BIO-ECOLOGY AND MANAGEMENT OF PERIANTH INFESTING MEALY BUGS *Dysmicoccus brevipes* (Cockerell) AND *Pseudococcus longispinus* (Targioni-Tozzetti) ON COCONUT

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Dedicated to
My Parents

DECLARATION

I hereby declare that this thesis entitled "**Bioecology and management of perianth infesting mealybugs *Dysmicoccus brevipes* (Cockerell) and *Pseudococcus longispinus* (Targioni-Tozzetti) on coconut**" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar title, of any other university or society.

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CERTIFICATE

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LIST OF ABBREVIATIONS

TPMB	Two tailed perianth mealy bug
B	Bunches
CBM	Coconut button mealy bug
DAR	Days After Release
EC	Equatorial Circumference
G	Gram
ie	That is
MAE	Months After Emergence
MAS	Months After Spraying
PC	Polar Circumference
PMB	Perianth infesting mealy bugs
PPMB	Pink perianth mealy bug
Viz.	Namely
WCT	West Coast Tall

INTRODUCTION

1. INTRODUCTION

The coconut palm, *Cocos nucifera* L. is one of the most important cultivated perennial crops in India. Kerala is the leading coconut growing state in India where coconut play a major role in the economy of the state.

The coconut palm provides copra, oil, fuel, coir, roofing, timber and has a host of other uses. It supplies raw materials to a number of industries and provides employment to lakhs of people. It has also an ubiquitous role in the ethos of the people of Kerala.

In recent times, the productivity of the coconut palm has been adversely affected. Eventhough the maximum area under coconut in India is in Kerala, the nut yield at 33 nuts per palm per annum is lower compared to the neighbouring states of peninsular India. One among the reasons attributed to low yields is the infestation by pests. Of late, pests hitherto regarded as minor have assumed serious proportions and inflict economic damage to coconut.

The evolution of a sucking pest complex comprising of the coconut eriophyid mite. coreid bug and button mealybug were reported by Nair (2000) and Saradamma *et al.* (2000).

The mealybug *Pseudococcus longispinus* Targioni Tozzetti was first reported by Ayyar (1919) on coconut leaves in the Malabar coast. This pest has been observed in the nursery and adult coconut palms by later workers. Another species *Dysmicoccus brevipes* was found on fruit bunches of oil palm. Studies have shown that the pacific coconut mealybugs, *Dysmicoccus* spp. are distributed throughout Southern Asia. These mealybugs are attended to and protected by formicids.

The mealybugs infest the emerging fronds and inflorescence resulting in delayed emergence of the same. The presence of barren bunches with one or two developing nuts with the remaining ones either falling off immaturely or stunted with tightly closed perianths indicate mealybug infestation (Radhakrishnan, 1987). Yield losses to the tune of ten per cent due to coconut mealybug have been reported (CPCRI, 1994).

The control measures recommended against the mealybug involve the use of chemical pesticides. Thiodemeton and carbaryl have been used to control the mealybugs. The application of monocrotophos and dimethoate at 0.25 per cent was recommended by the CPCRI (1994). The Kerala Agricultural University (2002) recommended the use of less residual organophosphorus insecticides against the mealybugs.

However the mealybug problem has received scanty attention compared to other pests like the eriophyid mite. The information on the species composition, bioecology and yield losses caused by mealybugs is limited. Moreover the existing management practices against the mealybugs have to be improved upon. In the light of the above, the present study was envisaged with the following objectives.

1) To study the biology, species composition and symptomatology of the perianth infesting mealybugs, *Dysmicoccus brevipes* and *Pseudococcus longispinus* on coconut.

2) To assess the yield losses in coconut due to mealybug infestation

3) To evolve a suitable management strategy to contain the mealybug.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

India has an annual production of 13 billion nuts accounting for 24.5 per cent of world coconut production (Ramaraju *et al.*, 2000). Kerala is the leading coconut producing state in India contributing to 44.3 per cent of production in the country from 53.4 per cent area (Nair *et al.*, 2000). The coconut palm is prone for infestation to a large number of insect and non-insect pests and total of 547 species of insects and mites are reported (CPCRI, 1979). The pseudococcid mealybugs are one group among the pests of coconut. Of late, the perianth infesting mealybugs are causing substantial reduction in the yield of coconuts in the state of Kerala.

Ayyar (1919) reported the presence of *Pseudococcus longispinus* Targioni-Tozzetti on coconut leaves on the Malabar Coast.

Dakshinamurthy and Giridharan (1976) observed the attack of *P. longispinus* in coconut nursery.

Though the mealybugs were considered initially as minor pests (Mathen *et al.*, 1962), later they were identified as serious pests causing heavy damage (Radhakrishnan, 1987).

2.1 PINK PINEAPPLE MEALYBUG, *Dysmicoccus brevipes* Cockerell (Homoptera: Pseudococcidae)

This mealybug is primarily a pest of pineapple and other bromeliads. However it also infests cacao, oil palm, banana, groundnut, date palm, soybean, mango, sugarcane and coffee (Frolich and Rodewald, 1970). *D. brevipes* is a well known pest of agricultural crops throughout the tropics (Rohrbach and Johnson 2002). Anithakumari *et al.* (2003) reported mealybug as a most important pest of coconut in Trivandrum district causing yield loss.

According to Ben-Dov (1985), *D. brevipes* caused minor damage to date palms in Israel. Mani and Thontadarya (1987) reported *D. brevipes* as a pest of minor importance on grapes in India. Das and Ray (1988) reported the incidence of *D. brevipes* on groundnut in Tripura. According to Dhileepan (1991). *D. brevipes* was recorded on fruit bunches on oil palm plantations and nurseries in India and the incidence ranged from 3.2 to 100.0 percent. Williams (1994) reported distribution of pacific coconut mealybug D. *cocotis* and *D. finitimus* in southern Asia. Mortality in groups of 5-20 trees, was noticed in plantations of *Casuarina equisetifolia* due to the infestation by *D. brevipes* (Ciesla, 1995) in Kenya.

2.1.1 Morphology, Biology and Damage

D. brevipes belongs to the family Pseudococcidae. Adult females are plumpy and convex in body shape with an average life span of about 56 days. Beardsley (1965) reported that male pineapple mealybugs observed from Brazil were approximately 1/25 inch long. Beardsley (1959) reported that *D. brevipes* reproduces non-sexually. According to Ito (1938), *D. brevipes* has three larval stages with the life span averaging 95 days. The larval period averages to about 34 days.

D. brevipes was observed as a major pest of pineapple, causing pineapple wilt disease which reduces the yield by 40 per cent. Damage to host plants is caused by a phytotoxic reaction to the injection of salivary fluids into host plant tissue and thus facilitate for entry of fungi and bacteria (Frolich and Rodewald, 1970).

D. brevipes caused an yield loss of about 25 per cent on groundnut in Tripura (Das and Ray,1988).

2.1.2 Role of Ants

Ants provided the mealybugs shelter, protection from predators and parasites, and keep them clean from detritus that may accumulate in the secreted honey dew and be deleterious to the colony. Three ant species are associated with mealybug populations on pineapple in Hawaii. 1) *Pheidole megacephala* 2) *Iridomyrmex humilis* (Mayr.) and *Solenopsis geminata* (Fab.) (Rohrbach *et al.* 1988., Gonzalez-Hernandez *et al.* 1999).

2.1.3 Role of Climatic Factors on Population

Rainfall was the most important factor, having an adverse effect on the pest population. High infestation levels were associated with low relative humidity and maximum temperature (Santa-Cecila *et al.* 1992).

2.1.4 Management

2.1.4.1 Chemical Control

Das and Ray (1988) reported that aldicarb G at 1kg ai ha^{-1} applied 15 days after sowing followed by a spray of chlorpyriphos at 0.5 kg ai ha^{-1}. was effective against *D. brevipes* on groundnut.

2.1.4.2 Biological Control

Natural enemies reported in Hawaii included parasitoids such as *Aenasius cariocus* Compere, *Aenasius colombiensis* Compere, *Anagyrus ananatis* Gahan, *Euryhopauus propinquus* Kerrich, *Hambletonia pseudococcina* Compere and *Ptomastidae abnormis* (Girault). Predators include *Cryptolaemus montrouzieri* Mulsant, *Lobodiplosis pseudococci* Felt, *Nephus bilucernarius* Mulsant, *Scymnus* (*Pullus*) *unicatus* Sicard and *Scymnus pictus* Gorham. Although many natural enemies of the pineapple mealybugs are present, they exhibit minimal control if protective ants are tending the mealybug colony (Rohrbach *et al.*, 1988).

2.2 LONG TAILED MEALY BUG *Pseudococcus longispinus* Targioni-Tozzetti (Homoptera: Pseudococcidae)

The long tailed mealybug *P. longispinus*, is widespread throughout the world. It is found indoors in the warmer parts of America, Europe and

Africa. In northern latitudes, it occurs in greenhouses (Mc Kenzie, 1967). First collected in Hawaii before 1900, it was present in the six major islands (Zimmerman 1948 and Hawaiian Terrestrial Arthropod checklist, 1992).

The long tailed mealybug has a wide host range, including air plant, asparagus, avocado, banyan, begonia, betel nut, caladium, coconut and other palms, coffee, citrus, cycads, dracaena, gardenia, floral ginger, guava, heliconia, hibiscus, kamani, lilies, macadamia, mango, orchids, philodendron, pigeon pea, pineapple and other bromeliads, potato, sugarcane and soybeans (Zimmerman, 1948, Mc Kenzie, 1967, Furness 1976, Heu, 1990).

Koya *et al.*, 1996 reported *P. longispinus* on black pepper (*Piper nigrum* Linnaeus).

2.2.1 Morphology, Biology and Damage

P. longispinus belongs to the family Pseudococcidae. The adult female is about three mm long, oval and wingless. Females live for two to three months. The male is a tiny, winged creature, necessary for reproduction but living only a few days (Metcalf and Flint, 1939).

James (1937) reported the occurrence of three nymphal stages in the female and two nymphal plus one prepupal and one pupal instar in males as a common feature of pseudococcid mealybugs. All life stages of the female feed, as well as the male nymphs. Pupating and adult males do not feed.

According to Mc Kenzie (1967), long tailed mealybugs do not produce an egg sac. The eggs may hatch as soon as they are laid. A range of 20 to 240 eggs have been observed per female under laboratory condition.

Dakshinamurthy and Giridharan (1976) reported that adults and nymphs congregated in large numbers and desapped the unopened leaves of the young coconut seedlings.

According to Radhakrishnan (1987), severe infestation in coconut seedlings aged two years led to the decay of the bud and ultimate death of the plants. In yielding palms, presence of barren bunches with one or two developing nuts with the remaining ones either falling off immaturely or seen stunted with tightly closed perianths is the visual symptom of infestation.

Mealy bugs feed by inserting their slender mouth parts into plant tissues and sucking the sap. Plant parts may be spotted, curled, or wilted (Metcalf and Flint, 1939).

Hamlen (1975) reported that infestation reduced the vigour and growth of foliage plants, which affected the beauty and marketability of the plant.

Healthy trees with severe infestation of mealybugs have even five barren bunches in their crown (Radhakrishnan, 1987). CPCRI (1994) recorded an average annual yield of 42.4 nuts palm^{-1} in mealybug affected palms as against 46.4 nuts palm^{-1} in healthy ones and on an average, 25.9 per cent of coconut bunches were infested with mealybugs.

2.2.2 Role of Ants

Radhakrishnan (1987) reported ants as carriers of mealybugs. Three species of ants *viz.*, *Oecophylla smaragdina*, *Technomyrmex* sp. and *Solenopsis geminata* were symbionts on mealybugs (CPCRI, 1994).

Sumalde and Calilung (1982) reported the association of *Cerataphis palmae* with mealybugs and ants, of which one species (*O. smaragdina*) sewed coconut leaves together to make shelters for themselves and for *C. palmae*.

Ant attendance was indispensable to the persistence of the mealybug populations and ants nurtured mealybug populations (Itioka and Inone, 1996a and Conway, 1997).

Sugonyaev (1996) reported that ants nesting on living plants in the tropics served as refuges for soft scale insects (Homoptera : Coccidae), protecting them from attacks of Chalcidoid parasites. Ant attendance caused decrease in percentage of parasitism and an increase in the growth rate of the host populations in red wax scale insect *Ceroplastes rubens* (Itioka and Inone, 1996b). There existed a mutualistic relationship between the ant *Dolichoderus thoracicus* and the Pseudococcid, *Cataenococcus hispidus* (Ho and Khoo, 1977). Malsch *et al.* (2001) reported transfer of subterranean mealybugs (Hemiptera : Pseudococcidae) by *Pseudolasius* spp. (Hymenoptera : Formicidae) during colony fission.

2.2.3 Role of Climatic Factors on Population

Dakshinamurthy and Giridharan (1976) reported that the infestation was severe during the months of March and April. The pest population was present in the crown throughout the year but low during the rainy months (Radhakrishnan, 1987). Population build-up of mealybugs on coconut started from November after the rains, reaching its peak in February and this level continued till onset of monsoon in May-June. The lowest population was recorded during July-August (CPCRI, 1994).

2.2.4 Management

2.2.4.1 Chemical Control

The prime method of control of mealybug is by the application of chemical pesticides. Soil application of thiodemeton (disystox) 0.5 g.a.i. plant^{-1} and methyldemeton (metasystox) 0.05 per cent controlled *P. longispinus* infesting coconut seedlings (Dakshinamurthy and Giridharan

1976). Furadan 3 G @ 1-2 g/plant was effective in reducing the population of pseudococcids in oil palm nursery (Nantwi *et al.*, 1985). One spraying with dimethoate could check the pest in the inflorescence only for a short period of 30 days (Radhakrishnan, 1987). According to John (1988), repeated spraying of carbaryl 0.2 per cent at two to three weeks interval on the heart leaves, spathe, buttons and nuts would be effective against mealybugs. Cent per cent mortality of adult females of *Palmicultor* sp. was observed when exposed to residues of 0.1 per cent malathion, 0.025 per cent methomyl, 0.025 per cent demeton-o-methyl, 0.04 per cent monocrotophos, 0.03 per cent dimethoate and 0.05 per cent phosphamidon on pieces of coconut leaves in the laboratory (Jalaluddin *et al.*, 1991).

CPCRI (1994) recommended the application of 0.1 per cent dimethoate or monocrotophos for effective control of mealybug. Hu *et al.* (1996) recommended hot water as a potential treatment for root mealybugs.

Verghese (1997) observed maximum mortality of early first instar nymphs of mealybugs with five per cent neem seed extract whereas for late first instar nymphs, the greatest mortality was with nine ppm azadirachtin. Mourier (1997) reported that three applications of neem kernel water extract in different concentrations at weekly intervals protected cassava against mealybugs.

According to Mc Connell and Short (1999), application of disulfoton and aldoxycarb incorporated at one per cent in individual 6 g fertilizer on spikes could control *P. longispinus* on dieffenbachia whereas on cordyline, *P. longispinus* was eliminated by carbofuran, disulfoton and aldoxycarb at double application rates. Karunanithi *et al.* (2002) recommended spraying of 1.5 ml. monocrotophos or four ml. of methyl demeton in one litre of water along with adhesive material for effective control of sucking pests of coconut.

2.2.4.2 Biological Control

A number of natural enemies of mealybugs have been reported.

Population resurgence after insecticide spraying in Australia end up with that natural enemies are an important control factor for mealybugs. The encyrtid wasp, *Anagyrus fusciventris* Girault parasitized long tailed mealybug in Australia (Furness, 1976 and Blumberg *et al*. 2001). This parasite was present in Hawaii on the six main islands (Hawaiian Terrestrial Arthropod checklist 1992).

Alaptus ramakrishnai, a parasitic hymenopteran was reared from mealybugs on coconut in Madras (Mani, 1942). The coccinellid beetle, *C. montrouzieri* fed on long tailed mealybug in California and Hawaii (Fullaway and Krauss, 1945 and Furness, 1976). The lacewing, *Sympherobius barberi* (Banks) consumed long tailed mealybugs in Hawaii (Zimmerman, 1948 and Hawaiian Terrestrial Arthropod checklist, 1992). The entomophthoraceous fungus, *Neozygites fumosa* (Speare) parasitized the cassava mealybug, *Phenacoccus manihoti* (Homoptera : Pseudococcidae), in the People's Republic of the Congo (Ru *et al*., 1985). Swirski *et al*. (1988) reported release of the encyrtids *Hungariella peregrina* and *Anagyrus fusciventris* had controlled the outbreaks of *P. longispinus* in the avocado orchards of Israel. According to Gordon and Hilburn (1990), adults and larvae of the coccinellid *Decadiomus hughesi*, preyed on *P. longispinus*.

