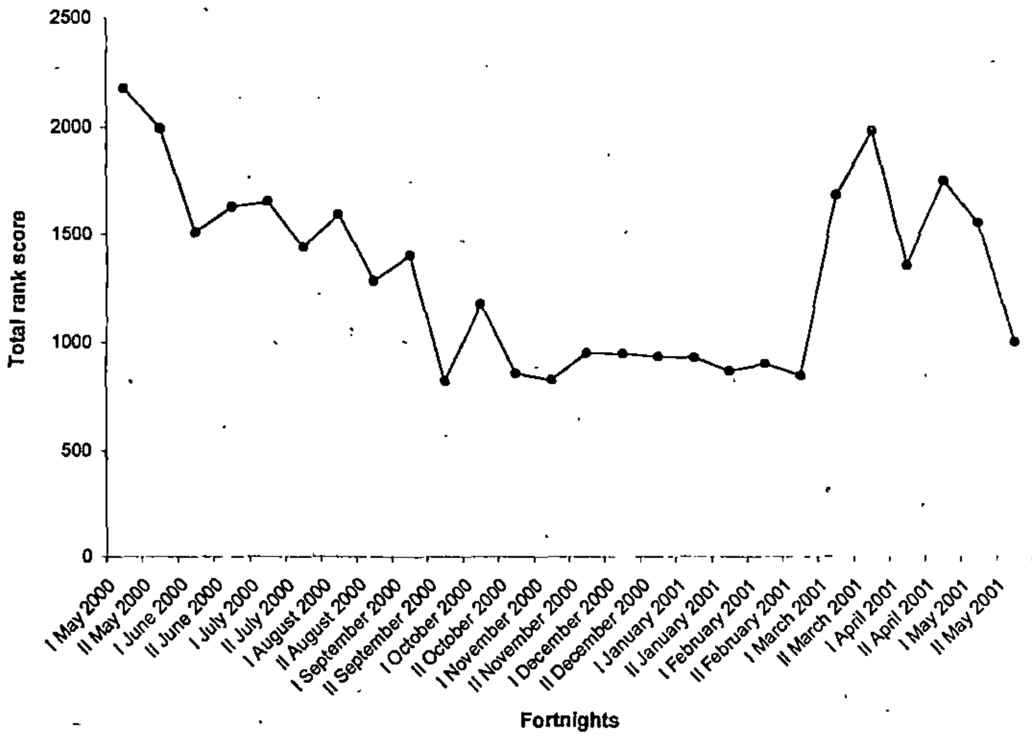
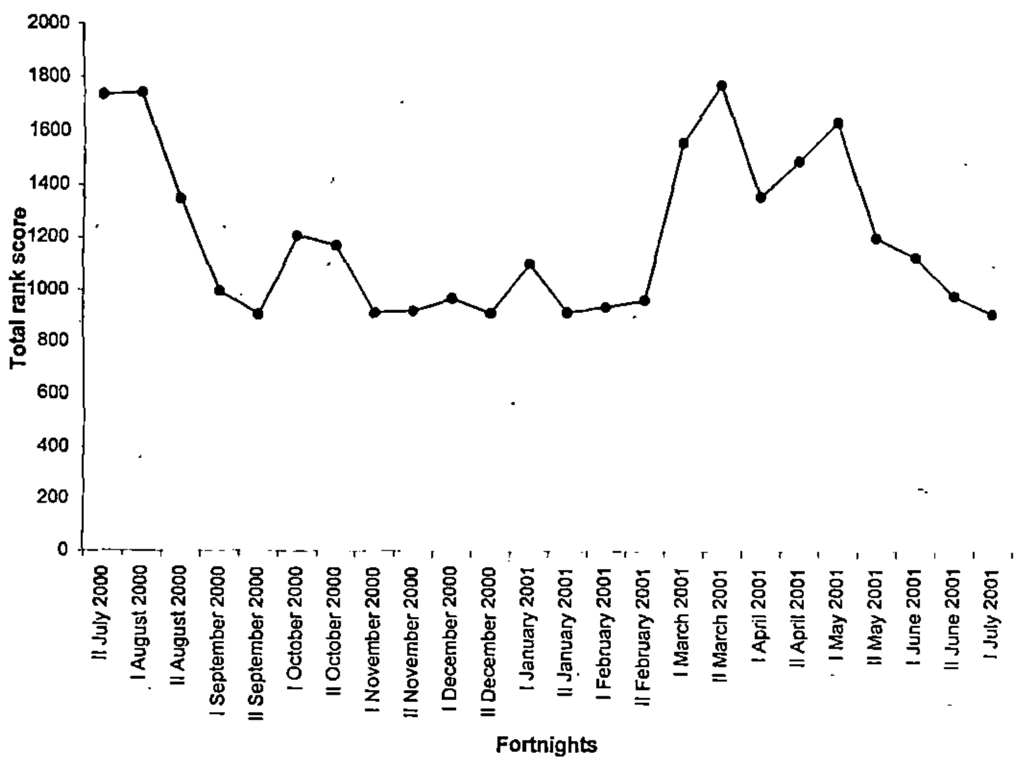


Fig. 10. Percentage of infestation of mites from July 2000 to July 2001



consideration were temperature (minimum and maximum temperature), rainfall, relative humidity (morning and evening humidity), wind speed and sunshine hours.

5.3.1.1 Population of mites and temperature

Population of mites was found to be varying with the change in temperature. Maximum temperature of -2 fortnight (Fig. 11) is positively correlated with the mite population. The coconut mite attack are more severe in relatively dry climates or during dry seasons of wetter climates (Zuluaga and Sanchez, 1971). A positive relationship between the population density of the mite and temperature was reported by Haq (1999a). Under the hot humid conditions of Kerala, maximum temperature cannot be a limiting factor for the eriophyids, which are generally thermophilic. However, it usually never exceeds 40^0C, and hence is not having any detrimental effect.

Generally minimum temperature is found to be significant than maximum temperature. Fig. 12 is a graphical representation of the influence of minimum temperature on the population of mites. In case of low minimum temperature the duration of development would be prolonged excessively so that the normal life cycle of around 10 days (Mariau, 1977) would get extended. Here the number of generations within the next one month will be either one or at best the beginning of the next generation also. This is more so because within this critical period of one month the button also matures so that the site of infestation i.e. the inner face of the perianth gets hardened. This would make the site of infestation less acceptable for the survival and multiplication of the mite.

Fig. 11. Relationship of mite population with maximum temperature of -2 fortnight

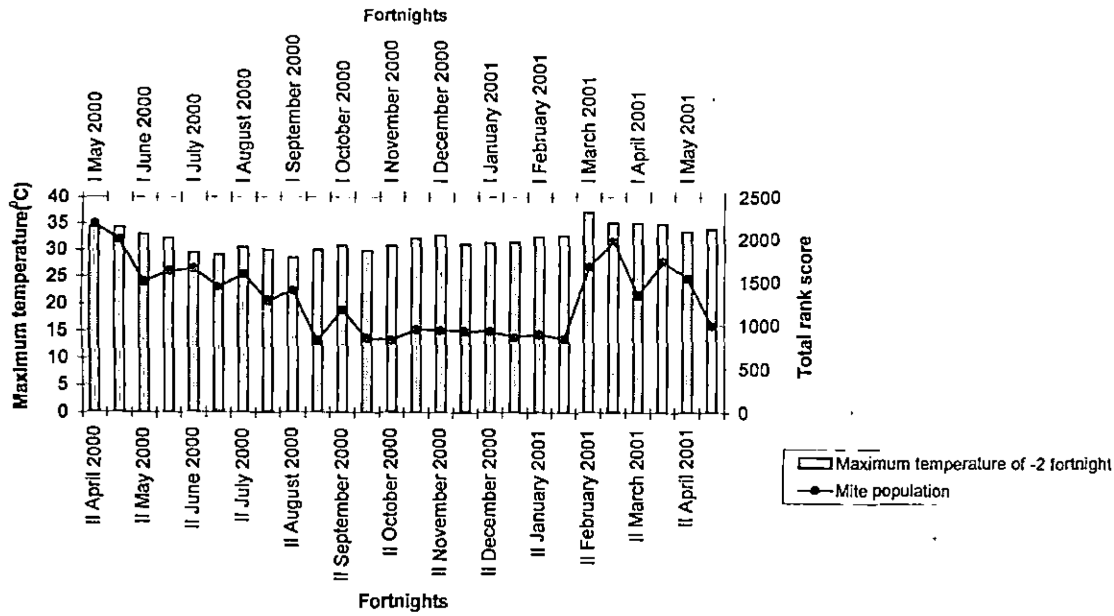
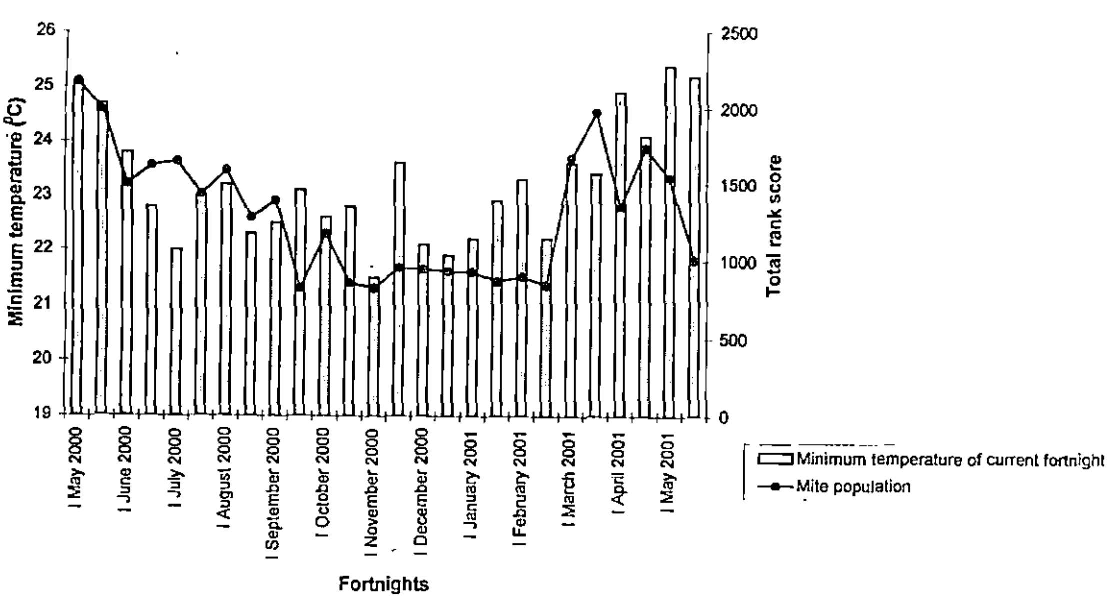


Fig.12. Relationship of mite population with minimum temperature of current fortnight



5.3.1.2 Population of mites and rainfall

It was seen that the rainfall of current fortnight and of the previous fortnights upto -3 fortnights were not having any influence on the population of mites. Haq (1999a), however, had obtained a negative correlation between population density of mites and rainfall.

To further investigate the problems of rain, the existence of correlation between mite population and number of rainy days was also worked out. This also failed to give any positive indication. This is quite unexpected. Normally heavy rain may be expected to reduce the temperature and also to wash off the mites which are dispersed either through phoresy or by wind. The present results however indicate a situation, which is contrary to this belief. It may hence be reasonably believed that rainfall neither affects the dispersing population nor its multiplication. Lack of response on dispersal means that the number of initial colonizers on the second or third button or sometimes on older bunches is extremely low. The actual number may be less than a handful. The number of these initial colonizers is entirely due to chance and would amount to only infinitesimal fractions of dispersing population. Secondly, lack of influence on population build up is explainable due to the fact that once inside the protected environment of the perianth, rainfall cannot have any effect.

5.3.1.3 Population of mites and humidity

Even though the evening humidity has no influence in determining the mite population, positive correlation exists with morning humidity of current week and all the fortnights. Population of mites as well as morning humidity was minimum during the period between November 2000 and February 2001 (Fig. 13).

