DISTRIBUTION OF THE SPINDLE BUG OF ARECANUT *CARVALHOIA ARECAE* MILLER AND CHINA IN KERALA, ITS BIOECOLOGY, SUSPECTED ROLE AS THE VECTOR OF YELLOW LEAF DISEASE AND CONTROL

BY

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THESIS

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DECLARATION

I hereby declare that this thesis entitled "Distribution of the Spindle Bug of Arecanut, *Carvalhoia arecae* Miller and China in Kerala, its bioecology suspected role as the vector of yellow leaf disease and Control" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship, or other similar title, of any other University or Society.

STANLEY A. JACOB

Place: Vellayani
Date : 28th December 1989

CERTIFICATE

Certified that this thesis, entitled "Distribution of the Spindle Bug of Arecanut, *Carvalhoia arecae* Miller and China in Kerala, its bioecology suspected role as the vector of yellow leaf disease and Control" is a record of research work done independently by Sri. STANLEY A. JACOB under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship, or associateship to him.

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INTRODUCTION

1. INTRODUCTION

In India arecanut, Areca catechu L. is grown along the narrow coastal belt extending from Kutch to Maharashtra, Karnataka, Kerala and in the east coast Tamil Nadu, Andhra Pradesh, Orissa, Tripura, Bengal and Assam, with larger concentration in south west India (Rao, 1982). India is the largest producer of arecanut contributing 88 per cent of the world production. According to an estimate done in 1980-81 around 33 per cent of the area under the crop in India was found in Kerala and 27.8 per cent of the total production of arecanut in the country was being contributed by the state (Das, 1985; Sikka, 1985). Since then considerable increase in the area, production and productivity of arecanut had taken place in the country. But it has been mainly in the states of Karnataka and Assam. In Kerala, the arecanut production had a fall during the period mainly because of the fall in productivity. The lower productivity adversely affected the returns from the crop and consequently there was a reduction in the area under areca cultivation also. This downward trend was particularly seen in Quilon, Alleppy, Trivandrum and Kottayam districts (Sikka, 1985).

The incidence of yellow leaf disease (YLD) and the spindle bug of arecanut, which arose as serious problems

in the region in recent years, were attributed as major factors causing the fall in the productivity of arecanut (Nair, 1964A; Abraham et al., 1976; CPCRI, 1976; George et al., 1985).

Thirty five to forty per cent of area under arecanut in Kerala was affected by YLD (Bopaiah, 1985; George et al., 1985). The yellowing appearing at the tips of leaflets in two or three outermost whorls extended to the middle lamina rapidly and the leaflets eventually dried up. In the advanced stage the leaves of the inner whorls also got affected. They got reduced in size, stiffened, pointed and closely bunched. The root tips turned dark and gradually rotted. Fruits turned black internally and fell off prematurely. The crown got reduced in size, yellowed, crinkled, spindle became necrotic and the tree might ultimately collapse (Menon, 1963· Rawther, 1976; Nayar and Seliskar, 1978). The YLD has partially wiped out the arecanut gardens in southern Kerala and the disease is rampant in the central and also in some pockets in the northern Kerala.

Though more than ninety insects and non-insect pests have so far been reported on arecanut, the spindle bug Carvalhoia arecae Miller and China is the worst pest of the crop. The nymphs and adults of this bug remain clustered at the top two or three leaf axils. At day time they remain

hiding and at dawn and dusk they wander over the spindle and tender leaves and feed. The necrosis and drying up of the tissues around feeding spots cause extensive damage to the leaves and crown of the palms. In the long run, retarded leaf production and stunting of the leaves were seen (Nair, 1964A). Severe infestation causes drastic reduction in the size of leaves, vigour of the palm, yield, tapering of the crown and ultimate death of the palm.

In view of the importance of YLD and C.arecae, investigation on these received the attention of many researchers in Karnataka and Kerala for long (Khandige, 1955; Pillai and Kurian, 1959; Nair and Das, 1962; Nair and Menon, 1963; Nair, 1964A; (Abraham 1970 to 1972; Sathiamma, 1972 to 1974; Abdulla Koya, 1974 to 1977; Sathiamma, 1977 to 1980) - CPCRI, 1982). Attempts were being made to establish the etiology of the disease, to evolve technologies for effective control of the pest and also to assess the role of the insect as a vector of the disease.

The etiology of the YLD was a disputed point for long. The recent findings on the association of mycoplasma like organisms (MLO) in the affected tissues and conspicuous absence of the same in the healthy tissues has led to the identification of the pathogen as the causative organism of

the disease (Nayar and Seliskar, 1978; Seliskar and Wilson, 1981; CPCRI, 1984). The control methods evolved for tackling the pest problem were partially successful and were mostly expensive.

The MLOs are known to be transmitted by bugs and leaf hoppers of the Super Order Hemiptera (Maramorosch and Harris, 1981). All the insects of this order associated with arecanut had to be screened for their involvement in the spread of disease and C. arecae was one among them. The association of the two have not been established so far. In this context investigations on the following aspects were carried out under the project:-

1. Distribution and extent of damage caused by C. arecae in major areca growing tracts of Kerala

2. Relative abundance of the pest in different seasons and its correlation with YLD, if any

3. Biology of the pest on areca palm and on the alternate hosts

4. Histological and histochemical studies of plant tissues at different intervals after feeding

5. Standardisation of the newly evolved sachet method of insecticidal application for the control of the bug

6. Comparing the recommended methods of the bug control viz. spraying the crown and filling granular insecticides in leaf axils, with the prophylactic sachet method

7. Electron microscopic examination of salivary glands and blood of C. arecae to assess its role as a vector of YLD.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

2.1.

The literature available on the systematic position of Carvalhoia arecae Miller and China, its distribution, biology, ecology, behaviour, control and on the yellow leaf disease (YLD) of arecanut, which is believed to be transmitted by insect vectors including C. arecae, have been briefly reviewed.

2.1.1. Distribution of C. arecae and the extent of damage caused by the insect to areca palms

C. arecae was first recorded from Dakshina Kannada of Karnataka State by Khandige (1955). A random survey conducted in Nedumangad taluk of Trivandrum district in 1962 (Nair, 1964 A) showed that 87.5 per cent of the areca gardens had the attack of this pest and the intensity of attack also was quite high. CPCRI (1982) observed that C. arecae was the major pest of arecanut all along the West Coast of Kerala, Karnataka and certain parts of Tamil Nadu.

2.1.2. Seasonal distribution and population dynamics

The population was reported to be high from June to October, the maximum level being in August-September (Nair, 1964 A). A survey conducted by CPCRI at two locations in Kerala, (Krishnapuram in Alleppy district and Palode in Trivandrum district) and one location in Karnataka State

(Sullia in Dakshina Kannada district) during 1976-78 showed that the intensity of the pest population in different seasons varied in the three locations. The population of C. arecae was maximum in January and November at Krishnapuram, July at Palode and February at Sullia. The population was minimum in March and April at Krishnapuram and Palode and during August at Sullia. However, statistically significant differences in the levels of population in different months were not observed at Sullia. Compared to Krishnapuram and Palode, the intensity of spindle bug population was lower at Sullia (CPCRI, 1982; Sathiamma et al., 1985A).

2.1.3. Influence of weather factors on the population of C. arecae

The variations in the population of C. arecae did not show statistically significant correlation with temperature and relative humidity. A positive correlation was noticed between rainfall and population of C. arecae (CPCRI, 1982; Sathiamma et al., 1985A).

2.2. Systematic position, biology and nature of damage caused by the spindle bug

2.2.1. Systematics

Specimens of areca spindle bug first collected by Khandige 1955, was got identified by the Govt. Entomologist,

Agricultural College, Coimbatore, South India through Miller and China in 1956. Carvalhoia was a new genus errected by Miller and China in the tribe Odoniellini of subfamily Bryocorinae under family Miridae in sub-order Heteroptera. As per the first description male and female insects were noted for the bright orange fulvus. The eyes, antennae (except basal segments), scutellum, margin of clavus close to scutellum and along claval commissure were dark brown and extreme apex of corium, cuneus and membrane were black. Head was more than two and a half times wider across eyes than long in the middle. Total length was observed as 5.8 mm for male and 6.0 mm for female.

2.2.2. Biology

Nair and Das (1962) studied the biology of C. arecae. They observed that the eggs were thrust into plant tissues singly or in pairs, visible externally by two silvery filaments projecting out and rest of its body being hidden inside the tissues. The eggs were oriented parallel to the plant surface. The eggs were oval produced at their anterior ends into a short neck, bearing at its tip an oval convex operculum. When laid they were milky white in colour, the operculum being slightly black and the neck nearly transparent. The eggs gradually turned pinkish and then reddish due to the development of the nymph inside. The eggs hatched

in nine days during February. The newly hatched nymphs, 1.07 mm in length, were very active. Moulting took place in 2 - 3 days after emergence.

The second instar nymphs were 2.6 mm long, reddish violet and green coloured. Body segments were with deep brown warts possessing hairs. The third instar nymph 2.9 mm long had rudiments of wings and warts on abdomen were more conspicuous. The fourth instar nymphs were 3.8 mm long with conspicuous wing buds and outgrowths on the body. The fifth instar nymphs were 4.4 mm long with highly protuberant eyes and the wing pads reached the third abdominal segment. Abdomen was triangular, greenish yellow and the margin and terminal three segments had reddish brown tinge. Sexes were easily distinguishable. The black colouration extended to lateral border of the sixth, seventh and whole of eighth segment in males while in females the colouration extended medially up to the fourth abdominal segment only. The abdomen in female was broader and stouter also. Nair (1964A) studied the life history of the pest and the details observed were as those observed by Nair and Das (1962). Santhakumari (1972) described the external morphology of the immature stages and adults of C. arecae.

2.2.3. Alternate hosts

Besides the areca palm, Areca catechu Linn. C. arecae has been reported to feed and breed on Areca lutescens L. and Loxococcus sp. (Nair and Das, 1962), Chrysalidocarpus lutescens H-wendl., Chrysalidocarpus madagascariensis Comores and Pemba, Pinanga sp., Areca triandra Roxb., Areca concinna Thw. (Nair, 1964A) and Elaeis guineensis (Jacquin) (CPCRI, 1982).

2.2.4. Nature of damage

Khandige (1955) observed that the bug sucked sap from tender unfolded shoots, hiding inside the angles of spindle leaf and the infested spindles which did not open easily and exhibited linear dried up patches when unfolded. Pillai and Kurian (1959) confirmed the above observation. Nair and Das (1962) observed that the bugs usually remained clustered within the top most leaf axil, moved out on to the tender leaves for feeding and returned to axil after feeding. While feeding the stylets pierced the leaf tissues, the rostrum being kept slightly bent. As soon as the leaf was pierced, a longitudinal narrow decoloured zone developed on the lamina on either side of the puncture, commencing from the point of puncture. The decolouration progressively extended longitudinally between the parallel veins, towards

either side. The bug remained feeding at a place for about 20 minutes. As a result of the feeding the cells collapsed leading to the shrinkage of these leaves. When the attack was severe, the leaves shredded, and the tree became stunted. The discoloured zone was described as water soaked areas of the affected leaves with a depression in the centre by Menon et al. (1962). They further reported that the point of damage in the creamy white leaves caused longitudinal streaks which became necrotic and dried in due course. The affected portion flaked off, leaving shot-holes. Nair and Menon (1963) found that the affected leaf streaks were secondarily invaded by fungi and occasionally the entire spindle got killed.

Nair (1963) observed that extensive patches of dead tissues appearing on the leaf buds especially towards the tip caused the failure of the leaves from growing out fully. As a result, the leaves stood erect and it gave a stunted appearance to the plants. In severe cases of pest incidence, most of the leaves were seen damaged and the condition affected the vigour of the plant markedly.

Abraham et al. (1976) reported that with severe infestation there was reduction in size of leaves, tapering of crown, loss of vigour and yield. They further observed that toxin in the saliva, injected into the tissues for

liquefying the chlorophyll content for feeding, might have resulted in the drying of lamina and development of necrotic patches. The loss of vigour of the affected palms and the consequent sickly appearance was reported by Abdulla Koya et al. (1979) also.

2.3. Control of C. arecae

Khandige (1955) and Pillai and Kurian (1959) suggested spraying of fish oil rosine soap @ 12.4 g/l of water. Menon et al. (1962) tried folidol 605, DDT, endrin, HCH (WP) for control of C. arecae and best results were obtained with endrin. Nair and Das (1962) sprayed HCH 0.2% and endrin 0.025% and found that both the treatments kept areca palms free from the pest.

Nair and Menon (1963) suggested the adoption of control measures against C. arecae according to the severity of infestation. Ekatin/endrin (one l in 100 l water), folidol (30 cc in 100 l water) or HCH 50% (200 g in 100 l water) was recommended for the control of the pest.

Nair (1964A) conducted spraying trials with ekatin 0.1%, HCH 0.2%, dimecron 0.02%, endrin 0.03%, rogor 0.1%, systox 0.02%, folidol 0.02% and found that all the treatments were effective for two weeks and recommended monthly sprayings with one of the insecticides for effective control of the pest.

Three granular insecticides viz. phorate, carbaryl and thiodemeton were tried against C. arecae by Abraham et al. (1976). The granules were put in the leaf axils. The population of the bug in all the treatments were significantly lower compared to that of control. Hence the application of any of the three insecticides in the leaf axils, once in four months, was recommended for the control of spindle bug in areca palm.

Abdulla Koya et al. (1979) tried the granules of lindane, Carbaryl + lindane (Sevidol), carbaryl, mephosfolan, thiodemeton and quinalphos in the field against C. arecae. All the insecticides gave good control of the pest. Quinalphos was superior to mephosfolan and thiodemeton.

Granules of phorate, lindane and quinalphos tested in field showed that the former two insecticides applied in the inner most two or three leaf axils @ 10 g per palm, at three month intervals, gave significant control of the pest (CPCRI, 1982; Sathiamma et al., 1985B). Considering the cost factor lindane was recommended as the best.

2.4. Yellow leaf disease (YLD) of arecanut and its transmission through vectors

2.4.1. Distribution of the disease in Kerala

The disease first appeared in Meenachal, Moovattupuzha and Chalakkudy areas of erstwhile Travancore State following

a heavy flood (Nambiar, 1949). Later the disease spread to other parts of Kerala and Malnadu areas of Karnataka where it was called "Chandiroga" (Dastagir, 1963). The malady was not fatal but was debilitating in nature.

By late fifties the disease was reported to have spread throughout Kerala with the maximum incidence in Quilon district where 90% of the palms were found affected in some areas (RARS, 1960). About 80% of the palms planted in a virgin soil at Palode in Nedumangad taluk contracted the disease within four years and spread did not follow any definite pattern (Rawther, 1982). A stratified multistage random survey, in the entire areca growing tracts of Kerala State and Chickmagalore district of Karnataka State from where the YLD has been reported, was conducted by the CPCRI in collaboration with the departments of agriculture, Kerala State and horticulture, Karnataka State during 1976-77 to estimate the intensity and extent of the disease (George et al., 1985). They found that 36% and 28% of the arecanut area in Kerala and Chickmagalore district of Karnataka State respectively, were affected by the disease. The disease was found to be very severe in the southern districts of Kerala viz. Trivandrum (72%), Quilon (75%), Kottayam (94%) and Idukki (97%) and gradually declined towards the north. They observed that yield reduction went to the extent of 50% over a period of three years immediately following the disease incidence.

2.4.2. Symptoms of yellow leaf disease of areca palm

The first symptom noted was the yellowing at the tips of leaf lets in two or three leaves of the outermost whorl. The yellowing gradually extended to the middle lamina. The chlorosis caused by YLD could be distinguished from other types of yellowing by the typical abrupt demarcation between the green and yellow regions in the diseased leaf. In the diseased portion the tissues adjacent to the veins remained green. The tips of the chlorotic leaflets dried up gradually. In the advanced stage, leaves got reduced in size, stiff, pointed and closely bunched. The root-tips of affected palms turned dark and gradually got rot. Fruits turned black and fell off prematurely (Rawther et al., 1982).

Nayar (1968) observed multinucleate cells, disturbed tissue differentiation and blockage of palisade cells with dark brown pigments in the affected leaves. Degeneration of phloem region, disturbed medullary rays and accumulation of starch grains in the diseased leaves indicated impaired translocation. Nair (1976) noted blocking of xylem vessels of the older leaves of diseased palms, degeneration of cortex and presence of tylose in the xylem of the roots.

2.4.3. Etiology of the disease

In a review of the literature on the etiology of the disease, Rawther et al. (1982) concluded that though pithiaceous fungi could be isolated from diseased roots and leaves none of them proved pathogenic to areca palm. Bacterial streaming was observed with diseased root tissues and the Pseudomonas sp. could be identified. But the bacterium did not produce any symptom on the inoculated areca seedlings. Chromatographic studies indicated the presence of some proteins or their subunits in diseased tissues. Serological investigations gave indications of precipitation reaction and antibody formation suggesting the involvement of a virus-like agent in the disease. But the electron microscopic (EM) studies failed to show the presence of any virus particle in the diseased tissues.

Nayar (1971 and 1976) cultured mycoplasma-like organisms (MLO) from bits of diseased yellow leaf of arecanut. EM studies (Nayar and Selviskar, 1978; Selviskar and Wilson, 1981) also showed the presence of MLO in the young sieve elements of YLD affected areca palms. Constant association of MLO in the phloem tissues of YLD affected palms and conspicuous absence of the same in the tissues of healthy palms were reported recently (CPCRI, 1984). The presence

of MLO was observed in the tender leaf tissues and root of YLD affected palms also (CPCRI, 1986). MLO could be observed in YLD affected palms even during the period when external symptoms were masked. But injection of the trees with antibiotics did not show any improvement on the diseased palms (CPCRI, 1987).

2.4.4. Vectors of the disease

2.4.4.1. Mites

Khandige et al. (1957) reported association of mites with yellowing which was identified as YLD. But Menon (1960) attributed the above yellowing to the mite injury and concluded that mites did not play any role as a vector of YLD.

2.4.4.2. Nematodes

Nair (1964B) observed the presence of nematodes Meloidogyne javanica (Treub.), Helicotylenchus sp. and Tylenchorhynchus sp. in the root zone of YLD affected palms and indicated its involvement in the disease. Among 22 genera of plant parasitic nematodes isolated from the root zone of healthy and diseased palms, Radopholus similis (Cobb.) Throne was the predominent species and it was present in 111 out of 218 root samples examined. Koshy et al. (1976) could not find any correlation between the population of R. similis and the yellow leaf disease.

2.4.4.3. C. arecae and plant hoppers

Nair and Menon (1963) observed that adult C. arecae, in all probability, was a vector of YLD of arecanut palm. Inventory of insects in YLD affected gardens revealed the presence of C. arecae, Proutista moesta Westwood (Homoptera : Derbidae) and Oliarus sp. (Homoptera : Cixiidae). These were suspected as vectors of MLO (CPCRI, 1984). The leaf hopper, Sophonia greeni Dist. (Homoptera : Cicadoidea) which was recorded as a new pest on arecanut was also suspected to be a vector of YLD (CPCRI, 1985 A). In an observational trial it was seen that seedlings kept in insect proof cage did not develop the disease symptoms while those kept in the open contracted the disease (CPCRI, 1986). The finding indicated the involvement of the insects in the transmission of the disease. Typical MLOs were observed in the salivary glands of P. moesta fed on diseased palms, giving 30, 31, 36, 37, 38 and 41 days as aquisition and incubation periods (CPCRI, 1988). But the transmission studies have not so far proved the role of the insect as a vector of the disease.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

3.1. Distribution of C. arecae in the State

Based on the topography, climate, soil, sea water intrusion and land use pattern, Kerala has been divided into five agroclimatic zones, (1) southern, (2) middle, (3) northern, (4) hill and (5) problem zones (NARP, 1985). The distribution of C. arecae in Kerala was studied adopting stratified two stage sampling procedure. The above NARP regions were taken as the strata. In each stratum nine locations were purposively selected based on the area of the crop. From each location 5 to 21 palms were selected based on proportional allocation. Incidence of yellow leaf disease and the fauna available on the crown of the marked palms were recorded (Fig. 1).

The number of C. arecae (immature stages and adults), feeding marks caused by the insect and other arthropod fauna available were recorded by direct counting. The data were entered in a proforma (vide. Appendix I).

Total number of leaves on each palm, the extent of yellowing and necrosis on outer four leaves and the condition of the crown were recorded. From the data the indices of yellow leaf disease (YLD) were calculated following the method of George et al. (1980). The survey was done during

Fig. 1. Locations covered in the survey of the incidence of *C. arecae* and YLD in Kerala

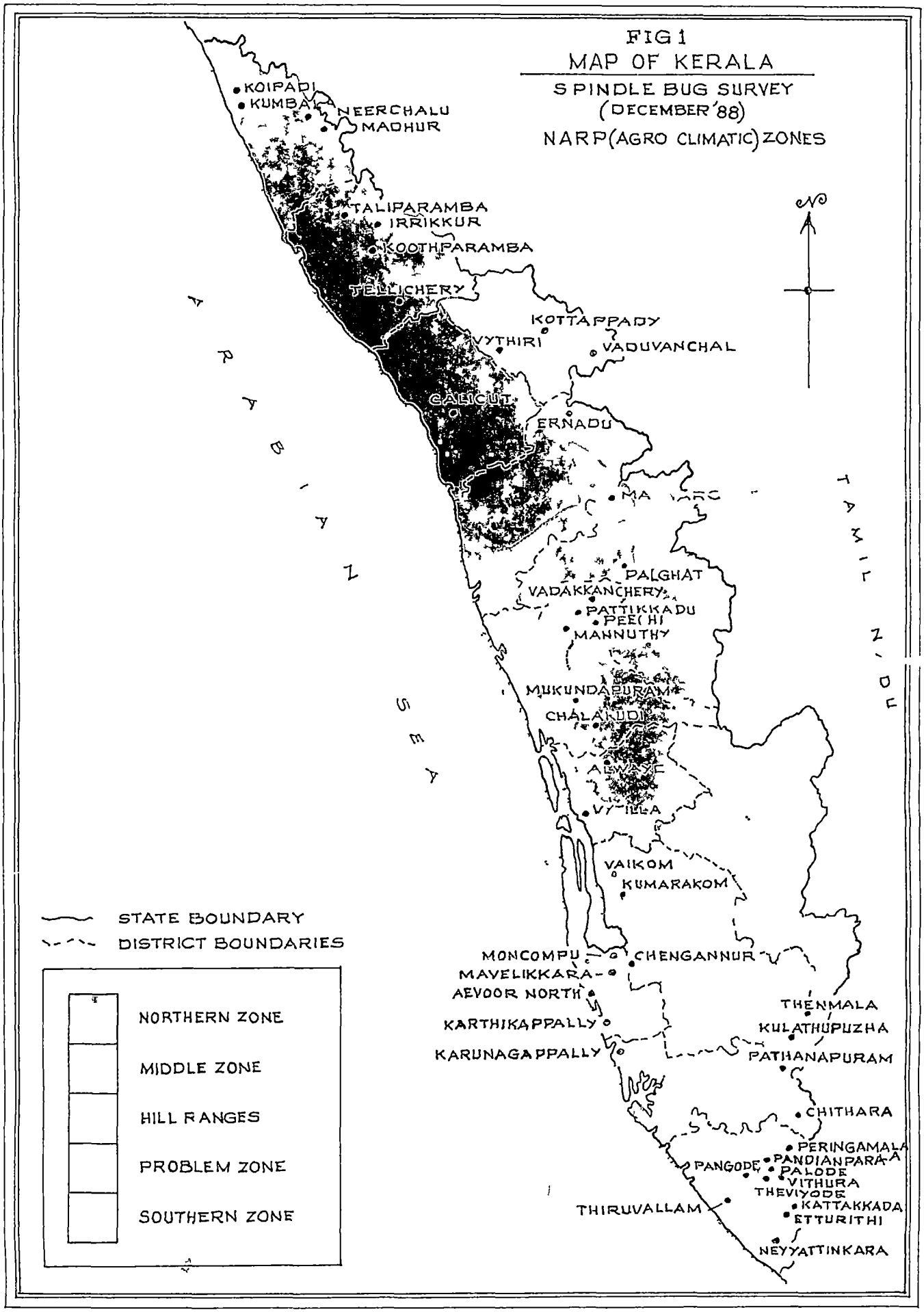


FIG 1
MAP OF KERALA
SPINDLE BUG SURVEY
(DECEMBER '88)
NARP(AGRO CLIMATIC) ZONES
KOIPADI
KUMBA
NEERCHALU
MADHUR
TALIPARAMBA
IRRIKKUR
KOOTHPARAMBA
TELLICHERY
KOTTAPPADY
VYTHIRI
VADUVANCHAL
CALICUT
ERNADU
PALGHAT
VADAKKANCHERY
PATTIKKADU
PEECHI
MANNUTHY
MUKUNDAPURAM
CHALAKUDI
VYTILLA
VAIKOM
KUMARAKOM
MONCOMPU
CHENGANNUR
MAVELIKKARA
AEVOOR NORTH
KARTHIKAPPALLY
KARUNAGAPPALLY
THENMALA
KULATHUPUZHA
PATHANAPURAM
CHITHARA
PERINGAMALA
PANDIANPARA
PANGODE
PALODE
VITHURA
THEVIYODE
KATTAKKADA
ETTURITHI
THIRUVALLAM
NEYYATTINKARA
ARABIAN SEA
TAMIL NADU
STATE BOUNDARY
DISTRICT BOUNDARIES
NORTHERN ZONE
MIDDLE ZONE
HILL RANGES
PROBLEM ZONE
SOUTHERN ZONE

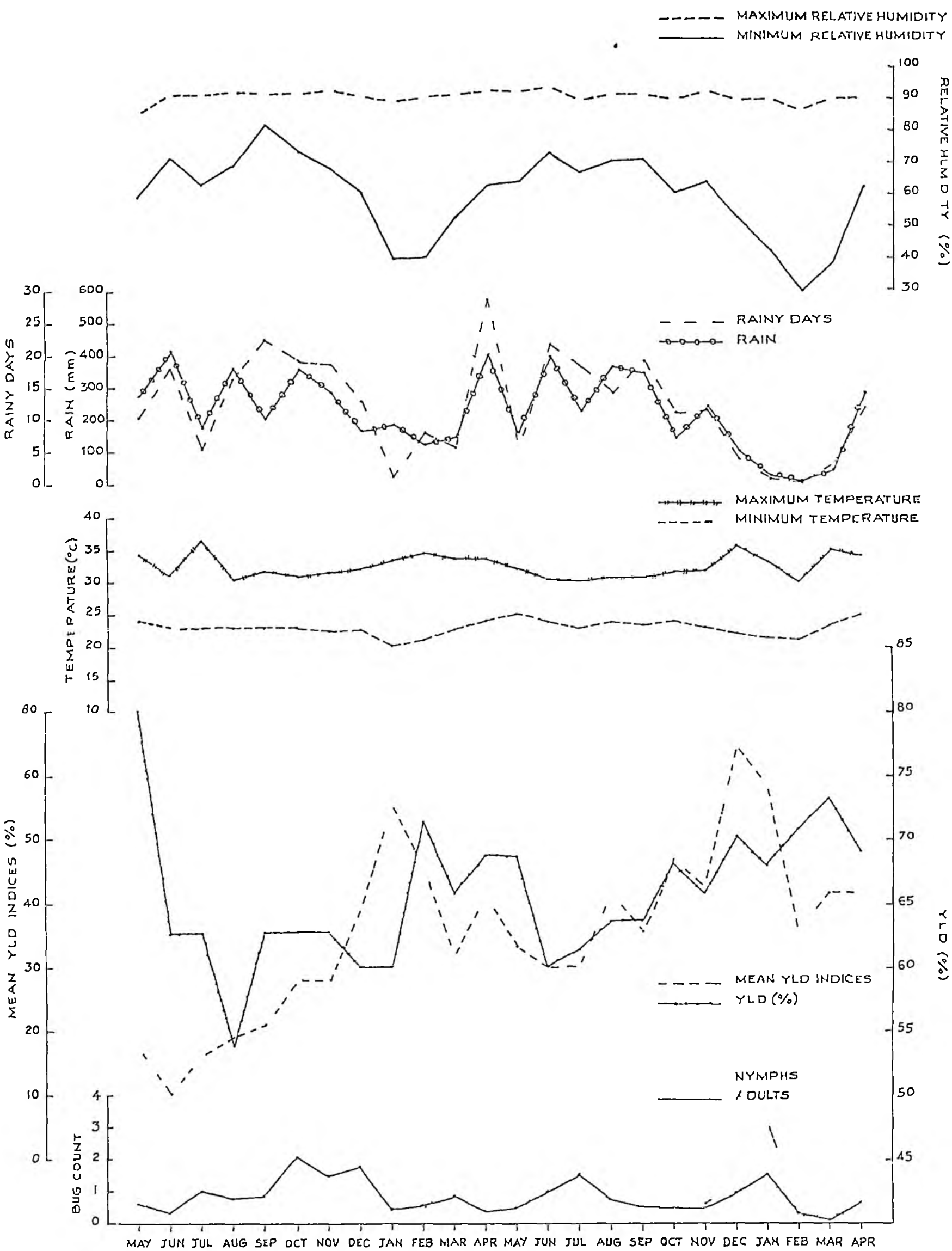
December/January when the incidence of disease and the pest population were reported to be generally high (Rawther et al., 1982; Sathiamma, 1985A).

3.2. Seasonal occurrence of C. arecae

To study the association between the YLD of areca palm and the population dynamics of C. arecae the occurrence of the pest and the incidence of the disease were recorded at monthly intervals in three gardens each of Palode and Vithura villages of Nedumangad taluk (an area known as severely affected by YLD), two gardens of Kattakkada village (representing moderately affected area), three gardens from Neyattinkara village and two gardens of Thiruvallam village (both coming in apparently disease-free regions). The data were collected and recorded as detailed in para 3.1. The feeding mark count on the youngest leaf of each palm was recorded and the leaf was marked to avoid the same being included in succeeding observations and to ensure that the feeding marks caused during the month preceding the period of observation alone were included in each observation. The data were recorded for 24 months from May 1987. The meteorological data in different localities were also collected for assessing the influence of climatic factors on the population of the insect (Fig 2).

Fig. 2. Seasonal abundance of C. arecae and incidence of YLD and weather parameters between May 1987 and April 1989 at Palode

FIG 2


MAXIMUM RELATIVE HUMIDITY
MINIMUM RELATIVE HUMIDITY
RELATIVE HUMIDITY (%)
100
90
80
70
60
50
40
30
RAINY DAYS
RAIN
RAINY DAYS
RAIN (mm)
30
25
20
15
10
5
0
600
500
400
300
200
100
0
MAXIMUM TEMPERATURE
MINIMUM TEMPERATURE
TEMPERATURE (°C)
40
35
30
25
20
15
10
85
80
75
70
65
60
55
50
45
MEAN YLD INDICES
YLD (%)
MEAN YLD INDICES (%)
YLD (%)
80
60
50
40
30
20
10
0
NYMPHS
ADULTS
BUG COUNT
4
3
2
1
0
MAY JUN JUL AUG SEP OCT NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC JAN FEB MAR APR

3.3. Correlation studies

The association between the weather factors and the population of C. arecae as well as the extent of damage was assessed by estimating the coefficients of correlation. Similarly the yellow leaf disease was correlated with the population of the insect and weather parameters.

3.4. Biology of C. arecae on different host plants

Biology of C. arecae on A. catechu, A. triandra, Pinanga sp., C. lutescens, E. guineensis and Cyrtostchys renda (Blume) were studied in detail.

3.4.1. Raising the host plants in pots

Pot mixture was prepared by mixing sand, cowdung and soil in 1:1:2 ratio and 35 cm earthen pots were filled to $3/_4$th the height with the mixture. Nine month old seedlings/ suckers of the host plants were planted in the above pots at the rate of one per pot. Around 150 potted plants of each host species were raised and maintained in green house giving uniform fertilization and irrigation.

3.4.2. Mass culturing of the insect

Adult bugs collected from A. catechu grown in field were used for starting the culture. Small batches of 3 to 5

Plate I. Rearing of *C. arecae* in green house.

1. nylon sleeve enclosing the spindle of the leaves

PLATE I

male-female pairs were confined on the emerging spindle leaf of a potted seedling using close meshed nylon net sleeves (10 to 15 cm broad and 50 to 75 cm long, suiting the size of the spindle as shown in Plate 1). In about 10 days of confinement, first instar nymphs could be obtained from the leaf folds or axil around the spindle leaf. When all the tender leaflets on the potted palm dried up, by the feeding of the insect, the nymphs were transferred to fresh seedlings in pots and were kept caged. The adults emerged in 15 to 20 days and they were used for further multiplication.

3.4.3. Handling of first instar nymphs

First instar nymphs, soon after their emergence had to be individually transferred on fresh host plants for studying the biology of the insect. Being very soft bodied and fragile, a device fitted with a 'vacuupet' was used for collecting and transferring the nymphs from plant to plant avoiding any mechanical injury. The apparatus consisted of a transparent polythene tube 30 cm long and 6 mm diameter fitted to a vacuupet. The mouth of the vacuupet was covered with a bit of muslin cloth before fixing the tube to prevent the nymphs from getting sucked into the bulb. Through the distal end of the polythene tube the nymphs could be drawn in by letting air into the bulb of the vacuupet and by forcing

air out of the vacuupet the nymph sucked into the polythene tube could be placed on any desired site.

3.4.4. Assessment of incubation period

Eggs thrust into the tissues of tender leaves, leaflet axils, or leaf tips of plants exposed for egg laying could be identified by the silvery egg filaments projecting out. The plants intented for egg laying were daily examined and when eggs were observed on a plant the same was removed and kept caged without the bugs. Thus it was ensured that the eggs laid on the same day alone were present on each plant. The dates of emergence of the nymphs from each plant were recorded and from the data the mean and range of incubation period could be obtained.

3.4.5. Rearing nymphs of C. arecae on different host plants and ascertaining duration of different instars

The potted host plants were thoroughly cleaned to remove predators like ants and spiders. One freshly emerged first instar nymph was then introduced into the leaf axils of each plant with the help of the device described in para 3.4.3. Three topmost leaves including the spindle leaf of each plant were covered with the nylon net sleeve. The nymph was daily examined for moulting if any. The exuvium could be

seen sticking to the spindle leaf or leaf axil and after recording the moulting, the same was removed so as to avoid confusion in recording subsequent moults. The observation was continued till the nymphs moulted as adults. From the data recorded, the duration of different nymphal instars could be assessed. Two generations of C. arecae were raised on each host plant.

High moisture was found essential for proper moulting and survival of the immature stages of the insect. Water was hence sprayed on the crown of the plant 2-3 times daily using a hand atomiser.

Special conditions had to be satisfied for the successful rearing of the insect on different host plants. In the case of C. lutescens dense clusters having a number of tender leaves were found essential for the feeding, survival and completion of nymphal instars. In the case of E. guineensis (oil palm) the bug laid eggs only on young palms and seedlings grown in the field. Hence they could not be reared in the green house. The breeding was restricted to the rainy season when moist, soft and succulent spindles were available. On C. renda, the sealing wax palm, the bugs did not breed in green house though they fed on it and survived for 5 to 10 days.

3.4.6. Biometrics of the immature stages and adults of C. arecae

About fifteen numbers of each nymphal instar and adults of C. arecae were collected from each host species during rearing and they were preserved in five per cent formalin. Length and width of the body and antennal length were measured using a calibrated stereozoom binocular microscope. Length and width of the eggs laid by the insect reared on different hosts also were similarly recorded.

3.5. Assessment of the nature of damage caused by C. arecae

The gross damage done by the pest was observed in detail in the areca palms of the infested areas of farm attached to the Central Plantation Crop Research Institute (CPCRI), Palode and of the nearby farmers' fields. Histological and histochemical changes in the leaf caused by the feeding of the insect also was studied.

3.5.1. Histological changes in the damaged portion of areca leaf caused by C. arecae

Adult bugs, starved overnight, were confined singly on leaflets of newly emerging leaves of small potted areca palms using glass vials and cotton plugs. When water soaked lesions were formed on the leaflet due to the feeding, the bug was moved on to a fresh area of the leaflet. Each feeding

mark was labelled noting the time of formation of the injury. This facilitated the collection of leaf tissues at different intervals after the occurrence of injury. The feeding spots together with portions of the healthy area around were collected at 0.25, 0.5, 1, 2, 4, 6, 8, 10 and 120 hours after the formation of the lesion. Hand sections of the material were taken and the sections were preserved in 5% formalin-acetic acid alcohol (FAA) fixative. They were later washed with distilled water to remove FAA. The tissues were dehydrated by passing through a graded series of ethanol (50, 70 and 95) and stained in 0.5% fast green for 30 seconds to 4 minutes (Jensen, 1962). The stained sections were cleared in a mixture of clove oil, absolute alcohol and xylene. The mixture was changed twice. The processed and fresh sections were mounted in glycerine jelly and examined under a microscope. The selected slides were photographed using a Nikon Optiphot microscopic camera (Microplex UFX II).

3.5.2. Histochemical studies of the leaf tissues damaged by *C. arecae*

The localisation of proteins, lipids, starch and tannins in tender areca leaves damaged by *C. arecae* was studied through histochemical analysis.

Proteins were located using filtered amido black stain (Weime, 1959). Fresh freehand or fixed and microtomed

sections of the damaged tissues of leaf were washed in 2% acetic acid for 5 minutes and then washed in distilled water.

The stained material was mounted temporarily on slides in glycerine jelly and photographed. Proteins in the tissues appeared blue.

Lipids: The sections were placed in absolute alcohol for 3-5 minutes and subjected to occasional shaking. They were transferred to sudan black-B dye (Chiffelle and Putt, 1951). After thorough washing for 3-5 minutes with distilled water, the sections were mounted in glycerine jelly and photographed. Lipids had a violet blue colour.

Starch: Sections were kept in IKI solution (iodine 0.2 g, potassium iodide 2 g, distilled water 100 ml) (Johansen, 1940). The starch turned blue to black within a few minutes. Those sections were mounted in glycerine jelly and were photographed.

Tannins: Sections were treated in Lugol's solution (iodine 4 g, potassium iodide 6 g and distilled water 100 ml) and a drop of 10% ammonium hydroxide was added to it (Gopinathan and Ananthakrishnan, 1985). Tannins appeared in bright red colour and the sections were photographed after mounting in glycerine jelly.

3.6. Insecticidal control of C. arecae

Different insecticides and different methods of application were evaluated through field experiments for the control of C. arecae.