Commonly occurring predators *Pullus* sp. (Coccinellidae) and *Spalgis* sp. (Lycaenidae) were observed feeding on coconut mealybug. The newly recorded natural enemies of coconut mealybug includes *Scymnus* sp. (Coccinellidae), *Berginus maindroni* Grouvelle (Mycetophazidae), *Dicrodiplosis* sp. (Cecidomycidae), *Cacoxenus* sp. (Drosophilidae) and *Homalotylus oculatus* Girault (Encyrtidae) (CPCRI, 1994).

Van Baarren *et al.* (1996) reported *Epidinocarsis lopezi* (De Santis) and *Leptomastix dactylopii* (Howard) as parasitoids of pseudococcid mealybugs.

2.3 OTHER MEALYBUGS INFESTING COCONUT

Williams (1981) reported *Palmicultor palmarum* infesting coconut in Micronesia, Hawaii and Bahamas. *D. finitimus* was distributed in the countries of Southern Asia (Williams, 1994).

A mealybug species of the genus *Rhizoecus* was found infesting roots of coconut in the sandy tracts of Thiruvananthapuram district (Nair *et al.*, 1980). Two species of mealybugs, *P. palmarum* affecting spindle and *P. cocotis* affecting spathe were found in the coconut growing tracts of Kerala (CPCRI, 1994).

The species *P. palmarum* was described by Ehrhorn (1916) on coconut from Hawaii. Ayyar (1919) reported *P. cocotis* on coconut leaves in the Malabar Coast. Kanagaratnam *et al.* (1977) reported *Pseudococcus citriculus* Green on coconut in Sri Lanka. *Palmicultor* sp. and *P. citriculus* were observed on coconut in India by Jalaluddin and Mohanasundaram (1989).

2.4 OTHER IMPORTANT BUTTON INFESTING ARTHROPODS

2.4.1 Coccids

A hard scale, *Lepidosaphes mcgregori* Banks (Diaspididae) was observed as a minor pest of coconut (Nair, 1978). According to Jalaluddin and Mohanasundaram (1989) *Aspidiotus destructor* Sign and *Pseudaulacaspis* sp., infested the nuts in Tamil Nadu.

2.4.2 Mites

Coconut eriophyid mite *Aceria guerreronis* Keifer was first reported as a pest of coconut from the west coast of Mexico in the state of Guerrero in 1960

(Cartujano. 1963) and was first described by Keifer (1965). Mohanasundaram and Karuppuchamy (1989) reported *Colomerus novahebridensis* Keifer from the underside bracts of coconut buttons.

Other mites recorded on coconut palms were *Brevipalpus phoenicis* Geijkes on nuts (Chandra and Channabasavanna, 1976) and *.Tetranychus fijiensis* and *Amensosius* sp. infesting flowers (Nair, 1978) .

Sathiamma (1985) reported the incidence of *Dolichotetranychus vandergooti* Oudemans as a perianth mite of coconut. The mite damage under the perinath resulted in discolouration of the buttons and nuts.

2.4.3 Coreid Bugs

Lever (1969) reported the coreid bugs *Amblypelta cocophaga* China, *A. lutescens* Distant and *Pseudotheraptus wayi* Brown as serious pests of coconut in the Solomon Islands, Papua New Guinea and East Africa, respectively. In India, the coreid bug *Paradasynus rostratus* Distant was first reported as a pest of coconut from Alleppey district of Kerala (Kurien *et al.*, 1972).

MATERIALS AND METHODS

3. MATERIALS AND METHODS

3.1 EXPERIMENT 1 : BIOLOGY OF PERIANTH - INFESTING MEALYBUGS UNDER LABORATORY CONDITIONS

Biology of perianth infesting mealybugs *Dysmicoccus brevipes* and *Pseudococcus longispinus* was studied under laboratory condition during September-December, 2001.

3.1.1 Studies on Species Composition of PMB

Species composition of the mealybug colonies in the infested buttons and immature nuts studied after preserving in 80 per cent ethyl alcohol. Based on morphological characters, the specimens were grouped and sent for identification.

3.1.2 Evaluation of Different Host Materials to Culture PMBs

3.1.2.1 Pumpkin

The mealybugs were reared in bulk on ripe pumpkins. Ripe pumpkins without any injury on the surface were selected. These pumpkins were dipped in a solution of five per cent formaldehyde for five minutes and then dried in the sun. The pumpkins were then placed in a sterilized circular glass troughs. The glass troughs contained a steel stand over which the pumpkin was placed.

Gravid females of the mealybugs collected from affected buttons from field were liberated on these pumpkins and distributed in different areas of their surface. Separate pumpkins were used for rearing the two species. Troughs with the pumpkins were kept in a cool shaded place in the laboratory. Once in a week, these pumpkins bearing the culture were exposed to the sun for drying up of the honeydew secreted by the bugs and also to prevent fungal growth. The females were removed from the host surface with a camel hair brush leaving only the crawlers.

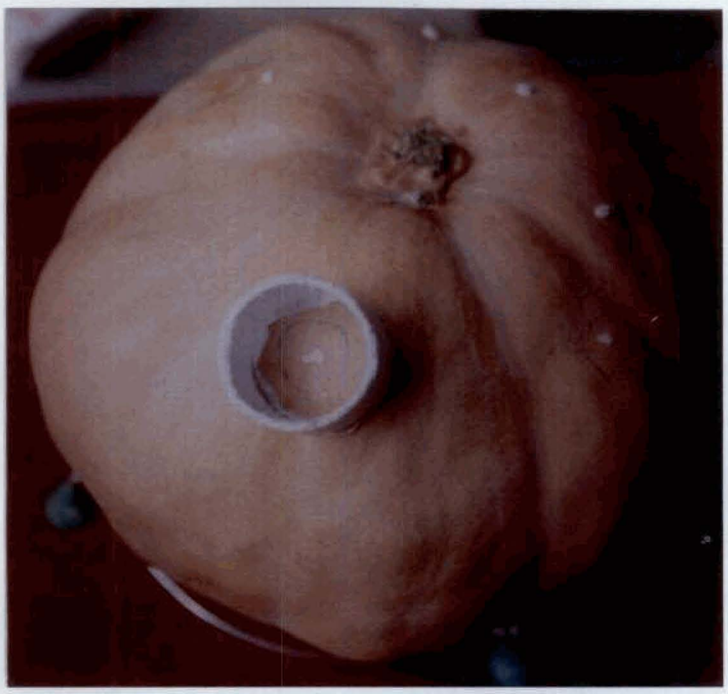
These crawlers got established on the host surfaces within two days. The time taken for the crawlers to become adult male or female was observed. On the pumpkin surface crawlers were confined in groups of 10 each by releasing them within cut PVC ring (2.5 x 2.5 cm) pasted on the surface of the pumpkin (Plate 1). Muslin cloth sleeves were used to cover these tubes with crawlers. Observations were recorded daily on developmental durations.

Fecundity studies were made by examination of the total number of crawlers given birth by gravid females. For this, the gravid females were kept in specimen tubes and the number of crawlers emerging each day was counted. Sex ratio was determined by observing the development of 100 crawlers in four lots. The morphology of different stages of the mealybug was studied by preparing temporary mounts of the insect in glycerine as well as by dissolving the waxy covering of the body in Essig's Aphid Fluid mixture.

3.1.2.2 Uninfested Buttons

Mealybug free buttons from the first to fifth bunch was excised along with rachis and fed with 10 per cent sucrose solution kept in plastic vials. An iron frame was fabricated to support the vials containing excised nuts in upright position (Plate 2). The vials were kept on the iron frame and ant wells were provided around the four legs to prevent invasion of ants. To one set of such buttons, five gravid female mealybugs were released. To another set of such buttons, five crawlers each were released. Observations were recorded at 15 days interval on developmental durations.

Plate 1 Pumpkin fruit (ridged variety) with PVC ring (2.5 x 2.5 cm) fixed to confine gravid females of *P. longispinus*



3.1.2.3 Potato Sprouts

Mealy bug cultures were also maintained on sprouted potato tubers. Healthy potato tubers with dormant buds were kept immersed in water for 24 hours. These tubers were then kept on a layer of sand in cylindrical glass jars. The tubers sprouted in a week's time. Gravid female bugs were then released on the potato sprouts using a camel hairbrush. To study the life history of the mealybug, gravid females were put on sprouted potato. On the following day, the gravid females were removed from the host surface leaving only the crawlers.

3.1.2.4 Excised Tepals

Attempts were also made to rear the mealybugs on tender tepals of coconut buttons and on tender coconut buttons in the laboratory. For this, tender and succulent tepals were taken from first to fifth bunch nuts. Inner tepals free from insects and mites were used for this purpose. Moist cotton was used as a cap on the tepals to keep the tepals fresh.

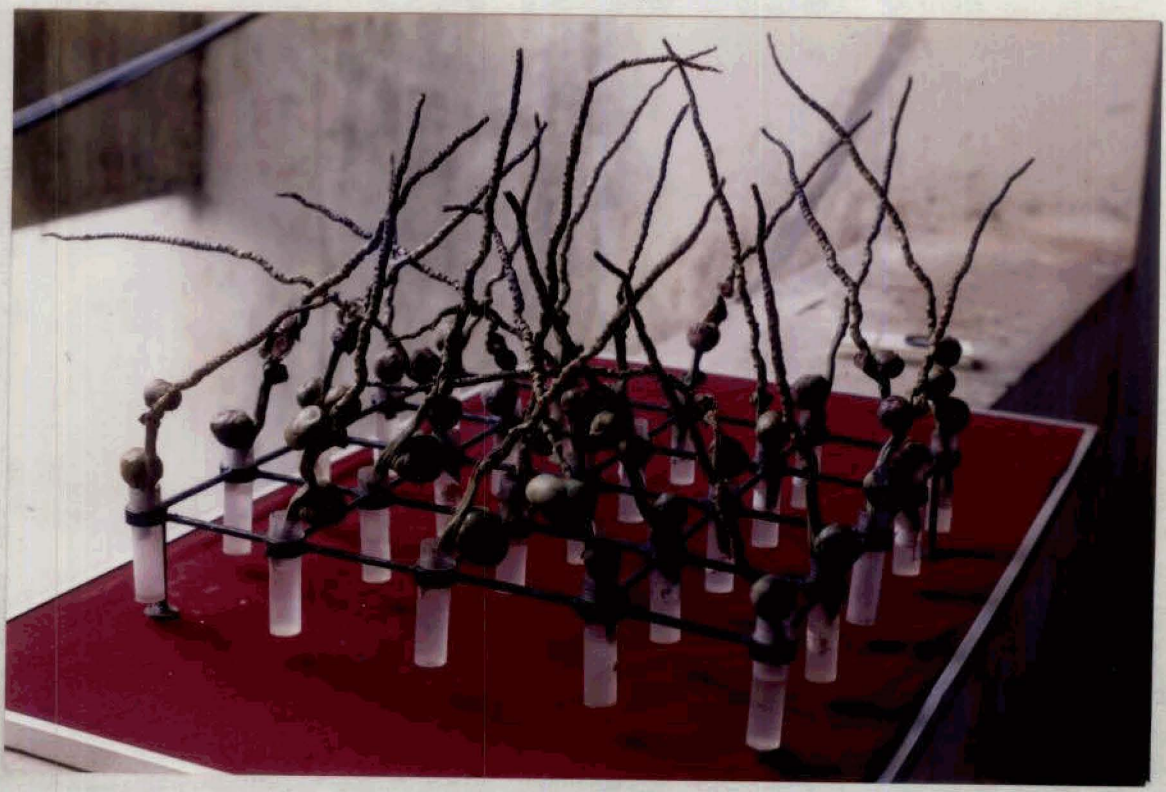
Gravid female mealybugs were placed singly on the inner side of the tepals by using a camel hair brush. On the following day, the gravid females were removed from the host surface. Also tepals excised from infested nutlets which harboured gravid females were used for this purpose (Plate 3).

3.2 EXPERIMENT II : STUDIES ON YIELD LOSSES DUE TO PMBS IN PALMS HAVING DIFFERENT DEGREES OF DAMAGE

3.2.1 Preliminary Evaluation of Coconut Palms (WCT) for Identification of Low, Moderate and High Incidence of Mealybugs

The experiment was conducted in B and D blocks of the Instructional Farm, Vellayani. Sixty coconut palms of the variety (WCT) in the Instructional Farm, Vellayani receiving fertilizers and manures as per Kerala Agricultural University recommendations (KAU, 2002) were selected.

Plate 2 Vials (containing excised nuts) kept in upright position on fabricated iron frame



Twenty palms each in high, moderate and low susceptible category were randomly selected for the preliminary evaluation to identify highly susceptible, moderately susceptible and low susceptible palms. Observations were made from two successive harvests during August and October 2000. Harvested huts were classified according to visible surface damage.

Based on percentage of nuts damaged, the selected palms were classified as low susceptible, moderately susceptible and highly susceptible. Five palms were selected for each category. These selected palms were used for further studies.

3.2.2 Assessment of Yield Losses in Coconut Due to Mealy bug Infestation

From the total numbers of damaged and undamaged buttons in each bunch (from 1-10th), the percentage damage to nuts by mealybugs in each month was calculated. From the percentage damage in the tenth bunch, yield loss/annum was calculated for the three categories. This experiment was also done on the palms selected under Experiment 3.2.1 for a period of one year. Damage was correlated with age and month of emergence of bunches. Ten successively emerged bunches were tagged at the male phase of the inflorescence as described under 3.2.3.1 and the week of bunch emergence was recorded to understand the correct age of each bunch as on the date of observation.

3.2.3 Study of Population Dynamics of Coconut Mealybugs in Low, Moderate and High Susceptible Palms

Population dynamics of mealybugs in buttons and immature nuts of coconut for one year was studied in the palms which were selected from Experiment 3.2.1.

Plate 3 Tepals (excised from infested nutlets) used for studying the biology of *D. brevipes*

In order to study the population dynamics, it was necessary to know the age and pattern of bunch production.

3.2.3.1 Arrangement of Young Bunches in the Crown

Arrangement of the youngest ten bunches were studied. The first (youngest) to tenth bunches were labelled in the sequence of flowering (in reverse order) in such a way that the last opened one was considered as the first bunch, the just previous inflorescence at 120^0 around the crown as the second bunch and so on. The third and fourth bunches were on either side of the first bunch. The fifth bunch was opposite to the first bunch on the other side of the crown and sixth one was always vertically below the first bunch and so on. Arrangement of young coconut bunches (1 to 10) in a coconut crown is diagrammatically represented in Fig. 1. Labels (3 x 3 cm) made of 'Sun pac' board were tied to the bunch stalk with plastic tape during October 2000.

3.2.3.2 Sampling and Assessment of Population

One nut each representing the ten bunches was sampled every month. Both damaged and healthy nuts were sampled from each bunch. The total number of damaged and undamaged nuts in each bunch was also recorded. During the next month, sampling was done from the then first, to the tenth bunch. Normally a new inflorescence emerged (opened) within a period of 20-25 days and therefore the bunch number as first in January became second in February, third in March and so on. Immediately after sampling, the nuts were brought to the laboratory for further examination.

In each month, damaged and undamaged nuts were sampled separately. Population of mealybugs under each tepal was counted immediately after removing the tepals very carefully using forceps. For counting population of crawlers, tepals were placed under the compound microscope. The total count of mealybugs in each button was taken.

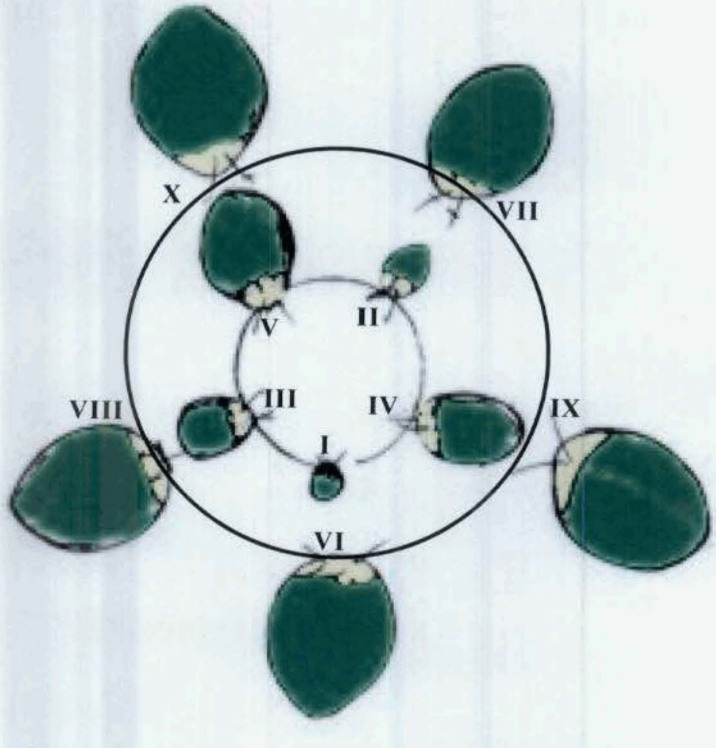


Fig. 1 Diagramatic representation of arrangement of young coconut bunches (1-10) in a coconut crown

Total population per nut was worked out by adding the population in all the colonies on a nut. The palms selected under Experiment 3.2.1 representing low, moderate and high susceptible palms were observed every month for a period of one year from January 2001 onwards.