Fig. 13. Relationship of mite population with morning humidity of current fortnight

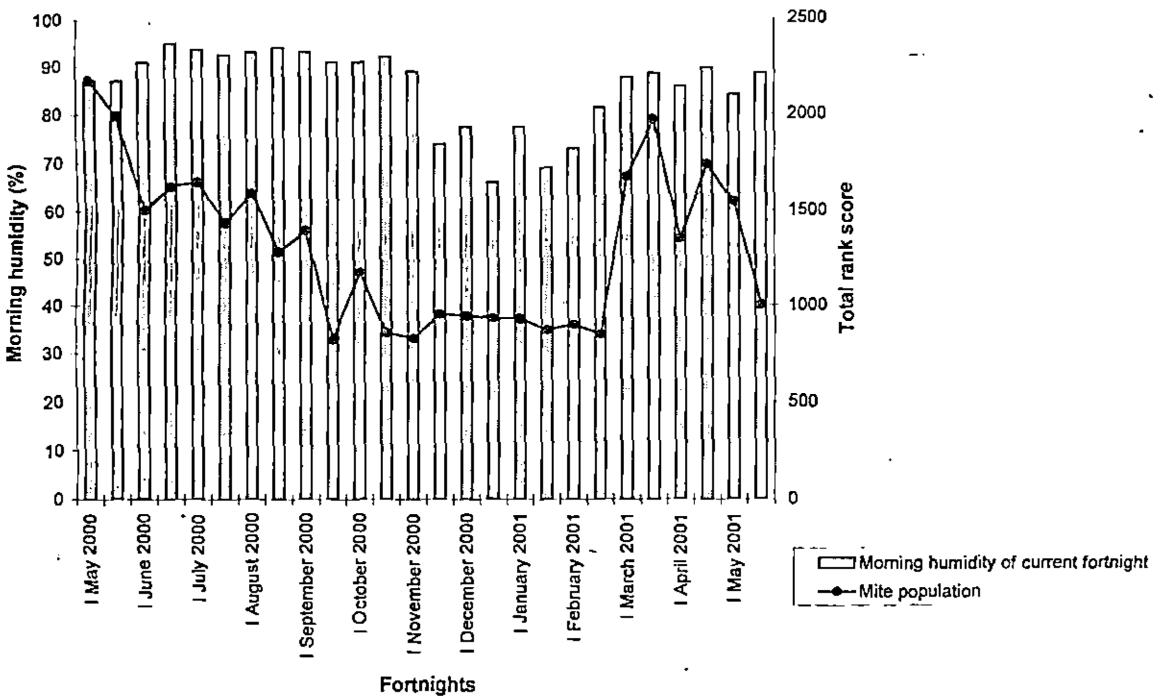
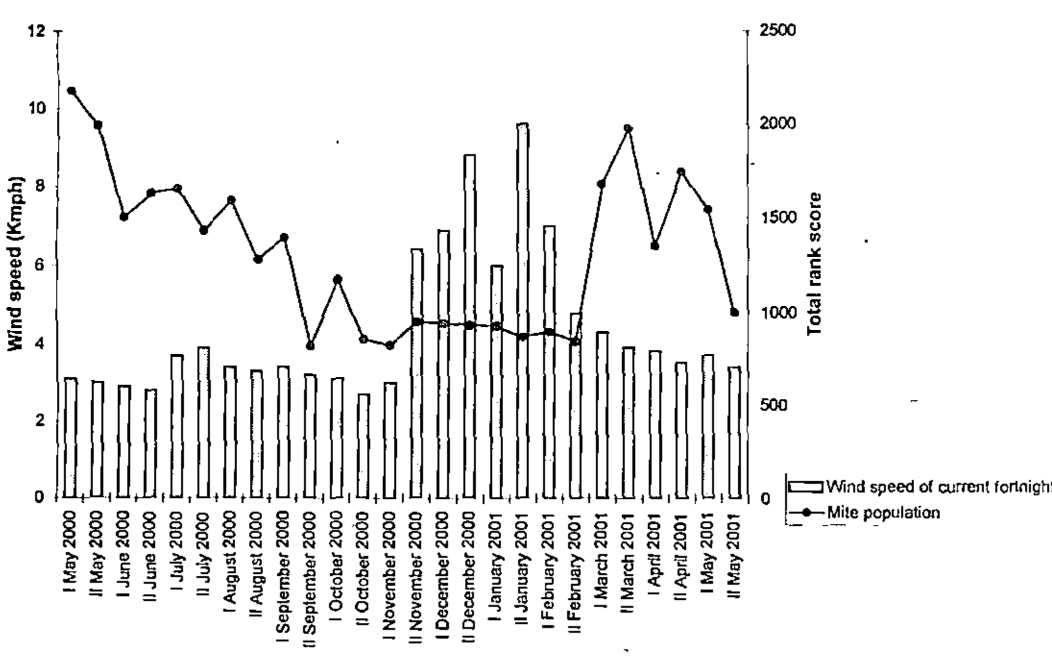


Fig. 14. Relationship of mite population with wind speed of current fortnight



The absence of any influence for the evening humidity, which ranged between 38 and 88 clearly indicates that the humidity *per se* does not influence the fluctuations of mite population. The positive influence shown by morning humidity also may not be a direct influence. This is because mites survive inside the protected environment of perianth, the humudity outside may not cause immediate fluctuations inside and hence the effect of fluctuating humidity may not be pronounced.

5.3.1.4 Population of mites and wind speed

Mariau (1977) reported that trees situated near the sea were observed to be attacked less than those inland, both because of the strong sea winds blowing the mites off the nuts and because of the deposit of salt spray on the nuts.

In our studies, which were done inland the mite population was negatively correlated with wind speed of current week and current fortnight. The speeds were below four Kmph upto October 2000. In November it drastically rose up beyond six and fell down by February 2001. The negative relationship of high wind speeds is clearly seen from Fig.14. It may be assumed that eventhough slight wind aid in the dispersal of mites, strong winds have a negative effect. There is also an indirect influence of high wind by reducing the relative humidity of the atmosphere. These two factors together cause the mites to be blown off from the nut surfaces and get desiccated. Since the outer surface of the buttons in the receptive stage, also get dried up, chances of the initial colonizing mites to get attached to the buttons are also removed. Due to these reasons, the population reduces.

5.3.1.5 Population of mites and sunshine hours

There was no direct influence for sunshine hours on the population of mites. This is expected since in the tropical conditions experienced in Kerala, the difference in sunshine hours is not drastic. Moreover, since the mites are inside the perianth and hence probably photo negative, sunshine may not be influencing them.

5.3.1.6 Multiple regression analysis for influence of weather factors on mite population

Regression equation arrived at in the present study helps to predict the population of mites with a 52.7% success probability. It is seen that morning humidity followed by maximum temperature influences the population build up substantially. Minimum temperature is the third factor followed by wind speed. The probability equation would help us to point out the range of maximum temperature, which is congenial for the development of mites. It may be expected that the maximum temperature of -2 fortnight should be <30^0C with morning humidity of current fortnight above 75-80%, minimum temperature above 25^0C with a wind speed not exceeding 5 Kmph. Under the conditions prevailing in Vellanikkara, where the above observations taken, the weather parameters are slightly different than majority of areas in Kerala. Here, during the period between October to February there is the prevalence of dry wind, which reduce the humidity and also increases the wind speed. However, the total contribution of increased wind speed and consequent increased humidity cannot substantially differ with the rest of Kerala. Hence the present regression equation can be applied to the whole Kerala, at the level of probability obtained.

5.4 Population of predatory mites

The predatory mites are practically negligible in their number. This may be because of the low fecundity and slower development of predatory mites when compared to the eriophyid mites. The occurrence of predatory mites varied with climate and they were more during summer period. This may be due to the increase in the number of eriophyid mites during summer rather than the influence of climatic factors. Predatory mites were more in fourth and fifth bunch. Generally any predatory agent develops after the establishment of the prey population. So the activity of predatory mites initiate mainly in the fourth bunch where the population explosion takes place. Since the life cycle of predatory mites may be longer, the population grows slowly and maximum number of predatory mites were noticed in fifth bunches. Further growth of the predatory population will not take place at a higher rate because of the lesser availability of the eriophyid mites in sixth and other older bunches.

Presence of appreciable number of predatory mites in the fifth bunch is a positive indication. The population explosion of mites is in the third and fourth bunches as explained earlier. It is at this time that a possible dispersal of the mites occur. The dispersing population moves out of the perianth and gets distributed through wind or by phoresy. High activity of predatory mites at this stage helps in checking their spread. The low number of predatory mites in comparison to population of eriophyids should not be misleading. This is because each adult predatory mite is capable of consuming hundreds of eggs or adult eriophyids per day and hence a large colony of the eriophyids can be wiped off by a single predatory mite in a matter of few days.

5.5 Influence of plant morphology on the distribution pattern of mites

Percentage of mite infestation and development of mites in the buttons were found to be varying with some of the tree characters.

5. 5. 1 Height of tree

The percentage infestation and development of mites was found to be irrespective of the height of the palm. Mites are suspected to be spread either by wind or by phoresy. The effect of wind is applicable to palms having different heights i.e. wind occur both on tall palms and short palms. In the same way pollinating insects also visit frequently for pollination to palms with varying height. Hence the occurrence of mites is almost same on palms of different heights. After getting entry to the buttons also, the height of the palm has no significance. The infestation was dependent on different months of observation, which was due to the change in weather factors as explained earlier.

5. 5. 2 Crown shape

Classification of palms to different crown shape was based on the orientation of leaves, which in turn determines the incidence of sunlight to the top bunches. It was seen that shape of the crown has no importance in determining the mite infestation. There was no significant relationship between the mite population and sunshine hours as explained earlier. It is very clear that the incidence of sunlight and hence the orientation of fronds has no significance in mite infestation.

5. 5. 3 Perianth arrangement

Mariau (1977) considered that a Cambodian variety was immune to the mite attack because of the firmly adhered floral parts allowing no space for access to the nut surface by the mite. The present observations also agrees with the opinion by Moore and Alexander (1987) that the perianth of round nuts adhered more tightly to the nut than with the elongated nuts and hence round nuts were less susceptible to attack than the more elongated ones. A further explanation is provided by Moore and

Howard (1996) who states that the space between the coconut surface and the perianth are sufficiently large within one month after fertilization and this permits the entry of coconut mites.

5.5.3.1 Variation in mite population with the adpression of perianth

There was no variation in the population of mites to two different types of perianth viz., less adpressed and tightly adpressed type of perianth arrangement. When the mites got attached to the button, they enter into the meristematic tissue through the available gap between the button and tepal. Besides, some portion of the tepal is not tightly adpressed to the button even in tightly adpressed type of perianth arrangement. So the mites prefer that less adpressed portion of the tepals for their entry. Results reported by Moore (1986) were also similar.

5.5.3.2 Variation in mite population with the arrangement of each tepal

The preference of mites to the three tepals in the inner side, which are arranged differently in less adpressed type of perianth arrangement, was studied. Among the three inner tepals, the surface damage was more on the face of fourth tepal followed by fifth and sixth tepal (Fig. 15). This may be due to the high colonization of mites under fourth tepal followed by fifth and sixth tepal. Since the fourth tepal overlaps the other two tepals, the portion, which overlaps, will be having maximum clearance with the button. The gap between the button and the tepal will be sufficient for the mites to enter into the meristematic portion. This gap is more in fourth tepal since both sides of the tepal overlaps the adjacent tepals. In fifth tepal one end overlaps the adjacent one and the other end is overlapped by another. So only one end of the tepal will be less adpressed to the button, hence the entry of mites will be less when compared to the fifth tepal. In case of sixth tepal, where the two ends are overlapped by the other tepals, the gap between the button and the tepal is less and

Fig. 15. Index of activity of mites in different tepals

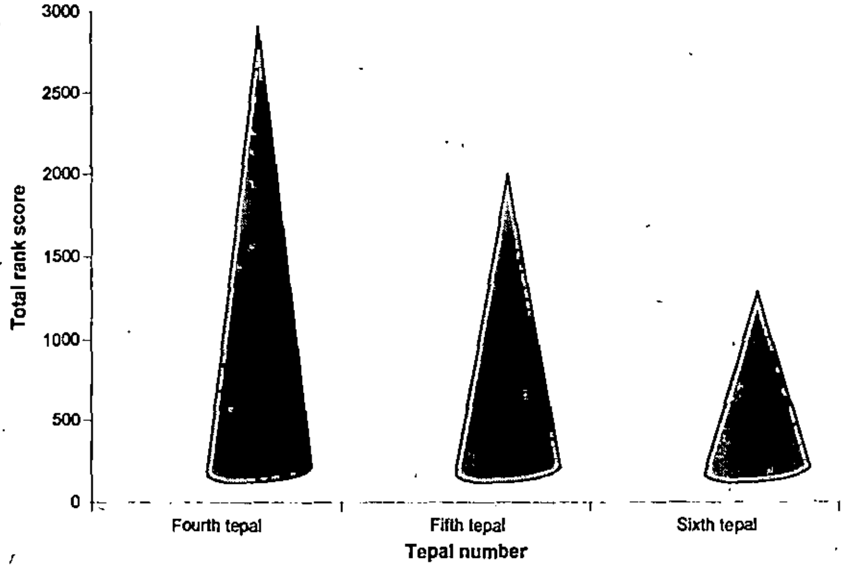
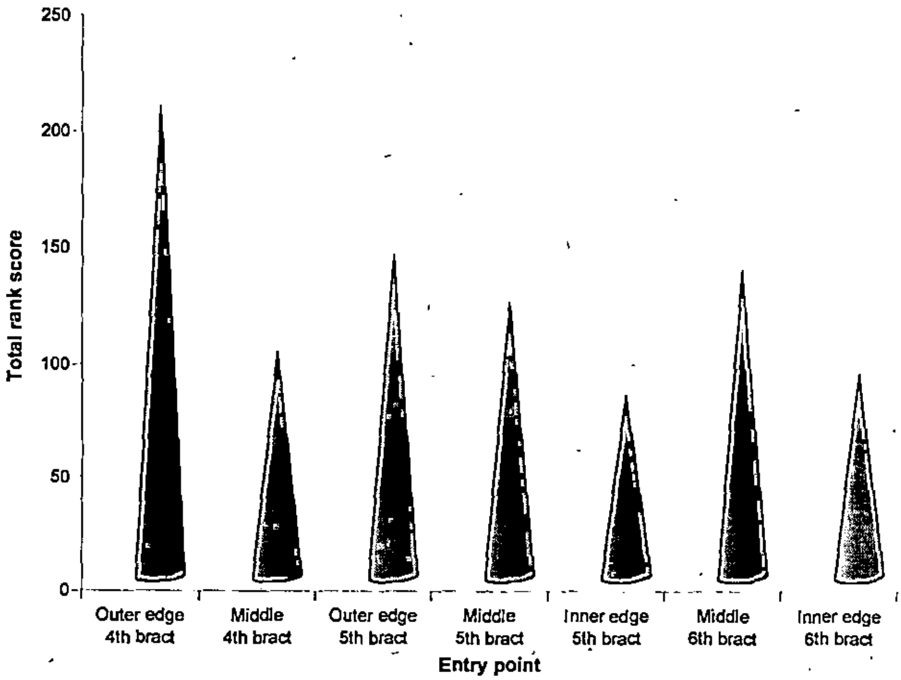


Fig. 16. Index of entry points of mites through different portions of tepals



hence the colonization of mites is also very less compared to the other two tepals. Results of Moore (1986) were also similar.