3.6.1. Raising the crop for the experiments

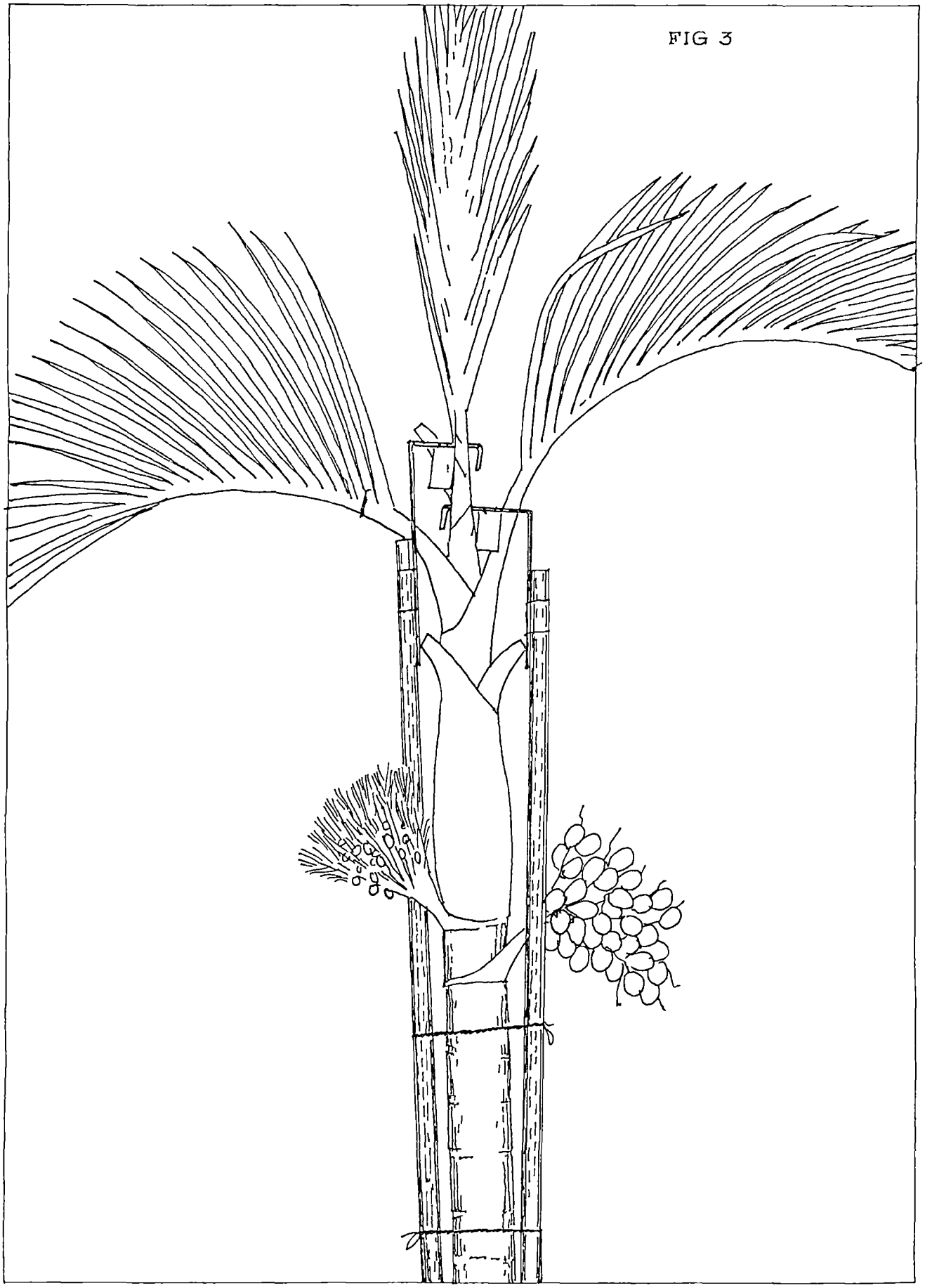
Nine month old seedlings of South Kanara variety of areca were planted giving a spacing of 2.7 m x 2.7 m in the farm attached to CPCRI Research Centre, Palode. The crop was grown in an area of 0.12 ha and was maintained as per the normal package of practices recommended by CPCRI (1985B).

3.6.2. Standardisation of the use of phorate sachets for preventing the incidence of C. arecae on areca palms

In a pilot study it was observed that perforated polythene sachet (5 x 3 cm), each containing 2 g of 10% phorate granules, effectively checked the damage done by C. arecae on areca palms (Jacob, 1985). To find out the optimum quantity of pesticide per sachet and optimum number of sachet per palm and the persistence of the efficacy of the insecticide under field conditions an experiment was carried out in the farm attached to the CPCRI, Palode. The sachets were prepared from 300 gauge polythene tube of 3 cm

Fig. 3. Thotta - device for placing sachets of phorate in the leaf axils of tall palms

FIG 3



diameter cut to the size 5 x 3 cm and one end was heat sealed. After filling the requisite quantity of pesticide the open end of each sachet was also heat sealed (Plate 2A). The sachets were placed in the top leaf axils and tied with nylon thread to the adjacent leaf petiole after making five pin pricks for perforating it (Plate 2B). The sachets were elevated to the top leaf axils as and when new leaves emerged in the palm.

In the case of tall palms, a sachet placing device (thotta) made of bent G.I. rod 10 mm dia. and 30 cm long fixed to a reed pole 2.5 m long as shown in Fig. 3 was used. The insecticide filled and perforated sachet was tied to the centre of the G.I.rod. The 'thotta' was hung in such a way that the sachet got placed in the required leaf axil. The lower end of the pole was tied to the stem below the level of the crown using a piece of coir. The sachet could be conveniently elevated to the upper leaf axils, as and when new leaves emerged in the palm, by lifting the 'thotta'.

3.6.3. Treatments

Nine treatments with varying quantities of the insecticide in each sachet and varying the number of sachet per palm, as detailed in Table 18, were included in the experiment. The experiment was laid out in the field in randomised block design (RBD) with 10 replications for each treatment. Each replication consisted of one areca palm. The experiment was carried out on three year old areca palms.

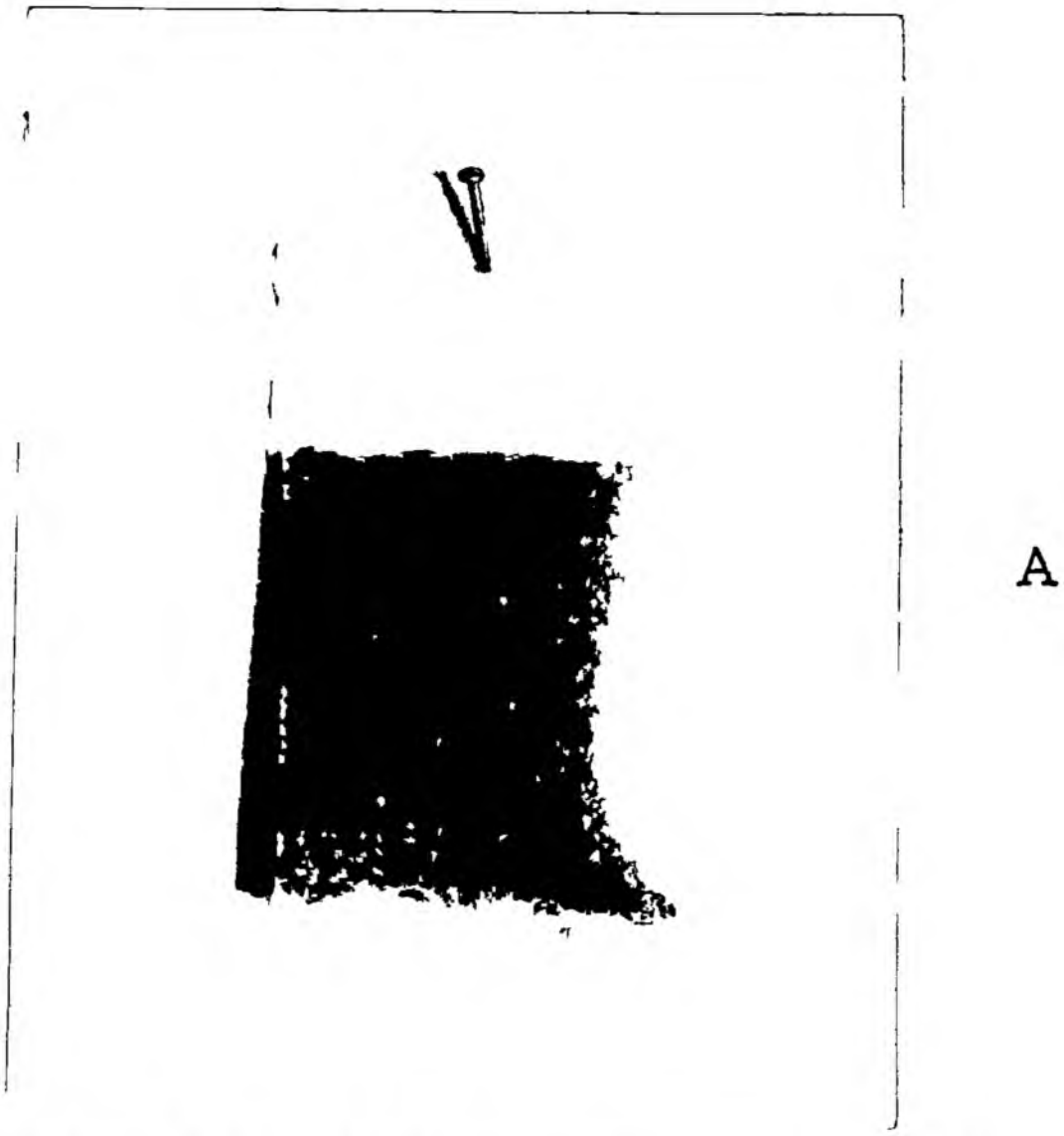
Plate II. Control of *C. arecae* using phorate in sachets

A. sachet containing phorate granules

B. phorate in sachets placed in leaf axils

1. sachet placed in first and second leaf axils

PLATE II



A

B

3.6.4. Assessment of treatment effect

Observation on the bug population in each replication and feeding marks were recorded at monthly intervals. Feeding marks on the newly formed leaf of each palm alone were recorded in each observation. The data were subjected to statistical analysis.

3.6.5. Evaluation of different insecticides and methods of application (spraying, leaf axil filling with granular formulations and the placement of granules in sachet) for the control of C. arecae

The comparative efficacy of different methods of insecticidal applications (foliar spray, filling leaf axil with granules and placing granules in sachets at leaf axil) and of different insecticides (HCH 0.2%, endosulfan 0.05%, fish oil rosine soap 5% and neem cake suspension 5%, phorate 10G, carbofuran 3G) were evaluated against C. arecae in a field experiment. There were eight treatments in the experiment (vide Table 22). Randomised block design was adopted for the experiments and each treatment was replicated on 16 palms. All the treatments except phorate in sachets were repeated once in two months. The phorate sachets were kept unchanged for eleven months though they were elevated to

upper axils when new leaves were formed. The results of the experiment were assessed as described in para 3.6.4.

3.7. Assessment of the impact of C. arecae incidence on the growth of young areca palms

To assess the extent of damage done to the palm by spindle bug, seedlings completely protected from bug using phorate in sachets were compared with seedlings infested by the bug. One hundred and forty seedlings were raised and maintained in the field as described in para 3.6.1. Half of the palms were kept free from bug incidence using phorate sachet (two numbers each with 0.2 g phorate a/i), changed at intervals of eight months after treatment. At the end of five years vigorous and non-vigorous palms could be distinctly identified in the protected and unprotected lots of palms. The bug population, height and girth of palms, number, length of leaves and length of leaflets of protected and unprotected palms in vigorous and non-vigorous categories were assessed separately for estimating the effect of pest incidence on the general growth of the palms. The data were subjected to statistical analysis.

3.8. Assessment of the association of C. arecae with mycoplasma-like organism (MLO) and yellow leaf disease (YLD) of areca palm

The areca spindle bug C. arecae was suspected to be a vector of the YLD of the areca palms. The histological

examination of the salivary glands and blood of the insect under electron microscope (EM) was done for confirming the role of the insect as a vector of YLD. The salivary glands and blood are known to be the principal reservoirs of disease causing organism in many sap feeding insect vectors.

3.8.1. Preparation of C. arecae for EM studies

The time taken by the bug to acquire, adapt, incubate, multiply and disseminate the MLO, if any, was not known. Therefore salivary glands of the bugs collected at different intervals of habitation and feeding on the diseased palms had to be examined. For this newly emerged adults were held captive in nylon net sleeves on the spindle leaf of palms confirmed to be affected by the yellow leaf disease. The bugs exposed on YLD palms for 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32 and 33 days for feeding were separately fixed in 2.5% gluteraldehyde in 0.05 M phosphate buffer (pH 7.4) having 0.17 M sucrose, taken in glass stoppered vials.

Processing of salivary glands and EM examination

The fixed insects (para 3.8.1) were dissected in the fixative and the salivary glands were excised. The air, trapped in the tissues, was removed by applying mild vacuum through a pump. The fixative in the vial was replenished and held at $4^{o}C$ for 4 h. Then the fixative was decanted and

tissues were washed in several changes of 0.05 M phosphate buffer. The samples were post fixed in 1% osmic acid (OSO_4) in 0.1 M phosphate buffer for 2 h. The tissues were then washed in three changes of buffer and three changes of cold double distilled water. Block staining of the samples was performed by changing the tissues to 2% uranyl acetate for about 2 h. The staining solution was decanted and the tissues were washed again in several changes of cold distilled water. The samples were dehydrated in graded series (25, 50, 75, 95 and 100%) of ethyl alcohol giving 15 minutes at each change and it was done at $4^{o}C$. The vials containing the samples were brought to room temperature and given two changes in 100% acetone for 30 minutes duration in each. The materials were then dehydrated and made free of water moieties. They were infiltrated in the embedding resin mixture. Acetone from the vials was decanted and replenished with a mixture of 1 vol. of Spurr's resin and 3 vols. of acetone and held in rotator for about 3 h. The mixture was decanted and a fresh resin mixture having equal amount of resin and acetone was added and held for about 3 h. This was again replenished with a mixture of 3 vols. of resin and 1 vol. of acetone and stored overnight. This was followed by infiltrating the sample in pure resin for about 2 h- offering two changes in between. Finally the samples were embedded in freshly prepared Spurr's resin poured into clean flat embedding moulds. The samples

were oriented in the moulds and the resin was polymerised by keeping them in an incubator set at a constant temperature of 70°C for 12 h. The blocks were machine trimmed in LKB Ultratome III and semithin sections of about 1 μ were made prior to ultra thin sectioning.

The 1 μ sections, made in the ultra microtome with a glass knife, were transferred to drops of 10% acetone on micro slide. The slides were heated on a 'slide warming plate' at a temperature of 80°C until the acetone in the slide evaporated and the sections got uniformly spread out. The slides were stained following the schedule of Humphrey and Pittman (1974). The staining was done in methylene blue-azure II stain at 65°C for 20 minutes. The stain filled coupling jar was kept in a water bath for this purpose. The slides were rinsed in distilled water to remove the excess stain and stained with basic fuchsin at room temperature for about 5 minutes. The slides were washed to remove excess stain and dried in a slide warming plate and examined under a light microscope.

For EM studies the machine trimmed blocks were sectioned with a glass knife at an angle of 4° in the automode set to deliver sections of 600-700 A° thick. The ribbons of sections floating in the trough were exposed to chloroform vapours briefly to remove the folds and the

stretched ultra thin sections were picked over 200 mesh uncoated copper grids. The grids were stained with 2% aqueous uranyl acetate for 20 minutes, followed by repeated washings in distilled water and staining with lead citrate for 5 minutes (Reynolds, 1963). Lead deposits from the grid were rinsed in distilled water and grids were air dried before examination under Carl Zeiss EM 109 Transmission Electron microscope.

3.8.2. EM examination of haemolymph

Mycoplasma in most insects are carried in haemolymph. Hence the haemolymph drawn from C. arecae adults which were continuously exposed on YLD affected palms for ten days, was transferred to carbon coated copper grids and examined under electron microscope for detecting mycoplasma, if any.

RESULTS

4. RESULTS

4.1. Survey on the incidence of C. arecae and yellow leaf disease in different agroclimatic zones of Kerala

The survey was carried out covering the different areca growing regions of the State with the objectives of assessing the severity of spindle bug attack on arecanut, incidence of yellow leaf disease and the association between the insect and disease, if any.

4.1.1. Southern zone

The data relating to the southern zone and the results of statistical analysis of the same are presented in Table 1. All the palms covered in the survey at Kattakkada were seen infested by the adults/nymphs of C. arecae. It was followed by Pandianpara (75% palms infested), Ettiruthi (63%), Neyattinkara (57%), Thiruvallam (57%) and Theviyode (50%). At Vithura, Palode and Pangode the infestation ranged from 45 to 31 per cent only.

Neyattinkara, Ettiruthi, Kattakkada and Theviyode had more number of trees infested by adults than those infested by the nymphs. At Pandianpara the trees infested by the nymphs were more in number and at other places the number of palms infested by adults and nymphs were the same.

Table 1. Distribution of C. arecae in Kerala (southern zone)

locations	total palms observed	percentage of palms affected by A	N	A+N	mean bug population/palm adults	nymphs	total	percentage of palms affected by f.m	mean number of f.m per palm	percentage of palms affected by YLD	mean YLD indices
Neyattinkara	21	52	38	57	1.361 (1.537)	1.819 (1.679)	3.278 (2.068)	48	77.24 (8.85)	0.00	0.00
Ettiruthi	8	57	29	63	1.972 (1.724)	2.445 (1.856)	4.814 (2.411)	71	67.47 (8.27)	0.00	0.00
Kattakkada	7	88	50	100	1.458 (1.568)	0.795 (1.340)	2.559 (1.887)	38	134.58 (11.64)	14.29	14.00
Thiruvallam	21	43	43	57	1.057 (1.434)	1.983 (1.727)	3.083 (2.021)	48	98.44 (9.97)	0.00	0.00
Vithura	11	27	27	45	0.428 (1.195)	1.230 (1.493)	1.790 (1.670)	55	13.19 (3.77)	72.73	20.66
Theviyode	10	30	20	50	0.336 (1.156)	0.609 (1.269)	1.029 (1.425)	50	47.40 (6.96)	90.00	39.63
Palode	10	30	30	40	1.265 (1.505)	1.659 (1.631)	2.815 (1.953)	90	47.08 (6.93)	100.00	52.02
Pandianpara	12	42	50	75	1.408 (1.552)	1.873 (1.695)	3.502 (2.122)	83	123.63 (11.16)	91.67	46.08
Pangode	13	15	15	31	0.416 (1.190)	0.633 (1.278)	1.155 (1.468)	85	7.92 (2.99)	46.15	39.12
F test					S	NS	NS		NS		
C.D.					0.150**						

S : significant NS : not significant ** at 1% level

Figures in parentheses are transformed values ($\sqrt{x + 1}$)

A : C.arecae adults N : C.arecae nymphs f.m : feeding marks

The adult population of C. arecae observed at different locations in the southern zone showed statistically significant variations. The highest population (1.972 bugs/palm) was observed at Ettiruthi and it was significantly higher than the population observed at the remaining locations. It was followed by Kattakkada (1.458), Pandianpara (1.408), Neyattinkara (1.361), Palode (1.265) and Thiruvallam (1.057) and the population at those locations were on par. The least population was observed at Theviyode (0.336) and it was on par with the population observed at Vithura (0.428) and Pangode (0.416).

The population of nymphs observed at different locations did not vary significantly. The highest population (2.445/palm) was observed at Ettiruthi. When compared with the occurrence of adults the population of nymphs observed at Kattakkada was low. The number of nymphs recorded at Theviyode (0.609) was the least and it was closely exceeded by the population observed at Pangode (0.633) and at Vithura (1.230). In remaining locations the population ranged from 1.873 to 1.659/palm.

With reference to the total population of C. arecae also, the worst affected location could be identified as Ettiruthi (4.814 bugs/palm) and it was followed by Pandianpara (3.502), Neyyattinkara (3.278), Thiruvallam

(3.083), Palode (2.815) and Kattakkada (2.559). The population observed at Theviyode, Pangode and Vithura were comparatively low ranging from 1.029 to 1.790 per palm.

The variation observed in the mean number of feeding marks (f.m) also revealed that Kattakkada was the worst affected location in southern zone (134.58 f.m/palm) and it was closely followed by Pandianpara (123.63). Least number of f.m was observed at Pangode (7.92) and it was close to the number observed at Vithura (13.19). Theviyode which showed the least population showed comparatively higher leaf damage (47.40 f.m) than Pangode, Vithura and even Palode (47.08).

Neyattinkara, Ettiruthi and Thiruvallam were free from yellow leaf disease. At Palode 100 per cent of the palms covered in the survey were disease affected ones and the percentage of YLD affected palms in the nearby locations of Pandianpara, Theviyode and Vithura also were comparatively higher (72.73 to 91.67). At Pangode the percentage of diseased palms was 46.15 while at Kattakkada a southern location, it was 14.29 per cent only.

The disease intensity as revealed from the indices was at the maximum level at Palode (52.02) and the place

Table 2. Distribution of *C. arecae* in Kerala (problem zone)

locations	total palms observed	percentage of palms affected by			mean bug population/palm			percentage of palms affected by f.m	mean number of f.m per palm	percentage of palms affected by YLD	mean YLD indices
		A	N	A+N	adults	nymphs	total				
Karunagapally	14	7	21	29	0.107 (1.052)	0.516 (1.231)	0.647 (1.283)	79	117.52 (10.89)	50.00	25.81
Karthikapally	8	25	13	25	0.307 (1.143)	0.106 (1.052)	0.385 (1.177)	88	120.77 (11.04)	0.00	0.00
Mavelikkara	15	47	40	60	0.824 (1.351)	1.084 (1.444)	1.960 (1.721)	87	230.62 (15.22)	93.33	38.43
Chengannur	10	20	30	30	0.532 (1.238)	2.523 (1.877)	2.888 (1.972)	50	268.41 (16.41)	20.00	43.81
Aevoor North	8	50	38	50	0.716 (1.310)	0.961 (1.401)	1.696 (1.642)	88	225.29 (15.04)	62.50	40.69
Moncompu	16	56	44	75	1.265 (1.505)	2.039 (1.743)	3.518 (2.126)	81	376.33 (19.42)	6.25	20.00
Kumarakom	18	15	15	15	0.217 (1.103)	0.252 (1.119)	0.419 (1.191)	20	12.94 (3.73)	16.67	22.04
Vaikom	18	33	44	50	0.477 (1.215)	1.967 (1.728)	2.414 (1.848)	44	64.50 (8.09)	27.78	18.56
Vyttila	20	50	35	65	1.091 (1.446)	1.667 (1.633)	2.874 (1.968)	90	198.96 (14.14)	5.00	24.00
F test					S	NS	NS		NS		
C.D.					0.150**						

S : significant NS : not significant ** at 1% level

Figures in parentheses are transformed values ($\sqrt{x + 1}$)

A : *C.arecae* adults N : *C.arecae* nymphs f.m : feeding marks

was closely followed by Pandıanpara (46.08), Thevıyode (39.63) and Pangode (39.12). The dısease ıntensıty was less at Vıthura (20.66) and ıt was least at Kattakkada (14.00).

4.1.2. Problem zone

The percentage of areca palms ınfested by the nymphs/ adults of C. arecae was hıghest at Moncompu (75.00) and ıt was closely followed by Vytılla (65.00), Mavelıkkara (60.00), Aevoor North (50.00) and Vaıkom (50.00). The percentage of ınfested palms observed at Chengannur (30.00), Karunagapally (29.00), Karthıkapally (25.00) and Kumarakom (15.00) were comparatıvely lower.

At Moncompu, Vytılla, Aevoor North, Mavelıkkara and Karthıkapally the percentage of palms ınfested by adults of C. arecae exceeded the percentage seen ınfested by nymphs. At three locatıons the palms harbourıng the nymphs exceeded those harbourıng adults and at Kumarakom percentage of palms ınfested by the nymphs and adults were 15 each.

The populatıon of adults of C. arecae recorded at dıfferent locatıons showed statıstıcally sıgnıfıcant varıatıons. The hıghest populatıon (1.265/palm) was observed at Moncompu and ıt was on par wıth the populatıon observed at Vytılla (1.091). The latter was on par wıth the populatıon recorded at Aevoor North (0.716), Chengannur (0.532) and

Vaikom (0.477). The least population was observed at Karunagapally (0.107) and it was closely exceeded by the population at Karthikapally (0.307) and Kumarakom (0.217).

The population of nymphs observed at different locations did not show statistically significant variations. The highest nymphal population was observed at Chengannur (2.523/palm) and it was closely followed by the populations at Moncompu (2.039), Vaikom (1.967), Vytilla (1.667), Mavelikkara (1.084) and Aevoor North (0.961). Population observed at Karthikapally, Kumarakom and Karunagapally were very low ranging from 0.106 to 0.516/palm only.

With reference to the total population also Moncompu was found to be the worst affected location (3.518/palm). In this criterion Chengannur (2.888) came between Moncompu and Vytilla (2.874) the difference between them being very marginal. Chengannur was followed by Vaikom (2.414), Mavelikkara (1.960) and Aevoor North (1.696). The total population also was low at Karthikapally, Kumarakom and Karunagapally (0.385 to 0.647/palm).

The number of feeding marks (f.m) noted on the palms at different locations ranged from 12.94 to 376.33. But the variations were not statistically significant. The leaf damage was maximum at Moncompu (376.33 f.m/palm) and it was

followed by the number of f.m observed at Chengannur (268.41), Mavelikkara (230.62) and Aevoor North (225.29). Though the insect population was high at Vytilla the leaf damage was comparatively low there (198.96/palm). The feeding marks ranged from 12.94 to 120.77 at Kumarakom, Karunagapally, Karthikapally and Vaikom though the last location had a high nymphal population and consequent higher rank with reference to the total population of the insect.

In the problem zone Karthikapally was the only location free from yellow leaf disease. The highest percentage (93.33) of disease affected palms was recorded at Mavelikkara and it was followed by the incidence at Aevoor North (62.50 per cent) and Karunagapally (50.00). In the remaining locations viz. Vytilla, Moncompu, Kumarakom, Chengannur and Vaikom the percentage of diseased palms ranged from 5.00 to 27.78 only.

The disease intensity as shown by the indices was at its peak at Chengannur (43.18) where the percentage of diseased palms was comparatively lower (20.00 only) compared to 93.33 at Mavelikkara. On this criterion Chengannur was followed by Aevoor North and Mavelikkara. Though Vytilla and Moncompu had very low percentage of diseased palms the disease intensity observed at those locations were higher (24 and 20 respectively).

Table 3. Distribution of C. arecae in Kerala (middle zone)

locations	total palms observed	percentage of palms affected by			mean bug population/palm			percentage of palms affected by f.m	mean number of f.m per palm	percentage of palms affected by YLD	mean YLD indices
		A	N	A+N	adults	nymphs	total				
Alwaye	15	53	73	80	1.580 (1.606)	4.583 (2.363)	6.401 (2.720)	93	449.73 (21.23)	40.00	23.53
Chalakkudy	8	13	50	63	0.106 (1.052)	3.457 (2.111)	3.678 (2.163)	75	83.42 (9.19)	0.00	0.00
Mukundapuram	13	8	0	8	0.065 (1.032)	0.000 (1.000)	0.065 (1.032)	38	40.09 (6.41)	0.00	0.00
Mannuthy	13	14	50	50	0.122 (1.059)	1.103 (1.450)	1.197 (1.482)	93	241.16 (15.56)	23.08	36.28
Peechy	14	36	36	50	0.814 (1.347)	1.583 (1.607)	2.416 (1.848)	93	491.78 (22.20)	64.29	44.53
Pattikkad	13	38	46	69	0.769 (1.330)	2.954 (1.988)	3.924 (2.219)	100	323.34 (18.01)	0.00	0.00
Vadakkanchery	7	0	0	0	0.000 (1.000)	0.000 (1.000)	0.000 (1.000)	0	0.00 (1.00)	0.00	0.00
Palghat	6	0	0	0	0.000 (1.000)	0.000 (1.000)	0.000 (1.000)	0	0.00 (1.00)	0.00	0.00
Mannarghat	12	42	50	67	0.557 (1.248)	1.918 (1.708)	2.552 (1.885)	92	221.31 (14.91)	0.00	0.00
F test					S	NS	NS		S		
C.D.					0.150**	--	--		3.00*		

S : significant NS : not significant ** at 1% level * at 5% level

Figures in parentheses are transformed values ($\sqrt{x+1}$)

A : C.arecae adults N : C.arecae nymphs f.m : feeding marks

4.1.3. Middle zone

The data collected from different locations in the middle zone and the results of statistical analysis of the same are presented in Table 3. The percentage of palms infested by adults/nymphs of C. arecae was high at Alwaye (80.00) and it was followed by the incidence at Pattikkad (69.00), Mannarghat (67.00), Chalakkudy (63.00), Mannuthy (50.00) and Peechy (50.00). All the palms observed at Vadakkanchery and Palghat were free of the pest and only eight per cent of the palms were seen infested at Mukundapuram. In all the locations, (except Peechy) higher percentage of palms harboured the nymphs than the adults. At Peechy the percentage of palms infested by the adults and nymphs were the same. At Mukundapuram none of the palms was seen harbouring the nymphs.

The data relating to the incidence of C. arecae adults showed statistically significant variations among the different locations. Alwaye had the highest population of 1.58 bugs/palm and it was significantly higher than the rest of the locations. The population observed at Peechy, Pattikkad and Mannarghat came on par (0.557 to 0.814) and was significantly higher than the population at the rest of the locations. Mannuthy, Chalakkudy and Mukundapuram had low population (0.065 to 0.122/palm).

As in the case of adults, the nymphal population was at the highest level at Alwaye (4.583) and at Peechy, Pattikkad and Mannarghat (1.583 to 2.954) it remained high. Chalakkudy which had low adult population supported a heavy population of nymphs (3.457/palm). Palghat, Vadakkanchery and Mukundapuram did not show the presence of the nymphs of C. arecae. The variations in the nymphal population observed at different locations did not show statistical significance.

The data relating to the total population of C. arecae also did not show statistically significant variations. The highest population of 6.401/insect/palm was observed at Alwaye. It was followed by the population at Chalakkudy, Pattikkad, Mannarghat, Peechy and Mannuthy (1.197 to 3.678).

The percentage of palms manifesting leaf damage was high at all locations (75 to 100), except Mukundapuram, Vadakkanchery and Palghat (38, 0 and 0 respectively).

The data relating to the leaf damage (feeding marks (f.m)) showed statistically significant variations among the different locations. It remained significantly higher (491.78 and 449.73 f.m/palm) at Peechy and Alwaye, the difference between them being insignificant. Pattikkad, Mannuthy and Mannarghat with mean f.m of 323.34, 241.16 and 221.31 respectively suffered significantly higher

Table 4. Distribution of C. arecae in Kerala (hill zone)

locations	total palms observed	percentage of palms affected by A	N	A+N	mean bug population/palm adults	nymphs	total	percentage of palms affected by f.m	mean number of f.m per palm	percentage of palms affected by YLD	mean YLD indices
Peringamala	15	47	33	60	0.665 (1.290)	1.754 (1.659)	2.482 (1.866)	100	323.74 (18.02)	40.00	44.17
Chitara	8	13	25	38	0.106 (1.052)	0.553 (1.246)	0.684 (1.298)	100	203.25 (14.29)	37.50	54.17
Pathanapuram	7	14	14	28	0.122 (1.059)	0.989 (1.410)	1.160 (1.470)	57	79.33 (8.96)	42.86	40.83
Kulathupuzha	13	23	15	38	0.200 (1.096)	0.326 (1.151)	0.555 (1.247)	92	352.64 (18.81)	46.15	51.22
Tenmala	6	33	0	33	0.626 (1.275)	0.000 (1.000)	0.626 (1.275)	33	1.63 (1.62)	16.67	30.00
Ernadu	7	43	86	86	0.707 (1.307)	2.838 (1.959)	3.612 (2.148)	71	112.71 (10.66)	0.00	0.00
Vaduvanchal	10	0	20	20	0.000 (1.000)	0.432 (1.197)	0.432 (1.197)	70	24.32 (5.03)	30.00	17.47
Kottapady	7	14	14	14	0.122 (1.059)	0.122 (1.059)	0.220 (1.105)	100	101.90 (10.14)	28.57	16.43
Vythiri	21	52	41	52	0.693 (1.301)	1.192 (1.480)	1.854 (1.689)	69	109.42 (10.51)	0.00	0.00
F test					NS	NS	NS		NS		
C.D.					--	--	--		--		

NS : not significant

Figures within parentheses are transformed values ($\sqrt{x + 1}$)

A : C.arecae adults N : C.arecae nymphs f.m : feeding marks

leaf damage than the remaining locations in which insect feeding marks ranged from 0 to 83.42 only.

Among the nine locations covered in the survey, Peechy, Mannuthy and Alwaye had yellow leaf disease affected palms (64.29, 23.08 and 40.00 per cent respectively) and the disease intensity wise also Peechy ranked top (index 44.53) and it was followed by Mannuthy (36.28) and Alwaye (23.53).

4.1.4. Hill zone

Data relating to the infestation of areca palms by C. arecae and the incidence of yellow leaf disease in nine locations of hill zone and the results of statistical analysis of the same are presented in Table 4. The variations in the insect population and in the extent of damage caused by the insect did not show statistical significance.

The percentage of infested palms were conspicuously higher at Ernadu, Peringamala and Vythiri (86.00, 60.00 and 52.00 respectively) than the percentage in the remaining locations (14 to 38). At Chitara, Ernadu and Vaduvanchal the percentage of palms harbouring the nymphs exceeded the percentage of palms harbouring the adults.

The population of adults observed in different locations ranged from 0.00 to 0.707/palm only and the variation did not

show statistical significance. Though the nymphal population also failed to show statistically significant variations at Ernadu, Peringamala and Vythiri, mean nymphs/palm were 2.838, 1.754 and 1.192 respectively and these were distinctly higher than the count in the remaining locations which ranged from 0.00 at Tenmala and 0.989 at Pathanapuram.

The total population at Ernadu, Vythiri and Peringamala were 3.612, 1.854 and 2.482 respectively, while in remaining locations it ranged from 0.220 (Kottapady) to 1.16 (Pathanapuram). The variations in the data were not statistically significant.

In the hill zone a high percentage of the palms showed insect feeding marks (f.m). It was low at Tenmala (33.0%). At Peringamala, Chitara and Kottapady 100 per cent of the palms had feeding marks and at Kulathupuzha 92 per cent of the palms manifested the damage. In the remaining four locations the percentage of palms infested by the bug ranged from 57.0 to 71.0.

The mean number of feeding marks caused by the bug also was least at Tenmala (1.63/palm) and it was closely ascended by the count at Vaduvanchal (24.32) and Pathanapuram (79.33). The mean f.m was maximum at Kulathupuzha (352.64) and it was

closely followed by the f.m observed at Peringamala (323.74) and Chitara (203.25). The damage observed at Ernadu, Vythiri and Kottapady were of an intermediate level, the mean number of f.m recorded being 112.71, 109.42 and 101.90 respectively.

The yellow leaf disease was not detected in the samples observed at Ernadu and Vythiri. At Tenmala where the insect population was least the percentage of disease affected palm was low (16.67) but the intensity of the disease was quite high (index 30.00). At Kulathupuzha, Peringamala and Chitara, where the damage caused by the pest remained high, the percentage of diseased palms (46.15, 40.00 and 37.50 respectively) were high and the intensity of disease also were high (indices 44.17 to 54.17). At Pathanapuram though the leaf damage caused by C. arecae population was low (79.33 f.m/palm) the disease incidence (42.86%) and its intensity (index 40.83) were quite high. At Ernadu and Vythiri the disease incidence was not noted while at Vaduvanchal the disease incidence and the intensity were comparatively lower.

4.1.5. Northern zone

The data collected from the northern zone and the results of statistical analysis of the same are presented

Table 5. Distribution of C. arecae in Kerala (northern zone)

locations	total palms observed	percentage of palms affected by A	N	A+N	mean bug population/palm adults	nymphs	total	percentage of palms affected by f.m	mean number of f.m per palm	percentage of palms affected by YLD	mean YLD indices
Calicut	12	33	75	83	0.593 (1.262)	5.973 (2.641)	6.736 (2.781)	100	193.590 (13.949)	8.33	35.56
Tellichery	6	0	33	33	0.000 (1.000)	1.191 (1.480)	1.191 (1.480)	83	83.580 (9.197)	0.00	0.00
Koothuparamba	13	23	38	38	0.254 (1.120)	1.664 (1.632)	1.851 (1.688)	92	168.230 (13.009)	15.38	24.00
Irrikkur	15	20	47	47	0.307 (1.143)	2.627 (1.904)	2.883 (1.971)	93	199.200 (14.149)	86.67	53.72
Taliparamba	13	23	77	85	0.357 (1.165)	6.893 (2.809)	7.566 (2.927)	85	174.180 (13.236)	0.00	0.00
Koipady	6	50	50	50	0.588 (1.260)	1.853 (1.689)	2.315 (1.821)	100	39.650 (6.376)	0.00	0.00
Kumbla	7	0	0	0	0.000 (1.000)	0.000 (1.000)	0.000 (1.000)	100	10.520 (3.394)	0.00	0.00
Madhur	13	23	46	46	0.449 (1.204)	3.953 (2.226)	4.357 (2.315)	100	207.500 (14.440)	0.00	0.00
Neerchalu	21	19	52	52	0.259 (1.122)	2.219 (1.794)	2.454 (1.858)	71	142.840 (11.993)	0.00	0.00
F. test					S	NS	NS		NS		
C.D.					0.150**	--	--		--		

S: significant NS: not significant ** at 1% level

Figures within parentheses are transformed values ($\sqrt{x+1}$)

A: C. arecae adults N: C. arecae nymphs f.m : feeding marks

in Table 5. The percentage of infested palms were high at Taliparamba (85.00) and Calicut (83.00). The incidence was lacking at Kumbla and it was comparatively low at Tellichery (33.00) and Koothuparamba (38.00). The percentage of infested palms at Madhur, Irikkur, Koipady and Neerchalu were of an intermediate range (46.00 to 52.00). In seven out of the nine locations the percentage of palms infested by nymphs were higher than the percentage of palms infested by adults of C. arecae and only in two locations they were on par.

The adult population showed significant variation among the different locations in the northern zone. At Tellichery and Kumbla the adults of C. arecae were lacking during the survey. In the remaining locations the population ranged from 0.254 to 0.593/palm only. All the locations where the adults were observed came on par with reference to the number of adults of C. arecae.

The variations in the distribution of the nymphs of C. arecae, among the different locations in northern zone, were not statistically significant. But the population observed at Calicut (5.973), Taliparamba (6.893), Madhur (3.953) and Irrikkur (2.627) were conspicuously higher than the population observed in the remaining locations in which it ranged from 0.0 to 2.219 only.

The total population of C. arecae observed at different locations did not show statistically significant variations. But the population observed at Taliparamba (7.566), Calicut (6.736), Madhur (4.375) and Irrikkur (2.883) were conspicuously higher. At the remaining locations the total population ranged from 0.0 to 2.454 insects/palm only.

The percentage of palms showing insect feeding marks in the different locations were relatively higher and it ranged from 71.00 to 100.00.

Though the insects were not observed at Kumbla the topmost leaf showed slight insect injury and the mean number of insect feeding marks was 10.52. At Tellichery the insect population as well as feeding marks was low (83.58/palm). At Koipady with a higher insect population level the extent of leaf damage observed (39.65/palm) was comparatively lower. In all the remaining locations the leaf damages shown by the feeding marks (142.84 to 207.5/palm) were quite high.

Irrikkur alone showed a high percentage of YLD affected palms (86.67) and the intensity of the disease in these palms also was high, the index being 53.72. At Koothuparamba and Calicut the percentage incidence of the disease (15.38 and 8.33) and the intensity of disease (24.00

Table 6. Distribution of *C. arecae* in different zones of Kerala state

zones	mean adults/ palm	mean nymphs/ palm	mean total bugs/ palm	mean feeding marks/palm in top leaf
southern zone (SZ)	1.0300 (1.4248)	1.4849 (1.5764)	2.6222 (1.9032)	61.8750 (7.9294)
problem zone (PZ)	0.6152 (1.2709)	1.1996 (1.4831)	1.8168 (1.6783)	146.6350 (12.1505)
middle zone (MZ)	0.4988 (1.2240)	1.6960 (1.6419)	2.2052 (1.7903)	195.5433 (14.0194)
hill zone (HZ)	0.4159 (1.1899)	0.9307 (1.3895)	1.3465 (1.5318)	137.9388 (11.7872)
northern zone (NZ)	0.3197 (1.1488)	2.9482 (1.9870)	3.2629 (2.0647)	144.2668 (12.0527)
F. test (zones)	S	S	S	S
	C.D. for comparing			
SZ vs PZ	0.1047**	0.2234	0.2393	2.0468**
SZ vs MZ	0.1110**	0.2368	0.2533	2.1696**
SZ vs HZ	0.1110**	0.2368	0.2533**	2.1696**
SZ vs NZ	0.1102**	0.2344**	0.2511	2.1480**
PZ vs MZ	0.1099	0.2297	0.2461	2.1049
PZ vs HZ	0.1099	0.2297	0.2461	2.1049
PZ vs NZ	0.1066**	0.2273**	0.2435**	2.0826
MZ vs HZ	0.1138	0.2427**	0.2601	2.2245**
MZ vs NZ	0.1128	0.2410**	0.2576**	2.2034
HZ vs NZ	0.1128	0.2410**	0.2576**	2.2034

S : significant ** Significant at 1% level

figures within parentheses are transformed values $\sqrt{x + 1}$

and 35.56 respectively) were high. At six out of the nine locations covered in the survey yellow leaf disease was absent.