3.2.4 Spatial and Temporal Distribution of Mealybugs

Spatial and temporal distribution of the two species of PMBs were studied. The nuts representing one to 10 bunches occupying different positions in the crown were observed at monthly intervals for one year. This experiment was also done on the palms selected under Experiment 3.2.1.

3.2.5 Investigation on the Development of Damage Symptoms as a Consequence of Feeding Injury by PMBs

Symptom of mealybug damage in nuts of 1-10th bunches were studied for one year. Different types of symptoms were categorized based on the susceptibility of the palm and described.

3.2.5.1 Stunting

The extent of stunting of nuts of 1-10 month old bunches coming under each damage category of palms was recorded for one year.

3.2.5.1.1 Length of Nut (Polar Circumference)

Length of both damaged and undamaged nut from calyx end to other end through curved surface of nuts coming under each category was measured using a thread and a scale. This was referred to as the polar circumference of the nuts.

3.2.5.1.2 Equatorial Circumference of Nut

Equatorial circumference of both damaged and undamaged nuts coming under each category was measured using a twine and scale along the equatorial plane of the nuts.

3.2.5.1.3 Fresh Weight of Unhusked Coconut

Weights of both damaged and undamaged unhusked nuts were taken by using a pan balance and expressed in 'g'.

3.2.5.2 Deformities or Malformation on Coconut Buttons as a Consequence of Feeding by PMBs

Different types of deformities in the infested buttons and nuts were studied and the malformations were recorded from the selected palms.

3.2.6 Population Buildup of Different Species of Perianth Infesting Arthropods

Population of other arthropods such as mites, ants, stem weevil and scales, inside perianth of infested nuts as either primary or secondary cause of damage was also recorded as described under item 3.2.3.2 and the mean population in ten nuts representing 10 bunches over a period of 12 months was observed.

3.2.7 Population Buildup as Influenced by Morphological Characteristics

3.2.7.1 Relation between Number of Female Flowers / Spikelet and Susceptibility to PMBs

3.2.7.1.1 Mean Number of Female Flowers / Spikelet

The number of female flowers per spikelets was counted in the tagged bunches just after the male phase is over and in the succeeding 12 months. The mean number of female flowers per spikelet in a set of third to eight bunches as on the date of observation was calculated for 12 months.

3.2.7.1.2 Mean Number of Fertilized Female Flowers / Spikelet in 4 (7-10) Bunches Observed at Maturity

The number of nuts in 7-10 bunches of the selected palms for one year was counted and the mean number of healthy nuts retained per spikelets was calculated for one year.

3.2.7.2 Influence of Bract Arrangement

Type of tepal arrangement in each damage category of palm was studied by carefully removing the individual tepals using forceps.

3.2.7.3 Influence of Tepal Colour on Mealybug Population

The colour preference of mealybugs in terms of tepal colour was studied in mealybug free buttons with varying tepal colour from first to fifth bunch. Gravid females were released and observations on progeny production were recorded at 15 days interval.

3.2.8 Role of Ants in Dispersal of PMBs

The species of ants associated with PMBs were identified in the low, moderate and highly infested category of palms selected under Experiment 3.2.1.

3.3 EXPERIMENT III : EVALUATION OF SELECTED INSECTICIDES FOR THE MANAGEMENT OF PMBs

3.3.1 Laboratory Evaluation

3.3.1.1 Mortality of Mealybugs on Excised Undamaged Buttons Collected from 2nd, 3rd and 4th Bunches of Highly Damaged Category of Palms

Healthy buttons were collected from second to fourth bunches. They were excised along with the rachis and fed with 10 per cent sucrose solution kept in plastic vials as described under item 3.1.2.2. Insecticides were sprayed at the recommended doses, using an atomizer. The spray fluid on nut surface was allowed to dry for a few minutes. Five mealybugs were released on each sprayed button using camel hair brush.

Ten replications were maintained for each treatment. Out of the ten replications under each age group, five replicates were observed at 24 hrs after spraying and the remaining five at 48 hrs after spraying, as destructive sampling was necessary to observe mortality. From the observations, mean mortality percentage was calculated.

3.3.2 Evaluation of Selected Insecticides for the Management of PMB

3.3.2.1 Layout of the Experiment

Forty five highly infested palms of var. WCT having more or less uniform infestation of the mealybugs were selected in the Instructional Farm, Vellayani for conduct of the experiment. Each palm was labelled indicating treatments given and the youngest five bunches were tagged as described under item 3.2.3.1. The experiment was laid out in completely randomised design (CRD) with nine treatments replicated five times.

The treatments were :

Triazophos	:	0.05%
Quinalphos	:	0.05%
Endosulfan	:	0.05%
Chlorpyriphos	:	0.05%
Profenophos	:	0.05%
Azadirachtin	:	3ml/l
Diafenthuron	:	0.05%
Dimethoate	:	0.05%

3.3.2.2 Spraying of Insecticides

The insecticides were prepared at the required concentration. Ten litres of spray fluid were prepared for each treatment.

The pesticides were sprayed targetting the first five bunches including the just opened one so that spray fluid fell on the unopened spadices also. Two litres of spray fluid were used for each palm. Spraying was done using a rocker sprayer. The spray fluid was directed towards the perianth portion of the nuts using cone nozzle from the crown.

Spraying was done upto the point of complete wetting of the buttons. before the onset of run off.

3.3.2.3 Assessment of Damage in the Sprayed Bunches

The youngest five bunches in the most critical stage as on the date of spray were observed at four months after spraying. Number of total and damaged nuts in each bunch was recorded and the per cent reduction in damage over corresponding control (bunches of the respective age) was calculated. Similar observations were also recorded in the next set of five successively emerged bunches at six months after spray which were at different stages of spadix development on the date of spray. Mean per cent reduction was calculated using the formula :

$$\frac{\text{Per cent damage in control palm} - \text{Per cent damage in treatment palm}}{\text{Per cent damage in control palm}}$$

3.3.2.4 Statistical Analysis

All the values were analysed using CRD. The data were tabulated and subjected to statistical analysis.

RESULTS

4. RESULTS

4.1 EXPERIMENT I : BIOECOLOGY OF PERIANTH - INFESTING MEALYBUGS (PMB)

4.1.1 Species Composition of PMBs

Studies on the species composition of mealybugs collected from infested buttons and nuts revealed the occurrence of two species of mealybugs. These species were identified by Dr. B.K. Rajagopal, Department of Agricultural Entomology, UAS, Bangalore. They were :

1. *Dysmicoccus brevipes* (Cockerell)
2. *Pseudococcus longispinus* (Targioni-Tozzetti)

Other two species of mealybugs *viz.*, *Palmicultor palmarum* Ehron and *Pseudococcus cocotis* Maskell which were previously recorded from coconut inflorescences and buttons in South India were not observed during the course of the present study. Among the two species recorded, *D. brevipes* could be easily identified by its pink colour and *P. longispinus* could be identified by the two characteristic long tail like filaments. For easy reference, two common names are being proposed to describe the species *viz.*, Pink Perianth Mealy Bug and Two tailed Perianth Mealy Bug that may be abbreviated as PPMB and TPMB respectively.

4.1.2 Biology of PMBs When Reared on Pumpkin Fruits

4.1.2.1 Biology of PPMB on Pumpkin

Since both the species of perianth mealybugs inhabit the inner surface of tepal, biology could not be studied on infested buttons without removal of tepals for taking observations. As it would interfere with colonization and development of the mealybugs, the bioecology of the two species was studied after rearing them on pumpkin fruits. *D. brevipes* preferred colonization around fruit stalk of pumpkin fruits (Plate 4a) and the red ant species (*Anoplolepis longipes*) was also found associated with *D. brevipes* (Plate 4b) in the laboratory.

The most important feature in the biology of PPMB was that it did not lay eggs at all. Instead they were ovoviviparous. The eggs hatched within the female body and she gave birth to larvae. Larvae, called "crawlers" are the primary dispersal stage of the mealybug. They remain protected underneath the mother's body for a short time before developing a waxy covering. The crawlers emerging out from the female bug moved out from underneath the bug and settled around it within 24 hours of their emergence. After settling on the host, they started to feed. Sometimes they moved out again to new areas on the host material. They showed the habit of congregation. The fecundity and larvi position period of *D. brevipes* when reared on pumpkin fruit are given in Table 1.

Table 1. Fecundity and larvi position periods (days) of *D. brevipes* when reared on pumpkin fruits

Sl. No.	Fecundity	Pre larvi position period	Larvi position period	Post larvi position period	Total life cycle
1	284	27	20	61	135
2	207	25	18	66	135
3	101	21	24	55	134
4	256	26	16	57	140
5	148	26	22	53	151
6	196	18	18	65	144
7	237	23	26	58	162
8	116	24	21	60	132
9	90	28	22	53	133
10	74	20	21	59	129
Mean	170.9	24	21	58.7	139.5

Plate 4 (a) Colony of *D. brevipes* around the fruit stalk of pumpkin

Plate 4 (b) Close up view of the colony along with red ant, *Anoplolepis longipes*

Plate 4 (b)

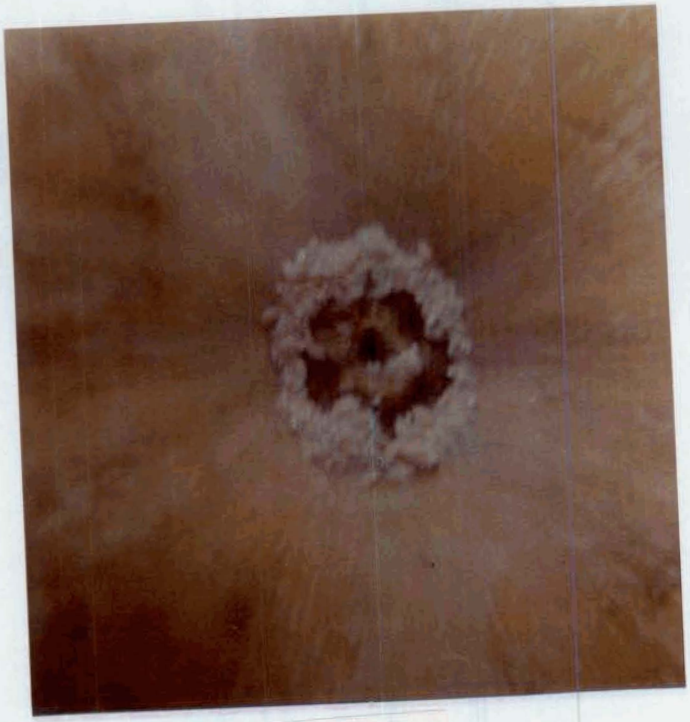


Plate 4 (a)

The observations made on the fecundity showed that in the case of *D. brevipes*, number of larvae laid by the female ranged from 74 to 284 with a mean of 170.9 larvae per female. The adult female of *D. brevipes* had a mean pre larvi position period of 24 days, larvi position period of 21 days, post larvi position period of 58.7 days and total life cycle of 139.5 days (Table 1). Close up view of the gravid females of *D. brevipes* on damaged nutlets is shown in Plate 5.

4.1.2.2 Biology of PPMB on Pumpkin

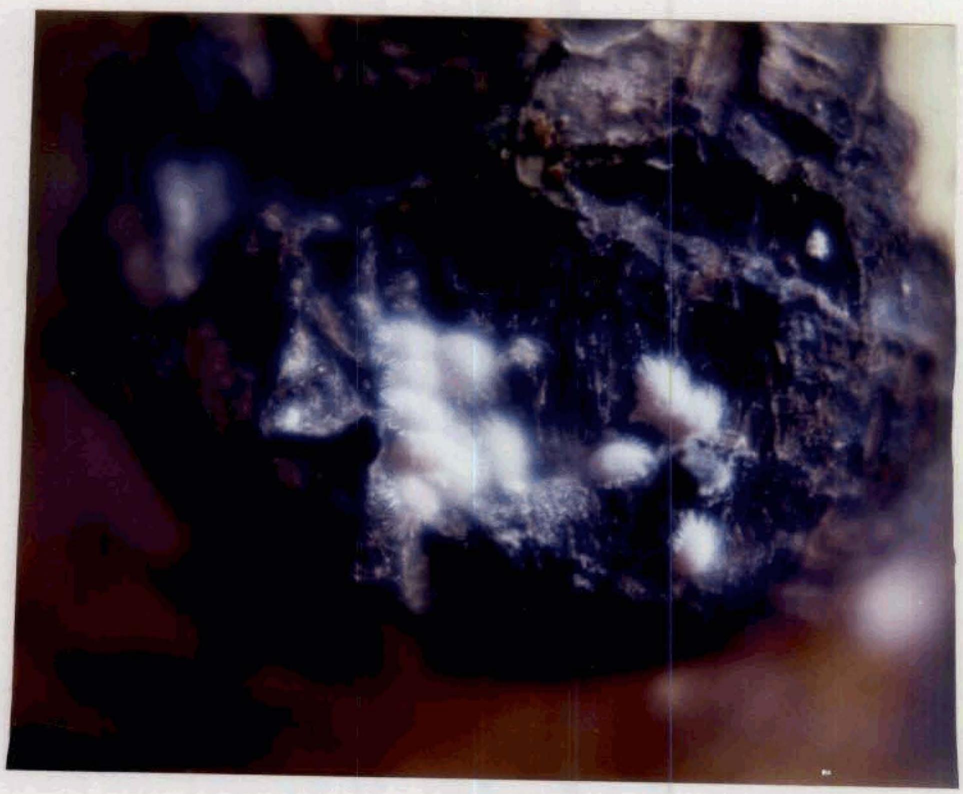
The fecundity and larval position periods of *P. longispinus* when reared on pumpkin fruit are given in Table 2.

Table 2. Fecundity and larvi position periods (days) of *P. longispinus* when reared on pumpkin fruits

Sl. No.	Fecundity (No.)	Pre viviparous period	Viviparous period	Post viviparous period	Total life cycle
1	26	15	10	28	76
2	57	13	8	27	73
3	102	12	12	30	74
4	99	15	14	33	91
5	217	18	20	28	96
6	230	19	18	18	76
7	185	12	12	26	74
8	116	13	11	25	78
9	127	15	18	29	88
10	240	17	19	31	95
Mean	140	15	14	27.5	82.1

In the case of *P. longispinus* the number of eggs laid by females ranged from 26 to 240 eggs with a mean of 140 eggs per female, when reared on pumpkin fruits. The adult female had a mean previviparous period of 15 days, viviparous period of 14 days, post viviparous period of 27.5 days and a total life cycle of 82.1 days (Table 2).

Plate 5 Close up view of the gravid females of *D. brevipes* on damaged nutlets



Females were wingless, but freely mobile, though sluggish. They sought a protected place to lay eggs. All life stages of female were seen feeding on pumpkin fruits. TPMB did not produce an egg sac. The eggs hatched as soon as they were laid, giving the impression that young crawlers were born rather than hatching. Eggs were straw yellow colour at first and their colour deepened towards hatching. The larval duration and adult longevity (days) of female perianth mealybugs, *D. brevipes* and *P. longispinus* when reared on pumpkin are presented in Table 3.

Table 3. Larval duration and adult longevity (days) of female perianth mealybugs *D. brevipes* and *P. longispinus* when reared on pumpkin fruit

Sl. No.	*D. brevipes*		*P. longispinus*	
	Larval duration	Longevity	Larval duration	Longevity
1	27	108	23	53
2	26	109	25	50
3	34	100	20	54
4	41	99	29	62
5	50	101	30	66
6	43	101	21	55
7	55	107	24	50
8	27	105	29	49
9	30	103	26	62
10	29	100	28	67
Mean	36	103.3	26	57

In the case of *D. brevipes*, the larval period ranged from 26 to 55 days in the female with an average of 36 days. The larvae moulted three times before reaching adult stage. The adult female had a mean longevity of 103.3 days. Adult females are plump and convex in body shape and pinkish in body colour. There are 17 pairs of lateral wax filaments. The larval duration of *P. longispinus* when reared on pumpkin fruits ranged from 21 to 30 days with an average of 26 days. The adult female of *P. longispinus* had a mean longevity of 57 days. After hatching, the crawlers left the mother. They were flattened, oval, light yellow, six legged insects with smooth bodies. Soon after beginning to feed, they exuded a white, waxy covering over their bodies, giving them a mealy appearance. The female had gone through three stages to reach adulthood. The female body is oval and covered with waxy filaments. The larval duration, pupal duration and adult longevity of male perianth mealybugs, *D. brevipes* and *P. longispinus* when reared on pumpkin fruits are presented in Table 4.