5.5.3.3 Variation in mite population with the regions under each tepal

The region within each tepal where mite prefers for their entry also vary significantly (Fig. 16). Maximum entry points were noted in the fourth tepal followed by fifth and sixth. Among the different tepals, maximum entry of mites was through the 'outer edge' of the fourth tepal. When the mites come near the fourth tepal, since the gap between the button and the tepal is more towards the 'outer edge', the mites enter through that portion of the tepal. They rarely enter through the 'middle' portion of the fourth tepal. In fifth tepal, mites prefer the 'outer edge' followed by the 'middle' portion and the 'inner edge'. This is because the 'outer edge' is less tightly adpressed to the button and hence the gap between the tepal and the button is more in the 'outer edge' portion followed by the 'middle' portion and then the 'inner edge'. In the sixth tepal only 'inner edge' and the 'middle' portion is present. When the mites reach the face of the button below the sixth bract, they enter through the 'middle' portion more than the 'inner edge'. Here, the 'inner edge' is overlapped by the adjacent tepal so the gap between the 'inner edge' and the button will be less when compared to the 'middle' portion. So the mites prefer the `middle` portion more.

The 'outer edge' is preferred more in the fourth and fifth bract. An overlapping bract cannot adpress so tightly to the nut surface at the overlap and this may allow access of mite to initiate infestation (Moore, 1986). Since there are two 'outer edges' in the fourth bract the entry of mites through the 'outer edge' is more in fourth tepal and the entry through the 'middle' portion is less than that of the fifth tepal having only one 'outer edge'. Since there is no 'outer edge', the entry through the 'middle' portion of sixth tepal is more than that of the other two tepals. The 'inner edge' of the sixth tepal is more preferred than that of fifth tepal for the entry of mites.

This is because, there is an 'outer edge' in the fifth tepal through which mite can enter easily. So the mites coming below the fifth tepal prefer the 'outer edge' where gap is more. But in the sixth tepal, there is no 'outer edge' and two 'inner edges' are present. So naturally the entry through the 'inner edge' of the sixth tepal will be more than that of fifth tepal.

5.5.4 Nut shape

The mite population (Fig. 17) and percentage of infestation (Fig. 18) of mites present in the button is found to be less in round nuts compared to oval and oblong nuts. Ranjith *et al.*(2000) reported that oblong shaped nuts were infested to a higher degree than the round and oval nuts. The perianth of rounded nuts adhered much more tightly to the nuts than the elongated nuts (Moore and Alexander, 1990). Mariau (1977) suggested that mites could not get under the perianth of the apparently resistant Cambodian cultivar because it adhered tightly to the very rounded form of fruits. But there was no significant difference in the percentage of infestation and mite population of oval and oblong nuts.

In round shaped nut, the perimeter of the tepals that covers the nut surface as a ratio is much higher than the other two shapes. The growth pattern of the round nuts also does not allow the development of appreciable gap between the tepals and nut surface. Moreover, in oblong and oval shaped nuts, the rate of growth of perianth is much less in comparison to the nut proper. Consequently, the perianth has to support a much heavier weight in these two types of nuts than in round nuts. All these factors contribute the development of gap between tepals and nut surface, which facilitates easy entry of the mites. However, viewing the infestation in isolation as due to nut shape, nut colour, perianth arrangement and such other factors may not be appropriate. Infestation by *A. guerreronis* is the net result of the complementary action of all the above mentioned factors and hence cannot be separated in piece meal.

Fig. 17. Relationship of mite population with nut shape

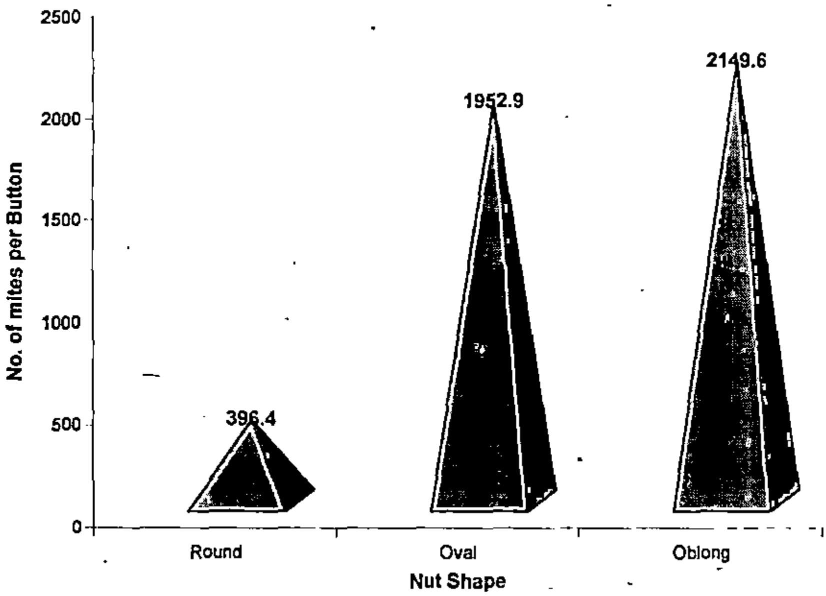
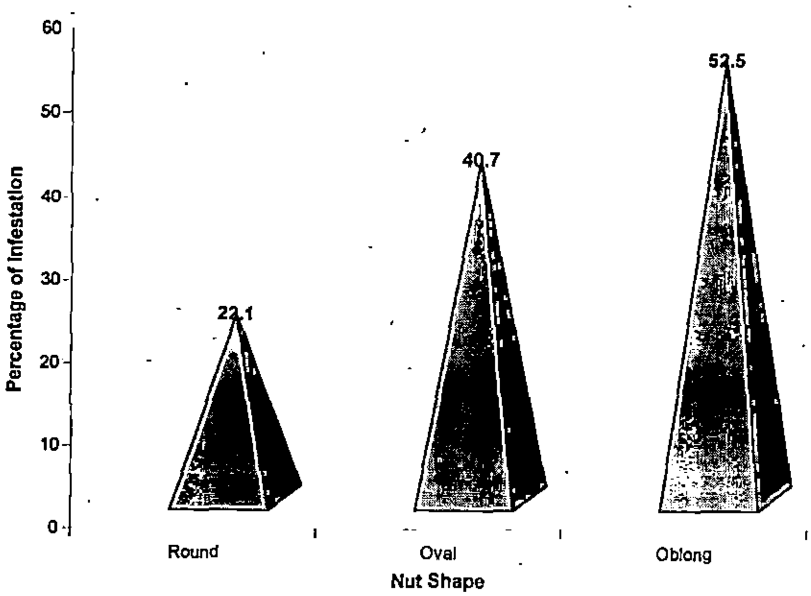


Fig. 18. Relationship of percentage nut infestation with nut shape



5.5.5 Nut colour

Mite population (Fig. 19) and the percentage of nut infestation (Fig. 20) were found to be very much influenced by the colour of the nuts. Maximum infestation was noticed in green coloured nuts followed by greenish yellow nuts. Infestation was very negligible in orange coloured nuts. Similar results were given by Muthiah and Bhaskaran (2000) and Ranjith *et al.* (2000). Contradictory results were given by Moore and Alexander (1990), who reported reduced mite attack in green coloured nuts.

Since the mites are blind, the colour preference is not due to the attraction of mites to a particular colour. Some other constituents, which can influence the colour development, may be responsible for the change in preference of mites to different colours of nuts. The effect of radiation can also be considered for the preference of mites to different colours. There was some variation in the intensity and percentage of infestation at different intervals in accordance with the colour of nuts. It is likely that the green coloured nuts cultivated in South India derived their parentage to a common source, which has other factors contributing to susceptibility. The observations of Moore and Alexander (1987) pertain to green coloured nuts of an entirely different parentage in St. Lucia. It thus becomes evident that nut colour by itself may not be the cause for preference by mites.

5.6 Ecological management

The absence of response of different practices in managing the coconut perianth mite is discussed below.

Fig. 19. Relationship of mite population with nut colour

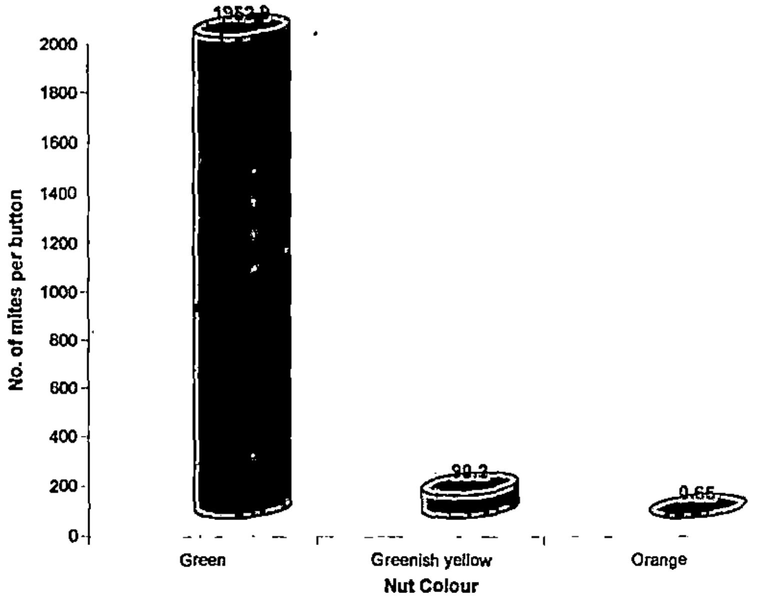
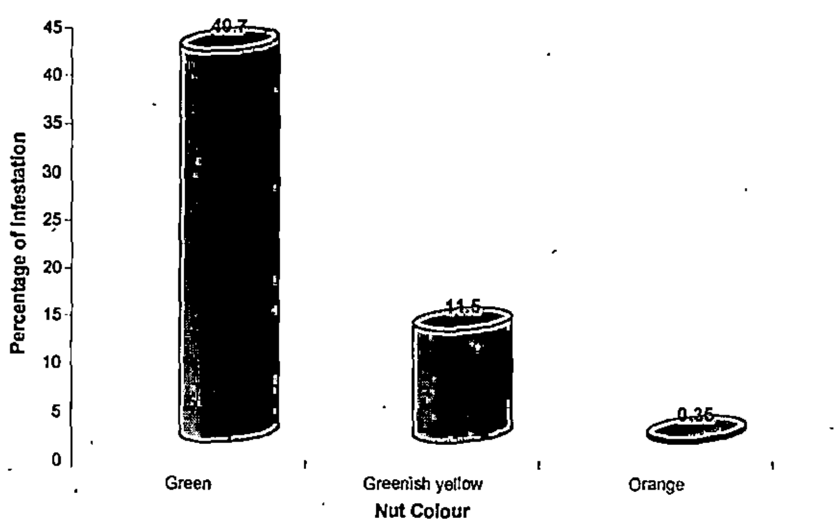


Fig. 20. Relationship of percentage nut infestation with nut colour



5.6.1 Water availability

There was no much difference in the mite attack due to the availability of water from different sources. Equal amount of infestation was noticed in rainfed, channel irrigated and drip irrigated condition.

Mariau (1986) observed that drought aggravated the pest problem by causing the nuts to develop more slowly and consequently remain at the susceptible stage. But under our condition, drought problem is not severe and a minimum amount of water is available to the palms by monsoons. Nut development may be faster, if the water availability is high. Since nucleus population of the mites is already available in Kerala throughout the year, and since the nuts remain turgid under good water availability, there is not much difference in the mite population as a consequence of water regimes. So within the susceptible stage of button, enough population will develop. Hence much difference cannot be noticed in palms with different sources of water availability under the conditions experienced in Kerala.

5.6.2 Fertilizer treatments

The mite infestation was almost same before and after the fertilizer treatments. There was no variation between the different treatments and control. Better cultivated trees, with appropriate fertilizer application were described to suffer less coconut mite attack (Mariau, 1977). The fertilizer application was modified to impart resistance to the palms.

However, differences in fertilizer application did not help to mitigate husk damage. There is a possible explanation that the impact of fertilizer application on new bunch production and consequent yield can be expressed only after three years when the flower primordia at the time of application grows up and is harvested as a nut. But good management also has to have an impact on the health and vigour of the plant and hence should be reflected on pest resistance. Reduction in the husk damage was hence expected. Absence of mitigation of surface damage explains that even a vigourous tree may not be able to resist the attack by the mites solely based on NPK nutrition.

5.6.3 Micronutrients

A very similar situation was seen as a response to application of micronutrients. This lack of response to micronutrients is not easily explainable since they are supported to be associated with secondary plant metabolic production and consequent acquisition of resistance to pests. It might thus be plausible to assume that the microscopic mites may not bė restricted by plant resistance in the short run. Since the initial colonization by mites are mostly on the second, third and fourth bunches, when the plants pump in all the nutrients to this reproductive part for furtherance of the species, there might not be any imbalance of nutrients or toxemia at the meristematic region which can resist mite attack. Also it has been proven by studies described in 5.2.1., that necrosis of the husk and the further development of husk damage is almost solely due to a plant reaction and not by the presence of mites. It is hence necessary to evaluate the responses to micronutrients and also NPK nutrition by resorting to per cent retention of buttons and also reduction in per cent incidence of mite attack on a tree/ plantation basis rather than evaluating the husk damage.

5.6.4 Crown cleaning

·Crown cleaning has no effect on mite infestation. Mites are present only on the buttons. No mites were noticed on any other part of the crown (Ranjith, 2001). So no part of crown can act as a source of inoculum of mites. Hence the crown cleaning by itself may not help in reducing the attack by *A. guerreronis*.

Summary

6. SUMMARY

The eriophyid mite, *Aceria guerreronis* (Keifer) has become a serious pest of coconuts in South India. Until 1998, when it was first reported from Kerala, the mite was not much familiar to the scientific community of India. Since it is an introduced pest and reported only recently detailed information about this pest is very scanty. Hence the study was conducted to gather some basic information about the coconut eriophyid mite.

Observations from the field were done to study the symptoms of damage. Mites inhabit the tender portions inside the perianth and they feed by lacerating the meristematic tissue covered by perianth. Mites can be seen on the tepals corresponding to the damage in meristematic tissue of button. Initially there will be development of whitish triangular patch at the level of perianth. As the population develops the area of whitish patch increases and later it turns brownish and finally necrotic. In some cases development of pinkish streak inside the perianth, cracks, cuts and gummosis on the husk were also seen.