4.1.6. Zonal distribution of the bug in Kerala

Table 6 provides the pooled data obtained from the survey conducted at five different zones of the State and the results of the statistical analysis of the same. The population of adults of C. arecae observed in different zones showed statistically significant variations. The mean number of adults observed per palm in the southern zone (1.0300) was significantly higher than the numbers observed in the problem zone (0.6152), middle zone (0.4988), hill zone (0.4159) and northern zone (0.3197). The least population observed in the northern zone was significantly lower than that of the problem zone but was on par with the population observed in middle and hill zones.

The highest mean population of nymphs was observed in the northern zone (2.9482/palm) and it was significantly higher than the population recorded in other zones. The least nymphal population (0.9307/palm) was observed in hill zone and the population was significantly lower than the population observed in the middle zone (1.6960) while it was on par with the population observed in the southern zone (1.4849) and problem zone (1.1996).

The mean bug population (adults + nymphs) was highest in the northern zone (3.2629) and it came on par with the population in southern zone (2.622) and significantly higher than the population observed in middle zone (2.2052), problem zone (1.8168) and hill zone (1.3465). Comparison among the remaining zones did not reveal significant variations.

The mean leaf injury in southern zone (61.8750 f.m/palm) was significantly lower than the f.m observed in the middle zone (195.5433), problem zone (146.6350), northern zone (144.2668) and hill zone (137.9388). The injury in the hill zone was significantly lower than that of the middle zone but that was on par with the damage in problem zone and northern zone. Significant differences were not seen in comparing the remaining sets of zones.

4.2. Seasonal fluctuations in the population of the adults and nymphs of *C. arecae* and of the yellow leaf disease

The pest was monitored at monthly intervals, over a period of two years, at five locations in Trivandrum District with a view to ascertaining the periods of occurrence of peaks in the population, if any, for adopting control measures and for identifying the association between the disease symptoms and pest population if any (Table 7 to 13, Fig. 2).

Table 7 Seasonal distribution of *C arecae* and yellow leaf disease at Palode, Trivandrum district, 1987-89

month	number of palms affected by YLD	percentage of palms affected by YLD	YLD indices	mean bug population			mean feeding marks	meteorological data					
				adults	nymphs	total		total rain	rainy days	temperature °C max	temperature °C min.	R.H. percent max	R.H. percent min.
May 87	28	80.00	17.19	0.619 (1.272)	0.482 (1.217)	1.062 (1.436)	164.59 (12.87)	209.2	14	34.4	24.0	84.97	58.71
June 87	22	62.85	9.97	0.443 (1.201)	0.764 (1.328)	1.216 (1.489)	28.30 (5.41)	362.4	21	31.4	23.4	91.30	70.67
July 87	29	62.85	16.11	1.037 (1.427)	2.041 (1.744)	3.207 (2.051)	37.82 (6.23)	105.8	9	36.6	23.3	90.64	63.42
Aug 87	19	54.29	19.35	0.849 (1.360)	1.485 (1.577)	2.284 (1.812)	30.67 (5.63)	331.4	17	30.7	23.0	91.77	68.81
Sep. 87	22	62.85	21.06	0.856 (1.362)	0.997 (1.413)	1.860 (1.691)	51.96 (7.28)	449.2	10	31.8	23.0	90.83	81.12
Oct 87	22	62.85	28.05	2 062 (1.749)	3.886 (2.210)	5.927 (2.632)	173 62 (13.21)	384.2	18	31.3	23.1	92.35	74.16
Nov 87	22	62.85	28.35	1.478 (1 574)	2.783 (1.945)	4.217 (2.284)	38.66 (6.30)	366.4	14	31.6	22.8	92.67	68 70
Dec 87	21	60 00	39.42	1 805 (1.675)	4 033 (2.243)	5.818 (2.611)	195.05 (14.00)	255.2	8	32.1	22.7	91.81	61.32
Jan. 88	21	60.00	55 52	0.457 (1.207)	1.162 (1.470)	1.590 (1.609)	57.46 (7.65)	2.0	9	33.5	20.2	90.16	39.10
Feb 88	25	71.43	45.57	0.610 (1.269)	0.537 (1.240)	1.128 (1.459)	45.32 (6.81)	155.8	6	34.7	21.3	90.89	40.38
Mar 88	23	65.71	31 86	0.927 (1.388)	1 241 (1.497)	1.979 (1.726)	54.07 (7.42)	109.4	7	34.3	22.7	92.19	53.38
Apr 88	24	68.85	40.91	0.399 (1.183)	0 654 (1.286)	0.996 (1.413)	46.23 (6.87)	577.6	20	33.6	24 2	93.40	62.93
F test (months)			S	NS	NS	NS	NS						
May 88	24	68.57	33.23	0.460 (1.208)	0.229 (1.108)	0.672 (1.293)	41 27 (6.50)	108.6	8	32.2	24.8	93.22	63.87
June 88	21	60.00	30.00	1.046 (1.430)	1.419 (1.555)	2.478 (1.865)	88.03 (9.44)	432.4	20	30.8	23.9	94.53	74.20
July 88	21	60.00	32.69	1.483 (1.576)	3.080 (2.020)	4.595 (2.365)	47.16 (6.94)	351.0	13	30.1	23.1	90.10	68.39
Aug. 88	23	65.71	37.37	0.756 (1.325)	1.232 (1.494)	1.950 (1.718)	44.73 (6.76)	269.6	18	30.5	23.9	91.96	71.00
Sep 88	22	62.85	37.30	0.573 (1.254)	1.371 (1.540)	1.944 (1.716)	88.52 (9.46)	375.6	17	30.5	23.6	92.06	71.30
Oct 88	24	68.57	46.10	0.487 (1.220)	0.502 (1.226)	1.031 (1.425)	36.93 (6.16)	215.2	7	32.3	23.9	90.32	61.19
Nov 88	23	65.71	41 42	0.520 (1.233)	0.591 (1.261)	1.118 (1.455)	67.84 (8.30)	224 7	12	31.7	22.9	93.60	64 27
Dec 88	27	77.14	50.51	0.971 (1.404)	1.316 (1.522)	2.352 (1 831)	46.09 (6.86)	72.2	5	35.5	22.3	89.97	53.10
Jan 89	26	74 29	45.75	1.522 (1 588)	3.056 (2 014)	4.559 (2.358)	30 69 (5.63)	7.4	1	33.3	21.7	89.70	42.38
Feb 89	22	62.86	51.38	0.356 (1.164)	0.220 (1.104)	0.573 (1.254)	25.55 (5.15)	0.0	0	30.0	20.9	85.78	29 25
Mar 89	23	65.71	56.43	0 048 (1.024)	0 212 (1 101)	0.246 (1.116)	35.08 (6.01)	64.5	2	35.2	23.2	90.03	38.00
Apr. 89	23	65.71	48.03	0 664 (1.290)	0.331 (1.154)	1 008 (1.417)	37.18 (6.18)	238.0	14	34.1	24.8	89.80	61 66
F test (months)			S	NS	NS	NS	NS						

NS not significant S significant C D value given in Appendix

Figures within parentheses are transformed values ($\sqrt{x + 1}$)

Total palms surveyed per month 35

4.2.1. Seasonal fluctuations of C. arecae and yellow leaf disease in the arecanut gardens at Palode of Trivandrum district

Data relating to the survey done at Palode and the results of statistical analysis of the same are presented in Table 7. The fluctuations in the population during the different months of 1987-88 and 1988-89 did not show statistical significance. But the peak population of the adults (2.062 bugs/palm) occurred in October during 1987-88 and the levels remained high in November and December (1.478 and 1.805) also. Another peak was observed in July (1.037). The population remained low during the hot months of April (0.399) and in the remaining periods it was widely fluctuating between the levels of 0.443 in June to 0.927 in March.

The counts of the nymphs also were high during October, November and December (range 2.783 to 4.033/palm) compared to the remaining months. It was followed by the population in July (2.041) and August '87 (1.485). During hot months of February to May the population of the nymphs remained relatively low (0.482 to 1.241) and in the rest of the period the population were fluctuating.

With reference to the total population the periods from October to December were found more congenial for the

build up of the pest (5.818 to 5.927/palm). Another peak could be seen in July (3.207/palm). The population was at its lowest level in April and May (0.996 and 1.062) and during the rest of the months the population were seen fluctuating.

With reference to the data collected in 1988-89 also higher population of C. arecae adults could be seen in June/July (1.483 and 1.046). It was highest in January (1.522) and in December also the number (0.971) was relatively high. But in October and November the population were low when compared to the previous year (0.52 to 0.971) and thus the first peak was seen delayed during 1988-89.

The nymphal population also reached the peak level of 3.08/palm in July and in June also it was quite high (1.419). In January and December another rise could be noted (3.056 and 1.316) and during the remaining months population fluctuated within a range of 0.212 in March to 1.371 in September 1988. During the hot months of March to May the nymphal population also remained low ranging from 0.212/palm to 0.331/palm.

With reference to the total population two peaks in June/July (2.478 and 4.594) and December/January (2.352 and 4.559) could be seen compared to the population in rest of

the months (0.246 to 1.950). The population in March (0.246) and in April/May remained low (1.008 and 0.672).

The extent of leaf damage, revealed from the number of feeding marks showed an irregular pattern not corresponding with the fluctuations in the population levels of the adults and nymphs. The highest damage during 1987-88 was observed in December 1987 (195.05 f.m) and it was followed by the damage in October (173.62) and May (164.59). In the remaining months the mean number of marks ranged from 28.3 to 57.46 only.

During 1988-89 the damage was generally less than in the previous period. Peak damage was in September '88 (88.52 marks) and it was similar to the damage noted in June 1988 (88.03). In the month of November '88 also it was at a high level (67.84) and during the rest of the period the fluctuation in the damage was not high (25.25 to 47.16).

With reference to the percentage of areca palms showing yellow leaf disease symptoms in 1987-88 the peak (80%) was found in May and it remained high from February to April (65.71 to 71.43). The least incidence was in August (54.92) and it remained with little fluctuation in the rest of the months (60 to 62.85 per cent).

During 1988-89 the per cent of palms showing disease symptom was comparatively higher in December, January, May and October (77.14, 74.29, 68.57 and 65.71 respectively) and the lower incidence was in the months of June/July (60 per cent each) and February 62.86. In March to May the incidence reached an intermediate level of 65.71 to 68.57 per cent only. The fluctuation in the percentage of the diseased palms during the remaining months did not show any definite trend.

The disease indices showed a clear gradation in the occurrence of the symptoms. In both the years the data had the same trend. The index in 1987-88 remained at the lowest level of 9.97 in June '87 and showed a gradual rise reaching the peak of 55.52 in January '88 and then started declining. It remained high during February, March, April (45.57, 31.86 and 40.91 respectively) and suddenly declined to the level of 17.19 in May 1988.

In 1988-89 also the least index in disease intensity was observed in June '88 (30.00) and the intensity was gradually increasing reaching the peak (56.43) in March 1989. It remained high (48.03) in April also and the index dropped to the level of 33.23 in May.

4.2.2. Seasonal fluctuations of *C. arecae* and yellow leaf disease in the arecanut gardens at Vithura of Trivandrum district

The relevant data and the results of statistical analysis of the same are presented in Table 8. Variations in the population of the insect during different months did not show statistically significant variations.

During 1987-88 in June/July (1.4 and 1.831 bug/palm) and November/December (1.338 and 1.408) the adult population of *C. arecae* were higher than the population in the rest of the months (0.219 to 0.974/palm). But in February 1988 a high population of (1.386/palm) of the bug was observed. In 1988-89 higher levels of adult population were observed in June (1.464/palm), April (1.106) and January (1.004). In the remaining months the numbers of adults/palm varied between 0.112 and 0.831.

In 1987-88 the nymphal population was higher in November (4.384/palm), December (3.133) and January (2.073) and another hike was seen in July and August (4.186 and 2.087). During the remaining months the mean population ranged from 0.203 to 1.739/palm. In 1988-89 the higher levels of nymphal population were seen in the months of

Table 8 Seasonal distribution of C arecae and yellow leaf disease at Vithura, Trivandrum district, 1987-89

months	total palms	number of palms affected by YLD	percentage of palms affected by YLD	YLD indices	mean bug population			mean feeding marks	weather data	
					adults	nymphs	total		total rainfall	rainy days
May 87	15	8	53.00	8.45	0.219 (1.104)	1.573 (1.604)	1.736 (1.654)	36 43 (6.12)	169.9	11
June 87	15	7	46.67	8.27	1.400 (1.549)	0.523 (1.230)	1.968 (1.723)	33.84 (5.90)	294.5	18
July 87	15	10	66.67	11.56	1.831 (1.683)	4.186 (2.277)	6.388 (2.718)	91.17 (9.60)	41.2	5
Aug 87	15	9	60.00	10.40	0.916 (1.384)	2.087 (1.757)	3.066 (2.016)	93.68 (9.73)	409.5	15
Sep 87	15	10	66 67	8.97	0.966 (1 402)	1.061 (1.436)	2.190 (1.786)	3.89 (2.21)	528.6	13
Oct 87	15	13	86 67	12.08	0 974 (1 405)	1.739 (1.655)	2.626 (1.904)	162.28 (12.78)	459 0	23
Nov 87	15	13	86.67	23.78	1.338 (1.529)	4 384 (2.320)	5.578 (2 565)	19.32 (4 51)	287.0	17
Dec 87	15	12	80.00	23.96	1 408 (1.552)	3.133 (2.033)	4.458 (2 336)	122.19 (11.10)	473.0	12
Jan 88	15	14	93 33	28.02	0 633 (1.278)	2.073 (1.753)	2 594 (1.896)	137.99 (11.79)	0.0	0
Feb. 88	15	12	80.00	13.91	1.386 (1.545)	1.095 (1.448)	2.637 (1.907)	9.04 (3.17)	40.2	3
Mar 88	15	4	26.67	7.22	0.915 (1.384)	0.203 (1.097)	1.104 (1.451)	134.89 (11.66)	79 0	5
Apr. 88	15	8	53.33	33.66	0.319 (1.523)	1.492 (1.579)	1.785 (1.669)	125.52 (11.25)	236.8	12
F test (months)				S	NS	NS	NS	NS		
May 88	21	15	75.00	33 80	0.616 (1.271)	3.233 (2.057)	4.070 (2.252)	200.32 (14.19)	172.0	11
June 88	21	14	70.00	39.48	1.464 (1.570)	0.909 (1.382)	2.365 (1.834)	79.30 (8.96)	472.5	18
July 88	21	14	70.00	35.69	0.487 (1.220)	0.646 (1.283)	1.060 (1.435)	21.38 (4.73)	411.3	14
Aug 88	21	16	80 00	37 28	0.551 (1.246)	1.143 (1.464)	1 571 (1.603)	74.09 (8.67)	333.5	13
Sep 88	21	13	65 00	31.93	0.420 (1 192)	1.278 (1.509)	1.661 (1.631)	54.21 (7 43)	685.5	23
Oct 88	21	15	75.00	42.73	0.112 (1 055)	1.001 (1.415)	1.081 (1.442)	11.64 (3.56)	42.0	2
Nov 88	21	16	80 00	36.06	0.831 (1.353)	0.937 (1.392)	1.751 (1.659)	81.26 (9.07)	161.1	9
Dec 88	21	16	80 00	34.12	0.384 (1.176)	0.922 (1 386)	1.413 (1 553)	26.95 (5.29)	43 1	3
Jan 89	21	16	80 00	35.61	1.004 (1.416)	1.382 (1.543)	2.409 (1.846)	24.99 (5.10)	0.0	0
Feb. 89	21	13	65 00	48 68	0.556 (1.247)	0.295 (1.138)	0.803 (1.343)	16.76 (4.21)	0.0	0
Mar 89	21	18	90.00	28.96	0.564 (1.251)	2.641 (1.908)	3.238 (2.059)	41.43 (6.51)	93.0	5
Apr 89	21	13	65.00	34.11	1.106 (1.451)	1.536 (1.592)	2.635 (1.907)	94.37 (9.77)	140.5	8
F test (months)				NS	NS	NS	NS	NS		

NS not significant S significant C D value given in Appendix

Figures within parentheses are transformed values ($\sqrt{x + 1}$)

May, March, April and January (1.382 to 3.223/palm). The count in remaining months ranged from 0.295 to 1.278 only.

With reference to the total population, in 1987-88, two peaks could be identified one in November/December (5.578 and 4.458/palm) and another in July/August (6.388 and 3.066). The population observed in the remaining months ranged from 1.104 in March to 2.637 in February. The population in the summer months of March to May were in comparatively lower levels. But the bug population (nymphs and adults) observed in 1988-89 were high during March, April and May (3.238, 2.635 and 4.070 respectively) compared to those of the remaining months (0.803 to 2.409). The total population in June/July and November/December were low during the year.

During 1987-88 the mean number of feeding marks was comparatively higher in October (162.28), March (134.89), January (137.99), April (125.52), December (122.19), August (93.68) and July (91.17). The feeding marks observed in the remaining five months ranged from 3.89 to 36.43 only. In 1988-89 higher levels of feeding injury were observed in May (200.32), April (94.37), November (81.26), June (79.30), August (74.09), September (54.21) and March (41.43). During the remaining months mean number of feeding marks ranged from 11.64 to 26.95 only.

In 1987-88 the percentage of palms showing yellow leaf disease symptoms was comparatively higher from October 1987 to February 1988 (93.33 to 80.0 per cent), low in March and June (26.67 and 46.67) and were of intermediate range in the remaining months (53.0 to 66.0 per cent). In 1988-89 the percentage of palms exhibiting yellow leaf disease symptoms was comparatively higher than in the previous year. In February, April and September the percentage of affected palms were 65 only and in the remaining months the percentage ranged from 70 to 90.

The intensity as revealed by the disease indices showed statistically significant variations among different months of 1987-88. The highest index (33.66) was observed in April. The indices relating to January (28.02), December (23.96) and November (23.78) came on par with that of April. The lowest disease index was observed in March (7.22). The indices relating to May, June, July, August, September, October and February (8.27 to 13.91) came on par with the index obtained for March 1988. The disease indices observed in different months of 1988-89 did not show significant variations. The intensity was comparatively higher in February (index 48.68) and October (42.73) and lowest in March (28.96) while in the remaining months the indices fluctuated within a narrow range of 31.93 to 39.48 only.

4.2.3. Seasonal fluctuations in the population of C. arecae and the incidence of YLD in the areca gardens of Kattakkada in Trivandrum district

The relevant data and the results of statistical analysis of the same are presented in Table 9. The variations in the population of C. arecae (adults and nymphs) observed in different months of 1987-89 did not show statistical significance. In 1987-88 the adults of C. arecae were more during September/August (2.472/1.875 per palm) and November/December (1.504/1.400). The population in summer months March/April/May (0.880/1.191/0.106) were low. In 1988-89 also high population levels were observed in October/November/December (1.838/2.047/1.726). Unlike 1987-88 the population in May (2.037) was high. There was another peak in July/August (1.376 and 1.336). In the remaining months the population ranged from 0.280 to 1.069 only and in the summer months of March/April the counts were 0.397 and 0.663 respectively.

In 1987-88 the nymphs were high in the months of December (4.368/palm), July (4.144), October (3.745) and September (3.152). The population in January and November also were comparatively high (2.999 and 2.464). The observations in the remaining months ranged from 0.00 to 1.906 only. In March the nymphal population was low but in April it had gone up to the level of 1.746/palm and in May and June it

Table 9. Seasonal distribution of C. arecae at Kattakkada, Trivandrum district, 1987-89

months	total palms	number of palms affected by YLD	percentage of palms affected by YLD	YLD indices	mean bug population			mean feeding marks	weather data	
					adults	nymphs	total		total rainfall	rainy days
May 87	8	0	0.00	0.00	0.106 (1 052)	0.106 (1.052)	0 218 (1.104)	197.37 (14.08)	237 5	10
June 87	8	0	0.00	0 00	0.106 (1.052)	0.000 (1.000)	0.106 (1.052)	2 49 (1.87)	161.6	15
July 87	8	0	0 00	0 00	1 382 (1.543)	4.144 (2.268)	5 624 (2.574)	56.34 (7.57)	26.3	3
Aug 87	8	0	0 00	0 00	1 875 (1.695)	1 906 (1.705)	3 782 (2.187)	9 15 (3.19)	225 7	12
Sep 87	8	0	0 00	0 00	2.472 (1.863)	3 152 (2.038)	5.930 (2.633)	66.58 (8.22)	263.7	11
Oct 87	8	0	0 00	0.00	1.106 (1.451)	3.745 (2.178)	4.761 (2.400)	128.59 (11 38)	435.6	17
Nov. 87	8	0	0.00	0.00	1.504 (1.583)	2.464 (1.861)	4.000 (2.236)	39.63 (6.37)	200.0	10
Dec 87	8	0	0 00	0.00	1.400 (1.549)	4.368 (2.317)	5.631 (2.574)	141.29 (11.93)	86.1	6
Jan. 88	8	0	0.00	0.00	1.077 (1.441)	2.999 (2.000)	4.104 (2.259)	54.47 (7.45)	14.2	1
Feb. 88	8	0	0.00	0.00	1.191 (1.480)	1.836 (1.684)	3.297 (2.073)	23.33 (4.93)	74.0	2
Mar 88	8	0	0.00	0.00	0.880 (1.371)	0.706 (1.306)	1.503 (1.582)	66.97 (8.24)	187.1	5
Apr 88	8	0	0 00	0.00	1.191 (1.480)	1.746 (1.657)	2.969 (1.992)	66 65 (8.22)	318 2	15
F test (months)					NS	NS	NS	NS		
May 88	15	1	6 67	24 00	2 037 (1.743)	4.773 (2 403)	7 033 (2.834)	172 64 (13 18)	71.1	3
June 88	15	1	6 67	22 22	0 837 (1.355)	2 205 (1 790)	3 083 (2.021)	54 60 (7 52)	402.5	21
July 88	15	1	6.67	18 00	1 375 (1.541)	3 192 (2.047)	4 773 (2 403)	31 91 (5.74)	221 8	9
Aug 88	15	1	6 67	24 00	1 336 (1.528)	3 337 (2.083)	5.165 (2.483)	56 89 (7.61)	131.2	7
Sep 88	15	1	6 67	21.82	0.280 (1.131)	1.024 (1.423)	1.349 (1.533)	79 32 (8.96)	305.4	19
Oct 88	15	1	6.67	23.64	1.838 (1.685)	2.885 (1.971)	5 050 (2.460)	32.91 (5.82)	108.1	5
Nov. 88	15	1	6.67	31.11	2.047 (1.746)	4.835 (2.415)	6 110 (2.813)	164.32 (12.86)	149 4	5
Dec. 88	15	1	6.67	14 00	1.726 (1.651)	1.608 (1.615)	3.693 (2 166)	94.71 (9.78)	42.2	2
Jan 89	15	1	6.67	24.00	1.069 (1.439)	1.884 (1.698)	2.842 (1.960)	36.96 (6.16)	14.2	1
Feb 89	15	1	6.67	26.67	0.472 (1.213)	0.485 (1.219)	0.888 (1.374)	30.14 (5.58)	0.0	0
Mar 89	15	1	6.67	16.00	0 397 (1.182)	0.450 (1.204)	0.849 (1 360)	118.19 (10.92)	126.8	4
Apr 89	15	1	6.67	17.78	0.663 (1.289)	0.751 (1.323)	1.473 (1.572)	55 06 (7.49)	57.1	5
F test (months)					NS	NS	NS	NS		

NS not significant

Figures within parentheses are transformed values ($\sqrt{x + 1}$)

declined. The nymphal population observed in 1988-89 also did not vary significantly. The population observed in October-November (2.885 and 4.835 per palm) and July-August (3.192 and 3.337) were distinctly higher than the population in the remaining months with the exception of the population observed in May (4.773). Thus two peak periods viz. October-November and July-August could be made out from the data unlike the data collected during 1987-88.

With reference to the total population observed in 1988-89 the peak was observed in the month of May (7.003/palm). The population in November/October (6.110/5.050) and July/August (4.773/5.163) were comparatively higher than the population observed in the remaining months. Population observed in the summer months February-April (0.888 to 1.473) were comparatively low. In general distinct peak periods in the occurrence of the pest population were evident. But on 1987-88 the total population remained at high levels from July 1987 to February 1988 (3.297 to 5.930) when compared to the incidence observed in the remaining months (0.106 to 2.969 per palm).

The extent of damage, as observed from the feeding marks, in 1987-88 was high in the months of May (197.37), December (141.29) and October (128.59). The feeding marks

were less during June and August (2.49 and 9.15). In the remaining observations it ranged from 23.33 to 66.97/palm. During 1988-89 high levels of injury were recorded in May (172.64), March (118.19) and December (94.71). In the remaining months the feeding injury varied between 30.14 to 79.32 per palm only.

During 1987-88 the palms under observation did not show any symptoms of yellow leaf disease. But in 1988-89 one of the fifteen palms under observation developed the disease and the intensity of the symptoms, as revealed from the indices in different months (14 to 26.67) was high throughout the year.

4.2.4. Seasonal fluctuations in the population of C. arecae and the occurrence of yellow leaf disease in the arecanut gardens at Neyattinkara, Trivandrum district

The relevant data and the results of statistical analysis of the same are presented in Table 10. In 1987-88 the population of the adults of C. arecae were seen in the peak in December (2.071/palm) and it remained high in January (1.077) and also in November (1.503). The population was relatively high in March also (1.720/palm). But during the remaining months the population remained low ranging from

Table 10 Seasonal distribution of C. arecae at Neyattinkara, Trivandrum district, 1987-89

months	total palms	number of palms affected by YLD	mean bug population			mean feeding marks	weather data	
			adults	nymphs	total		total rainfall	rainy days
May 87	37	0	0.000 (1.000)	0.000 (1.000)	0.000 (1.000)	220.67 (14.89)	242.8	8
June 87	37	0	0.120 (1.058)	0.091 (1.044)	0.216 (1.103)	2.08 (1.75)	319.3	14
July 87	37	0	0.063 (1.031)	0.793 (1.339)	0.877 (1.370)	4.57 (2.36)	42.8	4
Aug. 87	37	0	0.342 (1.158)	0.658 (1.288)	0.878 (1.371)	3.14 (2.04)	391.5	15
Sep. 87	37	0	0.330 (1.153)	0.138 (1.067)	0.467 (1.211)	7.99 (2.10)	227.6	10
Oct 87	37	0	0.583 (1.258)	1.245 (1.498)	1.736 (1.654)	47.51 (6.96)	470.3	17
Nov 87	37	0	1.503 (1.582)	3.356 (2.087)	4.802 (2.409)	44.28 (6.73)	329.0	11
Dec. 87	37	0	2.071 (1.752)	3.565 (2.137)	5.485 (2.547)	147.82 (12.20)	364.8	8
Jan. 88	37	0	1.077 (1.441)	1.433 (1.560)	2.553 (1.885)	37 07 (6.33)	0.0	0
Feb 88	37	0	0.581 (1.257)	1.325 (1.525)	1.958 (1.720)	14.51 (3.94)	10.8	2
Mar 88	37	0	1 720 (1.649)	2.239 (1 800)	3.724 (2.174)	77.24 (8.85)	158 8	3
Apr 88	37	0	0 882 (1.372)	1.507 (1.583)	2.349 (1.830)	51.79 (7 27)	231.3	11
F test (months)			NS	NS	NS	NS		
May 88	31	0	0 748 (1 322)	1.311 (1 520)	2.189 (1.786)	127.90 (11.35)	36.8	4
June 88	31	0	0.528 (1.236)	1.436 (1.561)	1.995 (1.731)	35.15 (6.01)	673.0	22
July 88	31	0	0.417 (1.190)	0.337 (1.156)	0.746 (1.321)	18 22 (1.38)	292.0	8
Aug. 88	31	0	0.250 (1.118)	2.076 (1.754)	2.331 (1.825)	33.85 (5.90)	95.8	7
Sep. 88	31	0	0.354 (1.164)	1.995 (1.731)	2.381 (1.839)	40.69 (6.46)	460.8	17
Oct. 88	31	0	1.078 (1.442)	1.852 (1.689)	2.944 (1.986)	20.77 (4.67)	23.5	3
Nov 88	31	0	1.524 (1.589)	2.289 (1.813)	3.771 (2.184)	32.97 (5.83)	268.0	14
Dec. 88	31	0	1.414 (1.553)	1.565 (1.602)	3.075 (2.019)	110.61 (10.56)	0.0	0
Jan. 89	31	0	1.943 (1.716)	4.743 (2.397)	6.703 (2.775)	24.61 (5.06)	6.5	2
Feb 89	31	0	1.271 (1.507)	1.756 (1.660)	3.168 (2.042)	26.81 (5.27)	0.0	0
Mar. 89	31	0	0 172 (1.083)	0.668 (1.291)	0.888 (1.374)	98 20 (9.96)	24.0	2
Apr. 89	31	0	0 561 (1.249)	0.752 (1.324)	1 374 (1.541)	45 30 (6.80)	46 0	3
F test (months)			NS	NS	NS	NS		

NS not significant

Figures within parenthesos are transformed values ($\sqrt{x+1}$)

0.00 to 0.822. During the month of May nymphs and adults were wanting in the locality. In 1988-89 also high levels of adult population were seen during November, December, January and February (1.524, 1.414, 1.943 and 1.271 respectively). The least population was observed in March 1989 (0.172). The mean number in May 1988 (0.748 per palm) gradually declined to the level of 0.250 per palm in August and then increased to 1.078 in the month of October 1988.

The population of the nymphs observed in November (3.356) and December (3.565) of 1987 remained distinctly higher than the population observed in the remaining months of the year. Nymphs were lacking in May 1987 and the population was very low in June (0.091). Then it gradually got built up and reached the peak in December. In the survey conducted in 1988-89 the peak population was observed in January 1989 (4.743/palm) and it was succeeded by the population observed in November (2.289), August (2.076), September (1.995) and October (1.852). During the summer months March to May the nymphal population remained low (0.668 to 1.331 per palm).

With reference to the total population in 1987-88 also a distinct peak could be seen in November (4.802), December (5.485) and January (2.553). The population was seen high in March 1988 also. During the remaining months the

population ranged from 0.00 to 2.349. In 1988-89 the peak population was seen in January 1989 (6.703) and the population remained comparatively higher during the period from August 1988 to February 1989 the range being 2.331 to 3.168 per palm (excluding January population). During the remaining months of the year 1988-89 the population ranged from 0.746 to 2.189.

The feeding marks observed in 1987-88 were high during May (220.67) and December (147.82). From June to September the mean feeding marks ranged from 2.08 to 47.99 and in the remaining months the count ranged from 14.51 to 77.24 only. During 1988-89 the damages observed were high in December (110.61), May (127.90) and March (98.20). In the remaining observations the number ranged from 18.22 to 45.30 only.

The location was free from yellow leaf disease during the entire period of observation (May 1987 to April 1989).

4.2.5. Fluctuations in the population of C. arecae and the yellow leaf disease in the arecanut plantations of Thiruvallam, Trivandrum district

The relevant data and the results of statistical analysis of the same are presented in Table 11. The data did not show statistically significant variations. The adult population of C. arecae was at its peak (1.488/palm) in December 1987 and

Table 11 Seasonal distribution of *C arecae* at Thiruvallam, Trivandrum district, 1987-89

months	total palms	number of palms affected by YLD	mean bug population			mean feeding marks	weather data					
			adults	nymphs	total		total rainfall	rainy days	temperature °C		R H per cent	
									max	min	max.	min
May 87	11	0	0.000 (1.000)	0.000 (1.000)	0.000 (1.000)	419.86 (20.51)	83.0	7	33.6	25.2	72.90	71.38
June 87	11	0	0.077 (1.038)	0.360 (1.166)	0.397 (1.182)	19.82 (4.56)	224.4	19	31.4	23.5	73.93	72.40
July 87	11	0	0 304 (1.142)	1.327 (1.526)	1.551 (1.597)	43.48 (6.67)	21.4	6	30.9	24.3	76.77	74.65
Aug 87	11	0	0.284 (1.133)	1.434 (1.560)	1.646 (1.627)	0.00 (1.00)	271.2	18	30.3	23.3	83.19	79.84
Sep 87	11	0	0.520 (1.233)	0.000 (1.000)	0.520 (1.233)	32.63 (5.80)	128.2	12	31.3	24.2	82.03	75.63
Oct 87	11	0	1.253 (1.501)	2.201 (1.789)	3.277 (2 068)	210.52 (14.54)	306 9	16	30.9	23.9	86.39	81 13
Nov 87	11	0	1 287 (1 512)	3 448 (2.109)	4.898 (2.429)	57.66 (7 66)	180.3	13	30.2	23.6	85.60	75.50
Dec 87	11	0	1 488 (1 577)	3 444 (2.108)	4.711 (2.390)	201.85 (14.24)	233.7	7	30.5	22.0	85 2	73.97
Jan 88	11	0	0.669 (1.292)	1.482 (1.576)	2.277 (1.810)	21.60 (4.75)	0 0	0	31.3	21.2	87.29	80.84
Feb 88	11	0	0.284 (1 133)	1.268 (1.506)	1 482 (1.576)	19.56 (4.53)	6.6	2	32.5	22.4	81.90	78.41
Mar 88	11	0	0.844 (1.358)	0.860 (1.364)	1.565 (1.601)	16.67 (4.20)	55.3	3	33 5	25.3	76.74	71.24
Apr 88	11	0	0.528 (1.236)	1.895 (1.702)	2.361 (1.833)	46.72 (6.91)	62.8	10	32.4	24.2	85.00	72 24
F test (months)			NS	NS	NS	NS						
May 88	21	0	0.274 (1.129)	0.423 (1.19ɔ)	0.646 (1.283)	66.10 (8.19)	51.2	7	32 6	24.8	73.10	71.62
June 88	21	0	0 206 (1.098)	1.167 (1.472)	1.367 (1.539)	52 62 (7.32)	307.0	23	30.6	23.9	73.70	72 80
July 88	21	0	0.766 (1.329)	1.020 (1.421)	1.939 (1.714)	5 35 (2.52)	204.8	14	30.7	23.1	75.98	74.10
Aug. 88	21	0	1.167 (1.472)	4.226 (2.286)	5.933 (2.633)	88.25 (9.45)	102.3	12	30.6	23.1	81.25	75.45
Sep. 88	21	0	1 233 (1.494)	3.546 (2.132)	5.192 (2.488)	86.65 (9 36)	320.6	17	29.8	23.6	82.48	76.10
Oct 88	21	0	1.123 (1 457)	2 030 (1.741)	3.441 (2.107)	46.50 (6 89)	11 6	1	31.7	23 9	85 92	80.91
Nov 88	21	0	1.276 (1.509)	3 608 (2 147)	4.881 (2.425)	44 56 (6.75)	78.8	11	31 0	23 0	84 72	74 81
Dec 88	21	0	1 057 (1 434)	1 983 (1.727)	3 083 (2.021)	98.44 (9.97)	6.4	1	31.8	23.3	85 10	74 12
Jan 89	21	0	0 949 (1.396)	1.460 (1.568)	2 334 (1.826)	15.58 (4.07)	4.4	2	31.7	21.7	86.38	80 90
Feb 89	21	0	0 930 (1 390)	1.363 (1 537)	2.150 (1 775)	61 28 (7 89)	0.0	0	31.8	20.9	80.85	76 00
Mar. 89	21	0	0.386 (1.177)	0.931 (1.390)	1.241 (1.497)	94.95 (9.80)	43.3	4	32.7	23.2	76.13	70.85
Apr 89	21	0	0.498 (1.224)	2.094 (1.759)	2.642 (1.908)	44.26 (6.73)	129.2	8	32.0	24.8	86.14	72.38
F test (months)			NS	NS	NS	NS						

NS not significant

Figures within parentheses are transformed values ($\sqrt{x+1}$)

it remained high in November (1.287) and October (1.253) also. In May adult bugs were absent in the field. Then the population showed an increasing trend till it reached the peak in December (0.077 to 1.488). From January to April (summer months) the count remained in the range of 0.284 to 0.844 bugs/palm. In 1988-89 the population of adult bugs remained at a higher level ranging from 1.057 to 1.276/palm between August and December. In the remaining months the population remained in the range of 0.206 to 0.949 per palm.

In 1987-88 the nymphs were more in the field during November (3.448), December (3.444) and October (2.201). Nymphs were absent during May and September 1987. Population was least in June (0.360) and it ranged from 0.860 to 1.895 per palm in the remaining months. During 1988-89 the nymphal population was at its peak in August (4.226) and it remained higher in September, October, November and December (range 1.983 to 3.608) than in the remaining months in which the nymphal count ranged from 0.423 to 2.094 per palm.

The total bug population during 1987-88 reached the peak in November (4.898) and the population remained at higher levels ranging from 2.277 to 4.711 during October, December and January. During April also the total population

was quite high (2.361/palm). In the remaining months the population ranged from 0.00 to 1.646 per palm. During 1988-89 the peak population was in August (5.933) and it remained high till the end of December (range 3.083 to 5.933). In the remaining months the count was relatively low (0.646 to 2.642). As observed in other locations the variations in feeding marks were not synchronising with the fluctuations in population. During 1987-88 the peak in feeding marks was in May (419.86) and it remained high in October and December (210.52 and 201.85 marks respectively). Feeding marks were not seen during August 1987 and it ranged between 16.67 and 57.66 during the remaining months. During 1988-89 the injury levels were lower and it ranged between 86.65 and 98.44 marks in December, March, August and September. In the remaining months the feeding marks ranged from 5.35 to 66.10/palm only. The location was totally free from the yellow leaf disease.

4.2.6. Relative abundance of *C. arecae* at the different locations selected for the study of the seasonal fluctuations in the population during 1987-89

Results of statistical analysis of the pooled data relating 1987-88 are presented in Table 12. The population of the adults of *C. arecae* was highest at Kattakada (1.1416/palm) and the population at Vithura (0.9994) and Palode

Table 12. Relative abundance of C. arecae at five selected centres of Trivandrum district, 1987-88

centres	Mean population per observation			
	adults	nymphs	total	mean feeding marks
Palode	0.9295 (1.3891)	1.5523 (1.5976)	2.4267 (1.8511)	67.9944 (8.3063)
Vithura	0.9994 (1.4140)	1.8302 (1.6823)	2.8759 (1.9687)	68.1238 (8.3176)
Kattakkada	1.1416 (1.4634)	2.0817 (1.7555)	3.2252 (2.0555)	59.6670 (7.7889)
Neyattinkara	0.7146 (1.3094)	1.2321 (1.4940)	1.8540 (1.6894)	39.4377 (6.3590)
Thiruvallam	0.5949 (1.2629)	1.3523 (1.5337)	1.8746 (1.6955)	62.1893 (7.9492)
F test (places)	S	S	S	S
	C.D. for comparison of			
Palode vs Vithura	0.0836	0.1434	0.1683	1.3631
Palode vs Kattakkada	0.1062	0.1821	0.2137	1.7309
Palode vs Neyattinkara	0.0639**	0.1096	0.1286**	1.0415**
Palode vs Thiruvallam	0.0937**	0.1606	0.1885	1.5267
Vithura vs Kattakkada	0.1186	0.2034	0.2388	1.9337
Vithura vs Neyattinkara	0.0829**	0.1422*	0.1670**	1.3520**
Vithura vs Thiruvallam	0.1076**	0.1844	0.2165**	1.7533
Kattakkada vs Neyattinkara	0.1057**	0.1812*	0.2127**	1.7222
Kattakkada vs Thiruvallam	0.1259**	0.2159*	0.2534**	2.0523
Neyattinkara vs Thiruvallam	0.0931	0.1596	0.1873	1.5168**

S : significant ** at 1% level * at 5% level

Figures within parentheses are transformed values ($\sqrt{x + 1}$)

(0.9295) came on par with the same. Neyattinkara (0.7146) was on par with Thiruvallam (0.5949) and they had significantly lower bug population than in Kattakkada, Vithura and Palode.

Population of nymphs was highest at Kattakkada (2.0817/palm) and it was on par with the population at Vithura (1.8302) and Palode (1.5523) and significantly higher than the mean population observed at Neyattinkara (1.2321) and Thiruvallam (1.3523). Neyattinkara and Thiruvallam were on par.

