ACARINE PESTS OF CROP PLANTS

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CERTIFICATE

This is to certify that this thesis is an authentic record of the work carried out by **Ms. T. R. SOBHA** under my supervision and guidance in partial fulfilment of the requirements of the degree of Doctor of Philosophy in Zoology, under the faculty of science of the University of Calicut. No part of this work has been presented before for any other degree. I also certify that Ms. T. R. Sobha, has passed the M. Phil. Degree examination held in 1996.

21.12.02

Dr. M. A. Haq

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DECLARATION

I, hereby declare that this thesis is an authentic record of work carried by me under the supervision and guidance of Dr. M. A. Haq, Professor, Division of Acarology, Department of Zoology, University of Calicut and no part of this has been published previously or submitted for the award of any Degree or Diploma.

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INTRODUCTION

INTRODUCTION

Mites comprise an interesting group of organisms exhibiting profound diversity. They enjoy cosmopolitan distribution, inhabiting extreme conditions available in biosphere ranging from abyssal zone of oceans to sky-high peaks of mountains. Several species are equipped with abilities to exploit hostile environments like thermal springs, glacier lakes, polluted soils and water. Mites have attained tumidous importance during recent times owing to their increasing involvement and interference with human interests. Many of them gained notoriety owing to their status as pests of plants, parasites of animals and even human beings and vectors of plant, animal and human diseases. Meanwhile, an equally good proportion among them has been proved to be beneficial to human beings and the environment in general. Biodegradation of organic residues and humification in edaphic environment, bio-indication of ecological alteration in microhabitats of terrestrial and aquatic ecosystems and biological control of pests, parasites and weeds, represent some of the noble activities of mites towards the enrichment of environmental condition in various dimensions.

Among the various groups of acari, the phytophagous members represent an important group owing to their species diversity. Their interaction with plants and economic status on them represent one of the

fascinating avenues in acaroligical research. The major groups of phytophagous mites include members of the family Tetranychidae, Tenuipalpidae, Eriophyidae and Tarsonemidae. Apart from these, a few groups of oribatid mites which are known to colonize a variety of forest and garden plants also exhibit phytophagous habit.

Almost all groups of crop plants are found to be infested with one or the other species of mites. The number of species of mites and the host range of plants invaded by them vary considerably. Among the phytophagous mites, the eriophyids represent host specific forms. Most of them are single host mites. Excellent examples are the petiole gall mite of American walnut, *Eriophyes caulis* and the camphor leaf gland mite, *Gammaphytoptus camphorae*. An exceptional case is that of tomato russet mite, *Aculops lycopersici* which can live on several species of broad leaved plants of solanaceae. Tetranychidae, Tenuipalpidae and Tarsonemidae are not host specific. Some are phytophagous and occur on a wide variety of host plants. The best known species under this category include the two spotted spider mite, *Tetranychus urticae*, the strawberry spider mite, *T.turkestani* and the vegetable mite, *T.neocaledonicus*. Among these, *T.neocaledonicus* alone has been reported on more than 110 species of plants including flowers, peach, coconut, papaya and many vegetable crops. Some mite species and genera inhabit on a restricted group of plants. Mites of the genera *Platytetranychus* are found

only on conifers. The honey locust mite, *Eoteranychus multidigituli* has been found only on honey locust.

Some of the phytophagous mites are quite injurious, as they cause damage to their host directly or indirectly. Direct injuries are better explained in terms of their feeding habits. As a result of continuous feeding by tetranychid mites, various symptoms are produced on the host plants which may appear as stippling, bronzing, defoliation, retardation of growth, reduction in size and number of flowers and fruits, appearance of various other types of plant deformities etc. All these affect the crop yield. The damage symptoms produced by tenuipalpid mites are almost similar to those produced by the tetranychids. However, *Brevipalpus californicus* is known to cause leprosy in citrus. The mites of the family Tarsonemidae cause curling, twisting etc. on their host plants. Members of the family Eriophyidae are known to cause various types of damages. Of these, the most common one is the formation of galls and hence their name "Gall mites". In addition to this, other types of plant abnormalities are also caused by them which include formation of blisters, erinea, russetting of leaves, brooming, leaf edge rolling and bud damage. Besides these, some of the eriophyids and tetranychids are known to act as vectors of some plant viral diseases. White streak mosaic virus is transmitted among barley, oats, corn etc. by *E. tulipae*. Tobacco ring spot virus, tobacco mosaic virus, southern

bean mosaic virus etc. are apparently transmitted by the two-spotted spider mite, *T. urticae*.

The four plants considered during the present study represent vegetable crop, tuber crop, fruit crop and plantation crop. The creeper plant *Mucuna deeringiana* is important not only as a vegetable but also as a fodder for cattle and sheep. Seeds from unripened pods are used as vegetables. The plant itself is used as pasture or fed as hay. *Syzygium jambolanum* is cultivated in India as a fruit crop for its rose scented fruits as well as an ornamental plant. Fruit is eaten fresh, it is crisp with pleasant flavour. It is used for making candied fruits, jellies and sauces. The leaves of the plant on steam distillation yields, an yellow aromatic essential oil. Cassava is one of the most important tuber crops, as it is used as a subsidiary food item among the poor section of population in many tropical countries including India. Cassava is a native of tropical America. It was introduced in India by Portuguese during the seventeenth century. The different food products from cassava include boiled tubers, cassava chips, cassava flour, and sago. The most important commercial use of cassava is the production of starch and sago.

Coconut palm is one of the most useful plantation crops in the world which is grown in more than eighty countries of the tropics. It is the most important of all the cultivated palms in Kerala, yielding a variety of

products useful to man kind. Scientifically, coconut palm is known as *Cocos nucifera* belonging to the order Arecaceae (Palmae), an important member of Monocotyledons. Coconut palm is looked upon with reverence and affection by the inhabitants of coconut producing countries and has given some eulogistic epithets such as "Kalpa vriksha", "tree of abundance", "tree of plenty" etc.

The home of coconut palm is not clearly known and hence opinion varies among scientists regarding the origin of coconut. Three school of thoughts are prominent in this regard. First one relates to a South American origin for coconut which was proposed by O. F. Cook. Second one suggests a Polynesian origin due to ubiquity of coconut in Oceania. The third hypothesis suggests a South-East Asian origin for coconut palm.

The major coconut growing regions of the world include Philippines, India, Indonesia, Ceylon, Malaysia, Thailand, Fiji, Papua New Guinea, Solomon Islands, French Polynesia, The New Hebrides, Samoa, Tonga, Brazil, Mozambique, Tanzania and Seychelles. Among these, the most important coconut producing countries are Philippines, India, Indonesia and Malaya.

Coconut is a humid tropical crop. This plantation crop is grown in an area of 9 million hectares with an annual production of 33,700 million nuts. The great bulk of the world's total production of coconut comes from

countries in the regions of Asia and Oceania. Philippines occupies the first place in the production of coconut in the world. Indonesia and India occupy second and third places respectively in the production of coconut.

Being the third largest coconut producing country in the world, the percapita availability of coconut in India is low when compared to other countries like Philippines, Indonesia and Sri Lanka. The main reason for this situation is the population factor in India. Apart from this, coconut is not grown in all the states of the country. It is confined mainly to the coastal states which ultimately have to meet the entire domestic demand. As much as 65% of the total coconut area in the country is located in Kerala.

In India, coconut plantation occupies about 1.1 million hectares, spread over the entire coastal belt. Among the major coconut growing states, Kerala ranks first where 59.09% of total coconut hectarage and 43.14% of total production in the country are concentrated. The productivity of the crop in Kerala is as low as 3,172 nuts/ hectare where it is 11,538 nuts in Tamil Nadu and 5,199 nuts in Karnataka. Therefore, productivity in Tamil Nadu and Karnataka is higher than that in Kerala.

Almost all parts of coconut is useful to mankind in one way or other. The tender coconuts are used in large numbers in all coconut producing countries. About 55 million tender nuts are consumed annually in India. The

water of tender coconut is one of the finest and refreshing drinks in the world and the gelatinous part is used as delicious food. Mature coconuts are used for fresh kernel, copra making, religious offerings and raising seedlings.

Coconut is the major source for yielding vegetable oil in the world. Copra, the main product of the palm which has an oil yield up to 65% is the richest material for vegetable oil extraction. Copra and coconut oil are traditional commodities in the world market for oil seeds, oils and fats. Oil is obtained from the endosperm which may be dried and exported as copra. Coconut oil is mainly used for edible purposes. In the western world, coconut oil is used in the manufacture of soap and resins. In south India, particularly on the west coast it is used in almost every household, both for bath and for dressing the hair and also for cooking purposes. It is used in cosmetics. In East it is used as an unguent, hair oil and as a substitute for ghee.

Coconut cake known as 'poonac' is the residue from the copra after extracting the oil. It is widely used as cattle and poultry feed and also reported to be used for human consumption. Poonac is exceptionally rich in oil, albuminoids and digestible carbohydrates. Coconut milk is widely used in curries, sweets and other cooking purposes. The coconut apple or haustorium of germinating nut is edible.

The shell or hard stony endocarp comprises about 25% of weight of husked nuts and is used for fuels. The whole shell from which the meat has rotted or been removed through one of the eyes is used for bottles and in hook ash. Half shells are used for bowls, cups, measures, soups and ladles. The shells after polishing are used as decorative items. A number of articles are made out of shells by the local crafts men. They are also used for making buttons, combs bangles, musical instruments etc. Shells are used in the preparation of gas arborent charcoal. Shell ash has some manurial value, but it is very difficult to obtain the ash in sufficient quantities. It is also reported that the shells are powdered and exported as shell powder.

Coir is obtained from the husk or mesocarp which is removed in the preparation of copra. The area of maximum production of coir is Kerala in South Eastern India. In Kerala state alone coir and coir products valued at about Rs. 600 million are manufactured annually providing direct employment to more than half a million people. This accounts for the bulk of the export trade in coir and coir products and the annual export earnings from these come to about Rs. 258 million.

Much of the production of coir in Southern India is made into yarns. This thrives well as a cottage industry in Kerala. Most of the spinning is done by hand or with the help of two simple wheels. Superior quality yarns are manufactured into mats, matting, rugs and carpets while inferior grades

are used for ropes and twines. Best grade yarns are produced from the nuts which are harvested before they are quite ripened. Coir dust which is left over after the extraction of fibre can be used as a rooting medium, as a mulch for nurseries and for composting with other materials. It is highly resistant to bacterial and fungal break down.

Sweet toddy is an excellent drink and produced by tapping the unopened flower spathe. Sweet toddy is the unfermented, refreshing and health giving drink. Toddy ferments readily to give an intoxicating drink. The sweet toddy when boiled to 118^{0}C to 120^{0}C and allowed to cool solidifies. This solid mass in known as coconut jaggery or gur. After 24 hours, the toddy is unpalatable as a beverage and can be used for the production of vinegar. Fermented toddy may be distilled to produce arrack. Fresh fermented toddy can be used instead of yeast in bread making.

The freshly cut terminal bud known as palm cabbage may be eaten, in cooked or raw condition. The leaves are plaited and used for thatching, mats, screens, walls of temporary buildings, hats, baskets and other articles. The leaves are often used for decoration at festivals. Dried leaflets are tied together to produce torches. The midrib are made into brooms, baskets, fish traps, fences and other articles.

The trunks are used for building. The close-grained outer wood known as porcupine wood, is used for carving and veneers. It is imported into this country for use in cabinet making. The stem is also utilised for making furniture, fancy articles, sailing boats, rafters, laths etc. Hollowed-out stems are used as channels, gutters etc. The roots are used for tooth sticks which take the place of tooth brushes. The root of the palm possesses some narcotic properties and is some times chewed by the natives of India instead of arecanut.

Coconut palm is prone to infestation by a large number of organisms including insects and mites. Among the insects recorded on coconut in India, the Rhinoceros beetle (*Oryctes rhinoceros* L.), the red palm weevil (*Rhynchophorus ferrugineus* Fab.), the black headed caterpillar (*Opisina arenosella* Walk.) and the white grub (*Leucopholis coneophora* Burn.) are the major pests occurring in most of the coconut growing regions. Besides these, pests like scale insects, mealy bugs, coreid bugs, defoliating caterpillars, termites etc, cause considerable damage, though generally they are of minor importance. But in certain parts of the country, coreid bugs, mealy bugs and scale insects are becoming a menace threatening the crop. Rodents like rats and bandicoots also affect the coconut palm at various stages of growth.

Rhinoceros beetle is a serious and ubiquitous pest of coconut palm. The adult beetle bores into the soft tissue of the bud or cabbage by cutting

and chewing the tender unopened fronds and spathes. The affected fronds when fully opened show characteristic geometric cuts making the leaves unsuitable for thatching purposes. In India the beetle destroys an average of one inflorescence per palm there by causing 10 percent reduction in the yield every year.

The red palm weevil, *R. ferrugineus* is another dangerous pest of coconut and is found distributed in all the major coconut growing countries. The adult is not capable of producing any damage to the palm. The damage is caused by the grubs which live inside the palm, feeding on the soft tissue. Their attack is more severe in young plantation below 20 years. The damage caused by the pest is very severe and in the advanced stage, crown of the affected palm topples.

The leaf eating black headed caterpillar, *O. arenosella* is a major pest in all coconut growing areas of India. The larva of this, itself feeds on the undersurface of leaflets resulting considerable reduction in photosynthetic areas of the palm. Severe infestation of the palm by the pest affects the yield very much. In case of severe infestation, the whole plantation presents a scorched appearance.

The larvae of *L. coneophora* are popularly known as white grubs which cause damage to the coconut palms by feeding on the root system and also

tunnel into the tree trunk and collar region of the seedlings. They live inside the soil and usually occur in the sandy or loam soil tracts of Kerala and Karnataka. The leaves of the affected palm turn pale yellow and in severe case of attack, the immature nuts fall off.

Coreid bug, *Paradasynus rostratus* is a minor pest of coconut palm. The adults and nymphs of this pest feed on buttons and developing nuts. They suck the sap by piercing the stylets into the tissue just below the perianth. Feeding marks later develop into brown lesions. Infestation results in immature nut fall and also formation of malformed nuts with cracks and crinkles on the surface. Gummosis is also seen on the infested nuts.

Scale insects like *Aspidiotus destructor* Sign., *Aonidiella orientalis* Mask. and *Lepidosaphes mcgregore* Banks. are seen on leaves, buttons and rachillae. The infested leaves turn yellowish and dry up. Button shedding is noticed from the infested palms. Pest incidence is at its peak during summer months. The mealy bugs like *Palmicultor palmarum* Ehron., *Pseudococcus cocolis* Maskel. and *P. longispinus* Tag. colonize on all tender plant parts like bases of spear leaf, spadix, and inflorescence and inside the perianth of nuts. The presence of the insect is indicated by the appearance of the waxy white powdery coating. The pest infestation results in deformation or suppression of heart leaf. The spadix remains stunted and in severe cases of infestation immature nut fall is also observed.

Termites like *Odontotermes obesus* Ramb· damage the seedlings by attacking the husk portion. The attack appears to be severe in laterite and sandy loam soil. 20% of the seedlings in the nursery are usually destroyed by termite attack.

There are numerous other insect pests of minor importance which are not mentioned here. In addition to these insect pests, mites are also known to attack the coconut palm, causing severe damage. The important acarine pests occurring on coconut foliage are the red mite, *Raoiella indica* Hirst, the spider mite, *Oligonychus iseilemae* Hirst and *Tetranychus ludeni* Zacher which cause mild injury to the palm leaves. They usually inhabit the lower surface of leaves. Seedlings are more prone to mite infestation. *Dolichotetranychus vandergooti* Oudemans infests the perianth of nuts.

Besides these minor acarine pests, in recent years on eriophyid mite, *Eriophyes (Aceria) guerreronis* has become a serious pest of coconut in South India, especially in Kerala. Spreading of this mite infestation is very severe and it has become a serious threat to the coconut farmers of Kerala and hence a detailed study on this eriophyid mite, has been included in the present thesis. Apart from this the thesis also comprises the results of an extensive survey made on the mite fauna infesting various species of economically important plants and detailed aspects of the biology of a few selected species.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Mite-plant interaction represents one of the fascinating avenues of acarological research. The economic status of a country, to a certain extent depends on the agricultural products and hence any event which may adversely affect the agricultural production should be considered seriously. Agricultural crops are of commercial importance. Most of the agricultural crops habour a number of pests which curtail their yield and productivity quite often, threatening even the survival of the plants themselves. Major pests of crop plants include insects and mites. The present review of literature is limited solely to mite pests of various crop plants, nature and extent of damage caused by them, their bionomics, distribution and control aspects.

First report of plant mites was provided by Peal (1868). Banks later (1900) started the study of plant mites in the United States and reported several species of plant mites belonging to two genera *Tetranychus* and *Stigmaeus*. Misra (1913) recorded *T. bioculatus* on jute which was a common pest of tea in India. McGregor (1916) recorded *Panonychus citri* which was found as a serious pest of citrus. Garman (1923) provided notes on the life history of spurce mite, *O. ununguis*.

It was Hirst (1924) who first reported the association of mites with coconut palm. He found *R. indica* on coconut foliage in India and the tetranychid mite, *T. fijiensis* inhabiting the flower of coconut in Fiji. Later, Sigmonds (1925) confirmed the presence of *T. fijiensis* on coconut flowers. A detailed study on the mites attacking mulberry leaves and the morphology and biology of *P. mori* was made by Yokoyama and Ishii (1934). Cherian (1938) recorded mite pests of crops in South India and suggested methods for their control. Subsequently, *R. indica* was also reported from Egypt on the coconut foliage by Sayed (1942). Januja (1942) studied the biology of red spidermite *T. telarius*. The life history of the spidermite, *T. schoenei* was studied by Cagle (1943). *Acamina coconuciferae* on coconut foliage in Florida was described by Keifer (1944).

Biology of the vegetable mite, *T. cucurbitae* was studied by Rahman and Sapra (1946). Cagle (1946) studied the life history of the European red mite. Baker (1949) made a detailed study on the members of the genus *Brevipalpus* and recorded *B. phoenicis* on the nut of coconut palm from Netherlands. Biology of *B. australis* was studied by Manglitz and Cory (1953) who found the period required for each developmental stages by recording 8.6 days for larva, 6.2 days for protonymph, and 7 days for deutonymph, at 21-30^{0}C. Pierce

(1953) observed *E. hicoriae* as a major pest of pecan and chest nut trees which produced the scorched areas. Investigation on the pests of coconut palm by Nirula (1955) yielded 106 insects and one species of mite, *R. indica* which sucked the sap from the leaves. Ubertally (1955) studied the life history of *E. uncatus*. The life history of the spidermite, *T. atlanticus* was studied by Cagle (1956). Ehara (1956) enumerated the tetranychoid mites of mulberry in Japan and observed *T. truncatus* as a major pest of mulberry and other plants.

Muller (1957) provided information on the morphology, biology and control of the hawthorne spidermite, *T. viennenis*. Observations made by Elmer and Jeppson (1957) on the biology and control of the citrus flat mite, *B. lewisi* revealed that the mite could produce conspicuous scab like scars on the surface of fruit which entirely reduced the quality of fruit. Studies carried out on some phytophagous acarina and their predators in Mauritius by Moutia (1958) enabled to record four species of phytophagous mites namely *O. plegas, O. pratensis, T. ludeni* and *R. indica*. Morishita (1958) studied the biology and control of *B. inornatus* at different temperatures and found that 30°C was more favourable for its development. Biology of the red spidermite, *T. telarius* was studied by Lal and Dutta (1959). Das (1959) studied the bionomics of the tea

red spider, *O. coffeae*. Puttarudraiah and Channabasavanna (1959) provided a preliminary account on the phytophagous mites of Mysore.

Injuries caused to citrus by *Brevipalpus* mites were described by Knorr *et al.*, (1960). Baker and Connell (1961) reported that *T. yusti* was one of the most abundant and injurious mites to soybean in Delaware and the other economic host plants of the pest were recognised as cotton, roses, okra, sweet potato, marigold, peas, beans, cowpeas and peanuts. Rimando (1962) studied the tetrarychoid mites of Philippines and reported *T.fijiensis* and *T. neocaledonicus* as the two coconut foliage mites. Goldsmid (1962) reported that the vegetable mite, *T. neocaledonicus* occurred on more than 110 plants including flowers, peach, coconut, papaya and many vegetable and field crops. Biological study of a red spidermite, *Panonychus* sp. on raspberry in Virginia was carried out by Cagle (1962). Keifer (1962 a&b) described two new eriophyid mites, *Acathryx trymatus* and *Dialox stellatus* on coconut foliage from Philippines.

Ananthakrishnan (1963) studied the biological aspects of the scarlet mite, *B. australis* on tea. The habitat, morphology and

geographical distribution of four new species of eriophyid mites from coconut in Philippines were studied by Briones and Still (1963). Keifer (1963) recorded *A. guerreronis* from Dahomey and Venezuela. Reeves (1963) reported that *T. mcdanieli* was a serious pest of deciduous fruit trees, grapes, berries and ornamental plants. Manson (1963) provided a detailed account on the mites of the families Tetranychidae and Tenuipalpidae associated with citrus in South East Asia. The occurrence and control aspect of *T. ludeni* were studied by Bullock (1963). While conducting a survey on the false spidermites of Arizona, Baker and Tuttle (1964) reported *B. obovatus* as a main pest of privet and citrus and other 50 genera of ornamental plants. Knorr (1964) studied the various damage symptoms of *B.phoenicis* on citrus and noted gall like proliferation along the main stem of the seedlings. Population studies of the red and false spidermites were carried out by Zaher and Elbadry (1964) who reported population peak in July followed by a gradual decrease in December. Dosse (1964) studied the *T. cinnabarinus* complex in citrus plantation in Lebanon.

It was Keifer (1965) who first reported the incidence of *A. guerreronis* on coconut buttons from the Guerrero state of Mexico. Later Ortega *et al.*, (1965) conducted a preliminary investigation on

the coconut eriophyid mite, *A. guerreronis* on the Costa grande of Guerrero. The seasonal fluctuation and population density of the tea red spidermite, *T. kanzawai* were studied by Osakabe (1965). Butler and Abid (1965) studied the biology of *O. platani* on Pyracantha. The effect of temperature and humidity on the development of tea spidermite, *O. coffeae* was studied by Das and Das (1967) who reported that the optimum condition required for hatching was within a temperature range of 20-30^{0}C and R.H range of 49-94%. Dean and Maxwell (1967) reported the association of *B. phoenicis* and *B. californicus* with spotting of grape fruit in Texas. Survey on the mites of the families Tenuipalpidae and Tetranychidae from Netherlands was conducted by Manson (1967) who recorded *Tetranychus* sp. from coconut foliage. Various tenuipalpid and tetranychid mites infesting citrus in Taiwan were listed out by Lo and Hisa (1968). According to Baker (1968), *T. turkestani,* best known in American mite literature as *T. atlanticus* was one of the most wide spread and serious mite pests of agricultural crops. Goksu (1968) studied the bionomics, control, distribution and food plants of hawthorne mite, *T. viennensis* in the Marmara region. Estebanes and Baker (1968) reported the occurrence of *Mononychellus caribbeanae* on cassava and platymiscium in Mexico. Studies on the biology and

control of *B. chilenis* were carried out by Gonzales (1968) who found the average time required for the completion of one generation was 25.3 days. Doreste (1968) reported the coconut flower mite, *A. guerreronis* from Venezuela. *A. guerreronis* was recorded as a new addition to SaoThome and Prince by Cabral and Carmona (1968). Mathen *et al.,* (1968) showed that the parasitic mite, *Pyemotes ventricosus* was an efficient biocontrol agent of coconut caterpillar, *O. arenosella.*

Mariau (1969) reported *A. guerreronis* as an introduced pest on coconut palm in Dahomey Islands. In the monograph of coconut pests, Lever (1969) listed 110 pests comprising two species of mites. Arruda and Aquino (1969) made attempts to control the mite that caused necrosis of shoots of coconut in Pernambuco. Qureshi *et al.,,* (1969) studied the biology of the spidermite, *T. evansi* and reported that the average incubation period ranged from 60 to 72 hours. Laing (1969) provided information on the life history and life table of *T.urticae* . Indepth studies on the coconut mite, *A. guerreronis* made by Mariau and Julia (1970) showed that this mite was able to penetrate between the upper and lower tepals. A preliminary report on the tetranychid mites of Brazil was made by Fletchmann and Baker (1970). The study further revealed the occurrence of *M. planki*

on soybeans, peanut, bean, cotton and other plants. Westgard and Berry (1970) provided information on the life history and control of the yellow spidermite on pear in Southern Oregon. Gupta (1970) provided a preliminary note on plant mites from West Bengal. Siddig and Elbadry (1971) carried out biological studies of *E. sudanicus* in Sudan. Biological studies of citrus red mite, *P. citri* was made by Beavers and Hampton (1971) which provided information on the mating behaviour, fecundity, development and longevity of this mite. Singh and Saini (1971) provided information on the seasonal activity and control of red spidermite, *T. telarius* in Punjab. A preliminary note on the phytophagous and predatory mite fauna of Punjab and Himachal Pradesh was made by Gupta *et al.*, (1971a). The occurrence and control of tenuipalpid mites on citrus in Punjab were studied by same authors (1971b). Menon *et al.*,, (1971) reported some new records of tenuipalpid mites from India. Zuluaga and Sanchez (1971) conducted population studies of *A. guerreronis* and revealed that the mite attack was more severe in dry seasons.

Banu and ChannaBasavanna (1972) studied the biology of the spidermite, *E. orientalis.* A nut infesting eriophyid mite *Notostrix jamaicae* was described by Keifer (1972) from West Indies. ChannaBasavanna and Banu (1972) recorded *O. indicus* on coconut

from India. Sadana and Joshi (1974) provided information on the host range of the mite, *B. californicus* infesting citrus. Guttierrez (1974) recorded *T. fijiensis* on coconut from Seychelles. The economic significance of green mite *M. tanajoa* in Uganda was analysed by Nyiira (1975). Nair (1975) described 38 species of insects and 4 species of mites as pests of coconut palm from India. Estrada and Gonzalez (1975) studied the various damages caused to coconut by *A. guerreronis* from South East Asia and Japan. Jeppson *et al.*, (1975) provided a detailed information on the mites injurious to economic plants.

Jesioter and Zbignui (1976) studied the influence of host plants on the reproduction potential of the two spotted spidermite, *T. urticae*. Nageshchandra and ChannaBasavanna (1976a) made a list on the host plants of *B. phoenicis*. Faunistic studies of false spidermites of India were carried out by Nageshchandra and ChannaBasavanna (1976b). Navaranjan *et al.*, (1976) recorded *B.phoenicis* and its varietal incidence on guava in Tamil Nadu. Occurrence of tetranychid mites, *E. orientalis* and *O. biharensis* was reported by Lal and Pillai (1976). Baker (1976) recorded *O. modestus* on coconut foliage. Hussein (1977) studied the morphology and biology of carmine mite *T. cinnabarinus* and showed that the incubation period of this mite ranged from 3 to

8 days. Feeding influence of tetranychid mites and biochemical changes in cassava leaves were studied by Maini and Lal (1977). Maini *et al.*, (1977) carried out studies on maturity index in cassava. Biological studies of *P. citri* were carried out by Maity and Chakrabarty (1977). Hernandez (1977) provided information on the nature of damage caused by *A. guerrreronis* which resulted in uneven growth, distortion and stunting of the coconut leading to 30% reduction in copra yield. Mariau (1977) stressed *A. guerreronis* as an important pest of African and American coconut groves. The damage caused to coconut by *A.guerreronis* in Cuba was reported by Estrada and Gonzales (1977). Annon (1977) recorded two mite species namely *Oligonychus sp.* and *T. fijiensis* from coconut palm in Sri Lanka.

Tanigoshi and Davis (1978) carried out an ultra structural study of *T. mcdanieli* feeding on the leaves of Red delicious apple. Bellotti and Schoon hoven (1978) gave an account on cassava pests and reported that mites and insects attacked mainly the foliage. Lal and Pillai (1978) reported a new record of the spidermite, *T. neocaledonicus* on cassava. Biology of *E. uncatus* was studied by Lakshmanlal and Mukharji (1978). While collecting tetranychid mites from Madhya Pradesh, Gupta and Gupta (1978) recorded a predatory

mite, *Amblyseius alstoniae* from coconut foliage. Comparative studies on the life histories of three species of spidermites were made by Saito (1979). Bellotti and Byrne (1979) studied the host plant resistance to mite pests of cassava. Tanigoshi and Logan (1979) studied tetranychid development under variable temperature regimes. Kurian *et al.,,* (1979a) made a detailed list of insects and mites associated with coconut palm. Kurian *et al.* (1979) studied the world distribution of the pests of coconut. Investigation on coconut mite, *A. guerreronis* conducted by Julia and Mariau (1979) in the Ivory Coast provided knowledge on incidence and symptoms of attack, mechanisms of infestation, varietal sensitivity, seasonal variation and means of its control. Studies conducted by Keifer (1979) helped to report the incidence of eriophyid mite *Nacerimina guiterrezi* from coconut in Samoa.Puttaswamy and ChannaBasavanna (1980a) studied the life history of *T. ludeni* under field conditions. The same authors (1980b) studied the effect of temperature and relative humidity on the development and oviposition of *T. ludeni.* Gerson and Aronowitz (1980) made a comparative study on the feeding behaviour of the carmine spidermite, *T. cinnabarinus* on seven host plants. Yousef *et al.,* (1980) studied the effect of season and grapevine variety on the biology of *T. granati* and described its immature

stages. A detailed survey on biological control agents of the coconut mite, *A. guerroronis* was made by Hall *et al*, (1980). Perera (1981) recorded a beneficial mite, *Neocypholaelaps ampullala* from the flower of coconut in Sri Lanka. According to Hall and Espinosa (1981), the invasion of *A. guerreronis* occurred within a few weeks to one month after fertilization. Kang (1981) studied the various eriophyid and tarsonemid mites of coconut in Malaysia. Sathiamma (1981) provided information on the mite fauna associated with coconut palm in Kerala. In their study on minor pests of coconut in Srilanka, Kanagaratnam *et al.*, (1981) showed the presence of *T. fijiensis* on coconut foliage and *Dolichotetranychus* sp. on coconut button. Puttaswamy and ChannaBasavanna (1981) studied the influence of host plants on the development, fecundity and longevity of *T. ludeni*. Lal and Pillai (1981) provided information on the cassava pests and their control in South India. The relative resistance of high yielding cassava cultivars to infestation by tetranychid spidermites and white fly was studied by Lal and Hrishi (1981). Gupta and Nahar (1981) provided list of plant mites of agricultural importance in Bihar. Kumar and Prasad (1981) studied the survival and development of *T. fijiensis* on *Citrus reticulate* leaves of different ages. Ray and Rai

(1981) studied the biology and control of *T.neocaledonicus* on ladies finger at Varanasi.

Nyiira (1982a) studied the biology, ecology and economic importance of *M. tanajoa.* The same author (1982 b) made a detailed account on the implications and management of *M.tanajoa.* The seasonal trend of green spidermite, *M. tanajoa* on cassava and its relationship with weather factors were studied by Akinlosotu (1982). Byrne *et al.,,* (1982) studied the behaviour and development of *M. tanajoa* on resistant and susceptible cultivars of cassava. Influence of weather factors on the population of spidermites and thrips on cassava was studied by Lal (1982). Dhooria (1982) provided information on ovipositional preference, host range and seasonal incidence of *E. orientalis* in Delhi. Reduction in plant processes by *T. urticae* feeding on strawberry was reported by Sances *et al.,* (1982). Puttaswamy and ChannaBasavanna (1982) studied the influence of host plants on the reproduction biology of *T. neocaledonicus.* Capuno and Pedro (1982) studied the varietal reaction of coconut to *O. velascoi.* Control aspects of spidermites on cassava were analysed by Pillai and Palaniswamy (1983). Influence of morphological and

biochemical characteristics of host plants on the life cycle of *B. obovatus* was studied by Sadana and Meena (1983). Boyne and Hain (1983) studied the effect of constant temperature, relative humidity and rainfall on development and survival of the spruce spidermite, *O. ununguis*. Detailed studies on the susceptibility of different varieties of brinjal to *T.neocaledonicus* were carried out by Ashok Sharma and Kushwaha (1983). Ayanru and Sharma (1983) studied chlorophyll depletion in leaves of field grown cassava clones infested by cassava green spidermite, *M. tanajoa*.

Nageshchandra and ChannaBasavanna (1984a) studied the development and ecology of *R. indica* on coconut. The same authors (1984b) carried out studies on seasonal fluctuation and population density of *R.indica* on coconut with reference to weather parameters. Meena *et al.,,* (1984) conducted studies on the host range of privet mite *B. obovatus*. Pillai and Palaniswamy (1984) provided a list of the pests of tuber crops. Nadayilragije (1984) reported that the principal enemies of cassava in Burundi were cassava mosaic disease and *M. tanajoa* which were found reducing the yield by 40% and 13-22% respectively. Doreste (1984a) reported spidermites as important pests of cassava. The same author (1984b) conducted field test to

evaluate varietal resistance to tetranychid mites especially to *Mononychellus* sp. on cassava. Feeding effect of *M.tanajoa,* on cassava yield, in relation to chemical control measures was studied by Sauti (1984). Al-Gboory *et al.,,* (1984) studied some aspects of the biology of *T. punicae* under constant temperature and relative humidity. An account of cassava pests, their spread and control was provided by Herren and Bennet, (1984). Murphy (1984) studied the history of cassava green mite. *M. tanajoa* in Africa. While studying the development of citrus mite, *E. orientatalis,* Dhooria (1984) observed that its development was influenced by age and surface of leaves of the host plant. In his book on coconut, Ohler (1984) listed two species of eriophyid mites damaging the nuts. The problems of coconut mite *A. guerreronis* in coconut groves of Trinidad and Tobago were studied by Griffiths (1984). Mohanasundaram (1984) reported three new species of mites with records on the occurrence of *N. attenuata* on coconut foliage from South India.

Neelunangia and ChannaBasavanna (1985) made observation on the biology of *T. cinnabarinus* on different varieties of mulberry. The effect of host plants on the biology of *T.neocalidonicus* was studied by Pande and Reddy (1985) Pillai and Planiswamy (1985 a) made a detailed investigation on the bionomics, distribution, extent

of damage and control measures including host plant resistance of cassava spidermite complexes in Kerala. The same authors (1985b) studied the biology of spidermites, *T. cinnabarinus* and *E. orientalis* on cassava. Gupta (1985) recorded a predatory mite, *A.nuciferae* on coconut foliage in India. Sathiamma (1985) recorded *D.vandergooti*, a perianth mite on coconut foliage in India. The bract arrangement in the coconut fruit in relation to attack by the coconut mite, *A.guerreronis* was studied by Moore (1986). Sathiamma (1986) made a detailed study on the habitat, distribution, host range and economic importance of *O. iseilemae* on coconut. Studies on the behaviour of *A. guerreronis* with respect to different varieties of coconut were conducted by Mariau (1986) which revealed differences in sensitivity. Olevera (1986) stressed the symptoms of infestation and nature of damage produced by *A.guerreronis* which revealed that the mite attack reduced nut size and diminished the quality and quantity of coir and copra. Biological studies using *Hirsutella thompsonii* on *A.guerreronis* carried out by Espinosa and Carillo (1986) achieved 75% mortality of the pest. Bhumannavar and Singh (1986) studied population dynamics of the oriental red mite of citrus, *E. orientalis*, on coorg mandarin. Ghosh *et al.*, (1986) recorded the incidence of pests and diseases of cassava. James (1986) provided a detailed

account of tetranychid mites of cassava in Sierra Leone. Sadana *et al.*, (1986) reported the tetranychoid mites infesting vegetables in Punjab. An investigation on the morphology and biology of *T. lintearicus* was made by Stone (1986). Pande and Sharma (1986) studied the effect of temperature on the biology of *T. neocaledonicus*.

Gupta (1987) gave a report on the plant mites of Arunachal Pradesh providing information on 17 species of tetranychids which were found associated with fruit and vegetable crops and ornamentals. Akinlosotu *et al.*, (1987) evaluated the resistance of cassava to green spidermites using improved cassava cultivars. Infestation and reproduction of the citrus red mite, *P. citri* on leguminous plants like kidney bean and soybean were examined by Wataru (1987). The biological aspects of *O. mangiferus* infesting mango in Gujarat were studied by Rai *et al.*,, (1987). Rogo *et al.*,, (1987) conducted a preliminary study on the taxonomic status of the cassava green spidermite complex, *Mononychellus*. One of the acerogenous species attacking *A. guerreronis*, viz., *H. nodulosa* was reported from Cuba by Cabrera and Dominguez (1987). Moore and Alexander (1987a) provided information on the aspects of migration and colonization of coconut palm by the coconut mite, *A. guerreronis*. According to them, the mites were not found on unfertilized flowers

but were found within a few weeks after fertilization. Experimental studies were made by Moore and Alexander (1987b) by injecting vamidothion on the stem of coconut for the control of coconut eriophyid mite, *A. guerreronis*.

Shah *et al.,,* (1988) recorded some new insects and pests of coconut in Gujarat. The population trends of two species of spidermites and their effects on leaf injury were studied by Lee *et al.,,* (1988). Holtzer *et al.,,* (1988) studied the effect of microenvironment on dynamics of spidermite population. The annual life cycle of the spidermite, *E. dissectus* on apple was traced out by Tetsuo (1988). Vaninek (1988) studied the continental dispersal of the cassava green mite, an exotic pest in Africa. Pillai and Palaniswami (1988) made an evaluation of cassava accessions resistant to spidermites and investigated factors governing its resistance. Guttierrez *et al.,,* (1988) analysed the methods for the biological control of cassava pests in Africa. James (1988) provided a list of tetranychid mites on cassava in Sierra Leone. Chia Luiz Gonzaga (1988) traced the biology of the citrus mite pest, *P. citri*. A review on the biological agents of the pests of tropical tuber crops in India was made by Palaniswamy *et al.,,* (1988). Rogo *et al.,,* (1988) studied the *Mononychellus* sp. complex from selected cassava growing areas of Africa using principal

component analysis. Gonzales *et al.,* (1988) provided a detailed account on various tetranychid and phytoseiid mites associated with *M. esculenta.* While conducting a survey on the mites injurious to orchids in Thailand, Charanasri *et al.,,* (1988) recorded *T. pacificus, D. vandergooti, B. californicus and B. phoenicis* as major pests.