Table 4. Larval duration, pupal duration and adult longevity (days) of male perianth mealybugs *D. brevipes* and *P. longispinus* when reared on pumpkin fruit

Sl. No.	*D. brevipes*			*P. longispinus*		
	Larval duration	Pupal duration	Longevity	Larval duration	Pupal duration	Longevity
1	20	4	5	18	7	5
2	22	5	4	15	6	8
3	18	3	3	17	5	4
4	24	4	2	14	6	5
5	21	5	3	19	6	4
6	26	4	4	18	5	5
7	19	4	3	18	6	4
8	24	5	4	13	7	4
9	25	4	4	16	8	4
10	21	4	4	15	6	5
Mean	22	4.2	3.6	16	6	5

The mean larval and pupal duration for *D. brevipes* were 22.0 and 4.2 days respectively whereas the adult longevity ranged from two to five with an average of 3.6 days. The male nymphs, when about to pupate moved away from their original feeding point and congregated at a point where they secreted cotton like wax strands (cylindrical) forming a covering. Pupae were formed within the cottony cover. In the case of *P. longispinus*, the mean larval and pupal durations were 16 and six days respectively. Adult longevity of *P. longispinus* ranged from four to eight with an average of five days. The male larvae stop feeding near the end of the second stage and migrated towards a protected place where they secreted waxy cocoons in which they completed their development.

The observations on sex ratio of *D. brevipes* under laboratory conditions are presented in Table 5a. The observations on sex- ratio showed that in a colony of crawlers, an average of 76 per cent developed into females while the remaining ones were males. The mean sex ratio was 3.17.

The observations on sex ratio of *P. longispinus* under laboratory conditions is presented in Table 5b. The sex ratio observations showed that in a colony of crawlers, an average of 78 per cent developed into females while the remaining ones were males (Table 5b) and the mean sex ratio was 3.54.

4.1.3 Biology of Perianth Mealy Bugs after Artificial Inoculation on immature nuts

The data on the number of crawlers settled inside perianth of immature nuts collected from successive bunches are presented in Table 6.

In the case of *D. brevipes*, the number of crawlers settled was more in the nuts collected from 5th bunch after 15 (DAR) and in the nuts collected from 3rd bunch after 30 days whereas for *P. longispinus* the number of crawlers settled was more in the nuts from 4th bunch 15 and 30 DAR.

Table 5a. Sex ratio of *D. brevipes* under laboratory conditions

Sl. No.	No. of nymphs reared and observed	Number of males produced	Number of females produced	Sex ratio
1	25	5	20	4.00
2	25	7	18	2.50
3	25	4	21	5.25
4	25	8	17	2.13
Total	100	24	76	3.17

Table 5b. Sex ratio of *P. longispinus* under laboratory conditions

Sl. No.	No. of nymphs reared and observed	Number of males produced	Number of females produced	Sex ratio
1	25	7	18	2.50
2	25	5	20	4.00
3	25	3	22	7.30
4	25	7	15	2.14
Total	100	22	78	3.54

In the case of *D. brevipes*, progeny production was maximum in the nuts from 4th bunch at 15 DAR and in the nuts from the 3rd bunch at 30 DAR whereas for *P. longispinus* progeny production was maximum in the nuts from 3rd bunch at 15 and 30 DAR.

Table 6. Establishment of crawlers settled inside perianth of immature nuts collected from successively emerged bunches

Successive bunches	Crawlers released				Gravid females released			
	D. brevipes		*P. longispinus*		*D. brevipes*		*P. longispinus*	
	15 DAR	30 DAR	15 DAR	30 DAR	15 DAR	30 DAR	15 DAR	30 DAR
B1	0	0	0	0	0	0	0	0
B2	0	0	1	0	0	0	0	0
B3	2	4	2	1	8	17	8	10
B4	2	3	3	3	12	6	3	3
B5	3	2	1	1	10	3	2	3
B6	0	0	0	0	0	0	0	0

DAR : Days After Release

4.1.4 Effect of Different Hosts on Biology of PPMB and TPMB

The developmental period of PPMB and TPMB on potato sprouts are presented in Table 7a. In the laboratory, *D. brevipes* and *P. longispinus* were reared on two host materials *viz.*, potato sprouts and ripe pumpkins. It was observed that the biology of the bugs varied on these two host materials. On pumpkins, it took on an average of 36 days for completion of larval duration of *D. brevipes*, while on potato sprouts it took 40 days. In the case of *P. longispinus* it was 26 days on pumpkins and 35 days on potato sprouts respectively. The mean fecundities of PPMB and TPMB on potato sprouts were 25 and 18 respectively whereas on pumpkin the fecundities were 170.9 and 140 respectively. The longevity of PPMB and TPMB on potato sprouts were 53 and 50 respectively whereas on pumpkin, the mean longevity was 103.3 and 57 respectively.

Pumpkin appeared to be a better host material as it could be kept upto 75 days without decay and it could support large colonies of the insect during this period with shorter nymphal periods. Potato sprouts, however, could be kept only for about 55 days and multiplication of the insect was less and the size of the progeny was also less compared to pumpkin.

Table 7a. Biology of female *D. brevipes* and *P. longispinus* on potato sprouts

Biology	Mean developmental period (days)	
	D. brevipes	*P. longispinus*
Larval duration	40	35
Fecundity (number)	25	18
Pre larvi position	5	7
Larvi position	5	5
Post larvi position	2	3
Longevity	53	50

4.1.5 Progeny Production of PMB on Tepals Removed from Perianth

Progeny production of PMBs on excised tepals after 30 days is presented in Table 7b.

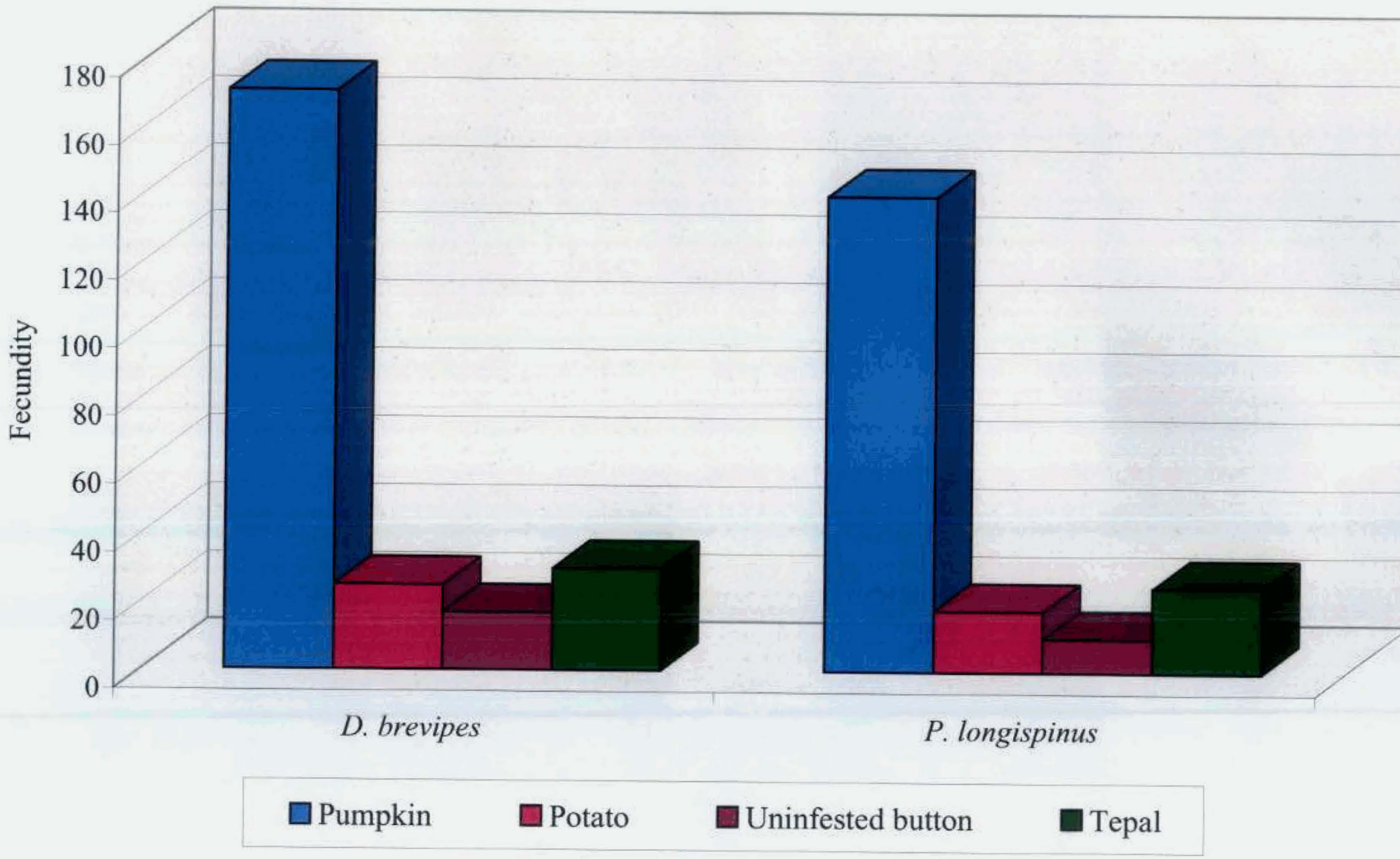


Fig. 2 Fecundity of PMBs on different host materials

Table 7b. Progeny production of PMB on excised tepals

Mean Progeny production	*D. brevipes*	*P. longispinus*
After 30 days	30	25

The mean progeny production of gravid females of *D. brevipes* on excised tepals was 30 and the mean progeny production of gravid females of *P. longispinus* on excised tepals was 25 (Table 7b). Results of the fecundity of PMBs as influenced by different host materials are presented in Fig. 2. Pumpkin appeared to be a better host material for rearing PMBs followed by excised tepals and potato. Uninfested buttons were the least preferred host material.

4.2 EXPERIMENT II : STUDIES ON YIELD LOSSES DUE TO PMBs IN PALMS HAVING DIFFERENT DEGREES OF DAMAGE

4.2.1 Preliminary Evaluation of Coconut Palms (WCT) for Identification of Low, Moderate and High Incidence of MEALYBUGs

Sixty palms of WCT were selected for preliminary evaluation in order to identify at least five palms each under low, moderate and high categories. Observations were made from mature nuts in two harvests from these palms (August and October, 2000). The data on the damage intensity of the nuts are presented in the Table (8,9 and 10).

Within the sixty palms selected, those palms that had less than 26 per cent of damaged nuts in the two harvests were categorized as low susceptible palms. Based on this criteria, the palms B147, B945, B1000, B1015 and B1 (Table 8) were selected as low susceptible palms.

Table 8. Preliminary evaluation of coconut palms (WCT) for identification of low susceptible types in 2000

Sl. No.	Palms	Months of harvest	Percentage of infested nuts in damage category
1	*B 147	August	18
		October	22
2	B 944	August	26
		October	27
3	*B 945	August	16
		October	16
4	B 946	August	27
		October	31
5	B 124	August	21
		October	15
6	B 1080	August	10
		October	12
7	B 1002	August	13
		October	11
8	B 1006	August	29
		October	31
9	*B 1000	August	16
		October	23
10	*B 1015	August	20
		October	24
11	B 1016	August	26
		October	28
12	B 1030	August	23
		October	18
13	B_2	August	21
		October	22
14	B 1031	August	23
		October	23
15	B 1026	August	21
		October	40
16	B 1024	August	31
		October	28
17	*B_1	August	15
		October	9
18	B 1029	August	22
		October	26
19	B 1042	August	23
		October	24
20	B 1092	August	20
		October	26

*Selected palms

Table 9. Preliminary evaluation of coconut palms (WCT) for identification of moderately susceptible types in 2000

Sl. No.	Palms	Months of harvest	Percentage of infested nuts in damage category
1	B 1004	August	50
		October	46
2	*B 1010	August	56
		October	55
3	*B 1012	August	57
		October	59
4	*B 1094	August	55
		October	48
5	B 1072	August	52
		October	49
6	B 1076	August	47
		October	49
7	B 1074	August	45
		October	47
8	B 1073	August	46
		October	43
9	B 1049	August	52
		October	39
10	*B 1071	August	52
		October	56
11	B_4	August	43
		October	42
12	B_3	August	49
		October	32
13	B_2	August	35
		October	42
14	B_5	August	41
		October	47
15	B 781	August	52
		October	40
16	B 1061	August	46
		October	41
17	B 1011	August	52
		October	50
18	B 1019	August	50
		October	43
19	*B 2004	August	56
		October	59
20	B_1	August	46
		October	42

*Selected palms

Table 10. Preliminary evaluation of coconut palms (WCT) for identification of highly susceptible types in 2000

Sl. No.	Palms	Months of harvest	Percentage of infested nuts in damage category
1	B 1111	August	62
		October	70
2	B 1059	August	58
		October	73
3	*KD 232	August	80
		October	81
4	B 1055	August	72
		October	81
5	*B 1011	August	89
		October	85
6	B 1004	August	58
		October	63
7	B1019	August	72
		October	61
8	B 1014	August	62
		October	64
9	B 1083	August	56
		October	63
10	B 1032	August	76
		October	83
11	B 1043	August	74
		October	70
12	B 1044	August	65
		October	71
13	B 1029	August	70
		October	62
14	B 1042	August	67
		October	63
15	*B 651	August	79
		October	76
16	*B_2	August	81
		October	76
17	*B_3	August	84
		October	80
18	B 1055	August	62
		October	74
19	B 1058	August	60
		October	60
20	B 1069	August	55
		October	63

*Selected palms

Within the sixty palms selected, those palms with 50 to 60 per cent of infested nuts from the two harvests were categorized as moderately susceptible palms. Based on this criteria, the palms B1010, B1012, B1094, B1071 and B 2004 (Table 9) were identified as moderately susceptible palms.

Those palms that had greater than 75 per cent of infested nuts in the two harvests were categorized as highly susceptible palms. Based on this criteria, the palms KD 232, B 1011, B651, B2 and B3 (Table 10) were selected as highly susceptible palms.

4.2.2 Assessment of Yield Losses in Coconut due to Mealy Bug Infestation

Annual loss in high, medium and low category palms were worked out for 2001 and the results are presented in Table 11.

Table 11. Annual yield loss in different categories of palms

Month of harvest	High		Medium		Low	
	Number of nuts/palm	Amount (Rs/palm)	Number of nuts/palm	Amount (Rs/palm)	Number of nuts/palm	Amount (Rs/palm)
January	7.6	22.8	7.6	22.8	1.4	4.2
February	4.2	12.6	1.8	5.4	1.0	3.0
March	2.2	6.6	2.4	7.2	0.0	0.0
April	2.4	7.2	2.2	6.6	3.0	9.0
May	4.6	13.8	0.6	1.8	0.6	1.8
June	4.0	12.00	1.8	5.4	0.8	2.4
July	3.2	9.6	0.6	1.8	0.0	0.0
August	2.6	7.8	1.0	3.0	2.2	6.6
September	3.6	10.8	3.4	10.2	0.6	1.8
October	4.6	13.8	1.8	5.4	0.6	1.8
November	4.4	13.2	2.8	8.4	0.8	2.4
December	3.0	9	2.0	6.0	2.6	7.8
Total	46.4	139.2	28.6	85.8	13.6	40.8

Nut loss was maximum in the high category palms with an annual loss of 46.4 nuts / palm / year whereas the nut losses for medium and low category palms were 28.6 and 13.6 nuts / palm / year respectively. In the case of high category palms this nut loss accounted to Rs. 139/ palm/ year whereas the medium and low category palms the nut loss accounted to Rs. 86 and Rs. 41 / palm / year respectively. When the monthly variation in yield loss was considered, the highest nut loss due to infestation by PMB, was observed in the month of January 2001 and the lowest was observed in the month of March for the high category of palms. In the case of medium category of palms the highest annual yield loss was observed in January and the lowest in May and July. The low category palms showed maximum yield loss in the month of April and the lowest in the months of March, May, September and October.

The mean per cent damage due to mealybug infestation in 15 selected palms was observed for a period of one year (January to December 2001) and the results are presented in Table 12.