With reference to the total population also, Kattakkada, Vithura and Palode came on par and significantly higher than the mean population at Neyattinkara. The population at Palode did not significantly differ from the mean population at Thiruvallam, while the population at Vithura and Kattakkada were significantly higher than that of Thiruvallam. Thiruvallam and Neyattinkara did not show significant variations with reference to the total bug population.

The feeding marks as seen at the different locations did not agree with the bug population. The highest mean number of marks was seen at Vithura and the lowest mean number of feeding marks was seen at Neyattinkara and the difference between the two was statistically significant. All other locations came on par with Vithura. Palode and Thiruvallam also differed significantly from Neyattinkara.

Table 13. Relative abundance of C. arecae at five selected centres of Trivandrum district, 1988-89

centres	mean population per observation			
	adults	nymphs	total	mean feeding marks
Palode	0.7153 (1.3097)	1.0305 (1.4250)	1.7262 (1.6511)	47.2873 (6.9489)
Vithura	0.6570 (1.2872)	1.2677 (1.5059)	1.9369 (1.7137)	52.1450 (7.2901)
Kattakkada	1.1275 (1.4586)	2.1188 (1.7660)	3.3227 (2.0815)	70.7104 (8.4682)
Neyattinkara	0.8154 (1.3474)	1.6399 (1.6248)	2.4912 (1.8685)	46.0018 (6.8558)
Thiruvallam	0.8022 (1.3425)	1.8824 (1.6978)	2.7433 (1.9348)	53.9377 (7.4120)
F test (places)	S	S	S	S
	C.D. for comparison of			
Palode vs Vithura	0.0742	0.1304	0.1461	1.2430
Palode vs Kattakkada	0.0830**	0.1457**	0.1633**	1.3897**
Palode vs Neyattinkara	0.0663	0.1165**	0.1305**	1.1107
Palode vs Thiruvallam	0.0742	0.1304**	0.1461**	1.2430
Vithura vs Kattakkada	0.0909**	0.1597**	0.1789**	1.5224
Vithura vs Neyattinkara	0.0760	0.1355	0.1495**	1.2727
Vithura vs Thiruvallam	0.0830	0.1457**	0.1633**	1.3897
Kattakkada vs Neyattinkara	0.0845**	0.1485	0.1664**	1.4164**
Kattakkada vs Thiruvallam	0.0909**	0.1597	0.1789	1.5224
Neyattinkara vs Thiruvallam	0.0760	0.1335	0.1495	1.2727

S - significant ** Significant at 1% level

Figures within parentheses are transformed values ($\sqrt{x + 1}$)

4.2.7. Relative abundance of C. arecae at different locations selected for study on the seasonal fluctuation of the pest during 1988-89

During 1988-89 also Kattakkada had the highest population of adults (1.1275/palm) and it was significantly higher than the population in all the remaining locations. Palode, (Table 13) Vithura, Neyattinkara and Thiruvallam came on par with respect to the adult population the least being 0.7153/palm at Palode.

The highest nymphal population was observed at Kattakkada (2.1188/palm) and it was significantly higher than the mean population recorded at Vithura and Palode which were on par with those of Neyattinkara and Thiruvallam, the latter two being on par between themselves. Minimum population of nymphs per palm was 1.0305, seen at Palode.

With reference to the total population Kattakkada had the highest level (3.3227/palm) and it was on par with the mean population at Thiruvallam alone. Thiruvallam came on par with Neyattinkara and Palode and the latter with Vithura. Mutual comparisons of remaining locations showed statistically significant variations. Least population (1.7262/palm) was at Palode.

The mean number of feeding marks also was seen at the highest level at Kattakkada (70.7104) and it was significantly

higher than the damage observed at Neyattinkara and Palode. The remaining locations did not show statistically significant variations. Minimum feeding marks were observed at Neyattinkara (46.0018/palm).

4.3. Correlation between C. arecae population/YLD indices and weather parameters

The results of statistical analysis of the data (Table 7 to 11) for evaluating the association between the available weather parameters and the varying population of C. arecae observed at different intervals and locations are presented in Table 14 and Fig. 2.

4.3.1. Correlation between the bug population and rainfall

At Palode monthly rainfall showed significant positive association with the nymphs and total population of C. arecae and feeding marks caused by the insect. At Thiruvallam and Vithura also similar positive associations were observed but the correlation coefficients were statistically insignificant. At Neyattinkara and Kattakkada the adult, nymph and the total population of C. arecae showed a negative association with rainfall. Here also the correlation coefficients did not show statistical significance.

Table 14. Correlation between C. arecae population / YLD indices and weather parameters

parameters	adults	nymphs	total population	f.m on leaves	YLD indices
		Palode			
rainfall	0.0660	0.0760*	0.8190*	0.0758*	-0.531**
rainy days	0.0519	0.0492	0.0600	0.0566	-0.636**
max. temp.	-0.1147**	-0.1763**	-0.1745**	0.0508	0.636**
min. temp.	-0.0141	-0.0634	-0.0519	-0.0011	-0.355
max. RH%	-0.0060	-0.0021	-0.0039	-0.0582	-0.196
min. RH%	0.1328**	0.1493**	0.1619**	0.0961*	-0.635**
total bug population					-0.235
		Thiruvallam			
rainfall	-0.0043	0.0779	0.0628	0.0260	
rainy days	-0.0623	0.0532	0.0225	-0.0311	
max. temp.	-0.1459**	-0.2276**	-0.2379**	0.0907	
min. temp.	-0.1176**	-0.0622	-0.0917	0.0364	
max. RH%	-0.0233	-0.0385	0.0238	-0.1164**	
min. RH%	-0.0928	-0.0110	-0.0409	-0.0200	
		Neyattinkara			
rainfall	-0.0523	-0.0170	-0.0307	-0.0188	
rainy days	-0.1170**	-0.0420	-0.0718**	-0.0888**	
		Kattakkada			
rainfall	-0.0460	-0.0103	-0.0660	-0.0520	
rainy days	-0.0992	-0.0307	-0.0579	-0.0170	
		Vithura			
rainfall	0.0404	0.0001	0.0134	0.0848	
rainy days	0.0587	0.0309	0.0456	0.1262**	

* significant at 5% level f.m : feeding marks

** significant at 1% level

4.3.2. Correlation between bug population and rainy days

Number of rainy days during the period of observation did not show significant association with the population of C. arecae at different locations covered in the survey except at Neyattinkara where significant negative correlation with the adult/total population was observed. The associations were mostly positive at Palode, Thiruvallam and Vithura. At the remaining locations the variables were negatively correlated but not statistically significant.

4.3.3. Temperature

Data on maximum and minimum temperature and maximum and minimum relative humidity were available for two locations only. They were Palode and Thiruvallam. The results of statistical analysis of the data showed that maximum temperature had highly significant negative association with the adult/nymph/total population of the insect at both the locations. Minimum temperature had a negative association with the pest population. The correlation between the adult population and minimum temperature at Thiruvallam alone showed statistical significance.

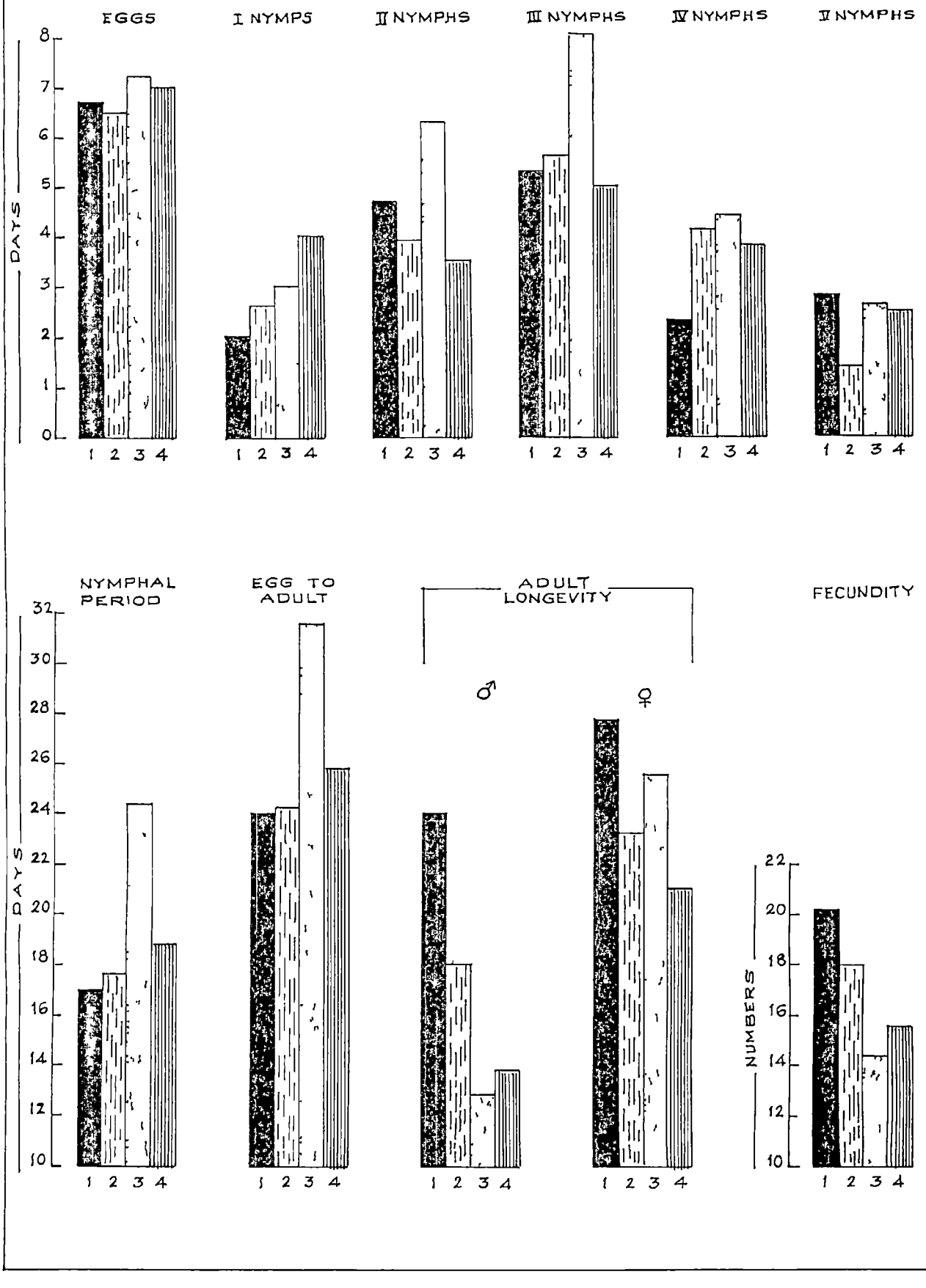
4.3.4. Relative humidity

The variation in feeding marks caused by the pest showed positive and significant association with the varying rainfall

Fig. 4. Effect of different host plants on the biology of *C. arecae*

1. *Areca catechu*
2. *Areca triandra*
3. *Pinanga* sp.
4. *Chrysalidocarpus lutescens*

FIG 4


EGGS
I NYMPS
II NYMPHS
III NYMPHS
IV NYMPHS
V NYMPHS
DAYS
0
1
2
3
4
5
6
7
8
1 2 3 4
NYMPHAL PERIOD
EGG TO ADULT
ADULT LONGEVITY
♂
♀
FECUNDITY
NUMBERS
10
12
14
16
18
20
22
24
26
28
30
32

and minimum relative humidity at Palode and with rainy days at Vithura. The number of feeding marks were negatively and significantly correlated with the maximum relative humidity at Thiruvallam and with rainy days at Neyattinkara. There was a positive and significant association between feeding marks and rainy days at Vithura.

4.3.5. Yellow leaf disease

The indices of yellow leaf disease of arecanut showed negative correlation with rainfall, rainy days and minimum RH and significant positive correlation with maximum temperature. The correlations between pest and disease incidence and the weather factors have been depicted in Fig. 2 also. The variations in bug population and the indices of yellow leaf disease did not show significant correlations when the data were subjected to statistical analysis.

4.4. Biology of C. arecae on different host palms

Data relating to the biology of C. arecae on different host plants and the results of statistical analysis of the same are presented in Table 15 and Fig. 4. The results revealed that the different host plants had significant influence on nymphal duration, and longevity of male adults.

Table 15 Effect of different host plants on the biology of C arecae

host plants	egg period	mean duration of nymphal instars (days)					nymphal period	egg to adult duration	fecundity (eggs/ female)	adult longevity	
		first	second	third	fourth	fifth				male	female
A catechu	6 67 (6-7)	2 00 (2)	4 67 (3-6)	5 25 (4-7)	2 33 (2-3)	2 83 (1-7)	17 08 (16-20)	24.08 (23-27)	20 12 (9-28)	24 00 (23-28)	27 75 (23-37)
A triandra	6 50 (5-8)	2.64 (2-4)	3 93 (2-6)	5 64 (4-8)	4.07 (3-5)	1 42 (1-2)	17 71 (14-20)	24 21 (21-28)	18 00 (17-20)	18 00 (11-22)	23 33 (18-26)
Pinanga sp	7 20 (6-8)	3 00 (3)	6 33 (4-8)	8 11 (8-12)	4.44 (2-6)	2 55 (2-5)	24.44 (20-27)	31 66 (27-36)	1: 40 (12 17)	12 86 (11-13)	25 50 (22-29)
C lutescens	7 00 (7)	4 00 (4)	3 50 (2-5)	5 00 (4-6)	3 83 (3-4)	2 50 (2-3)	18 83 (16-21)	25 83 (23-28)	15 66 (12-19)	13 75 (12-15)	21 00 (20-23)
F test	NS	S	S	S	S	NS	S	S	NS	S	NS
					C D for comparison of						
A catechu vs A.triandra		0.47**	1.11	1 25	0 77**		1 81	1.67		4 43**	
A catechu vs Pinanga sp		0.52**	1 25**	1 41**	0.86**		2 03**	1 87**		4 04**	
A catechu vs C lutescens		0.60**	1 41	1.36	0 83**		1 97	1.81		4 72**	
A triandra vs Pinanga sp		0 51	1 21**	1.59**	0.97		2 31**	2.12**		3 92**	
A triandra vs C lutescens		0.59**	1 38	1 56	0 95		2 25	2 07		3.92**	
Pinanga sp vs C.lutescens		0 60**	1.48**	1 68**	1 03		2 43**	2 23**		3.48	

** significant at 1% level

S significant

figures within parentheses are the range

NS not significant

The data on egg period, female longevity and fecundity did not show significant influence from different host plants.

4.4.1. Incubation period and nymphal duration

Incubation periods of the eggs laid on different hosts varied from 6.5 to 7.20 days. But the variations were not statistically significant.

Duration of first instar nymph was shortest on A. catechu (2 days) and it was significantly lower than the durations in A. triandra (2.64), Pinanga sp. (3) and C. lutescens (4). The nymphal durations on A. triandra and C. lutescens were on par.

The second instar had the shortest duration on C. lutescens (3.50) and it was significantly higher on Pinanga sp. (6.33). Nymphal duration on A. catechu was significantly shorter (4.67) than on Pinanga sp. With reference to the duration of second instar A. catechu, A. triandra and C. lutescens were on par. The same trend was seen in the case of third instar also. The different durations were 5.25, 5.64, 8.11 and 5.00 days for A. catechu, A. triandra, Pinanga sp. and C. lutescens respectively.

In the case of fourth instar the duration on A. catechu was the shortest (2.33 days) and it was significantly lower

than the durations on A. triandra (4.07), Pinanga sp. (4.44) and C. lutescens (3.83) and the latter three were on par.

The fifth instar duration was not significantly altered by the different host plants. It ranged from 1 to 7 days on A. catechu and Pinanga sp. In case of A. triandra and C. lutescens it was from 1 to 3 days only.

The total nymphal duration was significantly prolonged on Pinanga sp. (24.44 days) compared to the durations on A. catechu (17.08), A. triandra (17.71) and C. lutescens (18.83), the latter three being on par.

4.4.2. Fecundity of bugs reared on different hosts

Number of eggs per female was the least among the insects reared on Pinanga sp. (14.40) and it was gradually increasing in the case of the insects reared on C. lutescens (15.66), A. triandra (18.00) and A. catechu (20.12). But these variations were found statistically insignificant.

4.4.3. Longevity

Longevity of males obtained from nymphs reared on A. catechu (24 days) was the longest and significantly higher than the rest. A. triandra was significantly better than Pinanga sp. and the latter came on par with C. lutescens on

Table 16. Effect of different host plants on the size of eggs and early nymphs of C arecae (measurements in mm)

host plant	eggs				first instar nymph			second instar nymph		
	length	width	length of spines of eggs longer	shorter	length	width	length of antenna	length	width	length of antenna
A catechu	1 51 (1.44–1 58)	0 36 (0 34–0 38)	0 66 (0 62–0.75)	0.13 (0 15–0 23)	1 33 (0 91–1.55)	0 63 (0 50–0 82)	0 93 (0 68–1 05)	1 °8 (1 86–2 14)	1 09 (1 05–1 36)	1 23 (1 00 1 5°
A triandra	1 56 (1 50–1 64)	0 32 (0 32)	0 68 (0 64–0 73)	0 19 (0.18–0 23)	1 19 (1 09–1 27)	0 63 (0 59–0 68)	1 02 (0 99–1 09)	2 00 (1 77–2 14)	1.07 (0 95–1 27)	1 23 (1.14–1 32
Pinanga sp	1.57 (1 45–1 64)	0 36 (0 32–0.41)	0 66 (0.50–0 77)	0 18 (0.14–0.2>)	1 5> (1.4>–1 62)	0.71 (0.48–0.91)	1.05 (0.°5–1 23)	2 00 (1.73–2 18)	1 09 (0.91–1.18)	1.15 (1.05–1 23
C lutescens	1.50 (1 40–1 63)	0 36 (0.34–0.38)	0 63 (0.>8–0.68)	0 16 (0 15–0.20)	1 33 (1 14–1 50)	0 72 (0.68–0 77)	1 00 (0 95–1.05)	2.13 (2.09–2 18)	1 20 (1.18–1 23)	1 23 (1 23)
E guineensis	1.60 (1.55–1.67)	0 36 (0 34–0 38)	0 64 (0 65–0 70)	0 18 (0 16–0.21)	1 34 (1 20–1 60)	0 6> (0 53–0 73)	0 91 (0 83–1 00)	2.13 (2.05–2 20)	1.19 (1 08–1 30)	1 20 (1 10–1 >5
F test	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

NS not significant

figures within parentheses are the range

this criterion. Though the female longevity was longest in the insects reared on A. catechu, the life span of the insects reared on other hosts (21.00 to 25.50 days) was not significantly lower.

As clearly seen from Fig. 4, the prolongation of the nymphal duration (total) on Pinanga sp. was contributed by its effect on the second and third instar nymphs and variations in the durationsof fourth and fifth instars reared on different hosts were marginal. C. lutescens which caused the longest duration in first instar was completing the second and third instar stages with the shortest time and in fourth and fifth instar it came on par with Pinanga sp. Favourable influence of A. catechu and A. triandra on adult males and on fecundity was also brought out conspicuously in the figure.

4.4.4. Biometrics of immature stages and adults of C. arecae

Effects of different host palms on the eggs and first and second instar nymphs are presented in Table 16. Though slight variations were observed in the length, width and spines of the eggs laid on different hosts the variations were not statistically significant. The length and width of the first and second instar nymphs reared on different host palms and the length of their antennae showed variations. But they were also not statistically significant.

Table 17 Effect of different host plants on the size of nymphs and adults of C arecae (measurements in mm)

host plants	third instar nymph			fourth instar nymph			fifth instar nymph			adult male			adult female		
	length	width	antenna length	length	width	antenna length	length	width	antenna length	length	width	antenna length	length	width	antenna length
A catechu	2 89 (2 82-3 05)	1 85 (1 77-1 91)	2 03 (1 91-2 18)	3 69 (3 45-3 95)	2 20 (1 80-2 50)	2 75 (2 55-2 91)	4 74 (4 18-5.23)	2 35 (1 91-2 68)	2 73 (2 50-3 00)	4 97 (4 77-5 18)	2 65 (2 41-2 82)	3 68 (3 32-4 09)	5 32 (5 14-5 50)	3 10 (2 80-3.27)	3 74 (3 41-4 09)
A triandra	2 52 (2 27-2 73)	1 52 (1 36-1.68)	1 66 (1.55-1 82)	3.20 (3 05-3.45)	1 84 (1 59-2 14)	2 25 (2.00-2 50)	4 39 (4 00-4.64)	2.35 (2.00-2 73)	2 77 (2 59-2 86)	4 74 (4.41-5 15)	2 39 (2 36-2 50)	3 36 (3 22-3 43)	4 97 (4 77-5 18)	2 61 (2 41-2 82)	3 52 (3 52)
Pinanga sp	2 65 (2 55-2.73)	1 53 (1 30-1 73)	1 68 (1 59-1.82)	3.50 (3 41-3.64)	2.49 (2.41-2 55)	2 97 (2 91-3 05)	4 57 (4 09-4 50)	2 33 (2 27-2 41)	2.76 (2 59-3.10)	4.64 (4 27-4 86)	2.46 (2 36-2 71)	3 06 (2 59-3 45)	5 05 (5 05)	2 68 (2 68)	3 86 (3 86)
C lutescens	2 45 (2 41-2 50)	1 57 (1 50-1 64)	1.61 (1.50-1 72)	4 12 (3.95-4.25)	2 49 (2.35-2.60)	2 72 (2 65-2.80)	5 34 (5 09-5 95)	2 12 (1 90-2.28)	3.07 (2 62-3 47)	6 12 (5 24-6.90)	2 67 (2 38-3 19)	3 70 (3.57-4.05)	6 35 (4.68-7.14)	2 90 (2 70-3.09)	4 04 (3 99-4 09)
E guineensis	3 16 (3 00-3.33)	2.02 (1.90-2.14)	2 50 (2 14-2.86)	4 55 (4.29-4.76)	2 56 (2.38-2.86)	2 85 (2 71-2 95)	5 83 (5 48-6 19)	2.78 (2 62-2 82)	3 13 (2 86-3.33)	5 95 (5.71-6 43)	2 78 (2 71-2 86)	3 87 (3 81-4.05)	6 18 (5 71-6 90)	2 96 (2 80-3 11)	3 67 (3 23-3 81)
F test	S	S	S	S	S	S	S	S	S	S	NS	S	NS	NS	NS
	C.D. for comparison of														
A catechu vs A triandra	0.14**	0.12**	0 23**	0 22**	0.28**	0 19**	0.35*	0 22	0.23	0 56		0.47			
A catechu vs Pinanga sp	0 16**	0.14**	0 25**	0.26	0 30*	0 22*	0 45	0 28	0 27	0 56		0 44**			
A catechu vs C lutescens	0 16**	0 14**	0 24**	0.27**	0 26**	0.20	0 42**	0 26	0.25**	0 56**		0 44			
A catechu vs E guineensis	0.21**	0.18	0 31**	0.28**	0.25**	0 23	0 40**	0 25**	0 25**	0.51**		0 41			
A.triandra vs Pinanga sp	0 21	0.18	0 31	0.24**	0.28**	0 20**	0 37	0 23	0 21	0 51		0 41			
A triandra vs C lutescens	0 23	0 19	0.32	0.24**	0 28**	0 19**	0 46**	0 29	0.26**	0 51**		0 37**			
A triandra vs E guineensis	0 21**	0.18**	0 31**	0.26**	0.28**	0 21**	0.41**	0 25**	0.25**	0.56**		0.44**			
Pinanga sp vs C lutescens	0 21	0.18	0 30	0.22**	0 24	0 18**	0 37**	0 23*	0.21**	0 56**		0 44**			
Pinanga sp vs E guineensis	0.23**	0.19**	0.32**	0.27**	0 25	0.24	0 46**	0 29**	0 26**	0 56**		0 41**			
C.lutescens vs E guineensis	0 26**	0 23**	0 37**	0 24**	0.22	0.18	0 41**	0 26**	0 24	0 51		0 37			

S significant
NS not significant
** significant at 1% level
* significant at 5% level
Figures within parentheses show the range

The effect of different host palms on the size of later instar nymphs of C. arecae and of the adults is presented in Table 17 and Fig. 5.

The length of the third instar nymph grown on A. catechu (2.89 mm) was significantly higher than the length of the nymphs reared on A. triandra (2.52), Pinanga sp. (2.65) and C. lutescens (2.45) and they were significantly lower than the length of nymphs reared on E. guineensis (3.16 mm). A. triandra, Pinanga sp. and E. lutescens were on par. Same trend was seen in the case of antennal length of the third instar nymph also.

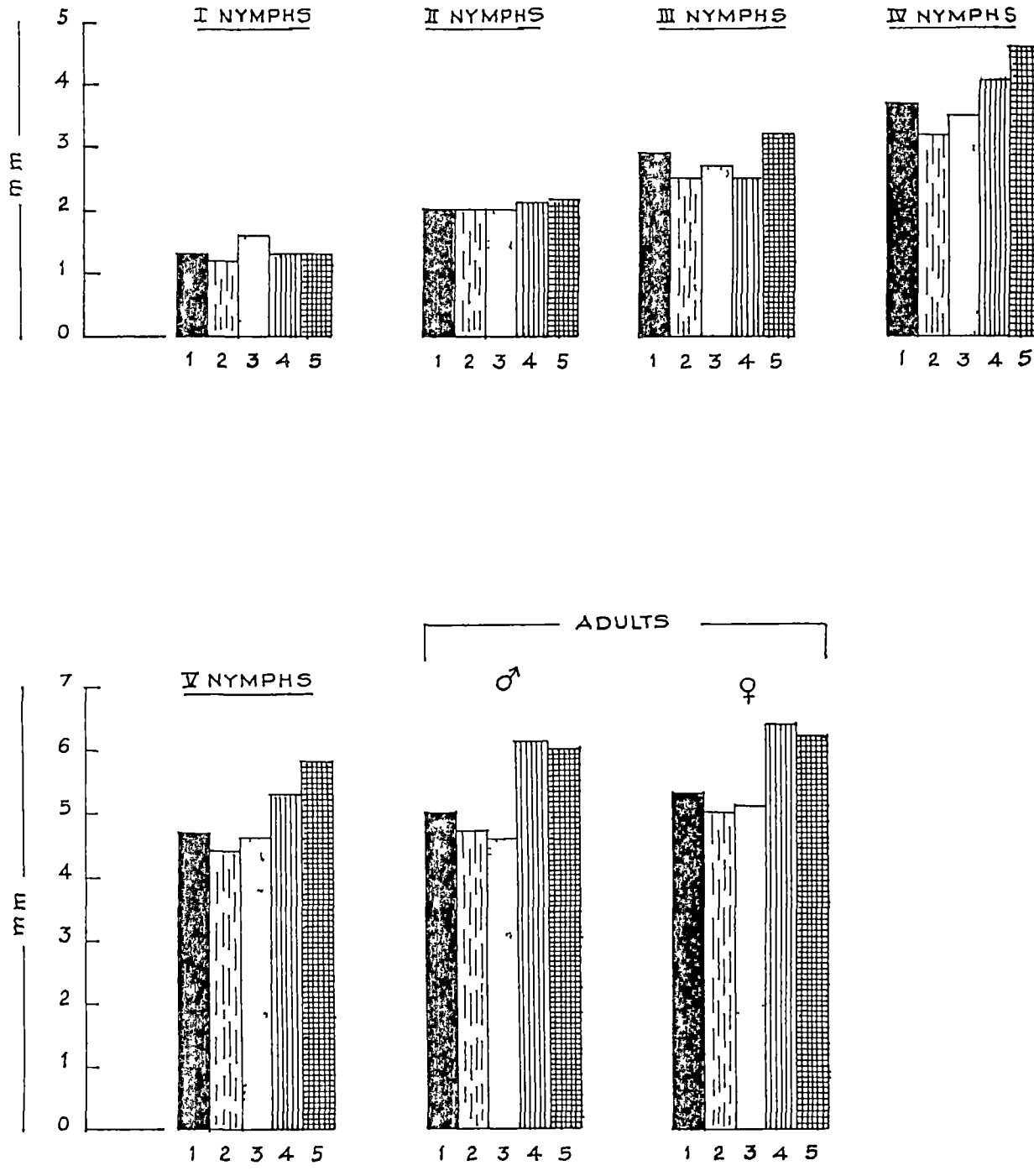
The body width of nymphs reared on A. catechu (1.85) was significantly higher than the width of nymphs reared on A. triandra (1.52), Pinanga sp. (1.53) and C. lutescens (1.57), the latter three being on par. Nymphs reared on A. catechu and E. guineensis (2.02 mm) came on par with reference to the body width.

The body length of the fourth instar nymphs reared on A. catechu (3.69 mm) was significantly higher than the length of nymphs reared on A. triandra (3.20 mm) and they were on par with that recorded on Pinanga sp. (3.50). The three had significantly lower body width compared to the nymphs reared on E. guineensis (4.55 mm), C. lutescens (4.12).

Fig. 5. Effect of different host plants on the size of different life stages of *C. arecae*

1. *A. catechu*
2. *A. triandra*
3. *Pinanga* sp.
4. *C. lutescens*
5. *E. guineensis*

FIG 5


I NYMPHS
II NYMPHS
III NYMPHS
IV NYMPHS
V NYMPHS
ADULTS
♂
♀
mm
0
1
2
3
4
5
6
7
1 2 3 4 5

Based on the body width of fourth instar nymphs also the different host palms were found to have significantly varying effects on the nymphs. The body width of nymphs reared on A. catechu (2.2 mm) was significantly higher than the body width of nymphs reared on A. triandra (1.84 mm) and was significantly lower than the body width of nymphs reared on Pinanga sp. (2.49 mm), C. lutescens (2.49 mm) and E. guineensis (2.56 mm) and the latter three were on par.

The antennal length of the nymphs reared on A. catechu (2.75 mm) was significantly higher than the antennal length of the nymphs reared on A. triandra (2.25 mm) and was on par with the antennal length of nymphs reared on Pinanga sp. (2.97 mm), C. lutescens (2.72) and E. guineensis (2.85 mm).

The size of the fifth instar nymph also was seen influenced by the different host palms significantly. The body length of the nymphs on A. catechu (4.74 mm) was higher than that occurring on A. triandra (4.39 mm) and Pinanga sp. (4.57 mm), but all the three were statistically on par. The mean length of the nymphs on C. lutescens (5.34 mm) was significantly higher than the length of nymphs on A. catechu and was significantly less than the length of the nymphs reared on E. guineensis (5.83 mm).

With reference to the body width of the fifth instar, those reared on A. catechu (2.35 mm) came on par with those reared on A. triandra, Pinanga sp. and C. lutescens and the latter three were on par. Nymphs on E. guineensis (2.78 mm wide) had significantly higher body width than those on A. catechu.

With reference to antennal length of 5th instar nymph C. lutescens and E. guineensis were found significantly longer than those of the nymphs reared on A. catechu while A. triandra and Pinanga sp. came on par with it.

Body length of male bugs reared on A. catechu (4.97 mm) came on par with those reared on A. triandra (4.74 mm) and Pinanga sp. (4.64 mm). The body length of males reared on C. lutescens (6.12 mm) was the maximum and the insects reared on E. guineensis (5.95 mm long) came on par with the same. The body width of the males reared on different hosts ranged between 2.39 and 2.78 mm and the variations were not statistically significant. The antennal length of the males reared on Pinanga sp. was the least 3.06 mm and it was significantly lower than the antennal length of males reared on other hosts. Antennal length of males reared on A. triandra was significantly less than those of C. lutescens and E. guineensis and A. catechu came on par with the latter two.

Body length of the females reared on different hosts ranged from 4.97 to 6.18 mm, body width from 2.61 to 3.10 mm and antennal length from 3.52 to 4.04 mm. But the variations in the data relating to these characters did not show statistical significance.

As seen clearly in Fig. 4, different host palms did not affect the size of the first and second instar nymphs. The favourable effect of E. guineensis was manifested from the third instar onwards while the effect of C. lutescens became more conspicuous in the fourth and fifth instar nymphs.

4.5.1. Nature and extent of damage caused by C. arecae

The adults and immature stages of C. arecae usually remained in the topmost two or three leaf axils of the areca palms. During day time, they remained congregated at the interior of the leaf axils and at dusk and early morning they migrated on to the spindle leaf or the first leaf of the palm and fed.

The feeding behaviour of the insect was observed in the laboratory under a binocular microscope by confining the insect in a specimen tube in which the upper half of a fresh tender leaflet or arecanut was inserted, the distal end of which was wound with a wet cotton swab. The tube was closed with a cotton plug to prevent the escaping of the bug.

Plate III. Injury caused to areca leaf by *C. arecae*

A. injury caused by feeding

1. insect feeding on the leaf

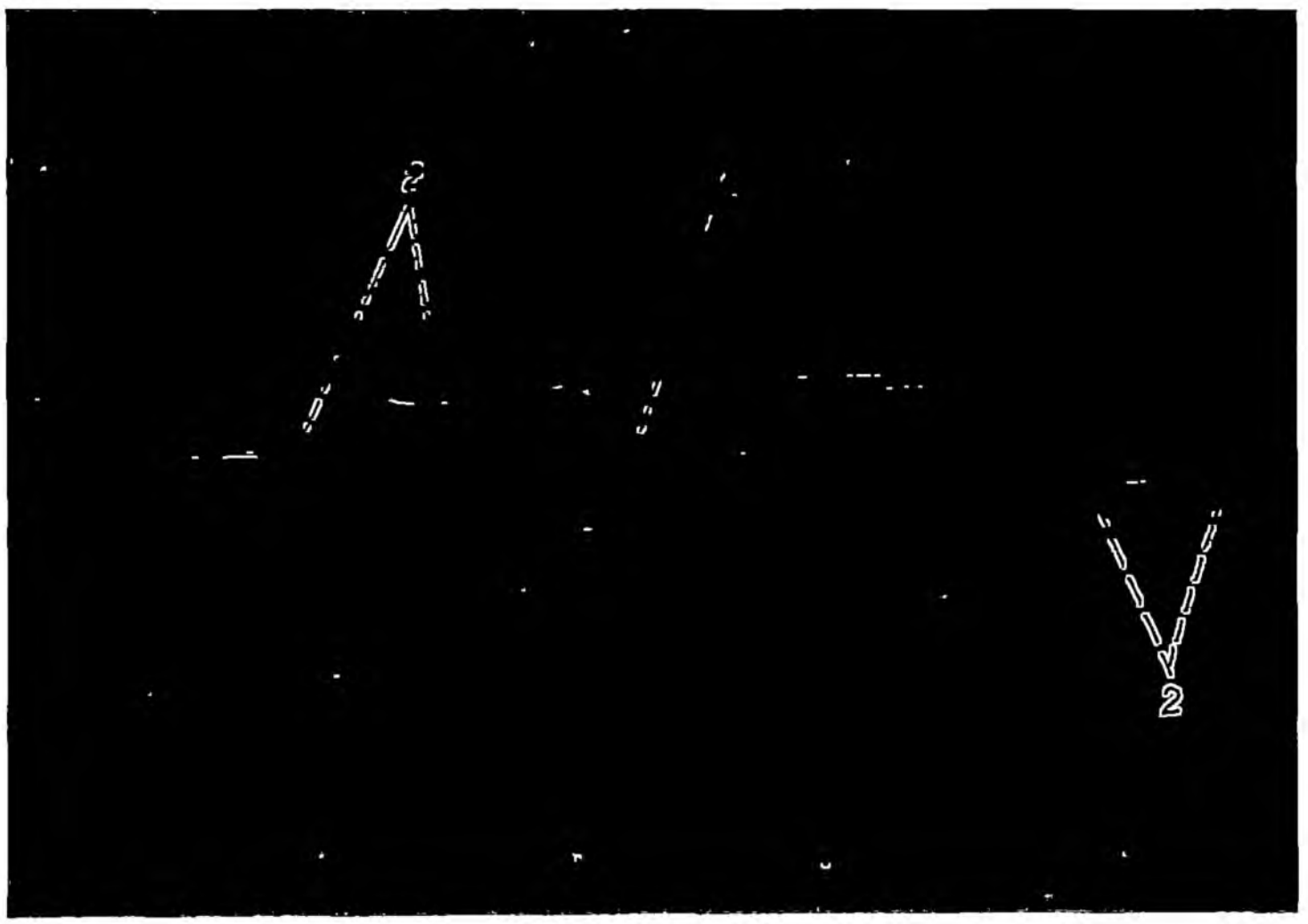
2. feed marks

B. injury caused by egg laying

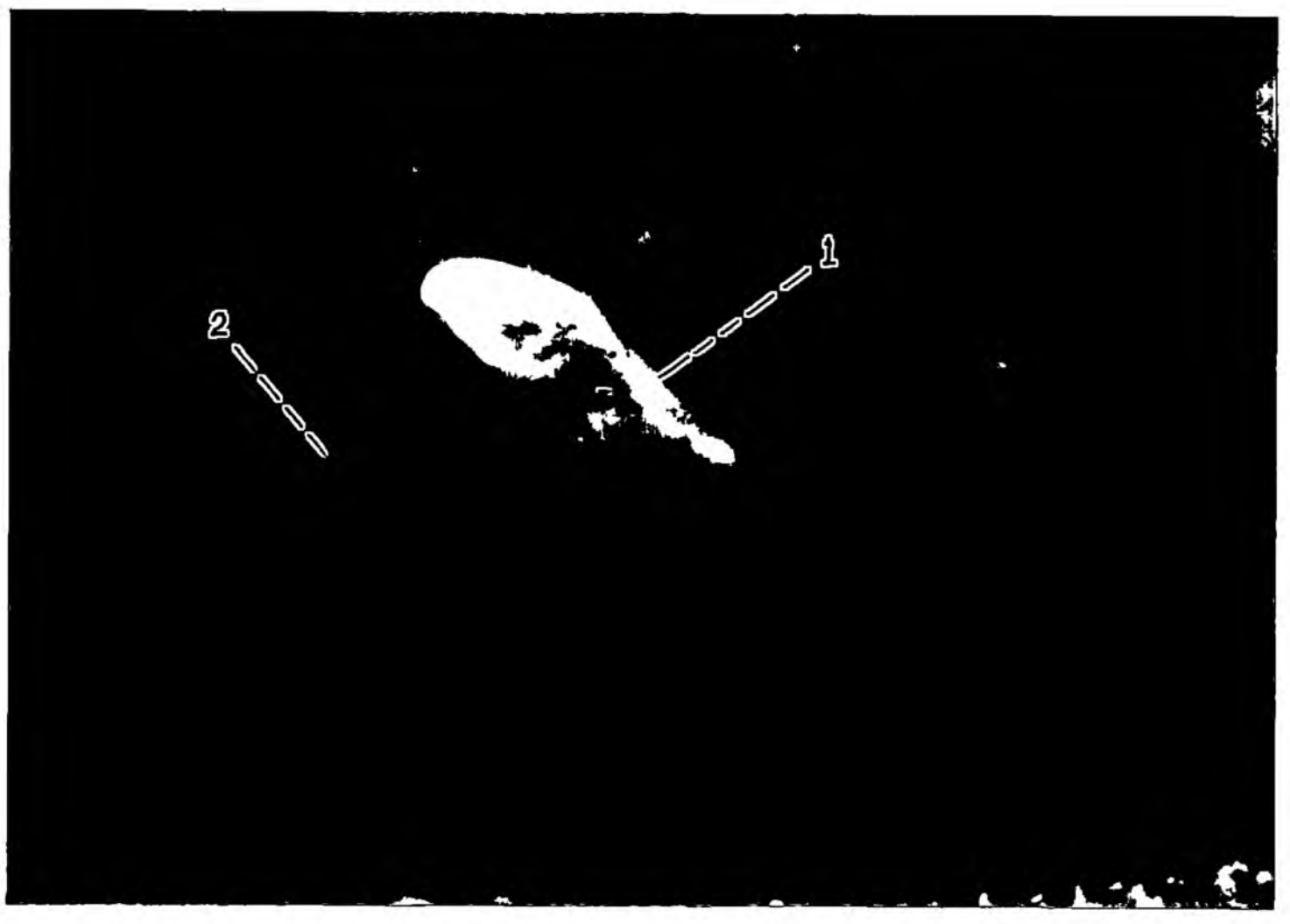
1. egg

2. leaf tissue damaged around the puncture made for laying the egg

PLATE III



A



B

Plate IV. Lower portion of the emerging spindle damaged by *C. arecae*

A. at emergence of spindle

B. after opening of the spindle leaf

PLATE IV

A

B

The insect briskly moved on the leaf tapping the surface with the tip of the protracted labium and antenna. Then it settled on a selected spot and thrust the stylets into the leaf lamina with a quick jerk, shaking the head and bending the proboscis backwards.