Sadana and Rajinder Sharma (1989) studied the influence of temperature on the development of *B. rugulosus.* Guttierrez *et al.,,* (1989) recorded five tenuipalpid species feeding on conifers and identified three of their predators. Some ecological aspects of the pomergranate false spidermite, *T. punicae* were studied by Al-Gboory and El-Haidary (1989). Sarkar and Somchoudhury (1989) provided information on the influence of major abiotic factors on the seasonal incidence of *R. indica* and *T. fijiensis* on coconut. Gupta and Gupta (1989) carried out a survey on mites associated with vegetable crops in West Bengal. The biology of *E. hicoriae* was studied on the leaves of guava in the laboratory by Mallikarjunappa and Nageshchandra (1989). Bionomics of the spidermite *T. macfarlanei* injurious to cotton were studied by Jose and Shah (1989). Braun *et al.,,* (1989) described the distribution of *M. tanajoa* on cassava. Murega (1989) conducted cross breeding studies on the cassava green mite, *M. tanajoa* in East Africa. Welter *et al.,,* (1989) provided information on the effect of

feeding of Willamette mite, *E. willametti*, and pacific spidermite, *T. pacificus* which reduced grape leaf photosynthesis and stomatal conductance. Later, Welter *et al.*,, (1989) studied the effect of feeding by Willamette mite on grape productivity and quality. The effect of temperature on the life history and population parameters of kanzawa spidermite, *T. kanzawai* was studied by Tsai *et al.*, (1989). Vaninek *et al.*,, (1989a) analysed the population dynamics of *M. tanajoa in* relation to temperature and host plants. The same authors (1989b) studied the seasonal factors affecting phenology and abundance of *M. tanajoa* population. The egg production and population growth of the citrus red mite were studied by Hare *et al.*,, (1989). Meena Goyal and Sadana (1989) studied the development, fecundity and longevity of *B. obovatus* on different host plants. Manjunatha and Puttaswamy (1989) provided information on the life history of *T. neocaledonicus* under green house condition where the developmental duration ranged from 8.9 to 11.7 and 8.7 to 11.38 days for female and males respectively. Flechtmann (1989) reported *C. weddelliana* as a new host plant for *A. guerreronis* in Brazil. Moore *et al.*, (1989) provided information on yield losses produced by the coconut mite, *A. guerreronis* and attempted to control it with acaricide, polybutene and *Hirsutella* fungus. *H.thompsonii* strains

were selected by Lampedro and Rosas (1989) to test against the coconut mite, *A.guerreronis* Mohanasundaram and Karuppachamy (1989) provided a review on the mites attacking coconut in Tamil Nadu and reported the tetranychid mites, *T. fijiensis* and *T.neocaledonicus,* the tenuipalpid mites, *R. indica, B. phoenicis* and *B. californicus,* the eriophyid mite, *N. attenuata,* the ameroseiid mite, *N. stridulans* and the acarid mite *Tyrophagus putriescentiae.* Mohanasundaram *et al.,* (1989) recorded a new ternuipalpid mite, *Dolichotetranychus sp* from coconut button and studied its significance. Mallikarjunappa and Nageshchandra (1989) studied the biology of *E. hicoriae* on guava.

While studying the oribatid mites from coconut palm, Ramani and Haq (1990a) reported a new species, *Uracrobates indicus* from Kerala. The same authors (1990b) reported another new species of oribatid mite *Notogalumna nortoni* from coconut foliage. Schliesske (1990) provided information on the gall mite fauna of *C. nucifera* in Costa Rica. The resistance of coconut in St Lucia and seasonal distribution of coconut mite, *A. guerreronis* in Puerto Rico and Florida were studied by Howard *et al.,*(1990). Jalaluddin and Mohanasundaram (1990) suggested that coconut mite, *R. indica* could be effectively controlled by spray of monocrotophos 0.04 % or

dimethoate 0.03% or Phosphamidon 0.05% or methomyl 0.025%. Bonato *et al.,* (1990)provided information on the influence of temperature on the life history parameters of yellow grape vine mite *E. carpini.* Goodwin (1990) studied the seasonal abundance and control of spidermites infesting commercial strawberries in coastal New South Wales. Oviposition response of *T. urticae* to treatment of pyrethroids on soybean was carried out by Donahue and McPherson (1990). Chy-chen (1990) observed that *T. kanzawai* distributed equally between inner and outer layers of mulberry leaves. Rosero *et al.,* (1990) provided information on the embryological development of *T. cinnabarinus,* a pest of carnation. Biology and control of *O. mangiferus* on *Terminalia* spp. were studied by Neelunaungia *et al.,*(1990). Host plant resistance to mite pests of cassava was worked out by Bellotti and Byrne (1990). Gosta *et al.,*(1990) provided sampling strategies for assessing the intraplant density of cassava green mite, *M. tanajoa.* Millikarjunappa *et al.,*(1990) studied the nutritional preference of *E. hicoriae* on guava.

Mohanasundaram and Parameswaram (1991) recorded an acarid mite, *T. longior* on rotting coconut in India. Sathiamma (1991) made investigation on *O. iseilemae* and other tetranychid mites on coconut foliage. The relationship between tightness of perianth of

coconut to infestation by coconut mite, *A. guerreronis* was studied by Howard and Abreu (1991). Moore *et al.*,(1991) studied the relationship between the nutrition of coconut with attack by coconut mite, *A. guerreronis* in St Lucia. Rai *et al.*,(1991) carried out studies on okra mite, *T. macfarlanei* and its chemical control. Biology and life table of *E. banksi* on grape fruit leaves at different temperature were recorded by Childers *et al.*, (1991). Beitia Crespo and Vivas (1991) studied the differences in the development of *P. citri* on leaves of several citrus species. Jaikumar *et al.*, (1992) reported 21 species of oribatid mites belonging to 19 genera and 14 families associated with coconut palm. Ramani and Haq (1992) reported a new species of *Afronothrus* from coconut palm in Kerala. The induction of diapause in the carmine spidermite, *T. cinnabarinus* was studied by Wu and Jing (1993). Bali (1993) made preliminary studies on the demography of the pacific spidermite, *T. pacificus*. Wilson (1994) studied the effect of plant quality on the life history parameters of two spotted spidermite, *T. urticae*. Biology of the two spotted spidermite, *T. urticae* on some resistant plants was studied by Amer and Rasmy (1994). Wood *et al.*, (1994) adopted various biological control measures of the two spotted spidermite, *T. urticae* on raspberries. Akbar and Aheer (1994) surveyed the mite fauna of summer

vegetables in Punjab. Comparative studies on the developmental biology of carmine and green forms of *T. urticae* were carried out by Pringle *et al.*,,(1994). A preliminary survey on mites associated with some vegetable crops in Hisar, Haryana was made by Mathur *et al., (1994).* Ahuja (1994) studied the seasonal incidence and chemical control of oriental mite, *E.orientalis.* Mohanasundaram (1994) recorded a new species of tarsonemid mite, *Xenaster longiadominalis* on coconut buttons from India.

Mukherjee *et al.,* (1995) reported the incidence of figmite, *E. hirsty* in relation to weather factors in Varanasi. The effect of temperature, humidity and photoperiod on the mortality of *M. tanajoa* infested by *Neozygites floridana* was studied in laboratory by Moreas *et al.,* (1995). Sadana and Meenakumari (1995) studied the influence of host plants on the development of *B. phoenicis.* Bonato *et al.,* (1995) described methods for sampling of cassava plants for collection of *M. progressivus* and *O. gossypii* in Africa. Analytical studies of chlorophyll fluorescence and leaf chlorophyll content of bean leaves injured by spidermites were carried out by Latrou *et al.,* (1995). Nandagopal and Gedia (1995) studied the biology of the red spidermite *T. cinnabarinus,* a pest of ground nut. Dispersal mechanism of *T. cinnabarinus* on various tomato cultivars was

studied by Kielkiewicz (1995). Young *et al.*, (1995) conducted population studies of *B.phoenicis* and assessed damage potential on Indonesian tea. Smiley and Gerson (1995) provided a review of the Teruipalpidae of Australia with description of two new genera and four new species. Studies concerning the biology, control and natural enemies of coconut eriophyid mite, *A.guerreronis* were carried out by Moore and Howard (1996).

Mc Murtry (1997) studied the biology, life table and mating behaviour of *O. perseae*. Gotoh and Kubota (1997) carried out studies on the population dynamics of citrus red mite, *P. citri* on Japanese pear orchards. Flechtmann (1997) reported mite associates on the palms in Brazil. Zacharda and Hulchy (1997) carried out studies on the biological control of two spotted spidermite, *T. urticae* on strawberries using predatory phytoseiid mite, *T. pyri*. Effect of neem guard on the phytophagous and predaceous mites was tested by Mansour *et al.*, (1997). Gillespie *et al.*, (1997) collected four species of natural enemies of two spotted spidermite, *T. urticae*. Ramani and Haq (1997) reported a new species of *Caloppia* from coconut palm in Kerala. Odongo *et al.*, (1998) studied the comparative efficacy of *H. thompsonii* and *N. teke* against the cassava mite, *M. tanajoa*. The nut infesting eriophyid mite, *A. guerreronis* from Kerala was reported by

Sathiamma *et al.* (1998). Ramani and Haq (1998a) recorded a new species of *Siculobata* from coconut palm in Kerala. The same authors (1998b) reported a new species of *Scapheremaeus* from coconut palm in Kerala. Mohanasundaram *et al.* (1998) studied the management and control practices of coconut eriophyid mite, *A. guerreronis* and suggested root feeding of 4% triazophos as a control measure. Ramarethinam and Marimuthu (1998) suggested integrated pest management for the control of the eriophyid mite, *A. guerreronis*, an emerging menace in the coconut palm of South India.

Haq and Sumangala (1999) provided a detailed account on mite pests of Cassava from Malabar. The effect of temperature on the life history parameters of *T. evansi* was studied by Bonato (1999). Haq (1999a) studied the incidence and out break of the coconut mite, *A. guerreronis*. The same author (1999b) provided information on the distribution of coconut mite, *A. guerreronis* in peninsular India and adjacent islands. Management and control of coconut eriophyid mite, *A. guerreronis* in Tamil Nadu were carried out by Ramaraju *et al.*, (1999). Feeding and breeding strategies of *A.guerreronis* and its predators in the laboratory were discussed by Haq (2000). Moore (2000) provided some information on the nonchemical control of *A.guerreronis* on coconut. Mohanasundaram (2000) studied the bio-ecology and management of the coconut eriophyid mite, *A.*

guerreronis. A detailed account on the out break of coconut mite in Kerala was provided by Haq (2001a). The same author (2001b) reported the phoretic honey bee mite, *N. stridulans* as a conventional pest of coconut from India. The culturing and rearing techniques of *A. guerreronis* and its predators were established by Haq (2001c). Sumangala and Haq (2001) studied the diurnal periodicity of coconut mite, *A. guerreronis*. Haq and Sumangala (2001) provided information on the relationship between infestation of *A.guerreronis* and premature nut fall in coconut. The invasion, injury and distribution of *A. guerreronis* was studied by Haq *et al.*, (2001).

MATERIALS AND METHODS

MATERIALS AND METHODS

The present study was conducted to procure knowledge on the major acarine pests associated with important crop plants of Kerala. The survey was carried out from August, 1998 to August, 2000. A total of 43 species of economically important crop plants comprising vegetable crops, tuber crops, plantation crops, fruit crops, oil yielding crops, garden crops etc. were examined to assess the mite fauna associated with them.

1. Sampling localities

Species of plant mites considered during the present study were collected from plant parts sampled from various localities distributed in three districts of Northern Kerala, namely Malappuram, Kozhikkode and Thrissur. In the Malappuram district, Calicut University Campus and its nearby areas were the collection and sampling sites for the host plants. A dozen localities including Botanical garden, Ladies hostel, kitchen garden of different quarters in the campus and private and government fields were surveyed for collection of host plants and examination of mite fauna.

Samples of vegetable crops were regularly collected from the nearby fields of Calicut University campus. These fields were originally

used for paddy cultivation where intermittent cultivation of vegetables was also practiced by the local farmers. The common vegetable crops cultivated were *Abelmoschus esculentus, Solanum melongena, Cucurbita maxima, C. pepo, Capsicum frutescens, Lagenaria vulgaris, Trichosanthes anguina, Momordica charantia, Cucumis sativus, Canavalia gladiata and Pisum sativum.* In addition to these vegetable crops, several tuber crops such as *Manihot esculenta, Dioscorea alata, Amorphophallus companulatus* and *Colocasia esculenta* were also cultivated in these fields. Adjoining to this is vast areas of arecanut, coconut and banana plantations from where also samples were obtained regularly for collection of mites.

2. Plants surveyed

A total of 43 species of economically important plants comprising vegetable crops, tuber crops, plantation crops, fruit crops, Oil yielding plants, garden crops etc. were examined to assess the mite fauna associated with them. Several mite pests were procured from the crop plants screened, but all of them were not selected for a detailed study. A selection was made based on the economic importance of the plant, its availability, mite species infested, nature of damage produced and its impact on the host plant. A brief account provided here on the selected plants would be helpful in getting a general idea of the plant and their economic importance.

a. *Mucuna deeringiana* Bort

It is commonly known as velvet bean and is a herbaceous, pubescent, trailing or twining annual. It reaches up to 18m or more in length and introduced in India as a fodder plant. Leaves are trifoliate, leaflets are rhomboid and 5-15 cm long. Flowers are purple in pendent recemes. Pods are turgid, 5-15 cm long, ridged and densely covered with black pubescence. Seeds are 3-5 in a pod and are globular, speckled and marble brown or black colour.

M. deeringiana is considered to be a native of Asia. It has spread into many tropical countries and grown as fodder, green manure and a cover crop. Seeds from unripened pods are used as vegetable. The plant can be grown in any soil, but prefers medium to light loam. In India it is grown as a kharif crop either alone or mixed with maize or jowar. The plant may be grown pure and used pasture or fed as hay. It provides good fodder for cattle and sheep. It is regarded as an excellent feed for farm animals, particularly young growing stock. Dry pods and seeds are energy rich, used in rations for dairy cows and for fattening cattle and sheep. The pods contain rich sources of protein.

b. *Manihot esculenta* Crantz

It is a low shrubby plant of 2-5m height with a cluster of tuberous roots. Stem varies in colour from pale or dirty white to brown, marked

by numerous scars left by fallen leaves. Leaves are palmate, pale green in colour with 5-9 lobes. Flowers are unisexual, grouped in terminal cymes. Male and female flowers are on same inflorescence. Fruit is capsule containing three seeds. Cassava is a native of South America and has been introduced into Africa, India, countries of South East Asia and Pacific Islands. Cassava is the staple food of the poorer section of the population in many tropical countries. It is consumed as sweet potato in the form of tubers, chips, flour and sago. In India, cassava along with fish forms the main item of diet for the working classes in Kerala. They are cooked and eaten or powdered into flour and used in the same manner as rice flour. Tubers are grated, juice out and the residue made into pellets is used in the production of starch and sago. They are produced both in cottage and industrial scale in many cassava producing countries including India.

c. *Syzygium jambolanum* Linn

This is a handsome evergreen spreading tree reaching up to 9 m or more in height. It is cultivated in many parts of India, as an ornamental plant or for its rose scented fruits. Leaves are lanceolate, 12.5-20 cm long, narrow with short petioles. Flowers are greenish white in short terminal recemose cymes with numerous long yellowish to pinkish white. Seeds are grey and placed in the cavity of succulent

pericarp. The fruit is eaten fresh. It is crisp with pleasant flavour. It is used for making candied fruits, jellies and sauces. The edible portion of fruits contain nutrients such as protein 0.7, fat 0.2, fibre 1.2, carbohydrate 9.7, mineral matter 0.3 and water 89.1. The leaves on steam distillation yield a yellow essential oil.

d. *Cocos nucifera* Linn

Coconut palm is one of the most important plantation crops in the world. It belongs to the family arecaceae and is an erect tree with a terminal crown of leaves growing to a height of 20-30m, with a life of 80-100 years. The roots are adventitious. The stem is composed of inter node. Leaves are borne in a terminal radiating crown which in adult palm consists of 25-35 opened leaves with a central bud. Inflorescence are monoecious with numerous male and female flowers, in each spadix. Fruit is a fibrous drupe about 20-30 cm long. The nut of commerce consists of seed and endocarp. Mature fruit is usually ovoid varying in size and colour, taking 12 months to mature. The outer skin or the endocarp is tough, smooth, hard and may be green, yellow, orange or reddish brown. Mesocarp or fibrous layer which is pale brown, 4.8 cm thick and produces coir of commerce. The endocarp or shell is ovoid, hard, storny dark, brown with three ridges on outside and three eyes at basal end. A single seed with a thin testa closely

appressed to endocarp and adhering firmly to endosperm or meat which is firm, white oily, 1-2 cm thick and supplying the copra and oil. Embedded in endosperm at the basal end is a small peg like embryo. The centre of seed is hollow filled with coconut water.

3. Sampling

Aerial parts of the crop plants were chosen for study, particularly the leaves and branches showing symptom of infestation were collected by using scissors and transferred them to separate polythene bags and labelled. The mouth of each polythene bag was tied with rubber band and immediately brought to the laboratory. Sampling was made at regular intervals on respective host plants.

Collection of velvet bean plant was made from various kitchen gardens of Chenakkal, near Calicut University Campus. The infested leaves of *S. jambolanum* were collected randomly from ladies hostel and Botanical garden of Calicut university Leaves for the collection of mites from Velvet bean and *S. jambolanum* were grouped according to their age. Collection of cassava leaves for the present study was made from Thalappara in Malappuram district. This site constituted an open field of 10 acres of cassava cultivation at about 6 km. south of Calicut University along the side of NH-17.

Leaf samples for collection of mites from cassava were made from three different tiers. The principal method of collection of mites from crop plant was hand picking. For this, samples of leaves were carefully observed under a Wild M420 stereomicroscope. When mites were encountered during observation they were picked up using a moistened camel hair brush. They were then transferred in to collection bottles containing 70% alcohol as the preservative.

Coconut samples were collected from plantation of about one acre from Pudukad area of Thrissur district, Kerala State which was characterised by the presence of other cultivations like arecanut, mango Artocarpus, nutmeg, and banana. The coconut trees selected were belongs to the age group of 20-30 years. comprising mainly two varieties, of which West Coast tall was predominated. Green variety was also seen intermingled with West Coast tall. Both the varieties of coconut plants were invariably found invaded by the mites.

Infested samples of nut from the above plot were regularly collected from, for a period of 2 years, 1998-2000. Random collection of nuts of various age groups from 1-7 months were made for studying the damage symptoms as well as for assessing the degree of infestation with the age of the nut.

4. Identification of mites

I. Preservation

a. Ethyl alcohol:

The plant mites, except the members of Eriophyidae were best preserved in ethyl alcohol (70-80%). A few drops of glycerine were also added to avoid drying up of specimen through evaporation of alcohol.

b. Alcohol glycerine acetic acid fluid (AGA fluid)

Another preservative used for preserving Tetranychid specimen was AGA fluid.

Preparation- 80 ml of ethanol was taken in a conical flask and 10 ml each of acetic acid and glycerin were added and mixed by shaking. A small pinch of sorbitol was added to the mixture and dissolves by stirring. It was often transferred to a bottle, stoppered tightly and kept for frequent use. The medium prevented hardening of specimen and facilitated easy orientation during slide preparation.

c. Sorbitol- isopropyl alcohol mixture

For the preparation of this medium, sorbitol and isopropyl alcohol solution was used. A thin solution of sorbitol was added into 25% isopropyl alcohol solution in a beaker. It was then kept in a stand until the sugar got dissolved and the fluid became a thick syrup. Small

amount of iodine crystals were also added to prevent mould formation.

d. Lactic acid-ethanol fluid

This was another medium employed particularly for preserving and clearing the dehydrated specimens of oribatid mites. This medium was prepared by mixing lactic acid and ethanol in equal proportion. 50 ml of ethanol and 50 ml of lactic acid were taken in a conical flask, mixed well by shaking. It was transferred to a clean bottle, stoppered and kept for frequent use.

II. Clearing of specimens

This was done by passing the specimens first through alcohol series, 70%, 80%, 90%, and absolute respectively. When the specimens were completely dehydrated, they were then transferred to clearing medium prepared by lactic acid and glycerine in the ratio of 1:1. The time taken for clearing the specimen depended on degree of sclerotisation of the specimen which often ranged from few to several days.

III. Mounting of specimens

In the present study, Hoyer's medium was used for mounting acarine specimens.

Preparation:- 40 ml of distilled water was taken in a beaker. 30 gm of gumarabic and 200 gm of chloral hydrate were weighted and added to the distilled water in the beaker and dissolved. 20ml of glycerine was added to the above solution and the contents were mixed well. The mixture was filtered through cotton wool and the solution was used for mounting the specimens.

1. Preparation of slides

Two types of mounting procedures were employed during the study for the preparation of slides.

a. **Temporary Mounting:** This was practiced for the immediate observation of the cleared specimens. A drop of glycerine was placed on a clean microscopic slide by means of a needle. The specimen was directly transferred from the preservative to the drop of glycerine and oriented properly. A piece of clean glass bristle, slightly larger than the size of the mite, was then introduced into glycerine. The specimen was then covered by 18mm diameter round cover glass for observation. While mounting, care was taken not to trap air bubble in the medium.

b. **Permanent Mounting:** This method was employed for the preparation of permanent slides of the specimen. A clean glass slide was taken and a drop of Hoyer's medium was placed at the middle

of the slide. Well cleared specimen was transferred from the preservative to the mounting medium with the help of a camel hair brush. The specimen was then oriented according to the need. A clear glass bristle of suitable size was introduced into the mounting medium. Subsequently, a round cover glass of 18 mm diameter was placed on top of mounting medium. In the case of Tetranychids, Tenuipalpids and Eriophyids the specimens were directly mounted in Hoyer's medium without clearing. The mounted slides were kept at 50°C in an oven. The slide was sealed by means of commercial nail polish and used for observation and drawing.

c. **Identification of the Mites:** Identification of the known mite species was made by studying and comparing the morphological characters of the species with appropriate literature described earlier. For this the morphological characters of the moutned specimens were studied under a Leitz Aristoplan Research Microscope and drawing were made by using wild Leitz GMBH Camera lucida. Confirmation of the species identification was made by consultation with experts in the field.

V. Laboratory rearing of mites

I. Culture methods

Biological studies were carried out in special culture cells in the laboratory. For the laboratory rearing of mites different culture

methods were adopted.

a. Leaf disc methods

This method was commonly used for rearing and culturing of Tetranychids and Tenuipalpids. These culture cells were prepared with petridishes measuring 10 cm in diameter with lids. Freshly collected uninfested leaves of the host plants were spread out on the petridishes which were lined with moistened cotton pads basally. Mites originally collected from the infested leaves from the field were introduced into the fresh leaves in the petridishes in batches of 10 individuals, each consisting of two males and eight females. Laboratory cultures of individual species of mite was maintained at different temperatures. Biological studies of *T. ludeni* on velvet bean, *R. macfarlanei* on *S.jambolanum* and *T. cinnabainus* on cassava were studied at a temperature of 26± 1^0C, 27±1^0C, 28 ± 2^0C and RH of 70-72%, 65-70% and 68-75% respectively. When sufficient number of eggs were laid, the adults were transferred to new culture vessels. Constant observations were made on mating, oviposition, incubation, hatching, active and quiescent periods, moulting, number of generations etc. Data collected on the sexual progeny were tabulated and presented.

b. Glass bowl method

This method was mainly used for culturing and rearing of *A. guerreronis* in the laboratory. A glass bowl of 3.5 cm diameter with a height of 8.5 cm was used for rearing *A. guerreronis*. Coconut buttons of suitable age groups were selected and fixed on appropriate plastic rings, the arrangement was placed in the centre of the bowl. The bowl was then filled with water below the level of meristematic zone of the nut. Gravid females released on to the button were forced to remain mostly on the top region, facilitating their observation through the microscope. Care was taken to retain the water level below the meristematic zone so as to prevent the movement of mites away from the meristematic zone. When sufficient number of eggs were laid, the adults were transferred to new culture vessels. Constant observations were made on oviposition, moulting, number of generations etc. Data collected on postembryonic development were tabulated and presented.

c. Plaster of Paris charcoal method

This method was used for culturing predatory mites and insects. Special plastic chambers of 3 cm diameter and 4 cm height with lid were used for this purpose. These chambers were half filled with plaster of paris and animal charcoal mixture in the ratio 5:1 Fresh buttons were embedded in these culture vessels to which known number of

A.guerreronis were released along with its predators for observing their feeding habits and breeding biology. A drop of 2% thymol mycostat suspension was also added to the culture base as bacteriostatic and fungistatic agents. Several such culture vessels were prepared and maintained for rearing the predatory fauna.

VI. Population estimation

Population density of *A. guerreronis* on coconut was made during a period of two years, that is from September, 1998 to August, 2000. Population was assessed on nuts of 2-4 months age through biweekly observation. Population density of mite was estimated by enumerating the number of adults and nymphs per one centimetre square area of meristematic zone of affected nuts. For counting purpose, the tepals of the nut was carefully removed and 1 cm^2 feeding area of meristematic zone was marked. The nut was then placed in a freezer for 10-15 minutes in order to arrest the movement of mites. Counting was done under a stereobinocular microscope immediately after freezing of mites.

For estimating the population density, sampling of nuts was made at biweekly intervals. On each sampling occasion, 4-5 infested nuts were collected from each of the 10 randomly selected palms. Care was taken to collect similar age group of nuts from different palms. Data on average population of the mite are presented at monthly

intervals along with monthly average of temperature, R.H, and rainfall of the area. In order to assess the influence of temperature, relative humidity and rainfall on population density of the mite, multiple regression analysis of the above data was done.

Population dynamics of the individual species of mites on the concerned plants were recorded during different season of the study period. Population studies of *T. ludeni* on velvet bean were made from August, 1998 to July, 1999 and that of *R. macfarlanei* on *S. jambolanum* from January, 1999 to December, 1999. For studying the population density of these two species of mites, 3 plants were selected randomly and from each plant, 3 leaves of different age groups (younger, middle aged and older) were plucked and brought to the laboratory. Observation was made twice in a month. The population density of *T.cinnabarinus* on cassava was monitored from October, 1999 to June, 2000. In this case, 5 plants were selected and marked from the field. Three leaves were plucked from three different tiers (upper, middle and lower) of each plant twice in a month. Mites were usually present on the lower surface of leaf and number of mites present per 2 cm^2 of individual leaf was counted with the help of stereobinocular microscope. The temperature and relative humidity were recorded from the field during the sampling period. Influence of weather factors on

population density was determined statistically by computing simple correlation.

VII. Estimation of crop loss in weight of copra content

In order to assess the loss in weight of copra content, the nuts were categorised into four groups viz., uninfested, mild infested, medium infested and highly infested. Collected the nuts from each category which were processed at uniform atmospheric temperature of 30-32°C for about 2 weeks. Then the weight of copra in each category was found out separately. The obtained weight of copra from each category was analysed statistically by analysis of variance or ANOVA. Percentage of loss in weight of each category was also found out separately. The damaged area of the nuts of the infested category had also been analysed in order to study the influence of total surface area on damaged area. The area of infestation was measured by using tracing paper and graph paper. For this the damaged area was marked on the tracing paper. Removed the paper and counted this area by using the graph paper. The obtained data of the damaged area of the affected nuts were analysed statistically following analysis of regression and analysis of variance.

OBSERVATION

OBSERVATION

A. GENERAL SURVEY OF PHYTOPHAGOUS MITES

Results of the general survey carried out on the phytophagous mites infesting 43 species of host plants from different localities of Kerala enabled to yield 37 species of mites (Table 1). As presented in the table, maximum species diversity of mites could be recorded on two species of plants, such as the common tuber crop, *M. esculenta* popularly called cassava and the oil yielding crop, *C. nucifera* or the coconut. Both the above species of plants harboured five species of mites each. As indicated in the table, seven species of plants revealed the presence of four species of mites each, while the remaining plant species exhibited still lower numbers of mites. However, all the plant species disclosed the presence of atleast a single species of mite.

The mites collected during the study belonged to 24 genera and nine families (Plate-I, Table 1). Of these, Tetranychidae, could be recognised as the dominant family comprising 13 species of mites, constituting 35% of the total mite population. This was followed by Tenuipalpidae (22%) and Eriophyidae (19%). Tarsonemidae, Galumnidae and Oribatellidae exhibited an equal pattern of distribution constituting 6% each. The remaining oribatid families viz.,

TABLE I

Host range and relative abundance of phytophagous mite recovered during the survey

	Mite/ Host Plants	*Tetranychus cinnabarius*	*T. ludeni*	*T. macfarlanei*	*T. neocaledonicus*	*T. pappayae*	*T. urticae*	*Oligonychus mangiferous*	*O. biharensis*	*O. indicus*	*O. iselimae*	*Eutetranchus orientalis*	*Eotetranychus hicoriae*	*Petrobia latens*	*Brevipalpus obovatus*	*B. rugulosus*	*B. phoenicis*	*Tenuipalpus yousefi*	*Dolichotetranychus palmae*	*D. floridanus*	*Raoiella macfarlanei*	*R. indica*	*Polyphagotarsonemus latus*	*Tarsonemus sp.*	*Aceria guerreronis*	*A. jasmini*	*Calacarus carinatus*	*Cisaberoptus kenyae*	*Nothopoda sp.*	*Phyllocoptruta oleivora*	*Phyllocoptes sp.*	*Caloppia sp.*	*Lamellobates palustris*	*Notogalumna nortoni*	*Orthogalumna terrebrantis*	*Paralamellobates bengalensis*	*Scheloribates decarinatus*	*Uracrobates indicus*	Total
VEGETABLE CROPS																																						
1	*Abelmoschus esculentus*	--	--	+++	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	++	-	-	2
2	*Amaranthus tricolor*	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	++	-	3
3	*Canavalia gladiata*	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	3
4	*Capsicum frutescens*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	++	-	-	-	-	-	-	-	-	-	-	-	++	+	-	3
5	*Cucurbita maxima*	-	-	-	++	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	2
6	*C. pepo*	-	-	-	+++	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
7	*Cucumis sativus*	++	+	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	4
8	*Dolichos lablab*	-	-	-	+++	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
9	*Lagenaria vulgaris*	-	++	-	-	-	-	-	-	-	-	-	-	-	-	-	++	-	-	-	-	-	-	++	-	-	-	-	-	-	-	-	-	-	-	+	-	4
10	*Lycopersicum esculentum*	++	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
11	*Momordica charantia*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	++	+	-	++	-	3
12	*Mucuna deeringiana*	-	++ +	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1

	Mite/ Host Plants	*Tetranychus cinnabarius*	*T. ludeni*	*T. macfarlanei*	*T. neocaledonicus*	*T. pappayae*	*T. urticae*	*Oligonychus mangiferous*	*O. biharensis*	*O. indicus*	*O. iselimae*	*Eutetranchus orientalis*	*Eotetranychus hicoriae*	*Petrobia latens*	*Brevipalpus obovatus*	*B. rugulosus*	*B. phoenicis*	*Tenuipalpus yousefi*	*Dolichotetranychus palmae*	*D. floridanus*	*Raoiella macfarlanei*	*R. indica*	*Polyphagotarsonemus latus*	*Tarsonemus sp.*	*Aceria guerreronis*	*A. jasmini*	*Calacarus carinatus*	*Cisaberoptus kenyae*	*Nothopoda sp.*	*Phyllocoptruta oleivora*	*Phyllocoptes sp.*	*Caloppia sp.*	*Lamellobates palustris*	*Notogalumna nortoni*	*Orthogalumna terrebrantis*	*Paralamellobates bengalensis*	*Scheloribates decarinatus*	*Uracrobates indicus*	Total
13	*Psidium sativum*	+++	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	-	3
14	*Solanum melongena*	+++	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+++	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	++	+	-	4
15	*Trichosanthes anguina*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	++	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	+	-	3
	FRUIT CROPS																																						
16	*Achras sapota*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+++	++ +	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
17	*Annona squamosa*	-	-	-	-	-	-	-	-	-	-	-	-	-	++	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
18	*Carica papaya*	-	-	-	-	+++	-	-	-	-	-	-	-	-	-	-	++	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
19	*Citrus limon*	-	-	-	-	-	-	-	-	-	-	++	-	++	-	-	++	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	4
20	*Citrus medica*	-	-	-	-	-	-	-	-	-	-	-	-	+++	-	-	+++	-	-	-	-	-	-	-	-	-	-	-	-	+++	-	-	-	+	-	-	-	4
21	*Garcinia cambogia*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	1
22	*Mangfera indica*	-	-	-	-	-	-	+++	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	++	3
23	*Morus alba*	++	-	-	-	-	-	-	-	+	-	+	-	-	-	-	++	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4
24	*Musa sapientum*	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	2
25	*Passiflora edulis*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+++	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	2
26	*Psydium gujava*	+	-	-	-	-	-	-	-	-	-	-	++	-	-	-	+++	-	-	-	-	-	-	-	-	-	-	-	-	++	-	-	-	-	-	-	-	4
27	*Syzygium jambolanum*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	++	-	-	-	+++	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	3

	Mite/ Host Plants	*Tetranychus cinnabarius*	*T. ludeni*	*T. macfarlanei*	*T. neocaledonicus*	*T. pappayae*	*T. urticae*	*Oligonychus mangiferous*	*O. biharensis*	*O. indicus*	*O. iselimae*	*Eutetranchus orientalis*	*Eotetranychus hicoriae*	*Petrobia latens*	*Brevipalpus obovatus*	*B. rugulosus*	*B. phoenicis*	*Tenuipalpus yousefi*	*Dolichotetranychus palmae*	*D. floridanus*	*Raoiella macfarlanei*	*R. indica*	*Polyphagotarsonemus latus*	*Tarsonemus sp.*	*Aceria guerreronis*	*A. jasmini*	*Calacarus carinatus*	*Cisaberoptus kenyae*	*Nothopoda sp.*	*Phyllocoptruta oleivora*	*Phyllocoptes sp.*	*Caloppia sp.*	*Lamellobates palustris*	*Notogalumna nortoni*	*Orthogalumna terrebrantis*	*Paralamellobates bengalensis*	*Scheloribates decarinatus*	*Uracrobates indicus*	Total
28	*Zyzyphus jujuba*	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	2
	TUBER CROPS																																					
29	*Amorphophallus companulatus*	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+++	-	-	-	-	2
30	*Colocasia esculenta*	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	2
31	*Curcuma domestica*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
32	*Dioscorea alata*	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	+++	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+++	-	+	-	-	4
33	*Manihot esculanta*	+++	-	-	++	-	++	-	++ +	-	-	+++	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5
34	*Zyngiber officinales*	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	2
	PLANTATION CROPS																																					
35	*Areca catechu*	-	-	-	-	-	-	-	-	++	-	-	-	-	-	++	-	-	-	-	-	+++	-	-	-	-	-	-	-	-	-	-	-	+++	-	-	-	-	4
36	*Cinnamon zylanicum*	+	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
37	*Elatteria cardamomum*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	++ +	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
38	*Thea sinensis*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+++	-	-	-	-	-	-	-	-	-	-	-	1
39	*Myristica fragrans*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+++	-	-	-	-	-	-	-	-	-	1

	Mite/ Host Plants	*Tetranychus cinnabarius*	*T. ludeni*	*T. macfarlanei*	*T. neocaledonicus*	*T. pappayae*	*T. urticae*	*Oligonychus mangiferous*	*O. biharensis*	*O. indicus*	*O. iselimae*	*Eutetranchus orientalis*	*Eotetranychus hicoriae*	*Petrobia latens*	*Brevipalpus obovatus*	*B. rugulosus*	*B. phoenicis*	*Tenuipalpus yousefi*	*Dolichotetranychus palmae*	*D. floridamus*	*Raoiella macfarlanei*	*R. indica*	*Polyphagotarsonemus latus*	*Tarsonemus sp.*	*Aceria guerreronis*	*A. jasmini*	*Calacarus carinatus*	*Cisaberoptus kenyae*	*Nothopoda sp.*	*Phyllocoptruta oleivora*	*Phyllocoptes sp.*	*Caloppia sp.*	*Lamellobates palustris*	*Notogalumna nortoni*	*Orthogalumna terrebrantis*	*Paralamellobates bengalensis*	*Scheloribates decarinatus*	*Uracrobates indicus*	Total
	OIL YIELDING CROPS																																					
40	*Cocos nucifera*	-	-	-	-	-	-	-	-	-	++	-	-	-	-	-	-	-	+++	-	-	+++	-	-	+++	-	-	-	-	-	-	+	-	-	-	-	-	5
41	*Ricinus communis*	-	-	+++	-	-	-	-	-	-	-	-	-	-	-	-	++	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
	GARDEN CROPS																																					
42	*Jasminum grandiflorum*	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	++	-	-	-	-	-	-	-	-	-	-	-	2
43	*Rosa indica*	-	-	-	-	-	++	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
	No. of host plants harbouring the mite species	9	10	2	4	1	3	1	1	2	1	3	1	2	1	3	18	1	1	1	1	2	1	1	1	1	1	1	2	1	1	1	4	6	2	7	10	1	