In the second bunch which appeared to be the most critical stage of entry by crawlers, the highest per cent damage was observed in the bunch which was second (B_2) in May 2001 (22.38), followed by the second bunch observed during April (20.92), March (18.40) and January (18.35). The extent of damage in the above bunch increased to 32.33, 37.66, 35.01 and 31.50 in the succeeding months respectively.

When the extent of damage in ten bunches in the increasing order of age as on a particular month of observation was compared with those in the succeeding months, significantly higher damage was observed in the fifth bunch in the months of January (45.60), February (39.08), June (40.49), July (39.06), September (39.22), November (37.47) and December (37.45). In the months of March, April, May, June December and January , highest per cent damage was observed in the fourth bunch which ranged from 37.48 to 40.58 per cent. A mealybug damaged bunch showing completely stunted (tomato shaped) nutlets with one normally developed nut that escaped infestation and immature nuts damaged by *D. brevipes* collected from bunches 1-10 of a single highly susceptible palm, arranged in the order of increasing age of bunches are shown in Plates 6 a and b.

Plate 6 (a) A mealy bug damaged bunch (10th bunch, 9 MAE) showing completely stunted (tomato shaped) nutlets with one normally developed nut that escaped infestation

Plate 6 (b) Immature nuts damaged by *D. brevipes* collected from bunches 1-10 of a single highly susceptible palm, arranged in the order of increasing age of bunches

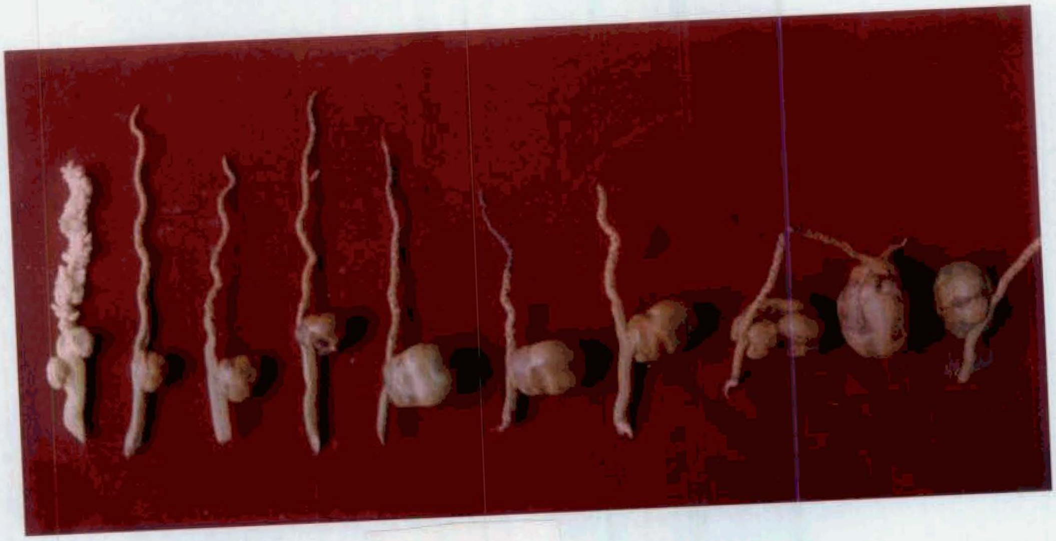


Plate 6 (b)

Plate 6 (a)

Table 12. Mean per cent damage due to PPMB and TPMB, in ten bunches observed at monthly intervals

	Serial number of bunches in the order of increasing age as on the month of observation										
Month of observation	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	Mean
January	0.00	18.35	28.60	38.63	45.60	36.23	32.95	24.29	25.58	16.48	26.67
February	0.00	15.41	31.50	36.55	39.08	39.12	34.03	31.10	17.70	23.12	26.76
March	0.00	18.40	32.08	38.86	36.13	31.39	34.10	24.17	21.12	11.86	24.81
April	0.00	20.92	35.01	39.27	35.80	31.05	29.25	33.96	18.05	11.00	25.43
May	0.00	22.38	37.66	40.58	37.92	34.77	27.80	25.40	22.26	13.54	26.23
June	1.32	14.89	32.33	38.00	40.49	38.26	33.04	31.60	22.62	20.16	27.27
July	0.96	8.74	26.52	35.19	39.06	37.11	32.66	22.53	26.09	25.66	25.45
August	0.00	10.93	23.14	30.47	32.88	32.75	39.12	26.60	16.87	15.05	22.78
September	0.00	13.40	24.99	35.41	39.22	31.27	32.55	31.48	29.13	19.36	25.68
October	1.97	10.63	27.59	33.76	35.59	35.48	32.94	27.33	24.27	19.45	24.90
November	0.00	12.67	26.87	34.00	37.47	37.27	30.44	31.57	16.26	19.30	24.58
December	2.35	14.29	26.76	37.48	37.45	37.20	33.62	27.89	16.91	18.36	25.23
Mean	0.55	15.08	29.42	36.52	38.06	35.16	32.71	28.16	21.40	17.78	

The bunch designated as B_1 in January becomes B_2 in February, B_3 in March and so on (indicated by the arrow line connecting the cells of the table diagonally)

CD (0.05) for months of observation = 3.57, CD (0.05) for bunch mean = 3.25, CD (0.05) for treatments = 11.29

When the influence of bunch age on the extent of damage by mealybugs was studied, highest mean per cent damage was observed in the fifth bunch (38.06) which was on par with the fourth (36.52) and sixth (35.16) bunches. The lowest mean per cent damage was noticed in the first bunch (0.55) followed by second (15.08) indicating initiation of colony buildup in the second bunch.

A severely infested 10^{th} bunch (nine months after emergence) showing infested nuts of very small size indicating earlier colonization and damage by perianth mealybugs is presented in Plate 7.

4.2.3 Population Analysis of PPMB and TPMB for the Period from January 2001 to December 2001

Data on the mean population of *D. brevipes* observed in ten bunches (in the order of increasing age) in fifteen selected palms was recorded for one year (January to December 2001) and the results are presented in Table 13.

Significantly higher mean population of *D. brevipes* was observed in the fifth bunch in the months of January (1.45), May (1.83), June (1.93), July (1.58) and August (1.87). However, in the months of February, March and April, highest mean per cent damage was observed in the fourth bunch which ranged from 1.38 to 1.76. The seventh bunch harboured maximum population of *D. brevipes* during September (1.97) followed by October (1.81) and November (1.34).

The mean population of *P. longispinus* observed in ten bunches (in the order of increasing age) in fifteen palms was observed for one year (January to December 2001) and the results are presented in Table 14.

Plate 7 Severely infested 10th bunch (9 MAE) showing infested nuts in a much smaller size indicating earlier colonization and damage by *D. brevipes* and *P. longispinus*

Table 13. Mean population of *D. brevipes* observed in ten successive bunches

Month of observations	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	Mean
January	1.00	1.02	1.17	1.38	1.45	1.24	1.10	1.14	1.00	1.04	1.15
February	1.00	1.07	1.11	1.38	1.19	1.34	1.28	1.28	1.15	1.04	1.18
March	1.00	1.06	1.12	1.76	1.44	1.65	1.21	1.07	1.12	1.10	1.25
April	1.00	1.00	1.33	1.59	1.55	1.28	1.20	1.14	1.00	1.04	1.21
May	1.00	1.00	1.53	1.61	1.83	1.77	1.23	1.10	1.06	1.00	1.31
June	1.00	1.00	1.21	1.77	1.93	1.00	1.02	1.24	1.02	1.02	1.22
July	1.00	1.00	1.00	1.51	1.58	1.59	1.18	1.13	1.00	1.00	1.20
August	1.00	1.00	1.10	1.45	1.87	1.53	1.08	1.14	1.10	1.00	1.23
September	1.00	1.02	1.00	1.00	1.00	1.07	1.97	1.61	1.00	1.00	1.16
October	1.00	1.00	1.00	1.00	1.00	1.63	1.81	1.31	1.11	1.00	1.18
November	1.00	1.00	1.00	1.00	1.10	1.00	1.34	1.69	1.02	1.00	1.11
December	1.00	1.00	1.22	1.23	1.27	1.35	1.09	1.13	1.04	1.00	1.13
Mean	1.00	1.01	1.15	1.39	1.43	1.37	1.29	1.25	1.05	1.02	

The bunch designated as B_1 in January becomes B_2 in February, B_3 in March and so on (indicated by the arrow line connecting the cells of the table diagonally)

B1 – B10 ⟶ First bunch to tenth bunch (1 MAE to 10 MAE)

CD (0.05) for months = 0.12
CD (0.05) for bunches = 0.11
CD (0.05) for treatments = 0.38

Table 14. Mean population of *P. longispinus* observed in ten successive bunches

Month	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	Mean
January 1	1.00	1.07	1.11	1.21	1.09	1.19	1.00	1.00	1.00	1.00	1.07
February	1.00	1.00	1.20	1.30	1.36	1.14	1.13	1.00	1.00	1.00	1.11
March	1.00	1.00	1.22	1.15	1.52	1.24	1.14	1.00	1.00	1.00	1.13
April	1.00	1.00	1.28	1.35	1.39	1.18	1.00	1.00	1.00	1.00	1.12
May	1.00	1.00	1.00	1.19	1.28	1.27	1.00	1.00	1.00	1.00	1.07
June	1.00	1.00	1.13	1.20	1.16	1.04	1.00	1.00	1.00	1.00	1.05
July	1.00	1.00	1.00	1.09	1.27	1.27	1.07	1.00	1.00	1.00	1.07
August	1.00	1.00	1.00	1.00	1.24	1.11	1.09	1.00	1.00	1.00	1.04
September	1.00	1.00	1.00	1.00	1.00	1.28	1.24	1.13	1.00	1.00	1.06
October	1.00	1.00	1.00	1.19	1.15	1.17	1.29	1.06	1.00	1.00	1.08
November	1.00	1.00	1.00	1.00	1.00	1.34	1.29	1.02	1.00	1.00	1.06
December	1.00	1.00	1.00	1.15	1.31	1.18	1.07	1.00	1.00	1.00	1.07
Mean	1.00	1.00	1.07	1.15	1.23	1.20	1.11	1.01	1.00	1.00	

The bunch designated as B_1 in January becomes B_2 in February, B_3 in March and so on (indicated by the arrow line connecting the cells of the table diagonally)

B1 – B10 ⟶ First bunch to tenth bunch (1 MAE to 10 MAE)

CD (0.05) for months = 6.30
CD (0.05) for bunches = 5.75
CD (0.05) for treatments = 0.19

The highest mean population of *P. longispinus* was observed in the fifth bunch during February (1.36), March (1.52), April (1.39), May (1.28), June (1.16), July (1.27), August (1.24) and December (1.31). However, in the months of September (1.28) and November (1.34), highest population was observed in the sixth bunch.

4.2.4 Spatial and Temporal Distribution of Mealy bugs

In order to study the spatial and temporal distribution of the two species of perianth infesting mealybugs, nuts representing bunches 1 to 10 occupying different positions in the crown were observed at different periods and data are presented in Tables 13 and 14.

Maximum mean population of *D. brevipes* was observed in the fifth bunch (1.43) which was on par with fourth (1.39) and sixth (1.37). Minimum mean population was noticed in the first button (1.00) which came on par with second (1.00), tenth (1.02) and ninth (1.05).

The mean population of *D. brevipes* was maximum during May (1.31) which was on par with that of March (1.25), August (1.23), June (1.22), April (1.21), July (1.20), October (1.18) and February (1.18). The population of *D. brevipes* was minimum during November (1.11), followed by December (1.13).

Maximum population of *P. longispinus* was observed in the fifth nutlet (1.23) followed by sixth (1.20) and fourth (1.15). Minimum population (one) was observed in tenth, ninth, first and second bunches.

The mean population of *P. longispinus* was maximum during March (1.13) followed by April (1.12) and February (1.11). The population was minimum during August (1.04), followed by June (1.05). The influence of bunches and month of observation on the incidence of PMBs are presented in figures 3 and 4. It was evident that the peak level damage coincided with the fifth bunch stage i.e., 100 to 150 days after opening of spadix.