The buttons and nuts from bunches of different age were collected and observations on the surface damage and population of the mite were taken. Mite population was taken from bunches to arrive at the exact bunches which had the maximum population of mites. There are no mites in male and female flowers and also on buttons of first bunches. Initiation of infestation develops from the second bunch onwards from top. Population increases further and reaches a peak in fourth bunch and then decreases. Hence, bunches three and four with maximum mite population were fixed as index bunches based on observations for a period of two months.

The area of damage was related with the mite population present. The symptoms will be visible outside as whitish patch from second bunch and as necrotic area from third bunch and increases further. From sixth bunch onwards maximum damage can be seen. Maximum mite population was noticed when the apparent surface damage was 1-3 cm^2 with 82.6 per cent necrotic area and 17.4 per cent whitish area and actual surface damage was 3-6 cm^2 with 73.6 per cent necrotic area and 26.4 per cent whitish area. When 1-3 per cent of the total surface area of the nut is showing surface damage maximum mite population is noticed.

Determination of mite population from buttons of third and fourth bunches from May 2000 to June 2001 revealed that high mite population was during May 2000 and from March 2001 to May 2001. Change in population during different season pinpointed the need to study the relationship of occurrence of mites with weather parameters. Minimum temperature is found to be very important in determining the population of mites. Minimum temperature of current week, current fortnight, -1 and -2 fortnights are positively related with mite population. Maximum temperature of -2 fortnight is positively related with the occurrence of mites. Significant positive relationship is noticed between the mite population and morning humidity. Mite population was found to be negatively related with wind speed of current week, current fortnight, -1 and -2 fortnights. There is no direct relation between mite population and rainfall, number of rainy days, evening humidity and sunshine hours.

Predatory mites are also seen along with eriophyid mites. The number of predatory mites is more in fifth and sixth bunches compared to third and fourth bunch. Predatory mites are more when the population of eriophyid mites is comparatively high mainly during summer period.

Influence of plant morphology on the distribution pattern of mites was also studied. Tree characters like height, crown shape, nut shape, nut colour and nut character like perianth arrangement were taken into consideration. Buttons from palms with these different characters were taken and mite population was determined. There is no difference in mite infestation depending on the height viz., <6m, 6-12m, >12m and crown shape viz., spherical, semi spherical and closed. Mites present in buttons having less adpressed and tightly adpressed type of perianth arrangement are almost same. Among the different inner tepals, infestation is more in fourth tepal followed by fifth and sixth tepals. Within the portions under each tepals, there is difference in the entry of mites. Maximum entry points were noticed through the 'outer edge' of fourth tepal followed by 'outer edge' of fifth tepal, 'middle' portion of sixth tepal, 'middle' portion of fifth and fourth tepal, and 'inner edge' of sixth and fifth tepal. Among the three nut shapes, round nuts has less mite infestation compared to oval and oblong nuts. Percentage of nut infestation and mite population is very less in orange coloured nuts followed by greenish yellow and green coloured nuts.

As a management strategy, ecological management practices with different water regimes, fertilizer regimes, applying micronutrients and crown cleaning at different intervals were done and observations were taken as scores before and after treatments. Observations showed that there is no variation in mite infestation of palms under rainfed, channel irrigated and drip irrigated conditions. Application of fertilizers in different concentrations (0.34:0.17:0.68 kg NPK/palm, 0.5:0.32:1.2 kg NPK/palm and 0.25:0.32:1.2 kg NPK/palm) did not show any significant difference in symptoms. Mite infestation before and after the application of different micronutrients viz., $MgSO_4$, $ZnSO_4$, MnSO4, Borax and Micronutrient mixture were same. Crown cleaning once and twice in an year also did not show any difference. Damage due to mites remained same even after crown cleaning.

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* Originals not seen

APPENDIX I

Meteorological data at fortnightly intervals for a period of one year (April 2000 to May 2001)

Interval	Temperature (^0C)		Rainfall (mm)	No. of rainy days	Humidity (%)		Wind Speed (kmph)	Sunshine Hours
	Maximum	Minimum			Morning	Evening		
II April 2000	34.2	24.7	14.0	1	88.5	58.0	2.6	8.0
I May 2000	34.3	25.1	7.4	1	87.0	54.5	3.1	7.7
II May 2000	32.9	24.7	46.4	4	87.0	52.0	3.0	9.2
I June 2000	32.2	23.8	98.3	5	91.0	66.0	2.9	6.6
II June 2000	29.4	22.8	482.5	9	95.0	77.0	2.8	3.4
I July 2000	29.1	22.0	362.1	11	93.6	75.0	3.7	3.0
II July 2000	30.5	23.0	54.8	3	92.5	64.0	3.9	7.1
I August 2000	30.0	23.2	102.3	5	93.0	74.5	3.4	4.5
II August 2000	28.5	22.3	372.3	11	94.0	83.0	3.3	2.2
I September 2000	30.0	22.5	76.1	5	93.0	71.0	3.4	5.9
II September 2000	30.8	23.1	16.2	3	91.0	68.5	3.2	5.7
I October 2000	29.9	22.6	229.3	10	91.0	77.5	3.1	3.9
II October 2000	30.8	22.8	178.9	5	92.0	68.5	2.7	5.4
I November 2000	32.1	21.5	7.2	1	89.0	57.5	3.0	8.0
II November 2000	32.8	23.6	23.1	3	74.0	53.0	6.4	6.4
I December 2000	31.1	22.1	5.4	1	77.5	56.5	6.9	7.3
II December 2000	31.3	21.9	0.0	0	66.0	39.5	8.8	8.5
I January 2001	31.4	22.2	8.0	2	77.5	52.0	6.0	7.6
II January 2001	32.5	22.9	0.0	0	69.0	37.0	9.6	8.9
I February 2001	32.7	23.3	12.2	1	73.0	45.5	7.0	6.2

II February 2001	37.1	22.2	0.0	0	81.5	40.5	4.8	8.4
I March 2001	35.1	23.6	0.0	0	87.5	50.5	4.3	8.7
II March 2001	35.1	23.4	2.2	0	88.5	57.0	3.9	8.4
I April 2001	35.0	24.9	9.3	2	85.7	56.7	3.8	7.2
II April 2001	33.4	24.1	234.6	6	89.5	64.5	3.5	6.9
I May 2001	33.9	25.4	14.4	1	84.0	64.0	3.7	6.2
II May 2001	33.9	25.2	18.1	1	88.5	63.0	3.4	7.8

APPENDIX II

Weather data of predecessor week of the date of observation

Fortnight*	Temperature (^0C)		Rainfall (mm)	No. of rainy days	Humidity (%)		Wind Speed (kmph)	Sunshine Hours
	Maximum	Minimum			Morning	Evening		
I May 2000	34.4	25.0	4.5	1	86	55	2.9	8.4
II May 2000	31.0	24.5	46.4	4	89	53	3.0	9.1
I June 2000	31.6	23.5	38.1	3	91	69	2.7	5.9
II June 2000	29.6	23.2	55	3	95	74	3.8	3.1
I July 2000	29.2	21.5	170	5	94	74	3.8	3.5
II July 2000	30.9	23.2	5.9	1	92	62	3.7	8.5
I August 2000	29.0	22.8	93.3	4	94	80	3.6	2.5
II August 2000	27.7	22.0	232.8	7	95	88	3.8	0.3
I September 2000	31.2	23.3	0	2	90	65	3.4	7.5
II September 2000	30.4	22.9	16.2	3	92	72	2.9	3.9
I October 2000	28.9	22.0	79.3	5	92	79	2.9	3.2
II October 2000	30.6	23.6	160.8	3	92	72	2.7	3.7
I November 2000	32.6	23.3	0.4	0	88	57	3.3	8.5
II November 2000	32.6	23.9	23.1	3	82	64	4.9	3.1
I December 2000	31.1	23.3	0	0	69	53	9.8	8.5
II December 2000	31.5	22.6	0	0	67	43	8.9	7.3
I January 2001	32.1	23.1	0	0	80	49	6.9	8.4
II January 2001	32.6	23.0	0	0	63	34	10.7	8.8
I February 2001	31.9	23.3	12.2	1	77	52	6.3	4.3

II February 2001	39.9	22.4	0	0	82	37	5.1	9.1
I March 2001	35.2	23.7	0	0	85	49	4.7	8.7
II March 2001	35.2	23.4	0	0	88	57	4.1	8.6
I April 2001	34.3	25.2	2.2	0	87	54	4.0	8.0
II April 2001	33.7	24.8	44.0	2	89	65	3.4	8.4
I May 2001	33.5	25.4	13.0	1	78	65	4.1	6.0
II May 2001	31.4	23.5	102.9	7	91	76	3.5	4.7

*The weather data corresponds to only one week prior to the fortnightly observation

APPENDIX III

Determinant matrix and ANOVA for multiple regression analysis

Determinant of matrix = 0.050586

	Regression co- efficient	Standard error	Std. Partial Regr. Co-efficient	Std. Error of partial co-efficient	Student t value	Prob ability
Maximum temperature	7.6225e+001	3.8766e+001	3.9859e-001	2.0271e-001	1.966	0.060
Minimum temperature	1.1749e+002	8.0620e+001	3.1185e-001	2.1400e-001	1.457	0.157
Morning humidity	5.4110e+001	2.4770e+001	1.0613e+000	4.8581e-001	2.185	0.039
Wind speed	1.3302e+002	1.0915e+002	6.0514e-001	4.9655e-001	1.219	0.234

Intercept = - 9097.155229

Co-efficient of determination (R square) = 0.527

Adjusted R square = 0.437

Multiple R = 0.726

Standard error of estimate = 311.814

ANALYSIS OF VARIANCE TABLE

	Sum of squares	Degrees of freedom	Mean square	F	Signific ance
Regression	2278823.9775	4	569705.9943	5.86	0.002
Residual	2041785.8653	21	97227.8983		
Total	4320609.8429	25			

BIONOMICS AND ECOLOGICAL MANAGEMENT OF COCONUT ERIOPHYID MITE *Aceria (Eriophyes) guerreronis* (KEIFER)

By

VIDYA C. V.

ABSTRACT OF THE THESIS

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ABSTRACT

The bionomics and ecological management of coconut eriophyid mite, *Aceria guerreronis* (Keifer) was studied under the Department of Entomology, College of Horticulture, Vellanikkara. The preference of mites to bunches of different maturity, symptoms of damage, population dynamics, relationship of mite population with weather factors and the distribution pattern of mites based on plant morphology were considered for the study. Some ecological management practices were also tried along with this. The experiment was laid out as completely randomised design.

Mites were absent in male and female flowers and also on buttons of first bunch. Initiation of infestation starts from buttons of second bunch and population increases further and maximum population is noticed in buttons of third and fourth bunches and thereafter it decreases. This is because after fourth bunch, the meristematic tissue becomes necrotic due to feeding of mites and hence mites cannot feed further easily. Traces of population were noticed even on nuts of ninth bunch. Predatory mites were also seen along with eriophyid mites even though they are very negligible.

Symptoms of damage were seen outside from second bunch onwards. The symptom initially appears as whitish streak or triangular patch and it increases further in length and breadth and becomes brownish and later necrotic. In some cases, cracks, cuts and gummosis can be seen on the husk. The relationship between surface damage and mite population was worked out. Maximum mite population was noticed when the surface damage was 1-3 and 3-6 cm^2 before and after the removal of perianth respectively and the percentage of damage was 1-3 per cent.

Mite population was found to vary with different weather parameters. Minimum temperature of current week, current, -1 and -2 fortnights and maximum

temperature of -2 fortnight were positively related with mite population. Morning humidity is also positively related with mite population. Mite population was negatively related with wind speed of zero current, current, -1 and -2 fortnights. There is no direct relation between mite population and rainfall, number of rainy days, evening humidity and sunshine hours.

Mite infestation was irrespective of the height of the palm, crown shape and perianth arrangement. The intensity of infestation varies between each inner tepals. Maximum infestation was under fourth tepal followed by fifth and sixth tepal. The preference of mites to different portions under each tepal also varies with maximum entry through the 'outer edge' of fourth tepal followed by 'outer edge' of fifth tepal, 'middle' portion of sixth tepal, 'middle' portion of fifth and fourth tepal, and 'inner edge' of sixth and fifth tepal. Infestation was found to be less in round shaped nuts compared to oval and oblong nuts. Maximum incidence was in green coloured nuts followed by greenish yellow and orange coloured nuts.

There was no reduction in mite damage by different water regimes (rainfed, channel and drip irrigated) fertilizer regimes (0.34:0.17:0.68 kg NPK/palm, 0.5:0.32:1.2 kg NPK/palm and 0.25:0.32:1.2 kg NPK/palm) micronutrients ($MgSO_4$, $ZnSO_4$, MnSO4, Borax and Micronutrient mixture) and crown cleaning (once and twice in an year).

MAJOR SPIDERS IN VEGETABLE ECOSYSTEM AND THEIR PREDATORY POTENTIAL

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Thesis submitted in partial fulfilment of the requirement
for the degree of

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Faculty of Agriculture
Kerala Agricultural University, Thrissur

2005

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DECLARATION

I hereby declare that this thesis entitled "**Major spiders in vegetable ecosystem and their predatory potential**" is a bonafide record of research work 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, associateship, fellowship or other similar title, of any other university or society.

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CERTIFICATE

Certified that this thesis entitled "**Major spiders in vegetable ecosystem and their predatory potential**" is a record of research work done independently by Ms. Manu P. Mani (2003-11-45) under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

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Introduction

1. INTRODUCTION

Agro-ecosystems constitute a major part of the terrestrial ecosystems. Adoption of newer technologies in agriculture wrought numerous changes in the systems. Human regulation of the structure. function and duration of agro-ecosystems contributed to their high instability. Commensurate with the changes, vulnerability to pests and diseases increased, leading to reduced productivity. Among the pests, insects are one of the most dominant biota that thrive and at times over dominate in agricultural fields. In natural systems, abnormal increase in insect population is checked by nature's own regulatory mechanism, the natural enemies. Predators, parasitoids and pathogens constitute the major groups of natural enemies, accounting for 40–60 per cent reduction in pest population in nature.