- absent; + present; ++ moderate; +++ abundant

Plate I

Percentage distribution of various families of phytophagous mites

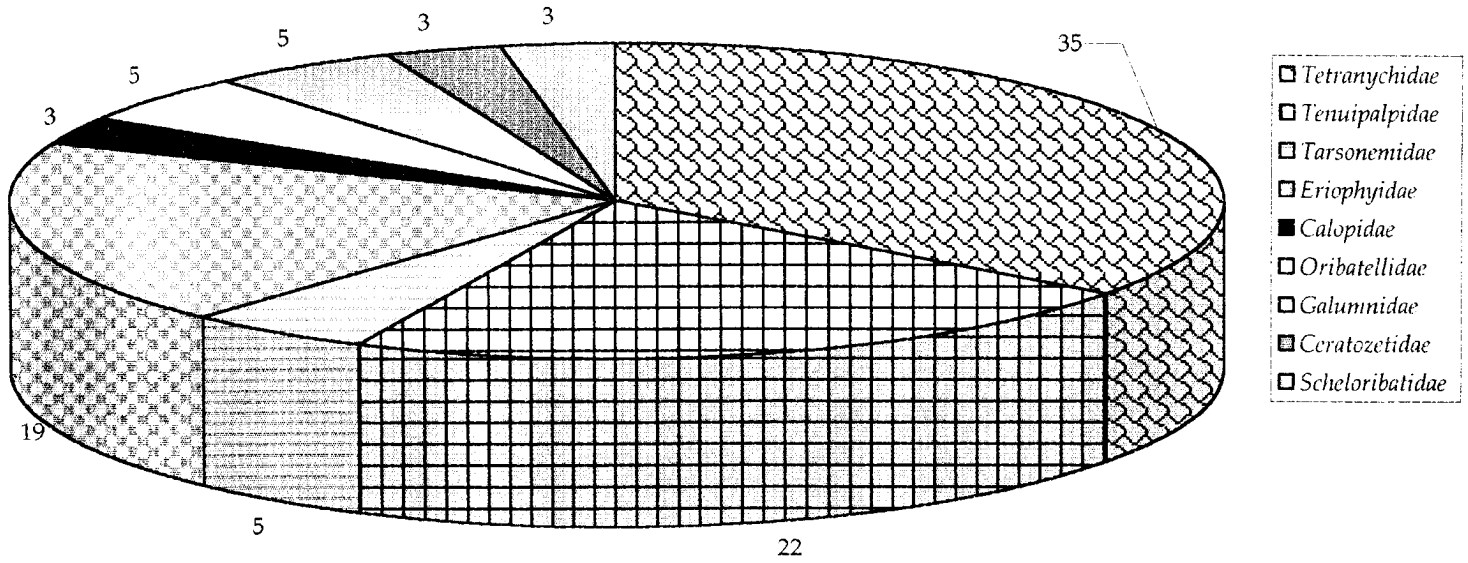
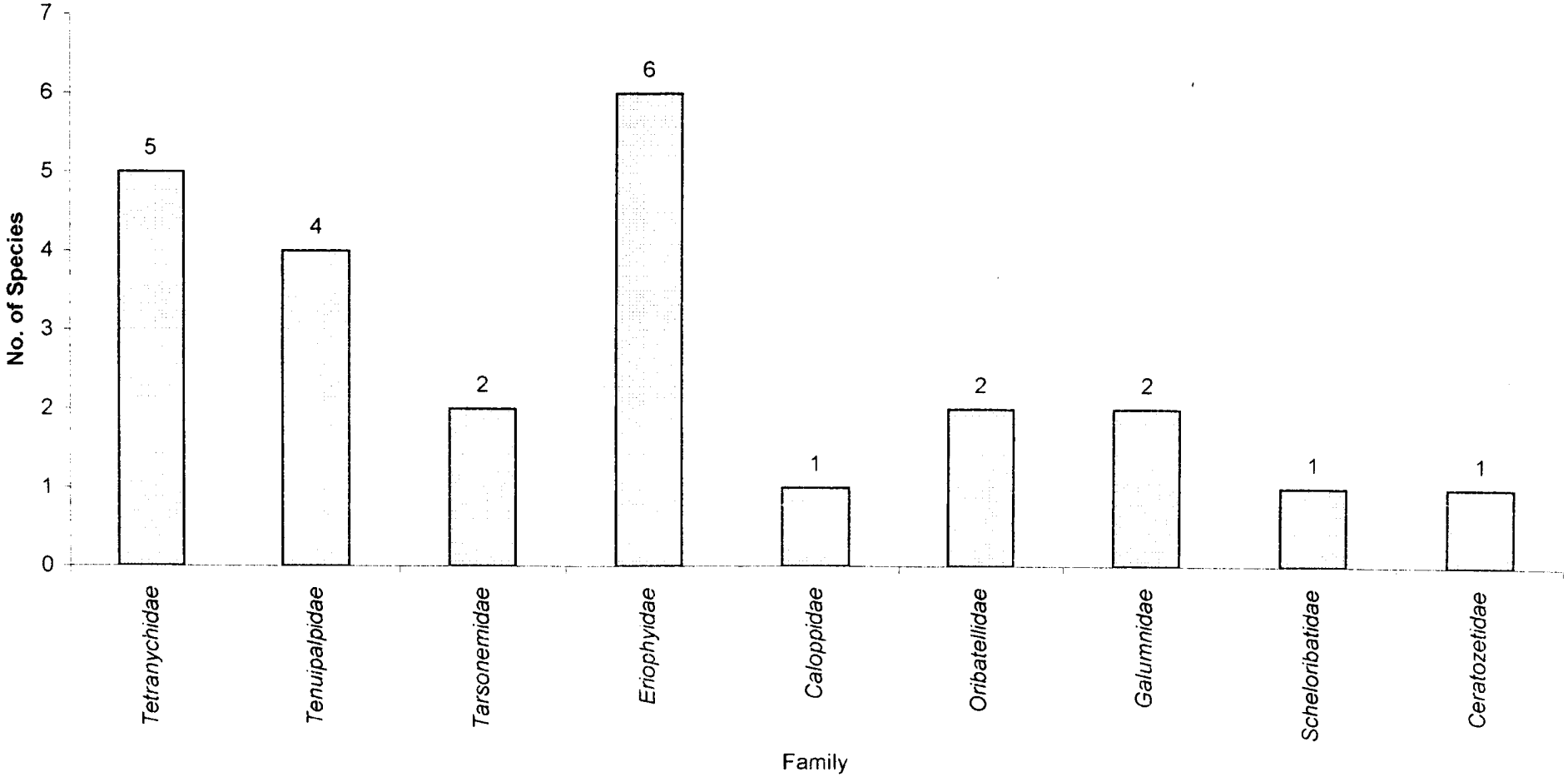


Plate II
Generic diversity of phytophagous mites



Scheloribatidae, Caloppidae and Ceratozetidae followed an equal trend of distribution comprising 3% each. The relative abundance of the various families recovered during the survey could therefore be represented as Tetranychidae > Tenuipalpidae > Eriophyidae > Tarsonemidae = Galumnidae Oribatellidae > Scheloribatidae = Caloppidae = Ceratozetidae

Family Eriophyidae occupied the first position in terms of generic diversity as it supported seven genera. The different genera recovered during the study under this family included *Aceria, Calacarus, Cisaberoptus, Phyllocoptruta, Phyllocoptes* and *Nothopoda*. Second position in terms of generic diversity was attained by the family Tetranychidae as it supported five genera such as *Tetranychus, Oligonychus, Eutetranychus, Eotetranychus* and *Petrobia*. This was followed by the family Tenuipalpidae comprising four genera including *Brevipalpus, Tenuipalpus, Raoiella* and *Dolichotetranychus*. Tarsonemidae and the oribatid families showed a gradual reduction in generic diversity as presented in Plate-II.

As indicated in Plate-III maximum species diversity was exhibited by members of the family Tetranychidae, comprising 13 species. This was followed by Tenuipalpidae and Eriophyidae showing slight reduction, with eight and seven species respectively.

Plate III
Species diversity of phytophagous mites

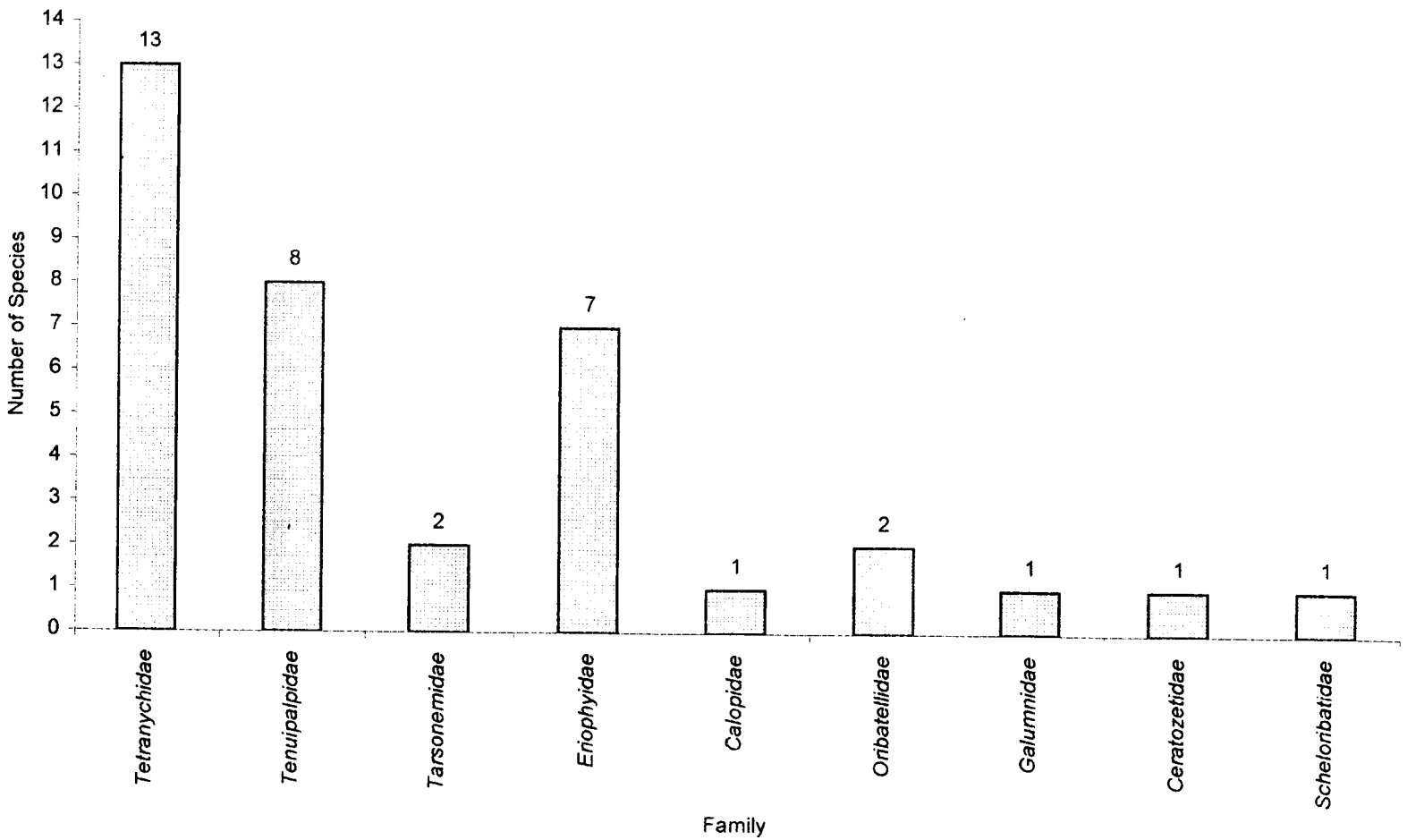
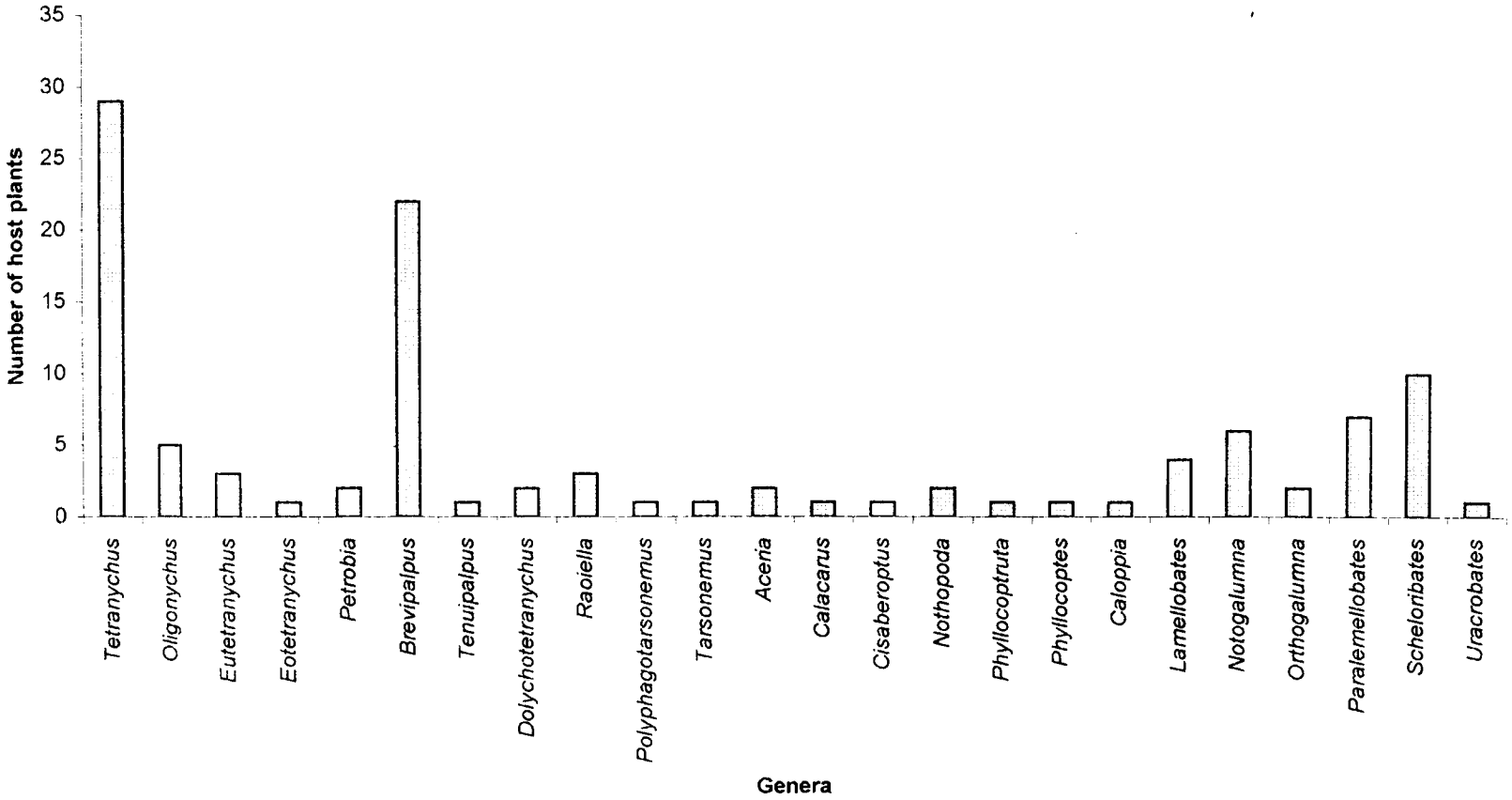


Plate IV
Host diversity of different genera of phytophagous mites



Tarsonemidae, Oribatellidae and Galumnidae showed an equal pattern of diversity constituting two species each. The remaining families were represented by a single species of mite each.

The various genera of the phytophagous mites recovered during the study exhibited wide host range (Plate-IV). Out of 24 genera of mites obtained, *Tetranychus* was found to extend its distribution to the maximum number of host plants (24). The genus *Brevipalpus* reached second position in this regard, extending its distribution to 22 species of host plants. The number of host plants infested by genera such as *Scheloribates, Paralamellobates* and *Notogalumna* were 10, seven and six respectively. The genus *Oligonychus* was found infesting five species of host plants. *Lamellobates* and *Eutetranychus* were found associated with four and three host plants respectively. Members of genera like *Dolichotetranychus, Raoiella, Aceria* and *Nothopoda* were recovered from two species each of the host plants surveyed whereas the remaining genera viz., *Eotetranychus, Polyphagotarsonemus, Caloppia, Phyllocoptruta, Phyllocoptes, Cisaberoptus, Calacarus* and *Uracrobates* were found associated with a single species of host plant each as represented in Plate-IV.

Among the 37 species of mites recovered during the survey, the tenuipalpid species, *B. phoenicis* exhibited widest host range,

harbouring 18 out of 43 species of plants screened. The other species of tenuipalpid mites showed comparatively lower host range. Two species of *Tetranychus* viz., *T. ludeni* and *T. cinnabarinus* could be encountered on 10 and nine species of host plants respectively. In addition to the above two species of mites, 11 more species of tetranychids were collected and their host range was comparatively low. *S. decarinatus*, *P. bengalensis* and *N.nortoni* out numbered all species of oribatid mites collected by showing association with 10, nine and six species of host plants respectively. Members of the families Tarsonemidae and Eriophyidae exhibited relatively narrow host range as indicated in Plate- IV.

The major symptoms of injury caused by the mites on their respective host plants were illustrated in Table 2. All the species collected under the genus *Tetranychus* were found confined to the lower surface of the leaves of the host plants. The various species were found to cause profuse webbing on the lower surface of the leaves. Such leaves were often found covered with dust particles. In advanced stages of infestation, the mites were found migrating to the upper surface of the leaves of the host plants. The population density of the members of the genus *Tetranychus* was high, particularly on the vegetable crops surveyed during the study. In severe cases of infestation, white spots

TABLE 2

Family and Generic Composition of Mites on Various Host Plants and Their Symptoms of Injury

Sl. No	Family	Genera	No. of plants habouring the genera	Location of mites/Symptoms/ Damage
1	Tetranychidae	*Tetranychus*	24	Lower surface of leaves, white or yellowish spots and patches, profuse webbing
		Oligonychus	5	Upper surface of leaves; yellowish brown patches; dense webbing with dust particles
		Eutetranychus	3	Upper surface of leaves; yellow spots and patches covered with webbing
		Eotetranychus	1	Lower surface of leaves; yellowish brown patches; no webbing
		Petrobia	2	Both the upper and lower surface of leaves; with yellowing or bronzing symptoms; with no web
2	Tenuipalpidae	*Brevipalpus*	22	Lower surface of leaves; chlorosis leads to brownish patches
		Tenuipalpus	1	"
		Raoiella	3	Lower surface of leaves; reddish or brownish patches
		Dolichotetranychus	2	Lower surface of leaf sheath or stem sheath and inner surface of the tepals of the nut; reddish or brownish patches
3.	Tarsonemidae	*Tarsonemus*	1	Both sides of leaves; crinkling of leaves
		Polyphagotarsonemus	1	"
4.	Eriophyidae	*Aceria*	2	Perianth of coconut; felt like white hairy out growth on the lower surface of leaves
		Calacarus	1	Copper brown discolouration on both surface of leaves

Sl. No	Family	Genera	No. of plants habouring the genera	Location of mites/Symptoms/ Damage
	Eriophyidae	*Cisaberoptus*	1	Silvery white or ashy white coating on the upper surface of leaves
		Phyllocoptruta	1	Both surface of leaves leads to slivery discolouration
		Phyllocoptes	1	Leaf vagrant; no visible symptoms
		Nothopoda	2	"
5.	Caloppidae	*Caloppia*	1	Lower surface of leaves; no apparent symptom
6.	Oribatellidae	*Lamellobates*	4	"
		Paralamellobates	7	"
7.	Galumnidae	*Notogalumna*	6	"
		Orthogalumna	2	"
8.	Scheloribatidae	*Scheloribates*	10	"
9.	Ceratozetidae	*Uracrobates*	1	Both surface of leaves; no visible symptoms

were developed which coalesced to form yellow patches (Plate-V, Figs. 1-6; Plate-VI, Figs. 1-2) at the sites of feeding, followed by withering and defoliation of affected plants. Incidence of *O. mangiferus* was very high on *Mangifera indica,* where it colonised on the upper surface of leaves causing profuse webbing entangled with dust particles. *O. biharensis* was found to infest both surfaces of the leaves of cassava. (Plate-VI; Fig. 3) Infested leaves developed bronzed brown chlorotic patches on them. The remaining two species of *Oligonychus* viz., *O. indicus* and *O. iselimae* were found attacking arecanut and coconut respectively. Both the species were found confined to the lower surface of the leaves. On feeding, yellowish brown patches were developed at the feeding sites. *E.orientalis* was found confining to the upper surface of the leaves of the host plants producing yellowish patches. However, the population density of this mite appeared to be low on all the host plants. *E.hicoriae* was found feeding on the lower surface of leaves of guava and feeding of which imparted yellowish brown patches on the affected leaves.

B. phoenicis was found extending its distribution to 18 out of the 43 host plants surveyed. The population density of this species was very high on *Lagenaria vulgaris, Solanum melongena, Achras sappota, Citrus medica, Passiflora edulis, Syzygium jambolanum* and *Dioscorea alata.*

EXPLANATION OF FIGURES

PLATE V

Symptoms of Mite Infestation on Different Host Plants

Fig. 1 Initial symptoms showing white spots on the leaves of *Pisum sativum* caused by *T.cinnabarinus*

Fig. 2 Secondary stage of infestation showing coalesced yellowish patches

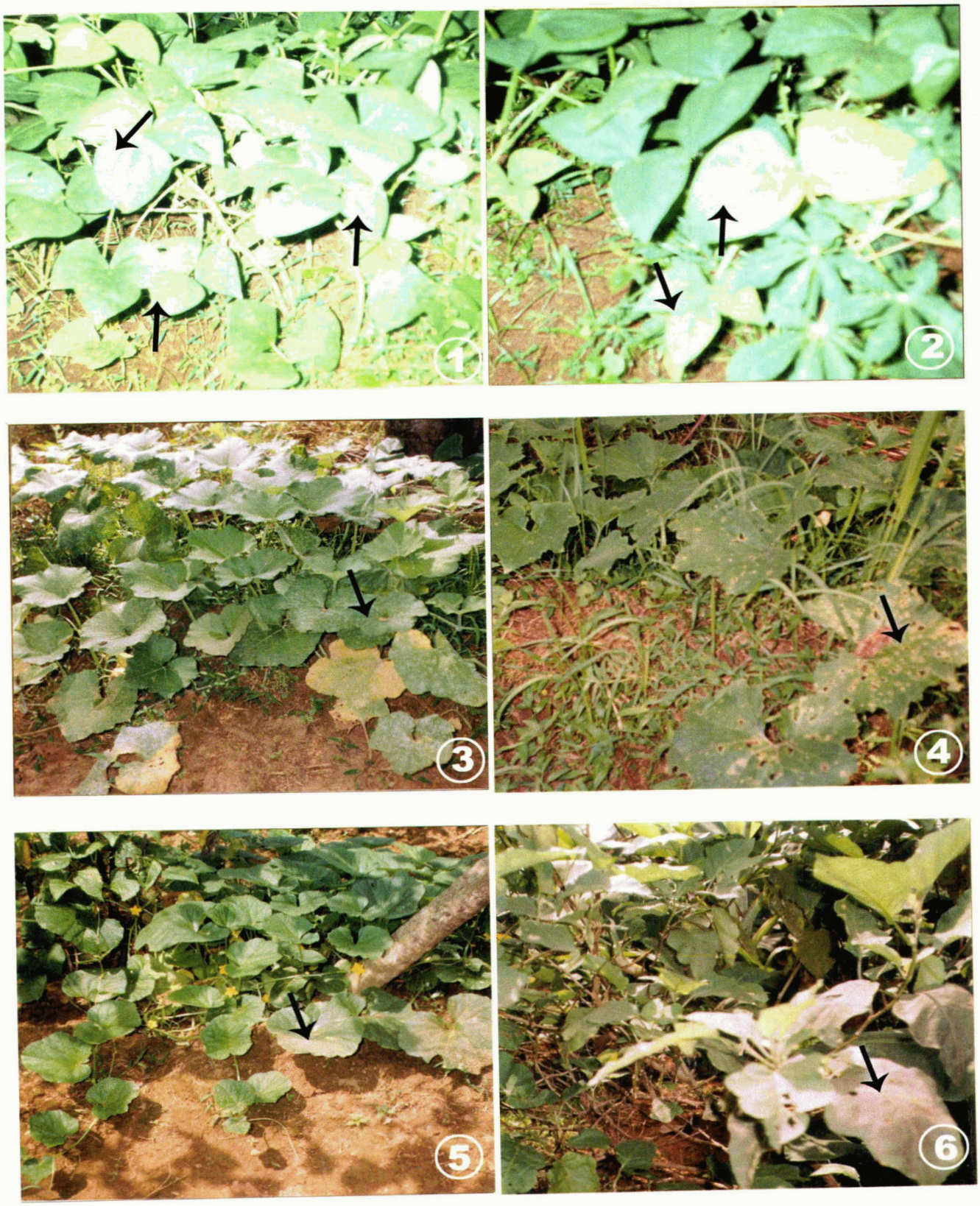
Fig. 3 White chlorotic spots on the leaves of *C. maxima* caused by *T.neocaledonicus*

Fig. 4 Coalesced yellowish patches on the leaves of *C.pepo* by *T.neocaledonicus*

Fig. 5 Yellowish spots on the leaves of *C.sativus* due to the infestation of *T.cinnabarinus*

Fig. 6 Initial symptoms of white chlorotic spots on *S.melongena* leaves due to the infestation of *T.cinnabarinus*

PLATE V



EXPLANATION OF FIGURES

PLATE VI

Symptoms of Mite Infestation on Different Host Plants

Fig. 1 White and yellowish spots and patches on the leaves of *A.companulatus* due to the infestation of *T.ludeni*

Fig. 2 White chlorotic spots on the leaves of *Okra* caused by *T.macfarlanei*

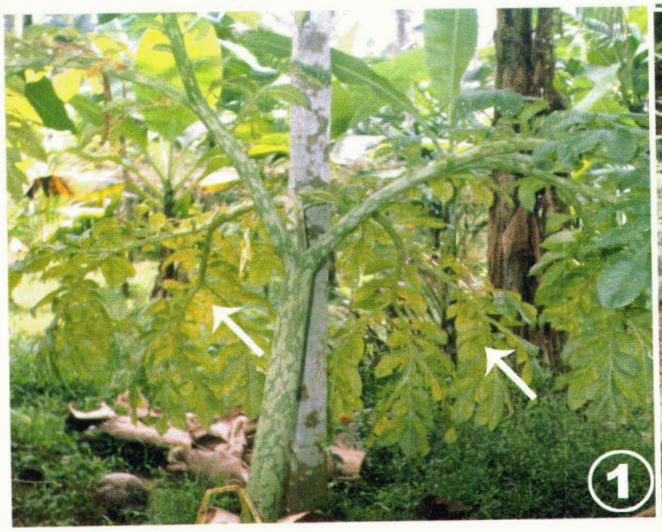
Fig. 3 Casava leaves showing brownish and yellowish patches due to the infestation of *Oligonychus* and *Tetranychus* spp.

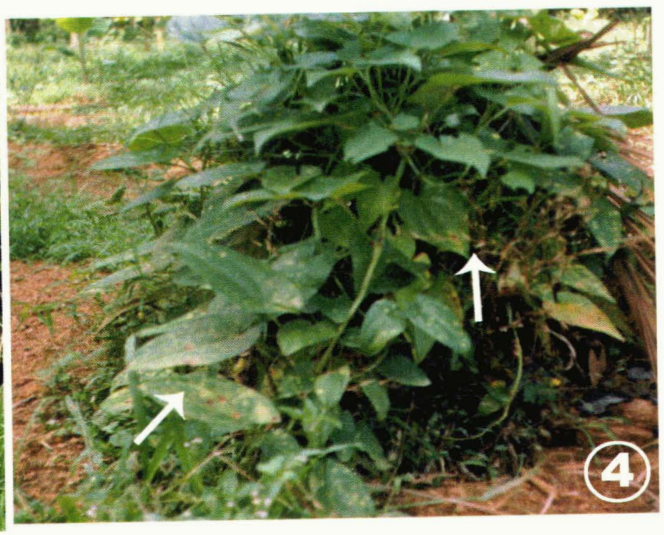
Fig. 4 Brownish yellow patches on the leaves on *D. alata* due to the infestation of *B. phoenicis*

Fig. 5 Jamba leaves showing white yellow and brownish patches caused by *R. macfarlanei*

Fig. 6 Yellow patches on the leaves of *arecanut* due to infestation of *R. indica*

PLATE VI





Infestation by this species was usually visible on the lower surface of midrib region of leaves where yellowish brown spots were found developed (Plate-VI, Fig. 4). The feeding symptoms of other species of the genus viz., *B. rugulosus* and *B. obovatus* were also similar to those of *B. phoenicis*. *Tenuipalpus yousefi* was found confined to the lower surface of the leaves of *A. suppota*, closely apposed to the midrib where it produced yellowish brown spots and patches. Unlike the other tenuipalpid representatives, *D. palmae* was found to infest the nuts and not the leaves of its host plant, *C. nucifera*. The species was found living under the tepals of coconut, sucking sap from the soft tissues at the meristematic zone. The second species under the genus *Dolichotetranychus* collected during the study viz. *D. floridanus* was found infesting the lower surface of leaf sheath, inner to the stem sheath and the inter-nodal areas. Members of *R. macfarlanei* were found in abundance on the leaves of *S. jambolanum* and their colonies were usually confined to the lower surface of the leaves (Plate-VI, Fig. 5). Brownish patches were detected at the affected region of the leaves as a result of feeding by this species. High population of *R. indica* could be noted on coconut and arecanut crops (Plate-IV, Fig. 6) where the mite species formed their colonies on the under surface of leaves causing the appearance of reddish spots and yellowish patches on the leaves.

The presence of *P. latus* was found in moderate numbers on the leaves of *C. frutescens* while *Tarsonemus* sp. could be detected on the leaves of *L. vulgaris*. These two species were found distributed on both surfaces of leaves and tender shoots of their respective hosts, causing crinkling in severe cases of infestation.

Among the eriophyid species collected during the study, *A. guerreronis* was recognised as the most vital and potential pest attacking coconut nuts in various far and wide locations. The species was found producing an array of sytmpoms which were summarised in the second half of the observation part. *A. jasmini* was found infesting the lower surface of the leaves of jasmine where it produced felt like white hairy outgrowth or erinea. *C. carinatus* could be collected during the study from tea leaves where it was recognised as an important species. The attacked leaves developed copper brown discolouration which later turned into purplish bronze. During the study, abundant population of *C. kenyae* could be collected from *M. indica*. The species was found producing silvery white or ashy white coating on the upper surface of leaves. The affected region later developed black colouration. *P. oleivora* could be detected on both surfaces of the leaves of citrus. Infestation by this species resulted in the appearance of silver colour which later turned to reddish or blackish colouration. The leaf vagrant

TABLE 3

New host records of the mite

Sl. No.	Species of Mite	New Host Plants
1	*Tetranychus cinnabarinus*	*Cinnamon xylanicum*
2	*T. ludeni*	*Amaranthus tricolor, Mucuna deeringiana, Jasminum grandiflorum, Zyngiber officinalis*
3	*T. urticae*	*Rosa indica*
4	*Oligonychus indicus*	*Morus alba*
5	*Brevipalpus rugulosus*	*Lycopersicum esculentum, Areca catechu*
6	*B. obovatus*	*Annona squamosa*
7	*Raoiella macfarlanei*	*Syzygium jambolanum*
8	*Lamellobates palustris*	*Amaranthus tricolor*
9	*Orthogalumna terrebrantis*	*Momordica charantia*

eriophyid species collected during the study included *Nothopoda* and *Phyllocoptes* and both the species were observed on the upper surface of leaves, without inducing much visible damage symptoms.

The various species of oribatid mites collected during the survey exhibited a general preference to the lower surface of leaves of their respective host plants without showing visible symptoms of damage. The population density of species like *N. nortoni* was particularly high on host plants like *A. companulatus* and *A. catechu*. Moderate populations of *S. decarinatus, P. bengalensis* and *U. indicus* were noticed on their respective host plants. The remaining 3 species of oribatid mites showed only low occurrence.

Results of the survey further helped to record new host plants for 9 species of mites as illustrated in Table-III. As represented in the table, *Cinnamon xylanicum* formed a new record of host plant for *T.cinnabarinus*. Similarly *Rosa indica, Annona squamosa, S. jambolanum, M.charantia, Amaranthus tricolor* and *Morus alba* were recognised as new host records for species like *T. urticae, B. obovatus, R. macfarlanei, O. terrebrantis, L. palustris* and *O. indicus* respectively. The survey helped to add 4 new hosts to *T. ludeni* and 2 new hosts to *B. rugulosus*.

B. BIOLOGY OF *TETRANYCHUS LUDENI* ZACHER ON VELVET BEAN, *MUCUNA DEERINGIANA*

I. Feeding activity and nature of injury

Adult females of *T. ludeni* were often found selecting interveinal areas of leaves near the midrib for initiating feeding (Plate-VII, Fig. 1). However, other areas of leaves were also found selected for the purpose. The mouth parts of this species comprised of an eversible stylophore formed by the fused cheliceral bases, as in other members of the family Tetranychidae. Movable chelae modified into long stylets, were used to penetrate the plant tissue for sucking the cell contents.

A sequence of events was seen involved during the feeding activity of the mite. Initially, the mite lowered its gnathosoma closely to the leaf surface raising its hysterosoma from the floor to a certain distance. Closer observation of feeding behaviour revealed alternate movements of pedipalp followed by tight application of cheliceral tip to the leaf surface. Then the chelicera, moved forward and backward on the rostrum for the insertion and retraction of stylets. The epidemal cells were pierced by stylets by the above process. The movement of stylets was slow during the phase of protraction while in retractive phase it was more rapid. The process of penetration often continued for several times for creating feeding puncture.

II. Symptoms of infestation

Adult females started feeding activity on the lower surface of the leaves, usually near the midrib or interveinal regions. Initial symptom produced by the feeding activity of the mite on the leaves was so microscopic which later turned into small etiolitic spots. On constant feeding of the adjacent surface, this etiolitic spots coalesced to form chlorotic spots which later turned into yellowish and finally became brownish (Plate-VII, Fig. 2). After some days, the plant was found defoliated. The middle aged leaves were attacked more severely than the younger and older ones.

Another interesting behaviour noticed during the feeding study was the formation of webbing by the mite. The intensity of webbing appeared to vary considerably. Each thread of web was transparent and produced without any consistency or regularity. Usually webbing was established between two adjacent veins or vein and midrib. Well established webs were often found adhered by various extraneous products of the mite namely, moulting skin and faecal pellets. In addition, eggs were also seen on the webs usually (Plate-VII, Fig. 3).

Two kinds of faecal pellets were seen on both laboratory and in field collected samples of the leaves. They constituted the creamy white, round, granular, air bubble like pellets called white pellets and black, berry like ones called black pellets (Plate-VII, Fig. 4). Each pellet carried a transparent

globular body with central opaque core region. The core region appeared to be white or black and was made up of very fine oval granules glued together. In white pellets the core region was homogenous with single type of granule where as in black pellets the core region was heterogeneous consisting of large black granules, small yellow granules and short fibre like structures.

The number and size of the faecal pellets were also found varying. The white faecal pellets were smaller in size and more in number compared to black pellets. The size difference was due to difference in the number of granules present in the core region. The number of granules in the core region of white pellets ranged from 5-8 while in black pellets the number exceeded 100. The outer matrix was same as both type of pellets were formed of transparent, hyaline, jelly like material bounded by thin membrane. When viewed on the web, both these pellets retained their original shape, but on falling the leaf surface they usually changed their shape considerably. So, in that case only the black pellets could be recognisable.

III. Breeding biology of *T. ludeni* on velvet bean

a. Mating Behaviour

The adult male individual sought out a quiescent female deutonymph, (Plate-VII, Fig.5), placed the anterior pair of legs on it and

awaited its emergence. Sometimes, three or four males were found surrounding a female deutonymph. Mating process was usually accomplished immediately after the final moult of the female. The initial step of mating process was often aided by the male pulling off the moulting skin from posterior part of female for easy emergence. Then the male crawled under the female and then clasped the opisthosoma of the female with its front legs. The male then curved its abdomen upward and backward until it touched the female abdomen. The time taken for individual mating was about 2-5 minutes.

b. Pre-oviposition period

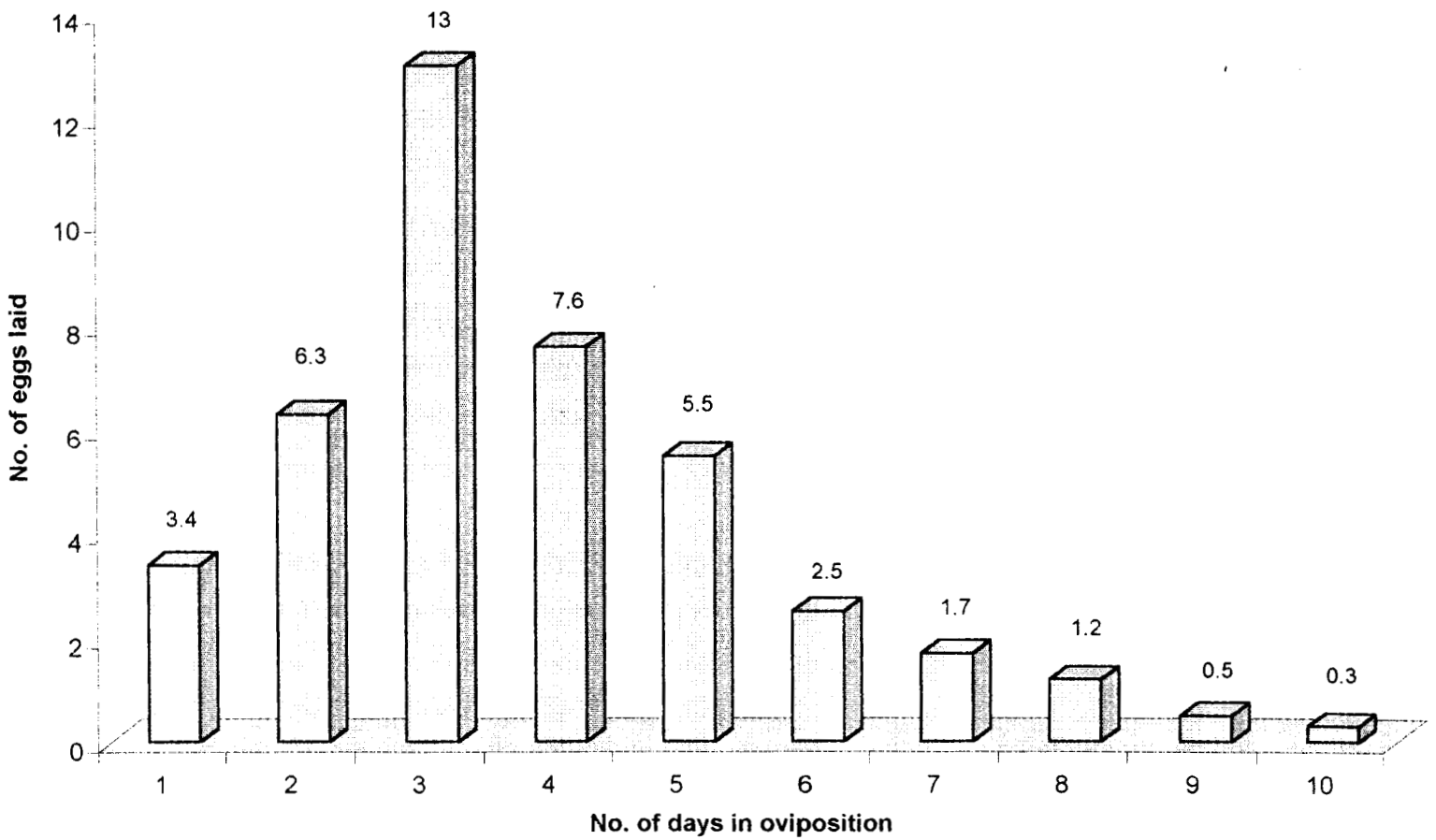
After mating, females were found involved in active construction of web and spinning the web was found more vigorous prior to oviposition. For the construction of web, they selected special areas on the lower surface of leaves, usually near the midrib or interveinal region which offered protection. The females laid eggs after a lapse of certain period.

c. Oviposition period

Generally, oviposition was found initiating a day after mating and this period often extended to 1-3 days. Adult females of *T. ludeni* started egg laying during this period. The eggs were laid either on or underneath the web, usually on the lower surface of the leaf. Only a few eggs were laid on the first day of oviposition with an average of 3.4 (Plate-VIII). Following this,

Plate VIII

Daily variation in the number of eggs deposited by female *T. ludeni* during oviposition period



there was an increase on the second day with peak being reached on the third day of oviposition with an average number of 13. From the fourth day onwards, there was a sharp decrease in egg deposition. The average number of eggs deposited during the last day of oviposition was found to be 0.3 which was recorded as the minimum. Active oviposition period ranged from 8-10 days. The mated female produced an average of 41.2 eggs during an average oviposition period of 9 days (Table 4).

d. Eggs

Eggs were laid on the lower surface of leaves and glued slightly to the surface. The eggs were small, smooth, soft, spherical, translucent and light brown in colour. Each egg measured an average diameter of 123.8µm (Table 5). Solitary eggs were found deposited one after another, forming separate batches. Sometimes, the eggs were found adhered to the web. As the embryo developed, the egg gradually turned creamy white (Plate-VII, Fig. 6), loosing its shiny nature and became faded. The incubation period ranged from 3-3.5 days (Table 6).

e. Hatching

The process of hatching was more or less similar in all tetranychid mites. At the time of hatching, the colour of the egg changed from creamy white to yellowish (Plate-VII, Fig. 6). Just prior to hatching the marginal area along with the periphery became transparent. A small vertical slit was

TABLE 4

Number of eggs laid by female *T. ludeni* on different days of oviposition

Sl. No.	Number of eggs laid per day during oviposition period										
	1	2	3	4	5	6	7	8	9	10	Total
1	3	6	12	8	4	2	2	1	1	0	39
2	4	8	14	6	4	3	2	1	1	1	44
3	3	5	14	8	5	3	1	1	0	0	40
4	3	7	12	7	4	2	2	2	0	1	40
5	4	8	14	10	6	3	1	1	0	0	37
6	3	5	13	7	6	2	2	1	1	0	41
7	3	6	12	8	5	2	2	2	1	1	44
8	4	6	12	10	4	3	1	1	1	0	42
9	4	7	14	7	5	2	2	1	0	0	42
10	3	5	13	6	4	3	2	1	1	0	38
Average	3.4	6.3	13	7.6	5.5	2.5	1.7	1.2	0.5	0.3	41.7

EXPLANATION OF FIGURES

PLATE VII

Life Stages of T. ludeni on Velvet Bean.