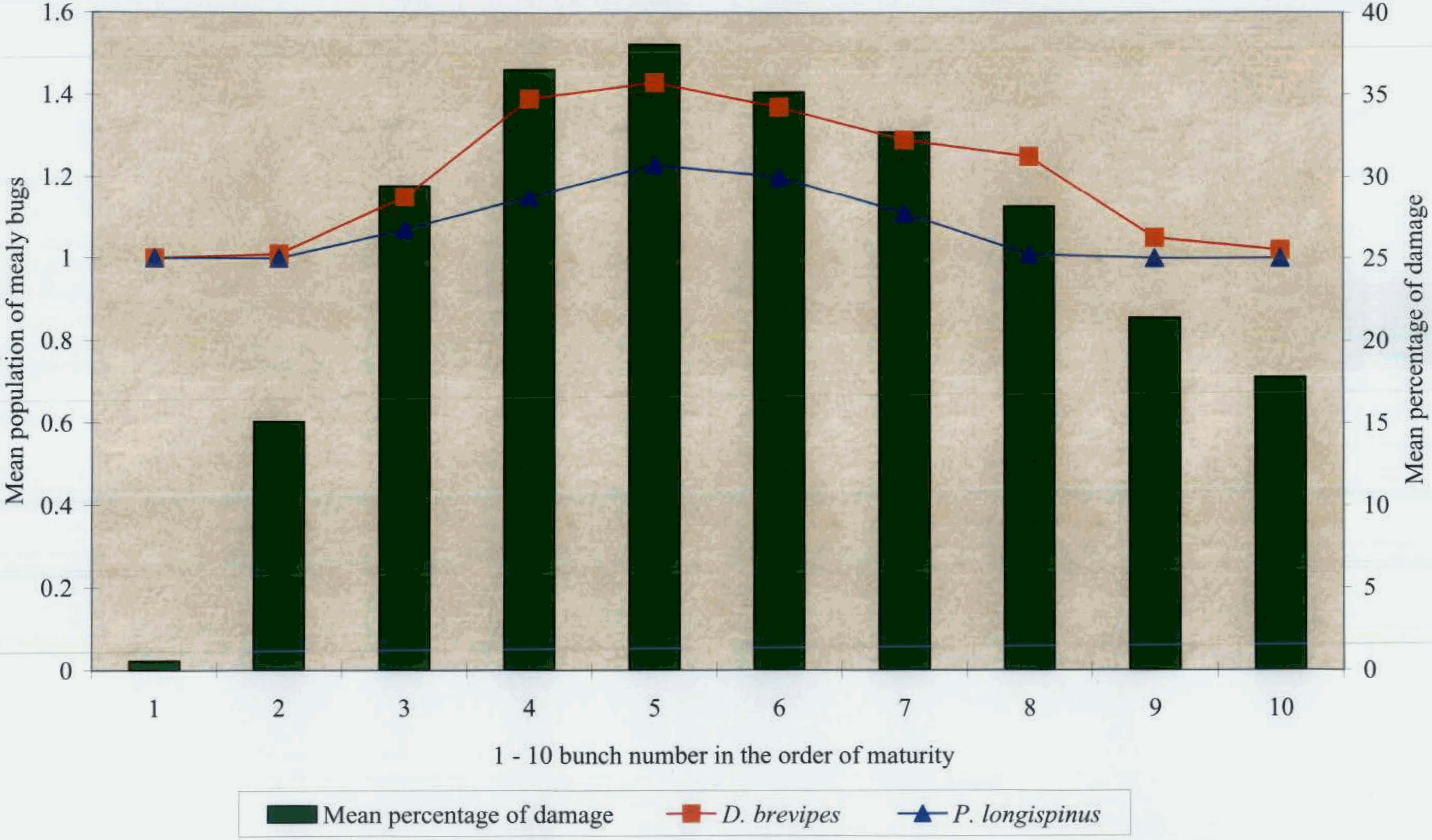


Fig. 3 Influence of bunch age on the incidence of perianth infesting mealy bugs

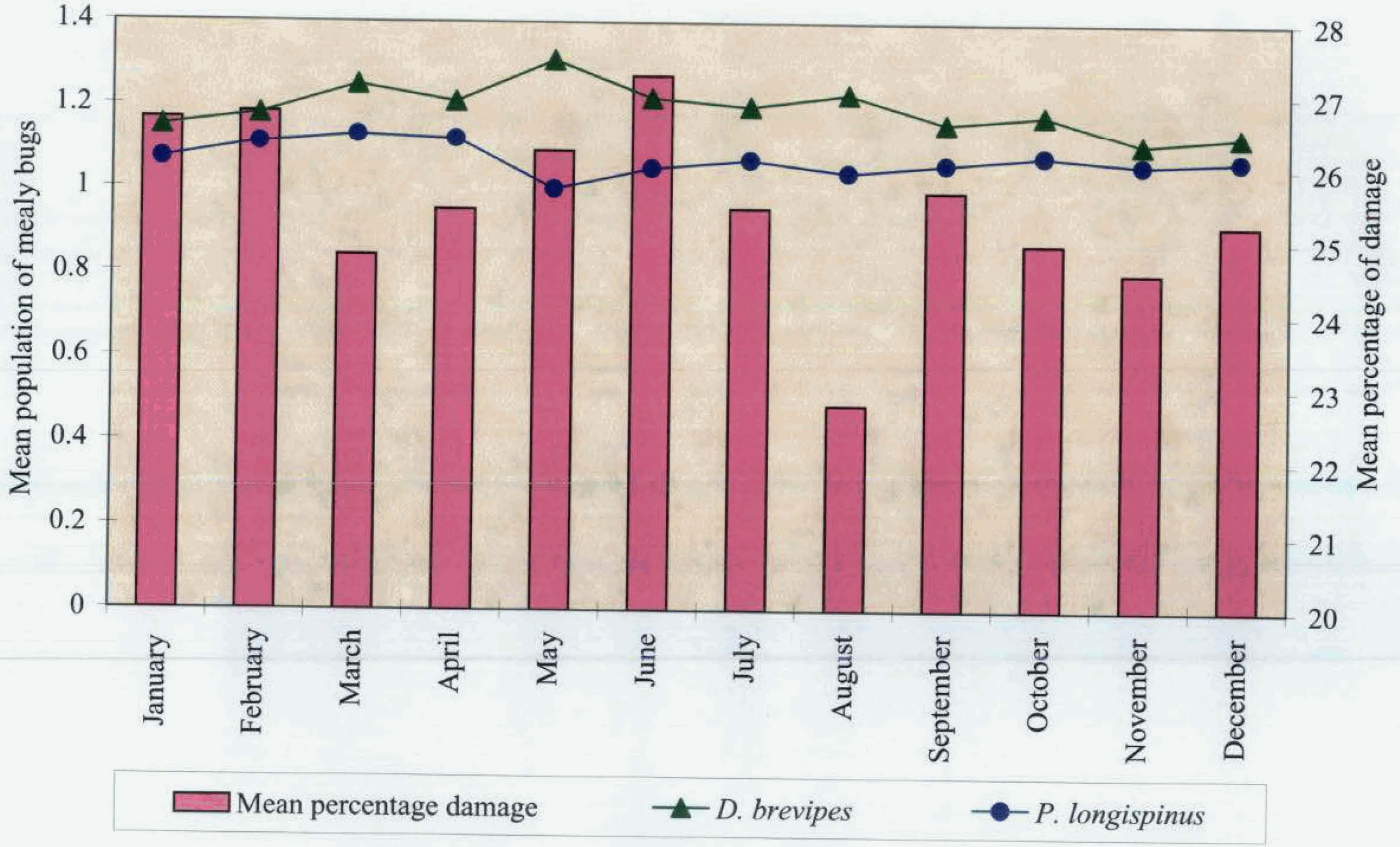


Fig. 4. Influence of observation months in 2001 on the incidence of perianth - infesting mealy bugs

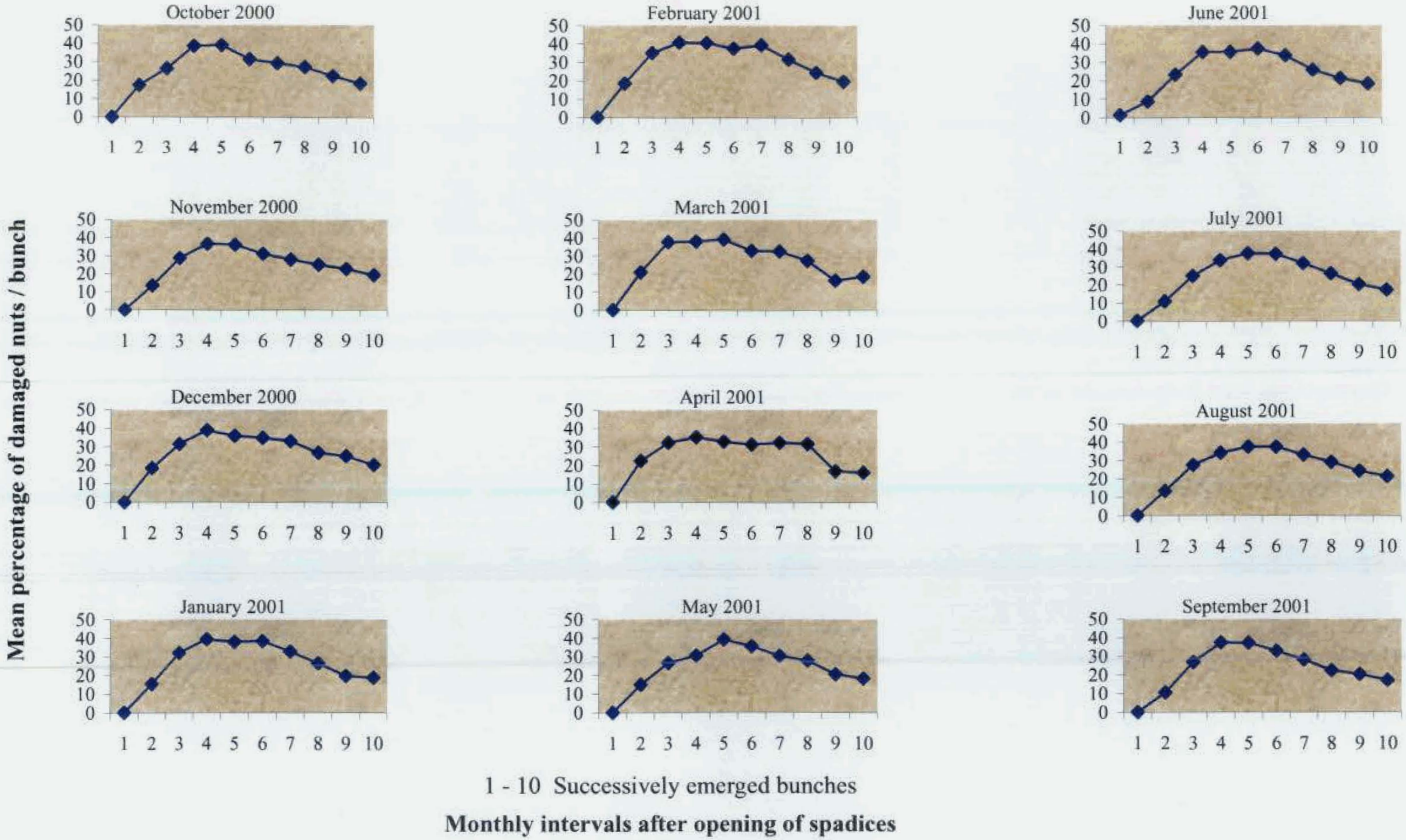


Fig. 5 Influence of period of spadix opening on the extent of damage by perianth mealy bugs

Extent of damage by perianth mealybugs in twelve successively emerged spadices and the influence of period of spadix opening was also studied. The trends in the extent of damage in each bunch observed at monthly intervals after opening are illustrated in Fig. 5. As the study was conducted in the highly infested category of palms, more or less uniform pattern of damage was observed in all the twelve bunches observed. This indicated that the period of spadix opening did not have any influence on the extent of damage.

4.2.5 Mechanism of Development of Symptoms as a Consequence of Feeding injury by Perianth Infesting Mealy bugs

4.2.5.1 Drying of Nut Without Drying of Calyx

In certain nuts with mealybug colonies inside the perianth, drying was observed only in the nuts (fruit) and there was no apparent drying symptom in the tepals. In such nuts, the external appearance of the perianth was like that of a normal nut, but only after removing the tepals, completely dried nuts were observed (Plate 8).

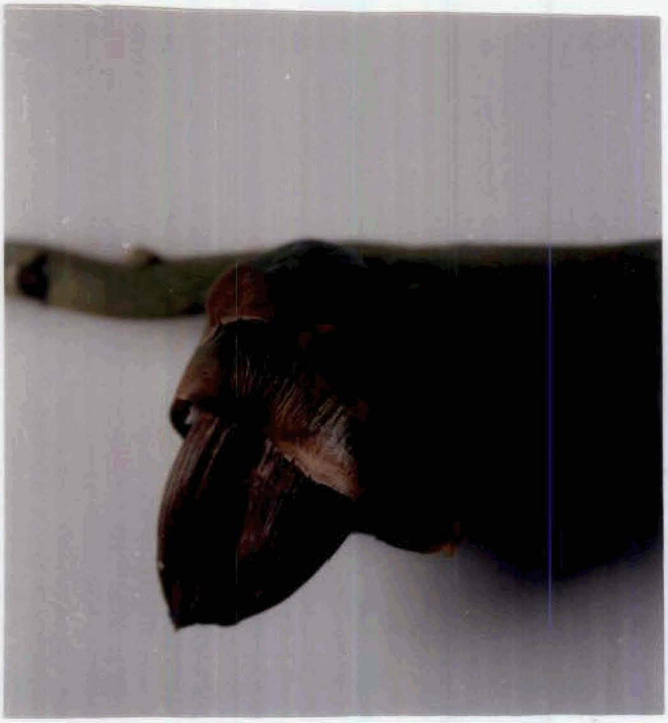
4.2.5.2 Nutfall

Studies revealed that nutfall was not at all conspicuous due to feeding injury by perianth infesting mealybugs. Nut fall could be attributed to injury from either coreid bug (*P. rostratus*) or coconut eriophyid mite (*A. guerreronis*).

4.2.5.3 Different Grades of Stunting

The experiment was conducted to assess the magnitude of stunting in terms of reduction in polar and equatorial diameters of nut and growth retardation in terms of reduction in weight. Damage and size reduction of immature nuts (left side) in ten successively emerged bunches, in comparison with uninfested nuts from the same bunch (right side) are presented in Plate 9.

Plate 8 Drying of nuts without drying of perianth



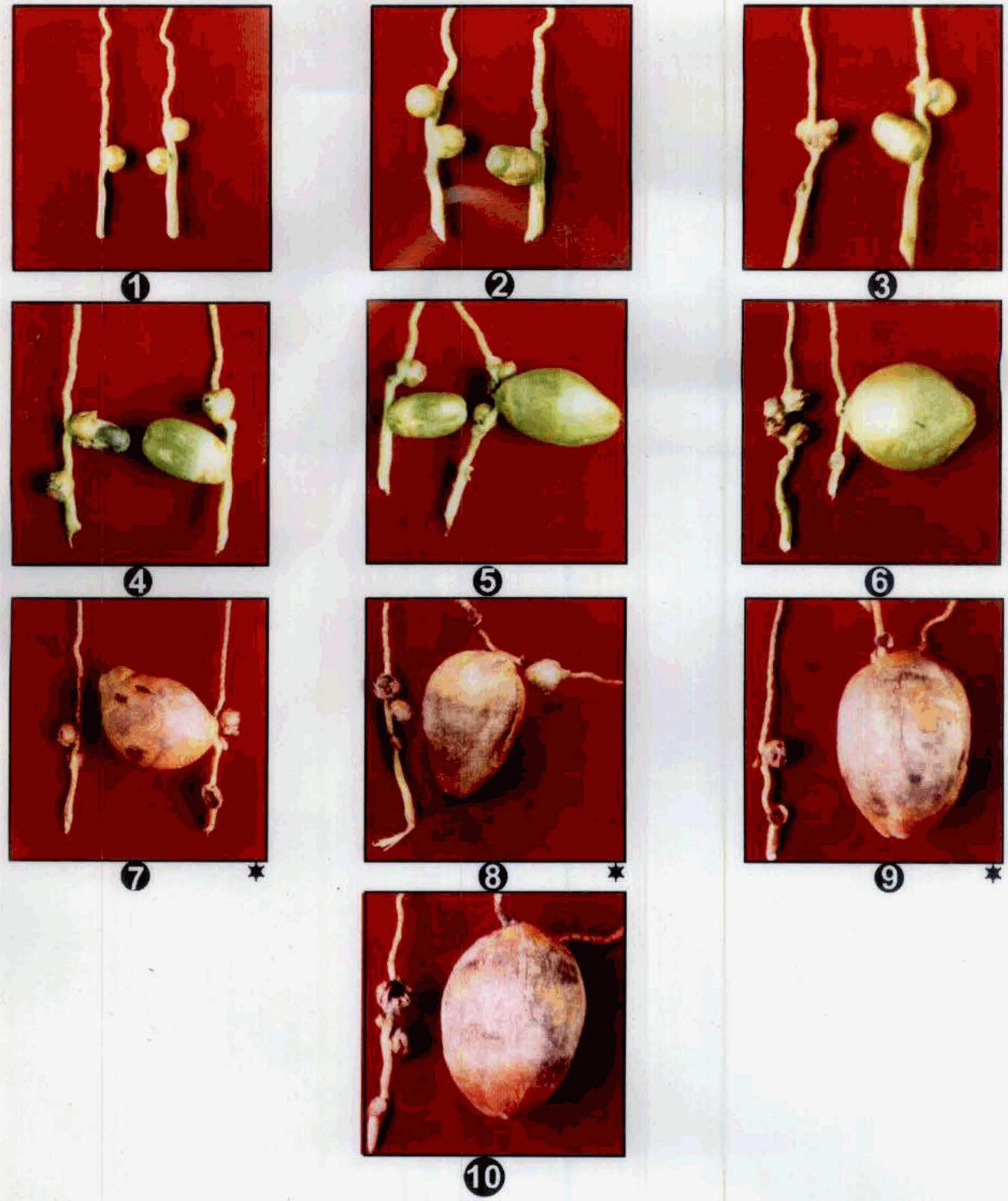
The mean percentage reduction in polar circumference (PC) of the damaged nuts over healthy nuts collected from successive spadices at the age of six months is given in Table 15.

Table 15. Percentage reduction in polar circumference (PC) in the damaged nuts over healthy nuts collected from successive spadices when they attained the age of six months (2001-02)

Month of emergence	Severity of infestation			
	High	Medium	Low	Mean
Sept. 4 – 16	52.13	45.06	43.39	46.86
Oct. 1 – 12	55.94	46.82	36.70	46.49
Oct. 14 – 30	55.15	52.43	47.46	51.68
Nov. 5 – 15	58.02	54.51	41.91	51.48
Dec. 1 – 15	62.36	54.79	39.40	52.19
Dec. 15 – 30	57.41	50.88	46.93	51.74
Jan. 20 – 31	66.26	53.98	52.02	57.42
Mar. 1 – 7	61.35	59.89	53.05	58.09
April 1 – 10	59.46	55.08	53.67	56.07
May 1 – 15	62.98	58.09	45.84	55.64
June 1 – 10	50.97	49.43	44.88	48.43
July 1 – 15	53.34	42.83	40.64	45.60
Mean	57.95	51.98	45.49	

CD (0.05) for severity of infestation = 2.65
CD (0.05) for month of emergence = 5.30
CD (0.05) for treatments = 9.18

Plate 9 Damage and size reduction of immature nuts (left side of each photo) in ten successively emerged bunches, in comparison with uninfested nuts from the same bunch (right side)



*Note: In bunches 7, 8 and 9 the nuts shown as uninfested by *D. brevipes* had mild infestation by coconut eriophyid mite, *Aceria guerreronis* and hence the damage on husk and reduction in symptoms.

The highest mean per cent reduction in PC was observed in the high category of palms (57.95) which came on par with medium category of palms(51.98). However, lower per cent reduction in PC was observed in the low category of palms (45.49).

Mean reduction in PC of coconut was highest in the bunch that emerged during the first week of March (58.09) which came on par with the bunch that emerged during last week of January (57.42), first week of April (56.07) and first week of May (55.64). However, lower mean per cent reduction in PC was observed in the bunch which emerged during first week of July (45.60) followed by first week of October (46.49), first week of September (46.86) and first week of June (48.43). The highest per cent reduction in PC was observed in the bunch which emerged during second week of January (66.26). However the lowest per cent reduction in PC was observed in the bunch that emerged during the first week of October (36.07).

Percentage reduction of equatorial circumference (EC) in the damaged nuts over healthy nuts collected from successive spadices when they attained the age of six months is given in Table 16.

Significant variation with respect to reduction in EC was observed among the three categories of palms.

The highest mean per cent reduction in equatorial circumference was observed in the bunch that emerged during April first week (59.78) which was on par with the one that emerged during first week of May (59.20), first week of March (58.71), second week of January (57.95) and second week of October (55.23). However mean per cent reduction in EC was lowest in the bunch which emerged during first week of July (47.45).