Immediately after the puncture on the leaflet a discoloured area around the point of insertion could be seen denoting the onset of feeding. If the insect found the location suitable it continued to imbibe the content up to a maximum of 20 minutes with an average time range of five minutes and then moved on to a fresh spot and fed. An insect may cause several such feeding marks in succession (Plate III A). The feeding spots measured 5 mm to 30 mm in length and 2 mm to 4 mm in width. In some cases several such feeding marks coalesced to form extensive contiguous areas of damaged leaf lamina. In the centre of each feeding mark a green island which turned yellow and black in due course could be observed. The leaf tissue around the point of insertion of the egg also developed brownish discolouration (Plate III B) and it gradually turned black.

The insects lived in the first two or three leaf axils of the palm. They preferred feeding on the emerging spindle (Plate IV A) and also laid eggs on it. As a result of this

Plate V. Whole spindle of the palm damaged by *C. arecae*

A. dead spindle rotting from tip

B. spindle dead and rotten by the attack of *C. arecae* followed by bud rot incidence

PLATE V

A

B

Plate VI. The spindle and top leaves of the palm severely damaged by the persistent incidence of *C. arecae*

PLATE VI

the spindle often suffered serious injury. If the incidence commenced after partial emergence of the spindle, the insect fed on the lower portions and the distal portion of the leaf remained unaffected when such spindle opened up (Plate IV B).

If the feeding commenced with the emergence of the spindle the damage occurred from the very tip of it. As a result the whole spindle got dried and often the spindle failed to open up (Plate V A). This affected the emergence of succeeding leaves and thus choked the very growth of the palm. Complete decay and death of the spindle during rainy seasons was often noted. Bud-rot disease of arecanut was also found to occur along with such damage (Plate V B) occasionally. Saprophytic flies namely Lamprolonchaea sp., Silba sp., Drosophyla melanogaster Megen, Atherigona pallidipalpis Malloch (Ord: Diptera) and fungi namely Fusarium sp., Coletotrichum sp. and bacterium namely Pseudomonas sp. were seen associated with the dead spindle. Persistent incidence of the pest on the crown resulted in the severe damage of leaves and the whole leaves showed spotted and holed appearance caused by the feeding injury (Plate VI). Prolonged maintenance of the palm without control measures, led to the drying up of the leaves and ultimate death of the palm.

Plate VII. Feeding injury on the leaf stalk caused by *C. arecae*

A. pox mark injury at the base of leaf stalk on the outer side

B. pox mark injury on the inner side of leaf stalk

PLATE VII

A

B

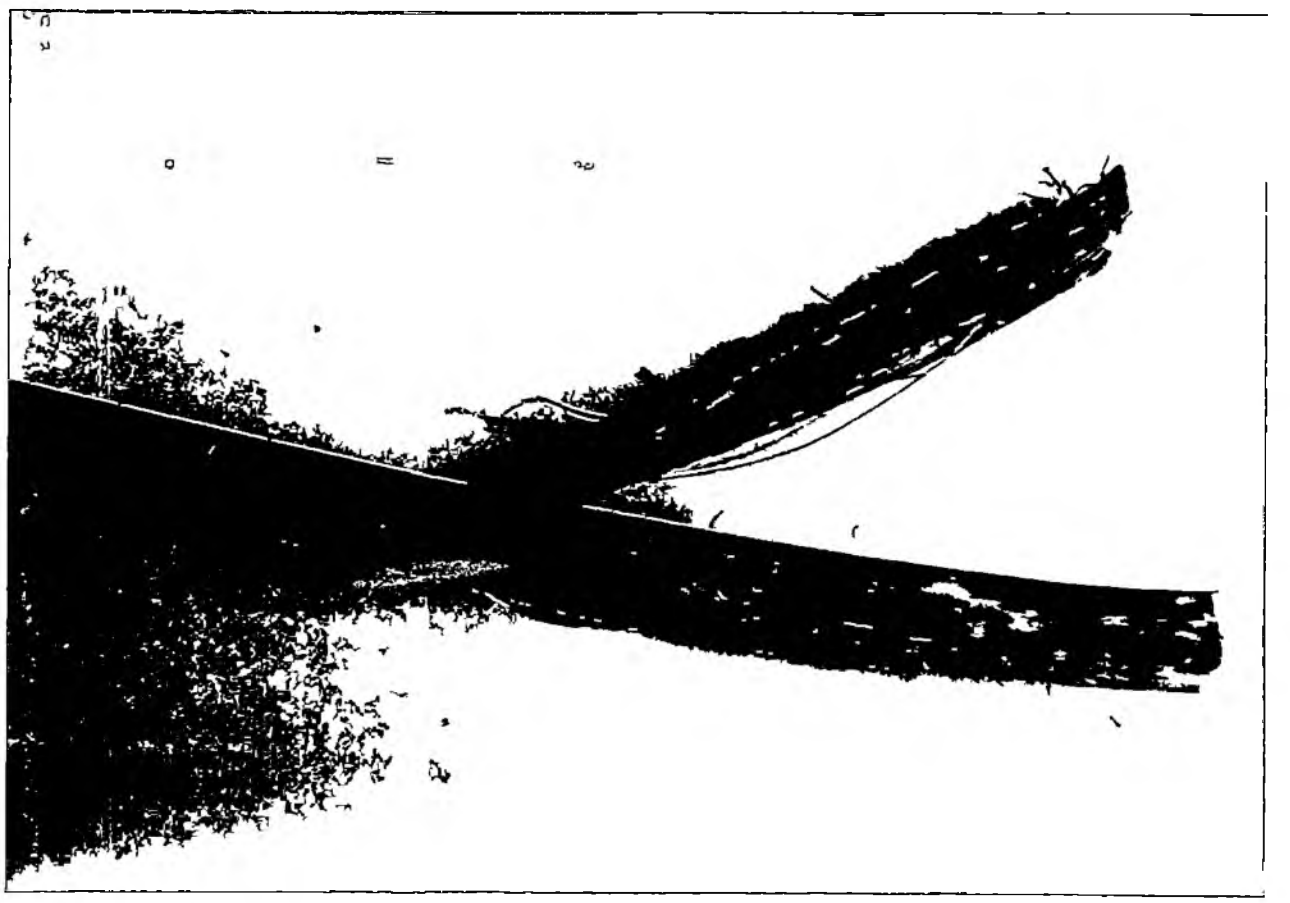
Plate VIII. Injury to the rachis of areca leaf caused by *C. arecae*

A. outer view

B. surface of the injured rachis split open showing the internal damage

PLATE VIII

A



B

While the insects remained in leaf axils, they fed and laid eggs on the inner and outer sides of the rachis of the tender leaves also (Plate VII A & B). This caused the development of typical pox marks on the surface of the rachis. In some palms it was seen along the entire length of the rachis on the back side (Plate VIII A). When such a leaf stalk was split open (Plate VIII B), extensive portions of necrotic dead tissues were seen around each feeding/egg laying spot. This type of damage adversely affected the transmission of food materials leading to the yellowing of leaflets and gradual death of the leaves. Persistent incidence of the pest would be detrimental to the general health and longevity of the palm. Often it turned fatal under field situations.

4.5.2. Histological changes in the leaf tissue damaged by the feeding of *C. arecae*

4.5.2.1. Histo-anatomical profile of areca leaf

The normal leaflet has an upper epidermis consisting of a single layer of small rectangular cells in T.S with a thick cuticle. The lower epidermis is similar in structure to the upper epidermis except that there are stomata (Plate IX). In between the two epidermis is the mesophyll composed of 2 to 3 layers of palisade parenchyma and spongy parenchyma.

Plate IX. Healthy areca leaf - transverse section (T.S) (40 X)

1. epidermis
2. palisade parenchyma
3. spongy parenchyma
4. vascular bundle
5. parenchymatous bundle sheath
6. chloroplast

Plate X. T.S. of areca leaf fed by C. arecae (15 minutes after feeding) (40 X)

PLATE IX

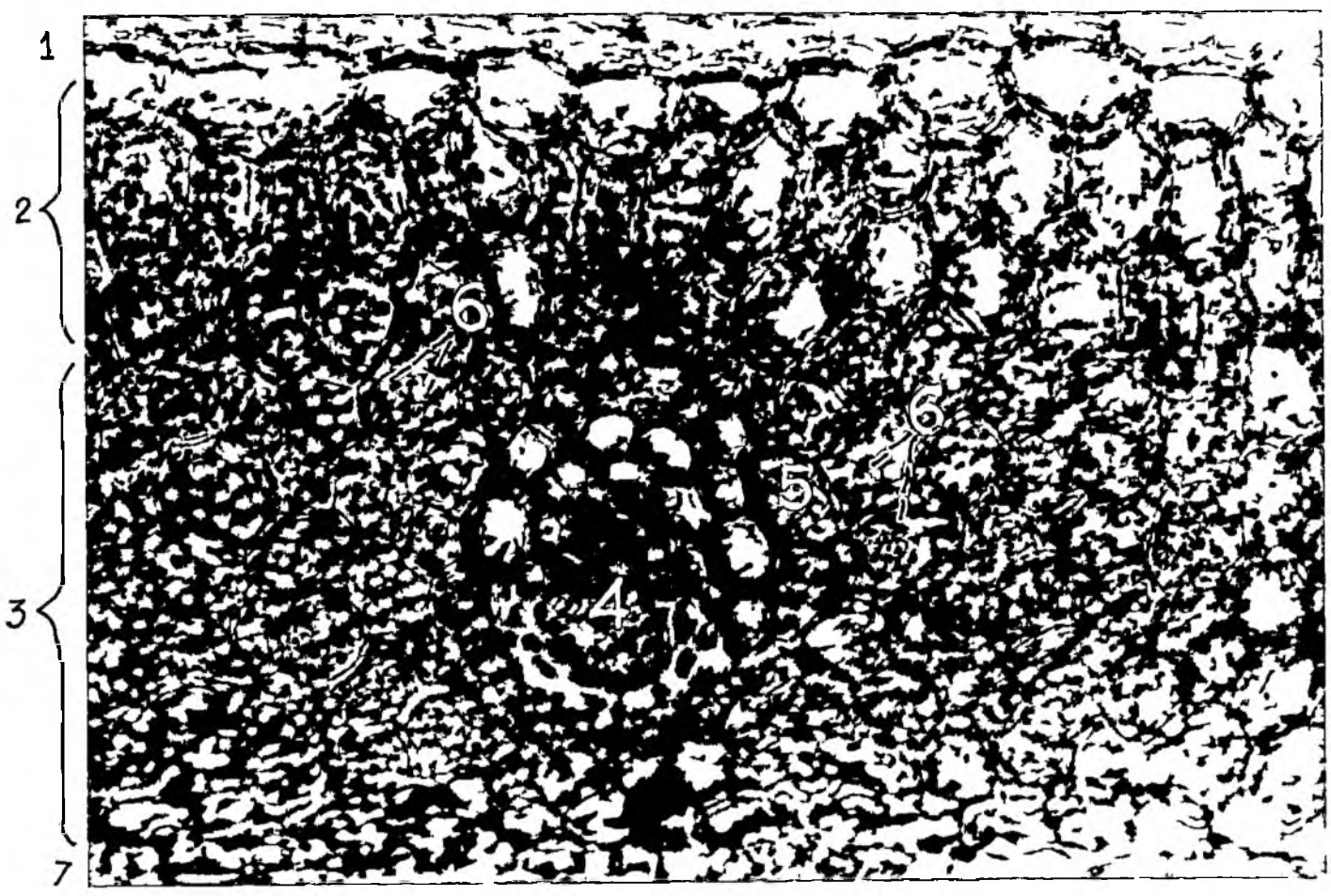
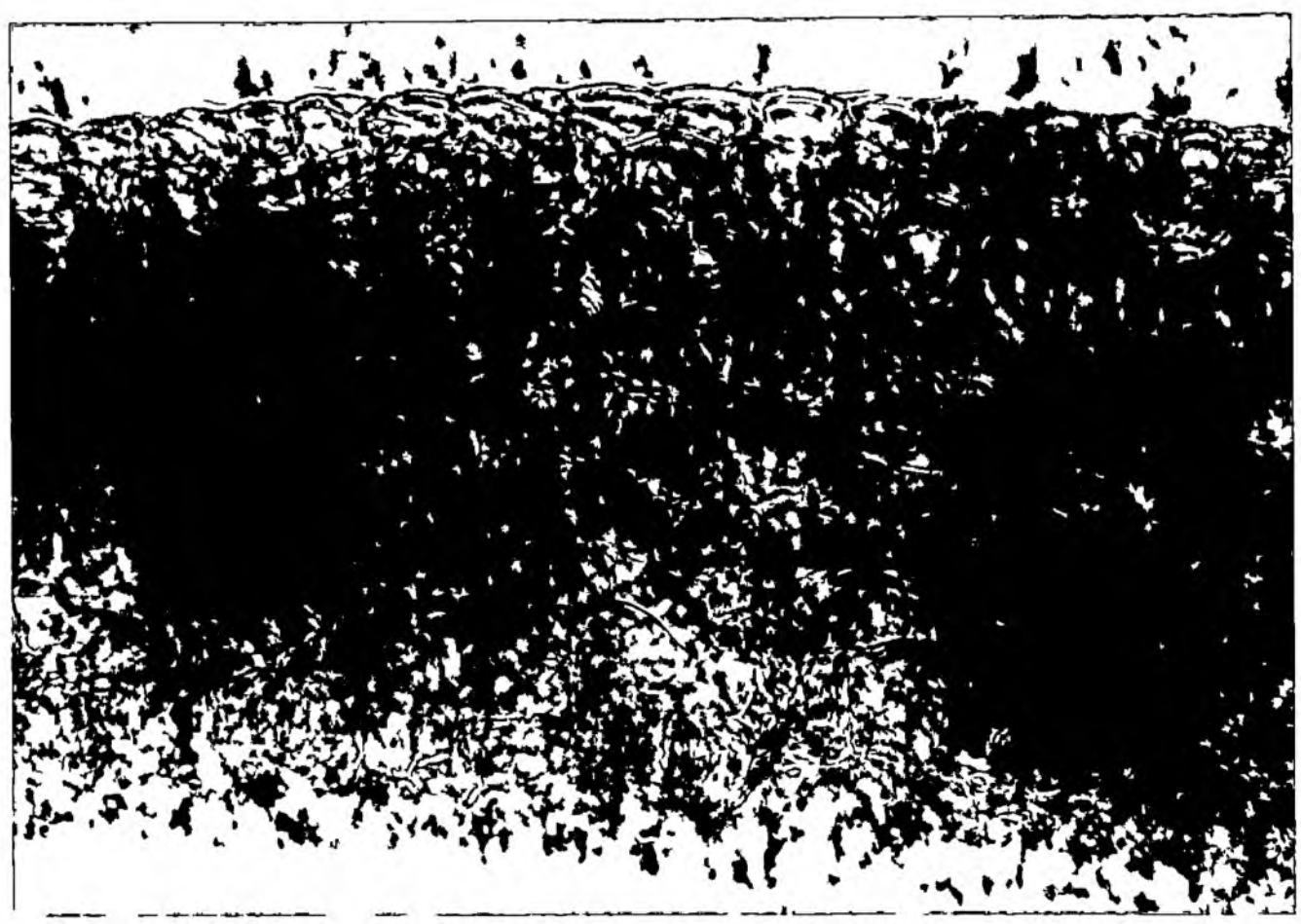


PLATE X



The palisade layer is made up of small slightly elongated hexagonal cells with their longitudinal axis perpendicular to the epidermis. The spongy parenchyma is made up of larger cells. Both the palisade and spongy cells contain abundant chloroplasts. The chloroplasts are seen arranged along the cell walls, leaving the centre of the cells almost free of it. The vascular bundles are surrounded by a layer of parenchyma cells or bundle sheath which are practically devoid of chloroplasts.

4.5.2.2. Histo-anatomical changes caused by the feeding of C. arecae

Soon after the insertion of the stylets into the plant tissue for feeding, an irregularly shaped discoloured dull green area became visible around the spot. The transverse section (T.S) of the area 15 minutes after the formation of the lesion showed that plasmolysis of the palisade and spongy parenchyma cells had commenced then. The protoplasm got detached from the cell walls and started shrinking. The normal position of the chloroplasts along the cell wall (Plate IX) was disturbed (Plate X) and they were seen scattered in the cytoplasm.

T.S. taken 30 minutes after the formation of feeding mark showed further advancement of plasmolysis and chloroplasts turned yellowish in colour.

Plate XI. T.S. of areca leaf tissue 2 h after feeding by C. arecae (40 X)

1. epidermis
2. vascular bundle
3. cell wall

Plate XII. T.S. of areca leaf tissue 4 h after feeding by C. arecae (40 X)

1. epidermis
2. vascular bundle
3. plasmolised mesophyll cells at the fed area
4. normal cells at unfed area

PLATE XI

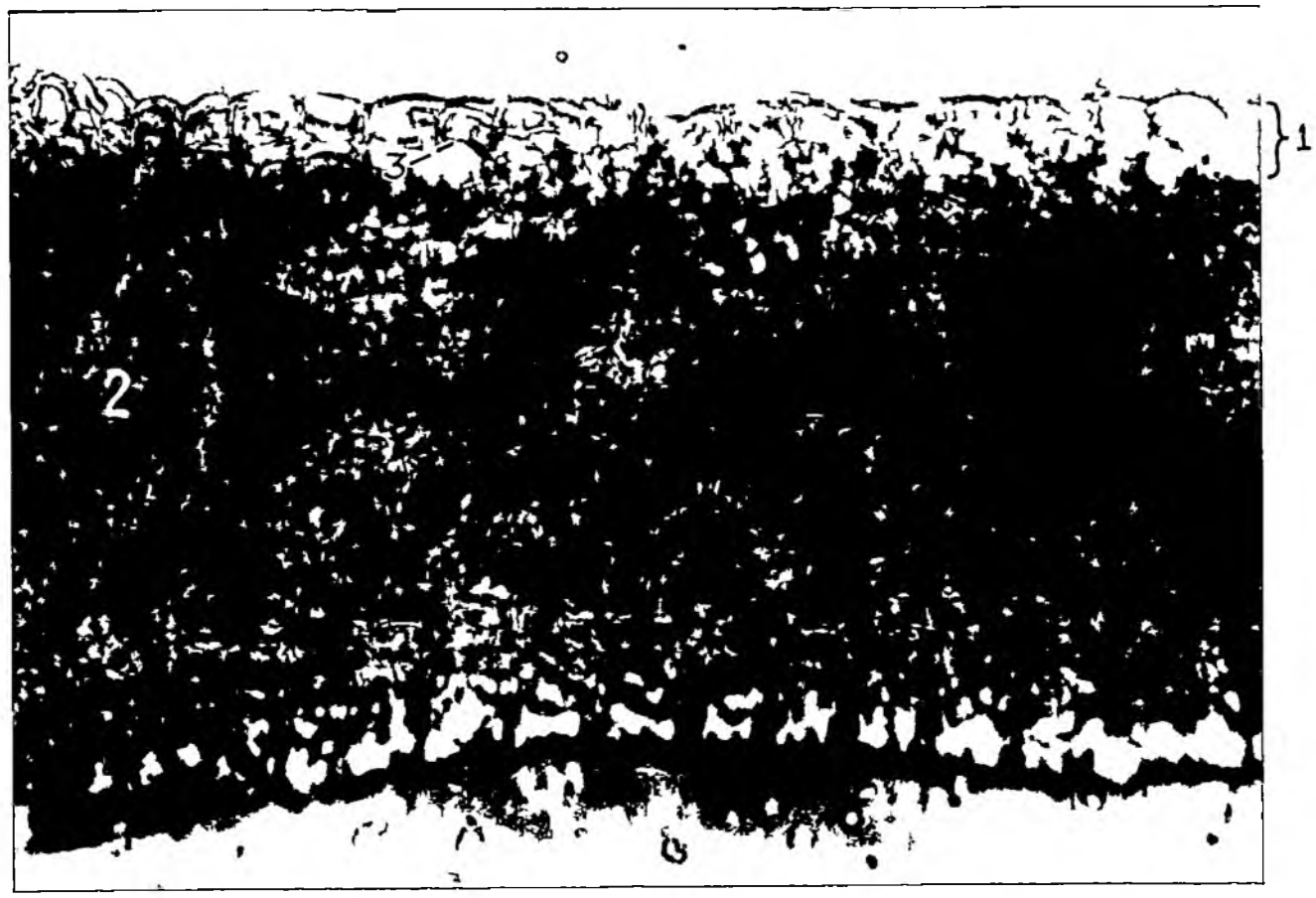
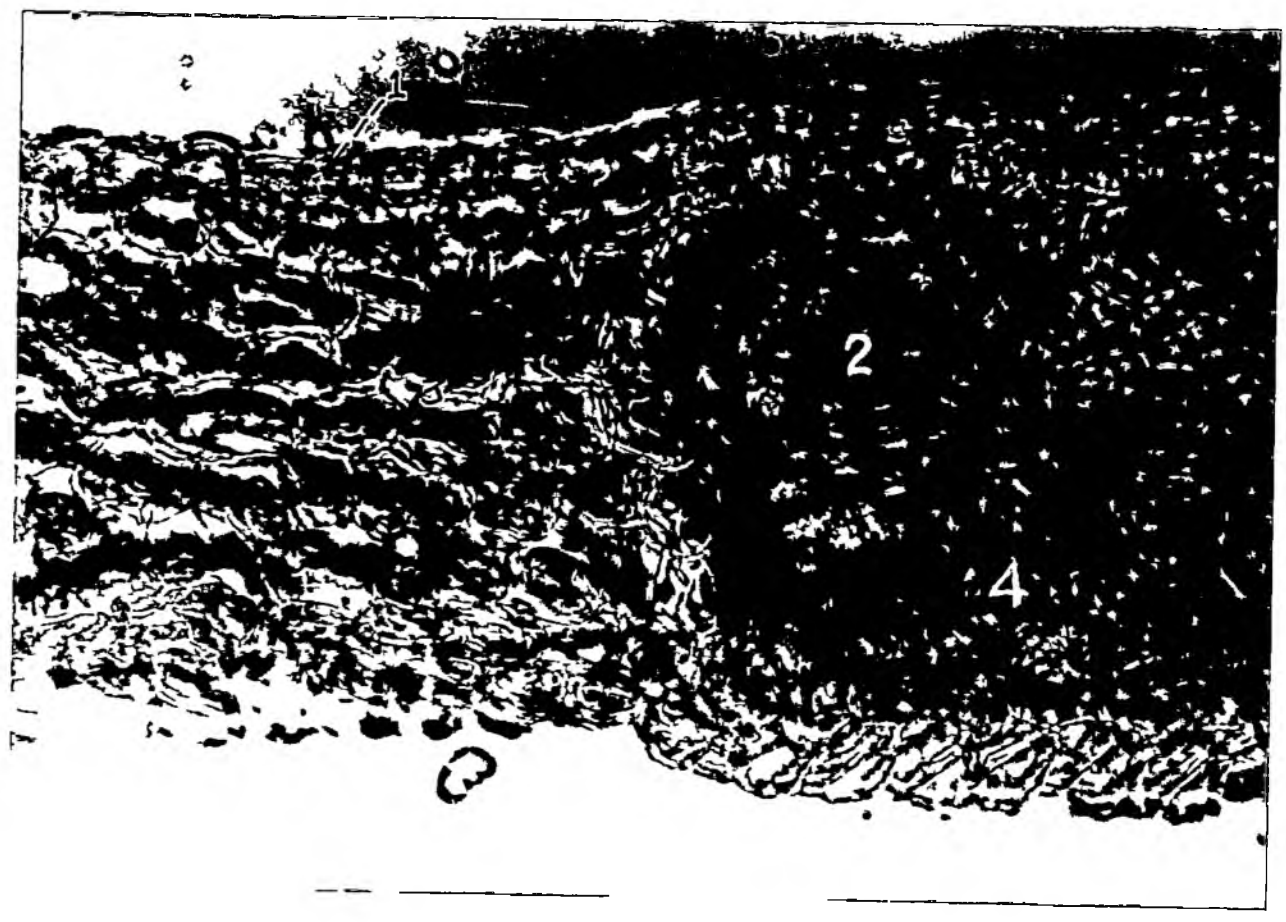


PLATE XII



The plastids lost their green colour within an hour after the formation of the feeding mark. Then the protoplasm within the affected cells was seen drawn towards the centre. The mesophyll cells which had undergone plasmolysis, collapsed so that the affected portion of the leaf began to shrink.

Two hours after the development of feeding mark the leaf lamina at the spot was 150 μ lesser in thickness compared to the undamaged portions of the leaf. The vascular bundles in the affected area however remained intact.

At four hours after commencement of feeding (Plate XII) the affected portion was seen shrunk to about 5/7th the thickness of the healthy area. The cells were almost fully plasmolized and the rolled up protoplasm was seen to fill only half the area within the cell walls. At that stage the upper and lower epidermis and the vascular bundles remained almost intact.

At eight hours (Plate XIII) the mesophyll cells were in a state of progressive collapse and the cell walls appeared wavy in the section. The affected cells collapsed further so that the affected area had only half the thickness of the normal area.

At ten hours after the feeding the fed portion had less than half the thickness of healthy area and the mesophyll cells in the region were barely distinct since the cells had almost fully collapsed. The contents of the cells turned black. During the period the epidermal cells and vascular bundles also remained intact.

Plate XIII. T.S. of areca leaf tissue 8 h after feeding by C. arecae (40 X)

1. epidermis
2. vascular bundle
3. plasmolised mesophyll

Plate XIV. T.S. of areca leaf tissue 10 h after feeding by C. arecae (40 X)

1. epidermis
2. vascular bundle

PLATE XIII

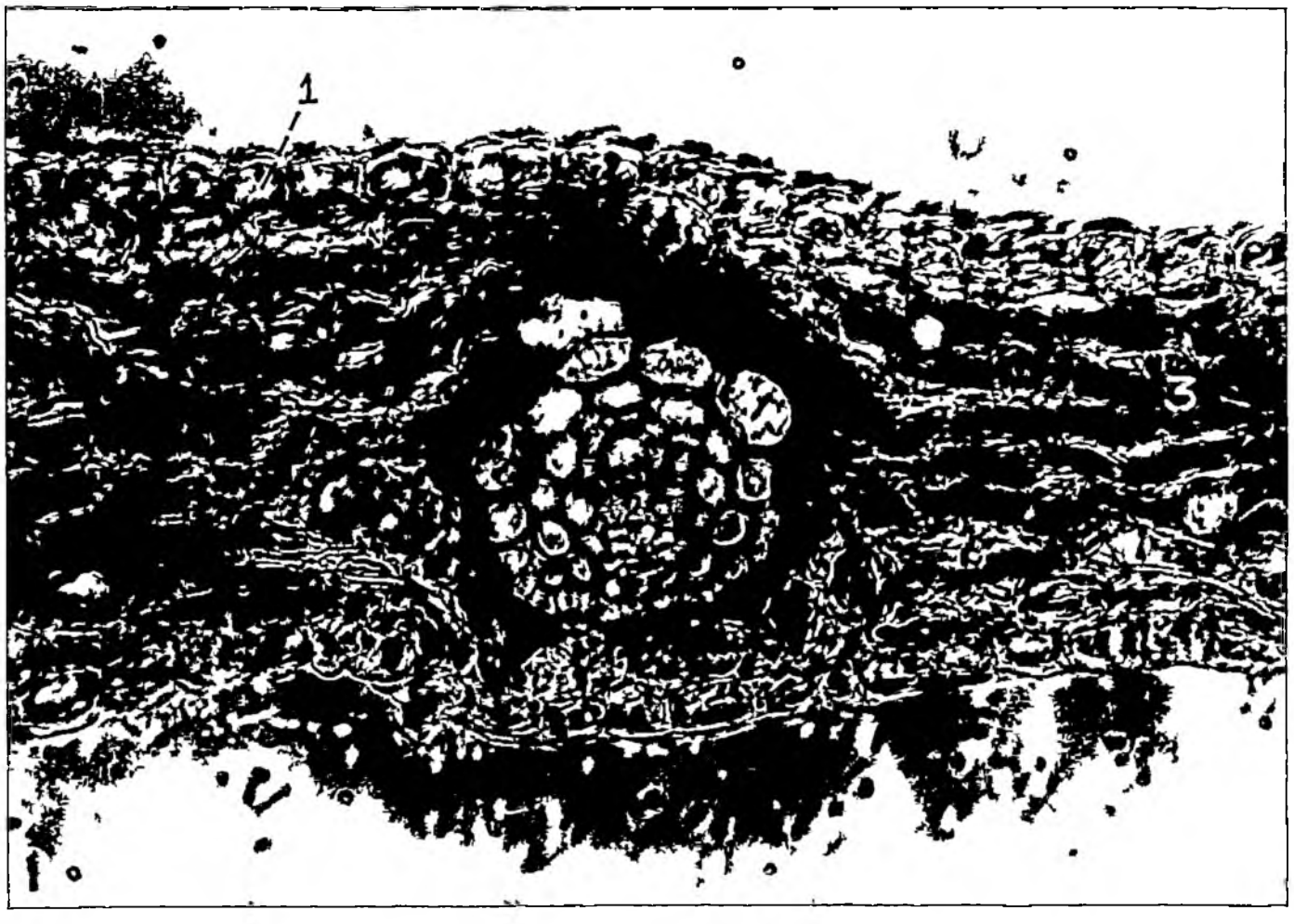


PLATE XIV

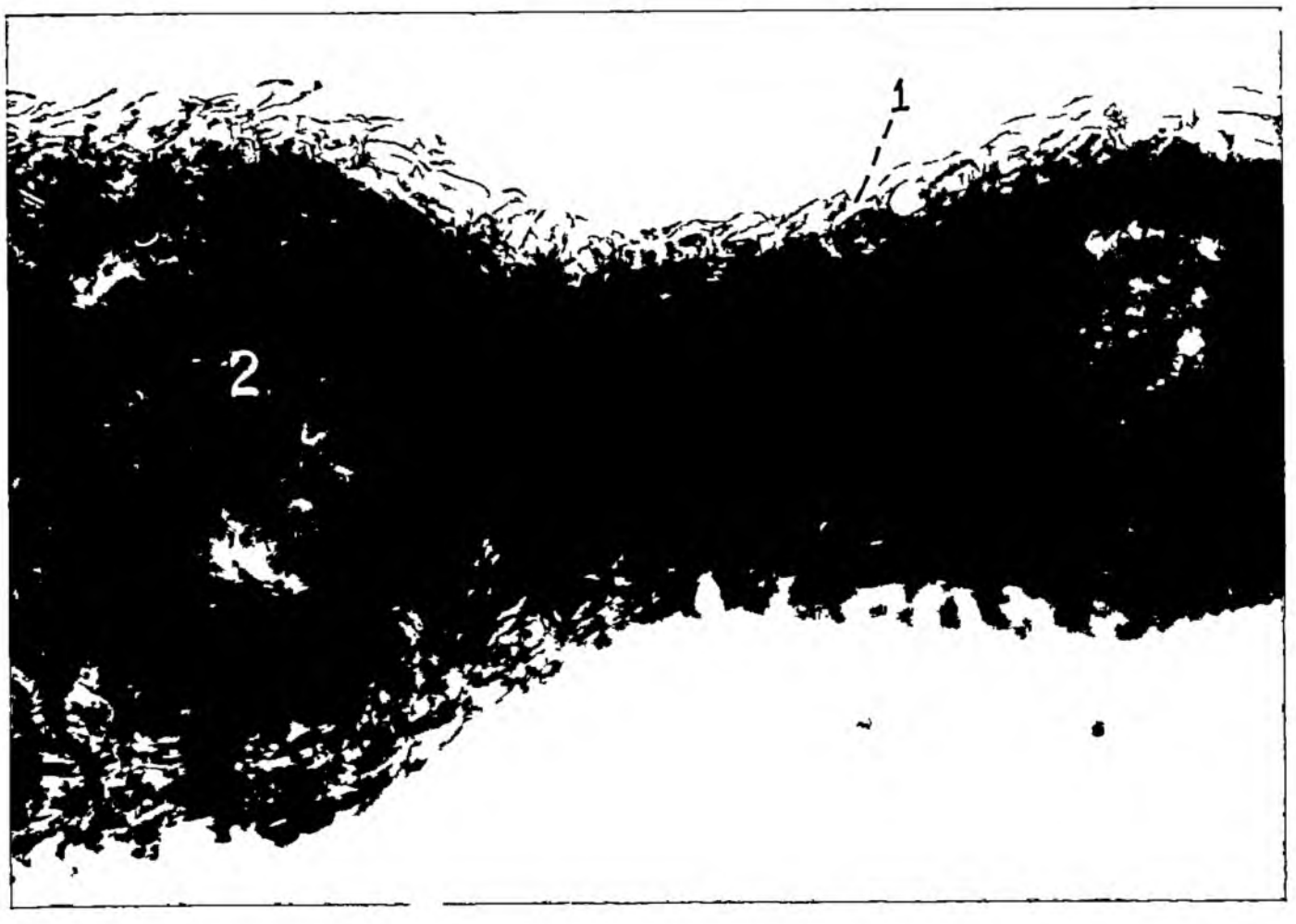


Plate XV. T.S. of areca leaf tissue 120 h after feeding by *C. arecae*

A. unfed area

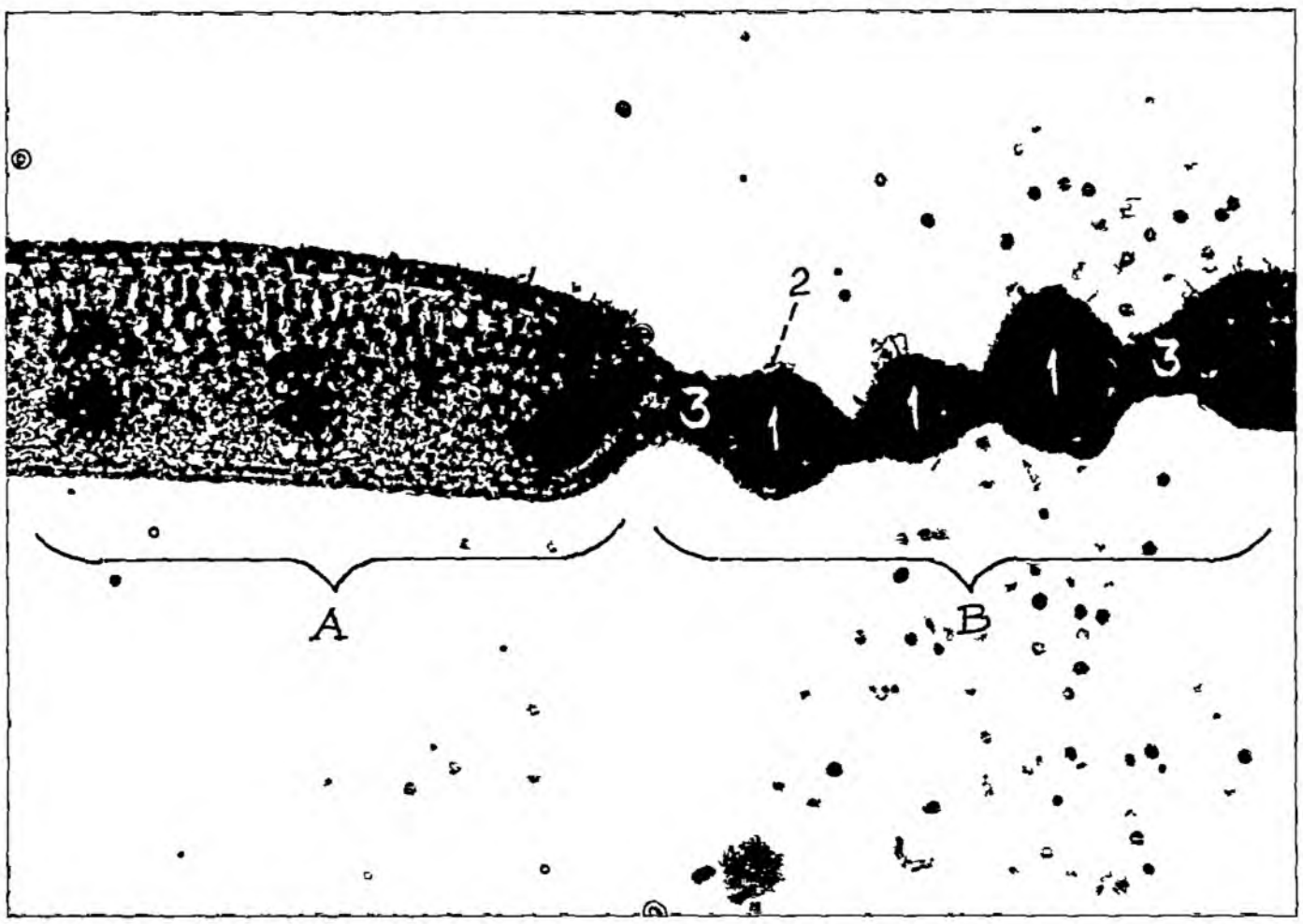
B. fed area

1. vascular bundle

2. epidermis

3. mesophyll

PLATE XV



At 120 h after feeding also the vascular bundles were distinct in T.S though the bundle sheath became black in colour (Plate XV). By that time the mesophyll or the entire area had dried up and turned almost dark brown in colour. The area between the vascular bundles became 1/5th to 1/6th in thickness compared to healthy areas. In the region of the vascular bundle also the cells other than the epidermis and the vascular bundles collapsed so that the area in transverse section appeared as a string of beads, the vascular bundles making the beads and the inter-vascular region making the string.

4.5.3. Histochemical changes in the leaf tissue damaged by the feeding of C. arecae

The histological studies of areca leaves revealed a collapse of mesophyll cells consequent on feeding of C. arecae and hence histochemical localisation of proteins, lipids, starch and tannin was done at different intervals after feeding. Starch and tannin did not show variations in the normal and damaged tissues and hence the details on their localisations were not included in the description.