Fig. 1 Feeding sites of adult females of *T. ludeni* near the interveinal areas of the velvet bean leaves.

Fig. 2 Leaf surface showing yellowish and brownish patches due to the infestation of *T. ludeni.*

Fig. 3 Adult and eggs of *T. ludeni.*

Fig. 4 Black faecal pellets of *T. ludeni* on the velvet bean leaves

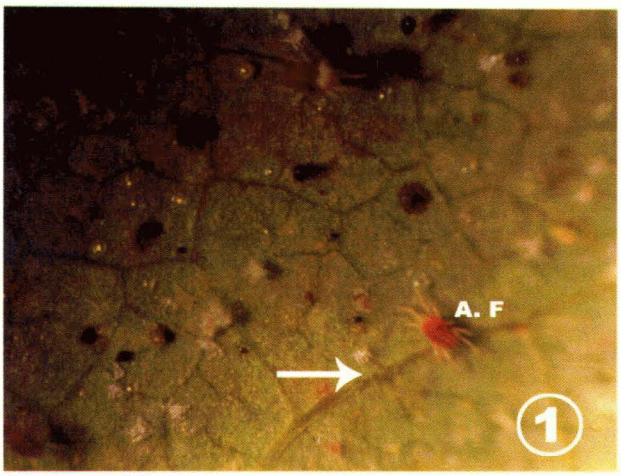
Fig. 5 Guarding of male *T. ludeni* near the quiescent female deutonymph.

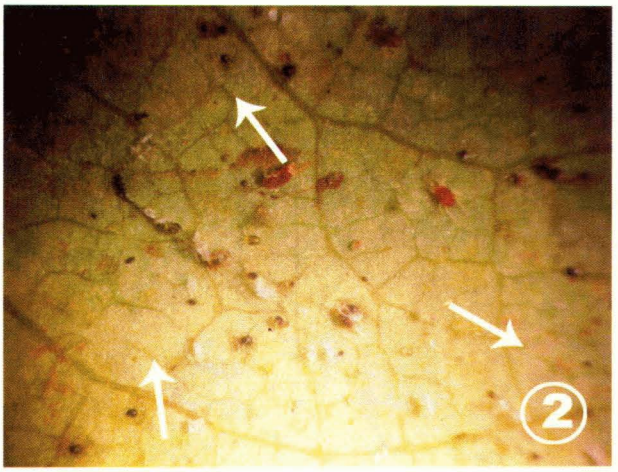
Fig. 6 Creamy white eggs, newly emgerged larva and protonymph of *T. ludeni* .

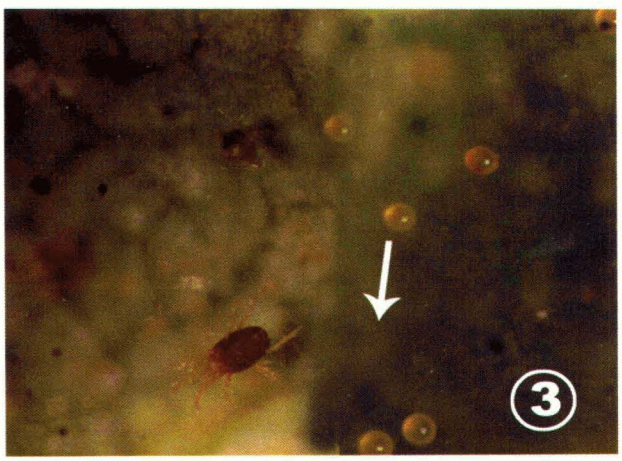
Fig 7 Eggs, adult, deutonymph and quiescent protonymph of *T. ludeni.*

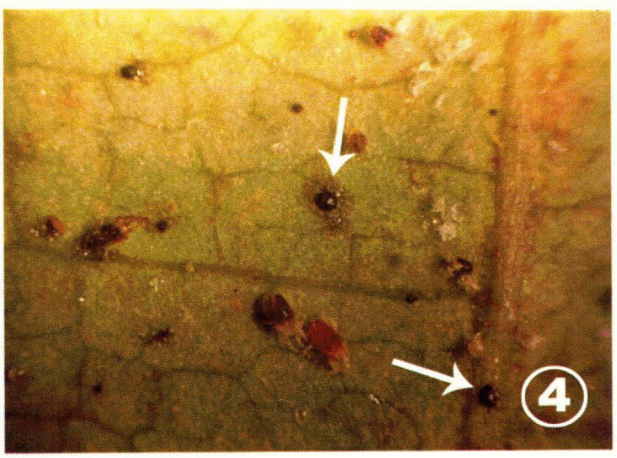
Fig 8 A view of moulting skin of *T. ludeni.*

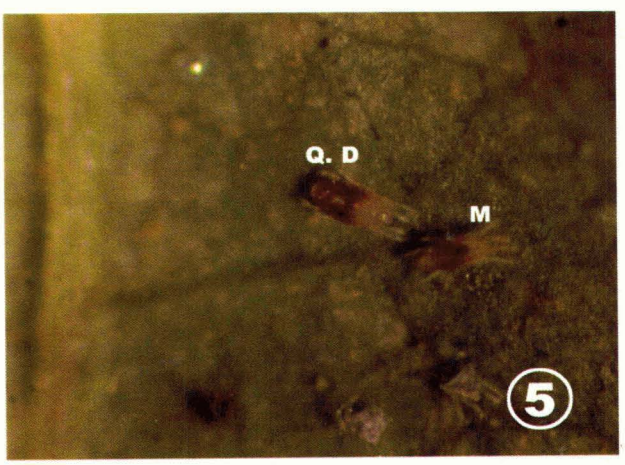
PLATE VII











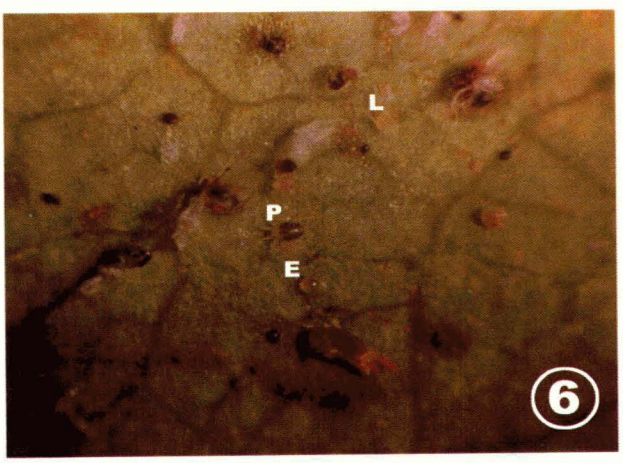


TABLE 5

Measurements (in μm) of the life stages of *T. ludeni*

Sl. No.	Egg	Larva	Proto Nymph	Deuto nymph	Adult	
					Female	Male
1	120	171.6/136	221.6/149.1	316.9/256.5	390.5/312	238/182.4
2	123.2	180/138.4	224.2/144	310.4/259	400.3/301.4	240.6/178.5
3	120.1	176.2/137.1	228/142.5	318.1/250.2	413.306.8	239.4/180.2
4	122.4	178.4/136.5	225/143.4	317/254.1	410.6/310	240/181
5	123.5	175/138	220/146	314.8/257.3	405/300.7	238.5/180
Average	123.8	176.24/137.5	223.78/145	315.44/255.42	403.88/306.2	180.46/239.32

formed at the apical pole of the egg. The slit gradually widened and the first pair of legs of larva slowly came out. The protruded legs vibrated upon all sides which allowed the slit to widen further, through which the gnathosoma of the larva projected out. Then, by the combined thrusting action of the legs and propodosoma, the basal segment and the entire body of the larva protruded and finally emerged out of the egg case, leaving egg shell intact. The time taken for the completion of hatching process was found to be 10-15 minutes. There was 96 percent hatching.

f. Larva

The newly emerged larva (Plate-VII, Fig. 6) was small, transparent, spherical in outline and creamy white in colour with three pairs of legs and two prominent red eye spots on the side of the dorsal propodosomal region. The larva had an average length of 176.24μm and breadth of 137.5μm (Table 5). After emerging from the eggs, the larva was found inactive for a period of 5 minutes, then crawled around the leaf and began to feed. By active and continuous feeding on cholorphyll the larva turned greenish yellow and finally became dark green. The active larval period extended for 1-1.5 days (Table 6). After the active period, the larva became inactive and entered into the first quiescent phase.

g. Protonymph

The newly moulted protonymph (Plate-VII, Fig. 6) was amber coloured. It was slightly larger than larva with four pairs of legs. The average length and breadth of protonymph was measured as 223.78µm and 145µm respectively (Table 5). Feeding protonymphs were greenish in the beginning and later turned dark green. Protonymphs were active feeders and their feeding period was greater than that of larval stage and lasted for 2-2.5 days (Table 6). Before moulting to deutonymph, there was a quiescent period.

h. Deutonymph

Deutonymph was slightly larger and broader than the protonymph (Plate-VII, Fig. 7). It was light red in colour and measured an average length of 315.44µm and an average breadth of 255.42µm (Table 5). Deutonymphs actively fed on the leaf tissue and on continuous feeding they turned red in colour. The feeding period lasted for 2.5 to 2.8 days (Table 6). The mature deutonymph underwent a quiescent stage and then moulted into adult stage.

i. Quiescent periods

At the end of active period of all developing stages, there was an inactive period. During this period (Plate-VII, Fig. 7) the individual stopped feeding and other visible life activities. They selected some suitable secluded

TABLE 6

Duration (in days) of

Post Embryonic Development of *T. ludeni* on Velvet Bean

Sl. No.	Egg	Larva	I Quiescent	Proto Nymph	II Quiescent	Deuto nymph	III quiescent	Total
1	3.5	1	0.5	2	0.8	2..5	1	11.3
2	3	1.5	0.5	2.5	1	2.5	1.2	12
3	3.5	1.3	0.5	2.5	0.8	2.8	1	12.6
4	3	1	0.5	2	1	2.5	1	11
5	3	1.3	0.5	2.5	1	2.5	1.2	12
6	3.5	1	0.5	2	1	2.5	1	11.5
7	3.5	1.2	0.5	2	0.8	2.8	1.2	12
8	3	1	0.5	2.5	1	2.5	1	11.5
9	3.5	1.3	0.5	2	1	2.5	1	11.8
10	3	1	0.5	2.5	0.8	2.5	1.2	11.5
Average	3.25	1.16	0.5	2.25	0.92	2.56	1.08	11.72

areas, became dull and finally lethargic. They remained stationary there. At that time, the body appeared to be swollen, the legs and mouthparts seemed to be contracted. In the life cycle of *T. ludeni* three quiescent phases were present which occurred in between the larval and protonymphal stage, protonymphal and deutonymphal stage, deutonymphal and adult stage. The first quiescent phase extended for a period of 0.5 day, the second quiescent period lasted for 0.8 to 1 day and third quiescent period for 1 to 1.2 days (Table 6). Thus the total duration of the development of female *T. ludeni* was found to range from 11 to 12.6 days in the laboratory at 27±1^{0}C and a RH of 70-75 percentage (Table 6).

j. Moulting

Each of the quiescent phase was followed by moulting. It was a common feature for larva, protonymph and deutonymph. The time taken for each moulting was about 5-10 minutes. During this process a horizontal slit was formed on the outer silvery white cuticle along with mid dorsal region of the body between the second and third pairs of legs. This slit extended along the ventral region, as a result of which the cuticle divided into anterior and posterior halves. The posterior part of the body came out first by the backward and forward movement. Later on, the anterior half came out by slow sliding movement. Numerous discarded moulting skins (Plate-VII, Fig.

8) of the life stages were found scattered both in laboratory cultures and in field collected leaf samples.

k. Adult Female

The newly emerged adult female was bright red in colour, measured an average length of 403.88μm and average width of 306.2μm (Table 5). The fully mature adult female attained vigour by active feeding. After a period of feeding, the colour changed to dark red. They actively moved around the leaf surface for selecting suitable site for oviposition.

l. Adult Male

Adult male was light green in colour. The reddish eye spot of the individual was clearly visible. The size of the male was comparatively smaller than female with an average length and breadth of 239.32μm and 180.46μm respectively (Table 5).

m. Post-oviposition period

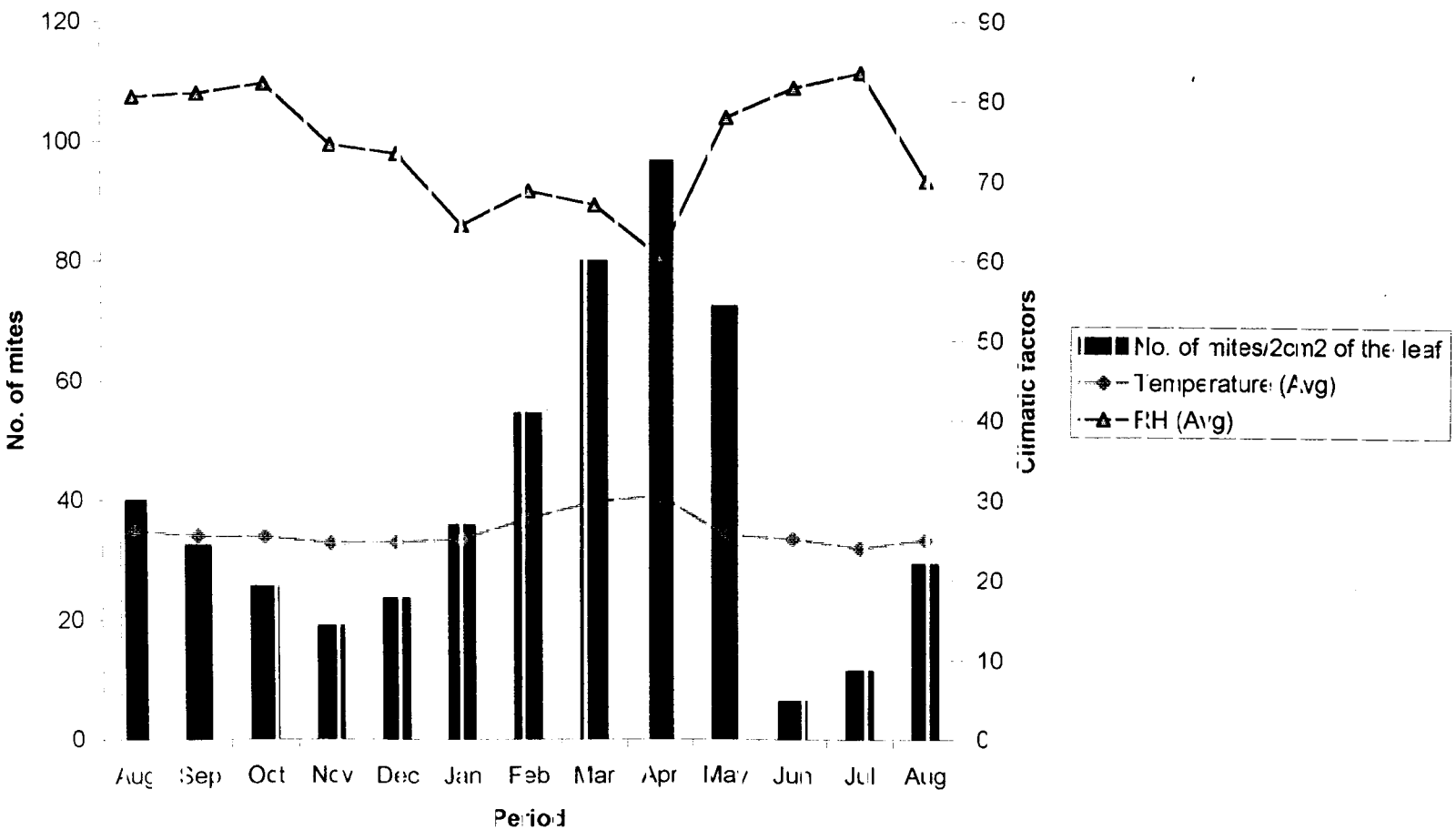
This period extended for 2-4 days. During this period, the adult individual became less active and lethargic. Feeding activity of the mite was seldom noted and finally it was found dead.

n. Longevity

Laboratory studies on the development of *T. ludeni* revealed that the mated females had a longevity of 11 to 17 days.

Plate IX

Influence of Climatic Factors on Population Density of T. ludeni on velvet bean leaves



IV. Population dynamics of *T. ludeni* on velvet bean in relation to environmental factors

The population estimation of *T. ludeni.* on velvet bean was carried out from August, 1998 to August, 1999. The adult mites and their developmental stages were found throughout the year. During the period of initial observation, the average population of mite recorded per 2 cm^2 of the leaf was 58.2 and this was considered as a medium population. The peak population of *T. ludeni* was observed during April when temperature attained maximum during the season, reaching 30.6^{0}C. However, RH showed a negative trend, reaching about 60.5%, registering the minimum for the season. This observation very clearly indicated a positive influence of temperature with r value of 0.88 and a negative influence of RH with r value of -0.643 (Table 7) on the population of *T. ludeni.*

During 1998, the population of the mite remained lowest during November which showed slight increase in December (Plate-IX). The mite built up a steady population during January- February, 1999 culminating in maximum level during April. Its incidence remained very low during the months of June to July. The minimum population of the mite was recorded during the month of June with an average population of 10.21/cm^2 of the leaf. The temperature and relative humidity during this period were 24.12^{0}C and 81.75% respectively. This observation clearly indicated that high RH and low temperature favoured minimum population of the mite. Again

TABLE 7

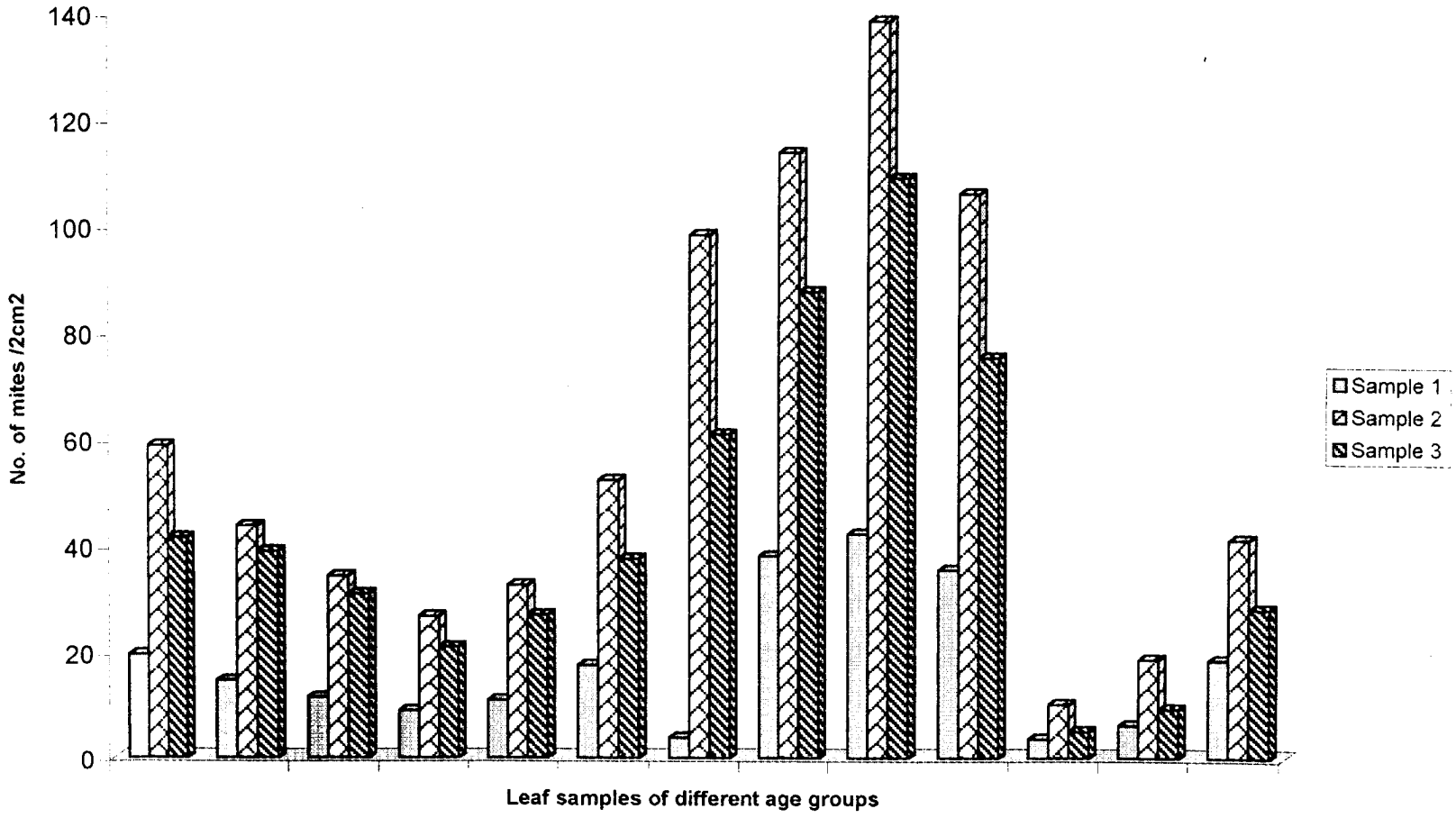
Influence of mean temperature and RH on the seasonal fluctuation of *T. ludeni* on velvet bean during August 1998 to August 1999

Months	No. of mites/cm²	Temperature (Avg)	RH (Avg)
Aug	39.99	26.10	80.6
Sep	32.44	25.60	81
Oct	25.54	25.50	82.2
Nov	18.90	24.64	74.6
Dec	23.51	24.70	73.4
Jan	35.79	25.10	64.4
Feb	54.46	27.74	68.7
Mar	79.95	29.80	67
Apr	96.76	30.60	60.5
May	72.44	25.70	78
Jun	6.34	25.12	81.7
Jul	11.49	24	83.6
Aug	29.40	25	70

	Correlation coefficient (r)
No. of mites Vs mean temperature	0.879626
No. of mites Vs mean RH	-0.643

Plate X

Distribution of *T. ludeni* on different age group of velvet bean leaves



during August, the population showed a slow and steady increase. The high temperature and low relative humidity were found responsible for significant increase during January to April.

V. Distribution of *T. ludeni* on velvet bean

Three age groups of leaves viz., younger leaves, middle aged leaves and older leaves of velvet bean were found infested by *T. ludeni* (Plate-X). Among the three age group of leaves, the distribution of mite was found varying. The middle aged leaves favoured flourishing populations of the mite species compared to the other two age groups. There was a least preference of mite population to the younger leaves and the middle aged leaves were preferred by an average population. Newly sprouted and tender leaves were completely devoid of mite attack..

C. BIOLOGY OF *TETRANYCHUS CINNABARINUS* BOISD ON *MANIHOT ESCULENTA*

Manihot esculenta, the cassava plant, had been known to be infested by various insects and mites. Among the mites, spidermites form a complex on the foliage of cassava. *T. urticae, T. neocaledonicus, T. cinnabarinus, O. biharensis* and *E. orientalis* were the most important among them. All of them were found to be foliage feeders, of which the biology of *T. cinnabarinus* was studied in detail.

I. Feeding activity and nature of injury

The type of injury caused by *T. cinnnabarinus* on cassava leaves had been studied both in the laboratory and in the field. The feeding activity of *T. cinnabarinus* was largely confined to the lower surface of leaves and initiated very close to the midrib of the leaflet (Plate-XI, Fig. 1). All the active stages of the mite punctured the leaf tissue with their cheliceral stylets and sucked the liberated plant sap. This had resulted in the formation of white spots on the leaf surface in due course, adjacent to the midrib on either sides.

II. Symptoms of infestation

As in other tetranychids, the feeding activity of *T. cinnabarinus* induced almost similar symptoms of injury characterized by the development of irregular yellowish patches. Continuous feeding

EXPLANATION OF FIGURES

PLATE XI

Life Stages of *T. cinnabarinus* on Cassava.

Fig. 1 Feeding posture of adult female of *T. cinnabarinus* near the midrib and the infested area showing brownish yellow patches.

Fig. 2 A view of eggs. Larva, and adult female of *T. cinnabarinus.*

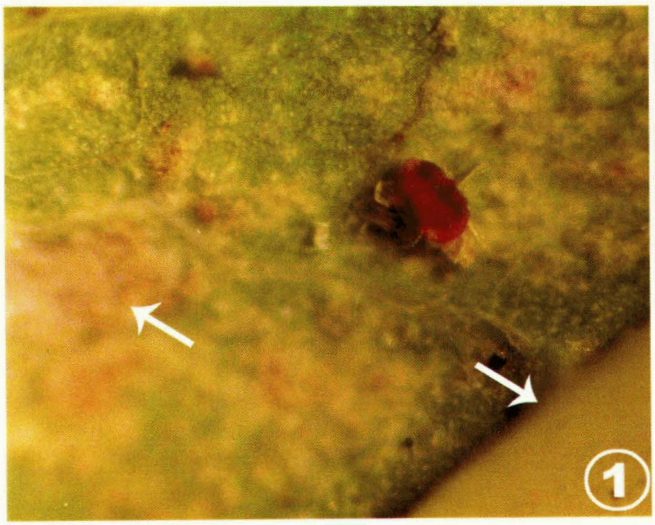
Fig. 3 Eggs, larva and protonymph of *T. cinnabarinus.*

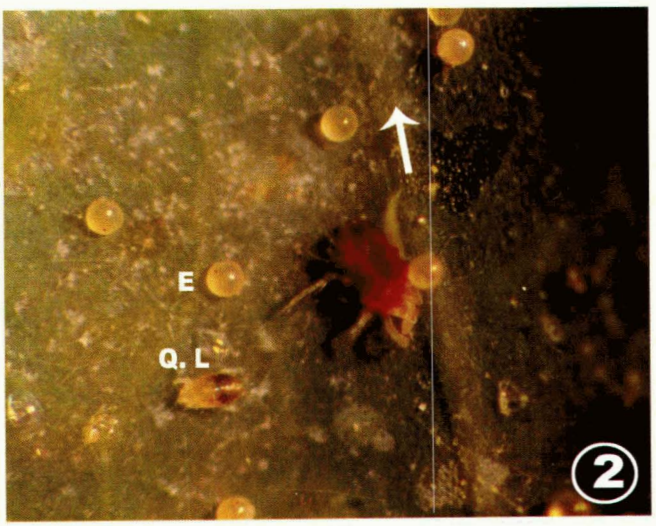
Fig. 4 Deutonymph and quiescent protonymph of *T. cinnabarinus.*

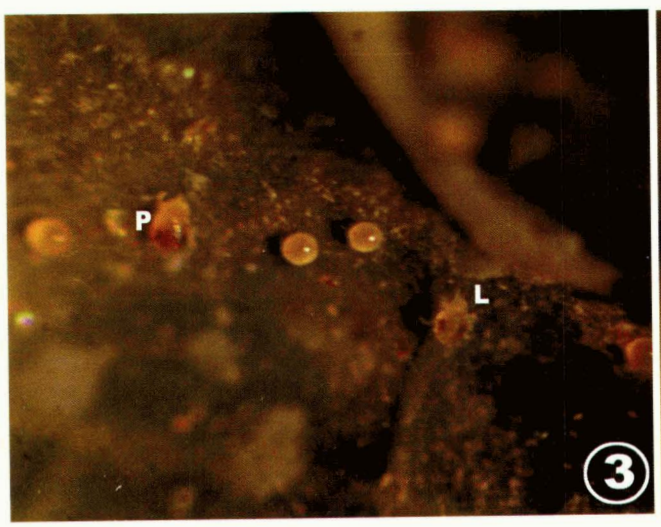
Fig. 5 A view of discarded egg cases and moulting skin of *T. cinnabarinus.*

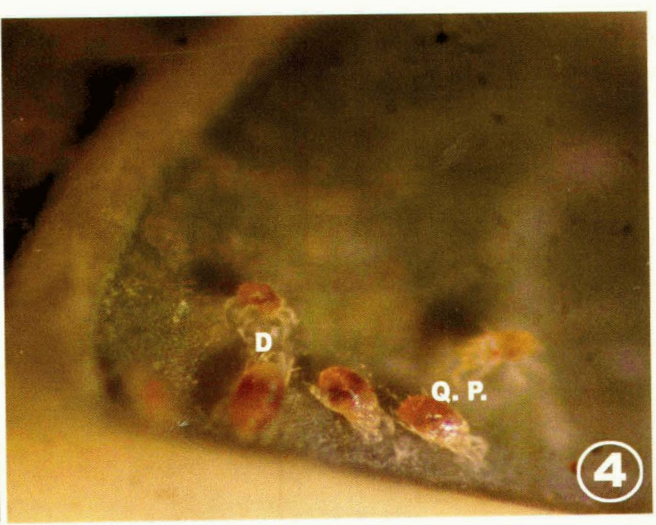
Fig. 6 Adult female and male of *T. cinnabarinus.*

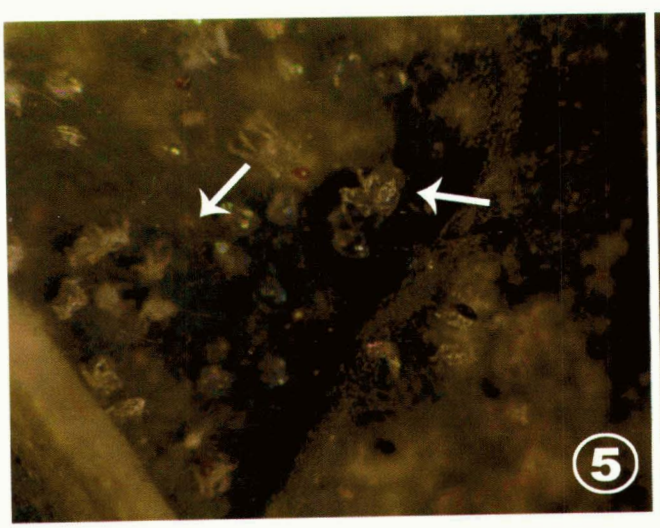
PLATE XI

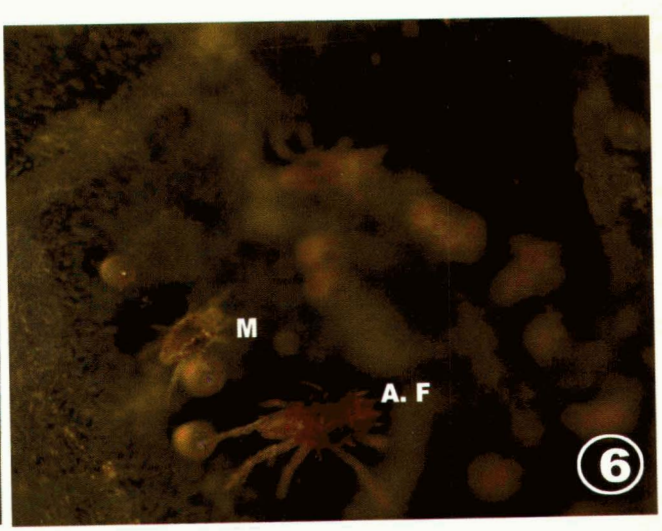












activity of individuals resulted in the development of a number of spots which gradually coalesced producing irregular yellowish white patches, leading to characteristic chlorosis (Plate-XI, Fig. 1). The leaves lost their green colour, gradually wilted, dried and fall off. The discolouration was seen on both the upper as well as lower surfaces of the leaves. During the initial stages of infestation, the mites were found confined to the lower surface of leaves but on prolonged feeding and establishment of the colony, the individuals migrated to the upper surface of the leaves as well.

Simultaneous with feeding activity of *T. cinnabarinus,* intense webbing of silken threads on host leaf surface was also noted. They spun fine webs over the leaves of the plant and at times the entire plant was found covered by this webbing. Sometimes, the webs were of such a thickness that dust particles carried over by the wind were deposited on them. In most cases, females constructed webs and the eggs and other life stages were protected by them.

III. Breeding biology of *T. cinnabarinus* on Cassava

Reproduction was primarily sexual and oviparous, while parthenogenesis had also been observed in this species. Life history studies were carried out at a laboratory temperature of 28±2^{0}C with 68-71% RH.

a. Mating behaviour

Mating occurred as soon as the female emerged from the quiescent deutonymph. Often three or four males were seen waiting around a female deutonymph and helped the female for its subsequent emergence. For copulation, the male crawled under the female and bent its abdomen up over the back. Copulation lasted for 1-5 minutes. One fertilization was sufficient for a female but often it mated more than once. After mating, the male moved away from the female. But the female remained in the same position or moved away.

b. Oviposition

The female usually started laying eggs within 24 hours of emergence. However, the pre-oviposition period ranged from 1-2 days. Eggs were laid singly at intervals on interveinal or midrib region of the cassava leaves (Plate-XI, Fig. 2). *T. cinnabarinus* exhibited an oviposition period of 11-13 days with an average of 11.66 days (Table 8). A female *T. cinnabarinus* usually laid 4-6 eggs per day, the highest number recorded being 10 eggs per day. Maximum number of eggs laid per day varied from 4 to 10 (Plate-XII) with an average of 9 while the minimum number of eggs laid per day varied from 0 to 3. The eggs laid by one female during the entire period of oviposition varied from 47 to 60 with an average of 55.2 (Table 8).