Table 16. Percentage reduction of equatorial circumference (EC) in the damaged nuts over healthy nuts collected from successive spadices when they attained the age of six months (2001-02)

Month of emergence	Severity of infestation			
	High	Medium	Low	Mean
Sept. 4 – 16	59.36	49.08	42.18	50.20
Oct. 1 – 12	60.14	53.16	52.12	55.14
Oct. 14 – 30	61.37	55.34	48.98	55.23
Nov. 5 – 15	62.72	51.30	45.42	53.15
Dec. 1 – 15	59.70	57.58	32.49	49.96
Dec. 15 – 30	56.00	56.79	47.26	53.35
Jan. 20 – 31	59.99	58.44	55.44	57.95
Mar. 1 – 7	70.62	55.28	50.22	58.71
April 1 – 10	66.53	59.29	53.52	59.78
May 1 – 15	68.53	59.55	49.34	59.20
June 1 – 10	62.83	51.34	44.18	52.78
July 1 – 15	53.09	49.64	39.62	47.45
Mean	61.76	54.75	46.73	

CD (0.05) for severity of infestation = 2.77
CD (0.05) for month of emergence = 5.55
CD (0.05) for treatments = 9.62

In the bunch which emerged during the first week of March, the highest per cent reduction in circumference was observed (70.62) followed by the bunch which emerged during first week of May (68.53). The lowest per cent reduction in EC was observed in the bunch which emerged during first week of December (32.49) which was on par with July first week (39.62).

Percentage reduction in weight in the damaged nuts over healthy nuts collected from successive spadices when they attained the age of six months is given in Table 17.

Table 17. Percentage reduction in weight in the damaged nuts over healthy nuts collected from successive spadices when they attained the age of six months

Month of emergence	Severity of infestation			
	High	Medium	Low	Mean
Sept. 4 – 16	85.31	80.56	65.54	77.14
Oct. 1 – 12	85.03	80.56	69.56	78.08
Oct. 14 – 30	86.54	78.80	66.89	77.41
Nov. 5 – 15	90.50	78.66	82.72	83.96
Dec. 1 – 15	89.24	82.22	85.28	85.58
Dec. 15 – 30	87.67	82.70	83.54	84.63
Jan. 20 – 31	88.42	88.03	82.3	86.25
Mar. 1 – 7	89.94	87.56	84.30	87.26
April 1 – 10	91.52	88.84	82.40	87.58
May 1 – 15	90.51	88.54	83.56	87.53
June 1 – 10	82.41	75.40	68.64	75.48
July 1 – 15	84.15	68.80	63.58	72.18
Mean	87.61	81.65	76.53	

CD (0.05) for severity of infestation = 1.96
CD (0.05) for month of emergence = 3.93
CD (0.05) for treatments = 6.82

Mean per cent reduction in weight of six month old immature nut was significantly different among the three categories such as high, medium and low.

The highest mean per cent reduction in weight was observed in the bunch that emerged during first week of April (87.58) followed by those emerged during the first week of May (87.53), first week of March

(87.26), second week of January (86.25) and December (85.58). However, the lowest mean per cent reduction in weight was observed in the bunch which emerged during the first week of July (72.18) which was on par with the bunch that emerged during first week of June (75.48). The highest per cent reduction in weight was observed in the bunch that emerged during first week of April.

4.2.5.4 Deformities or Malformation on Coconut Buttons as a Consequence of Feeding by Perianth Infesting Mealy bugs

4.2.5.4.1 Development of Cavities in Place of Embryo

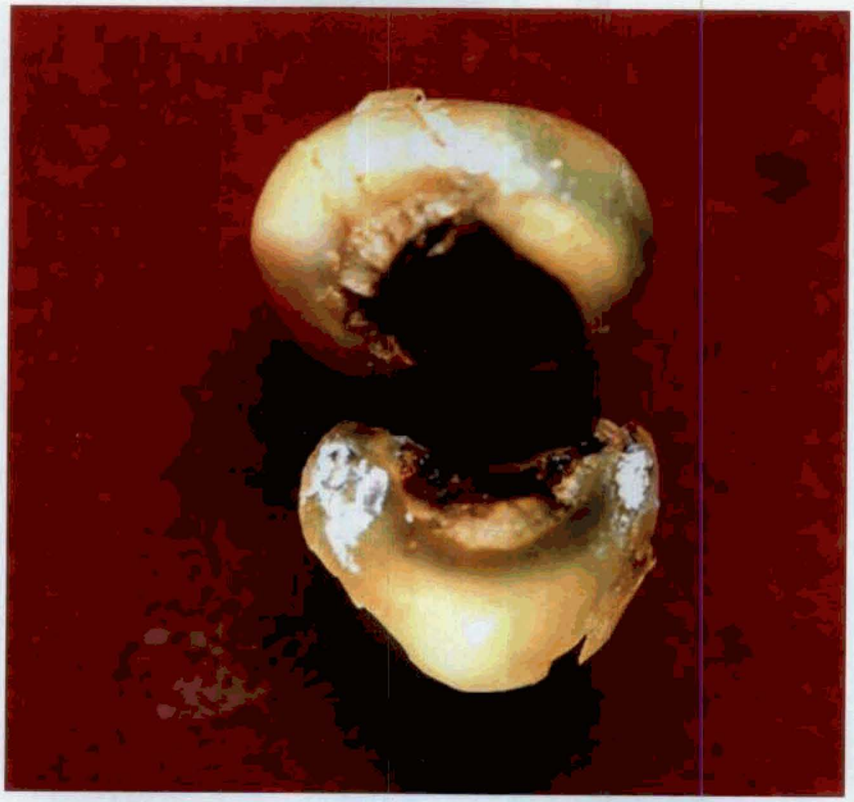
Sustained feeding by crawlers and adults of mealybugs caused stunting and malformation of nut lets. The typical symptoms of stunting and malformation of nutlets is presented in Plate 10.

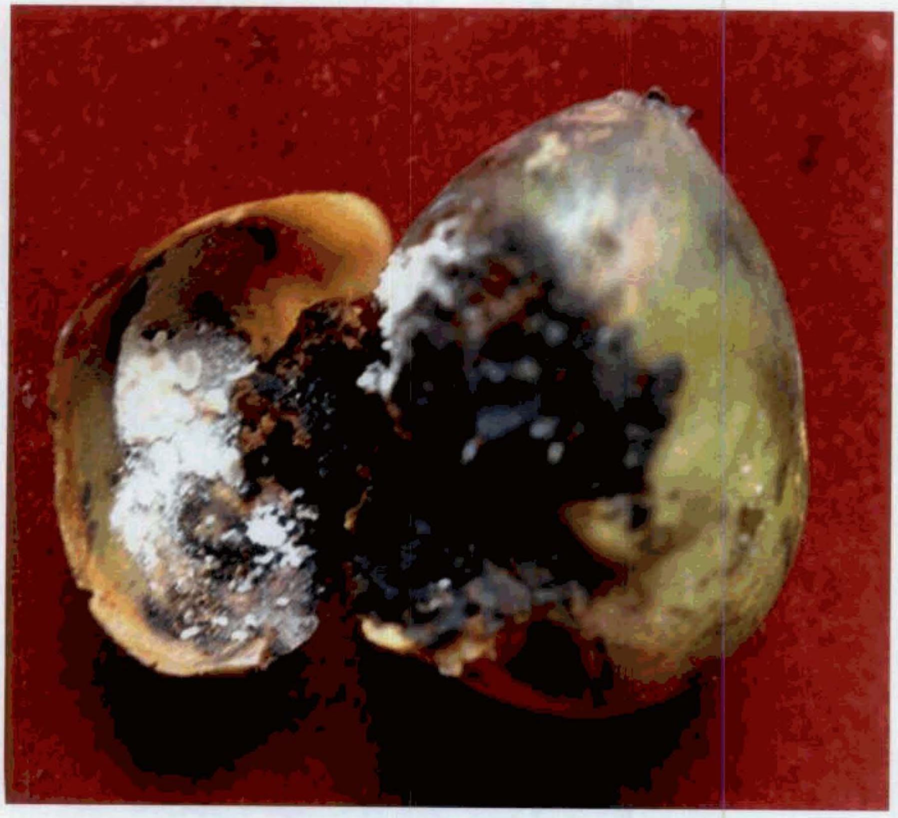
In a bunch, few nuts may develop normally and the infested nuts remained as stunted. In some cases the infested nuts showed a typical "tomato like appearance" with swollen or malformed pericarp. On removal of the tepals, colonies of mealybugs along with ants dwelling in a cavity formed in place of the embryo were observed. This favoured further colonization by ants as well as by mealybugs. Damaged (tomato shaped) immature nuts showing cavity development in place of embryo and the colonization by mealybugs are shown in Plates 11 a and b respectively. The longitudinal sections of damaged (tomato shape) nutlets at the age of four MAE and five MAE are shown in Plates 12a and b.

4.2.5.4.2 Gummy Exudation

Exudation of a gummy substance was also noticed in infested buttons and nuts. Gummosis was observed at the site of attachment of nuts to the fruit stalk and near the stigmatic surface (Plate 13a) and also at the meristematic surface covered by tepals (Plate 13b).

Plate 10 Stunting and malformation of nutlets caused by PMB





4.2.6 Population Buildup of Different Species of Perianth Infesting Arthropods

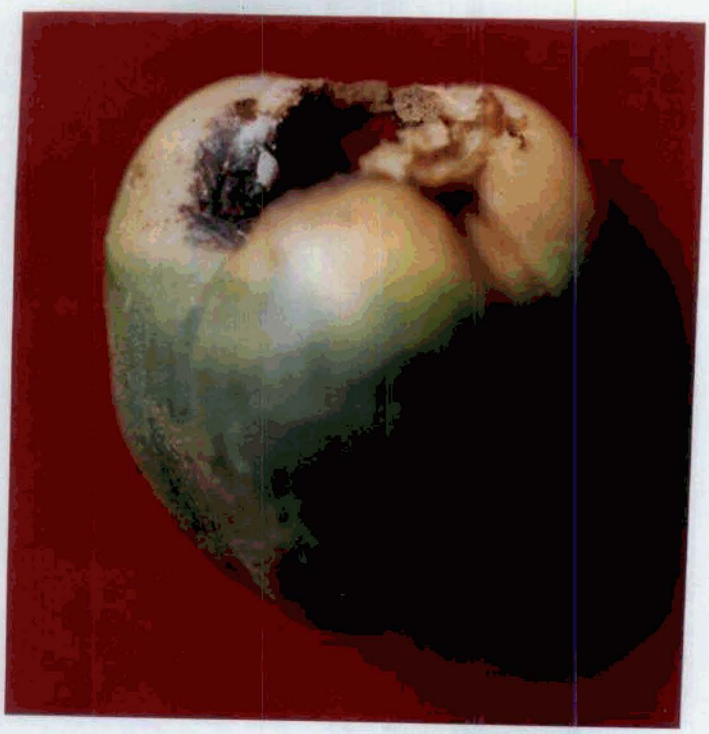
The mean population data of thrips, scales, stem weevil and pink perianth mite found associated with PMBs are presented in Table 18.

Table 18. Mean population of other arthropods found associated with mealybugs

Mean population of thrips, scales, stem weevil and pink perianth mite observed for one year				
Severity of infestation	Thrips	Scales	Stem weevil	Pink perianth mite
High				
KD 232	2.31	2.00	0.50	1.80
B 1011	1.75	3.76	0.00	1.00
B 651	0.75	1.11	0.40	1.50
B 2	3.92	1.50	0.25	1.11
B 3	2.25	0.75	0.30	1.32
Moderate				
B 1010	3.76	7.92	0.08	1.50
B 1012	4.51	9.01	0.00	1.00
B 1094	2.79	7.31	0.11	1.70
B 1071	3.65	9.02	0.00	0.11
B 2004	4.33	8.00	0.08	0.00
Low				
B 147	5.03	7.31	0.00	3.00
B 945	5.36	4.51	0.00	2.50
B 1000	4.77	6.04	0.00	2.00
B 1015	4.96	7.92	0.00	2.25
B 1	4.38	5.65	0.00	2.10

Plate 11 (a) Damaged (tomato shaped) immature nuts showing cavity developed in place of embryo]

Plate 11 (b) Damage and colonization by mealy bugs inside the cavity of the nutlet



Maximum mean population of thrips was observed in the low category of palms (5.36) and the minimum mean population of thrips (0.75) was observed in the high category of palms.

In the case of scales, maximum population was observed in the moderate category of palms (9.02) whereas the minimum population (0.75) was observed in the high category of palms.

The mean population of stem weevil was maximum in the high category of palms (0.50) and the minimum population was recorded in low category palms (0.00).

The maximum mean population of pink perianth mite was observed in the low category of palms (3.00). However the minimum mean population (0.11) of pink perianth mite was observed in the moderate category of palms.

4.2.7 Population Buildup of Pest as Influenced by Morphological Characters

4.2.7.1 Relationship Between Number of Female Flowers / Spikelet and Susceptibility to Perianth Mealy Bugs

Variation in the number of female flowers/ spikelet was observed among the palms selected for study of population build up. In general a positive relation between number of female flowers/ spikelet and susceptibility to mealybugs was noticed. The observations on the number of female flowers/ spikelet in six successively emerged bunches for one year are presented in Table 19.

Plate 12 (a&b) **L.S of damaged (tomato –shaped) nutlets at the age of 4 MAE and 5 MAE**

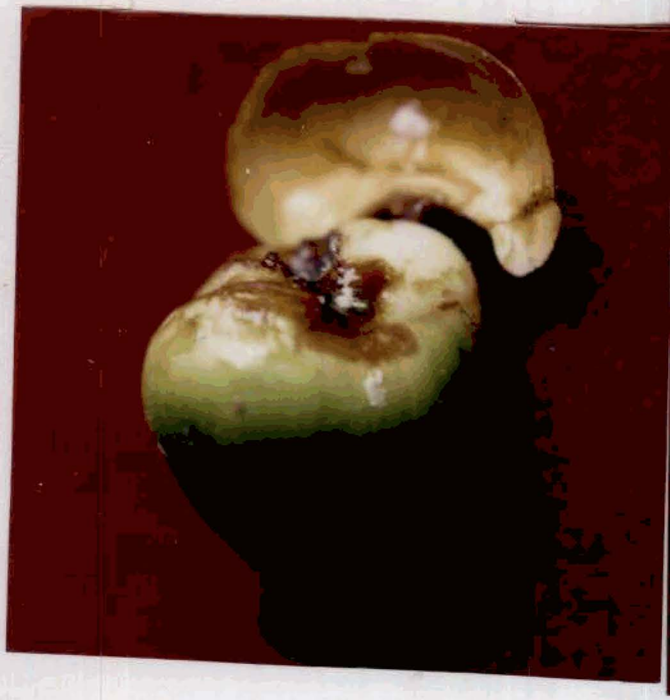
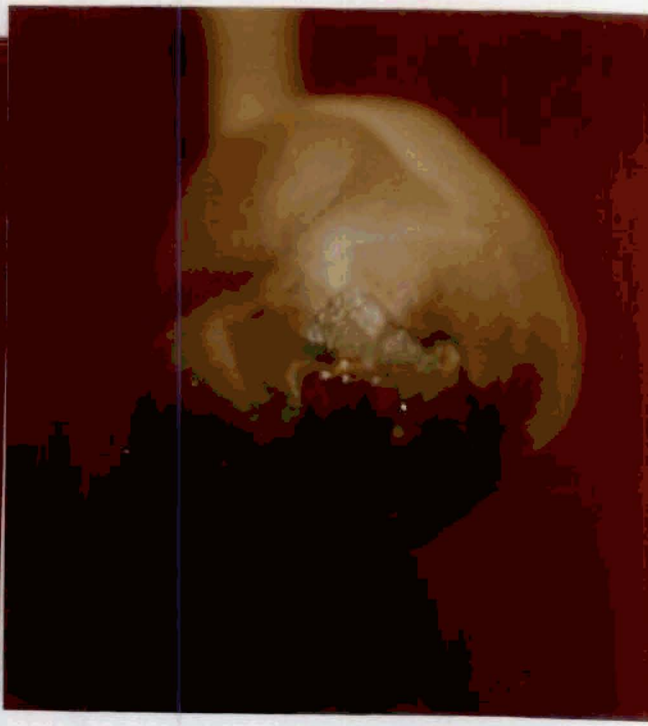
Table 19. Mean number of female flowers / spikelet recorded from six (3rd to 8th) bunches of the selected palms