4.5.3.1. Proteins

Proteins in the mesophyll cells appeared granular 15 minutes after the insect feeding (Plate XVI). The granular protein was sparsely distributed and found only in a few of

Plate XVI. T.S. of areca leaf tissue 15 minutes after feeding (stained for detecting protein localisation)

Plate XVII. T.S. of areca leaf tissue 12 h. after feeding (stained for detecting protein localisation

PLATE XVI

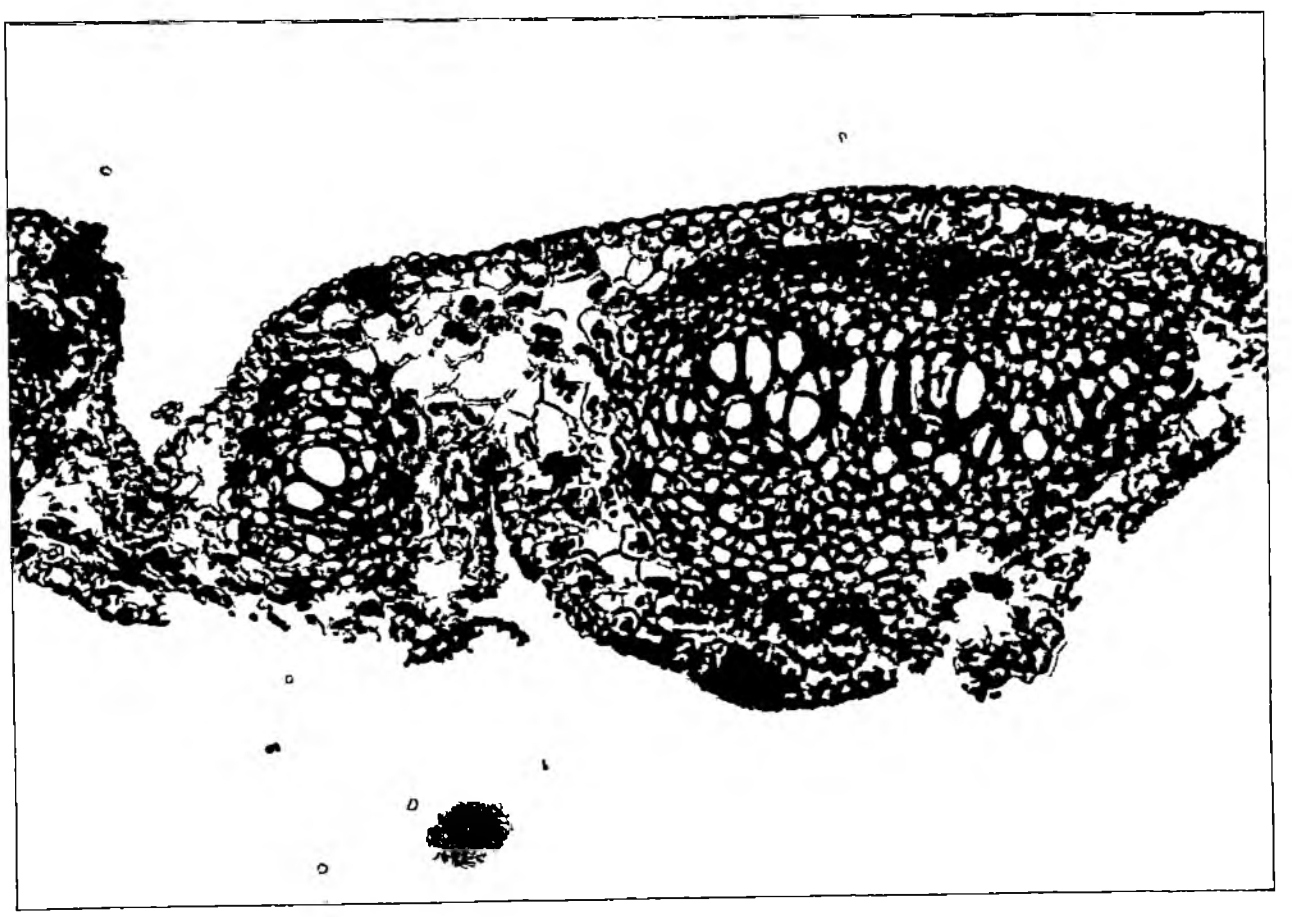


PLATE XVII

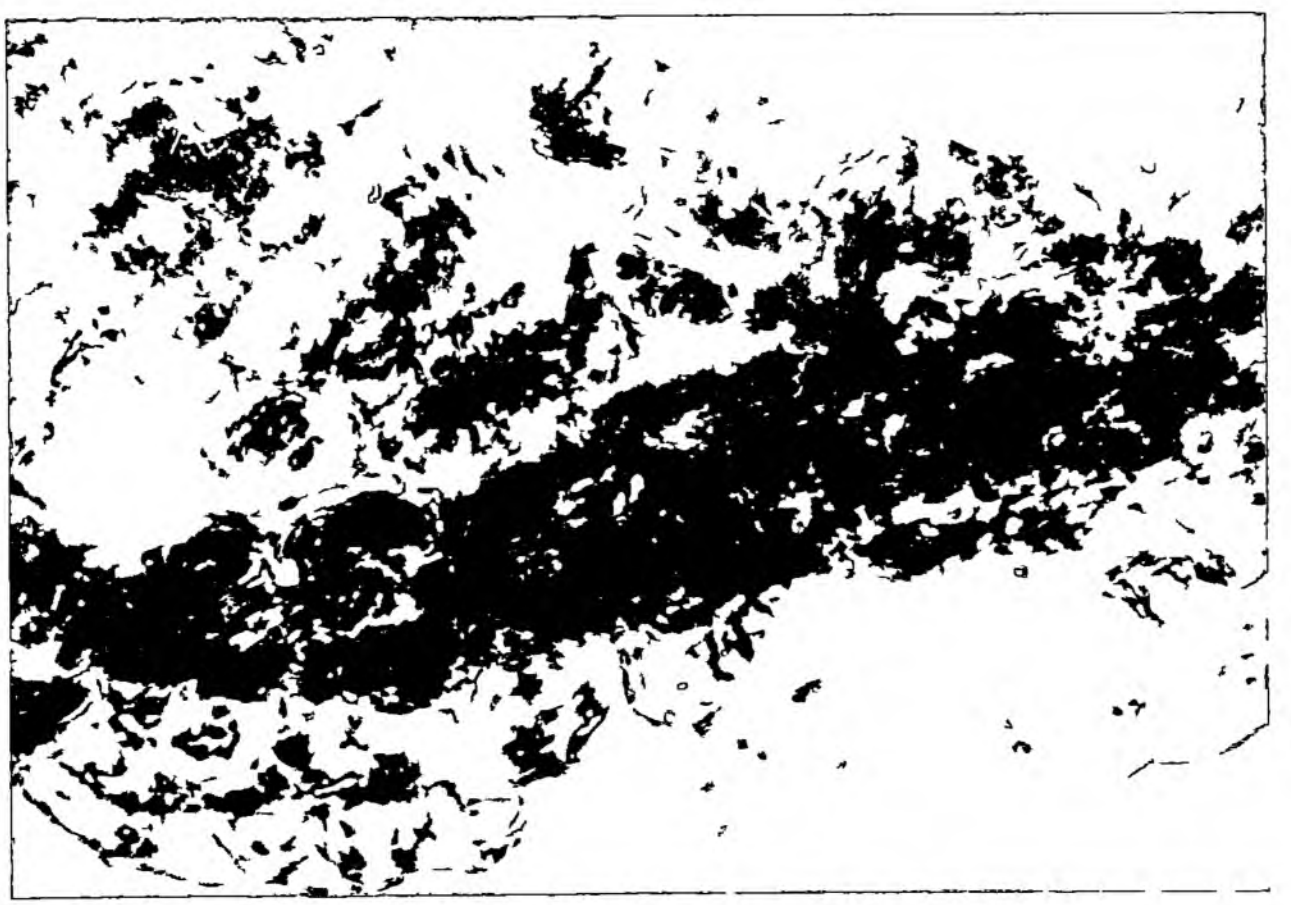


Plate XVIII. T.S. of areca leaf tissue 24 h. after feeding by *C. arecae* (stained for detecting protein localisation)

PLATE XVIII

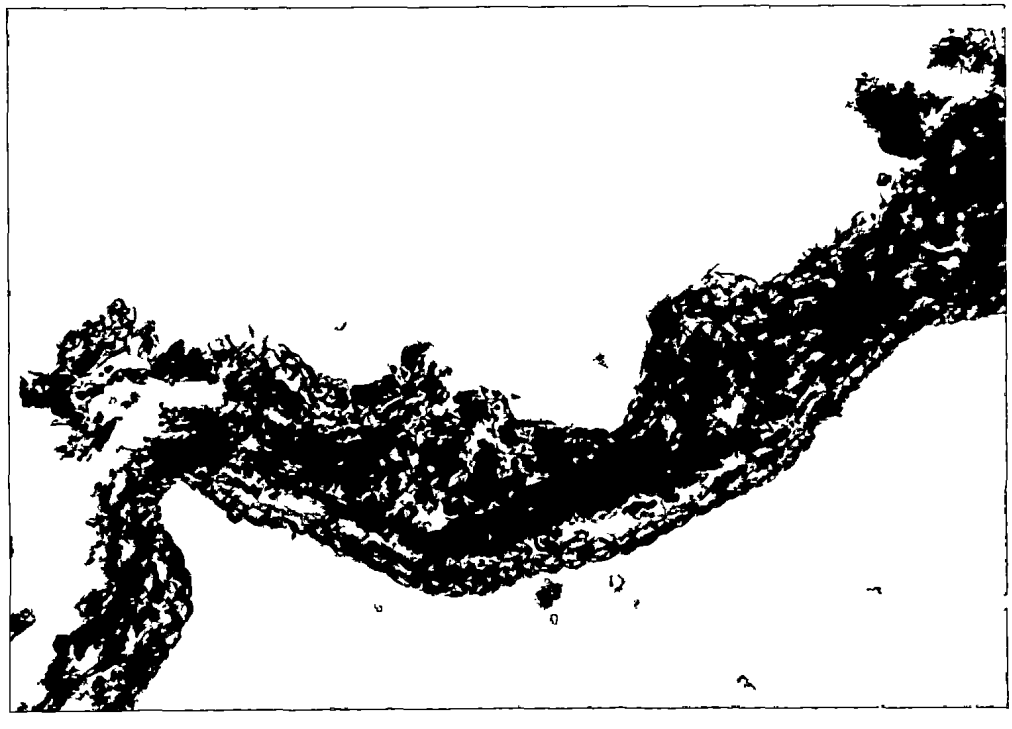


Plate XIX. T.S. of areca leaf tissue 12 h. after feeding by C. arecae (stained for detecting lipids localisation)

Plate XX. T.S. of areca leaf tissue 24 h. after feeding by C. arecae (stained for detecting lipids localisation)

PLATE XIX

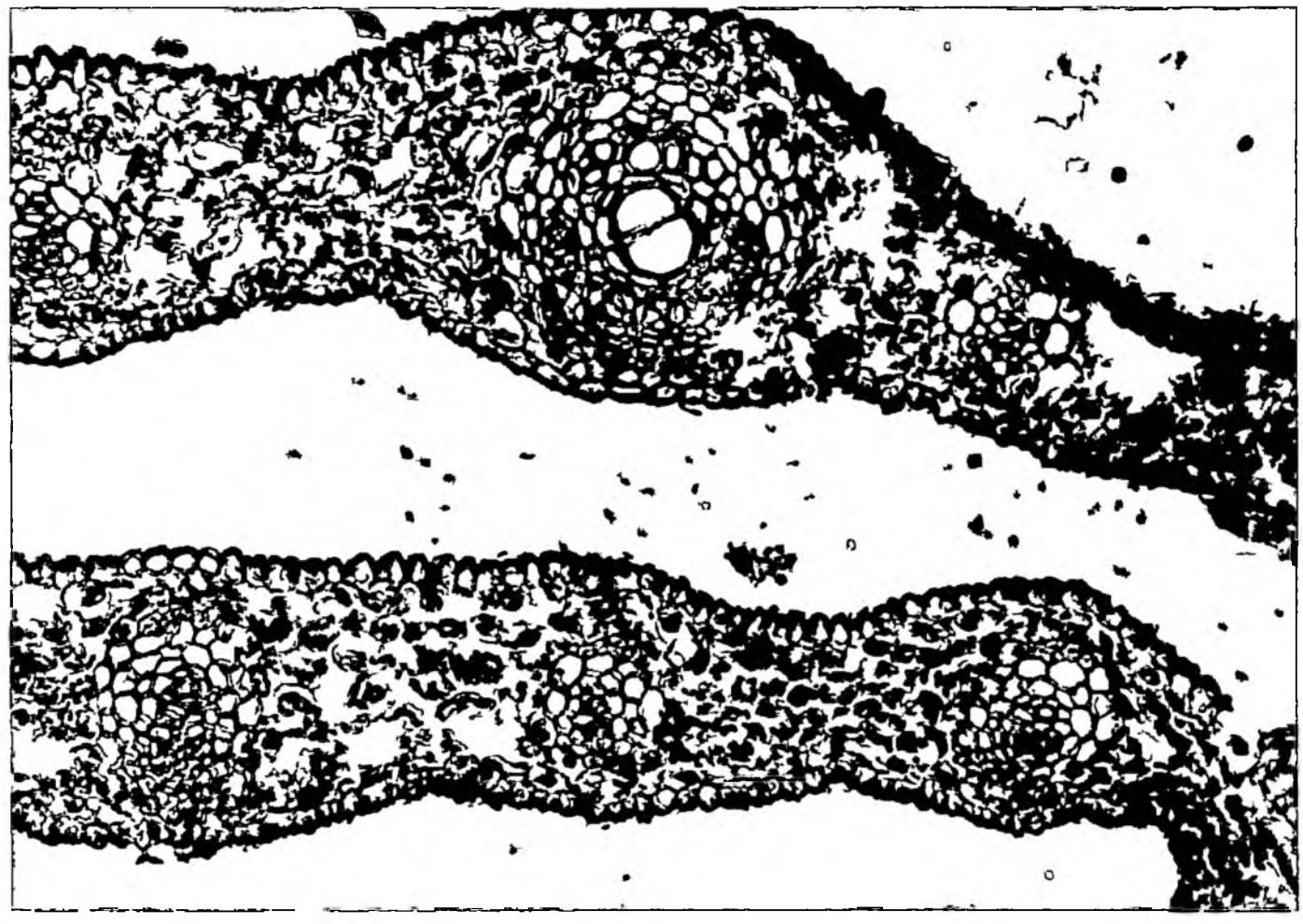


PLATE XX

the mesophyll cells. But 12 hours after the insect feeding mesophyll cells showed a heavy accumulation of amorphous proteins (Plate XVII). Many of the cells were heavily loaded with this protein and the proteinaceous substance persisted even after 24 hours of feeding (Plate XVIII).

4.5.3.2. Lipids

Twelve hours after feeding by C. arecae the cells in the leaf tissue showed the accumulation of lipids as evidenced by the intense colour developed with Sudan Black B stain (Plate XIX). The lipid accumulation continued and the cells were seen heavily loaded with lipid materials at 24 hours after feeding (Plate XX). The lipid observed at 24 hours was in two forms. The mesophyll cells showed heavy deposition of an amorphous type while in the epidermal cells the lipids were in granular droplet form.

4.6.1. Control of C. arecae by providing granular insecticides in perforated sachets at the leaf axils of the palm

The data relating to the experiment and the results of statistical analysis of bug population in different treatments are presented in Tables 18 to 20 and Fig. 6.

Results presented in Table 18 showed that except during the first month after treatment the adults of C. arecae were

FIG 6

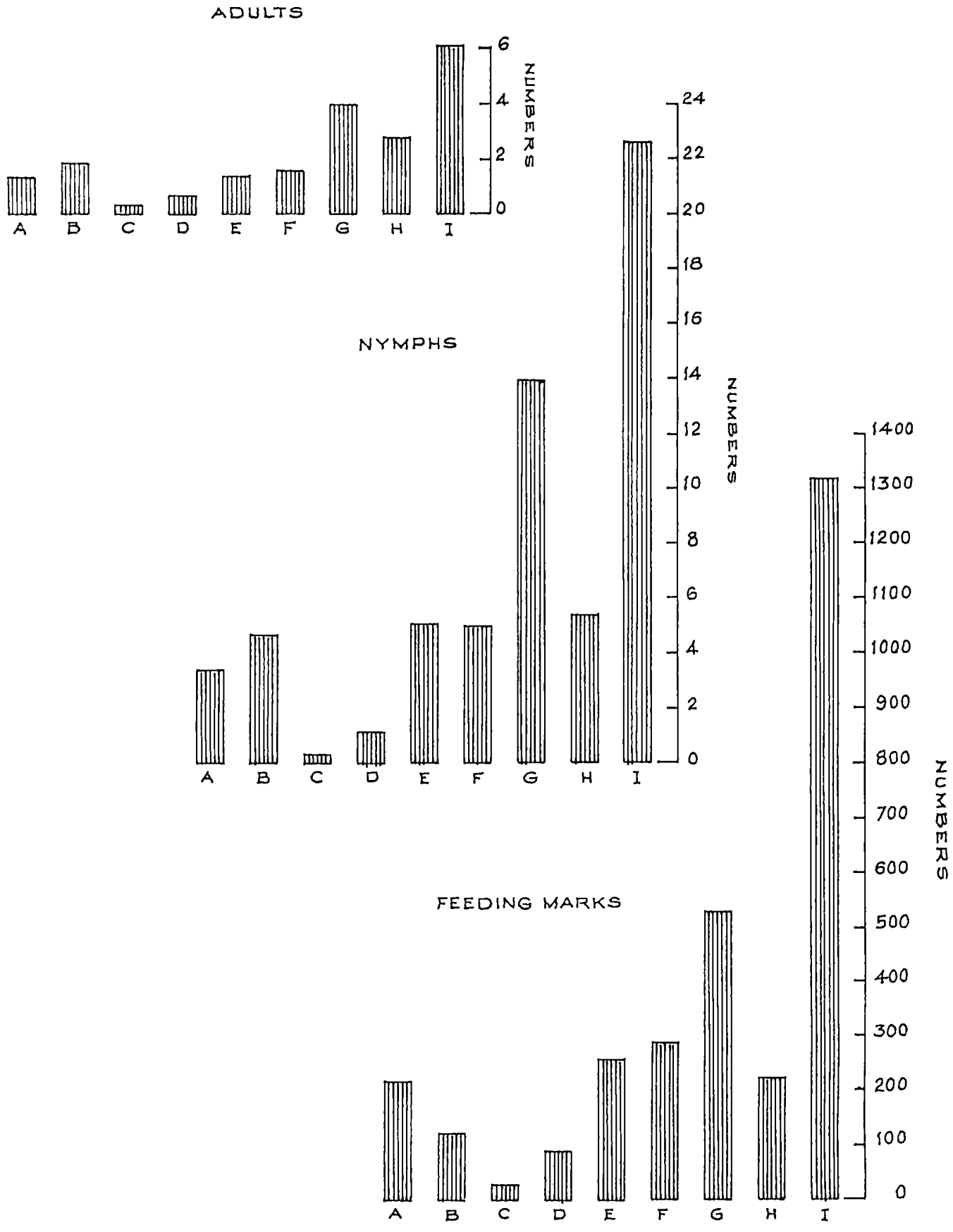

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Fig. 6. Control of C. arecae using granular insecticides kept in leaf axils in sachets

A. One phorate sachet of 2 g kept in leaf axil
B. Two phorate sachets of 2 g kept in leaf axil
C. One phorate sachet of 4 g kept in leaf axil
D. Two phorate sachets of 4 g kept in leaf axil
E. One carbofuran sachet of 2 g kept in leaf axil
F. Two carbofuran sachets of 2 g kept in leaf axil
G. One carbofuran sachet of 4 g kept in leaf axil
H. Two carbofuran sachets of 4 g kept in leaf axil
I. Control

Table 18. Control of C.arecae using granular insecticides kept in leaf axils of crown in sachets

treatments	mean adult population of C.arecae / palm observed at different intervals after treatment (months)										total of ten months
	1	2	3	4	5	6	7	8	9	10	
control	0.00	1.10	0.20	0.30	1.90	1.00	0.20	0.80	0.765 (1.329)	0.399 (1.183)	6.082 (2.661)
one phorate sachet of 0.2 g ai/palm	0.10	0.00	0.00	0.00	0.00	0.10	0.10	0.00	0.707 (1.306)	0.336 (1.156)	1.258 (1.503)
two phorate sachets of 0.2 g ai/palm	0.00	0.00	0.00	0.10	0.00	0.00	0.00	0.00	0.411 (1.188)	1.099 (1.449)	1.833 (1.683)
one phorate sachet of 0.4 g ai/palm	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.152 (1.073)	0.000 (1.000)	0.314 (1.146)
two phorate sachets of 0.4 g ai/palm	0.20	0.10	0.00	0.10	0.00	0.00	0.00	0.00	0.085 (1.041)	0.242 (1.115)	0.745 (1.321)
one carbofuran sachet of 0.06 g ai/palm	0.10	0.30	0.00	0.10	0.20	0.20	0.00	0.00	0.311 (1.145)	0.242 (1.115)	1.367 (1.539)
two carbofuran sachets of 0.06 g ai/palm	0.00	0.10	0.10	0.00	0.30	0.20	0.00	0.00	0.336 (1.156)	0.511 (1.229)	1.544 (1.595)
one carbofuran sachet of 0.12 g ai/palm	0.10	0.10	0.00	0.00	0.60	0.20	0.40	0.20	0.776 (1.333)	0.578 (1.256)	3.976 (2.231)
two carbofuran sachets of 0.12 g ai/palm	0.00	0.00	0.00	0.00	0.10	0.30	0.20	0.10	0.314 (1.146)	1.668 (1.633)	2.788 (1.946)
F. test									NS	S	S
C.D.									0.4042	0.3002**	0.605**

* significant at 5% level ** significant at 1% level NS not significant

figures in parentheses are transformed values $\sqrt{x+1}$ S : significant

present on the untreated palms throughout the period of the experiment while all the treatments warded off the bugs effectively from the palms up to a period of eight months after treatment. But mild incidence of the insect was observed in some of the observations in all the treatments.

On palms treated with phorate 0.2 g active ingredient (ai) in one sachet, 0.4 g ai in two sachets, 0.4 g ai in one sachet and 0.8 g ai in two sachets/palm, incidence of the bug was observed in three (0.1 bug/palm), one (0.1 bug/palm), one (0.2 bug/palm) and three (0.2 to 0.1 bug/palm) observations respectively. On palms treated with carbofuran 0.06 g ai in 1 sachet, 0.12 g ai in two sachets, 0.12 g ai in one sachet and 0.24 g ai in 2 sachets, bug incidence was observed in five (0.1 to 0.3 bug/palm), four (0.4 to 0.3 bug/palm) observations respectively.

During the ninth month after treatment incidence of adults of C. arecae was observed in all the treatments including the control. Though the population ranged from 0.085 bug/palm to 0.765 bug/palm the variations were not statistically significant.

Population of adults of C. arecae observed in different treatments, during the tenth month after treatment, showed

Table 19. Control of C.arecae using granular insecticides kept in leaf axils of crown in sachets

treatments	mean nymphal population of C. arecae /palm observed at different intervals after treatment (months)										total of ten months
	1	2	3	4	5	6	7	8	9	10	
control	0.40	2.20	2.00	1.10	2.30	6.40	1.60	0.10	4.520 (2.350)	2.344 (1.829)	22.673 (4.865)
one phorate sachet of 0.2 g ai/palm	0.00	0.40	0.00	0.00	0.00	0.00	1.30	0.00	2.311 (1.820)	0.262 (1.124)	3.438 (2.107)
two phorate sachets of 0.2 g ai/palm	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.262 (1.124)	4.368 (2.317)	4.704 (2.388)
one phorate sachet of 0.4 g ai/palm	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.356 (1.165)	0.000 (1.000)	0.356 (1.165)
two phorate sachets of 0.4 g ai/palm	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.845 (1.358)	0.262 (1.124)	1.196 (1.482)
one carbofuran sachet of 0.06 g ai/palm	0.00	0.30	0.00	0.00	0.30	1.20	0.00	0.00	0.690 (1.300)	3.295 (2.072)	5.706 (2.590)
two carbofuran sachets of 0.06 g ai/palm	0.00	0.60	0.10	0.00	0.20	0.50	0.00	0.00	2.234 (1.798)	0.715 (1.310)	4.956 (2.441)
one carbofuran sachet of 0.12 g ai/palm	0.00	0.20	0.00	0.00	0.10	0.50	1.80	0.00	4.318 (2.306)	1.173 (1.474)	13.958 (3.868)
two carbofuran sachets of 0.12 g ai/palm	0.00	0.00	0.00	0.00	0.10	0.00	1.30	0.20	2.599 (1.897)	0.991 (1.411)	5.421 (2.534)
F. test									NS	S	S
C.D.									1.0972	0.8285*	1.378**

* significant at 5% level ** significant at 1% level NS- not significant

figures in parentheses are transformed values $\sqrt{x+1}$ S significant

significant variations. The population was significantly higher (1.668/palm) on palms treated with 0.24 g ai carbofuran in 2 sachets while the population in other treatments (0.0 to 1.099/palm) came on par with the population on control palms (0.399 bug/palm).

When the total population of the adults of C. arecae in the different treatments, observed during the ten months after treatment, was subjected to statistical analysis, significant variations were observed in the efficacy of different treatments. Least population was observed on palms provided with 0.4 g ai phorate in one sachet (0.314 bug/palm): but it came on par with other treatments (0.314 to 1.833 bugs/palm) except carbofuran 0.12 g ai in one sachet (3.976) and 0.24 g ai carbofuran in two sachets (2.788) and control (6.082 bugs/palm).

The effect of granular insecticides kept in sachets on the build up of nymphal population at the crown of Areca palms is presented in Table 19 and Fig. 6. On control palms the nymphs were observed throughout the period of observation (ranging from 0.1 to 6.40 nymphs/palm). Compared to control, the counts of the nymphs in all the treatments were significantly lower, up to the end of the eighth month after treatment.

On palms treated with phorate 0.4 g ai in two sachets, 0.4 g ai in one sachet and 0.8 g in two sachets nymphs were absent for eight months after treatment. On palms treated with phorate 0.2 g ai in one sachet nymphs were observed (0.4 and 1.3/palm in two of the eight monthly observations.

On palms treated with carbofuran 0.06 g ai in one sachet, 0.12 g ai in two sachets, 0.12 g in one sachet and 0.24 g ai in two sachets the occurrence of the nymphs was noted in 3 (0.3 to 1.2 nymphs/palm), 4 (0.1 to 0.6 nymph/palm), 4 (0.1 to 1.8 nymphs/palm) and 3 (0.1 to 1.3 nymphs/palm) observations respectively.

There was a build up of the population of the nymphs in all treatments during the ninth month. The population ranged from 0.262 to 4.318/palm in the treatments while in control the count was 4.520/palm. On statistical analysis the variations among the treatments were found insignificant.

During the tenth month the population of nymphs showed statistically significant variations in treatments and control. On palms treated with 0.4 g ai phorate in single sachet the nymphs were absent. All other treatments came on par with control.

Based on total population of nymphs observed during the ten months in different treatments statistically significant

Table 20. Control of C. arecae using granular insecticides kept in leaf axils of crown in sachets

treatments	mean number of C.arecae / palm observed at different intervals after treatments (months)										total of ten months
	1	2	3	4	5	6	7	8	9	10	
control	0.40	3.30	2.20	1.40	4.20	7.40	1.80	0.90	5.155 (2.481)	2.608 (1.899)	28.741 (5.454)
one phorate sachet of 0.2 g ai/palm	0.10	0.40	0.00	0.00	0.00	0.10	1.40	0.00	2.956 (1.989)	0.587 (1.260)	4.568 (2.360)
two phorate sachets of 0.2 g ai/palm	0.00	0.00	0.00	0.10	0.00	0.00	0.00	0.00	0.636 (1.279)	5.929 (2.632)	7.248 (2.872)
one phorate sachet of 0.4 g ai/palm	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.440 (1.200)	0.000 (1.000)	0.621 (1.273)
two phorate sachets of 0.4 g ai/palm	0.20	0.10	0.00	0.10	0.00	0.00	0.00	0.00	0.959 (1.400)	0.484 (1.218)	2.135 (1.771)
one carbofuran sachet of 0.06 g ai/palm	0.10	0.60	0.00	0.10	0.50	1.40	0.00	0.00	1.088 (1.445)	3.447 (2.109)	6.921 (2.815)
two carbofuran sachets of 0.06 g ai/palm	0.00	0.70	0.20	0.00	0.50	0.70	0.00	0.30	2.552 (1.885)	1.301 (1.517)	6.732 (2.781)
one carbofuran sachet of 0.12 g ai/palm	0.10	0.30	0.00	0.00	0.70	0.70	0.20	0.20	4.876 (2.424)	1.907 (1.705)	18.346 (4.398)
two carbofuran sachets of 0.12 g ai/palm	0.00	0.00	0.00	0.00	0.20	0.30	1.50	0.30	2.973 (1.993)	2.976 (1.994)	9.161 (3.188)
F. test									NS	S	S
C.D.									1.176	0.834**	1.450**

* significant at 5% level ** significant at 1% level NS not significant

figures in parentheses are transformed values $\sqrt{x + 1}$ S significant

variations were observed among the treatments. Highest protection was seen in palms provided with 0.4 g ai phorate in one sachet which had the least number of bugs (0.356 nymph/palm). All treatments (0.696 to 2.534 nymphs/palm) except 0.06 g ai carbofuran in one sachet (5.706 nymphs/palm), 0.12 g ai carbofuran in one sachet (13.758 nymphs/palm) and control (22.673 nymphs/palm) came on par with the best treatment 0.4 g ai phorate in one sachet per palm.

Evaluation of the treatments based on the effect on the total population (nymphs and adults) has been presented in Table 20. During the first eight months after treatment the bug population in control ranged from 0.40 to 7.40/palm. The pest was not totally warded off the treated palms in any of the treatments. Palms treated with 0.2 g ai phorate in single sachet, 0.4 g ai phorate in two sachets, 0.4 g ai phorate in single sachet and 0.8 g ai phorate in 2 sachets had slight incidence of the pest in 4 (0.1 to 1.4 bug/palm), 1 (0.1 bug/palm), 1 (0.2 bug/palm) and 3 (0.1 to 0.2 bug/palm) observations during the first 8 months. In palms treated with carbofuran 0.06 g ai in single sachet, 0.12 g ai in two sachets, 0.12 g ai in single sachet and 0.24 g ai in two sachets slight incidence of the pest occurred in 5 (0.1 to 1.4 bug/palm), 5 (0.2 to 0.70 bug/palm), 6 (0.1 to 0.70 bug/palm) and 4 (0.2 to 1.5 bugs/palm) observations within eight months after treatment.

During the ninth month the total population of the bug ranged between 0.440 and 5.155 bug/palm. On statistical analysis the variations in the data were seen insignificant. In the tenth month palms treated with phorate 0.4 g ai in one sachet alone were free from bug infestation and the population in other treatments came on par with control.

When the population in the ten observations made after treatment were added up and statistically analysed the variations in the bug population showed significance. Population on palms provided with carbofuran 0.24 g ai in two sachets the bug population was very high (18.346/palm) and it came on par with control. The population in remaining treatments, ranging from 0.621 to 9.161, were on par and significantly higher than the population in the above two treatments.

Relative efficacy of different doses of phorate and carbofuran granules kept in the leaf axils of areca palms in perforated polythene sachets, as revealed from the feeding marks caused by the bug, is presented in Table 21 and Fig. 6.

The mean feeding marks ranged from 2.32 to 288.503/palm during the period of the experiment. During the first, third, fifth and tenth month, the data did not show statistically significant variations among the treatments

Table 21 Extent of damage caused by *C arecae* in areca palms treated with granular insecticides kept in leaf axils of crown in sachets

treatments	f m /leaf/palm/month observed at different intervals after treatment (months)										total of ten months
	1	2	3	4	5	6	7	8	9	10	
control	2 320 (1.822)	192.901 (13 925)	9 306 (3.210)	20.360 (4.622)	30.357 (5.600)	95.519 (9.824)	72.213 (8.556)	136.935 (11.745)	81.962 (9 108)	288 503 (15.149)	1315.111 (36.278)
one phorate sachet of 0 2 g ai/palm	5.521 (2.554)	0.479 (1.216)	3.305 (2.075)	0.000 (1.000)	1 261 (1.504)	1.932 (1.712)	7.728 (2.954)	17.167 (4.262)	25.683 (5.166)	96.778 (9.888	220 648 (14.888)
two phorate sachets of 0 2 g ai/palm	5 221 (2.514)	1 495 (1.580)	0 000 (1.000)	0.000 (1.000)	4.112 (2.261)	4 971 (2.444)	3.929 (2.220)	4 339 (2.311)	2 872 (1 968)	56 711 (7.600)	123 310 (11 149)
one phorate sachet of 0 4 g ai/palm	1.355 (1.535)	3 396 (2 097)	0 000 (1 000)	0.085 (1 041)	0 000 (1.000)	1 478 (1.574)	0 000 (1 000)	4 076 (2.253)	0.000 (1.000)	8 085 (3.014)	27 084 (5.299)
two phorate sachets of 0 4 g ai/palm	0 000 (1.000)	9.075 (3.174)	1 467 (1 571)	0.000 (1.000)	5.277 (2.505)	1.826 (1.681)	0.554 (1.246)	2.746 (1.936)	0 785 (1.336)	52.431 (7.310)	85.990 (9.327)
one carbofuran sachet of 0 06 g ai/palm	6.110 (2.666)	2.019 (1.740)	7.582 (2.930)	0 657 (1.287)	25 684 (5.166)	13.472 (3.804)	3.755 (2.181)	24.989 (5.098)	5.786 (2.605)	66 624 (8.223)	250.817 (15.869)
two carbofuran sachets of 0 06 g ai/palm	3.613 (2.148)	6.188 (2.681)	2 897 (1.974)	0.000 (1.000)	12.005 (3.606)	23.901 (4.990)	1.869 (1.694)	3.824 (2.196)	41.653 (6.531)	65.249 (8.139)	287 255 (16.978)
one carbofuran sachet of 0 12 g ai/palm	15 582 (4.072)	6.173 (2.678)	1 300 (1.516)	0.722 (1.312)	9.808 (3.288)	30.236 (5.589)	0 000 (1.000)	28.206 (5.404)	152 341 (12.383)	87 864 (9.427)	528 555 (23.012)
two carbofuran sachets of 0 12 g ai/palm	0.000 (1.000)	14.504 (3.937)	0.000 (1 000)	0.000 (1.000)	1.650 (1.628)	3.745 (2.178)	2.139 (1.772)	52.160 (7.291)	35 722 (6.060)	32 537 (5.791)	223 319 (14.977)
F test	NS	S	NS	S	NS	S	S	S	S	NS	S
C D	2 018	3 116**	2 051	1.337**	4.274	4.525**	4.366*	4.751**	6.830*	7.215	9.400**

S significant NS not significant ** significant at 1% level * significant at 5% level

figures in parentheses are transformed values $\sqrt{x+1}$

f m feeding marks

including control. In the observations made at the end of second, fourth, sixth, seventh, eighth and ninth months data showed statistically significant variations. In all these observations, mean feeding marks in control were significantly higher than the feeding marks in rest of the treatments which were all on par among themselves.

During the ninth month, palms treated with phorate 0.4 g ai in two sachets, 0.4 g ai in one sachet and 0.8 g ai in two sachets had low feeding marks (2.872, 0.785 and 0.0 respectively). The control treatment came on par with all the remaining treatments except 0.12 g ai carbofuran in one sachet/palm (152.341 feeding marks). During the tenth month all the treatments came on par and the damage was less in treatments compared to control.

When the data on total feeding marks in different treatments were subjected to statistical analysis significant variations were observed. The least damage was found on palms provided with 0.4 g ai phorate in single sachet and it came on par with palms treated with 0.4 g ai phorate in two sachets. The treatment with 0.2 g ai phorate in single sachet and all the four treatments using carbofuran granules were significantly less effective than the best treatment of one sachet containing 0.4 g ai phorate/palm. Feeding marks in control were significantly higher than those found in different treatments.

During the first eight months the sachets containing the insecticidal granules protected the crop effectively. Among the phorate treated palms in 8 out of 32 observations zero level damage was observed and in rest of the observations mean numbers of feeding marks ranged between 0.492 and 17.167. On palms treated with carbofuran, during first eight months feeding marks were higher than those on phorate treated palms; total absence being in 4 observations only and the range of feeding marks in treatments being 0.657 to 52.160. During 9th and 10th month the mean feeding marks on palms treated with phorate ranged between 0.0 and 96.778 while in carbofuran treated palms the range was 5.786 to 152.341/leaf. In general phorate was more effective in warding off the damage caused by C. arecae than carbofuran. Relative superiority of phorate over carbofuran in controlling the population of C. arecae and in reducing the leaf damage was clearly brought out in Fig. 6 also. It was also seen that in case of carbofuran 0.24 g ai kept in 2 sachets/palm was less effective than 0.12 g ai kept in single sachet in controlling the pest.

4.6.2. Relative efficacy of different insecticides used as foliar sprays and granules placed directly and in sachets in leaf axils in controlling C. arecae

The data relating to the experiment and the results of statistical analysis of the same are presented in Table 22

Fig. 7. Control of *C. arecae* with different insecticides used as foliar sprays, as granules in leaf axils directly and in sachets

A. HCH 0.2% a.i. spray

B. endosulfan 0.05% a.i. spray

C. fish oil rosine soap 5% spray

D. neem cake suspension 5% spray

E. phorate granules 10% a.i. @ 5 g placed in leaf axils

F. carbofuran granules 3% a.i. @ 5 g placed in leaf axils

G. two sachets of 2 g phorate granules 10% a.i. each placed in leaf axils

H. control

FIG 7

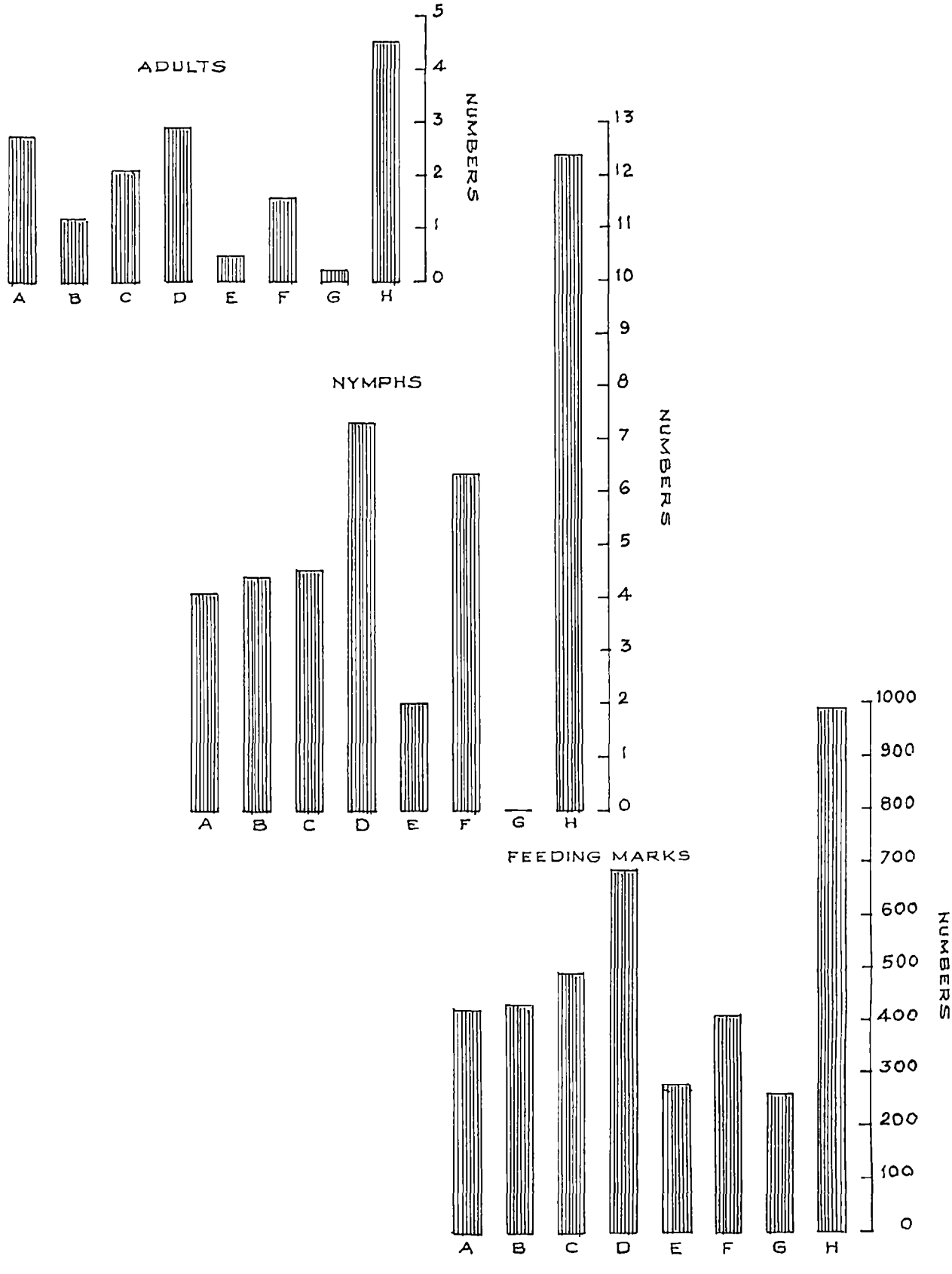
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Table 22 Control of C. arecae with different insecticides used as foliar sprays, as granules in leaf axils directly and in sachets (effect on nymphs)

treatments	mean number of nymphs/palm/month observed at different intervals after treatment (months)											mean total population/palm
	1	2	3	4	5	6	7	8	9	10	11	
HCH 0.2% ai (spray)	0.00	2 44	0.63	0.00	0 88	0 00	0.00	0.44	0.00	0 00	0.00	4.1416 (2 2675)
endosulfan 0.05% ai (spray)	0.31	1.31	0.00	2 00	0.00	0.25	0 00	0 00	0.00	0 00	0.13	4 3708 (2.3175)
fish oil rosine soap 5% (spray)	0.19	1.75	0.19	0.44	0.13	1.44	0.00	0 63	0.00	0 00	0.00	4.5460 (2 3550)
neem cake suspension 5% (spray)	1.44	1.44	2.31	1.94	0.13	0.69	0.00	0.00	0.00	0.00	0 00	7 3232 (2.8850)
phorate granules 10% ai @ 5g placed in leaf axils	0.00	1.44	0.00	0.19	0.00	0 50	0 00	0.00	0 00	0 00	0 00	2.0102 (1 7350)
carbofuran granules 3% ai @ 5g placed in leaf axils	1 06	1.50	0.06	1 56	0.00	1.88	0.00	1.06	0.00	0.00	0.00	6.3170 (2.7050)
two sachets of 10% ai phorate granules @ 2g each placed in leaf axils	0 00	0 00	0.00	0.00	0 00	0 00	0.00	0.00	0.00	0 00	0.00	0.0000 (1.0000)
control	2 31	2.25	1.44	2.25	1.25	1.94	0.38	0.75	0.00	0 31	0.00	12.3590 (3.6550)
F test												S
C D.												0.6989**

S significant

** significant at 1% level

figures within parentheses are transformed values ($\sqrt{x+1}$)

and Fig. 7. The palms provided with 0.4 g ai of phorate in 2 sachets were totally free from the incidence of the nymphs of C. arecae up to the end of 11 months after treatment, but during the 9th, 10th and 11th month the bug population was wanting in all the treatments including control. In control, the count of nymphs ranged from 0.38 to 2.31 per palm during the first eight months. Phorate granules put in leaf axils directly also reduced the nymphal counts significantly over control. In the second, fourth and sixth observation 1.44, 0.19 and 0.5 nymphs/ palm were observed. Fish oil rosine soap was found least effective, among the other treatments, in seven observations. Nymphs ranging from 0.13 to 1.44/palm were recorded in the treatments. In neem cake sprayed palms incidence was noted in six countings and the mean number ranged between 0.69 and 2.31. In endosulfan treated palms the nymphs were noted in four observations and the mean number ranged from 0.25 to 2.0/palm. In HCH also the nymphs were recorded in four observations and the mean numbers ranged between 0.44 and 2.44/palm.