Plate XII

Daily variation in the number of eggs deposited by female T. cinnabarinus during oviposition period

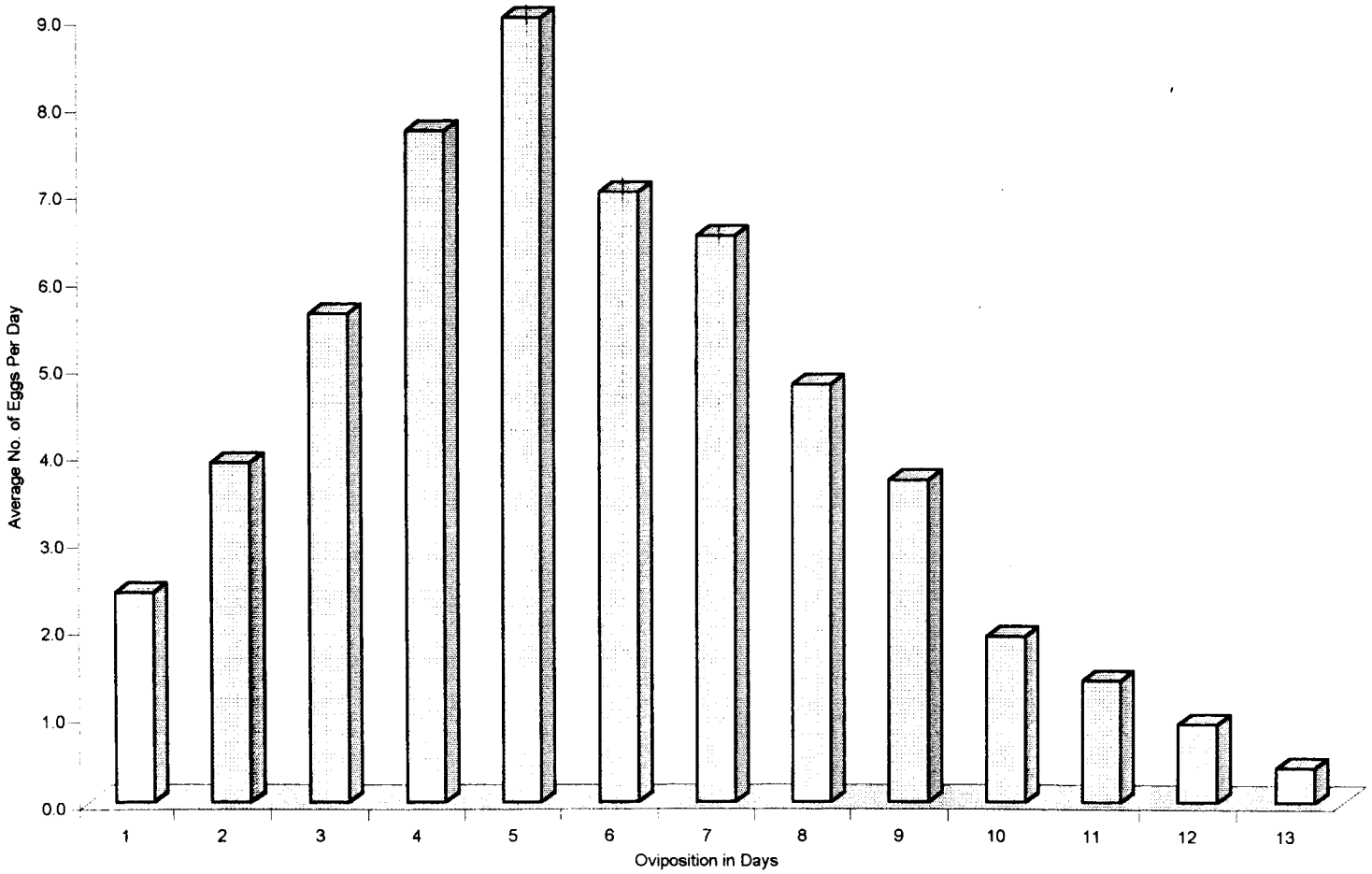


TABLE 8

Number of eggs laid by female

***T. cinnabarinus* on different days of oviposition**

Sl. No.	Number of eggs laid per day during oviposition period													
	1	2	3	4	5	6	7	8	9	10	11	12	13	Total
1	2	4	7	7	10	8	6	4	4	2	3	2	1	60
2	2	3	4	9	9	9	7	6	5	3	1	1	0	59
3	3	3	7	8	10	6	7	5	3	3	0	0	0	55
4	3	5	7	8	10	8	8	4	5	2	2	1	1	64
5	2	3	5	7	8	6	6	4	3	2	1	0	0	47
6	3	4	6	7	8	8	6	6	4	0	1	2	0	55
7	2	4	4	8	9	6	7	5	3	1	1	0	1	51
8	2	5	4	7	8	6	6	4	3	1	0	1	0	47
9	3	3	6	7	10	7	7	4	4	3	3	1	0	58
10	2	5	6	9	8	6	5	6	3	2	2	1	1	56
Average	2.4	3.9	5.6	7.7	9.0	7.0	6.5	4.8	3.7	1.9	1.4	0.9	0.4	55.2

c. Eggs

Usually the eggs were laid singly and were found scattered near the midrib of interviena1 region. Sometimes the eggs were found to be laid in groups but individual eggs were separated from one another. The eggs were pearl like, creamy white and spherical in shape (Plate-XI, Fig. 2) ranged from a diameter of 112-160μm (Table 9). During the successive stages of development, the colour faded and when the embryo developed, the egg became opaque. The average incubation period was noted as 3.3 days (Table 10).

d. Hatching

Hatching process was similar as in the case of *T. ludeni* described earlier and the time taken for the completion of hatching process was found to be 10-15 minutes.

e. Larva

The larva when first hatched appeared round, cream coloured, and having approximately the size of the egg and possessed six legs (Plate-XI, Fig. 3). The larva started active feeding after 4 to 5 minutes of emergence. Their active or feeding period ranged from 1-1.5 days (Table 10) with an average of 1.17 days. The colour of the larva subsequently changed from pale green to dark green with the appearance of dark spots on the abdomen with the consumption of

TABLE 9

Measurements (in μm) of various life stages of *T. cinnabarinus*

Sl. No.	Egg	Larva	Proto Nymph	Deuto nymph	Adult	
					Female	Male
1	112	215/242	210/151	250.4/156	260/149	220/152
2	156	188/148.5	222.3/148	253/150	258/160	215/140
3	122.5	194.6/152	227/143.7	249.8/145	255/155	219/148
4	160	205.4/143	218.5/149	245/149	250/158	210/150
5	134.5	188/150.6	220.1/150.3	247.2/152	254/154	213/143
Average	137	198.2/167.22	179.58/148.4	249.08/150.4	255.4/155.2	215.4/146.6

food. Size of the larva during this period ranged from 188-215µm in length and 142-152µm in width (Table 9).

f. Protonymph

Protonymphs were yellowish green to dark green and had 4 pairs of legs instead of the 3 pairs in larva. The form of the body was somewhat oval (Plate-XI, Fig. 3) and large in size, ranging from 210 to 227µm in length and 143 to 151µm in width (Table 9). Feeding activity of the protonymph was very active and the period ranged from 2-2.5 days (Table 10).

g. Deutonymph

The deutonymph was slightly larger than protonymph measuring 245-253 µm in length and 145 to 156 µm in width (Table 9). It was similar to adult but smaller in size and yellowish brown in colour (Plate-XI, Fig. 4). The feeding period of deutonymph ranged from 2-2.5 days with an average of 2.3 days (Table 10).

h. Quiescent period

All the three life stages i.e. the larva, protonymph and deutonymph passed through a period of inactivity (Plate-XI, Fig. 4) at the end of active feeding. The three quiescent periods existed between the life stages were named as the first, second and third quiescent phases which extended for an average of 0.5, 0.8 and 1.04 days

TABLE 10

Duration (in days) life stages of *T.cinnabarinus* on cassava

Sl. No.	Egg	Larva	I Quiescent	Protonymph	II Quiescent	Due to nymph	III Quiescent	Total
1	3	1.5	.5	2	1	2.5	1	11.5
2	3	1	.5	2.5	1	2.5	1.2	11.7
3	3.5	1.2	.5	2	.5	2	1	10.7
4	4	1	.5	2	.5	2.5	1	11.5
5	3	1.5	.5	2.5	1	2.5	1	12
6	3	1	.5	2.5	.5	2	1.2	10.7
7	3.5	1.2	.5	2	1	2.5	1	11.5
8	3	1.3	.5	2.5	1	2	1	11.3
9	4	1	.5	2	.5	2.5	1	11.5
10	3	1	.5	2	1	2	1.2	10.5
Avg	3.3	1.17	.5	2.2	.8	2.3	1.04	11.31

respectively. Thus the total duration of development of female *T. cinnabarinus* was found to range from 10.5-12 days in the laboratory at 29±1^{0}C and relative humidity of 65-70% (Table 10).

i. Moulting

The process of moulting occurred at the end of quiescent phase of the larva, protnymph and deutonymph. The mechanism involved in each moulting was similar as in the *T. ludeni* on velvet bean and the whole process of moulting took about 10-15 minutes. At the end of the process, the individuals discarded numerous moulting skins which were found scattered on the leaf surface (Plate-XI, Fig. 5).

j. Adult female

The adult females were larger and dark brown in colour (Plate-XI, Fig. 6) measuring 250-260 μm in length and 148-160μm in width (Table 9). The body of female was nearly elliptical, the abdomen being broadly rounded at its posterior end. Most of them were actively moving in search of suitable feeding areas on the leaf surface and started their feeding activity within a few minutes of their emergence.

k. Adult male

The adult male was cream in colour with transparent body and reddish eye spots. The male was comparatively smaller than the female measuring 210-220μm length and 140-152μm width (Table 9). Each male

individual (Plate-XI, Fig. 6) had a narrow body with the abdomen being much narrower and almost tapering to a posterior point. The first pair of legs were longer than those of female.

I. Post-oviposition period

At the end of the oviposition, the female was inactive, lethargic and completely stopped the feeding activity. The post-oviposition period extended for 2-4 days and this was followed by the death of the individuals. The longevity of adult female in the laboratory condition was found to be 13.5-18 days.

III. Population dynamics of T. *cinnabarinus* on cassava in relation to environmental factors

Preliminary survey was made during early October, 1998 when the cultivation of cassava was in its initial stage. During this period, the plants were free of mites. Periodic sampling was initiated during the first half of November and a notable population build up of the mite was observed during this time. The plants attained an age of two months by this time. A gradual increase in the population density of mite was observed from the second half of November to second half of January, 1999. From the first half of February, there a was sudden increase in the population density. This increasing population density was maintained throughout the second half of April. Then the

population density decreased from the first half of May to the last half of June, 1999. By the end of June the harvesting of the crop was initiated. The maximum population density was recorded in the month of March, 1999 with an average of 160 mites/2cm^2 on the three categories of leaf samples and the minimum population density was recorded during June, 1999 (Plate-XIII). In this case, the average number of mites/cm^2 on the three categories of leaf sample was 16.33.

Correlation of monthly population density of *T. cinnabarinus* with climatic factors prevailed during the sampling period enabled to establish a positive correlation between temperature and population density with an r value of 0.883 and a negative correlation between relative humidity and population density with an r value of -0.58 (Table 11). Population was found approaching peak levels during February, March and April. The mean temperature and relative humidity during the above period were 29.25^{0}C and 65.33%. Population density reached the lowest level during Junè, 1999 and the mean temperature and relative humidity recorded during this period was found to be 24^{0}C and 85% respectively. Therefore, it was evident that temperature influenced the population build-up while the relative humidity exerted a negative impact.

TABLE 11

Influence of mean temperature and RH on the seasonal fluctuation of *T. cinnabarinus* on cassava during November 1999 to June 2000

Months		No. of mites/cm²	Temp	RH
Nov 99	I	17.00	25	74
	II	20.00	26	70
Dec	I	12.33	24	71
	II	15.33	24	69
Jan 2000	I	25.66	24	64
	II	30.33	26	66
Feb	I	139.00	27	66
	II	138.67	28	68
Mar	I	153.67	29	60
	II	166.67	31	63
Apr	I	111.33	29	65
	II	70.00	28	70
May	I	64.00	26	76
	II	62.33333	25	80
Jun	I	16.66667	24	79
	II	15	23	81

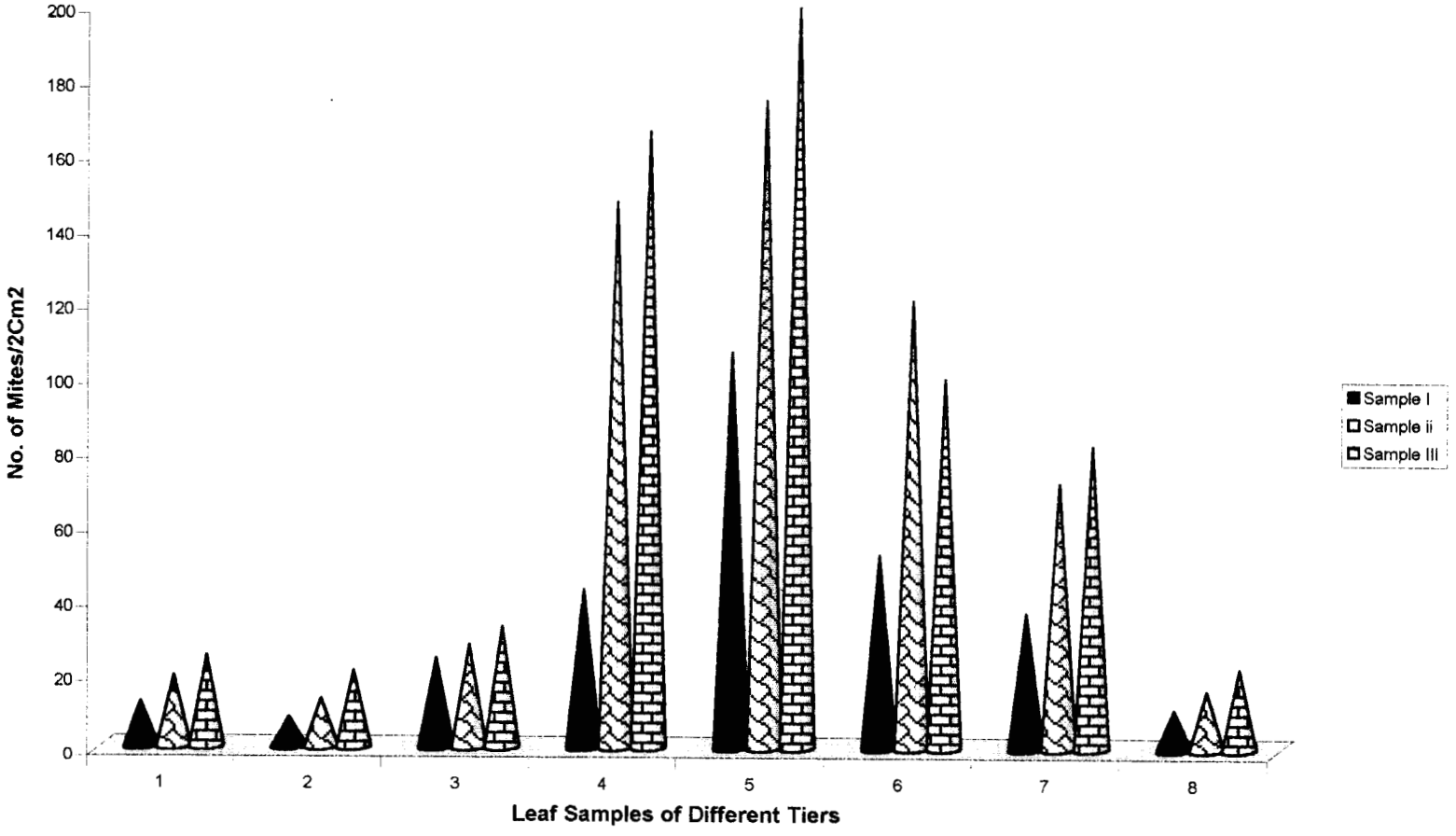
	Correlation coefficient (r)
No. of mites Vs mean temperature	0.883632
No. of mites Vs mean RH	-0.57685

Distribution of *T. cinnbarinus* on cassava leaves

Observation on the distribution of the mite on different parts of the plant showed that the mite could infest almost all leaves except the newly sprouted and tender ones. An analysis of the distribution pattern of *T. cinnabarinus* on the host plant during the study enabled to record varying degrees of preferences. Among the leaves, the lower tier showed a constant abundance of the mite. The upper tier showed minimum number of mites. An average number of mite population was recorded on the middle tier of the leaves (Plate-XIV).

Plate XIV

Distribution of T. cinnabarinus on Different Tiers of Cassava Leaves



D. BIOLOGY OF *RAOIELLA MACFARLANEI* PRITCHARD AND BAKER ON *SYZYGIUM JAMBOLANUM*

I. Feeding activity and nature of injury

Adult females of *R.. macfarlanei* and various life stages were usually found on the lower surface of the leaves of *S. jambolanum* (Plate-XV, Fig. 1), quite often they were also detected on the upper surface. Feeding was a slow and steady process. During feeding activity, the mite was found firmly attaching its chelicerae on the lower leaf surface. The chelicerae were further inserted down through alternate movements and punctured the leaf tissue. This would help to break the leaf tissue through which the cell sap was oozed out. This was sucked up by the mite with the help of long needle like stylophore. Feeding activity at a particular point lasted for 15-20 minutes.

II. Symptoms of infestation

The feeding activity of adult females of *R. macfarlanei* started on the lower surface of the leaves of *S. jambolanum*. Initially, small microscopic spots were formed at the point of penetration and later they became etiolate. Due to continuous feeding, these spots coalesced to form large cholorotic spots which finally became brownish patches (Plate-XV, Fig. 2). Numerous such brownish patches were found on the entire leaf surface. During heavy infestation and continuous feeding,

EXPLANATION OF FIGURES

PLATE XV

Life Stages of *R. macfarlanei* on Jamba.

Fig. 1 A view of lower leaf surface showing the adult and various life stages *R. macfarlanei.*

Fig. 2 Brownish patches on the leaf surface due to the feeding of *R. macfarlanei.*

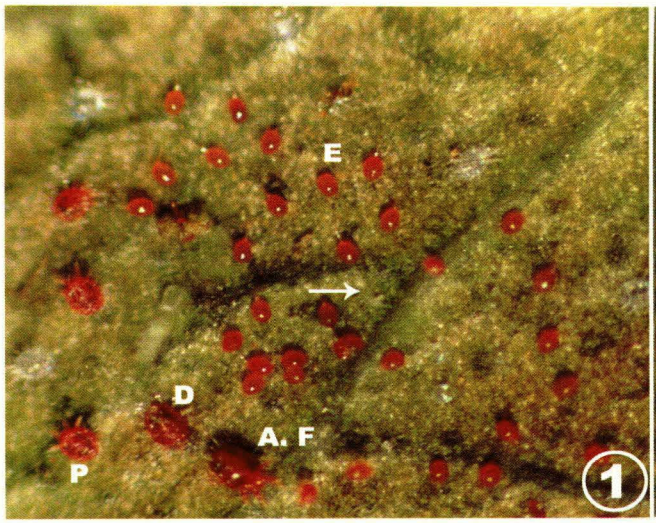
Fig. 3 Mating posture of *R. macfarlanei.*

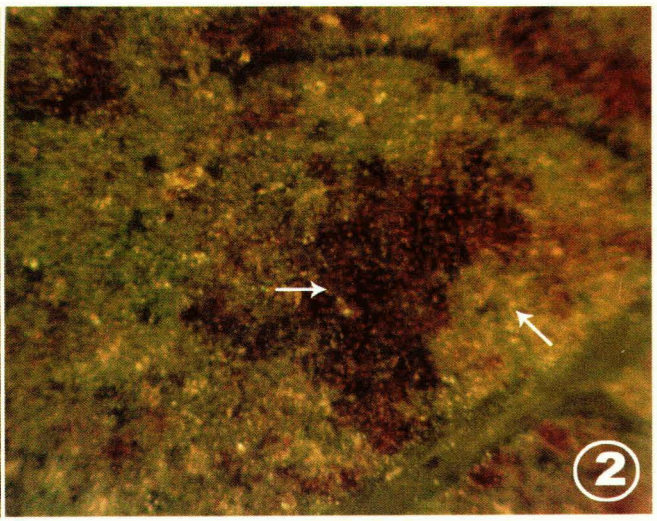
Fig. 4 A batch of eggs near the midrib of leaves of *S. jambolanum.*

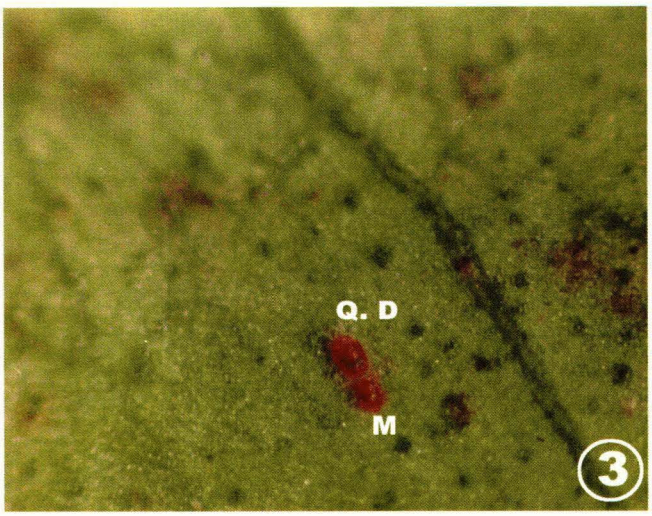
Fig. 5 Larva, protonymph and quiescent protonymph of *R. macfarlanei.*

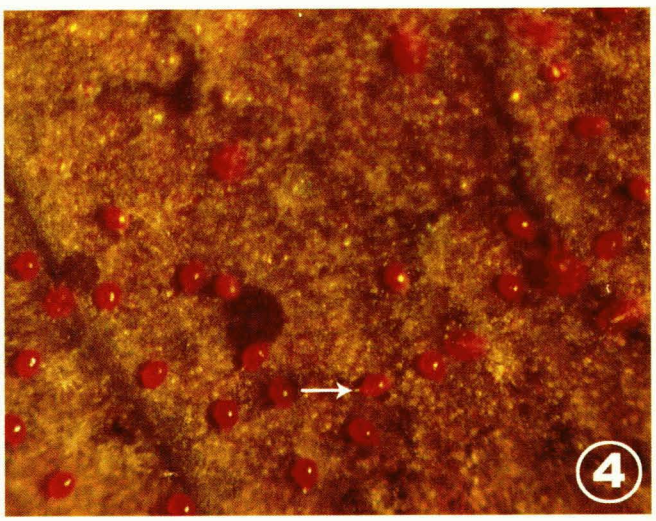
Fig. 6 Newly moulted female and the discarded moulting skin.

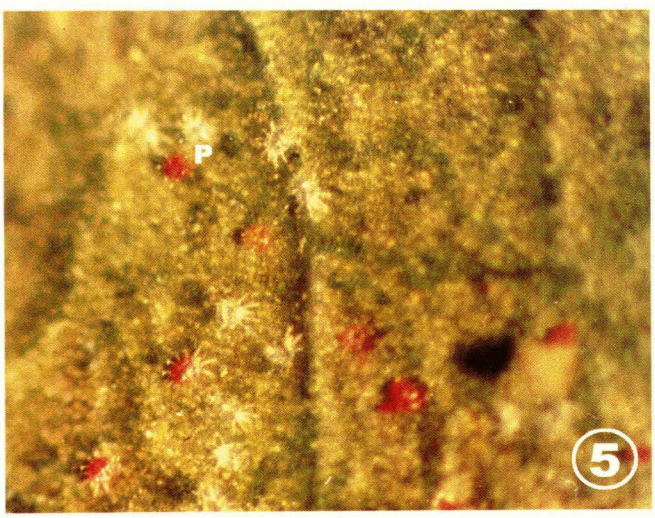
PLATE XV











the entire leaf became withered and finally defoliated. Mite infestation was evident in the field by the development of such brownish marks on the affected leaves. Older leaves were more susceptible to mite attack than the younger ones. Fresh tender leaves were often found devoid of any mite attack.

III. Breeding Biology of *R. macfarlanei on jamba*

a) Mating behaviour

Breeding biology of *R. macfarlanei* was found initiated by the process of mating. During the initiation of mating process, the males were found confining to the vicinity of the female quiescent deutonymph and copulation was achieved by the awaiting male immediately on emergence of the female (Plate-XV, Fig 3). The mechanism of copulation was same as in other Tetranychoidea and the time taken for completing the process was 15-20 minutes.

b) Pre-oviposition period

After the completion of mating process, adult females were found wandering over the lower leaf surface in search of favourable sites for oviposition. Active feeding was also noticed during this period. The pre-oviposition period extended for about 2-4 days.

c) Oviposition

The gravid females on selection of suitable sites, started oviposition from the third day onwards. During the process of oviposition, hysterosoma of the female mite was found lowered for extruding the eggs. A single egg was deposited during each oviposition. Solitary eggs were laid in close proximity, near the midrib or side veins of the leaves, so that it appeared like a batch (Plate-XV, Figs. 1&4). The number of eggs in each batch varied from 10-30. Sometimes, the eggs were seen on the entire leaf surface. In the laboratory, the average fecundity of individual female during the oviposition period of 9-12 days was found to be 36.4 (Table 12).

The number of eggs laid per day by a female depended on the age of the individual. Generally, oviposition activity initiated from the third day of emergence. The number of eggs laid during the first and second days of oviposition was found to be minimum ranging from 2-5 under laboratory condition (Plate-XVI). From the third day onwards, there was a sharp increase in number of eggs from 3-12. The maximum fecundity was attained during the fourth day of oviposition with the number of eggs ranging from 10-12. Succeedingly, there was a gradual decline from the fifth day onwards, reaching to a minimum number of eggs ranging from 2-0 on ninth to twelfth day of oviposition.

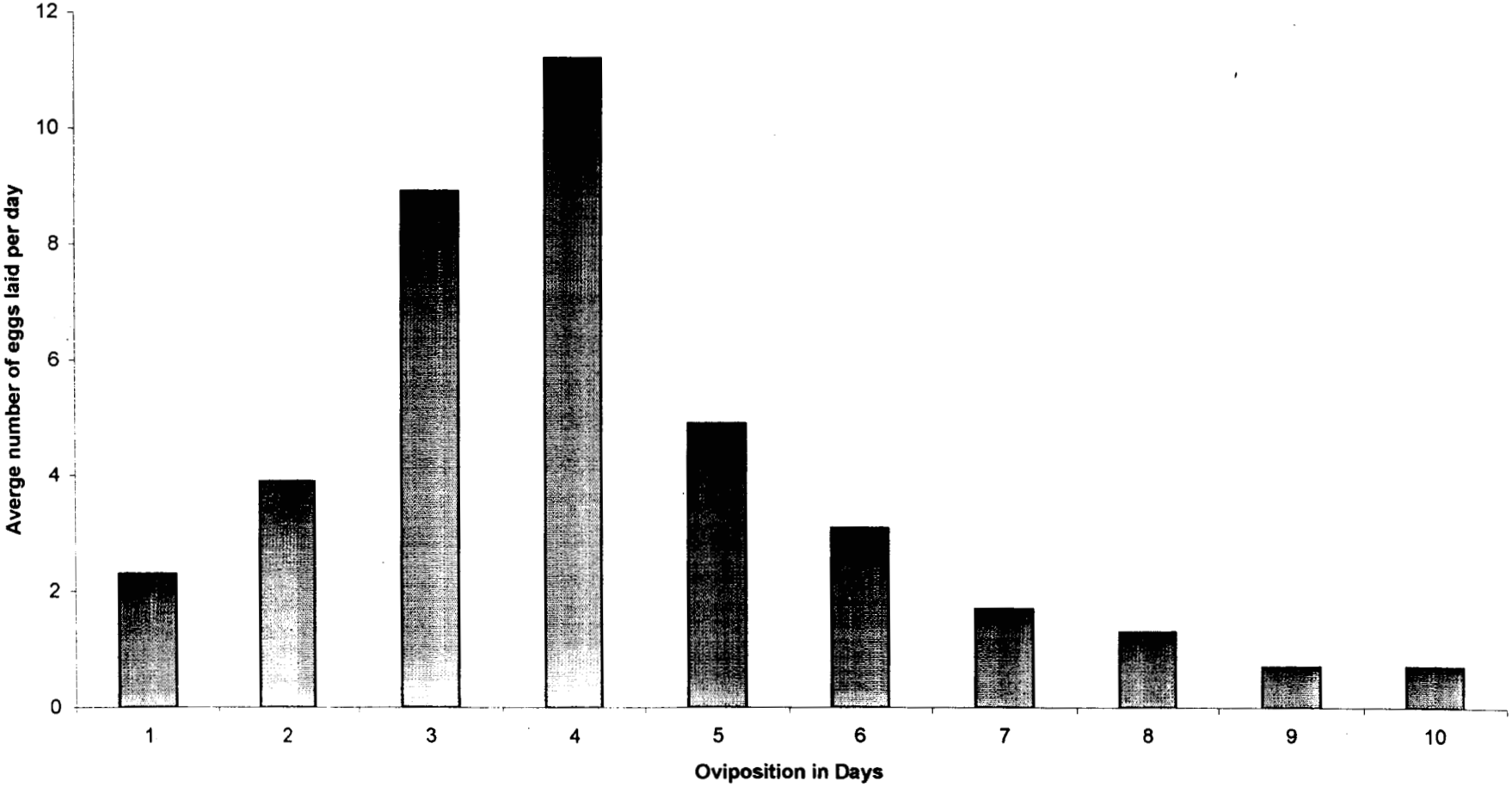
TABLE 12

Number of eggs laid by females of *R. macferlanei* on different days of oviposition.

Sl. No	Number of eggs laid per day during oviposition period.												
	1	2	3	4	5	6	7	8	9	10	11	12	Total
1	2	4	8	10	5	2	2	1	1	1	0	0	36
2	2	3	8	12	4	4	2	1	0	1	1	0	38
3	3	5	9	12	5	2	1	2	1	0	0	0	41
4	1	3	8	11	5	3	2	1	1	1	0	1	37
5	3	5	9	11	4	4	1	2	0	0	1	0	40
6	2	5	9	12	5	4	2	1	2	0	1	1	44
7	3	4	8	10	6	3	2	1	1	1	0	0	39
8	3	3	9	12	4	4	1	2	0	2	1	1	42
9	2	4	9	12	6	2	2	1	0	1	0	1	40
10	3	3	8	10	5	3	2	1	1	0	1	0	37
Average	2.4	3.9	8.5	11.2	4.9	3.1	1.7	1.3	0.7	0.7	0.5	0.4	36.4

Plate XVI

Daily Variation in the Number of Eggs Deposited by Female *R. macfarlanei* During Oviposition Period



d) Eggs

Freshly deposited eggs were smooth, transparent, oval in shape, reddish orange in colour and shiny in appearance. Each egg was anchored to the leaf surface by means of a long stipe. Length of each egg varied from 111-115μm and their width showed a range of 80-88μm (Table 13). The incubation period lasted for 8 days at 27 ±1^{0}C and 65-70% relative humidity.

e) Hatching

Prior to hatching, the shining nature of egg had lost and the chorion showed a wrinkled appearance. Later, a small slit was formed near the stipe and it got extended to either side and as a result it became widen. The first pair of legs of larva protruded out through the slit slowly and by further movements of the legs, the gnathosoma and remaining part of the body of hexapod larva (Plate-XV, Fig. 4) slipped out leaving the egg case. Numerous such egg cases (Plate-XV, Fig. 5) with long stipe had been observed in the laboratory cultures. Hatching period was extended for 20-30 minutes.

f) Larva

Larva was small, reddish orange in colour, shiny with 3 pairs of legs and measured 122.5-135μm in length and 39-105μm in width (Table 13). They were sluggish initially but in subsequent days started feeding the leaf tissue. The active period of the larva lasted for 1.5 days (Table 14) at the end of which they entered into an inactive phase followed by moulting.

TABLE 13

Measurements (in μm) of different life stages of *R. macfarlanei*

Sl. No.	Egg	Larva	Protonymph	Deutonymph	Adult Male	Adult female
1	111/81	135/90	157/1125	225/135	225/140	270/157.5
2	115/85	122.5/90	162/112.5	229/144	220/144	270/157.5
3	110/88	130/89	162/102	230/138	231/135	290/150
4	111/80	135/105	160/115	225/135	228/142	275/155
5	112/88	122.5/90	157/120	220/114	230/140	280/149
Average	111.8/84.4	129/92.8	156..6/112.4	225.8/133.2	226.8/140.2	277/153.8

g) Protonymph

Newly emerged protonymphs were larger in size and more active than the larva and were measuring 157.5-165μm in length and 102-120μm in width (Table 13). The protonymphs (Plate-XV, Fig. 5) were eight legged with dark spots on their body. They actively fed the chlorophyll tissue of the plant. Active period of this stage lasted for 1-5 days (Table 14) after which they entered the second quiescent stage.

h) Deutonymph

Deutonymphs were the largest among the immature stages, measuring 220-230μm in length and 135-144μm in width (Table 13). They actively moved on the leaf surface, nibbling the leaf tissue and sucking the chlorophyll content. The active period was found slightly greater than that of the larva and protonymph, which extended for 17-22 days (Table 14). At the end of active period, they became quiescent.

i) Quiescent periods

Each active period of the life stages of *R. macfarlanei* ended in a period of inactivity. This was recognized as the resting phase (Quiescent phase) during which the individual stopped feeding and most of the visible life activities. They remained stationary on certain selected sheltered areas, particularly near the midrib or interveinal regions of the lower surface of the leaves. During the quiescent phase, each individual lost its shiny nature and

TABLE 14

Duration (in days) of life stages

development of *R. macfarlanei* on *S. jambolanum*

Sl. No.	Egg	Larva	I Quiescent Phase	Proto nymph	II Quiescent Phase	Deuto nymph	III quiescent Phase	Total
1	8	1.5	1	1.5	1	2	1	16
2	75	1.5	1	1.5	1	2	1	15.5
3	8	1.4	1	1.5	1	2.2	1	16.1
4	8	1.5	1	1.5	1	2	1	16
5	8	1.5	1	1.5	1	1.7	1	15.7
6	8.5	1.5	1	1.5	1	2	1	16.5
7	8	1.4	1	1.5	1	1.8	1	15.7
8	8	1.6	1	1.5	1	2	1	16.1
9	8	1.5	1	1.5	1	2.3	1	16.3
10	7.5	1.5	1	1.5	1	2.3	1	15.8
Average	8	1.5	1	1.5	1	2	1	15.82

appeared to be flat and swollen. The legs and mouthparts appeared to be contracted. R. *macfarlanei* had three inactive phases during its development. They were the first, second and third quiescent periods which occurred at the end of the active period of larva, protonymph and deutonymph. Duration of quiescent period was same in all the three stages and was found to be 1 day. Thus, the total duration of development of female was found to range from 15.5-16.5 days (Table 14) in the laboratory at a temperature of 27± 1^{0}C and RH of 65-70%.

j) Moulting

During this period, a thin layer of white silvery coating was formed around the body of each quiescent sage. Moulting was achieved by the formation of a transverse slit mid-dorsally. The slit extended on either side through which the posterior half of the body first came out followed by the anterior half, leaving behind the moulting skin (Plate-XV, Fig. 6). The process of moulting was found extended for a period of about 20 minutes.

k) Adult female

The adult female differed from the deutonymph in being larger with a body length of 270-290μm and with of 149-157μm (Table 13). The colour of the body was reddish orange with some dark ornamentation present on the

hysterosomal region. The female started feeding after becoming free from deutonymphal exuvium. It had to feed before egg laying could commence.

l) Adult male

Adult males are light red in colour. The body appeared narrow than the adult female and measuring a length of 220-231μm to 135-144μm (Table 13).

m) Post-oviposition period

During this period the adult female became lazy and inactive. Feeding activity became slow. The post-oviposition period ranged from 5-6 days, at the end of which the individual died. Generally longevity of mated female ranged from 16-22 days.

IV. Population dynamics of *R. macfarlanei* on jamba in relation to environmental factors

Occurrence of *R. macfarlanei* on *S. jambolanum* was evident throughout the year, but the population started building up during February and reached its peak during March and April (Plate-XVII). Population densities of the mite were found to be closely associated with weather parameters. Increase in mite population was associated with period of lower relative humidity and higher mean temperature. During March and April, prevalence of high temperature and low humidity favoured build up of the population density of *R. macfarlanei* on the host plant.

Plate XVII

Influence of Climatic Factors on Population Density of *R. macfarlanei* on *S. jambolanum*

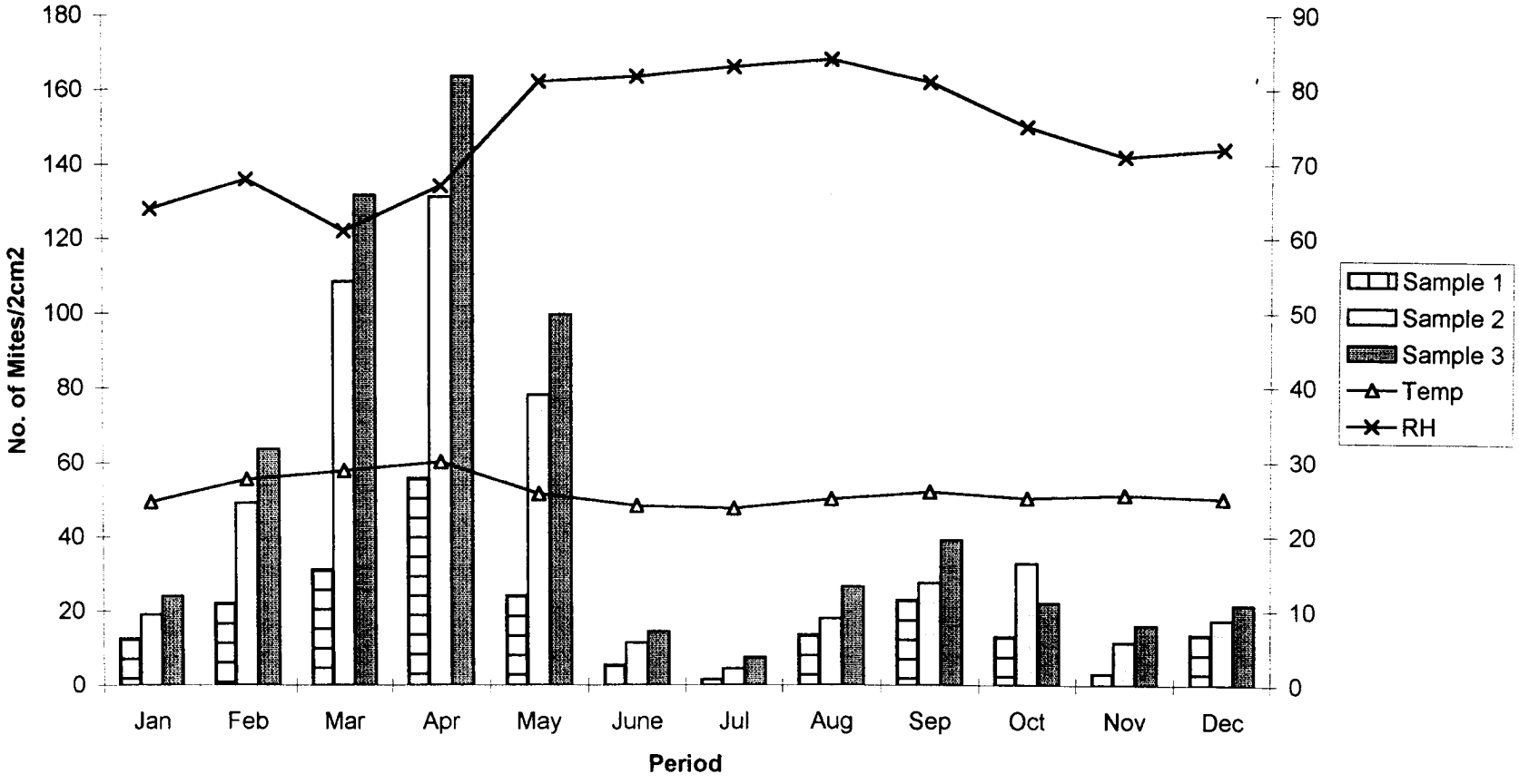


TABLE 15

Influence of mean temperature and RH on the seasonalfluctuation of *R. macfarlanei* on *S. jambolanum* during January 1999 to December 1999

Month	No. of mites/cm^2	Temperature	RH
Jan	18.50	24.7	64
Feb	44.83	27.7	68
Mar	90.33	28.8	61
Apr	116.66	30	67
May	67.17	25.7	81
June	10.50	24.1	81.7
Jul	4.50	23.8	83
Aug	19.33	25	84
Sep	29.83	26	81
Oct	22.58	25.1	75
Nov	10.17	25.5	71
Dec	17.50	25	72

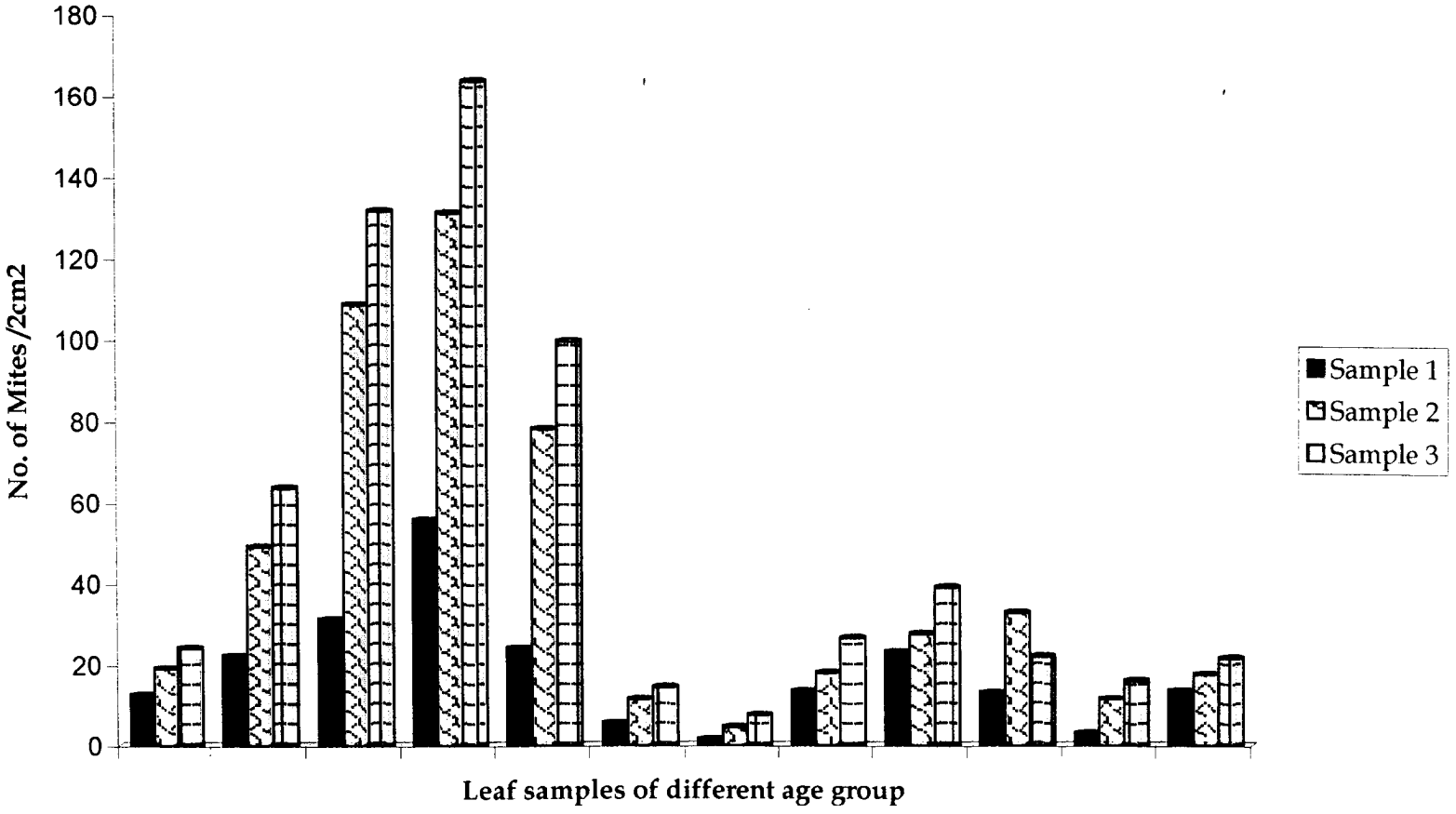
	Correlation coefficient (r)
No. of mites Vs mean temperature	0.913933
No. of mites Vs mean RH	-0.06995

Correlation of monthly analysis of the data on population density of *R. macferlanei* in relation to climatic factors prevailed during the sampling period enabled to establish a negative correlation between relative humidity and mite population with an r value of -0.07, and a positive correlation between temperature and mite population with an r value of 0.913 (Table 15). The population density attained the peak level during April, 1999. The mean temperature and RH recorded during the above period were 30°C and 67 percent. Population density reached the lowest level during July, 1999. The mean temperature and RH recorded during the above period were 23.7°C and 83%. The period from June-August was the monsoon months and in Kerala heavy rainfall obtained during these months which directly reduced the population density of the mite.