Exploitation of natural enemies is one of the oldest and best methods of pest control. The earliest record on the use of natural enemies for pest suppression dates back to fourth century China when ants were released to combat pests in the store and field. In 1767, mynahs (bird) were imported from India for the control of locusts in Mauritius. Since mid nineteenth century, ladybirds, green lacewings etc were utilized for pest control (Dhaliwal and Arora, 2001). Evidently, the early attempts at biological control were through the predators. Even the first successful biological control obtained was with a predator. In 1888, the predatory beetle, *Rodolia cardinalis* (Mulsant) was introduced in California, USA from Australia to control the cottony cushion scale *Icerya purchasi* Maskell that threatened the citrus industry. Despite these early attempts of control with predators, applied biological control is heavily biased towards parasitoids that show high specificity to a given pest, tracks its density and maintains it at low equilibrium level. The propensity towards specialist bioagents continues even today with the predators being a virtually ignored lot.

The new millennium gearing for an organic evergreen revolution in agriculture is on the look out for newer avenues of pest management devoid of ecological evils. Keeping pace with the changing scenario, the holistic pest regulatory effect of the natural enemies in agro-ecosystems is felt to be the best option for sustainable management of pests. Sustainability as observed by the United Nations is supported by five pillars, biodiversity being one of them (Swaminathan, 2002). Analysis of the biodiversity of the natural enemy community and an endeavour for beneficial use of each of the components will not only enhance the effectiveness of pest management strategies but also help in developing alternate components for a biointensive integrated pest management system. One natural enemy that could play a significant role in ecological pest management is the generalist predator, the spiders.

Spiders are carnivorous arthropods found in almost every kind of habitat, occurring in fairly large numbers and diversity. Although they have a wide range of prey, they feed mainly on insects, devouring a large number of the prey. Besides, they also threaten the prey with various foraging strategies and kill those living in their territory. Thus, a spider community that is diverse and that maintains a fairly constant numerical representation is prevalent in natural systems, exerting considerable control on the associated prey population and limiting their initial exponential growth without extinction (Riechert and Lockley, 1984).

As generalists, spiders may not contribute greatly to targeted control of pests. But being an important part of natural control mechanism they help to stabilize pest population. Spiders are highly abundant in agricultural fields and if conserved or augmented they can regulate many insect pests. As a group, they are highly resilient in agro-ecosystems, long lived and readily seek out new fields after harvest (Riechert and Lockley, 1984). The vital importance of spiders in the ever-growing field of biological pest control is now well recognized at least in certain agro ecosystems. They constitute a large part of the predatory arthropod fauna of rice ecosystem and prey on many insect pests (Barrion and Litsinger, 1980). Cereal and cotton fields are also rich in spiders contributing to pest regulation (Riechert and Lockley, 1984). In orchards, the spiders form the largest group of entomophages and are responsible for the reduction in pest population of almost all pest species (Amalin and Pena 2000; Brown *et al.*, 2003). For the most part, purposeful utilization of the araneae for pest management has been confined to rice and perennials. In vegetables, research efforts have largely being concentrated on pulses. Few studies have been attempted on the spiders in okra, brinjal, bittergourd, and amaranthus

With organic farming playing a pivotal role particularly in vegetable cultivation, it is all the more imperative to generate information on each of the components of natural enemy community for designing an insecticide free, nature friendly, economically viable and socially acceptable pest management strategy. As there is a dearth of information on the spider predators in vegetable ecosystem, the study was undertaken with the following objectives.

- To assess the density and diversity of the spider fauna in vegetable ecosystem.
- To determine their seasonal abundance.
- To evaluate their predatory efficiency
- To study their sensitivity to insecticides

Review of Literature

2. REVIEW OF LITERATURE

The role of spiders in the management of pests of vegetables is less explored even though they are widely exploited for the regulation of pests in rice and fruit orchards. The present study relates to the spiders in vegetable ecosystem, their relative abundance, predatory potential and impact of insecticides on them and the relevant literature is presented in this chapter. The spider fauna associated with annuals other than rice and influence of season and crop stages on their abundance in annuals alone is reviewed under 2.1 and 2.2.

2.1 SPIDERS IN AGRO-ECOSYSTEMS

Among annuals, most of the information available pertains to spiders in vegetable and cotton ecosystems.

2.1.1 Spiders in Vegetable Ecosystem

Despite being an important group of predators in vegetable ecosystem, the literature available on their role in pest regulation is mainly confined to pulses.

2.1.1.1 Spiders in Pulse Crops

Globally, a wide range of spiders associated with various pulse crops have been documented. Eighty one species of spiders in 34 genera belonging to 13 families were recorded from guar in Texas and Oklahoma. Among the species, while *Dictyna volucripes* Keyserling predated on adults of the midge, *Contarinia texana* (Felt) *Pardosa pauxilla* (Rogers) preyed on larvae of the pest (Rogers and Horner, 1977). Population of predatory spiders in soybean fields in Mississippi gradually increased during summer and was high in late than early planted crops (Buschman *et al.*, 1984). Several spiders were found to predate on the larvae of the soybean pest *Hedylepta indicata* (Fabricius) in Taiwan (Chien *et al.*, 1984). Over

25,000 spider species belonging to 17 different families were recorded from soybean fields in Virginia. Oxyopidae, Thomisidae and Salticidae were the dominant foliage dwellers while, Lycosidae and Linyphiidae were the important families retrieved from the ground (Ferguson *et al.*, 1984). A study on the effect of companion crops on the incidence of predatory spiders in rice and soybean fields in Nepal during the wet season revealed that the population densities of *Lycosa* sp., *Oxyopes* sp. and *Tetragnatha* sp. were higher in the maize-soybean intercrop than in soybean alone when observed 88 days after emergence (Gyawali, 1988). *Oxyopes* sp., *Tetragnatha* sp. and *Lycosa* sp. were present in the blackgram agro-ecosystem at Khumaltar in Kathmandu valley (Gyawali, 1989). Six species of spiders were recorded preying on adults of *Anticarsia gemmatalis* (F.) in soybean fields in Florida. *Peucetia viridans* (Hentz) accounted for over 65 per cent of the predation (Gregory *et al.*, 1989).

Studies from India too indicated the prevalence of different species of spiders in pulse plots. Several predatory spiders were seen preying on the leaf rollers, *H. indicata* and *Lamprosema diemenalis* (Gn) infesting soybean (Bhattacherjee, 1976). Similarly, a number of predatory spiders were documented from the fields of *Cajanus cajan* Millsp from Gujarat (Patel *et al.*, 1988). Survey of spiders associated with pigeon pea in Haryana revealed the abundance of four species of araneae *viz.*, *Hippasa haryanensis* Arora & Monga (25.30 per cent), *Pardosa tikaderi* Buchar (19.71 per cent), *Lycosa* sp. (25.35 per cent) and *Cheiracanthium punjabensis* Sadana and Bajaj (18.3 per cent) in the fields. Other species found were *Thomisus* sp., *Thomisus decoratus* Tikader *Neoscona theisi* (Walkenaer), *Oxyopes pandae* Tikader and *Steqodyphus* sp. When evaluated in the laboratory, the spiders fed voraciously on the thrips *Empoasca kerri* Pruthi and moderately on *Clavigralla* sp. None of the species fed on caterpillars of *Helicoverpa armigera* (Hubner) (Arora and Monga, 1993). While *Oxyopes shweta* Tikader, *Thomisus* sp. and *Salticus* sp. constituted predators of the legume pod borer *Maruca testulalis* Guen. (Borah and Dutta, 2001), the spiders *O. shweta*, *Neoscona* sp. and *Plexippus paykulli* (Aud) were found to predate on *H. armigera* in pigeon pea fields of Assam (Borah and Dutta, 2003). The natural enemies of pigeon pea pests included the spiders *Araneus* sp. and *Clubiona* sp. (Kumar and Nath,2003).

2.1.1.2 Spiders in Other Vegetables

Global records indicated that araneae constituted the most abundant predator group in tomato crop in Brazil (Raga *et al.*, 1990). In a mixed vegetable garden comprising of spinach, radish, cabbage, brussels sprout, potato, tomato and maize in USA, spiders formed 84 per cent of the predators and accounted for 98 per cent of observed predation (Riechert and Bishop, 1990). The thrips infesting potato *viz.*, *Thrips palmi* Karny and *Megalurothrips usitatus* (Bagnall) were found to be predated by the spiders *Neoscona pratensis* (Hentz) *Thomisus* sp., *Oxyopes salticus* Hentz and *Argyrodes* sp. in potato fields of Thailand (SEARCA, 1991).

The crab spider *Thomisus* sp. predated on caterpillars and adults of *H. armigera* in tomato fields of Bangalore in India (Ansari and Pawar, 1980). Numerous species of spiders were observed to prey on *Diaphania indica* Saund of pumpkin in Tamil Nadu (Peter and David, 1991) and *Plutella xylostella* (L.) in cabbage fields in the hill zones of Karnataka (Parvathi *et al.*, 2002). Survey conducted on the spiralling whitefly *Aleurodicus dispersus* Russel in vegetable fields of Coimbatore revealed the predation of the pest by the spider *Oxyopes* sp. (Geetha *et al.*, 2002). The intensity of predation by *O. shweta* and *P. paykulli* on *Phthorimaea operculella* (Zeller) was high in store and field (Debnath and Borah, 2002).

2.1.2 Spiders in Cotton Ecosystem

Spiders are the most familiar, efficient and obligate predators, which feed on different types of prey in cotton ecosystem. Several spiders were recorded from Arkansas cotton fields feeding on pests (Whitcomb *et al.*, 1963). Under favourable conditions, an average of about 30 spiders per plant was recorded from the cotton fields of Peru (Aguilar, 1975). Hunting spiders that rest on the plants were the most frequently observed group of spiders. It included the nocturnal hunters (Anyphaenidae and Clubionidae) that pursue their prey until it is caught, diurnal hunters (Saliticidae) that pounce on their prey and hunters that generally hide among plants (Aguilar. 1976). *Aysha gracilis* (Hentz), *P. viridans*. *Cheiracanthium inclusum* (Hentz). and *Neoscona arabesca* (Walckenaer) were observed to predate on eggs of the cotton leaf worm in a cotton field in Texas. Besides, the spiders *Misumenops* sp., *Tetragnatha laboriosa* (Hentz). *A. gracilis*, *P. viridans*. *C. inclusum* and *Hentzia palmarum* (Hentz) were found predating on the first instars of the leaf worm (Gravena and Sterling, 1983). A total of 31 species of spiders belonging to eight families were observed in the cotton fields in Heze county of China. Of these, *Pardosa astrigera* L. Koch., *Misumenops tricuspidatus* (Fabricius) and *Theridion octomaculatum* (Bosenberg and Strand) were the most important spiders preying on cotton aphids (Dong and Xu, 1984).

Natural enemies of *H. armigera* in cotton fields in Indonesia included 24 species of spiders in 10 families (Nurindah and Bondra, 1988). The orb weaver was the numerically dominant group of spiders in Texas cotton fields. Five species *viz.*, *N. arabesca* *Acantheneira* sp., *Gea heptagon* (Hentz), *T. laboriosa* and *Uloborus glomosus* (Nyffeler) constituted more than 80 per cent of the species sampled. They were found to predate on aphids, small dipterans, cicadellids, hymenopterans and coleopterans (Nyffeler *et al.*, 1989). Similarly, spiders formed one of the most important predators of cotton flea hoppers in East Texas. The araneae were worth three times the value of predatory insects (Sterling *et al.*, 1992).

Attempts made in India to record the spider fauna in cotton ecosystem also revealed the prevalence of several species. In Gujarat, the sac spider *Clubiona pashabhaii* Patel and Patel was observed to predate on several insect pests (Patel and Pillai, 1988). The spiders *Cheiracanthium melanostoma* (Thorell), *Oxyopes chittrae* Tikader *O. shweta*, *Lycosa poonaensis* Tikader and Malhotra and *T. pugilis* were found to prey on all the life stages of the aphid, *Aphis craccivora* Koch. available within its reach in cotton fields of North Gujarat (Sebastian and Sudhikumar, 2002).

2.1.3 Spiders Associated with Other Annuals

Survey conducted in USA in nine field crops *viz.*, cotton, soybean, lucerne, guar, rice, grain sorghum, groundnut, maize and sugarcane revealed the presence of 614 species of spiders of 192 genera under 26 families. The most frequent species in field crops were *Oxyopes* sp., *Salticus* sp., *Phidippus audax* (Hentz) and *T. laboriosa* (Young and Edwards, 1990). Natural occurrence of predatory spiders was observed in the lucerne fields of Uzbekistan and the spiders were found to predate on alfalfa bug *Adelphocoris lineolatus* (Goeze)(Shamuratova, 2002).

In India, eight species of spiders were found to predate on the maize borer *Chilo partellus* (Swinhoe) and the jassid *Zyginidia manaliensis* (Singh). The two species of spiders preying on the nymphs and adults of the jassids were identified as *Oxyopes* sp. and *Pardosa* sp. Early instar larvae of the maize borer was predated on by *Thomisus cherapunjeus* Tikader, *Marpissa tigrina* Tikader, *Phidippus punjabensis* Tikader, *Araneus sinhagadensis Tikader*, *Araneus* sp. and *O. pandae* (Singh and Sandhu, 1976). In a study conducted in Dehra Dun, two species of thrips *viz.*, *Thrips flavus* Schrank and *Thrips hawaiiensis* Morgan were found to be predated by the spiders *Marpissa* sp., *Tharpyna* sp., *Thomisus* sp., *Misumena* sp. and *Oxyopes* sp. (Veer, 1984).