Based on the nymphal population observed in different treatments during the 11 months after treatment the high efficacy of placing 2 sachets, each containing 0.2 g ai of phorate granules, could be clearly established. It was closely followed by the direct placement of 0.5 g ai phorate granules in

Table 23 Control of C arecae with different insecticides used as foliar sprays, as granules in leaf axils directly and in sachets (effect on adults)

treatments	mean number of adults/palm/month observed at different intervals after treatment (months)											mean total population/palm
	1	2	3	4	5	6	7	8	9	10	11	
HCH 0.2% ai (spray)	0 63	0.94	0.06	0.13	0 44	0.44	0 06	0 13	0 00	0 00	0.00	2.7539 (1.9375)
endosulfan 0.05% ai (spray)	0 06	0.56	0.06	0.25	0.00	0.19	0.00	0.00	0.00	0 00	0 06	1.1609 (1.4700)
fish oil rosine soap 5% (spray)	0.44	0.81	0.25	0.25	0.13	0.13	0 00	0.13	0 00	0 00	0.00	2 0713 (1 7525)
neem cake suspension 5% (spray)	0.88	1.06	0.31	0.25	0.19	0.38	0 00	0.00	0.06	0 00	0.00	2 9303 (1.9825)
phorate granules 10% ai @ 5g placed in leaf axils	0.00	0.25	0.00	0.31	0.00	0.00	0.00	0 00	0 00	0.00	0 00	0 5314 (1.2375)
carbofuran granules 3% ai @ 5g placed in leaf axils	0.25	0.63	0.06	0.19	0.06	0 19	0.00	0.25	0 00	0 00	0.00	1.6163 (1.6175)
two sachets of 10% ai phorate granules @ 2g each placed in leaf axils	0 00	0 00	0.00	0 00	0.06	0.00	0.13	0.00	0.00	0.00	0.00	0.1664 (1.0800)
control	0.94	1.13	0.19	0.56	0.63	0.63	0.44	0.13	0.25	0.13	0.00	4.4873 (2.3425)
F test												S
C D.												0 356**

S significant

** significant at 1% level

figures within parentheses are transformed values ($\sqrt{x+1}$)

leaf axil (2.0102 nymphs/palm). Highest mean count was seen on palms treated with neem cake suspension (7.3232/palm) but it was on par with fish oil rosine soap, endosulfan and HCH (4.1416 to 4.546 nymphs/palm). The count in control (12.359 per palm) was significantly higher than all other treatments.

The effect of treatments on adult population is presented in Table 23 and Fig. 7. Palms provided with 0.4 g ai of phorate in two sachets were free from the adults of C. arecae for the entire period of observation except in 5th and 7th month at 0.06 and 0.13 bugs/palm. Carbofuran granules placed in leaf axil was not very effective and the adult population were noted in 7 of the 8 observations and it ranged between 0.19 and 0.63 bug/palm during the period and in neem cake suspension (0.06 to 1.06/palm) and in fish oil rosine soap (0.13 to 0.81) also the bugs were present in seven of the first eight observations. On HCH treated palms the adult population was observed during the entire period of eight months and the count ranged from 0.06 to 0.94/palm. On endosulfan sprayed palms adult bugs were seen in 4 out of eight observations and the count ranged from 0.19 to 0.56/palm.

The total count of the bugs observed during 11 months after treatment also established the superiority of placing two sachets of 0.2 g ai phorate each in leaf axils. The count of

Table 24 Control of *C arecae* with different insecticides used as foliar sprays, as granules in leaf axils directly and in sachets (effect on total bug population)

treatments	mean number of total bug population/palm/month observed at different intervals after treatment (months)											mean total population/palm
	1	2	3	4	5	6	7	8	9	10	11	
HCH 0 2% ai (spray)	0 63	3.38	0.69	0.13	1 31	0 44	0 06	0 56	0 00	0.00	0 00	7 0940 (2 8450)
endosulfan 0 05% ai (spray)	0.38	1.88	0.50	2 25	0.00	0.44	0 00	0 00	0 00	0 00	0 19	3 5280 (2 5550)
fish oil rosine soap 5% (spray)	0.63	2 56	0 44	0.69	0.25	1 56	0.00	0.75	0 00	0 00	0 00	6 6591 (2 7675)
neem cake suspension 5% (spray)	2 31	2 50	2 63	2.19	0.31	1 06	0 00	0 00	0 06	0 00	0.00	10 3064 (3.3625)
phorate granules 10% ai @ 5g placed in leaf axils	0 00	1.69	0 00	0.03	0.00	0 50	0 00	0 00	0 00	0 00	0.00	2.3306 (1.8250)
carbofuran granules 3% ai @ 5g placed in leaf axils	1.31	2 13	0.13	1.75	0.06	2 06	0.00	1.31	0.00	0 00	0 00	8.0300 (3 0050)
two sachets of 10% ai phorate granules @ 2g each placed in leaf axils	0.00	0.00	0 00	0.00	0.06	0.00	0 13	0 00	0 00	0.00	0.00	0.1664 (1.0800)
control	3.25	3 38	1.63	2.81	1 88	2 56	0.81	0 88	0 25	0.44	0.00	16 8929 (4.2300)
F. test												S
C D												0.7014**

S significant

** significant at 1% level

figures within parentheses are transformed values ($\sqrt{x+1}$)

the adults was the least (0.1664/palm) in the treatment. The direct placement of 0.5 g ai phorate granules in leaf axil also came on par with it (0.5314 bugs/palm). Among the remaining treatments palms sprayed with endosulfan showed least incidence (1.1609/palm) and it was on par with carbofuran granules (1.6163/palm) and fish oil rosine soap (2.0713/palm and HCH (2.7539/palm).

Based on the count of nymphs and adults (total) of C. arecae (vide Table 24) placement of 2 sachets filled with 0.2 g ai phorate granules each was found superior among the treatments. In the counts during the first eight months only in two observations the bugs were noted in the treatments and they were in a very low range of 0.06 to 0.13 bugs/palm in comparison with the counts in different observations in control during the period which were in the range of 0.25 to 3.38/palm. It was followed by the direct placement of phorate granules (0.5 g ai) in leaf axils which showed the bug population in three observations (0.03 to 1.69/palm), endosulfan (bugs present in 6 observations within a range of 0.19 to 2.25/palm), neem cake suspension (7 observations in the range of 0.06 to 2.63/palm), fish oil rosine soap (7 - range 0.25 to 2.56), carbofuran granules (7 - range 0.06 to 2.06) and HCH (8 - range 0.06 to 3.38). The decline in the population in 9th to 11th observations coincided with a fall in the incidence in control also.

Table 25 Control of C arecae with different insecticides used as foliar sprays, as granules in leaf axils directly and in sachets (effect on damage/feeding marks)

treatments	mean number of f m /leaf/palm/month observed at different intervals after treatment (months)											total leaf f m	palms affected by YLD	
	1	2	3	4	5	6	7	8	9	10	11		per cent	mean disease indices
HCH 0 2% ai (spray)	82 80	50.13	62 44	21.44	72 56	28 55	18.94	1 56	47.88	16 25	38 8o	417 51 (20 46)	50 00	11.42
endosulfan 0 05% ai (spray)	134.69	49 56	29 81	80 56	48 >8	41 00	18 00	0 00	5 56	1 69	27 25	433 72 (20 85)	31.25	21 87
fish oil rosine soap 5% (spray)	165 56	56 88	71 69	44 94	31 69	35 88	43 63	25.94	0 94	24 19	1 25	490 07 (22.16)	31 25	22 29
neem cake suspension 5% (spray)	222 69	96 00	111 00	110 63	65 75	52 88	7.38	0 00	31 19	6 63	0 00	685 31 (26 20)	25 00	21 64
phorate granules 10% ai @ 5 g placed in leaf axils	116 31	65.75	8 25	33.75	20 31	15.63	0.00	25.63	6.63	10 00	8.44	281.58 (16.81)	25.00	15.66
carbofuran granules 3% ai @ 5g placed in leaf axils	138.50	39.38	117 50	18.31	1o 69	15.13	0 00	19.50	24 06	>2.63	3 25	406 94 (20 20)	56 00	15 02
two sachets of 10% ai phorate granules @ 2 g each placed in leaf axils	175.44	11 19	4.13	8 06	>.81	1 81	41 50	1> 31	2.19	5 56	4.56	259.18 (16.1>)	37 50	21 23
control	262.63	68.38	154.81	111 31	63.75	66 00	75 56	77.88	47.50	66 25	5.50	986 37 (31.42)	37.50	28 47
F test												S		
C D.												5 983**		

S significant f m feeding marks

** significant at 1% level

figures within parentheses are transformed values ($\sqrt{x+1}$)

Based on total population observed during the entire period of the experiment also, phorate granules (0.4 g ai in 2 sachets) were found to be the best (0.1664 bugs/palm) and it was closely followed by the leaf axil filling with phorate granules (2.3306/palm). Among the remaining treatments endosulfan (5.528/palm), fish oil rosine soap (6.6591), HCH (7.094), neem cake suspension (10.3064) and carbofuran granules in leaf axil (8.03) came on par and significantly superior to control (16.8929).

The feeding marks (vide Table 25 and Fig. 7) revealed that the treatments did not totally repel the insects from the palm. The observation recorded during the first month after the spraying was high in all the treatments (82.8 to 262.63 marks) and it might be due to the involvement of pretreatment damage in the count. In the subsequent ten counts the least damage was seen in treatment with phorate in sachets (1.81 to 41.50 feeding marks/palm) and it was followed by the direct placement of phorate granules (8.25 to 65.75), carbofuran (3.25 to 117.5), HCH (1.56 to 72.56), and neem cake suspension (6.63 to 111.0).

Based on total leaf damage observed during the period of the experiment also the placement of phorate in sachet ranked first (259.18 feeding marks/palm) and it came on par

Table 26. Cost of controlling C. arecae infesting arecanut palms with different insecticides using different methods of application

treatment	dose/ palm/ treatment (a.i)	number of treat- ment per year	formulation of pesticide required/ year	cost of pesticide/ year/palm (Rupees) (a)	number of palms treated by one labourer in 8 h.	labour cost/palm/ year (Rupees) (b)	total cost of treat- ment/year (Rupees)
phorate granules (applied in leaf axils)	0.5g	6	30g of 10% granules	1.020	95	1.95	2.97
carbofuran granules (applied in leaf axils)	0.15g	6	30g of 3% granules	0.9855	95	1.95	2.94
phorate granules (placed in leaf axils in 2 sachets)	0.4g	1	4g of 10% granules	0.420(a_1)	90	2.066(c)	2.49
carbofuran granules (placed in leaf axils in 2 sachets	0.12g	1	4g of 3% granules	0.414(a_1)	90	2.066(c)	2.48
HCH (foliar spray)	0.2%	6	6g of 50% WP	0.051	88	2.114	2.17
endosulfan (foliar spray)	0.05%	6	2.1ml 35% EC	0.2205	88	2.114	2.33
fish oil rosine soap (foliar spray)	5.0%	6	75g fish oil rosine soap	1.500	88	2.114	3.61
neem cake suspension (foliar spray)	5.0%	6	125g neem cake	1.500	88	2.114	3.61

(a) cost of insecticides as on 30-5-1989

(b) labour charges as on 30-5-1989 Rs.31/- per 8 man h.

(a_1) including cost of materials and labour for sachet making

(c) cost of elevating sachets six times a year also included

with phorate granules placed directly in leaf axils (281.58), carbofuran (406.94), HCH (417.51) and endosulfan (433.72). Fish oil rosine soap and neem cake suspension reduced the leaf damage to the least extent (490.07 and 685.31). Feeding marks in control (986.37) were significantly higher than those in other treatments.

In spite of the varying effects of the treatments on the incidence of C. arecae and on the leaf injury, the incidence of yellow leaf disease (31 to 56 per cent of the palm) and the severity of the disease (indices 11.42 to 28.47) did not show wide variations. Apparent correlations between the disease and bug population/leaf injury were lacking in the data.

4.6.3. Cost of controlling C. arecae

The relative cost of the currently recommended insecticidal control methods as well as the new method of keeping phorate/carbofuran in sachets were worked out in detail and the same are shown in Table 26. For treating the palms, the least expenditure was for the spraying of HCH (Rs. 2.17/palm/year) and it was followed by the spraying of endosulfan (2.33), carbofuran granules (0.12 g ai) placed in two sachets in leaf axils (2.48) phorate granules (0.4 g ai) placed in two sachets in leaf axils (2.49), application of carbofuran granules (0.15 g ai) directly

Table 27. Effect of C. arecae incidence on the growth of areca palms

treatments	percentage of palms observed 5 years after commencement of treatment			bug count/ palm/12 monthly observations	palm height (cm)	palm girth (cm) at		leaf characters		
	healthy	withering	dead			collar	crown	number/ palm	length (cm)	length of leaflet (cm)
vigorous palms										
pest infested	43.50	26.1	30.43	90.410	391	41.0	12.0	5.0	122	56
pest controlled	93.59	5.13	1.28	1.739	684	61.0	24.0	8.0	197	84
T values				19.660**	5.31**	3.82**	6.96**	6.53**	5.21**	4.23**
non-vigorous palms										
pest infested	21.05	36.8	42.11	19.420	187	22.0	10.0	4.0	103	42.0
pest controlled	66.66	16.66	16.66	0.528	404	42.0	18.0	7.0	154	72.0
T values				2.946**	10.23**	8.06**	4.0**	5.72**	8.02**	7.67**

** significant at 1% level

* significant at 5% level

in leaf axils (2.94), application of phorate granules (0.5 g ai) directly in leaf axils (2.97), spraying of fish oil rosine soap (3.61) and spraying of neem cake suspension (3.61), in the ascending order.

4.7. Effect of persistent attack of C. arecae on areca palms, at early stages of growth

The data obtained from a field trial and the results of statistical analysis of the same are presented in Table 27.

The damage in the establishing transplanted seedlings was found to affect the growth and vigour of the palms and even caused the total death of the same. Among vigorously growing bug infested palms 26.1 and 30.4 per cent palms were seen withering and dead respectively in the course of first five years after transplanting while the palms well protected from C. arecae incidence had just 5.13 and 1.28 per cent of the palms in the withering and dead categories at the time of observation.

Among the non-vigorous palms left unprotected only 21 per cent remained healthy at the end of five years as against 66.66 per cent in the corresponding protected group.

On palms continuously protected with phorate granules enclosed in perforated sachets, the mean bug population per

Plate XXI. Extent of injury caused to vigorous areca palms

A. vigorous palm protected from the bug injury

B. vigorous palm unprotected

PLATE XXI

A

B

Plate XXII. Extent of injury caused to non-vigorous palms

A. non-vigorous palm protected

B. non-vigorous palm unprotected

PLATE XXII

A

B

observation were negligible whereas 7.5 and 1.6 bugs (adults/ nymphs) were seen in unprotected vigorous and non-vigorous palms respectively. The above population level was found sufficient to inflict very serious injury on the growing crop. The growth of the surviving palms, indicated by the stem height, girth at collar, girth at crown, number of leaves, length of leaf, length of leaflet also suffered highly significant suppression due to the persistent attack of C. arecae. The increase in the measures of the above (Plate XXI) characters manifested by the protected vigorous palms were 174.94, 148.78, 200.0, 160.0, 161.48 and 150.0 per cent of the unprotected palms respectively while the increase in corresponding protected non-vigorous palms were 216.01, 190.91, 180.0, 175.0, 149.51 and 171.43 per cent of the unprotected non-vigorous palms respectively (Plate XXII).

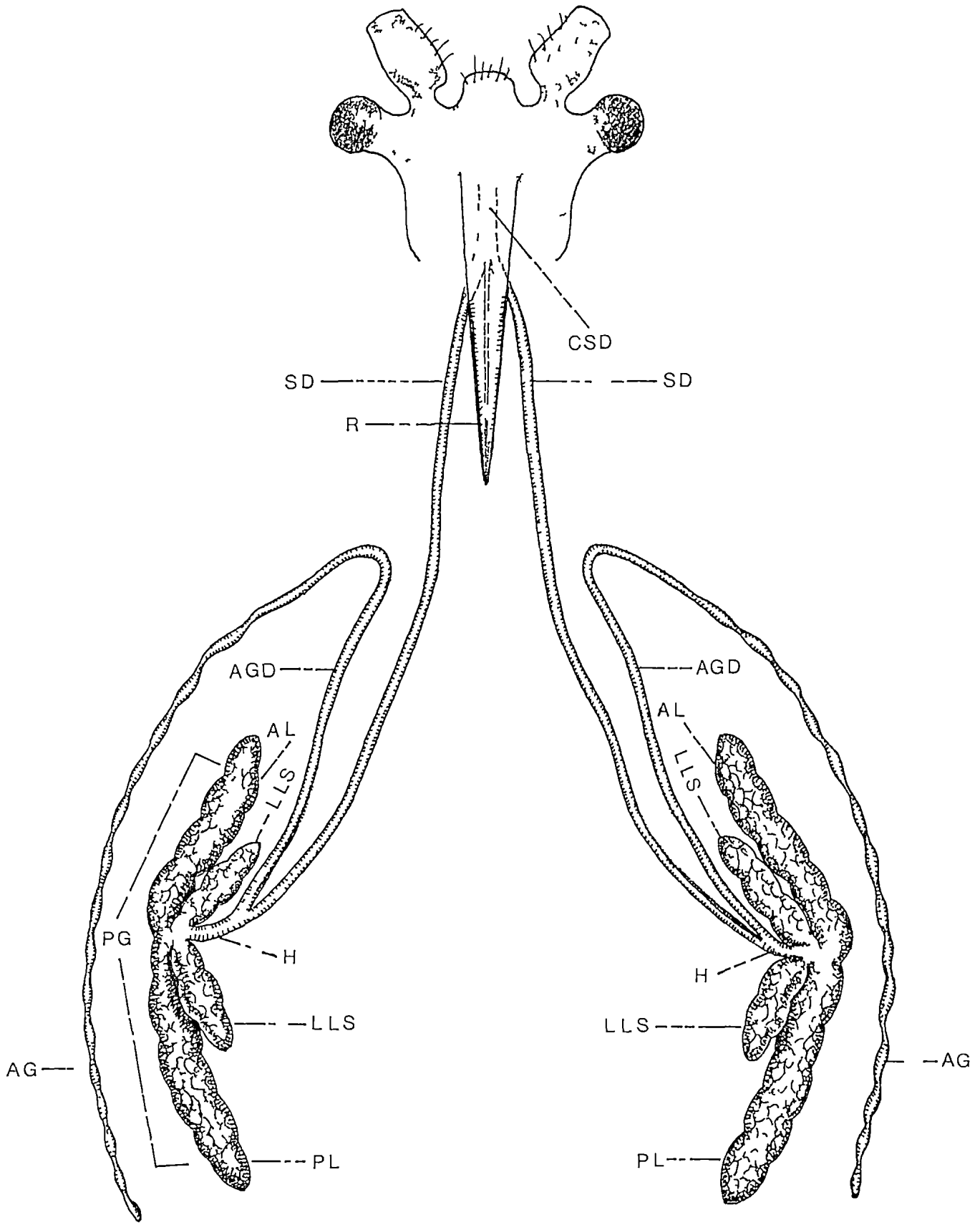
4.8. Investigations on the tissues of salivary apparatus and haemolymph of C. arecae

The salivary apparatus of the nymphs and adults of C. arecae were found to be similar except for size. They were bilaterally symmetrical lying on either side of the oesophagus, in the head, neck and thorax regions of the body. Each gland consists of two principal lobes (anterior and posterior) and two lateral lobes as shown in Fig. 8. Each gland has a long tubular accessory gland also.

Fig. 8. Salivary glands of *C. arecae* (diagramatic)

CSD : common salivary duct
SD : salivary duct
R : rostrum
ACD : accessory gland duct
PG : principal gland
AG : accessory gland
AL : anterior lobe
PL : posterior lobe
LLS : lateral lobes
H : hilus

FIG 8



All the four lobes of the salivary gland were carefully excised and processed for electron microscopy. Critical examination of ultra thin sections (600-700 A^{o} thick) failed to show any mycoplasma like structures in the acini of the four lobes of the gland. No viruses or rickettsia like bodies could be located in the preparations. MLOs were not observed in any of the haemolymph preparations also.

DISCUSSION

DISCUSSION

The objectives of this research programme were a detailed survey on the spindle bug incidence in Kerala, assessment of the possible build up of the pest on the important alternate hosts, studies on the nature and extent of damage caused by the pest, assessment of the relative efficacy of known methods of control in comparison with a novel technique of repelling the bugs from areca palms using granular insecticides kept in sachets and determining the association between the pest and the devastating yellow leaf disease (YLD) of areca palms, if any.

5.1. Survey on the incidence of C. arecae and yellow leaf disease in the different agro-climatic zones of Kerala

Incidence of C. arecae

The purpose of the survey was to assess the distribution of the pest in different areca growing tracts of the five agro-climatic zones of the state, to study the intensity of the pest and the YLD incidence in different locations and to assess the correlation between the pest and disease incidence, if any.

The results presented in para 4.1.1 to 4.1.6 showed that C. arecae enjoys a statewide distribution. The pest and the feeding marks on the leaves were totally absent at

Vadakkanchery and Palghat of the middle zone. These places have not been covered in surveys reported earlier. The identification of any spot free from the pest in the state is done for the first time. Pooled analysis of the entire data obtained in the survey indicated that the incidence of the pest had a significant negative correlation with maximum temperature and a positive association with the minimum relative humidity. The above locations situated in Palghat district, at the eastern border of the state has relatively higher temperatures and low levels of humidity. These factors might have limited the introduction and survival of the pest there. In the northern zone at Kumbla also the nymphs and adults of C. arecae were not observed but the feeding marks of the insect could be seen. This (vide Table 5) indicated the prevalence of the bug in the area, though they were absent at the time of the survey (December).

The prevalence of the nymphs in 41 of the 45 locations covered in the survey (absent at Palghat, Vadakkanchery, Kumbla and Mukundapuram) revealed that the insect has got itself adapted to the varying environmental conditions in the different agro-climatic zones in the state and in general they were successfully breeding in all situations. The mean percentage of palms infested by adults of C. arecae in southern, problem, middle, hill and northern zones were

43, 34, 23, 27 and 21 respectively and the corresponding mean percentages of palms infested by nymphs were 34, 31, 34, 28 and 46 respectively. Palms infested by adults were slightly higher in the southern zone while those infested by nymphs were higher in the northern zone. Percentage of total infested palms (adult, nymph or both) also were high in the southern zone (58%) and it was followed by the northern zone (48%) while the remaining zones were of intermediate range (41 to 44 per cent).

With reference to the percentage of palms showing feeding marks, the most affected zone was the northern zone (92%) and the least was the southern zone (63%). The other zones came in between with lesser variations (65 to 77%).

Regarding the intensity of incidence of the adults (actual count) in different agro-climatic zones pooled analysis of the data collected from the entire survey (Table 6) revealed significant variations among the zones (para 4.1.6). The adult population of the insect in the southern zone was significantly higher than the population in other zones. The remaining zones were on par except the northern zone which had a lower level of population and it differed significantly from southern as well as problem zones. The population of nymphs was highest in the northern zone

as a result of which the total population also reached the highest level there. It was least in the hill zone while other zones were generally on par. Based on total population the northern zone came on par with the southern zone and the latter came on par with the middle zone. The population was least in the hill zone and it was closely followed by the population in the problem zone. But with reference to the number of feeding marks, the least affected zone was found to be the southern zone and among the remaining zones the hill zone showed slightly lower level of damage while others ranked high and were on par.

Assessment of the pest problem based on the extent of injury (number of feeding marks) was being attempted for the first time. While the population levels reflected the pest situation at the time of observation, the feeding marks indicated the pest activity for the entire period during which the top most leaf remained susceptible to the feeding of the bug and it normally extended over 30 to 45 days preceding the period of observation. This phenomenon explained the lack of coincidence in the observed levels of pest population and the extent of injury. The leaf damage obviously is bound to be more reliable index of the severity of the pest incidence in a location. When all the criteria followed in the assessment were considered in conjunction

the zones did not appear to differ consistently with reference to the severity of the pest.

As seen in para 4.2.1 to 4.2.7 the seasonal fluctuations in the population of the pest varied widely from place to place and month to month even within a zone. It indicated the high sensitivity of the population to the changes in the climatic factors. The difference in the population observed in different zones in a single state wide survey, done in the month of December, might also be caused by the variations in the climatic factors at the time of observation in different zones rather than the influence of the long term agro-climatic variations characteristic of the zones. The discrepancy observed between the pest population and the extent of damage in the survey also may be attributed to the above factor. Informations gathered by repeated survey over a few years may be necessary to understand the aspect of population fluctuations in depth. No elaborate study covering the distribution of the pest in different regions of Kerala and the damage caused by the insect have been reported earlier. C. arecae had been reported as a serious pest of areca palms at Nedumangad in Trivandrum district (Nair, 1964 A); Krishnapuram in Alleppy district and Palode in Trivandrum district (CPCRI, 1982; Sathiamma et al., 1985 A).

The population fluctuated considerably in different locations within each zone. As shown in para 4.1.1 in the southern zone Pandianpara had a significantly higher population of adults and nymphs as well as feeding marks (Table 1). At Kattakkada adults and feeding marks were high but nymphal population was low. Ettiruthi had the highest insect population but the feeding marks were low in number. Theviyode, Pangode and Vithura may be ranked as less infested locations in the zone based on all the three criteria followed in the assessment. Neyattinkara, Thiruvallam and Palode had an intermediate position.

The fluctuations of the pest population at Palode, Vithura, Neyattinkara, Thiruvallam and Kattakkada were studied continuously for two years and the data (vide para 4.2.1 and Tables 7 to 11) showed that the pest population and feeding injury were low at Neyattinkara in 1987-88 and 1988-89 and in general the other places were severely affected and on par. Vithura which was found as a less affected location in the all Kerala survey emerged as a badly affected location in the second survey. This clearly indicated the necessity for a repeated survey of the population to assess the seriousness of the problem in a location.

In the problem zone, on similar criteria Moncompu and Vytilla were found to be worst affected locations with

uniformly high adult, nymph, total population and leaf injury. Chengannur had less adults, but nymphs and feeding marks were high. Aevoor north and Mavelikkara had comparatively lower nymphal and total populations but leaf injury was high there. Karthikapally, Kumarakom and Karunagapally had lowest population of adults and nymphs and feeding marks.

In the middle zone, Alwaye and Pattikkad had high pest population and feeding injury. At peechy the adult population and feeding marks were high while nymphal population was low. At Palghat and Vadakkanchery the pest and feeding marks were totally absent and at Mukundapuram feeding marks were seen even though the pest was negligible at the time of observation.

In the hill zone Peringamala had high levels of pest incidence (nymphs and adults) and feeding injury. Vythiri, Ernadu and Pathanapuram had lower levels of adults, but nymphs and feeding marks were high. At Vaduvanchal and Kottapady the incidence, shown by different criteria, was very low.

In the northern zone Calicut, Taliparamba and Madhur were the worst affected locations based on the population level and feeding marks. At Koipady the adult population and feeding injury were high though the nymphal population

was low. Kumbla, Tellichery and Koothuparamba had low pest population and feeding marks.

In brief the survey had proved that the pest has got established as a problem for arecanut cultivation all through the state except in a small pocket in Palghat district. The distribution of the less populated or more populated locations were not geographically contiguous (Fig. 1). However, the locations within each zone, in which the pest incidence and damage levels were comparatively lower have to be examined further with repeated assessments since locations identified with lesser infestation (Vithura) and intermediate levels of infestation (Palode) in the all Kerala survey came on par with the worst affected location (Kattakkada) when the incidence was continuously monitored over a period of two years. Obviously effective methods for containing the pest have to be adopted throughout the state for recouping the economic status of arecanut among different cultivated crops in Kerala.

5.2. Incidence of yellow leaf disease and its association with areca spindle bug

The incidence of yellow leaf disease observed in the present all Kerala survey agreed (Tables 1 to 5, para 4.1.1 to 4.1.5) broadly with the findings of the survey conducted

by George et al. (1985) adopting "stratified multistage random survey technique". The disease was severe in the southern parts of Kerala and it gradually declined towards north. But the disease incidence in Cannanore was not observed as negligible as that reported earlier. At Irrikkur near Cannanore 86.67 per cent of the palms were affected by YLD and the intensity of the disease as shown by the disease index (53.72) was also high (para 4.1.5 and Table 5). Yellow leaf disease was thus found taking root in the northern parts of Kerala also in recent years.

The disease incidence and pest infestation did not show significant association in any of the zones covered in the survey. In 18 out of the 45 locations surveyed the crop was totally free from YLD whereas the pest was absent only in two locations.

The disease incidence and intensity were high at Pandianpara, Theviyode, Vithura and Pangode in the southern zone. Among these Theviyode, Vithura and Pangode had comparatively low levels of pest population and leaf injury. But the incidence of pest and its damage also were high at Pandianpara. Similarly, Kattakkada and Ettiruthi which had high levels of pest population and leaf injury were largely free from the yellow leaf disease (para 4.1.1 and Table 1).

In the problem zone, Chengannur had high incidence of the pest and disease while at Moncompu and Vytilla the pest incidence was high but disease incidence was less. At Vaikom, Mavelikkara and Aevoor north the pest incidence was of intermediate level but disease incidence was recorded high. Karunagapally, Kumarakom and Karthikapally recorded low levels of the pest and disease (para 4.1.2 and Table 2).

In the middle zone, at Pattikkad and Chalakkudy pest incidence was high while disease incidence was low. Mannuthy, Mukundapuram, Palghat and Vadakkanchery had low levels of pest and disease incidence while at Alwaye and Peechy disease and the pest were found at high levels (para 4.1.3, Table 3).

In the hill zone the disease incidence was found high at Chitara, Kulathupuzha and Pathanapuram while the pest incidence evidenced by the population and feeding marks on the leaves were low there. At Ernadu and Vythiri high pest incidence and low levels of disease were observed. At Peringamala the pest and disease occurrence were severe while at Vaduvanchal and Kottapady disease and pest incidence were low (para 4.1.4 and Table 4).

In the northern zone Taliparamba, Madhur, Koipady and Neerchalu had high population of the pest while the disease incidence in the locations was low. At Calicut and Irrikkur

the pest and disease incidence were high while at Koothuparamba pest and disease were low (para 4.1.5, Table 5).

The lack of disease incidence in many locations having heavy population of C. arecae and the lack of synchrony in the occurrence of the pest and disease in the remaining locations strongly indicated the absence of significant association between the pest and disease. Correlation between the pest and disease incidence in different locations could not be assessed statistically, since the disease was mostly confined to the southern part of Kerala and also because the distribution was highly heterogeneous.

5.3. Seasonal incidence of C. arecae observed at selected centres of southern zone

The aim of the study was to assess the population fluctuation of the pest over the different months of the year and to identify the period in which the population increased so that appropriate control measures could be adopted during the period. The data presented in para 4.2.1 to 4.2.7 and Tables 7 to 14 showed that the variations in the population observed during the different months were not statistically significant in both the years.

The different life stages of the pest were observed concurrently in different observations and hence it could be

Table 28. Months in which peak incidence of C. arecae were recorded at five different locations in southern zone of Kerala

places	peak incidence of				low incidence of			
	adults	nymphs	total (A+N)	feeding marks	adults	nymphs	total (A+N)	feeding marks
1987-88								
Palode	October December	December October	October December	December October	April June	May February	April May	June August
Vithura	July December	November July	July November	October March	May January March	March June	March May	September February
Kattakkada	September August	December July	September December	May December	June May March	June May March	June May March	June August
Neyattinkara	December March	December November	December November	May December	May July	May June	May June	June August
Thiruvallam	December November	November December	November December	May October	May June	May June September	May June	August March
1988-89								
Palode	January July	July January	July January	September June	March February	March February	March February	February January
Vithura	June April	May March	May March	May April	October December September	February July June	February July	October February
Kattakkada	November May	November May	May November	May March	September March February	March February	March February	February July
Neyattinkara	January November	January November	January November	May December	March August	July March	July March	July October
Thiruvallam	November September	August November	August September	December March	June March	May March	May March	July January

A adults
N nymphs

inferred that the pest breeds throughout the year. Nair (1964 A) observed that the population showed an increasing trend from June to September with a peak in August-September at Palode. Sathiamma et al. (1985 A) made a study in the same location in 1976-78 and concluded that the maximum population occurred in July while at a coastal belt (Krishnapuram) the peak of the population occurred in January and November. The reports thus indicated that the peak incidence varied from place to place and from year to year. The above findings were confirmed in the present studies carried out at five locations and over a period of two years. As observed in the state wide survey the population level and intensity of feeding injury did not show strict agreement.

The pest incidence was highest at Kattakkada, Vithura and Palode than at Neyattinkara and Thiruvallam during 1987-89. With reference to feeding marks Neyattinkara alone differed significantly from other locations. The months in which maximum and minimum levels of population of the insect and extent of leaf injury were observed at different locations, are summarised and presented in Tables 27 and 28. It was very clearly seen that peak levels of population and leaf injury were recorded in all the months of the year at one place or other and in 1987-88 or 1988-89. The same trend was seen with reference to the low levels of pest incidence and leaf injury. It was interesting to find that the same month got

Table 29. Peak/low incidence of C. arecae observed during different months of 1987-89 at five selected locations of southern zone of Kerala

months	peak incidence of				low incidence of			
	adult	nymph	total	injury	adult	nymph	total	injury
1987-88								
April	-	-	-	-	b	-	b	-
May	e	-	-	c,e,d	a,c,e,d	b,c,e,d	b,a,c,e,d	-
June	-	-	-	-	b,c,d	a,c,e,d	c,e,d	b,c,e
July	a	a,c	a	-	e	-	-	-
August	c	-	-	-	-	-	-	b,c,e,d
September	c	-	c	-	-	d	-	a
October	b	b	b	b,a,d	-	-	-	-
November	d	a,e,d	a,e,d	-	-	-	-	-
December	b,a,e,d	b,c,e,d	b,c,e,d	b,c,e	-	-	-	-
January	-	-	-	-	a	-	-	-
February	-	-	-	-	-	b	-	a
March	-	-	-	a	a,c	a,c	a,c	d
1988-89								
April	a	-	-	a	-	-	-	-
May	c	a,c	a,c	a,c,e	-	d	d	-
June	a	-	-	b	d	a	-	-
July	b	b	b	-	-	a,e	a,e	c,e,d
August	-	d	d	-	e	-	-	-
September	d	-	d	b	a,c	-	-	-
October	-	-	-	-	a	-	-	a,e
November	c,e,d	c,e,d	c,e	-	-	-	-	-
December	-	-	-	d,e	a	-	-	-
January	b,e	b,e	b,e	-	-	-	-	b,d
February	-	-	-	-	b,c	b,a,c	b,a,c	b,a,c
March	-	a	a	c,d	b,c,e,d	b,c,e,d	b,c,e,d	-

a Vithura b Palode C Kattakkada d Thiruvallam e Neyattinkara

identified for occurrence of low and peak levels of pest population and leaf injury in different locations/year. Obviously any attempt to identify an optimum period of the year for the control of the pest would be futile.

Second aspect of the study was to find out the influence of the insect in the manifestation of symptoms of the yellow leaf disease, if any. Regarding the intensity of yellow leaf disease it generally remained low during the south west monsoon period (June-July-August) and following the season it showed an increasing trend and the symptoms remained acute during the summer months (January to April). There was no coinciding fluctuation in the levels of pest population. The pest incidences as evidenced by the insect count and feeding marks at Thiruvallam/Neyattinkara (two disease-free areas), Kattakkada (an area with moderate level of YLD), Vithura/ Palode (badly diseased area) were not varying significantly. The insect was found actively feeding and breeding throughout the year and it did not show any relation with the characteristic fluctuation in the intensity of the disease in different seasons of the year. Statistical analysis of the data also did not reveal significant association between the pest population and disease symptoms.

The pest population did not vary significantly in different months of 1987-89. Since the weather factors were

reported to influence the population of C. arecae (CPCRI, 1982; Sathiamma et al., 1985 A) the available data were utilised for assessing the association between the varying levels of pest and disease incidence and different weather factors. The results presented in para 4.3.1 to 4.3.5 and Table 14 showed that maximum temperature had significant negative influence on the pest population at Palode and Thiruvallam while minimum relative humidity showed a highly significant positive correlation with the pest at Palode only. The weather data available for Palode were obtained from the research station where the survey was conducted while the weather data relating to the pest population at Thiruvallam (farmer's field) were collected from a research centre located two kilometre away from the place. Obviously the inferences derived from the data at Palode would be more reliable. Hence the positive association with the minimum RH and negative association with maximum temperature may be accepted with a high levels of confidence. The lack of significant correlation with temperature and humidity reported by CPCRI (1982), Sathiamma et al. (1985 A) may be due to the inadequacy of the data. They reported positive association with the pest population and rainfall from the study at a single location. The rainfall data were available for all the five centres covered in the investigation and among the centres a positive significant association with rainfall was

observed at Palode only. The data relating to Neyattinkara, Kattakkada and Vithura were collected from research stations located at 3 to 4 km away from the concerned fields. Lack of correlation between rainfall and pest population have to be confirmed from further data. It appeared that the collection of data on pest incidence and weather parameters from same location was a pre-requisite for constancy in the inferences from such correlation studies.

5.4. Biology of *C. arecae* on different host plants

This aspect was studied in detail with a view to ascertaining the possibility of the survival of the pest on alternate hosts when suitable control measures were adopted on areca palms in arecanut gardens. The known alternate hosts were largely ornamental palms maintained in the households. Among them more common ones were selected for the study. The insect fed and multiplied successfully on all the hosts selected, namely *A. catechu*, *A. triandra*, *C. lutescens*, *Pinanga* sp. and *E. guineensis*. In the last host all life stages of the insect were found under field condition, especially in second stage nurseries, during rainy season. The insects fed and laid eggs on the emerging spindle only since the leaves became tough and leathery soon after the opening. As the immature stages were not thriving under laboratory condition the biology of the pest on *E. guineensis* could not be studied.