V. Distribution of *R. macfarlanei* on jamba leaves

Leaves represented the major portion of the host plant being infested by *R. macfarlanei*. However, obvious variation was noticed in the distribution pattern of the mite among leaves. The highest population of mite was recorded in the older leaves of the host plant, whereas the middle aged and younger leaves revealed comparatively lower population (Plate-XVIII). The apical tender leaves were usually found devoid of mites. The mite exhibited highest preference towards the older leaves than the middle aged and younger leaves.

Plate XVIII
Distribution of *R. macfarlanei* on Different Age Group of Leaves



E. BIOLOGY OF *A. GUERRERONIS* KIEFER INFESTING COCONUT

The coconut mite, *A. guerreronis* has gained considerable status as a pest. It was recorded in different parts of the world where coconut is being grown. Asian countries were free from this pest for a long time. But later, considerable yield loss has been reported from India particularly from southern states like Kerala, Tamil Nadu, Karnataka and Andhra Pradesh. This has prompted to study the biological aspects of the mites in more details.

I. Feeding Activity and Nature of Injury

Feeding activity of *A. guerreronis* was initiated from the meristematic region, underneath the perianth of young coconut buttons of about 4-6 weeks (Plate-XIX, Fig. 1). During feeding, the adults of *A. guerreronis* protracted the cheliceral stylets and pierce the tender meristematic tissue. This facilitated production of feeding punctures, allowing to suck the cell sap from the punctured cells. Repeated operation of syringe like stylets over the meristematic tissue caused the death of the cells. Continuous feeding activity led to the development of large number of colonies in the meristematic region which in turn resulted in various symptoms of infestation on the developing nut. Repeated feeding by mites resulted in the depletion of the whole cell sap imparting a brown colour at the fed area.

II. Symptoms of Infestation

The symptoms of infestation caused by *A. guerreronis* on nut could be categorized as follows:

i) Development of irregular patches

ii) Split formation

iii) Premature button fall

iv) Malformation

v) Early drying of nuts

i) Development of irregular patches

This is the first visible symptom that could be recognized early in button development. Initiation of mite infestation occurred on young coconut buttons of 4-6 weeks of development (Plate-XIX, Fig.1). The mites arriving by wind invade the meristematic region of the developing nut beneath the tepal. Intense feeding activity of preferred food under protected area often helped colony formation and population replenishment. The external symptoms of mite infestation at this stage were difficult to detect because the developing symptomatic area remain covered by the tepals. When the tepals were carefully removed, 'v' shaped whitish patchy areas (Plate-XIX, Fig 2) were observed. On closer observation this area disclosed the presence of thousands of individuals of various life stages of *A. guerreronis*.

EXPLANATION OF FIGURES

PLATE XIX

Symptoms of Infestation Caused by *A. guerreronis* on Coconut .

Fig. 1 Coconut button of 4-6 week old showing the path of invasion of *A. guerreronis.*

Fig. 2 White dusty areas where large colonies of *A. guerreronis* could be detected.

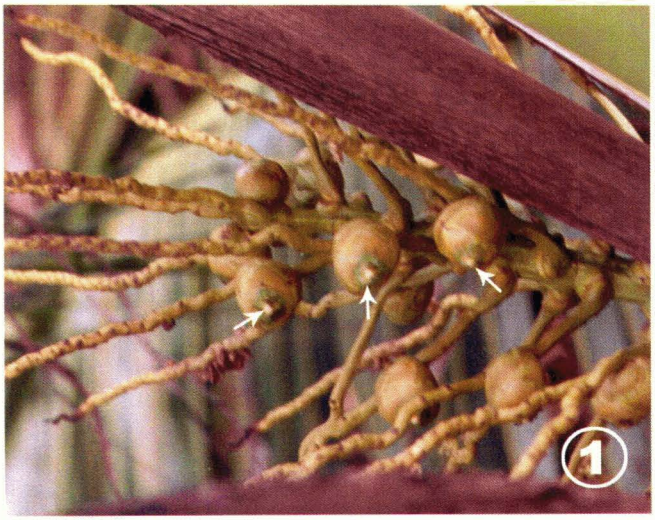
Fig. 3 Coconut showing 1-3 yellow or yellowish brown patches.

Fig. 4 Nuts showing cracks and crevices on their husk.

Fig. 5 A bunch of nut showing yellowish and brownish patches.

Fig. 6 A coconut tree showing highly infested nuts.

PLATE XIX



Normally, a single infested nut carried one or two feeding patches but rarely three or more can be seen which increases in size extending further down. Now the white patches turned into yellow and then to yellowish brown. (Plate-XIX, Fig. 3). During this time heavy population of mite could be seen which subsequently induced formation of numerous longitudinal fissures and furrows. Later this was transformed into cracks and crevices (Plate-XIX, Fig. 4). As a result, the nut surface became rough. Sometimes these cracks and crevices discharged an yellowish brown, transparent, resinous secretion. Sometimes, the whole bunch of coconut or the whole tree as such contain these type of infested nuts (Plate-XIX, Figs. 5&6).

ii) Split formation

During the sequence of patch development, some of the nuts developed longitudinal split medially along the patch (Plate-XX, Fig. 1). A 'v' shaped split developed later from the border of meristematic region. Further, this split extended downwards along the white patch taking the form of 'y' mark (Plate-XX, Fig 2). The extended tip of 'y' mark had been observed only, when the nuts were on the bunches. A full picture of 'y' could be detected when the perianth was removed. The split further grew deeper and deeper consequent with the severity of infestation. As a result, the nut was found broken and water content

EXPLANATION OF FIGURES

PLATE XX

Symptoms of Infestation Caused by *A. guerreronis* on Coconut .

Fig. 1 Nut showing development of yellowish and brownish patches and cracks with detached tepal.

Fig. 2 Nut showing 'Y' shaped split.

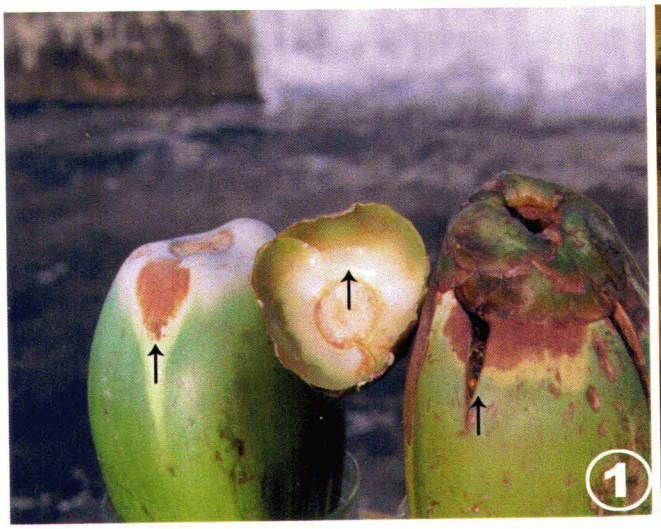
Fig. 3 Early button fall showing fallen nuts on the ground.

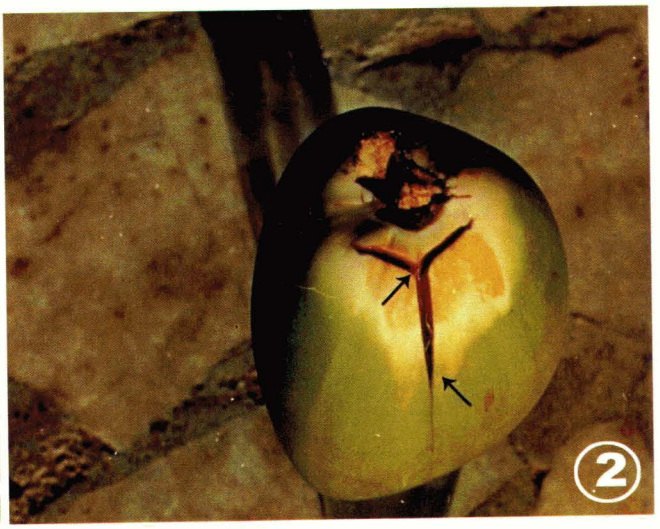
Fig. 4 Malformed nuts due to high infestation by *A. guerreronis.*

Fig. 5 Coconut showing the dry and tightly adhered endocarp.

Fig. 6 A bunch of dried up buttons due to high invasion of *A. guerreronis.*

PLATE XX





was oozed out (Plate-XX, Fig.2). Depending on the severity of infestation, additional cracks were also developed on the nut surface. Further development of nut was difficult and they eventually detached and fall off from the perianth. Such cracked fallen nuts were seen scattered on the ground in several study areas (Plate-XX, Fig. 3). Some of the nuts which developed the cracks below the margin of perianth did not fall off and continued their growth. In addition to the 'y' shaped crack, several irregular cracks or straight cracks were developed along the feeding area of the meristematic zone of the nut.

iii) Premature button fall

Drop of flowers and unripened fruits had been a common phenomenon in all the sites observed. Usually, button fall was a common feature in both infested and uninfested palms for a period of one to two months. After this period, in normal uninfested palm shedding of button was found ceased. While in infested palm, there was a continuous incidence of nut fall occurred for further months depending on the severity of infestation. Usually, tender coconut buttons of 2-5 months old shed periodically leaving a very few nuts in the bunches. Mite infestation appeared to cause this increasing incidence of button fall in several coconut palms scrutinizes. Regular observation made on this aspect showed that nut fall appeared to be

preceded by mite infestation in most cases. Such nuts carried large colonies of mites and associated feeding patches. Some times all nuts from the infested bunch had been found fallen on the ground (Plate-XX, Fig. 3).

iv) Malformation

Due to the increasing incidence of infestation, the region of feeding patch dried out with the formation of small fissures and furrows. The survived nuts of this category further developed greyish brown patches with cracks and crevices (Plate, Fig. 4). On further development, these patches enlarged and covered almost the entire length of the affected nut. As a result, the husk became thin, dry and tightly adhered to the endocarp (Plate-XX, Fig. 5) , thereby preventing the normal growth of the nut. The highly infested nuts turned smaller in size with a series of malformation. The entire husk got shrivelled forming longitudinal foldings or depression. In several other nuts, the deformation was observed at the calyx base and this region developed irregular folds, while in others the nut got completely shrivelled and developed larger cracks. Such damage reduced the size of the nut.

v) Early drying of nuts

One of the instances of infestation caused by *A. guerreronis* was early drying of the nut. Usually the mite attack, was found in

developing nuts at a very young age of about one month old. Unfertilized flowers and nuts of fresh spadices were devoid of mite attack. The fresh gravid female reached on the young nut surface through wind or by other visiting arthropods. Then the mite invaded the meristematic region and started feeding by sucking the cell sap of the soft meristematic tissue and developed into colonies. Continuous sucking of cell sap by these colonies of mites produced drying of nut. As a result of continuous sucking of the cell sap by invaded colonies of *A. guerreronis,* the young buttons slowly dried up without shedding. In several instances, the whole bunch remained with full of dried buttons only (Plate-XX, Fig . 6).

III. Breeding biology of *A. guerreronis*

The coconut eriophyid mite, *A. guerreronis* exhibited high breeding potentiality. One of the reasons for the quick transmission of this mite was its high breeding potentiality. Thousands of eggs and various life stages of *A. guerreronis* could be detected in a single colony (Plate-XXI, Fig. 1) and several such colonies were established within a single infested nut. The life cycle of *A. guerreronis* involved three active and three inactive stages. The first nymph, second nymph and adult were the active life stages and the egg, first and second quiescent phases were the inactive stages. Usually the adult females of *A.*

EXPLANATION OF FIGURES

PLATE XXI

Life Stages of *A. guerreronis.*

Fig. 1 A small portion of a single colony showing various life stages.

Fig. 2&3 Small, round or oval eggs of *A. guerreronis.*

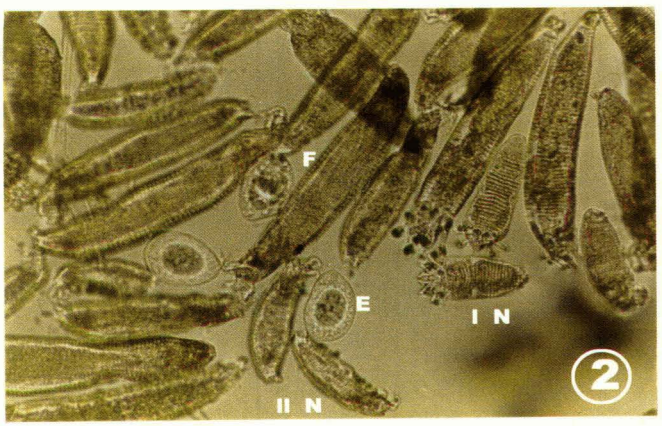
E-eggs; IN-1st nymph; IIN-2nd nymph; F-female; D.M-discarded Moulting skin.

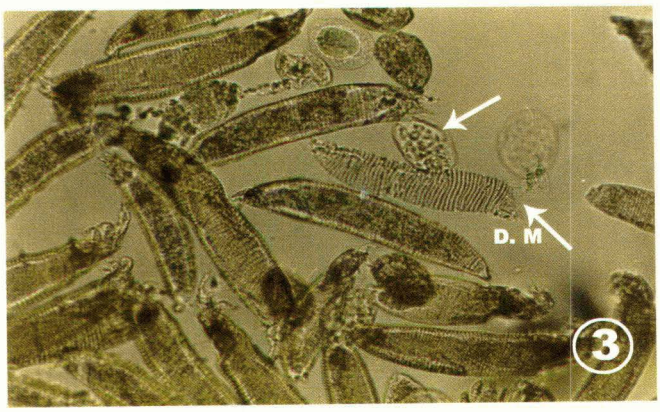
Fig.2 &4 Newly formed 1st nymph and 2nd nymph.

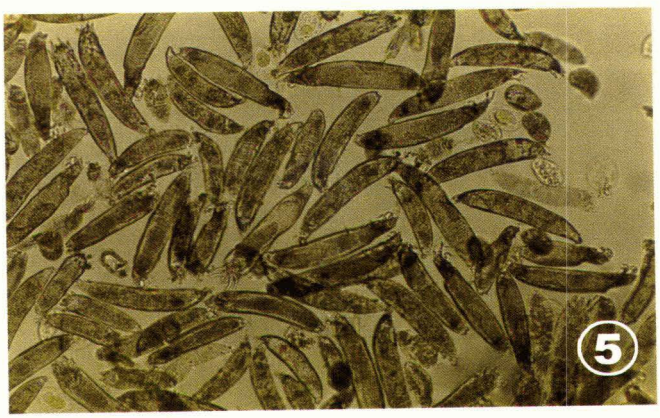
Fig. 3&5 Discarded moulting skin detected from the colony.

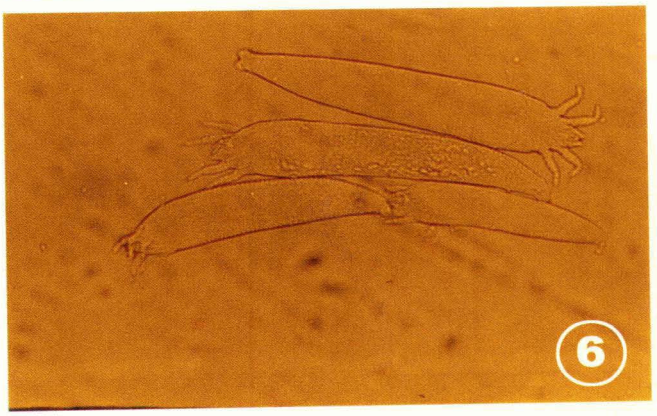
Fig. 6 Phase contrast view of four adults of *A. guerreronis.*

PLATE XXI









guerreronis invaded the floral bracts of young coconut buttons of 1-2 months old. From there, they moved to the growing meristematic zone under perianth. Active feeding of the succulent tissue induced oviposition of the mite. In the laboratory, the developmental biology was carried out at 27±1^{0}C and RH of 75-80%.

a. Oviposition

The developing colonies of *A. guerreronis* contained spermatophores and occasionally sperm transfer occurred when the females crawled on them. Oviposition started 2 or 3 days after adult emergence. The female mite laid the eggs on the tepals as well as on the meristematic region of the young coconut button. Most of the field collected samples of coconut, on examination were found to contain many groups of eggs. A single female laid about 60-72 eggs during the oviposition period of 12-15 days (Table 16, Plate-XXII). Field collected samples of nuts contained a total of 1000 or more eggs/cm^2 on the perianth during the peak period of mite population.

b. Eggs

Eggs were small, round or oval, glossy transparent (Plate, Fig. 2) and glittering which measured an average length of 65.8µm and a width of 41.37µm (Table 17). The eggs were usually laid on the meristematic region as well as on the overlapping portion or the free margins of the

TABLE 16

No. of Eggs Laid

by female of *A. guerreronis* on different days of oviposition

Sl. No	No. of eggs/ days during Oviposition period															Total
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
1	1	3	5	6	7	12	9	8	5	2	2	1	0	0	0	60
2	1	2	5	5	9	12	10	8	5	2	3	2	0	1	0	65
3	2	3	4	7	8	11	11	10	6	4	2	1	1	0	1	71
4	2	3	4	6	7	12	10	9	5	2	3	0	1	1	0	65
5	1	2	5	7	8	11	9	8	6	3	2	2	1	1	0	66
6	1	2	5	6	9	12	11	10	5	4	3	1	1	1	1	72
7	2	3	5	6	8	11	10	9	6	4	3	0	1	0	0	68
8	2	3	4	7	7	12	9	10	5	3	2	2	2	1	1	70
9	1	2	4	5	8	12	10	8	5	3	2	1	1	1	0	63
10	1	3	4	5	7	11	9	8	5	2	3	2	0	0	0	60
	1.4	2.6	4.5	6	7.8	11.6	9.8	8.8	5.3	2.9	2.5	1.2	0.8	0.6	0.3	66.1

TABLE 17

Measurements (in μm) of different life stages of *A. guerreronis*

Sl. No.	Egg	I Nymph	II Nymph	Adult
1	66.5/42.6	87.5/38.5	192.5/42.6	210/38.5
2	63/42.6	77/35	157.5/42.6	222.75/41.8
3	66.5/38.5	94.5/38.5	175/38.5	231/44.5
4	70/38.5	70/38.5	182/42.6	217/38.5
5	66.5/42.6	105/38.5	175/38.5	234.5/42.6

tepals. They glued to the substratum with a sticky material. The eggs were laid solitarily one after another so as to form separate groups. The average incubation period required was found to be 3.75 days (Table 18).

c. Hatching

Prior to hatching the transparent and glittering egg changed into milky white appearance. A small projection appeared at the animal pole of the egg and it acquired an oval outline (Plate-XXI, Figs. 2&3). Later it became elongated and protruded. From the protruded area a longitudinal slit appeared through which the legs and gnathosoma of first nymph came out. Then by wavy movements of legs and gnathosoma, the remaining part of the body emerged out, leaving the egg case. The process of hatching was completed within 30 minutes.

d. First Nymph

The newly hatched first nymph was very small, vermiform, sluggish and transparent (Plate-XXI, Figs. 2& 4). The length and breadth of the first nymph was measured 70-105μm and 35 to 38.5μm respectively (Table 17). They actively move and initiated their feeding activity within few minutes. The active feeding period of the first nymph lasted for an average period of 2.3 days (Table 18). At the end of

TABLE 18

Duration (in Days) of life stages of *A. guerreronis* on coconut

Sl. No.	Egg	I Nymph	I Quiescent	II Nymph	II Quiescent	Total
1	3	2.5	1	2.5	1.5	10.5
2	3	2	1	2.5	1	9.5
3	3.5	2	1	2	1.5	10
4	3	2.5	1	2.5	1.5	10.5
5	3.5	2.5	1	2.5	.5	10
6	3	2	1	2	1	9
7	3.5	2.5	1	2	.5	10
8	3	2.5	1	2.5	.5	9.5
9	3	2	1	2.5	.5	9
10	3.5	2.5	1	2.5	1	10.5
Average	3.75	2.3	1	2.4	1.3	10.65

active period, the first nymph entered into a resting period (I Quiescent period). At the end, they moulted into the second nymph.

e. Second nymph

Second nymph was pale white in colour, elongated, vermiform (Plate-XXI, Figs. 2&4) and measured 157.5 to 196μm in length and 38.5 to 42.6μm in width (Table 17). It was more active than the first nymph. They actively moved on the tepals and meristematic zone in order to feed the succulent tissues. Active feeding period of the second nymph averaged to 2.4 days (Table 18). They became quiescent at the end of active period and finally moulted into the adult.

f. Quiescent Stages

During the life cycle of *A. guerreronis* two quiescent phases were present. The first quiescent phase was observed in between the first nymph and the second nymph while the second quiescent phase occurred in between the second nymph and the adult. Actually, this was the resting period and during this period the mite became inactive and motionless. The body appeared to be milky, swollen, turgid and spindle shaped. Body annulations were clearly visible during this period. The average duration of the first and second quiescent periods were 1 and 1.3 days respectively (Table 18). The quiescent phase was followed by moulting.

g. Moulting

At the end of each quiescent phase, there was a moulting phase. During the process of moulting, a longitudinal split appeared at the anterior end of the body and it got enlarged through which the gnathosoma and legs were protruded out. The slit got widened by the constant movement of legs which finally led to the emergence of active stage, leaving behind the moulting skin (Plate-XXI, Figs. 3&5). The moulting skin appeared to be wrinkled and membraneous just after shedding. But on later observation, it appeared to be broken into pieces. Numerous such moulting skins were seen both in the field and laboratory observations. The whole process of moulting was completed within a period of 15-20 minutes.

Laboratory studies revealed that the post-embryonic development of *A. guerreronis* required 9-11.5 days (Table 18) with an average duration of 10.5 days at a temperature of 27±1^{0}C and RH of 75-80%.

h. Adult

The newly emerged adults were transparent, (Plate-XXI, Figs. 6) pale white in colour with a worm like body measuring 210-235µm length and about 38.5-44.5µm width (Table 17).

TABLE 19

Multiple Regression Analysis
Showing the Influence of Temperature on Population

Multiple Regression analysis using Forward Stepwised
R= .68768696 R^2= .47291336 Adjusted R^2= .44895487
F(1,22)=19.739 p<.00020 Std.Error of estimate: 210.88

Intercpt	BETA	St. Err. of BETA	B	St. Err. of B	t(22)	p-level
			-2856.26	772.7389	-3.69628	0.001261
TEMP	0.687687	0.154785	125.8303	28.32202	4.442845	0.000205

Only temperature significantly effecting on the population (observed significance level <0.01)
Other two factors have no significant influence on population

i. Post oviposition period

At the end of active oviposition period the adult female became less active and leathargic and finally stopped oviposition. This period extended for 2-4 days. After this, the female was found dead. Hence, the longevity of adult female was 15-22 days.

VI. Population dynamics of *A.guerreronis*

The population trend of *A.guerreronis* during 1998-2000 was presented in the figure (Plate-XXIII). The mite population occurred throughout the year. However, the density of population clearly showed fluctuations with corresponding climatic factors. The invasion of mite at Pudukad area of Trichur district was recorded during early August 1998. Regular observations on the population density was made during September 1998 onwards, when the average population density was found to be 568/cm^2 of perianth or meistematic zone. Then there was a gradual decline during October 1998. Subsequently the population showed an increase in November followed by a slight decrease in December. From January 1999 onwards the mite population raised up with a highest peak in March when a square centimeter area of meristematic tissue harboured 1142 mites. During April and May the mite population slowly decreased. Then there was a sharp decline during June 1999. The minimum incidence of mite was recorded during

Plate XXIII

Influence of Climatic Factors on Population Density of *Aceria guerreronis* During Sep 1999 to Aug 2000 at PuthuKkad Area of Trichur District

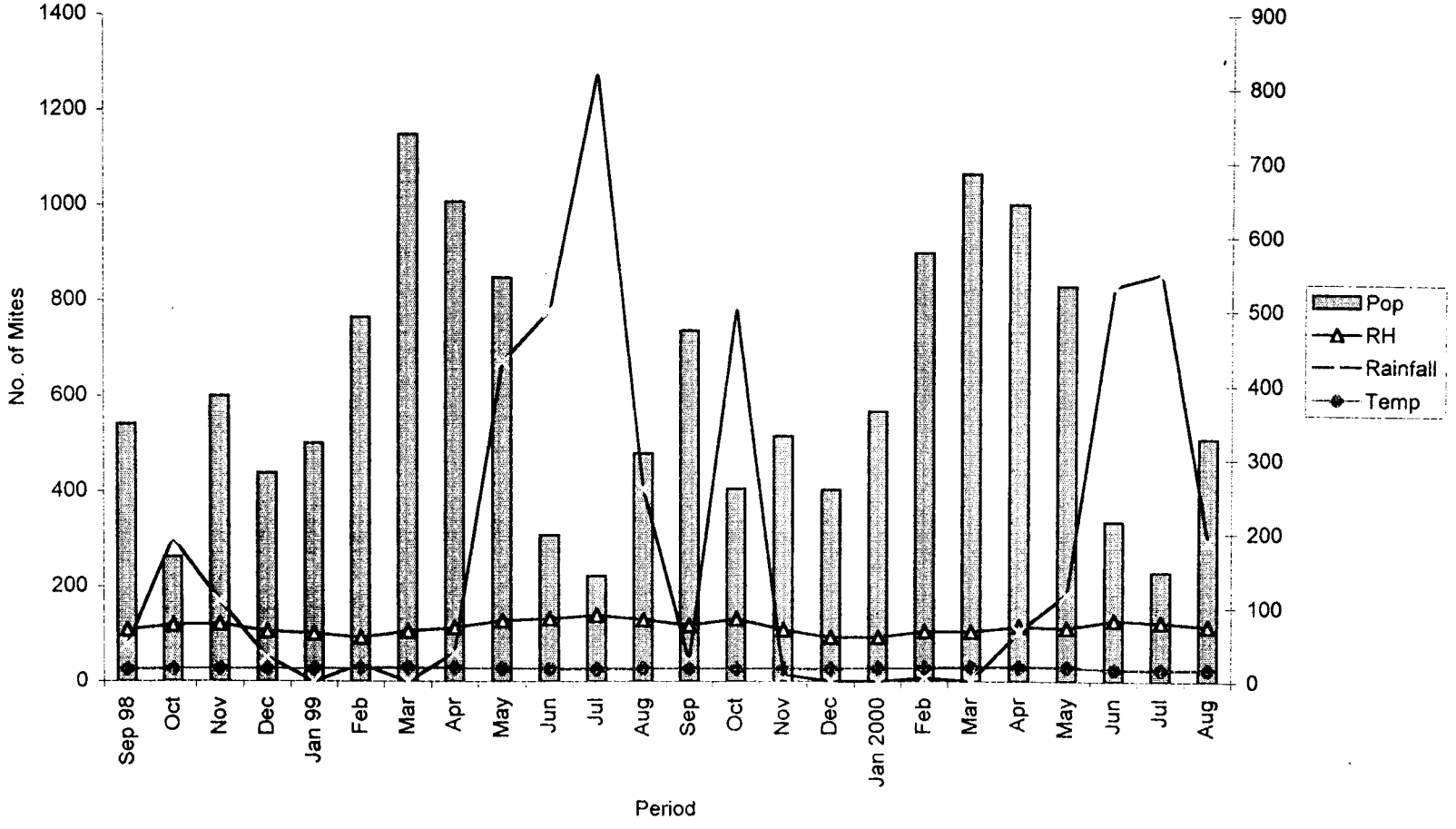


PLATE XXIV

Scatter plot Population Vs Temperature

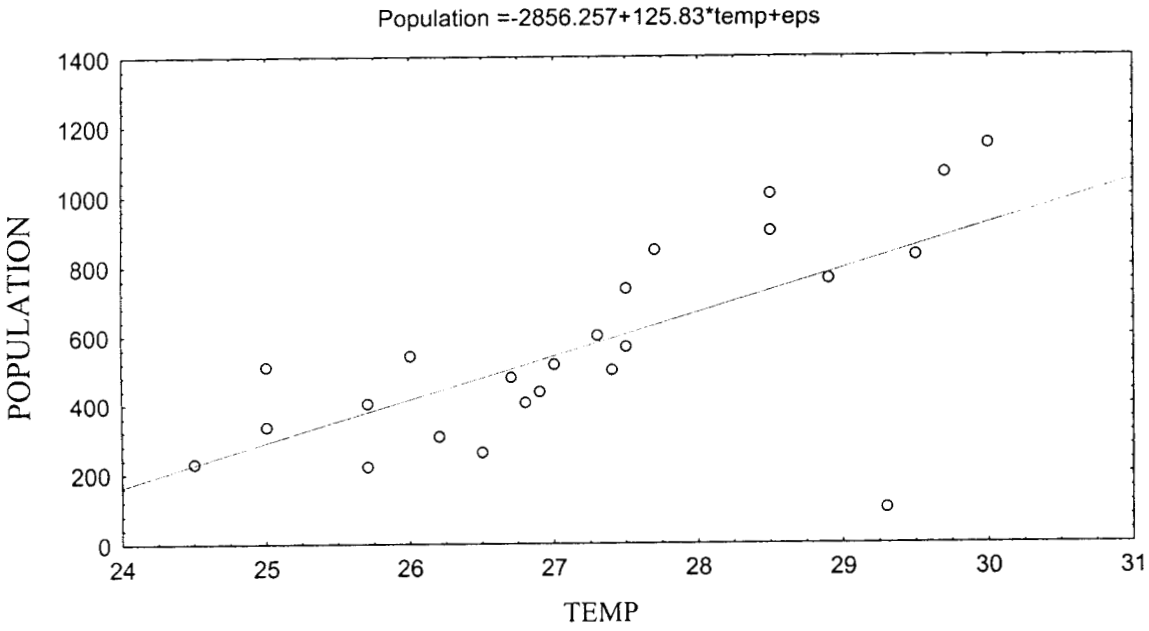
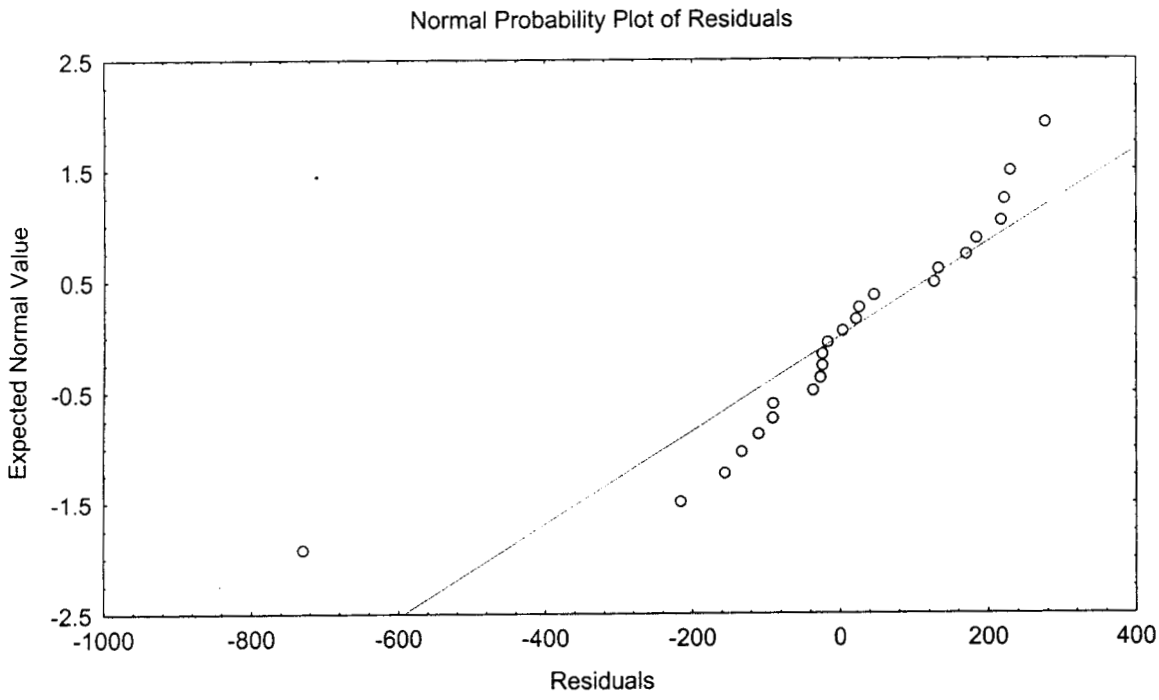


PLATE XXV


Normal Probability Plot of Residuals
Expected Normal Value
2.5
1.5
0.5
-0.5
-1.5
-2.5
-1000
-800
-600
-400
-200
0
200
400
Residuals

July, when average population density ranged from 200-237 /cm^2 area of mierstematic zone of the infested nut. Subsequently, the population showed increase in August 1999. The variation in population trend was almost similar during the next period of study viz., form September 1999 to August 2000.

Influence of weather factors on population density of mite was analysed statistically following multiple regression analysis using Forward Step-wised method. The results obtained from multiple regression analysis showed that only temperature influenced significantly the population density of the mite with R- value of 0.69 which is significant at 1% level. The obtained level of significance is less than 0.01 (Table 19). The other two factors viz., RH and rain fall have no significant influence on the population density. The scatter plot on population vs temperature (Plate XIV) showed that when temperature increased population also got increased. From the regression equation, it can be predicted that for a unit increase in temperature there is an increase of 125.83 increase in the average population density of the mite. The normal probability plot (Plate XXV) shows away from the normality, indicating that there may be some other factors influencing the mite population.

V. Distribution of *A. guerreronis*

The freshly opened inflorescence, their spadices and newly sprouted nuts of coconut were completely devoid of the mite attack. The invasion of mite started only on the nuts of 1-1.5 months old and during this time the average number of mites/cm^2 of the nut was 1.1. At this time the mite could be detected only on the overlapping portions of the tepals. Further, the development of the colony advanced with the increasing age of nut, and the mite invaded towards the inner surfaces of nut and developed newer colonies. Thus, there was a gradual and steady increase of mite population with respect to the increasing age of nut upto the age of 4.5-5 months. Subsequently, there was a gradual decline of mite population and none of the mite could be detected on the 7-12 month old nuts. The peak population of mites could be detected on 4.5-5 months old nuts and minimum population of mite was noted on 1-1.5 months old nuts (Plate XXVI).