Survey of spider fauna of groundnut fields in Gujarat revealed the presence of 2833 spiders belonging to 53 species, 34 genera and 14 families Of the 53 species collected, 31 species (55.98 per cent) were hunting spiders 6 species (8.51 per cent) ambushing, 11 species (29.51 per cent) web builders and 5 species (6.00 per cent) belonged to miscellaneus group of spiders (Patel and Pillai, 1988). Natural enemies of the sorghum ear head bug, *Calocoris angustatus* Leth. in sorghum tracts in Karnataka included several species of spiders like *Neoscona mukerjei* Tikader *N. theisi, Clubiona* sp., *Argyrodes* sp., *Oxyopes* sp. *Cheiracanthum* sp., *P. paykulli, Thomisus* sp. etc. (Hiremath, 1989).Larvae of the stem borer (*C. partellus*) of fodder maize were predated by 17 species of predatory spiders in Karnataka (Jalali and Singh, 2002).

2.2 INFLUENCE OF SEASON AND CROP STAGES ON SPIDER ABUNDANCE

2.2.1 In Vegetable Ecosystem

It has been hypothesized that as crops grow, increase in the prey availability supports more spiders to co-exist (Pianka, 1966). In soybean ecosystem in the predators were more abundant during pod fill stages, contributing to heavy larval mortality of *Plathypena scabra* (F), particularly late in the season (Bechinsk and Pedigo, 1981). Similarly, the number of foliage dwelling spiders peaked in early August and again in early September in1981 and in early to mid-August in 1982 in soybean cropping systems in United States of America (Ferguson *et al.*, 1984). Peak activity and higher density of spiders were recorded in summer, while the lowest were in winter in 8 vegetable crop fields in Egypt. The abundance of spiders in summer seemed to be the result of a combination of three factors *viz.*, dense vegetation cover, high temperature and significant relative humidity (Hussein, 1999).

In India, predatory spiders were seen in abundance on *H. indicata* infested soybean plants in September-November (Bhattacherjee, 1976). Appreciable population of the spiders *O. ratnae*, *O. shweta*, *Neoscona* sp. and *P. paykulli* and their predation on *H. armigera* in pigeon pea was seen when *H. armigera* appeared during flowering and remained till the maturity stage of the crop (Borah and Dutta, 2003).

2.2.2 In Other Annuals

The abundance of spiders in the cotton fields of Peru was directly linked to the development of plants rather than the season (Aguilar, 1976). Change in the species composition of spiders in groundnut fields was observed in Gujarat. The species diversity index increased from July through October attaining the peak in October coïnciding with the crop growth and consequent increase in prey availability (Patel and Pillai, 1988).

2.3 PREDATORY EFFICIENCY

Spiders predate almost exclusively on insects and consume a large number of the prey. Hence, the feeding potential and prey preference of spiders could play a crucial role in limiting the exponential increase of insect population in agricultural systems.

2.3.1 Feeding Potential

The consumption rate of *L. pseudoannulata* has been estimated to be 24 nymphs or adults of *N. lugens* (IRRI, 1975) or 8.5 nymphs (Chau, 1987) and 15.20 adults of plant hopper per day (Samal and Misra 1975). Studies conducted in Texas indicated that *A. gracilis* and *P. viridans* consumed 4.80 and 0.41 first instar larvae of cotton leaf worm per day respectively (Gravena and Sterling, 1983).

In a laboratory test conducted in Yugoslavia, *Cheiracanthium mildei* L. Koch and *Achaearanea lunata* (Clerck) predated on sycamore lace bug *Corythucha ciliata* (Say) at the rate of 8.2 and 3.1 bugs per day, respectively (Balarin and Polenec, 1984). Similarly, *Araneus marmoreus* Clerck preyed on Diptern and Hymenopteran insects at the rate of 14.1 prey per day (Parquet, 1984).

Shortest developmental period of spiderlings and highest survival rate and fecundity of. *L. pseudoannulata* were obtained when a mixture of larvae of *Drosophila* and nymphs of *N. lugens* were given when compared to spiderlings fed with each prey separately (Thang *et al.*, 1988). Studies on the predation by *T. octomaculatum* an important predator of rice hopper in the laboratory in China indicated that the spider attacked 0.25 to 1.88 individuals of *N. lugens* per day (Ge and Chen, 1989).

N. mukerjei, Cheiracanthium sp., *Thomisus* sp. and *Oxyopes* sp. were found to predate on adult and later instar nymphs of sorghum earhead bug, *C. angustatus* at the rate of 3.00, 4.00, 2.33 and 3.00 bugs per day (Hiremath, 1989). First instar larvae of *C. partellus* were consumed by *Oxyopes* sp. and *Cheiracanthium* sp. at the rate of 2.84 to 3.04 larvae in 24 h in the laboratòry (Mohan *et al.*, 1990).

When the feeding efficiency of six predatory spiders *viz.*, *Salticus scenicus* (Clerck), *Pardosa birmanica* Simon, *O. pandae Thomisus* sp. *Neoscona nautica* (L.Koch) and *Cassinoides indica* L. on whitebacked plant hopper was studied, *S. scenicus* was found to be the most efficient predator consuming 4.95 nymphs of white backed plant hopper per day followed by *O. pandae* (3.76), *P. birmanica* (3.67) *Thomisus* sp. (3.45), *N. nautica* (2.55) and *C. indica* (1.83) (Bhathal and Dhaliwal, 1990). Rubia *et al.* (1990) reported that *L. pseudoannulata* fed on a variety of prey, including hoppers, collembolans, flies and the mirid predator *C. lividipennis*. According to them the consumption of prey by individual spiders increased with prey density.

The adult of the spider, *Lyssomanes sikkimensis* Tikader had significantly more predatory potential compared to the developmental instars. While the consumption rate of the different instars ranged from 0.60 to 5.20 mango hoppers per day, it was 9.60 for the adult spider (Sadana and Meenakumari, 1991). Twenty five species of spiders were observed to consume 2.00to 36.00 *Monellia caryella* (Fitch) (black margined aphids) per day in pecan (Bumroongsook *et al.*, 1992).

Tetragnatha sp. consumed 0.90 to 3.50 adult delphacids per day. Similarly, *Synaemops rubropunctatum* Mello-Leitao consumed 1.80 delphacids per day and 2.50, 1.40and 0.60, 1st, 2nd and 6th instar larvae of *Spodoptera frugiperda* (JE Smith) per day. On the other hand *Argiope* sp. consumed 4.10 delphacids per day (Bastidas *et al.*, 1994). While, *O. javanus* could kill 2.00 to 3.00 delphacidsperday. *Pardosa pseudoannulata* (Boesenberg and Strand), *A. catenulata* and *Tetragnatha japonica* Boesenberg and Strand killed 1.00 to 2.00 delphacids per day in rice fields in Philippines (Kamal and Dyck, 1994).

In a trial conducted in India, *Pardosa* sp. consumed 10.33 hopers over a period of five days and *Tetragnatha* sp. and *Oxyopes* sp. consumed 4.81 hoppers each (Samiayyan and Chandrasekharan, 1998). 4.80, 4.23 and 3.79 green leafhoppers were consumed per days by *L. pseudoannulata*, *Clubiona* sp. and *A. catenulata* in rice ecosystem of India (Sahu *et al.*, 1996). *P. pseudoannulata* consumed 3.93 green leaf hopper adults per 24 h (Singh and Singh, 2001).

Lycosa sp. consumed 1.60 *Chilo infuscatellus* Snellen larvae per day, *Argiope* sp. consumed 5.30 *Pyrilla perpusilla* Wlk. adults per day in a laboratory experiment conducted in India (Patil *et al.*, 2001).

O. shweta, *C. melanostoma*, *L. poonaensis* and *Thomisus pugilis* Stoliczka consumed 3.40 to 5.40, 6.60 to 10.50, 24.50 to 51.50, 28.00 to 31.60 *A. craccivora* in 24 h in the laboratory (Sebastian and Sudhikumar, 2002). *P. viridana*, *A. catenulata*, *O. javanus* and *N. theisi* consumed *A devastans*, *A. gossypii*, *B. tabaci*, *H. armigera* (larva) and *S. litura* (larva) at the rate of 5.40, 7.30, 3.90 and 4.10 and 4.40, 7.50, 7.20, 4.10 and 4.40, 8.00, 7.20, 4.10 and 4.50 and 3.90, 6.40, 7.20, 4.30 and 4.00 per day (Mathirajan and Regupathy, 2003). *T. maxillosa* and *L. pseudoannulata* consumed *N. lugens*, *Sogatella furcifera* (Horvath) and *Nephotettix* sp. at the rate of 12.40, 15.20, 16.60 and 26.60, 22.20 and 17.00 in seven days, respectively (Premila, 2003).

2.3.2 Prey Preference

Eventhough spiders have no discriminatory reaction and consume whatever prey is available, they do show preference when different prey are available.

Lycosa pseudoannulata (Boesenberg and Strand) when fed with a mixture of the adults of *Drosophila, Musca* and Whitefly and larvae of *Musca* had a higher survival rate than those provided with Drosophila alone (Gavarra and Raros, 1975). *Oxyopes* sp. had a greater preference for *Nephotettix virescens* (Distant) (39.23 per cent) followed by *S. furcifera* (19.19 per cent) and *N. lugens* (14.40 per cent) in a mixed population. On the other hand, *Pardosa* preferred *N. lugens* (41.04 per cent) to *S. furcifera* (30.79 per cent) and *N. virescens* (14.05 per cent) (Chiu, 1979).

The spider *Peucetia viridana* Stoliczka preferred *Amrasca devasatans* Distant to *Aphis gossypii* Glover. two important pests of cotton (Nyffeler *et al.*, 1989). In another study *P. viridana, O. javanus, Argiope catenulate* (Doleschall) and *N. theisi* preferred *A. gossypii* as major food followed by *Bemisia tabaci* (Gennadius) and *A. devastans* in cotton (Alerweireldt, 1994).

Studies conducted in India too revealed the prey preference of several spiders. *Pardosa* had a distinct preference for *N. lugens* and *S. furcifera* than *N. virescens*. *Tetragnatha* sp. preferred significantly more *N. virescens* (16.23 per cent) to *S. furcifera* (11.08 per cent) and *N. lugens* (10.44 per cent) (Nirmala, 1990; Ganeshkumar, 1994). The host preference of *L. pseudoannulata, A. catenulata* and *Clubiona* sp. in the descending order was green leafhopper, rice hispa, stem borer and leaf folder (Sahu *et al.*, 1996).

In another study conducted in Tamil Nadu, *Pardosa* spp. preferred brown plant hopper (BPH), white backed plant hopper (WBPH) and green leaf hopper (GLH), *Tetragnatha* sp. preferred GLH, WBPH and BPH, *Oxyopes* sp. preferred GLH, WBPH and BPH in descending order respectively (Samiayyan and Chandrasekharan, 1998).

Again when the different prey of spiders in cotton ecosystem were tested for their relative preference, *P. viridana* showed highest preference for *A. gossypii* (36 per cent), followed by *B. tabaci* (29 per cent) and *A. devastans* (24 per cent). Similarly, *A. catenulata* preferred *A. gossypii* (24 per cent) to *B. tabaci* (22 per cent) and *A. devastans* (18 per cent). *Oxyopes javanus* Thorell preferred *A. gossypii* (19 per cent), *B. tabaci* (17 per cent) and *A. devastans* 17 per cent), and *N. theisi* preferred *A. gossypii* (19 per cent), *A. devastans* (14 per cent) and *B. tabaci* (13 per cent) in the descending order (Mathirajan and Regupathy, 2003). *Tetragnatha maxillosa* Thorell and *L. pseudoannulata* showed significant preference for *Nephotettix* sp. and *Nilaparvata lugens* (Stal) respectively when a mixed diet of *N. lugens*. *S. furcifera* and *Nephotettix* sp was offered (Premila, 2003).

2.4 EFFECT OF INSECTICIDES

Reports from abroad and India indicated varied effects of chemical, botanical and microbial insecticides on spiders.

2.4.1 Chemical Insecticides

Both toxic and non-toxic effects of synthetic chemical insecticides have been documented.

2.4.1.1 Toxic Effect

Dust (BHC) and granular (methomyl) formulations of insecticides were observed to be highly lethal to spiders (Takahashi and Kiritani, 1973). Application of dimethoate to winter wheat in southern England reduced the population of araneae by 90 per cent seven days after treatment (Vickerman and Sunderland, 1977). Of the seven insecticides commonly used for the control of bean looper *viz.*, carbofuran (0.2 per cent). methamidophos (0.15 per cent), triazophos (0.15 per cent), trichlorphon (0.25 per cent), deltamethrin (0.1 per cent), carbaryl (0.25 per cent) and dimethoate (0.1 per cent) tested, triazophos and dimethoate were most injurious to the spider population in the bean fields of Peru causing 36.49 and 33.31 per cent mortality respectively (Yabar, 1982).

Application of carbofuran (0.56 kg ha^{-1}) in the foliage of alfalfa for a short period caused significant reduction of only *T. laboriosa*, but dimethoate (0.41 kg ha^{-1}) and azinphos-methyl (0.41 kg ha^{-1}) significantly reduced all foliage spiders upto 14 days (Culin and Yeargan, 1983). Initial mortality of more than 92 per cent of Linyphiid spiders occurred due to spraying of deltamethrin (7.5g ai ha^{-1}) in winter wheat in Germany (Basedow *et al.*, 1985). Malathion at 240 g ai ha^{-1} caused greater mortality of spiders than endosulfan and trichlorfon applied at the rate of 240 g ai ha^{-1} in cocoa plantations in Brazil (Mendes *et al.*, 1985). Chlorpyriphos and methomyl were more detrimental than carbaryl to the spiders in lucerne field in Misouri (Brandenburg, 1985). Population of araneae were found adversely affected by dimethoate (400 g ai ha^{-1}) and phosalone (600 g ai ha^{-1}) in wheat fields of France (Fischer and Chambon, 1987).

Three pesticides commonly used to control apple pests in Israel were found to be highly toxic to the spider *C. mildei*, the order of toxicity being endosulfan > azinphos-methyl>cyhexatin when tested by dry film technïque and topical application (Mansour *et al.*, 1981).