The results presented in para 4.4.1 to 4.4.4 revealed significant variations in development of the insect on different hosts. The total nymphal duration was significantly higher on Pinanga sp. while on C. lutescens and A. triandra the durations were on par with that of A. catechu. It was interesting to note that the prolonging effect of Pinanga sp. was conspicuously seen in second and third instar stages of C. arecae. In the first and fourth instar stages Pinanga was on par with A. triandra and C. lutescens and all of them were found more favourable than A. catechu for the multiplication of the pest. At the fifth (final) instar stage all the hosts were found equally suitable. The longevity of the male and female insects reared on different hosts were broadly similar and their fecundity also did not show significant variations. The overall conclusion from the data would be that even when A. catechu was rendered unsuitable for the survival and breeding of C. arecae the insect could thrive successfully on the alternate hosts, if available. The population build up on Pinanga sp. may be slightly slower due to prolonged nymphal duration on the host and consequently a reduction in the possible number of generations during the year may occur.

The length and width of the egg, first instar nymph and second instar nymph were not significantly influenced by the different hosts on which the nymphs were reared. But in the

third instar stage E. guineensis appeared to influence the size (length and width of the nymphs favourably while the remaining host plants came on par.

Regarding fourth instar nymph, E. guineensis and C. lutescens resulted in nymphs with greater body length: Pinanga sp., A. catechu and A. triandra were inferior.

With reference to the body length, body width and antennal length the fifth instar nymph had a favoured effect from E. guineensis while others came inferior. The size of the adult females on different hosts did not cause significant variations. Adult males reared on Pinanga sp. were significantly smaller than the ones reared on C.lutescens and E. guineensis.

The favourable effect of E. guineensis on the immature stages of the pest would be a matter of concern in some parts of Kerala where oil palm cultivation is being launched in a big way. The possibility of the pest posing a threat to the new plantations have been strongly indicated. References on the biology of C. arecae on the alternate hosts were lacking in literature.

The fact that the investigated alternate hosts were as good as the primary host for the feeding and breeding of

C. arecae pointed out the necessity for detailed studies on all the possible alternate hosts of the insect. For effective control of the pest population, it would be necessary to remove the alternate hosts from the vicinity of arecanut gardens or the control measures adopted should be extended to the alternate hosts also.

5.5.1. Feeding habits and nature of damage done by C. arecae

Backus (1988) observed that the Hemipterans selected food plants within a range of host plants and preferred to specialise on certain regions and also on certain feeding tissues within the plant. Agreeing to this generalisation C. arecae was found to have a limited number of host plants confined to the family Palmae and fed and laid eggs on the unopened spindle leaf of palms. This habit of the bugs had been observed by the earlier workers also (Khandige, 1955; Pillai and Kurian, 1959; Nair and Das, 1962).

Miles (1972) made an exhaustive review of the feeding behaviour of the Hemiptera and identified two behavioural strategies employed by phytophagous Hemipterans viz. (i) lacerate and flush feeding and (ii) sheath feeding. The former was typified by Cimicomorphs (eg. Tingids and phytophagous Mirids) and some of the Pentatomorphs (eg. Lygaeids

and Pyrrhocorids) as observed by Cobben (1978) and Smith (1985). Behaviour of C. arecae was found to be in full agreement with the behaviour of the typical phytophagous Mirids described in detail in the papers referred above.

As typical of lacerate and flush feeder (Miles, 1972) C. arecae on exposure to the leaf surface, walked briskly dabbing at it repeatedly with the tip of the labium and antennae. They also released saliva on the leaf surface which could be observed as small droplets. The dabbing with the labium and antennae perform a chemo-sensory and mechano-sensory function in the plant surface exploration (Backus, 1988).

After the selection of a spot for feeding, the insect was found to insert the stylets and the feeding commenced immediately after that as evidenced by the discolouration of the lamina at the point of insertion of the stylet. In some cases they moved away from the spot within a few seconds after the insertion of the stylet while at some spots the feeding continued for longer periods extending up to 20 minutes. The former behaviour may be the test or exploratory probing described by Sogawa (1973). The small amount of plant material drawn into the cibarium during exploratory probing enabled the insect to discriminate between chemically different plants

(Backus and McLean, 1985) and in locating preferred feeding tissues (Backus, 1988). Along the length of pre-cibarium a large number of papillae, the ultrastructure of which resemble the known gustatory chemo-sensillae, have been identified and Wensler and Filshie (1969) and Backus and McLean (1982, 1983) attributed the above discriminating function to these sensillae. Such stylet insertion period was very short and rapidly repeated.

Since each insect fed on a number of spots causing feeding injury, damage done even by a small population of the pest became deleterious to the host. The spindle exposed to the feeding of C. arecae showed extensive feeding marks on the lamina, sometimes covering almost all the leaflets and the entire area of the leaflets which got manifested when the spindle opened up (Plate IV B and VI). Along with the feeding injury the characteristic discolouration and death of the tissues around the egg laying spot (III B (ii) destroyed the chlorophyll content of the leaves. This injury (observed for the first time) was also extensive since a large number of eggs were often laid on each spindle at a time.

The extent of chlorophyll containing leaf area left after such attack would be too low to sustain the minimum photosynthetic efficiency of the leaves which obviously

affected the vigour and growth of the plant and also the yield of the crop. The persistent damage on all the newly emerging leaves over a long period of time, turned fatal to the palm. Since the population of the pest was fluctuating in the different months of the year (Tables 28 and 29, vide para 4.2) the chances for getting a number of leaves damaged in succession remained low and the mortality of grown up palms from the attack of C. arecae occurred to a limited extent only. Frequent effect of the injury was the drastic reduction in the health of the palm and the yield.

Apart from the above direct damage on the leaves, the suppression of the emergence of the spindle (vide para 4.5.1, Plate V A) appeared to be more deleterious to the palm. When the feeding commenced at the emergence of the spindle it dried up and failed to emerge. Khandige (1955) also observed that the infested spindle of areca palms did not open early. Nair (1963) observed that extensive patches of dead tissues on the infested leaf buds especially towards the tip, caused failure of the leaves from growing out fully.

When the attack on the spindle occurred after partial emergence of the opening leaf, remained normal distally while the lower portion remained withered (Plate IV B) or dried up. In brief the damage done to the spindle appeared to be more deleterious to the palms than the direct chlorophyll destruction done by the feeding.

The incidence of secondary pathogens and insects invading the dead tissues of the affected spindle aggravated the symptoms often leading to the fast rotting of the tissues. The frequent association with the bud rot disease and the death of the spindle, attacked by C. arecae, was also noted for the first time.

A third type of injury caused by the pest was the feeding and egg laying injury on the leaf stalk which led to the formation of 'pox marks' on the surface of the rachis. The damage causing the death of tissues deep into the rachis would affect the food flow and thus explained the reduction in the size of leaves and leaflets (vide para 4.7, Table 27), generally noted as a corollary to the attack of areca palms by C. arecae.

The damage observed in areca plantations infested by C. arecae was a mixture of all the different types of injury described above. The predominance of one or other type of damage depended on the levels of population of the pest at different growth stages of the crop. If the population remained high at the time of spindle emergence, the very emergence of the spindle would be affected. If the population was high at subsequent stages of spindle emergence, leaves with varying levels of feeding and egg laying injury

would emerge. The distribution of the pest being highly heterogeneous and highly susceptible to the varying weather factors the type and extent of injury observed within garden and among different gardens in a location showed marked variations.

5.5.2. Histology and histopathology of the areca leaves exposed to the feeding of *C. arecae*

Nair and Das (1962) observed that the feeding of *C. arecae* on the tender leaves resulted in the formation of longitudinal decoloured zone commencing from the point of insertion of the stylets. After feeding, the area was reported to have undergone shrinkage due to the collapse of the cells. Menon *et al.* (1962) also described the development of water soaked areas with a 'depression' at centre while the insect fed on the areca leaves. They further observed that the affected portion later flaked off leaving 'shot-holes' on the leaves. The histology of the affected leaf tissues had not been studied in detail so far. With a view to gathering details about the formation of lesion and consequent withering of lamina at the site of feeding, histological examination of the fed leaf portion, collected at different intervals after formation of the water soaked lesion was studied.

Mode of feeding of Hemiptera has received attention of scientists from vary early days because of the varied effects of saliva noted on the plants on which they feed. Typical "phytotoxaemia" caused by the feeding of many Homopterans and a few Heteropterans and transmission of diseases among plants and animals through saliva, while feeding etc. have evinced considerable interest among the researchers.

Cimicomorphs including Tingids and many species of Mirids 'lacerate and flush feed' the tissues of the hosts. Tingids fed on single or small groups of cells beneath the epidermis while the Mirids fed on large pocket of cells at the feeding site (Miles, 1972). The liquefaction of the cell content had been suggested to be due to the mechanical movement of the stylets in different directions coupled with the release of large amounts of watery saliva (Miles, 1959; Saxena, 1963; Bongers, 1969). The liquefied material was imbibed by the insect causing water soaked patches of tissue with characteristic silvery appearance (Miles, 1972).

Such typical water soaked patches were formed on the leaf lamina within seconds after the insertion of the stylets by C. arecae. Obviously the mechanical effect of the stylet movements in the liquefaction of the cell content had to be

excluded in this case. The discolouration of the water soaked areas would have been caused by the action of watery saliva introduced at the spot immediately after the liquefaction of the cell.

The saliva of phytophagous Hemiptera were reported to contain amylase (Hori, 1970 B), several hydrolytic enzymes other than carbohydrases including polygalacturonases (Adams and McAllan, 1958; Laurema and Nuorteva, 1961), proteinases and esterases (Nuorteva, 1958; Feir and Beck, 1961). All the enzymes may not be present in a single species of insect and enzymatic content of saliva in a particular species may not remain constant (Nuorteva, 1956; Adams and McAllan, 1958; Hori, 1970 A). It appeared to be true for C. arecae also.

Even when C. arecae was removed from the feeding spot soon after stylet introduction large lesions developed at the points where they commenced feeding. The plasmolysis of the palisade and spongy parenchyma commenced then (vide para 4.5.2.2) and the process was completed in about 4 h after the commencement of feeding. After eight hours after the formation of the lesion the cell walls of the mesophyll tissue was seen collapsed and the thickness of the lamina got reduced less than half the thickness of the unaffected portion. The content between the upper and lower epidermis turned dark brown except the vascular bundles. In four to

five days after the lesion the entire tissue at the feeding spot, except the vascular bundle, withered. Strong (1970) proposed a new hypothesis explaining the formation of such lesions caused by Mirids that "polygalacturonase in the watery saliva caused a rapid spread of other salivary enzymes into the tissues. Since the time taken for the spread of the lesion after the insertion of the stylet was very small in the case of C. arecae, it appeared that the mechanical probe of the stylet did not aid the spread of saliva and polygalacturonase aided the entry of other salivary enzymes into the tissues. Kloft (1960) observed that in some aphids, amino acids present in the saliva increased the permeability of the plant cells and the protoplasmic streaming while feeding. Some such bio-chemical factors also may be involved in the feeding process of C. arecae.

After the introduction of the saliva into the plant tissue, even when the liquefied content was not imbibed by the insect, the tissues around the feeding spot underwent extensive necrosis. Strong (1970) observed that in the case of Lygus hesperus Knight the spread of salivary enzymes during the 'lacerate and flush feeding' practised by the insect caused a lesion such larger than one that would be produced by 'a sap-sucking insect of comparable size'. The observation appeared to hold good for C. arecae also. This

behaviour of the insect made the damage done by the insect much more extensive than that could have been caused by its feeding alone.

5.5.3. Histochemistry of the feeding lesions caused by *C. arecae* on areca leaves

The injuries of crops caused by Hemipterous insects have been studied extensively. But many questions relating to the physiological mechanism of injury still remain unanswered (Hori, 1974). Strong (1970) and Varis (1972) ascribed the lesions caused by some Mirid bugs to the mechanical destruction of growing plant tissue brought about by the stylet. Hori (1973 A) ascribed the malformations caused by *Lygus disponsi* Linnavouri (Miridae) to the salivary pectinase and the quinones produced in the injured tissues owing to the higher peroxidase and polyphenol oxidase activity at the injured site. Detailed histochemical studies have indicated the possible role of polysaccharides, proteins, polyphenol oxidase, peroxidase, acid phosphatase, lipids and tannins in the galls caused by insect feeding (Gopinathan and Ananthakrishnan, 1985). In this context an attempt was made to assess the histochemical localisation of proteins, lipids, starch and tannin at the lesion, at different intervals after the formation of the same.

Heavy accumulation of amorphous protein was observed in the mesophyll cells of the injured areca leaf between 15 minutes and 12 h after the injury and the proteinaceous substances persisted even after 24 h after the formation of the lesion. In normal tissue light granular deposition only. Increased levels of amino acids had been recorded in the damaged area of the hosts of a number of Hemipterous insects (Strong, 1970; Hori, 1973 B; Hori and Atalay, 1980). Raman and Sanjayan (1984) observed the accumulation of proteins at the feeding spot and the stylet path of Cyrtopeltis tenuis Reut. (Miridae) on Lycopersicon esculentum Mill. They attributed the phenomenon to a stimulatory act of the insect in the plant cells to ensure continuous nutrition suggesting a "sink-source" relationship as envisaged by Way and Cammel (1970). Hori (1975) observed that Eurydema rugosum Motschulsky (Pentatomidae) feeding on cabbage leaf resulted in an increase of 14 kinds of amino acids. Hori (1973 B) found that all amino acids increased the sugar beet leaf injured by L. disponsi. On the contrary Hori (1975) found that all the amino acids decreased when the leaf was artificially injured. The finding led to the assumption that the increase in protein content was not by the mechanical injury caused by the stylet but might be due partly to the action, directly or indirectly of the salivary amino acids. The present findings on C. arecae also lead to similar conclusion.

The protein accumulation commenced after the removal of the insect and probably due to the continued action of the saliva already injected by the insect at the commencement of the feeding. The biochemical basis of the protein build up in the plant tissues needed further elucidation.

Twelve hours after the formation of the lesion cells in the leaf tissue showed accumulation of lipids. The deposition of granular lipids in the epidermal cells and amorphous type in the mesophyll cells were noted. But lipids were lacking in the normal tissue. Such localisation of lipids in the tissues damaged by Hemipterans have not been reported so far. As in the case of proteins, lipid synthesis also might be stimulated by the enzymes in the watery saliva introduced at the lesion by C. arecae.

Feeding injury caused by C. arecae did not cause conspicuous changes in the starch and tannin content in the cells at the site of feeding when compared to healthy tissues. In some other Hemiptera accumulation of these constituents have been reported at the point where feeding injury was inflicted on the host (Raman and Sanjayan, 1984; Raman, Sanjayan and Suresh, 1984).

5.6.1. Control of C. arecae using granular insecticides kept in leaf axils in polythene sachets

Application of chlorinated hydrocarbons and organophosphate as emulsions at varying doses and frequencies and the filling of top leaf axils with granules had been recommended for the control of C. arecae (vide para 2.3). Many of those methods were giving partial control of the pest. The application methodology was tedious and the insecticides so applied did not persist on the palms for long, especially during the rainy days.

Ever since the yellow leaf disease emerged as a devastating problem for areca cultivation, the insect pests of the crop were being suspected as transmitters of the unknown pathogen. The discovery of MLOs as the possible pathogen responsible for the production of disease symptoms, the role of insects in transmitting the pathogen was very strongly suspected. Among those insects C. arecae received priority since it was the most serious pest of the crop. Attempts were being made to establish the role of C. arecae in the disease transmission by growing the palms free from insect infestation and then watching the development of disease symptoms. For this purpose the known methods which gave partial control of the pest were not adequate since a vector, even in low population, would transmit plant diseases.

In laboratory observations, high repellency of phorate to the immature stages and adults of C. arecae was observed and the idea of using this as a repellent in giving full protection to areca palms from C. arecae at field level was exploited. This led to the development of the technique of keeping insecticide granules in perforated polythene sachets at the crown of areca palms (vide para 3.6.2) and the methodology was observed to be highly effective in controlling the pest, often giving absolute protection to the palms, for months with a single application (Jacob, 1985).

In the first experiment under the control of C. arecae the sachet technique was evaluated with reference to different doses of two insecticide granules (phorate and carbofuran). Results presented in para 4.6.1 (Tables 18 to 21 and Fig. 6) showed that the insecticides filled in sachet controlled C. arecae effectively up to 8 months after exposure. Since the insects generally inhabit in the axil between the spindle leaf and the next leaf the sachet has to be lifted upwards as and when the new spindles emerged on the palms. While recommending the application of granular insecticides to be placed in leaf axils, a schedule of one application in 4 months was recommended by Abraham et al. (1976) and one application every three months by CPCRI (1982) and Sathiamma et al. (1985 B). The new technique obviously prolonged the

life of the pesticide under field condition to the extent of 200 to 267 per cent. Besides, the direct application of granules at the tree top kept the insecticides exposed to non-target organisms. Further it would cause serious environmental pollution; getting washed down in the rain, the toxicants would pollute soil and water and even air. When kept in sachets all these adverse effects of pesticides could be overcome. It would be possible to collect back the sachets after use and bury them safely. It might even be possible to revive the efficacy of the sachets by partial replacement of the deteriorated toxicant. The trees provided with sachets containing phorate were seen harbouring other insect species on the crown. The repellency of the insecticide is contributed by the specific response of C. arecae and hence to a limited extent the technique exerted a selective control of the pest, probably saving some of its natural enemies too (this aspect could not be covered in the investigation in detail).

The efficacy of different treatments against the adults of C. arecae one sachet of 0.2 g ai phorate or 0.06 g ai carbofuran was the lowest and effective dose. Against the nymphs two sachets of 0.2 g ai phorate each or 0.12 g ai carbofuran in one sachet was the least dose giving highest control. During the first eight months no nymphs were observed on the palms treated with

sachets containing phorate granules (Table 19). Negligible number of adult bugs were seen on treated palms. When the effect on the total population of C. arecae was computed all treatments except carbofuran at 0.24 g ai in two sachets came on par and significantly superior to control. With reference to the feeding marks, which gave a cumulative assay of the bug population for a period 30 to 45 days, 0.4 g ai phorate in one or two sachets were found as the best. A single sachet containing 0.2 g ai phorate was found to be less effective. Taking an overall assessment of the different treatments 0.4 g ai phorate in two sachets could be selected as the best treatment for the control of the pest.

The results presented in para 4.6.1 from different angles have established beyond doubt that phorate in sachets would be better for controlling C. arecae than carbofuran. It was noted that carbofuran at higher doses were less effective than the lower dose of the same insecticide and in some observations former came on par with control. This indicated the resurgence effect of the toxicant on C. arecae.

5.6.2. Relative efficacy of phorate granules kept in perforated polythene sachets at the crown and other recommended methods for the control of C. arecae

The results of the field experiment described in para 4.6.1 proved the efficacy of 0.4 g ai phorate/palm kept in

two perforated polythene sachets at the top leaf axil, compared with other recommended methods, for controlling C. arecae on efficacy cum cost basis. The results presented in para 4.6.2 clearly established the placement of phorate filled sachets in the leaf axil reduced the population of adults and nymphs of C. arecae and the extent of damage in terms of feeding marks to the least level. It was closely followed by the direct placement of phorate in leaf axils.

The high levels of mean leaf injury observed under different treatments in the first month after initiating the experiment (Table 25) was due to the involvement of the feeding marks caused on the palms prior to the commencement of the treatment also, in the first count.

On cost basis (Table 26, para 4.6.3) HCH spraying was found to be the cheapest method for controlling C. arecae. But it was least effective among the treatments. On bio-efficacy basis placement of 0.4 g ai phorate in sachet/s in leaf axils or direct application of 0.5 g ai of the granule/palm at the leaf axil were to be chosen. Between the two treatments, placing phorate in sachets worked out cheaper. Obviously the method can be recommended as the most effective and the cheapest. From safety angle also the new technology has to be preferred to the other recommended methods.

The incidence of yellow leaf disease on palms subjected to different treatments also was recorded regularly. The percentage of palms affected by the disease or the intensity of the disease did not have any bearing on the varying levels of pest population left on the palms following the control methods (para 4.6.2). This observation also indicated the lack of any association between YLD symptoms and C. arecae incidence.

5.7. Effect of persistent occurrence of C. arecae on areca palms at early stages of growth

The detailed investigations on the nature and extent of injury caused by C. arecae indicated that apart from the direct damage caused by the feeding of the insect, the biochemical lesions caused by the pest were likely to cause more serious adverse effect on the growth of the palms. The results of the field experiment detailed in para 4.7 showed that the protection from the pest was highly essential at the early stages of the crop growth. Even with a low population of the insect, many of the palms died out in the course of first five years when left unprotected. The growth of the palms as shown by the height and girth of the stem, number of leaves and size of the leaves suffered badly due to the pest incidence. This effect was much worse on non-vigorous palms found in the field.

Since the insect is normally distributed unevenly (Poisson distribution) in time and space older palms could survive the attack with a few of their leaves partially damaged here and there. Fatality may be less in that group. Still the control of the pest is likely to improve the stand and yield of the crop.

5.8. Investigations on the tissues of the salivary apparatus and the haemolymph of C. arecae for MLOs

The etiology of yellow leaf disease of areca palms is still unknown. The discovery of MLOs in the diseased palms and their absence in healthy ones led to the belief that the disease was caused by MLOs. But all attempts to transmit the MLOs to the healthy palms and to produce the symptoms have failed. In this context attempts were being made to screen the areca pests as vectors of the disease. Many Hemipterans were reported as vectors of MLOs on other crops. Obviously the most predominent Hemipteran pest of areca palms, C. arecae was suspected as a vector of the disease.

The present survey on the distribution of the pest and disease, as well as the evidence from the studies on seasonal fluctuations of the pest, failed to give any indication of an association between the yellow leaf disease and C. arecae.

Salivary glands of insects transmitting MLOs were reported to show the bodies under transmission electron microscopes (Raine and Forbes, 1969; Raine and Forbes, 1971). Hence a study of the salivary gland tissue under electron microscope was taken up.

Raine et al. (1976) reported that the MLOs in Macrosteles fascifrons (Stal) was confined to the type III, IV and V acini of posterior lobe of the salivary gland of the insect only. In M. fascifrons the salivary gland consisted of one posterior and one anterior lobe only while in C. arecae (Fig. 8) two lateral lobes were present. The origin of these lateral lobes were not definitely known. Some attributed such diverticula to the anterior lobe (Miles, 1967) while others considered them as arising from the posterior lobe (Baptist, 1941). To ensure elimination of chances of missing MLOs, if present, all the four lobes of the salivary glands were processed and serially sectioned for E.M. examination. MLOs were not observed in any of the sections. Some bodies showing superficial resemblance to MLOs were seen in some sections. But they were not consistently seen in all the preparations. Probably they were salivary bodies similar to one found in type III acini cells of M. fascifrons (Raine et al., 1976) which were concerned with secretions of saliva. They were not pathogens. Typical MLOs observed in the host tissues were totally lacking.

SUMMARY

SUMMARY

A detailed survey adopting stratified two stage sampling procedure, covering the entire area under areca palms in the State, was done for the first time with a view to assessing the incidence and severity of C. arecae and the yellow leaf disease. The entire cultivated tract except at two locations (Vadakkanchery and Palghat) was seen infested by the pest while 40 per cent of the locations covered in the survey were totally free from the disease. The identification of locations free from C. arecae in Kerala was done for the first time.

The percentage of palms infested by the adults of C. arecae was higher in the southern zone while those infested by nymphs were higher in the northern zone. Percentage of total (adult + nymph) infested palms also were high in southern zone than in the northern zone. Other zones came in intermediate levels of infestation. With reference to feeding marks the reverse trend was seen.

Based on the actual count of the adults of C. arecae the highest level was in southern zone and the remaining zones were on par. The population of nymphs remained high in the northern zone, least in the hill zone and other zones came in between and on par. Based on total population northern and southern zones were on par and hill zone was seen least

affected. With reference to feeding marks southern zone was found least affected while others were almost on par. Thus the results, on different criteria, did not agree consistently.

Within each zone the population of the pest and the extent of damage varied though in many cases the variations were not statistically significant; probably because of the high heterogeneity in the distribution of the insect. In southern zone Pandianpara, Kattakkada and Ettiruthi had high insect incidence while Pangode, Theviyode and Vithura were comparatively less affected. Neyattinkara, Thiruvallam and Palode came in an intermediate status.

When the population fluctuations in five locations in the southern zone were observed at monthly intervals during 1987-88 and 1988-89 results did not agree with the above observations. Places found less affected in all Kerala survey were found badly affected in the second assessment and vice versa.

In the problem zone Moncompu, Vytilla, Chengannur were more severely affected by the pest while Karthikapally, Kumarakom and Karunagapally were less affected and Vaikom, Mavelikkara and Aevoor north were in an intermediate position.

In the middle zone Alwaye, Pattikkad, Peechy were more affected, Vadakkanchery and Palghat were unaffected and

Mukundapuram was less affected. Chalakkudy, Peechy and Mannarghat came in intermediate level of infestation.

In the hill zone, Peringamala, Vythiri and Ernadu had high infestation, Vaduvanchal and Kottapady low level infestation while Chitara, Kulathupuzha and Tenmala came in between.

In the northern zone, Calicut, Taliparamba, Madhur, Koipady were more affected while Kumbla, Tellichery and Koothuparamba had least population while Irrikkur and Neerchalu came in between. Though different locations could be identified with less infestation of C. arecae results of repeated assessment at some of location had indicated the undependability of a single survey. Hence control measures planned against the pest would be desirable throughout the State.

The survey had shown that at Irrikkur near Cannanore, the yellow leaf diseas has taken root recently with reference to the percentage of affected palms and the disease indices. Apart from this the findings agreed with the findings in an earlier survey. In general the disease was severe in the southern districts and it declined towards the north.

No remarkable association between C. arecae incidence and yellow leaf disease was observed in the data obtained

from five different zones in Kerala. Many locations with high pest incidence were either free from the disease or had mild incidence of the disease, while in some locations pest and disease incidence were low or high concurrently.

The monthly assessment of the population of C. arecae at five selected centres in the southern zone (two disease affected, two disease free and one with moderate disease incidence) over a period of two years showed the lack of any definite trend in population build up of the pest. It varied from place to place and year to year. Months having peak/low levels of pest incidence could not be identified for rationalising control operations since the population was fluctuating erratically.

The intensity of yellow leaf disease, observed on affected palms at different periods of the year, were not associated with the occurrence and intensity of the pest incidence.

Among the weather factors maximum temperature and minimum relative humidity showed negative and positive associations respectively with the varying population levels of C. arecae. Positive association with rainfall noted at some locations was not confirmatory.

The feeding and development of C. arecae on selected known alternate hosts of the insect, were studied in green house on potted plants. This was done for the first time. C. arecae could breed and thrive as successfully on A. triandra, C. lutescens or Pinanga sp. as on A. catechu though on Pinanga sp. the nymphal duration was slightly prolonged. In field the pest was noted thriving successfully in the nurseries of E. guineensis also. The size of nymphs growing on the alternate hosts were better than those reared on A. catechu except on A. triandra which came inferior. The adaptation of C. arecae on E. guineensis is a threat to the large scale oil palm plantations planned in Kerala.

The feeding behaviour of C. arecae was observed in detail in the laboratory. The insect, as typically reported in other Cimicomorphs, made 'plant surface exploration', 'exploratory probes' and resorted to 'lacerate and flush feeding'. The feeding caused characteristic water soaked feeding marks which sometimes coalesced and extended over the entire leaf lamina of the leaflets and all leaflets in emerging spindle.

The feeding at the top of emerging spindle caused the death of tissues there and suppressed normal emergence of the spindle leaf. If the feeding happened at the lower portions, leaves opened up with normal distal part and unopened lower portions. Along with the choking of spindle secondary

invasion of fungi and saprophytic organisms aggravated the symptoms, sometimes resulting in the death of the palm. Bud rot incidence was seen associated with the damage.

Egg laying of the bug caused serious leaf injury, especially on spindle. This was observed for the first time. Characteristic 'pox mark' injury in the tissues of rachis, capable of obstructing food flow in the leaf, also was noted for the first time.

The histological studies of the leaf lamina, collected at different intervals after the formation of water soaked lesions, revealed that the liquefaction of the mesophyll cells on which the insect fed was through the enzymes in the saliva since the removal of the insect after the formation of the lesions did not stop the plasmolysis of the cells, collapse of cell wall, discolouration of plastids and shrinkage and withering of leaf lamina. The rapid spread of the discoloured zone also suggested enzymatic involvement in the spread of saliva within the cells. In 4 to 5 days the tissues at the lesion got dried up and later got flaked off. Since the lesions were formed irrespective of the imbibing of the liquefied cell content the insect always caused more elaborate damage than that could have been caused by its food requirement.

Histochemical examination of the lesion at the feeding spot of areca leaf showed heavy accumulation of protein in the mesophyll cells which would be surmised as a 'sink source' response of the host tissue. The reaction would have been caused by some biochemical mechanism in the saliva since continued mechanical injury of the cells by stylet was prevented by the removal of the insect, in the study.

Heavy deposition of granular lipids in the epidermal cells and amorphous lipids in the mesophyll cells also were observed at the lesion. No earlier report on such reaction of the host tissues caused by the feeding of Heteropterans is available in literature.

A new technique of protecting areca palms from C. arecae by placing perforated polythene sachets, filled with phorate/carbofuran granule, at the top most leaf axil was developed and the two insecticides were evaluated at different doses through a field experiment. Among varying numbers of sachets and doses of two insecticides phorate was found more effective than carbofuran and two sachets of 0.2 g ai of the toxicant/sachet was found to be the best and the protection persisted up to 8 months after treatment.

Through a second field experiment it was concluded that the placing of two perforated polythene sachets, each

filled with 0.2 g ai phorate was superior to the methods currently recommended for controlling C. arecae, on cost cum efficacy basis. It was ecologically safe also.

A field experiment was conducted in which areca palms were kept protected/unprotected from C. arecae, during the first five years from the time of planting. The results showed that even among vigorous palms the pest caused significant mortality, reduced height and girth of stems, rendered leaves and leaflets shorter. The effect was worse on non-vigorous palms in the experimental plots.

The salivary glands of the adults of C. arecae, exposed to diseased palms for varying periods, ranging from 20 to 33 days for ensuring sufficient acquisition and incubation periods, were dissected out, processed and cut in an ultratome II microtome into sections of 600 to 700 A^{o} thickness. The sections were spread over 200 mesh uncoated copper grids and stained with 2% aqueous uranyl acetate followed by lead citrate. The serial sections of all the lobes of the salivary gland of C. arecae so prepared were examined under Carl Zeiss EM 109 transmission electron microscope. None of the sections showed mycoplasma like bodies. The haemolymph drawn from each insects was also transferred to a carbon coated copper grid and examined

under electron microscope. Mycoplasma like bodies (MLOs) were absent in the haemolymph also. These findings along with the lack of any association between the incidence of YLD and the pest incidence in the field, proved conclusively that C. arecae is not the vector of yellow leaf disease of areca palms caused by the MLO.

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* Original not seen

APPENDICES

APPENDIX I

Proforma used for the survey of spindle bug on areca palm

Month·

Date

(1) Region (2) Location· (3) Total No.of palms observed:

palm no.	yellow leaf disease index (from overleaf)	appx.age of palm	spindle bug population			natural enemies count										Remarks
			adults	nymphs	bite count	spiders 1	2	3	4	ants A	B	C	D	ear-wings	others	

P.T.O.

YLD indices of palms

palm no.	yellowing of lower leaves (Y)					necrosis (N) on outer four leaves					condition of crown (R)	formula: $I = \left[\frac{(Y+N)}{L} + R\right] \times 10$ L = 50% leaves in crown	YLD index
	1	2	3	4	total	1	2	3	4	total			

APPENDIX II

Critical difference (C D) for comparison of mean YLD indices in different months at Palode and Vithura (reference Table 7 & 8)

between months	Palode		Vithura	between months	Palode		Vithura
	1987-88	1988-89	1987-88		1987-88	1988-89	1987-88
May vs Jun	4 747**	6.011	6.356	Aug vs Dec	5 276**	5 708**	5 416**
May vs Jul	4 494	6 011	5 826	Aug vs Jan	5 276**	5 758**	5 247**
May vs Aug	4 953	5 870	5 968	Aug vs Feb	5 071**	5.999**	5 416
May vs Sep	4 747	5 870	5.826	Aug vs Mar	5 166**	5 932**	7 381
May vs Oct	4 747**	5 749**	5 519	Aug vs Apr	5 117**	5 932**	5.968**
May vs Nov	4 747**	5 870**	5.519**	Sep vs Oct	5 024**	5 812**	5.166
May vs Dec	4 810**	5 644**	5 606**	Sep vs Nov	5 024**	5 932	5 166**
May vs Jan	4 810**	5 694**	5 443**	Sep vs Dec	5 084**	5.708**	5 259**
May vs Feb	4 585**	5 938**	5 606	Sep vs Jan	5 084**	5 758**	5 085**
May vs Mar	4 689**	5 870**	7 521	Sep vs Feb	5 871**	5 999**	5 259
May vs Apr	4 635**	5 870**	6 141**	Sep vs Mar	4.969**	5 932**	7 266
Jun vs Jul	4 786**	6 208	6 053	Sep vs Apr	4 918**	5 932**	5 826**
Jun vs Aug	5 219**	6 072**	6 189	Oct vs Nov	5 024	5 812	4 817**
Jun vs Sep	5 024**	6.072**	6 053	Oct vs Dec	5 084**	5 583	4 917**
Jun vs Oct	5 024**	5 955**	5 758	Oct vs Jan	5 084**	5.635	4 731**
Jun vs Nov	5 024**	6 072**	5 758**	Oct vs Feb	4 871**	5.881	4 917
Jun vs Dec	5 084**	5.853**	5 841**	Oct vs Mar	4 969	5.812**	7 022
Jun vs Jan	5 084**	5 902**	5 685**	Oct vs Apr	4 918**	5 812	5 519**
Jun vs Feb	4 871**	6 137**	5 841	Nov vs Dec	5 084**	5 708**	4 917
Jun vs Mar	4 960**	6 072**	7 698	Nov vs Jan	5 084**	5 758	4 731
Jun vs Apr	4 918**	6 072**	6 356**	Nov vs Feb	4 871**	5 999**	4 917**
Jul vs Aug	4 990	6 072	5 643	Nov vs Mar	4 969	5 932**	7 022**
Jul vs Sep	4 786	6 072	5 493	Nov vs Apr	4 918**	5.932**	5 519**
Jul vs Oct	4 786**	5 955**	5 166	Dec vs Jan	5 142**	5 527	4 832
Jul vs Nov	4 786**	6 072**	5.166**	Dec vs Feb	4 932**	5 778	5 014**
Jul vs Dec	4 848**	5 853**	5 259**	Dec vs Mar	5 029**	5 708**	7 091**
Jul vs Jan	4 848**	5 902**	5 085**	Dec vs Apr	4 979	5 708	5 606**
Jul vs Feb	4 625**	6 137**	5 259	Jan vs Feb	4 932**	5 827	4 932**
Jul vs Mar	4 728**	6 072**	7 266	Jan vs Mar	5 029**	5 758**	4 963**
Jul vs Apr	4 675**	6 072**	5 826**	Jan vs Apr	4 979**	5 758	5 443
Aug vs Sep	5 219	5 932	5 643	Feb vs Mar	4 814**	5 999	7 091
Aug vs Oct	5 219**	5 812**	5 326	Feb vs Apr	4 762**	5 999	5 606**
Aug vs Nov	5 219**	5 932	5 326**	Mar vs Apr	4 862**	5 932**	7 521**

** significant at 1% level

YLD indices during 1988-89 at Vithura are not significant

DISTRIBUTION OF THE SPINDLE BUG OF ARECANUT *CARVALHOIA ARECAE* MILLER AND CHINA IN KERALA, ITS BIOECOLOGY, SUSPECTED ROLE AS THE VECTOR OF YELLOW LEAF DISEASE AND CONTROL

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THESIS

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ABSTRACT

A state wide survey was conducted in Kerala during 1988 with a view to ascertaining the distribution and severity of incidence of C. arecae and yellow leaf disease on arecanut. The pest enjoyed a state wide distribution while the disease was present only in 40 per cent of the locations covered in the survey. Based on the percentage of the infested palms and on adult population of the insect, the southern zone was found as most affected and the nymphal population was more in the northern zone. Based on total population northern and southern zones came on par. The leaf injury caused by the bug was higher in the northern zone and other zones came on par and less affected. Thus on different criteria the severity of the pest infestation in different agroclimatic zones did not show consistency. Vadakkanchery and Palghat in the middle zone were identified for the first time as the only pest free locations in Kerala.

In southern zone, Pandianpara, Kattakkada and Ettiruthi had high pest incidence while at Theviyode, Vithura and Palode the infestations were found comparatively lower. A consecutive monthly monitoring of the populations in five of the above locations during 1987-89 revealed that places found less affected in the single state wide survey were seen badly affected and vice versa in repeated assessment.

In the problem zone Moncompu, Vytilla and Chengannur were much more affected than Karthikapally, Kumarakom and Karunagapally. In the middle zone, Alwaye, Pattikkad and Peechy were more affected than Vadakkanchery, Palghat and Mukundapuram. In the hill zone Peringamala, Vythiri and Ernadu had much higher population than Vaduvanchal and Kottapady. In northern zone Calicut, Taliparamba, Madhur and Koipady were more infested than Kumbla, Tellichery and Koothuparamba. Since repeated survey over two years reversed the relative position of the locations based on single survey, the latter did not appear conclusive thus suggesting the need for resorting to control measures throughout the state for tackling the pest problem.

A new spot of high incidence of yellow leaf disease in north Kerala was detected at Irrikkur near Cannanore. Incidence of C. arecae and yellow leaf disease did not show any association in different agroclimatic zones in Kerala or among different locations within each zone. Continuous monitoring of the population over 24 months revealed that the occurrence of immature stages and adults overlapped, indicating continuous breeding of the pest. Period of high/low incidence of the pest could not be identified consistently. The occurrence of the symptoms of yellow leaf disease did not coincide with the levels of fluctuating

pest population. Maximum temperature and minimum relative humidity showed negative and positive correlation with the pest population respectively.

C. arecae fed and multiplied on its alternate hosts A. triandra, C. lutescens and Pinanga sp. as favourable as on A. catechu. E. guineensis also was found a suitable host since the immature and adult stages of the pest on the host showed more favourable attributes when compared to those on A. catechu.

The feeding behaviour of the insect relating to the 'plant surface exploration', 'exploratory probes' and 'imbibing food' agreed with the behaviour of other 'Cimicomorphs' described by earlier workers.

The feeding suppressed the emergence of spindle leaf partly or fully depending on the period of occurrence of the damage. Total suppression of spindle leaf emergence even choked further growth of the palm. Injury caused by oviposition was observed in detail for the first time. Characteristic 'pox marks' made on the rachis of the leaf and the internal damage also were noted in detail for the first time.

Histological observations of the leaf along the feeding marks showed that the bug resorted to 'lacerate and flush'

feeding. Formation of water soaked areas soon after stylet insertion, continuance of plasmolysis after the removal of the insect from the feeding spot and later discolourations and collapse of cells indicated that the action of the saliva would have caused the injury. Histochemical studies of the injured leaf lamina showed accumulation of proteins and lipids in the portion. The above host reactions were detected for the first time.

A new technique of warding off C. arecae from the crown of areca palms by keeping phorate/carbofuran granules in perforated polythene sachets, at the leaf axil, was developed and standardised. The technique was evaluated at field level in comparison with the recommended methods of spraying insecticides on the crown or keeping granules directly in leaf axils. On the basis of cost and bioefficacy, the new technique was found far superior to the recommended practices.

Salivary glands of C. arecae, exposed on yellow leaf disease affected palms for 20 to 33 days (ensuring acquisition and incubation periods for MLOs), were excised, processed, stained and examined under electron microscope for locating mycoplasma like organisms in the acini of the anterior, posterior and lateral lobes, if any. The haemolymph

drawn from such insects also was examined under electron microscope. MLOs were absent in all the preparations. This finding in conjunction with the absence of correlations between the pest population and disease incidence ruled out the possibility of the insect being a vector of the disease.