Influence of age group of nut on the population of nut was analysed statistically through regression analysis in which initial taken as the dependent variable of mite population. The results obtained from the regression analysis were not found significant. However, a linear regression was noted suggesting that there may be some influence exerted by age group on the population density of mites. In order to

Plate XXVI
Distribution of A. guerreronis in Different Age of Group of Nuts

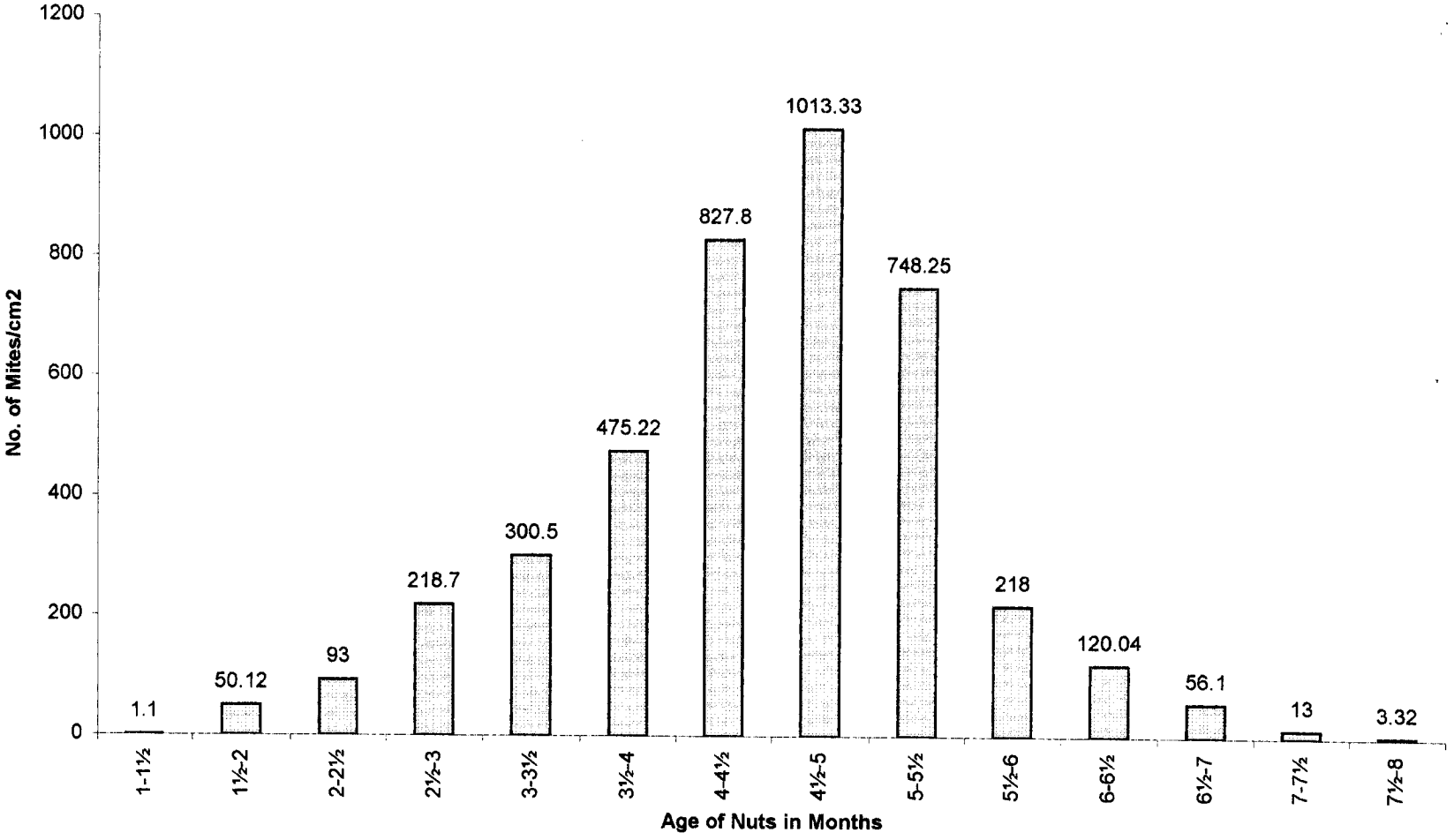


PLATE XXVII

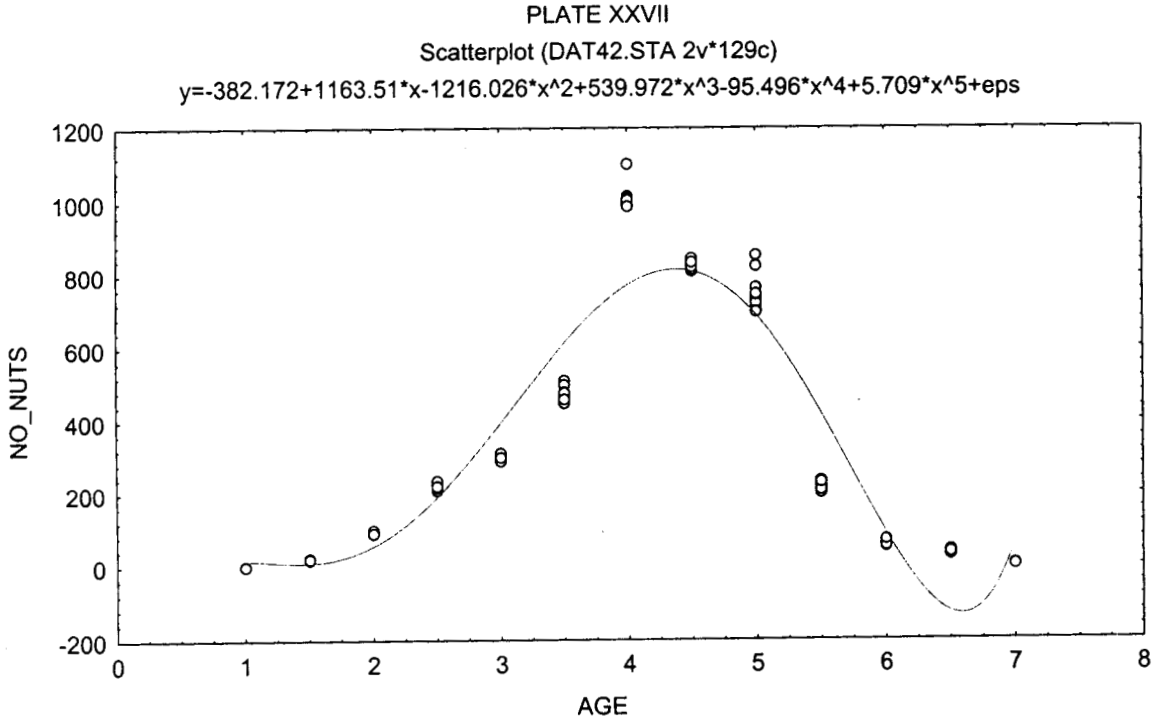

Scatterplot (DAT42.STA 2v*129c)
y=-382.172+1163.51*x-1216.026*x^2+539.972*x^3-95.496*x^4+5.709*x^5+eps
NO_NUTS
AGE
1200
1000
800
600
400
200
0
-200
0
1
2
3
4
5
6
7
8

TABLE 20

Regression Summary and ANOVA
Table of Influence of Age on Population Density of *A. guerreronis*

Regression Summary for Dependent Variable: NO_NUTS (dat42.sta)
R= .07502281 R^2= .00562842 Adjusted R^2= -----
F(1,127)=.71886 p<.39811 Std.Error of estimate: 333.20

	BETA	St. Err. of BETA	B	St. Err. of B	t(127)	p-level
Intercpt			250.8846	69.02654	3.634611	0.000403
AGE	0.075023	0.088486	13.24396	15.62057	0.847854	0.398115

Regression is not significant

ANOVA Table

Summary of all Effects; design: (dat42.sta)
1-AGE

	df	MS	df	MS		
	Effect	Effect	Error	Error	F	p-level
1	6	1572778	62	522.4256	3010.531	0
Significant effect						

confirm this analysis of variance was carried out between age groups and population density of mites. The results obtained through ANOVA clearly indicated that influence of age on population density of mites is significant at 0.01 level (Table 20). The scatter plot (Plate XXVII) made on the influence of age group on population of mite clearly showed a nonlinear regression pattern indicating a highly significant result. Thus, the scatter plot clearly showed that maximum population of mites occur on nuts of 4-5 month age group and nuts of 1-2 months old and 6-7 month old always harbour lower population of mites.

VI. Analysis of loss of weight of copra due to infestation by *A. guerreronis*

During the present study, the data obtained on the quantitative weight loss of copra due to mite infestation were subjected to statistical analysis (ANOVA). The results of ANOVA showed a highly significant value at 1% level, indicating that the weight loss in copra due to mite infestation is highly significant (Table 21). As indicated in the Plate XXVIII, increased weight loss was noted with advancement of mite infestation and an average loss of 32% (31.581) (Table 21) could be evidenced in highly infested nuts. That is, a gradual reduction in weight of copra was seen from uninfested group of nuts to highly infested group (Through low infested and medium infested). However, the categorized plot (Plate XXIX) falls within the upper and lower limits

TABLE 21

Percentage loss of weight of copra in different categories of coconut

Group	Average weight	Percentage loss weight with respect to control
Control	268.3200073	
Low	249.9799957	6.835126
Medium	223.8000031	10.47284
High	153.1199951	31.58177

Analysis of weight in copra due infestation

ANOVA table

	df	MS	df	MS	F	p-level
Factor	**Effect**	**Effect**	**Error**	**Error**		
Infestation	3	127718.1	196	359.5364	355.2299	0

The effect of infestation is highly significant (observed significant level < 0.01)

PLATE XXVIII

Average weight in copra Grouped by level of infestation

F(3,196)=355.23; p<0.000

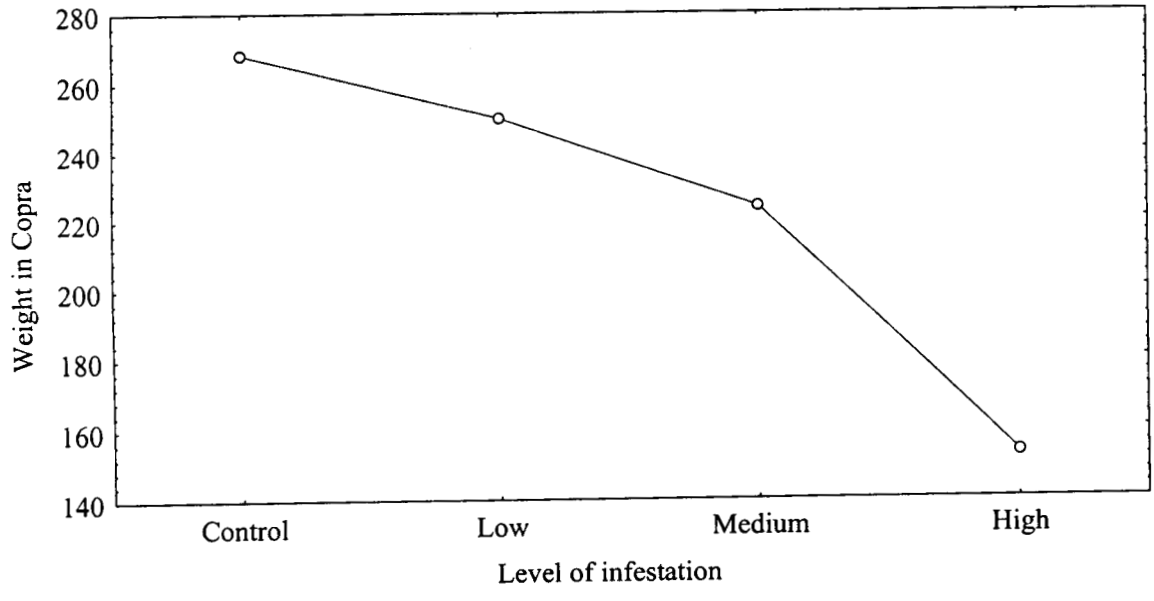


PLATE XXIX

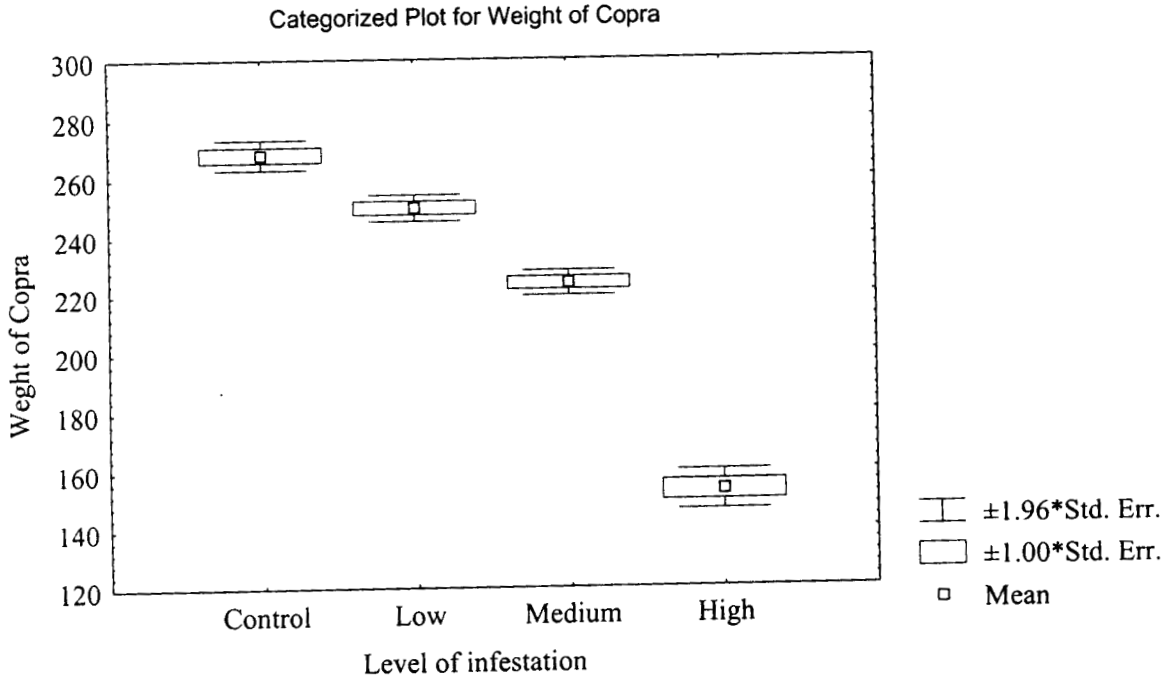
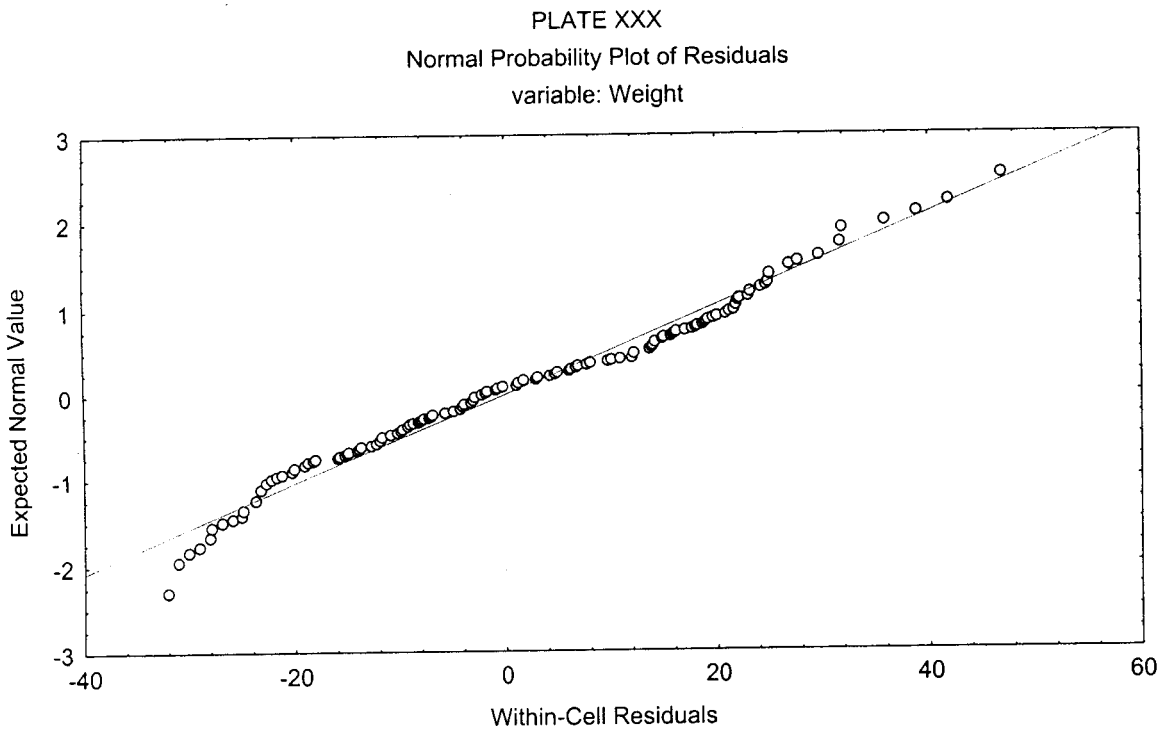

Categorized Plot for Weight of Copra
300
280
260
240
220
200
180
160
140
120
Weght of Copra
Control
Low
Medium
High
Level of infestation
±1.96*Std. Err.
±1.00*Std. Err.
Mean

PLATE XXX


Normal Probability Plot of Residuals
variable: Weight
Expected Normal Value
3
2
1
0
-1
-2
-3
-40
-20
0
20
40
60
Within-Cell Residuals

of the range showing that the value are not consistent and hence there are chances for variation. But, the average value obtained on weight loss of copra appears to be highly significant as 95% values are within the lower and upper lines of the box. However, since the gap between the border lines of the box and upper and lower limits of the plot is wide, the values are inconsistent and are likely to vary from the mean value. In the case of low infested groups, 7% weight loss obtained whereas moderately infested group experienced a weight loss of 11%. However, as indicated in the categorized plot, the values are more consistent for low and medium infested groups of nuts as the gap between upper and lower limits is narrow, suggesting that there are low chances of variation from the mean value. Thus, the results of ANOVA when represented through categorized plot enabled to understand that the weight loss in copra due to mite infestation is highly significant though it is inconsistent, as there are more chances of variation. The normal probability plot (Plate XXX) shows that the fluctuation in the weights of copra of each category from its mean is normal. Hence, the basic assumption for applying ANOVA is satisfied and the error from mean is symmetric.

VII. Influence of total surface area on damaged area of coconut due to infestation by *A. guerreronis*

Influence of total surface area on damaged area of different categories of nut was analysed statistically by regression analysis. The results of this study showed that the total surface area of the nut had no significant influence on the damaged area as a linear regression was obtained. However, when the data were subjected to ANOVA, a significant result was obtained at 1% level. The scatter plot (Plate XXXI) showed a nonlinear regression showing that influence of total surface area on damaged area was significant (P=0.003) (Table 22). The scatter plot clearly indicated the trend of influence of total surface area. For lower values of total surface area, there was a slightly increasing trend and for higher values there was a significant decreasing trend of damaged area.

VIII. Natural enemies of *A. guerreronis*

Several natural enemies of *A. guerreronis* could be encountered on infested coconuts collected from the field. Among these, the predatory mites as well as insect predators were more prevalent. Among the insect predators, staphylinid beetles, thrips belonging to *Tubulifera* sp. and an unidentified insect larva were found to be potential enemies of the mite. The predatory mites recorded were *Typhlodromus pyri* (Plate-

TABLE 22

Regression Summary and ANOVA table of influence of total surface area on damaged area of infested coconut

Regression Summary for Dependent Variable: DAREA (dat2.sta)
R= .42832663 R^2= .18346371 Adjusted R^2= .15481331
F(2,57)=6.4035 p<.00310 Std.Error of estimate: 80.253

	BETA	St. Err. of BETA	B	St. Err. of B	t(57)	p-level
Intercpt			135.2822	105.1375	1.286717	0.203394
TSA	2.067075	0.869077	0.689506	0.289894	2.378472	0.020758
TSA^2	-2.36742	0.869077	-0.0005	0.000184	-2.72406	0.008546

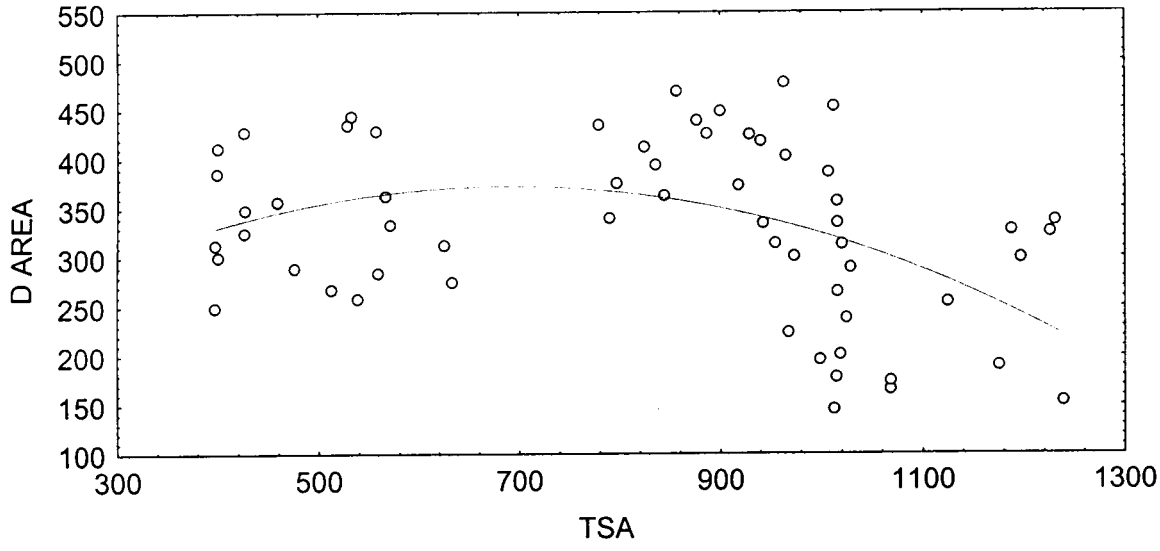
The non-linear influence of total surface area on damaged is significant (p=0.003)

PLATE XXXI

Influence of total surface area on damaged area of coconut

Scatterplot (DAT2.STA 5v*60c)

y=135.282+0.69*x-0.001*x^2+eps



XXXII, Fig. 1), *Agistemus industani* (Plate-XXXII, Fig. 2), *Amblyseus* sp. (Plate-XXXII, Fig. 3), *Eustigmaeus* sp. (Plate-XXXIII, Fig. 4), *Bdella* sp. (Plate-XXXII, Fig. 5) and *Cheyletus* sp. (Plate, Fig. 6). In the present study the feeding activity and potential of *T. pyri* was assessed under laboratory conditions at a temperature of 26±1^{0}C and RH of 60-70%.

IX. Feeding potentiality of *T. Pyri*

Close observation of the predatory habit of *T. pyri* on *A. guerreronis* revealed that all the life stages of the predator exhibited feeding by consumption of all life stages of the prey. The different stages of *T. pyri* were found moving very fast in search of the prey. Starvation of the predatory mites for a day induced vigorous movement along the entire surface of the nut to locale the prey. The location of prey was detected by using the palp and first pair of legs. When the prey was located once, the predator slowly catch hold of the prey with its palps and first pair of legs. Simultaneously the chelicerae were protruded towards the prey and penetrate the body. Then it slowly sucked the contents through the styletiform chelicerae.

Several feeding punctures were made on the various life stages of the prey. In the case of prey eggs the content was sucked by the predator and leaving behind the egg case which appeared as shrunken scale like structure. While in the case of prey nymphs and adults, the

EXPLANATION OF FIGURES

PLATE XXXII

Various Predatory Mites of *A. guerreronis*

Fig. 1 *Typhlodromus pyri.*

Fig. 2 *Agistemus industani.*

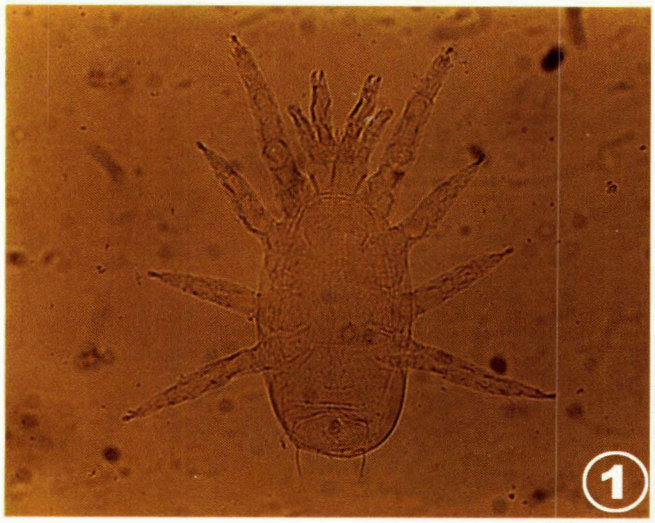
Fig. 3 *Amblyseius* sp.

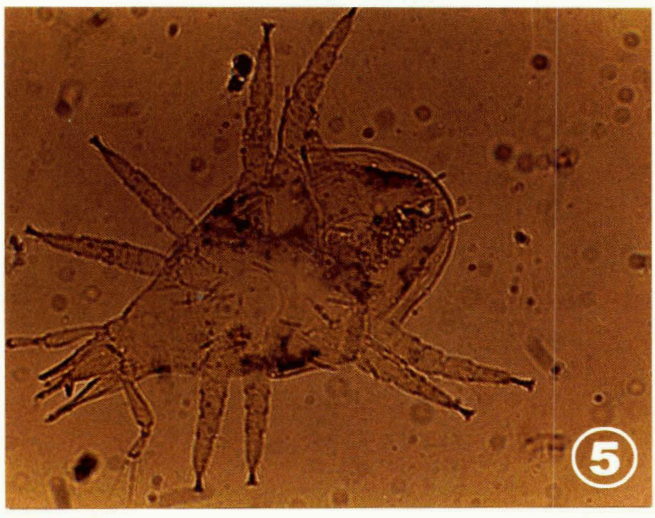
Fig. 4 *Eustigmaeus* sp.

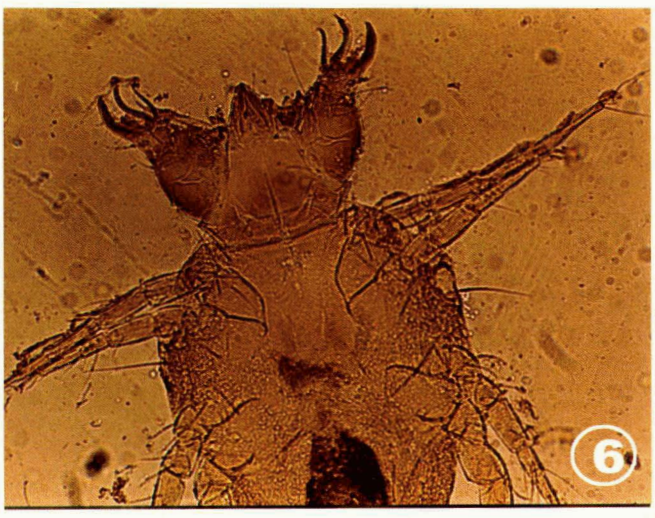
Fig. 5 *Bdella* sp.

Fig. 6 *Cheyletus* sp.

PLATE XXXII



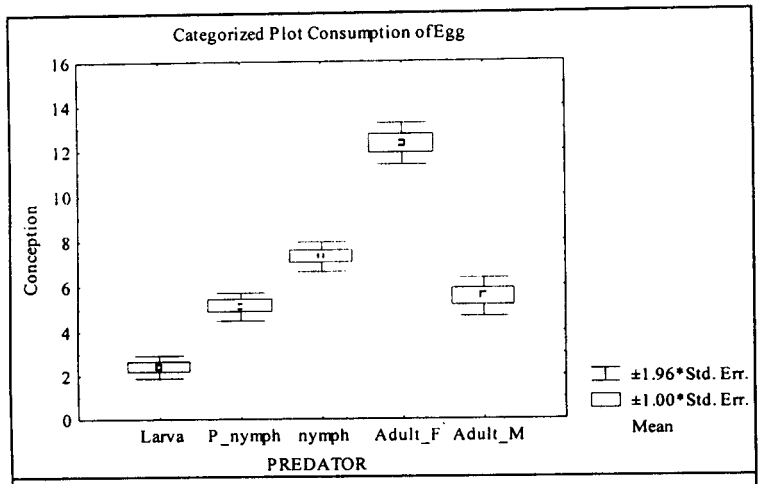


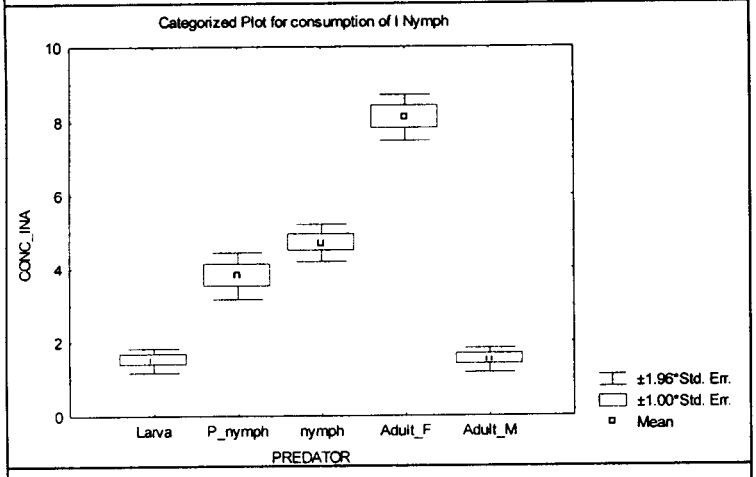


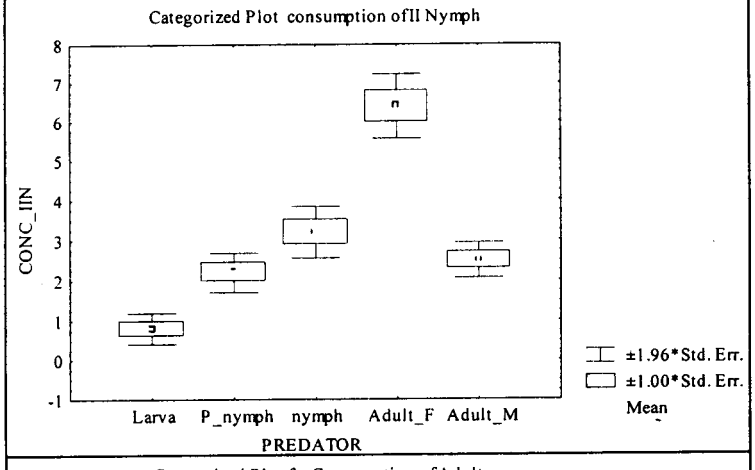
body was found shrunken and pinched. The feeding potentiality of individual stages of *T. pyri* was often found varying considerably. The adult *T. pyri* was more active in the capture and consumption of prey. The time taken for the consumption of various stages of predatory mites towards the corresponding stages of prey species also exhibit variation. It was noted that the adult *T. pyri* took lesser time to suck the contents of prey mite. It was observed that the adult female *T. pyri* took only 1 minute to suck the internal content of the prey egg, where the males and deutonymph took 1.5 minute, protonymph took 2.2 minute and that of larva took 2.5 minutes for the completion of sucking. The average consumption time taken by different stages of the predator increase with the progressive developmental stages of the prey.

Data on the feeding potential of the predatory mite *T. pyri* on *A. guerreronis* were statistically analysed, based on the different categorized box plot. Each categorized plot showed the rate of consumption of prey by the various stages of predator. From the categorized plot and ANOVA Table (Plate-XXXIII) it is clearly evident that the rate of feeding by individual stage of predator was quite different with respect to the different stages of the prey. In all cases, the feeding potential of adult females of *T. pyri* was comparatively high on the various stages of the prey, *A. guerreronis*

PLATE XXXIII







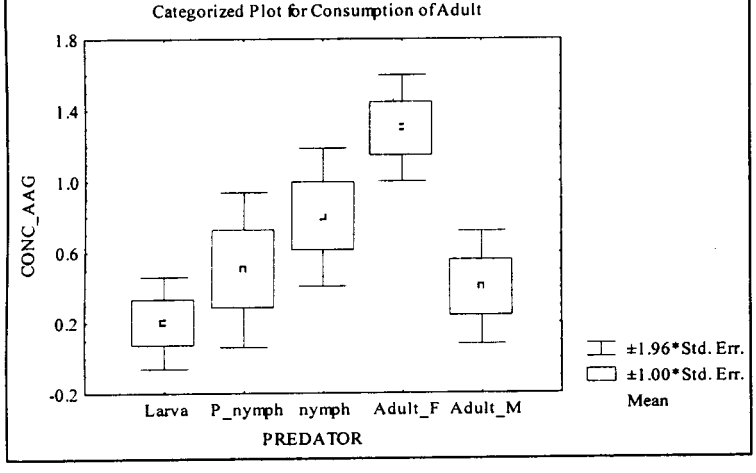
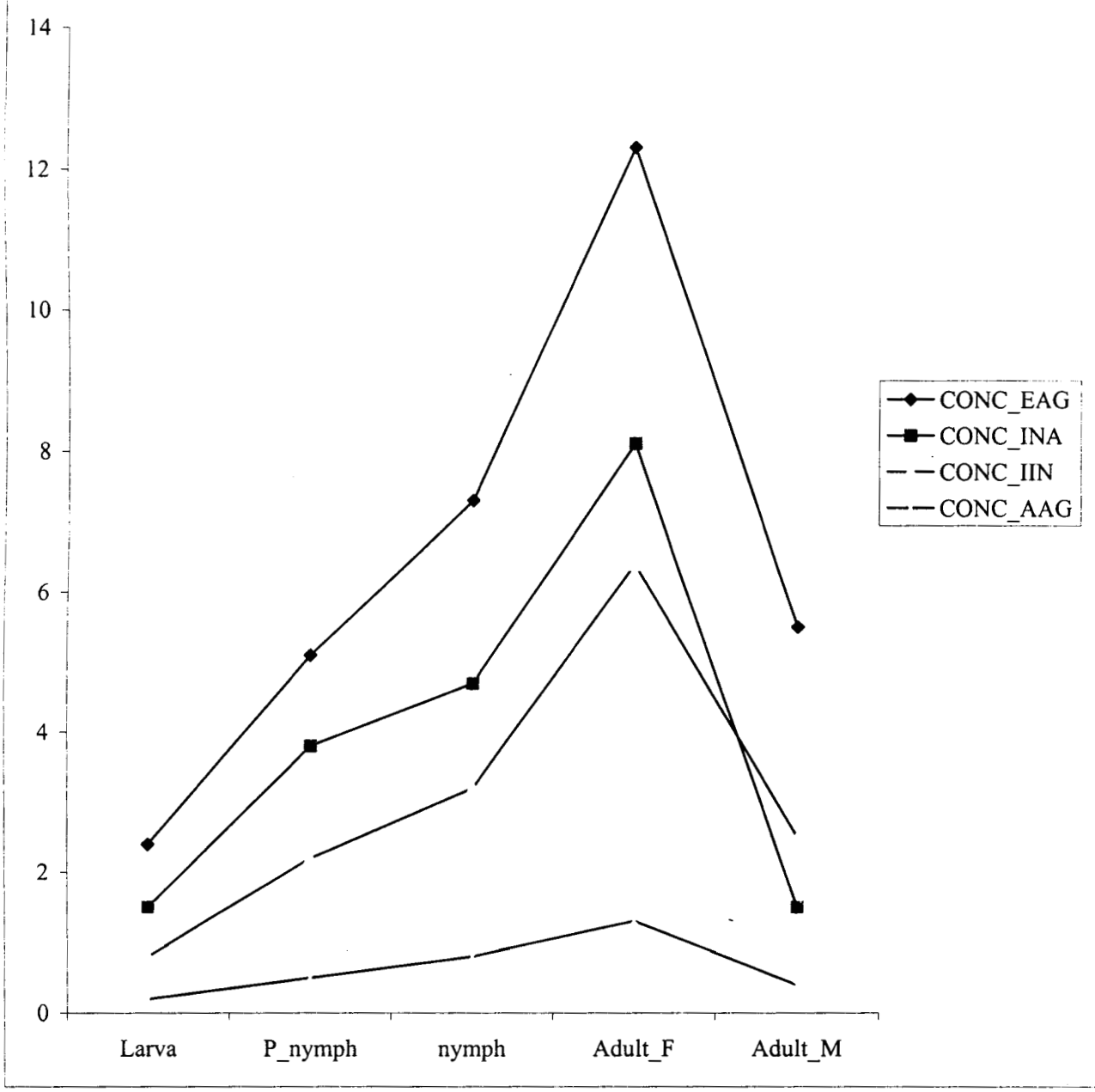


PLATE XXXVI

Feeding preference of various predatory stages to prey life stages



showed a normal pattern and could be in the decreasing sequence , represented as adult female > Deutonymph > protonymph = male > larva. The graph (Plate XXXIV) showed that most preferred food item for each of the predatory stage was the eggs of the prey. The adult stages of the prey formed the least preferred one for all the stages of predator

DISCUSSION

DISCUSSION

The phytophagous mites and their importance in agriculture have greatly attracted the attention of scientists during in the past few decades. Most of the phytophagous mites have been recognised as pests of various crop plants, leading to considerable loss in yield. This should be considered seriously, particularly in developing countries like

India which depends greatly on the agricultural products. In India, Kerala is one of the states where the livelihood of 50% of the people is based on agriculture. In this regard, the present work is thought highly warranted as it is an attempt to provide a general awareness on the important acarine pests of different crop plants in Kerala. The present work includes a general survey on acarine fauna of crop plants and also sheds light on the biological and population aspects of four potential pests viz., *T. ludeni, T. cinnabarinus, R. macfarlanei* and *A. guerreronis* on four species of economically important crops viz. , a creeper vegetable, a tuber crop, a fruit crop and an oil yielding crop.

Results of the survey carried out during the present investigation on the mite fauna of various crop plants clearly indicated the prevalence of major phytophagous groups of mites in different

localities of Kerala. The study further disclosed the extent of damage induced by various species on their respective host plants and their symptoms of infestation. More than 50% of the total species recovered during the study were recognised as major pests. A total of 37 species of mites belonging to 24 genera and nine families could be collected during the study. All the species of plants surveyed were found harbouring varying number of mite species with the maximum species diversity on cassava and coconut. Thus the study helps to expose the rich and diverse faunal composition of mites among the economic plants of Kerala. The study further points out the need to undertake extensive surveys to explore the acarine diversity harbouring the rich floral wealth of Kerala.