Far fewer spiders were found in fields treated with insecticides such as monocrotophos, phosphamidon, and fenvalerate at a concentration of 0.02 per cent and even eliminated them completely from the fields due to continuous application of insecticides at higher concentrations (0.03 per cent and0.02 per cent) (Patel and Pillai, 1988). Permethrin (25g ai ha^{-1}) was more toxic to spiders than cypermethrin (25g ai ha^{-1}) and cyfluthrin

(10g ai ha^{-1}) during low rainfall than during high rainfall in soybean fields of Brazil (Link and Costa, 1988). The effect of the insecticides parathion, deltamethrin and endosulfan on the orb weaving spider, *Araneus* sp. when studied in the laboratory indicated that greater mortality of the spider was caused by parathion, followed by deltamethrin and endosulfan (Polesny, 1988). Similarly, spider population in apple orchard was reduced significantly after the application of diazinon, phosphamidon and azinphos-methyl (Sechser, 1988). The epigeal spider fauna in polders, *viz.*, erigonids and linyphids were observed to be sensitive to deltamethrin, fenitrothion and bromophos-ethyl when the effects of above ground application of the insecticides was studied (Everts *et al.*, 1989; Lohuis, 1990). Deltamethrin, fenitrothion and maneb appeared to be moderately harmful to the spider *Oedothorax apicatus* (Blackwall) observed in cereal and vegetable crops in Netherlands (Aukema *et al.*, 1990).

Densities of araneids were significantly reduced by application of chlorpyrifos in groundnut fields in Florida (Funderburk *et al.*, 1990). Fenitrothion, deltamethrin and bromophos-ethyl adversely affected spider fauna of wheat, barley and rape fields (Everts, 1990). Parathion and dimethoate were toxic towards aranea and caused 18 and 11 per cent reduction in population respectively. Fenvalerate reduced araneae population by 30.00 to 33.00 per cent and the toxic side effects were most apparent during the first few weeks after application (Casteels and Clercq, 1990). Ekalux was toxic to araneae in cotton field of Egypt (Darwish and Farghal, 1990).

Application of aldicarb at planting or treatment during the early squaring period with aldicarb, carbofuran or acephate in cotton reduced the number of spiders in Arizona (Terry, 1991). Lambda-cyhalothrin (10 g ai ha^{-1}) almost completely suppressed the activity, density and abundance of males of *Erigone* sp. Cypermethrin (16g ai ha^{-1}) suppressed web building frequency and severely affected web size and building accuracy of *Araneus diadematus* Cl. when tested in the laboratory (Samu and Vollrath, 1992). Deltamethrin and methamidophos adversely affected araneae population in cereal fields (Volkmar and Wetzel, 1993).

Dimethoate was highly toxic to the predatory spiders seen in the citrus fields of Brazil. Application of the insecticide reduced the population of the predator up to four days after application (Bittencourt and Cruz, 1998). Similarly, dimethoate and deltamethrin had severe effect on spiders in cereal fields in United Kingdom (Huusela, 2000).

Avermectin was highly toxic to spiders in vegetable fields (Cheng *et al.*, 2000). While T. *maxillosa* was highly susceptible to diazinon, *L. pseudoannulata* was more susceptible to phenthoate and carbaryl both in laboratory and field experiments (Tanaka *et al.*, 2000). Spiders were negatively affected by chlorpyrifos, but their number increased two weeks after treatment in maize fields in Brazil (Filho *et al.*, 2002).

The effect of insecticides on spiders was extensively studied in India too. The synthetic pyrethroid, cypermethrin was observed to be toxic to araneae in cotton fields in India (Muralidharan and Chari, 1990). Dimecron 85 EC (Phosphamidon) and Parataf 50 EC (methyl parathion when tested at 0.4 per cent concentration were highly toxic to spiders (Shunmugavelu and Palanichamy, 1991). Carbofuran seed treatment reduced the number of spiders in groundnut fields (Rao *et al.*, 2001). Imidacloprid (RIL 18, 20 SL) at all concentrations (100, 125, 400 ml ha^{-1}) were toxic to predatory spiders (30.66 per cent mortality at 100 ml ha^{-1}). Monocrotophos killed 83.33 per cent of spiders (Manjunatha and Shivanna, 2001). Carbofuran (1 and 0.5 kg ai ha^{-1}) and carbaryl (0.1 per cent) were injurious to the predatory spiders in rice fields in Andhra Pradesh, India (Vardhani and Rao, 2002). Ezeetab (deltamethrin 25 per cent tablet) at 10 and 12.5 g ai ha^{-1} recorded moderate toxicity against predatory spiders with 40.66 to 42.66 per cent mortality (Manjunatha *et al.*, 2002). Granular insecticides, carbofuran and fipronil significantly reduced the spider population (65 per cent) in soybean field in Hyderabad (Rao *et al.*, 2003). Commonly used insecticides for rice pest control *viz.*, carbaryl (0.15 per cent) phosphamidon (0.05 per cent) monocrotophos (0.05 per cent), quinalphos (0.05 per cent) and methyl parathion (0.05 per cent) caused 80 to 100 per cent mortality of spider predators in a laboratory study (Premila, 2003).

2.4.1.2 Non Toxic Effect

Single application of acephate, malathion and methidathion did not cause any significant change in the spider population in citrus orchard of Florida (Fitzpatrick *et al.*, 1978). Carbaryl (0.25 per cent) and trichlorphon (0.25 per cent) caused only a low level of mortality of spiders (18.76 per cent and 21.05 per cent) in bean fields of Peru (Yabar, 1982). Diazinon, permethrin, malathion, methyl parathion and endosulfan did not produce any deleterious effect on predatory spiders in the vegetable patola Luffa cylindrica (L.) (Oben *et al.*, 1986). A laboratory study revealed that endosulfan was relatively harmless to the predatory spider *A. diadematus* (Polesny, 1988)

Carbosulfan and betacyfluthrin when applied to control *B. tabaci* were least toxic to araneae in cotton fields of Egypt (Darwish and Farghal, 1990). Deltamethrin, fenitrothion and maneb appeared to be harmless to moderately harmful to the spider *O. apicatus* (Aukema *et al.*, 1990). Propiconazole and dimethoate had only a weak effect on araneae of winter barley (Volkmar and Wetzel, 1993). Similarly, abundance of spiders was unaffected by imidacloprid and bendiocarb (Kunel *et al.*, 1999). Imidacloprid (Confidor 20 per cent) did not produce any side effects on predatory spiders after 30 days of application in rice fields of China (Ling and Wu 1999). Similarly in bean field of Brazil spraying of imidacloprid had no negative effect on predatory spiders (Marquini *et al.*, 2002). Like wise, imidacloprid did not reduce the number of spiders in citrus orchard in Australia (Mo and Philpot, 2003).

Studies on influence of commonly used insecticides on predatory population of rice indicated that acephate, chlorpyrifos and monocrotophos were safe to *L. pseudoannulata* and *Tetragnatha* sp. in rice fields of Tamil Nadu (Kumar and Velusamy, 2000). Spider population of okra was found unaffected by application of malathion in Orissa (Mishra and Mishra, 2002).

2.4.2 Botanical Insecticides

Population of araneae was not reduced in plots treated with neem seed kernal extract 48 days after treatment (Kareem *et al.*, 1988). Though there was an initial reduction in the number of *L. pseudoannulata* in neem treated rice plots, recolonisation was better (Mohan *et al.*, 1991). Similarly, neem products did not affect the population of *O. javanus* (TNAU, 1992). Commercial formulations of azdirachtin like neemgold (0.5 per cent) and Neemax (20 per cent) were safe to predators (Lakshmi *et al.*, 1998). Another formulation of azadirachtin, Nimbecidine did not show any toxic action or antifeedant effect on *L. pseudoannulata* (Ajayakumar, 2000). Neem formulations (Nimbecidine, Achook, Neemax, Neemgold, Rakshak and azadirachtin) did not reduce population of spiders such as *L. pseudoannulata*, *T. maxillosa* and *A. catenulata* (Dash *et al.*, 2001). Similarly, the neem formulations, Neemark (0.3 per cent) and Achook (0.3 per cent) wassafe to *Oxyopes* sp. in tea bushes in Himachal Pradesh (Sharma and Kashyap, 2002). The botanical insecticides Neemax (neem seed kernel extract) at 1.0 kg ha^{-1} and Multineem (neem oil) at 2.5 l ha^{-1} did not cause any effect on spiders of okra (Mishra and Mishra, 2002).

2.4.3 Microbial Insecticides

Few reports are available on the effect of microbial agents on spiders. The spiders belonging to the families Linyphidae, Lycosidae, Araneidae, Thomisidae and Salticidae when exposed to topical application of *Nomuraea atypicola*, developed mycosis (Greenstone *et al.*, 1987).

A spray of thuricide 90 TS was least injurious to spiders in rice ecosystem (Mendoza, 1972). Spraying of formulations of Bacillus thurinjiensis (Bt) like (Bitoxibacillin, Dendrobacillin, Entotaderin and BIP) in an orchard in USSR brought about an increase in spider population (Sklyarov, 1983). The Bt formulations (Delfin and Bactec) were less toxic to the predatory spiders in cotton fields in India (Patel and Vyas, 2000). Bt formulation Dipel 8L at 0.3 per cent was safe to predatory spiders in tea plantations of Himachal Pradesh. (Sharma and Kashyap, 2002). Spiders of okra were unaffected by the Bt formulation Biotox when applied at the rate of 1 kg ha^{-1} (Mishra and Mishra, 2002). Similarly, Biobit (Rao and Singh, 2003) and Delfin WG (Gopan, 2003) had only low toxic effect on spiders in rice fields.

Materials and Methods

3. MATERIALS AND METHODS

Survey was conducted in Kalliyoor panchayat, an important vegetable growing tract in Thiruvananthapuram district during the summer of 2004 to record the spider fauna in vegetable ecosystem. Studies on the seasonal abundance, predatory potential, prey preference and effect of insecticides on the major spiders encountered in the vegetable plots were conducted at the College of Agriculture, Vellayani.

3.1 DOCUMENTATION OF SPIDER FAUNA

Five vegetables of different architecture *viz.*, okra (*Abelmoschus esculentus* (L.) Moench.), brinjal (*Solanum melongena* L.), cowpea (*Vigna unguiculata* subsp. *sesquipedalis* (L.) Walp., bittergourd (*Momordica charantia* L.) and amaranthus (*Amaranthus tricolor* L.), were selected for the study. Four plots (approximately 20 cents) of each vegetable were selected at random in the Kalliyoor ward of the identified panchayat. The crops were examined carefully for the occurrence of spiders at fortnightly intervals from planting till the end of the cropping season (one month for amaranthus and three months for the other vegetables). The spiders observed were collected in small perforated polythene bags, labelled and brought to the laboratory. Additionally, ten plants were selected at random in each plot and the number of spiders on each plant was recorded every fortnight. The sampling units were changed randomly during each observation. The pests prevalent in abundance to moderate abundance in each of the vegetable plots and the plant protection measures adopted by the farmers were recorded.

3.1.1 Identification of Spiders

The spiders collected from the vegetable plots were sorted and the adults were separated and preserved in 70 per cent ethyl alcohol. The specimens were identified by Dr. P.A. Sebastian, Reader, Division of

Arachnology, Department of Zoology, Sacred Heart College, Thevara, Cochin, Kerala.

3.2 ASSESSMENT OF SEASONAL ABUNDANCE

A plot of each of the vegetables (okra, brinjal, cowpea bitter gourd and amaranthus) was selected in the Instructional Farm, Vellayani during summer and rainy seasons for studying the seasonal abundance of spiders. The crops were maintained as per the package of practices of Kerala Agricultural University (KAU, 2002). Plant protection measures were applied on need basis. The population of spiders on 10 plants selected at random was recorded as described in 3.1

3.3 DETERMINATION OF PREDATORY EFFICIENCY

The prey range, predatory potential and prey preference of the four major spiders observed in the vegetable ecosystem *viz*., *O. javanus*, *C. danieli*, *N. mukerjei* and *T. mandibulata* were studied in the laboratory.

3.3.1 Raising of Host Plants

Seeds of cowpea, bhindi and bittergourd were sown in clay pots (15 cm diameter) filled with potting mixture (soil, sand and cowdung in 1 : 1 : 1) at the rate of three seeds per pot. Seeds of brinjal and amaranthus were sown in pots filled with potting mixture and the seedlings were transplanted to the pots (15cm diameter) at four leaf stage at the rate of three seedlings per pot. The plants were watered daily. One-month-old plants covered with perforated polyethylene covers (50 x 35 cm) were used for the various studies.

3.3.2 Test Insects and Their Culturing

The pests recorded as mentioned in 3.1 were maintained in the unsprayed fields of the respective vegetables in the Instructional Farm, Vellayani and were collected as and when required.

3.3.3 Evaluation of Prey Range

The pests observed in each of the vegetable plots during the survey as mentioned in 3.1 were tested for their preference for feeding by the four dominant spiders in the vegetable ecosystem.

The adults of the spiders were collected from pesticide unsprayed vegetable plots, sorted to uniform size and starved for 24 hours. The spiders were then caged in the pots containing 30-day-old plants of the respective vegetable at the rate of one spider per cage. The pests (ten numbers each) of each vegetable were released together in a cage. Three replications were maintained for each treatment. Observations were taken daily on the number of individuals consumed for five days. The prey insects were replenished to maintain the prey density at ten after each observation.

3.3.4 Evaluation of Predatory Potential

Five pests preferred most by the spiders in the prey range test (3.3.3) were selected for determining the predatory potential. The experiment was conducted in completely randomized block design with ten replications as described in 3.3.3. The number of insects predated on was recorded 24 hours after release and the observations were continued for seven days.

3.3.5 Evaluation of Prey Preference

The relative preference of the dominant spiders for the preferred hemipteran and lepidopteran pests of different vegetables was determined as described in 3.3.3 and 3.3.4 by supplying a mixed population of the prey.

3.4 ASSESSMENT OF TOXICITY /SAFETY OF INSECTICIDES.

The chemical, botanical and microbial insecticides commonly used for the control of pests of vegetables (Table 1) were evaluated for their relative toxicity/safety to the spiders *O. javanus*, *C. danieli*, *N. mukerjei* and *T. mandibulata* at their recommended doses. Different doses of the chemical insecticides were also screened to determine their extent of toxicity.

Table1. Chemical, botanical and microbial insecticides tested against spiders in vegetable ecosystem

Sl no	Common name	Trade name	Dose (per cent)	Company/Source
a.	**Chemical insecticides**			
1	Dimethoate	Rogor 30EC	0.025 0.05 0.1	Sree Ramcides Chemicals Pvt. Ltd
2	Carbaryl	Sevin 50WP	0.15 0.2 0.3	Agrochemicals (India) Ltd.
3	Malathion	Malathion 50EC	0.05 0.1 0.2	Sree Ramcides Chemicals Pvt. Ltd
4	Quinalphos	Ekalux 25EC	0.025 0.05 0.1	Novartis India Ltd
5	Imidacloprid	Confidor 200SL	0.02 0.03 0.04	Bayer (India) Ltd.
b	**Botanical insecticides**			
1	NSKE		5	Preparation
2.	Neem leaf extract		5	Preparation
3	Neem oil		2	
4	Pongamia oil		2	
5	Iluppai oil		2	
6.	Marotti oil		2	
7	Azadirachtin 1 %	Neem Azal T/S	2ml/litre	M/S EID Parry (I) Ltd.
c	**Microbial insecticides**		Spores ml^{-1}	
1.	*Fusarium pallidoroseum*		7×10^6	Department of Agricultural Entomology, College of Agriculture, Vellayani
2.	*Fusarium* sp.		5×10^6	
3.	*Metarhizium anisopliae*		1×10^8	
4.	*Beauveria bassiana*		1×10^7	
5.	*Paecilomyces lilacinus*		1×10^8	
6.	*Bacillus thuringiensis* var *kurstaki*	Delfin WG.	0.2 per cent	Margo Biocontrol Pvt. Ltd.

count in a drop of the suspension was estimated using a haemocytometer. The suspension was further diluted to adjust the spore count to the desired concentration.

3.4.2 Testing for Toxicity

Topical application and release on sprayed plant technique were followed for testing the toxicity of the chemical and botanical insecticides to the spiders. Potted okra plants raised as described in 3.3.1 were used as test plants. Pathogenicity test was conducted to determine the infectivity of the microbial insecticides to the spiders.

3.4.2.1 Topical Application

Five adults of each spider were taken in a clean petridish and the insecticide solutions were sprayed directly on them with an atomizer. Spiders sprayed with water served as control. The treated spiders were kept exposed under a fan for the spray fluid to evaporate. The spiders were then transferred individually to the okra plants and were provided with food (prey insects–aphids, whiteflies and jassids). Three replications were maintained for each treatment. Mortality of the spiders was recorded every 24 hours upto seven days.

3.4.2.2 Release on Sprayed Plants

Bhindi plants sprayed with the respective insecticides were confined in cages and a spider was released to each plant. A set of five such plants served as a treatment and three replications were maintained for each treatment. Mortality of the spiders was recorded daily for seven days.

The mortality of spiders observed in 3.4.2.1 and 3.4.2.2 was corrected using Abbot's formula (Abbot, 1925).

3.4.2.3 Pathogenicity Test

The spiders were placed in small glass jars of 5 cm diameter and 10 cm height. The spore suspension was sprayed on the spiders and the jar

3.4.1 Preparation of Spray Solution

Commercial formulations

The required quantities of the chemical insecticides were weighed or pipetted and mixed with a small quantity of water and made up to 100 ml to prepare the spray solutions

Neem Seed Kernel Extract (NSKE)

Neem seed kernels were crushed to coarse powder and 50g of the powder was taken in a cloth bag and dipped in half a litre of water for 24 hours. The cloth bag was then squeezed repeatedly till the outflow turned light brown. Ordinary bar soap (5g) was sliced and dissolved in half a litre of water. The soap solution was added to the kernel extract and stirred well to prepare neem seed kernel extract.

Neem leaf extract

Fifty grams of neem leaves were macerated in a mixie and soaked in one litre of water for 48 hours. The solution was strained to obtain the neem leaf extract.

Oil emulsions

Sliced soap (5g) was dissolved in 500 ml of water to prepare soap solution. The plant oil (20 ml) were added to the soap solution with continuous stirring and the solution was made upto 1litre to prepare 2 per cent oil emulsion.

Microbial insecticides

The fungi were grown over potato dextrose agar (PDA) plated on sterilized petri-plates. Seven-day-old cultures of the fungi were used for making the spray solutions. Ten ml of distilled water was taken in a sterile test tube and five fungal discs of 7 mm diameter of the respective fungi were added to it and shaken vigorously for two minutes. The suspension obtained was filtered through a muslin cloth and the spore was closed with a wet muslin cloth and kept as such for 15 minutes. The treated spiders were then released individually into caged bhindi plants provided with prey insects. The mortality of the predator was recorded every 24 hours upto seven days.

The dead spiders were transferred to petridishes containing moistened filter paper. When fungal growth was noticed, the spiders were transferred to petridishes plated with PDA. The fungal growth obtained was sub-cultured. One week old fungal growth from the sub-culture was taken and made into spray solution as described in 3.4.1 and the spiders were treated as mentioned above. The experiment was repeated to get the same pathogen from the dead spiders.

3.5 STATISTICAL ANALYSIS

Data of each experiment were analysed, applying suitable methods of analysis (Panse and Sukhatme, 1967).

Results

4. RESULTS

Spiders are ubiquitous group of predators found in agro-ecosystems. Often, they occur in such convincing abundance, signifying the crucial role they could play in the dynamics of every habitat. Results of the study conducted on the spider fauna associated with five popular vegetables of Kerala, their prey range, predatory potential, prey preference and sensitivity to insecticides are presented in Tables 2 to 16.

4.1 SPIDER FAUNA IN VEGETABLE ECOSYSTEM

Survey undertaken in Kalliyoor Panchayat of Thiruvananthapuram district to document the spider fauna in vegetable ecosystem revealed the prevalence of an appreciable population of spiders in okra, brinjal, cowpea, bittergourd and amaranthus fields. Population of the natural enemy ranged from 6 to 35 per 10 plants in a cropping season (Table 2.). High population of spiders was recorded from okra, the number of spiders in the different fields ranging from 17 to 35 per 10 plants. Population of the araneae in brinjal ranged from 15 to 18 per 10 plants. In the climbers *viz*., cowpea and bittergourd, population of the predator ranged from 14 to 31 and 15 to 21 per 10 plants, respectively. The number of spiders ranged from 6 to 9 per 10 plants in amaranthus.

The two guilds *viz*., hunting and web building spiders were prevalent in the vegetable fields (Table 3). The hunters were significantly dominant in the vegetable ecosystem, constituting 65.50 per cent of the spider population. The web builders formed only 34.50 per cent of the population. However, among the various vegetable fields, there was no significant difference in the occurrence of hunting and web building spiders. While the occurrence of hunters in okra, brinjal, cowpea, bittergourd, and amaranthus ranged from 62.50 to 70.30 per cent, the presence of web builders ranged from 29.70 to 37.50 per cent.

Table 2. Population of spiders in different vegetable fields in Kalliyoor Panchayat of Thiruvananthapuram district during summer, 2004

Vegetables	Spider population in a crop period (number per ten plants)			
	F1	F2	F3	F4
Okra	35	34	17	32
Brinjal	17	16	15	18
Cowpea	21	31	14	30
Bittergourd	21	16	15	18
Amaranthus	8	9	8	6

F : Field
Crop period : Okra, Brinjal, Cowpea, Bittergourd – 3 months
Amaranthus – 1 month

Table 3. Relative abundance of hunting and web building spiders in vegetable fields (%)

Vegetables	Hunting spiders	Web building spiders
Okra	62.50	37.50
Brinjal	68.00	32.00
Cowpea	70.30	29.70
Bittergourd	62.80	37.20
Amaranthus	64.00	36.00
Mean	65.50	34.50

CD (0.05) Treatments : NS
CD (0.05) Spiders : 4.810

4.1.1 Species Diversity

Thirty species of spiders belonging to nine families were recorded from the vegetable fields during the period of study (Table 4). The hunting spiders included the diurnal hunters and the diurnal ambushers. Four species of *Oxyopes viz., O. javanus, O. shweta, O. quadridentatus* and. *Oxyopes* sp., *P. viridana* (Plate1), *Hyllus semicupreus* (Simon), *Hyllus* sp., *Carrhotus* sp., *Phidippus sp., Telamonia dimidiata* (Simon) (Plate2), *Cheiracanthium* sp, *Cheiracanthium danieli* Tikader, *Clubiona* sp.(Plate 3) and *Lycosa* sp. comprised the assemblage of diurnal hunters recorded from the plots. *Thomisus pugilis* Stoliczka, *Thomisus sorajaii* Basu, *Thomisus* sp (Plate3) and *Castineira 'zetes* Simon were the diurnal ambushers observed in the different vegetable plots.

Neoscona sp. was the important genera of orb weavers recorded, the different species observed being *Neoscona mukerjei* Tikader, *Neoscona vigilans* (Blackwall), *Neoscona molemensis* Tikader & Bal and *Neoscona poonaensis* (Tikader & Bal) and two other species (Plate4). The other web builders observed were *Araneus* sp., *Argiope anasuja* Thorell, *Argiope pulchella* Thorell, *Argiope aemula* (Walkenaer), *T. mandibulata* (Plate5) and *Tetragnatha* sp.

Among the different families of spiders seen, Araneidae consisting of ten species (six species of *Neoscona, Araneus* sp and three species of *Argiope*) was the most represented family in the vegetable ecosystem. Oxyopidae (four species of *Oxyopes* and *P. viridana)* and Salticidae (two species of *Hyllus, Carrhotus* sp. *Phidippus* sp. and *T. dimidiata.*) each comprising of five species too were well represented. These were followed by Thomisidae having three species and Miturgidae, and Tetragnathidae which were equally represented with two species each. Least diversity was observed in the families Corinnidae, Lycosidae and Clubionidae. Only one species of spider *viz., C. zetes, Lycosa* sp. and *Clubiona* sp., respectively was recorded in each of the families.

Table 4. Spiders encountered in the vegetable fields in Kalliyoor panchayat of Thiruvananthapuram district and their occurrence in different stages of the crop

Sl. No.	Spider species	Family	Habitat	Occurrence of spiders at various crop stages				
				O	Br	C	Bg	A
I	**Hunting spiders**							
	a. Diurnal hunters							
1	*Oxyopes javanus* Thorell	Oxyopidae	Upper and middle portion of plant – on leaves and stems	V&R	V, R & M	V, R & M	V, R & M	V
2	*Oxyopes shweta* Tikader			-	R	R&M	R&M	-
3	*Oxyopes quadridentatus* Thorell			R&M	R&M	-	-	-
4	*Oxyopes* sp.			V&R	-	R	R	-
5	*Peucetia viridana* (Stoliczka)			-	-	-	-	V
6	*Hyllus semicupreus* (Simon)	Salticidae	Upper, middle and lower portion of plant – on leaves and stems	-	V & R	-	-	-
7	*Hyllus* sp.			V, R & M	-	-	-	-
8	*Carrhotus* sp.			V&R	R	R&M	-	-
9	*Phidippus* sp.			V&R	R	V&R	R	-
10	*Telamonia dimidiata* (Simon)			V, R & M	V, R & M	V, R & M	V&R	-
11	*Cheiracanthium danieli* Tikader	Miturgidae	Upper portion of plant on inflorescences and inside tubular folds in leaves	V, R & M	V, R & M	V, R & M	V, R & M	V
12	*Cheiracanthium* sp.			V, R & M	V&R	V, R & M	R&M	V
13	*Clubiona* sp.	Clubionidae	Upper portion of plant – on leaves	V&R	V&R	R&M	V&R	V
14	*Lycosa* sp.	Lycosidae	Middle portion – leaves and stems	-	-	R&M	V&R	-
	b. Diumal ambusher							
15	*Thomisus pugilis* Stoliczka	Thomisidae	Upper portion of plant – more on flowers	-	-	-	V&R	-
16	*Thomisus sorajaii* Basu			-	-	-	V&R	-
17	*Thomisus* sp.			-	-	-	R	-
18	*Castineira zetes* Simon	Corinnidae	Upper portion of plant – on upper surface of leaves in web like coverings	V&R	-	-	-	-

Table 4. Continued

Sl. No.	Spider species	Family	Habitat	Stage of the crop				
				O	Br	C	Bg	A
II	**Web building spiders**							
	Orb web weavers							
19	*Neoscona mukerjei* Tikader	Araneidae	Upper and middle portion of plant – inside small leaf foldings and webs	R &M	R &M	R &M	V&R	V
20	*Neoscona vigilans* (Blackwall)			R &M	-	-	-	-
21	*Neoscona molemensis* Tikader & Bal			-	-	-	R &M	-
22	*Neoscona poonaensis* (Tikader & Bal)			-	-	-	-	V
23	*Neoscona* sp.			V&R	V&R	V&R	R	V
24	*Neoscona* sp.			V&R	V&R	V&R	-	-
25	*Araneus* sp.			-	-	R	-	-
26	*Argiope anasuja* Thorell			-	-	V&R	-	-
27	*Argiope pulchella* Thorell			-	R&M	-	-	-
28	*Argiope aemula* (Walkenaer)			R&M	-	-	-	-
29	*Tetragnatha mandibulata* Cambridge.	Tetragnathidae	Upper and middle portion – in webs constructed in between plant parts and plants	R&M	R&M	V,R&M	V,R&M	V
30	*Tetragnatha* sp.			-	R&M	R&M	V,R&M	V

O – Okra　Br – Brinjal　C – Cowpea　Bg – Bittergourd　A – Amaranthus

V – Vegetative　R – Reproductive　M – Maturity