In the present study, Tetranychidae could be recognised as the most diverse family, accommodating the maximum number of species (13). This was followed by Tenuipalpidae (8) and Eriophyidae (7). However, in terms of generic diversity, Eriophyidae occupied the first position as it supported six genera. This was closely followed by Tetranychidae and Tenuipalpidae comprising five and four genera respectively. Thus, the study helped to record intimate association of the members of Tetranychidae and Eriophyidae with the economic plants surveyed. Obligate phytophagy has already been assigned to the

members of these two superfamilies by various authors (Rodriguez and Rodriguez, 1987) as they possess movable styletiform chelicerae which can pierce the plant tissue. More than 450 species of Tetranychid mites have been reported under five families as phytophagous on various species of economically important plants. Majority of these species fall under two families viz., Tetranychidae and Tenuipalpidae. The results of present study also support this observation as it enabled to record 13 species under Tetranychidae and eight species under Tenuipalpidae. The members of Tetranychidae and Tenuipalpidae are reported to occur mainly in tropical and subtropical climates.

Eriophyid mites also constitute an economically significant group (Krantz, 1978) and majority exhibits high host specificity which have evolved intimate association with their hosts that in many cases both the host and parasite can survive (Hislop and Jeppson, 1976; Krantz and Lindquist, 1979). Such intensive host specificity would be attributed to all the eriophyid species recovered during the study with the exception of *Nothopoda* sp. which could be collected from two species of plants. However, all the eriophyid species included in the study were found infesting annual plants alone, despite the general statements that eriophyids usually feed on perennials and tetranychids quite often feed on annuals (Rodriguez and Rodriguez, 1987).

Members of genus *Tetranychus* collected during the study could be assigned to species such as *T. ludeni, T. cinnabarinus, T. macfarlanei, T. neocaledonicus, T. urticae* and *T. pappayae*. The host diversity of the genus was also profound as the members could be collected from 24 species of plants of various economic category. Members of this genus could already been recovered from 183 host plants by earlier workers (McGregor, 1917; Cherian, 1932; Rahman and Sapra, 1940; Januja, 1942). They were recognised as serious pests of fruit crops, cotton and majority of vegetables.

The tenuipalpid species *B. phoenicis* exhibited widest host range among all the species collected during the survey. This mite species has been reported to infest a wide variety of plants comprising fruits, vegetables, ornamentals, and medicinal plants as reported from many parts of the world. (Baker and Pritchard, 1960; Attiah, 1966; Meyer and Rodriguez, 1966; Zacher and Yousef, 1969; Meyer, 1970; Ghai and Shenmer, 1984; Sadana, 1985). Ochoac (1985) also reported that 95% of tenuipalpid mites collected from Costa Rica belonged to the genus *Brevipalpus*. These observations were in agreement with the result gathered during present study and this would enable to reveal the host diversity of the members of the above taxa.

By virtue of phytophagous nature and extent of damage caused

to host, *T. ludeni* and *T. cinnabarinus* have attained the status of major plant pests all over the world. The present survey enabled to record 10 and nine host plants respectively for these two species which include vegetables, fruit crops, tuber crops and plantation crops. Of these, some are new host records for *T. ludeni* and *T. cinnabarinus*. *T. ludeni* was also reported in abundance on weeds like waterhyacinth (Sumangala and Haq, 1992) which suggests their ability to extend distribution even to aquatic plants. This has revealed the potential of this mite in exploiting both terrestrial and aquatic plants.

Among the oribatid species collected, *.S. decarinatus*, *P. bengalensis* and *N. nortoni* exhibited high species diversity. High incidence of these species was reported on various species of economically important plants in Kerala by earlier workers (Ramani and Haq, 1984a; 1984b; Jaikumar *et al.*, 1992). During the current study, these species were recovered from 10, nine and six plants respectively many of which were not recorded earlier.

Feeding activity of the various species of phytophagous mites included in the study resulted in varying types of damage on their host plants. Based on the nature and extent of damage, the species could be assigned to the status of major or minor pests. The most specialized feeding structures were visible in Tetranychidae and Eriophyidae. The

mouth parts of tetranychids include an eversible stylophore, the movable chelae evolved into long stylets that can pierce the plant tissue (Evans *et al.*, 1961). On the other hand, Eriophyids lack a stylophore but instead four pairs of short immobile stylets present which are capable of only for shallow penetration (Nuzaci, 1979). Feeding injury by eriophyids is slight compared to that of tetranychoids and hence eriophyids keep the plant alive, where as tetranychids are prone to kill the plant. Tetranychid feeding causes plant cells to burst and the contents are sucked via the pharynx as observed during the study. Severe infestation caused chlorosis, formation of brown patches and ultimately leading to defoliation. Observation made on the eriophyid mites also disclosed the severe damage to coconut by killing the cells of perianth due to their continuous sucking of cells sap. As a result, formation of a number of cracks, crevices, and warts on the nut surface followed by drying was evidenced. A variety of abnormalities like development of irregular patches, split formation, premature nut fall, drying of nuts and other malformations were found induced by *A. guerreronis*. This definitely points out the fact that eriophyid injury can result in considerable yield loss.

All the species of *Tetranychus* collected during the survey were reported as major pests of crop plants. In the present study, pest status

could be attributed to two species viz., *T. ludeni* and *T. cinnabarinus* on the basis of the extent of damage induced by them and their relative abundance on various host plants. Vegetable crops were the major groups of host plants recognised for the members of *Tetranychus* which supports the earlier reports of Gupta (1985, 1991). *O. mangiferus* was reported as an important pest of mango and had been found widely distributed in India and Mauritius (Moutia, 1958; Gupta, 1985; Gupta and Gupta, 1985; Gupta, 1991). During the current study, *O. biharensis* and *E. orientalis* were found inducing serious damage to cassava thereby agreeing with the earlier findings of Pillai and Palaniswamy (1985) who reported that the above two species mainly feed on dorsal surface of cassava leaves while the remaining tetranychid mites feed on the ventral surface. The present study enabled to record *O. indicus* and *O. iselimae* as minor pests because their incidence and damage symptoms on respective host plants viz., arecanut and coconut relatively were low. However, Sathiamma (1986) recorded *O. iselimae* as a major pest on coconut leaves. A contrary observation made during the study was the detection of *P. latens* as a major pest of *C. acida* and *C. medica* unlike the report of Gupta (1991) who established it as a major pest of cereals.

Of the various species of false spidermites, the genus *Brevipalpus* was found dominate on the various host plants examined. Fruit trees were found to be more prone to infestation by these mites as suggested earlier by Gupta (1991) and Sadana and Meenakumari (1991). In the present study, *R. macfarlanei* was recognised as a major pest on the fruit crop, *S. jambolanum*. This mite was reported as a harmless species (Gupta, 1985) and the present observation contradicts this statement and assigns the species, the status of a major pest. Another member of the same genus viz., *R. indica* had been established as a major pest of coconut and arecanut and the species was recognised as a widely distributed one in India and Mauritius (Moutia, 1958). Similarly, *T. yousefi* could be reported for the first time as a major pest of *A. sapota* based on the results of the present study. Two species of *Dolichotetranychus* viz., *D. palmae* and *D. floridanus* were collected during the study and both the species exhibited severe damage symptoms so as to consider them as major pests of coconut and cardamom respectively. Apart from *D. palmae* two more species of the same genus were recorded from coconut earlier viz., *D. vandergooti* (Sathiamma, 1985) and *D. cocos* (Flechtman and Fernando, 2000). All the above species were known to enjoy concealed habitats available on the host plant such as perianth of nuts, internodal regions, leaf sheaths etc.

In the present study also, the members of the above genus were recovered from concealed habitats.

All the species of eriophyid mites, recovered during the study period were found to exhibit high host specificity with the exception of two species viz., *Phyllocoptes* and *Nothopoda*. The latter two species were recognised as leaf vagrants without inducing any visible symptoms. However, the remaining species induced severe damage symptoms based on which they could be assigned the status of major pests on their respective host plants.

Thus the results of the survey helped to reveal the status of various species of mites as major or minor pests on different species of economically important plants in Kerala. The survey further helped to report some of the mite species as major pests of so far unrecorded host plants. Excellent examples were T. *pappayae, O. mangiferus, P. latus, B. rugulosus, B. obovatus, D. floridanus, D. palmae, T. yousefi, E. hicoriae, C. carinatus, P. oleivora, Nothopda* sp and *Phyllocoptes* sp. which could be recorded for the first time from Kerala. Apart from this, the study has revealed new host records for nine species of mites. Thus, it helped to extend the known host range of these mite pests by adding new host plants from Kerala. Hence it is apparent that more studies on the species diversity, host range and distribution of the mite is highly

warranted in order to assess the extent of damage caused by these species and also to understand their host switching abilities.

During the present study, four species were selected for biological studies, based on the severity of damage symptoms induced by them on the respective host plants of varying economic categories. The species selected were *T. ludeni* on velvet bean *T. cinnabarinus* on cassava, *R. macfarlanei* on jamba and *A. guerreronis* on coconut. Of these, first two species were representatives of Tetranychidae, the third one was a tenuipalpid member while the last species formed an eriophyid mite. *T. ludeni* has been established as a serious spidermite pest of the tropics across the Southern United States in Mexico, central and South America, South Africa and Australia and is reported on a wide variety of host plants like hibiscus, beans, egg plant, potato, alfalfa, castor bean, Pumpkin and other cucurbitaceous plants (Moutia, 1958; Meyer and Rodriguez, 1966). In India, it infests several vegetable crops, exerting considerable reduction in yield (ChannaBasavanna, 1971). Owing to the economic importance of *T. ludeni* as a pest of several vegetable crops and its occurrence and population build up on an unrecorded plant viz., *M. deeringiana*, the so called velvet bean, it has been included in the present study so as to gather information on the biology, population and distribution pattern.

Cassava is a tropical crop, native of South America and its exploitation has been increasing in all tropical zones of the world. It constitutes one of the very important subsidiary foods for human beings. Further, it represent as a source of carbohydrates and protein for several animal foods. A major portion of cassava is starch for consumption and it is also used for alcohol production. The cassava plant is prone to attack by a variety of insects and non insect pests (Rao and Pillai, 1973; Lalad Pillai, 1980). Of the non insect pests, mites constitute an important group and the foliage of the plant supports complex of spidermites, often reaching more than 40 species (Flechtman, 1978; Rodriguez, 1978; Doreste, 1981). However, only 4 species of spidermites viz., *T. cinnabarius, T. neocaledonicus, E. orientalis* and *O. biharensis* have been reported from India (Pillai and Palaniswamy, 1985). Later, one more species viz., *T. urticae* has been added to the list (Sumangala and Haq, 1999). Of these *T. cinnabarinus* is found infesting the plant inducing considerable damage and hence included in the present study for detailed observation on the biology, population and distribution of the mite.

The tenuipalpid species, *R. macfarlanei* has been recognised as widely distributed in various localities of Kerala. The present record of this species on *S. jambolanum* forms a new addition to its host range. A

perusal of available literature shows lack of information on the biology and population dynamics of this species as it has been given the status of a non-economic species (Gupta, 1985). Contrary to the above assumption, the species was found causing severe damage to the new host, *S. jambolanum* during the present study and hence considered for detailed studies on biology and population.

Results of studies carried out on the feeding biology of tetranychoid mites enabled to follow a more or less similar trend of feeding activity in *T. ludeni, T. cinnabarinus* and *R. macfarlanei.* The feeding process was accomplished by puncturing the leaf tissue with their chelicerae and the sap oozed out form ruptured cells was sucked with the help of stylets. As a result, the affected tissues of the leaf became transparent and developed whitish spots. On progressive feeding, the white spots increased in number, gradually coalesced with one another and finally producing yellowish patches as observed in the case of *T. ludeni* and *T. cinnabarinus* on velvet bean and cassava. Thus the feeding pattern resembles that of other tetranychidoid members recorded earlier (Ubertally, 1955; Das, 1959; Lal and Pillai, 1981, Pillai and Palaniswamy, 1985, Sumangala and Haq, 1999). The sucking action of spidermites accounts for drastic reduction of cell contents and as a result, the leaves lost their green colouration and healthy appearance

and undergo wilting. The ultimate result is the defoliation of the plant as observed in the case of *T. ludeni* and *T. cinnabarinus* on various host plants (Rahman and Sapra, 1945; Srivastava and Mathur, 1962; Puttaswamy and ChannaBasavanna, 1980; Pillai and Palaniswamy, 1985; Sreenivas *et al.*, 1991).

The population build up and relative damage of various species of mites on the host plants as observed during the study enabled to acquire pest status of the members of Tetranychidae. This observation clearly supports the earlier reports of several workers (Bellotti and Byrne, 1979; Lal and Pillai, 1981). Contrary to this several other species were found causing minor injuries (Ehara, 1975; Gurrero and Bellotti, 1981). The extent of damage induced by tetranychoid mites show a range of variations such as loss of chloroplasts and cell contents, mechanical damage to the cell, injection of toxic chemicals and so on, finally affecting the normal growth and development of the plants (Avery and Briggs, 1968; Tanigoshi and Davis, 1978; Sances *et al.*, 1982). In the present study discolouration was seen on the upper and lower surface of leaves and the affected regions often developed spots and patches intermingled with normal greenish areas on the foliage. Thus mite infested leaves could be easily distinguished in the field.

Webbing of silken threads is a characteristic feature of red spidermites which was reported in some genera including *Tetranychus, Oligonychus* and *Eutetranychus* (Hazan, *et al.*, 1974). Colonization and webbing are inter-related in spider mite ecology and the web production in *T. urticae* female deutonymphs greatly increases the attractiveness to males as reported earlier (Penman and Cone, 1972). These mites spin webs of such a thickness over the foliage that the normal foliage functions get ceased. Moreover, dust particles also get deposited on the webs through wind. *T. ludeni* and *T. cinnabarinus* produced webbing of silken threads on the entire colony of their respective host plants which constituted an important structural component and can be taken as a typical manifestation of mite infestation. Laboratory observation on the activity of these species revealed total confinement of the eggs and developing stages within the webbed area. The process of webbing thus transforms the leaf surface into a suitable microhabitat for sheltering the immature life stages. The network of silken threads constitutes a major physical component of the colony providing support and space for the entire mite population. These observations were in agreement with those of Srivastava and Mathur (1962), Sumangala and Haq (1994), Nandagopal and Gedia (1995).

R. macfarlanei was found preferring mature leaves of *S. jambolanum* both for feeding and oviposition. This was true in the case of *T. cinnabarinus* also which showed maximum population on the bottom tier of cassava leaves. In both the above species, minimum population could be noted on the younger leaves and middle aged leaves exhibited an average population. The more tender and newly sprouted leaves were completely devoid of mite attack. This suggests that nutritional components available in the mature leaves might have favourably influenced the feeding activity of mites. Thus the finding agrees with that of Harrison (1938) who suggested that in old leaves the cells are not turgid and the flow of sap is slow and hence are preferred by red spidermites while the young leaves have a turgid condition with free flow of sap and are less attacked. Contrary to this *T. punicae*, a tenuipalpid representative always shows preference to younger leaves as reported by earlier workers (Al-Gboory and El-Haidary, 1989) and in this case tenderness of leaves helps the species to make easy penetration and drainage of sap from the host. However, during the present study the tenderness of leaves has not been found to exert any influence on the feeding activity of *R. macfarlanei* and *T. cinnabarinus*. *T. ludeni* on the leaves of velvet bean exhibited a slight variation in their distribution pattern as it preferred the middle aged leaves. Newly

sprouted and tender leaves were not attacked by *T. ludeni*. It is possible that some of the preferred biochemical constituents available in the middle aged leaves provide ideal nutritional components for the development of mite species.

Biochemical analysis of infested leaves of cassava established reduction in HCN content and an increase in crude protein and starch content in older leaves (Bruin, 1973; Maini and Lal, 1977). HCN has been considered to offer general resistance for the plant, including protection against attack by mites and hence depletion in the quantity of this component can be attributed as a reason for the increase in mite attack on older leaves (Jones, 1972; Maini and Lal, 1977). Therefore, it is reasonable to consider that reduction in HCN content, as noted in this study,s may stimulate feeding activity of the mites. This is followed by the increase in protein and starch contents of leaves which may aid in reproductive enhancement of the mites feeding on them, thereby helping their population build up on the older leaves. Further biochemical studies on the nutritional components of the leaves are needed to make a clear statement on the preference of the species to the leaves of different age groups of *S. jambolanum* and *M. deeringiana*.

Results of population studies revealed the occurrence of *T. ludeni* and *R. macfarlanei* on velvet bean and jamba respectively throughout the

year while *T. cinnabarinus* showed restricted distribution on cassava depending on the season of cultivation. The peak population of all the three species occurred during summer months when the temperature recorded was maximum and RH was minimum. Results of statistical analysis enabled to record positive correlation between mite population and temperature and a negative correlation between population and RH. This was true for all the species in which r values were always positive for temperature, thereby establishing a significant correlation. Information available on the influence of weather factors on the population of tetranychid mites indicates that high temperature coupled with low RH not only favours the population build up of tetranychid mites but also increases the feeding potential of these mites. Various authors have registered maximum injury by tetranychid mites during the operation of the above climatic parameters (Huffaker and Spitzer, 1950; Hamilton, 1962; Luing-shu *et al.*, 1984). Temperature coupled with low rainfall favoured increase in mite population. Reports on the population studies of tenuipalpid species also agree with the above observation (English and Turniseed, 1941; Puttarudriah and ChannaBasavanna, 1958; Mori, 1961; Nageshchandra and ChannaBasavanna, 1984b; Al-Gboory and El-Haidany, 1989). Contrary to this, high population of *Brevipalpus* and *R. indica* was found during

the warmer months of the year (Elmer and Jeppson, 1957; ; Sarkar and Somchoudhury, 1989; Sadana and Meenakumari, 1991). However, in the present study temperature acts as a deciding factor in the population build up of the mite specie. Boyne and Hain (1983) observed an increase in fecundity of tetranychid mites at higher temperature. This may be one of the reasons for high population density of the mite recorded in the field at higher temperature range as observed during the present study.

Generally, tetranychid mites exhibit certain degree of site selection for oviposition. Several species were found depositing eggs adjacent to the midrib or intervienal regions available on the lower surface of the leaves of the host plants (Banu and ChannaBasavanna, 1972). This type of ovipositional habit assures easy accessibility of preferred food to the emerging larva. Moreover, confinement to the lower surface affords sufficient protection to eggs. Similar trend of oviposition could be observed in all the 3 species considered for the present study. All species deposited solitary eggs near to the mid rib or side veins of the leaves in close vicinity, so as to form a batch. The number of eggs in each batch varied from 10-30 as in the case of *R. macfarlanei*. This seems to be an intermediate condition between solitary egg deposition and aggregate deposition. Egg deposition in batches also

seems to afford protection from predation and desiccation. The oviposition period in *T. ludeni* and *T. cinnabarinus* lasted for 8-10 and 1-13 days respectively while *R. macfarlanei* required 9-12 days. Oviposition periods of tetranychid and tenuipalpid mites also tend to vary. *T. cinnabarinus* on mulberry took about 16 days (Sreenivas *et al.*, 1990), *T. neocaledonicus* on cassava required about 18 days (Puttaswamy and ChannaBasavanna, 1980). *R. indica* took about 26-54 days (Nageshchandra and ChannBasavanna, 1984a). *T. punicae* took about seven days at 25^{0}C (Al-Gboory et al, 1984), *B. phoenicis* took about 10.57$\pm$ 1.3 days at 25^{0}C (Sadana and Meenakumari , 1991). Such types of variation in oviposition periods often result from differences in the host plant nutrients, texture, species specific variation coupled with the variations in climatic factors.

Parthenogenetic reproduction has been reported in several members of tetranychoid mites. During the present study, in all the 3 species, mated females were found to lay eggs which were developed into females. However, the eggs deposited by unmated females always developed into males only. This has clearly indicated the occurrence of both normal sexual reproduction as well as parthenogenetic development in the three species studied.

The daily output of eggs laid by a mature female often depends on the age, of the individual. In the present study, with the advancement of age the rate of oviposition also got increased and reached a peak level during the third day in *T. ludeni,* fifth day in *T. cinnabarinus* and fourth day in *R. macfarlanei* with a maximum number of 13, 10 and 9 eggs respectively. A gradual decline in egg production was noted from the next day and then reaching the minimum number on the last day of oviposition. Therefore, the rate of egg deposition appeared to be slow initially, then increased gradually approaching the peak level during the middle of oviposition period and then showed a decline. Such pattern of egg production has been recognised in many species of Tetranychoidea (Banu and ChannaBasavanna, 1972; Lakmanlal and Mukherjee, 1978; Wrensch and Young, 1978).

The number of eggs produced during the life time of a female tetranychoid mite may vary greatly depending on species and even the individuals of the same species often show variation in this regard. During the present study *T. ludeni* was found to deposit an average number of 41.2 eggs within an oviposition period of 8-10 days. The same species was found to deposit a total of 165.88±47.04 eggs during an average oviposition period of 22.83±4.56 days (Puttaswamy and

ChannaBasavanna, 1980b). During the present investigation, *T. cinnabarinus* deposited an average of 55.2 eggs within an oviposition period 10-13 days. Sreenivas *et al.* (1990) reported that *T. cinnabarinus* on mulberry exhibited an oviposition period of 16 days in which an average fecundity of 83.842 eggs could be recorded. Dhooria and Prem Sagar (1989) reported that the egg deposition by *T. cinnabarinus* on three species of *mentha* varied from 0-46, 37-77 and 0-29 within an oviposition period ranging from 4-16, 5-14 and 2-17 days. Puttaswamy and ChannaBasavanna (1981) reported that the fecundity of *T. neocaledonicus* on cassava leaf was 87 within an average oviposition period of 18 days. The present study revealed that *R. macfarlanei* deposited an average of 36.4 eggs during the oviposition period of 8-12 days. In another member of the same genus viz., *R. indica,* the oviposition period extended for 26-54 days with an average egg deposition of 22. (ChannaBasavanna and Nageshchandra, 1984a). Al-Gboory *et al.* (1984) found that *T. punicae* deposited an average of 21 eggs within an ovipoisition period of 5 days at 33^{0}C. Therefore, depending on the type of host plant and also the environmental condition, the fecundity exhibit much variation even in the same species.

The eggs often show varying shape and configuration in tetranychid mites. The freshly laid eggs of *T. ludeni* and *T. cinnabarinus*

were pearl like, globular or spherical in out line while that of *E. orientalis* were circular, flattened and disc shaped (Pillai and Palaniswamy, 1985). The eggs of *R. macfarlanei* appeared reddish orange, oval, solitary and attached to the leaf surface with a long stipe. A similar stipe was noticed in the case of *R. indica* also in which its tip shows a coiled appearance (Nageshchandra and ChannaBasavanna, 1984b). The possession of such stipes would be interesting for further studies in terms of their functional significance. In this regard it would be interesting to trace its role, if any, in the hatching process of egg.

The process of hatching in *T. cinnabarinus, T. ludeni* and *R. macfarlanei* was more or less similar and initiated with the formation of a vertical slit dorsally on the apical end, through which the first pair of legs of larvae protruded. Further thrusting action of the body and legs resulted in the emergence of the entire larva. Contrary to this, in *O. tylus*, at the time of hatching the chorion of the egg splits along the circumference (Sirsikar and Nagabhushana, 1986) and in *E. orientalis* the process involves the formation of an equatorial split on the egg case (Banu and ChannaBasavanna, 1972). Thus, the hatching process involves variation with respect to differences in genera and species.

The post-embryonic development of all the three species possess three developmental instars as larva, protonymph and deutonymph

before reaching the adulthood. Three active instars followed by their respective quiescent periods also exist in the life history. The average duration of post-embryonic development of *T. ludeni* on *M. deeringiana* was completed with 11.72 days at a temperature of 27±1°C and RH of 70-75%. *T. cinnabarinus* on cassava leaves completed its post- embryonic development within an average period of 11.3 days at a temperature of 29±1°C and RH of 65-70%. The same species on same host plant was reported to require 16.4 days (Pillai and Palaniswamy, 1985) and the same species completed the life cycle on mulberry leaves with an average period of 8.8 days (Sreenivas, *et al.*, 1990). The total time required to complete the development of *T. ludeni* on French bean was 12.33 to 12.83 days (Puttaswamy and ChannaBasavanna, 1980b). Thus the total duration of life cycle of tetranychids shows slight variation with respect to differences in host plant and climatic parameters. *R. macfarlanei* completed its development from egg to adult within an average period of 15.82 days at a temperature of 27±1°C and 65-70% RH. Another closely related species, *R. indica* took 24.5 days to complete its development. (Nageshchandra and ChannaBasavanna, 1984b). The development of another tenuipalpid species, *B. obovatus* required an average of 15.8±1.33 days on *Luffa aegylica* (Sadana, 1989). Thus, the life cycle of tenuipalpid species appears to be slightly extended when

compared to that of tetranychid members.

Cocos nucifera , the commonly known coconut, represents one of the most important plantation crops of South India, particularly of Kerala. It constitutes one third of the agricultural income of the state and hence any problem connected with coconut production may be considered seriously. Fortunately, this crop was saved from major pests and parasites for a long time except for few instances of the pest cases like rhinoceros beetle, red palm weevil and black headed caterpillar. Hence, the crop as a whole or coconut based industries like copra, oil, soap, coir, handicrafts, soft drinks etc. did not faced much problem. However, Sathiamma *et al.* (1998) reported the invasion of the notorious mite, *A. guerreronis* which subsequently created considerable havoc by way of crop loss. A recent estimate of the crop loss due to invasion by *A. guerreronis* sets to the tune of 3-4 crores of rupees annually from Kerala alone. This clearly indicates how quick a pest can bring agricultural disaster affecting a major sector of the people in Kerala. The mite evokes serious havoc to coconut plantations of even high orders and still assumes as a challenge to the nation.

A. guerreronis when first reported from Mexico (Keifer, 1965) had not attained the status of a pest. However, later its injurious effects were recorded from South America and neighbouring islands (Doreste,

1968). Subsequently, this pest status of the mite was demonstrated from Benin, Africa (Mariau, 1969). Later on, several countries within the range of Central America and West Africa experienced the injurious effects of the pest (Hall and Espinosa, 1981; Mariau, 1986; Griffith, 1984). The latest report of its incidence and invasion and injurious effects from peninsular region including India, Sri Lanka and Lakshdweep (Haq, 2000) more or less the same time depicts its quick reproductive potential.

Ever since the mite has appeared in Kerala in 1998, various control measures have been practiced by government and private agencies. Chemical means though practiced widely throughout it is not advocated because of its environmental hazards. Several workers (Haq 1999; Fernando *et al.* 2000; Nair *et al.*, 2000; Haq *et al.*, 2000; Haq and Sumangala, 2001; Rabindra and Karuppachamy, 2001) have established clear identity of *A. guerreronis* as a serious pest of the tropical countries. An analysis of the pattern of distribution of the pest in these countries would suggest a transoceanic migration from the continent to continent and main land to islands. During the process of such migration, the species might have acquired high resistance to various ecological parameters ascribed to each of these countries. Accordingly, the mite would have attained high virulent status which enabled them to exhibit

high breeding and dispersal strategies. This might have helped them to reach in unexpectable dimension in population leading to the current outbreak in Kerala.

Infestation of coconut button by *A guerrernis* though was not detectable in early stages of 1-2 weeks, it was quite evident in later sages. Appearance of white or creamy triangular patches extending the border of tepals downwards constituted the first visible sysmptoms of mite invasion. Such patch development of various formats depending on severity of infestation was noticed by earlier workers (Julia and Mariau, 1979., Sathiamma *et al.*, 1998., Ramarethinam and Marimuthu, 1998., Haq, 1999). Therefore the structure, number, length and width of patches can be considered as indicative of the population density of the mite under the tepals.

Development of patches depend on various factors of which variety of coconut, age of the nut, nutrient pool, accessibility of productive female and tightness of tepals play important roles (Mariau, 1975; 1986; Julia, *et al*, 1979; Moore and Howard, 1996; Moore, 2000; Howard and Abreu-Rodriguez, 1991). These factors very often independently and rarely collectively play as key role responsible for high infestation. All the factors though not formidable to seed selection for nurseries, it may be advisable to opt resistant coconut varieties like

Lakshadweep ordinary, Cochin china, Andaman ordinary and Ganga bondam (Muthiah and Bhaskaran, 1999) for better forming practices in future.

Young nuts though are prone to mite attack, physical availability of space within tepals was found to be an encouraging factor for easy invasion of mite. Mostly arrangement of tepals on young nuts decided the severity of mite attack. Loose fitting tepals providing space in between and meristematic zone were more vulnerable to mite attack than tight fitting ones (Moore, 1986; 2000). Therefore special attention may be paid to screen nuts with tight adpression tepals for checking mite entry on developing nuts. In this context poor fertility and adverse agricultural practices were found conditions favouring loose fit between tepals and nut (Julia and Mariau, 1979).

Mite invasion on palms is well exemplified by the appearance of various types of symptoms during the later stages of nut development (Haq *et al*, 2000). Severity of the symptom usually dependent on the population size of the mite and type of symptoms developed very often acts as indices of the population density of the mite under the petals. Invasion of mite on coconut may induce early nut fall, nut drying and nut malformations. In addition patch development and crack development were also been noted on nuts which can be considered as

signs leading to later nut fall or nut malformation. Detection of these symptoms early in the nut development therefore would be helpful in chartering control measures against the mite in the right time.

Invasion of *A. guerreronis* causes various degree of injuries of which longitudinal development of split and split formation across the meristematic zone are considered to be very serious effects. Split formations generally may appear in nuts of 3-4 months old or more when nuts may fall off. Deep crack often facilitated deprival of water content leading to subsequent dropping of nuts one after the other from a bunch. Such dropping of nuts at the time of attaining maturity is considered to be a drastic manifestation resulting yield loss even in well maintained plantation. Extreme loss of nutrients at the developing meristematic zone by heavy sucking of high population of mites may be treated as an attributing factor for this later nut fall.

Dropping of nuts, as a common tendency, has been noted in most of the coconut varieties studied for a period of 3-6 weeks. After this period, usually cessation of nut fall occurred. Haq (2002) showed that infested palm continue nut fall up to 8-16 weeks period but in the current study the process has been found continued up to eighteenth week. Probably high infestation coupled with the development of deep crack might have intensified continued nut fall. The above facts clearly

indicate that high population of mites at any stages of nut development induce nut fall, either sooner or later. Invasion and flourishing of populations depend on age of the nut as evidenced in the study. Therefore population density of the mite during different seasons shows peaks and fall within an year. This would indicate that repeated spraying of chemicals may be done for the control of heavy population of mites in coconut plantations.

Maintenance of healthy colony appears to be a strategic point for further dispersal and survival of the mite. Very often this was found disrupted by weather parameters like, temperature, RH and rain fall. These parameters, as influencing factors have been demonstrated by various workers (Zuluaga and Sanchez, 1971., Griffith, 1984). Of these, temperature as very prominent influencing factor on population density of the mite could be demonstrated as this was found significant at 1% level.

However, RH and rainfall were not found to be striking factors which is found contrary to earlier observation. (Haq, 1999).

Mite attack invites various types of impacts on agricultural economy of our state of which loss in weight of copra due to mite infestation is one of serious hazards. Statistical analysis of the quantitative weight loss in copra showed seven percent in low infested

nuts which is found increased to 11% in moderately infested nuts. In the case of highly infested nuts, loss in copra yield was 32%. Moreover, the results of ANOVA when analysed through categorised plot systems helped to understand that the weight loss in copra due to mite infestation was highly significant. In the light of the above, it is highly warranted that proper control measures may be insisted to safe guard our coconut plantations from mite pest on emergency basis.

Biological studies on *A.guerreronis* enabled to encounter two nymphal stages followed by subsequent quiescent stages. Both the nymphal stages were active feeders of meristematic zone resulting in nut fall during peek population period. Life history studies at a temperature of 27$\pm$ 1^{0}C and RH ranging from 75-80 % showed that the mite took an average of 10.5 days for the completion of its life cycle. This period was found varying to 1-2 days depending on the temperature provided in studies of earlier workers (Mohanasundaram, 2000., Nair et al . , 2000).

Ever since the mite has appeared in Kerala in 1998, various control measures have been practiced from time to time by various government and private agencies. Among these, chemical methods though practiced widely as immediate remedy, it has not been advocated by many because of its environmental hazards and danger

of using heavily sprayed tender coconuts for human consumption. Therefore, natural predators of *A`.guerreronis* and fungal and bacterial pathogens were on the lookout (Hall *et al.*, 1980., Espinosa and Carrillo, 1986., Cabrera and Dominguez, 1987). Several natural enemies of *A. guerreronis* have been encountered on infested coconuts collected from the field. Among these the predatory mites *Amblyseius* sp. *T. pyri*, *Bdella* sp., *Agistemus industani*, *Eustigmaeus* sp., *Cheyletus* sp. and insect predators like staphylinid beetle, *Tubulifera* sp. and one unidentified insect larva were found to be potential enemies of the mite. Among the six species of acarine predators located, during the study feeding specificity of *T. pyri* was studied in detail because its potential. Statistical analysis on feeding potential this mite on *A.guerreronis* showed that *T.pyri* could consume, the egg, immature and the adult stages of the pest. However, rate of consumptions of *T.pyri* considerably vary among the different stages of the pest mite. Accordingly, the most preferred food for all predatory stages were the eggs of *A.guerreronis*, while the adult prey stage was found to be the least preferred diet.

In general these studies showed a short life cycle for the mite. A well established colony of *A.guerreronis* may contain more than 1000 individuals per cm/sq of the meristematic area in Kerala conditions and of these 30-40 % can be located as productive female. An adult female

lays 60-72s eggs within the period of her life. Therefore the mite can establish high population within a period of two weeks time under normal climatic condition. Frequent raise in temperature within few degree centigrade often enhanced mite population as experienced in few localities during the present study. Probably this would have been instrumental to the recent coconut mite outbreaks in Kerala and Tamil Nadu.

SUMMARY

SUMMARY

The present study was initiated with an objective to provide information on the major acarine pests associated with some economically important crops grown in Kerala, India. For this purpose, a total of 43 species of plants have been surveyed representing vegetables, fruit crops, tuber crops, oil yielding crops and garden crops from different localities of Malappuram, Thrissur and Kozhikode districts. The thesis comprises a general survey of phytophagous mites. During the survey a total of 37 species of phytophagous mites were collected of which nine of them were recognised as new host records and 10 species were recorded for the first time from Kerala.

The current study has been mainly focussed on four crop plants such as *M. deeringiana* (velvet bean), *S. jambolanum* (jamba), *M. esculenta* (cassava) and *C. nucifera* (Coconut) representing a vegetable, a fruit crop, a tuber crop and a plantation crop respectively. The study involved analysis of feeding and breeding activities of the important species of mites and their injurious effects on population and distribution of the plants concerned.

T. ludeni collected from velvet bean was found inhabiting on the leaves of the host plant. The mite usually fed from lower surface of the leaves where they produced network of silken threads. Feeding activity

of the mite caused tiny chlorotic spots on the leaves in the beginning which later on turned yellow and overlapped with each other imparting a brown colour to the leaf. Observation on the breeding biology of this mite has indicated a larval and two nymphal stages in between egg and adult stages. The duration of ontogenic development required 11 to 12.6 days for completion. Analysis of the population dynamics of the species in the field has revealed positive correlation of the population with temperature and negative correlation with relative humidity and rain fall. Consequently, peak population was recorded during summer months.

Feeding and breeding activities of *T. cinnabarinus* on cassava resembled those of *T. ludeni* on velvet bean. Here also mite infested leaves of the plant showed severe chlorosis. Gradually the leaves, wilted, dried and fall off. Webbing with silken threads was a characteristic feature of red spidermite. *T. cinnabarinus* spin web over the leaves of the plant upon which they feed and at times the entire plant may be covered with webbing. Laboratory studies revealed that *T. cinnabarinus* took 10.5-12 days for the completion of its postembryonic development. Analysis of seasonal population revealed a positive correlation with temperature and negative correlation with relative humidity. The peak population was recorded during February, March and April months of the year 1999.

A. Tenuipalpid mite, *R. macfarlanei* has been found inhabiting the leaves of fruit tree *S. jambolanum*. Feeding activity of the mite produced damage to leaves leading to defoliation. Older leaves were attacked more frequently. Ontogeny of this mite involved egg, larva, protonymph, deutonymph and adult stages. The duration required for the completion of post embryonic development of the species was found to be 15.5-16 days. Each active instar was followed by a quiescent period and moulting to the next stage. Analysis of the population dynamics of *R. macfarlanei* has revealed highest population density during February-March on older leaves than younger ones.

The coconut mite, *A. guerreronis* affected the developing nuts. The individual fed on meristematic zone beneath the tepals on each nut. Mite feeding induced triangular white patches on the nuts. Later on the patches extend in length and turned brown in colour. This is followed by drying of the husk which turned gray in colour with cracks and crevices. Such nuts often exhibited distorted appearance and reduction in size. Some of the nuts fall off few weeks after the invasion by the mite. Apart from reduction in volume, the affected nuts showed reduction in weight of copra content on statistical analysis. Investigation on developmental biology of the mite has indicated the existence of two nymphal instars between eggs and adult stages. The

duration for the completion development was found varying from 10 to 12 days at a temperature of 28±1°C and a Rh of 68-70%.

Population density of *A. guerreronis* was assessed on 2-4 old nuts through biweekly observation by enumerating the number. Data on average population of mite was recorded at monthly intervals along with monthly average temperature, relative humidity and rain fall. Data showed that population of mite positively correlated with temperature with significant influence and RH and rain fall were not found significantly influenced the population density of the mite. Crop loss estimated due to the infestation by *A. guerreronis* revealed 32% reduction in the weight of copra.

Several natural enemies of *A. guerreronis* have been encountered on infested coconuts collected from the field. Among these, the predatory mites *Amblyseius* sp., *T. pyri, Bdella* sp., *Agistemus industani, Eustigmaeus* sp., *Cheyletus* sp. and insect predators like staphylinid beetle, *Tubulifera* sp. and one unidentified insect larva were found to be potential enemies of the mite. Among the various predators encountered during the study, the feeding activity and potentiality of *T. pyri* were carried out under laboratory conditions of temperature 26±1°C and a relative humidity of 60-70%. This study revealed that feeding potentiality of the predator towards various life stages of pray mite species was different.

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