Mean number of female flowers per spikelet												
Categories	**Observations recorded for 12 months**											
Highly Susceptible	**I**	**II**	**III**	**IV**	**V**	**VI**	**VII**	**VIII**	**IX**	**X**	**XI**	**XII**
B 651	3.1	3.5	3.5	3.0	2.6	2.3	2.0	2.3	2.6	3.0	3.5	3.3
B 3	2.8	3.0	3.1	3.5	3.0	3.0	2.1	2.5	2.1	2.6	3.1	2.8
B 2	3.5	3.3	3.5	3.0	3.1	3.0	2.6	2.3	2.3	2.8	3.0	3.0
KD 232	2.1	2.8	3.0	2.5	2.0	2.0	3.1	3.3	2.5	2.5	2.1	2.0
B 1011	3.1	3.5	3.2	3.0	3.0	2.3	2.0	2.3	2.6	2.8	3.0	3.3
Moderately susceptible												
B 1010	1.5	1.6	1.6	2.0	1.8	1.6	1.6	1.5	2.0	2.0	2.2	2.5
B 1094	1.3	0.8	1.0	1.2	1.5	1.3	1.3	1.0	1.2	1.0	1.2	1.3
B 1071	1.0	1.3	1.2	1.3	1.5	1.6	1.6	1.5	1.3	1.0	1.0	1.3
B 1012	0.3	0.5	0.5	0.8	1.0	1.0	1.3	1.0	0.8	1.2	1.3	1.0
B 2004	1.6	0.8	1.0	0.8	1.0	1.2	1.0	1.3	1.2	1.5	1.3	1.5
Low Susceptible												
B 147	0.3	0.5	0.6	0.8	0.8	1.0	0.8	0.8	1.0	1.0	1.1	1.1
B 1015	0.3	0.6	0.8	0.6	0.5	0.6	0.8	1.0	0.8	0.8	1.0	1.0
B 1	0.6	1.0	0.8	1.0	0.6	0.5	0.8	1.0	1.2	1.2	1.1	1.0
B 1000	0.6	1.0	0.8	1.0	0.5	0.6	1.1	1.0	0.5	0.5	0.6	1.0
B 945	1.2	1.0	0.8	1.0	1.0	0.6	0.8	1.2	1.0	1.0	0.6	0.8

Plate 13 (a) Gummy exudate at the site of attachment of nuts to the fruit stalk

Plate 13 (b) A gummy exudate at the meristematic surface covered by tepals



Mean number of female flowers/spikelet from (3rd- 8th) bunches ranged from 2.0 to 3.5 in the highly susceptible palms. In the moderately susceptible palms, the mean number of female flower/ spikelet from (3rd –8th) bunches ranged from 0.3 to 2.5 while in the case of low susceptible palms, the range was between 0.3 to 1.2. This indicated a strong positive association between the number of female flowers/ spikelet and mealybug incidence. Production of female flowers per spikelet in low, moderate and high category of palms as a pre-disposing factor of susceptibility is presented in Plate 14.

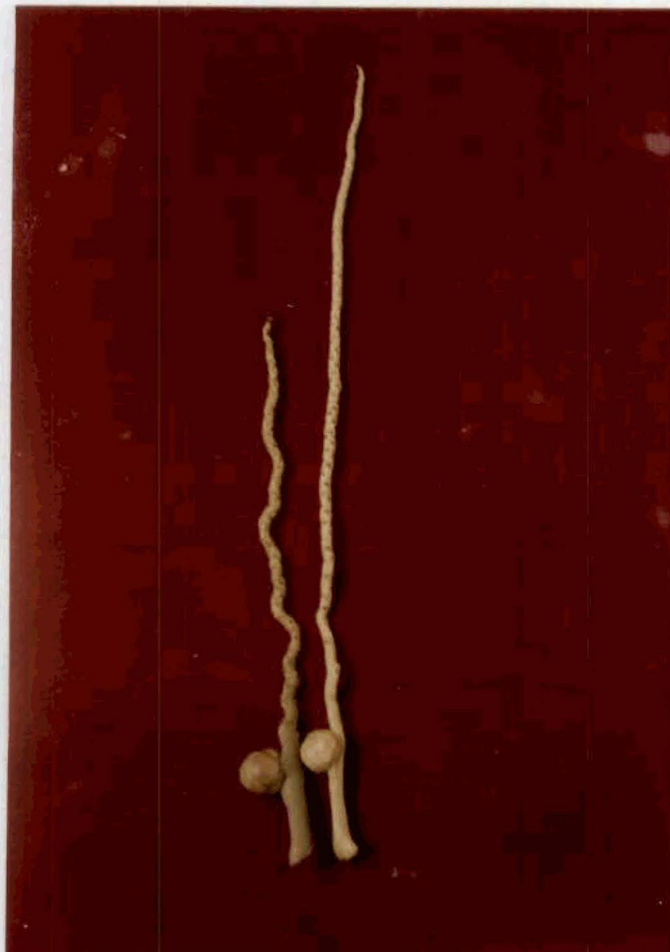
4.2.7.2 Relation between Number of Healthy Nuts Retained / Spikelet and Susceptibility to PMBs

The mean number of healthy nuts retained per spikelet in four (7 – 10) bunches at maturity is given in Table 20.

Table 20. Mean number of healthy nuts retained/ spikelet in four (7-10) bunches observed at maturity

Categories	Observations recorded for 12 months											
Highly Susceptible	**I**	**II**	**III**	**IV**	**V**	**VI**	**VII**	**VIII**	**IX**	**X**	**XI**	**XII**
B 651	1.0	1.0	1.0	1.0	1.0	1.2	1.0	1.0	1.0	1.0	1.0	1.5
B 3	1.0	1.0	1.0	1.2	1.0	1.0	1.5	1.0	1.0	1.0	1.0	1.0
B 2	1.5	1.0	1.2	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.2	1.0
KD 232	1.0	1.0	1.0	1.0	1.2	1.0	1.0	1.0	1.0	1.2	1.0	1.2
B 1011	1.0	1.0	1.0	1.0	1.0	1.0	1.5	1.0	1.2	1.0	1.0	1.0
Moderately susceptible												
B 1010	1.0	1.0	1.2	1.0	1.0	1.0	1.0	1.2	1.0	1.0	1.0	1.0
B 1094	1.2	1.0	1.0	1.0	1.0	1.0	1.2	1.0	1.0	1.0	1.2	1.0
B 1071	1.0	1.2	1.0	1.0	1.2	1.0	1.0	1.0	1.2	1.0	1.0	1.0
B 1012	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
B 2004	1.0	1.0	1.2	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Low Susceptible												
B 147	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
B 1015	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
B 1	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
B 1000	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
B 945	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

Plate 14 Production of female flowers per spikelets in low (1), moderate (2) and high (3) category infested palms



1

2

3

Mean number of healthy nuts retained per spikelet in four (7-10) bunches ranged between 1.0 and 1.5 for the highly susceptible palms. For the moderately susceptible palms, mean number of healthy nuts retained / spikelet in four bunches ranged between 1.0 and 1.2. For the low susceptible palms, the mean was 1.0.

4.2.7.3 Influence of Bract Arrangements

Two types of arrangement of tepals viz., arrangement I and II were observed in the coconut buttons. In type I, tepal number 4 overlapped tepal 5 and 6 at both ends, tepal number 6 was overlapped by tepals 4 and 5 at both ends and tepal number 5 overlapped only at one end. In bract arrangement II, each bract overlapped at one end and it was overlapping at the other end (Fig. 6).

It was observed that in all the coconut buttons studied, the arrangement was of type II, i.e., overlapping type and therefore the influence of bract arrangement on population buildup could not be observed in the present study.

4.2.7.4 Influence of Tepal Colour on Mealy Bug Population

In WCT palms selected for study, the major varietal character found to have influence on the population buildup was colour of tepals and therefore the influence of tepal colour was studied in detail.

Data on progeny production as influenced by the colour of tepals presented in Table 21.

In the case of *D. brevipes*, the number of crawlers produced was maximum in the immature nuts collected from third and fourth bunches having green and orange coloured tepals, when observed at 15 DAR and 30 DAR. In the case of *P. longispinus* also, the number of crawlers produced was highest in the immature nuts collected from third and fourth bunches having green and orange coloured tepals at 15 and 30 DAR.

External tepals (1 to 3)

Arrangement I

Arrangement II

Internal tepals

Fig. 6 Arrangement of tepals on coconuts

Bract arrangement I
Tepal 4 – overlaps 5 and 6 at both ends
Tepal 5 – overlaps 6 at one end
Tepal 6 – overlapped by 4 and 5 at both ends

Bract arrangement II
Tepal 4 – each bract overlaps at one end

Nutlets with yellow tepals recorded minimum progeny production. Different coloured tepals of WCT, used for studying influence of colour variation on mealybug population are depicted in Plate 15.

Table 21. Progeny production of *D. brevipes* and *P. longispinus* on excised nutlets collected from palms varying in tepal colour

Number of nymphs settled on buttons and immature nuts with varying tepal colour					
Tepal colour	Bunch number	Mealy bugs / DAR			
		D. brevipes		*P. longispinus*	
		15	30	15	30
Green	B_1	0	0	0	0
	B_2	0	0	0	0
	B_3	10	14	7	6
	B_4	12	17	4	3
	B_5	0	0	0	0
Orange	B_1	0	0	0	6
	B_2	0	0	2	1
	B_3	12	15	12	9
	B_4	9	14	13	15
	B_5	2	3	0	0
Yellow	B_1	0	0	0	0
	B_2	0	0	1	1
	B_3	1	1	2	1
	B_4	0	1	0	0
	B_5	0	0	0	0

DAR – Days After Release

4.2.8 Role of Ants in Dispersal of PMBs

The different types of ants found associated with mealybug infested palms are listed in Table 22.

Plate 15 Different coloured tepals of WCT, used for studying influence of tepal colour on mealy bug population

Table 22. Ant species associated with the palms

Palms	
High category	
B651	*Cardiocondyla nuda* Mayr, *Technomyrmex albipis* Smith, *Anoplolepis longipes* Jerdon, *Camponotus sericeus* Fabr., *Polyrachis exercita* Walker, *Oecophylla smaragdina* Smith, *Camponotus compressus*
B3	*C. nuda, A. longipes, C. sericeus, P. exercita, O. smaragdina*
B2	*C. nuda, A. longipes, C. sericeus, P. exercita, Camponotus paria* (Emery), *O. smaragdina*
KD232	*C. nuda, A. longipes, C. sericeus, P. exercita, C. paria, O. smaragdina*
B1011	*C. nuda, A. longipes, C. sericeus, P. exercita, O. smaragdina*
Medium category	
B1010	*C. nuda, T. albipis, C. sericeus, P. exercita, C. paria, O. smaragdina*
B1094	*T. albipis, A. longipes, C. sericeus, O. smaragdina*
B1071	*T. albipis, A. longipes, C. sericeus, P. exercita, O. smaragdina*
B1012	*T. albipis, O. smaragdina*
B2004	*T. albipis, A. longipes, C. sericeus, P. exercita, O. smaragdina*
Low category	
B147	*A. longipes, T. albipis*
B1015	*C. sericeus, O. smaragdina*
B1	*A. longipes, T. albipis*
B1000	*P. exercita, O. smaragdina*
B945	*O. smaragdina, T. albipis*

Ants found associated with high category of palms included *C. nuda*, *T. albipis*, *A. longipes*, *C. sericeus*, *P. exercita* and *O. smaragdina*. In the medium category of palms, ants usually found associated with mealybugs included *T. albipis*, *A. longipes*, *C. sericeus*, *P. exercita* and *O. smaragdina*. Low category of palms mostly harboured ants such as *A. longipes* and *O. smaragdina*.

4.3 EXPERIMENT III : EVALUATION OF SELECTED INSECTICIDES FOR THE MANAGEMENT OF PERIANTH INFESTING MEALY BUGS

4.3.1 Laboratory Evaluation

4.3.1.1 Mortality of Mealy Bugs on Excised Undamaged Buttons Collected from 2nd, 3rd and 4th Bunches of Highly Damaged Category of Palms

The results of experiment on mortality of mealybugs on excised undamaged buttons are presented in Table 23.

Table 23. Mortality of mealybugs on excised nutlets collected from 2nd, 3rd and 4th bunches of highly damaged category of palms

Sl. No	Insecticide concentration	Mean % mortality of mealybug observed after					
		24 hours			48 hours		
		B2	B3	B4	B2	B3	B4
T_1	Triazophos 0.05%	100	100	80	100	100	80
T_2	Quinalphos 0.05%	60	60	60	100	100	60
T_3	Endosulfan 0.05%	100	100	100	100	100	100
T_4	Chlorpyrifos 0.05%	80	80	40	100	60	60
T_5	Profenofos 0.05%	100	100	60	80	100	100
T_6	Azadirachtin 3 ml/l	60	60	40	100	60	20
T_7	Diafenthuron 0.05%	60	60	40	80	40	40
T_8	Dimethoate 0.05%	80	60	80	100	80	100
T_9	Control	20	20	40	20	20	20

B- Bunch

Hundred per cent mortality was observed in the 2nd and 3rd nutlet for triazophos, endosulfan and profenofos after 24 hours. In the fourth nutlet, endosulfan recorded cent per cent mortality after 24 hours.

Except profenofos and diafenthuron, all treatments showed cent per cent mortality in the nuts of second bunch when observed after 48 hours. In the nuts of the third bunch, cent per cent mortality was observed for triazophos, quinalphos, endosulfan and profenofos after 48 hours. Endosulfan, dimethoate and profenofos recorded cent per cent mortality after 48 hours in the 4th nutlet.

In general, the insecticides triazophos, profenofos, endosulfan and dimethoate were found as effective insecticides based on the mortality of PMBs in infested nutlets representing the bunches.

4.3.2 Evaluation of Selected Insecticides for the Management of PMB

In the field experiment, eight insecticides were evaluated by spraying on five successively emerged bunches and the results are presented in Tables 24 and 25.

Table 24. Percentage reduction in damage by perianth mealybug over corresponding control in the bunches that received spray (based on 4 MAS)

Treat-ments	Insecticide	Period of bunch emergence					Mean
		1st week of December	1st week of November	1st week of October	2nd week of September	2nd week of August	
T_1	Triazophos 0.05%	47.17	52.53	57.37	43.50	63.52	52.82
T_2	Quinalphos 0.05%	-13.63	-13.60	-32.27	-39.48	-4.78	-20.76
T_3	Endosulfan 0.05%	-24.80	-40.46	-36.95	-6.20	-25.57	-26.79
T_4	Chlorpyriphos 0.05%	-8.78	-10.71	-3.60	-24.34	12.98	-6.89
T_5	Profenofos 0.05%	32.85	70.36	70.11	47.37	26.44	49.43
T_6	Azadirachtin 3ml/l	-24.75	-25.20	-16.00	4.69	-6.18	-13.49
T_7	Diafenthuron 0.05%	-26.36	-45.76	-50.72	-10.65	24.99	-21.70
T_8	Dimethoate 0.05%	2.23	5.60	18.56	27.68	45.33	19.88
	Mean	-2.01	-0.90	0.81	5.32	17.09	

Date of spraying : December 2001, CD (0.05) for Bunch means = 8.03

CD (0.05) for insecticide mean = 10.16, CD (0.05) for treatments = 22.73

MAS – Months After Spraying

In the bunch that emerged during second week of August 2001, which was the fifth from the youngest bunch at the time of spraying, mean percentage reduction over corresponding control was the highest in triazophos (63.52), dimethoate (45.33) and profenofos (26.44) which was followed by diafenthuron (24.99). The effect on this particular bunch differed significantly from other bunches. The lowest mean percentage reduction was observed in the bunch that emerged during first week of December (-2.01) which was the first inflorescence at the time of spray.

In the fourth, third and second bunches that emerged in the second week of September (5.32), first week of October (0.81) and first week of November (-0.90) respectively, the mean per cent reduction over corresponding control was highest in profenofos followed by triazophos and dimethoate.

Triazophos (52.82) and profenofos (49.43) were found to be on par and the most effective treatments which differed significantly from all other treatments at 4 MAS. Endosulfan (-26.79) recorded minimum degree of control at 4 MAS which was on par with diafenthuron (-21.70) and quinalphos (-20.76).

The per cent reduction in damage over corresponding control was maximum for profenofos in the bunch that emerged during first week of November (70.36) followed by the bunch that emerged during first week of October (70.11). In the case of dimethoate (45.33), triazophos (63.52), quinalphos (-4.78), chlorpyriphos (12.98) and diafenthuron (24.99), per cent reduction over corresponding control was maximum in the bunch that emerged during second week of August, which was the fifth bunch at the time of spray. In endosulfan and azadirachtin treatment, the maximum percentage reduction in damage over corresponding control was observed in the bunch that emerged during second week of September, which was the fourth bunch at the time of spraying.

Mean per cent reduction in damage due to PMB in five successively emerged bunches that received single spray at their critical stage, over corresponding control when observed at 4 MAS is presented in Fig. 7.

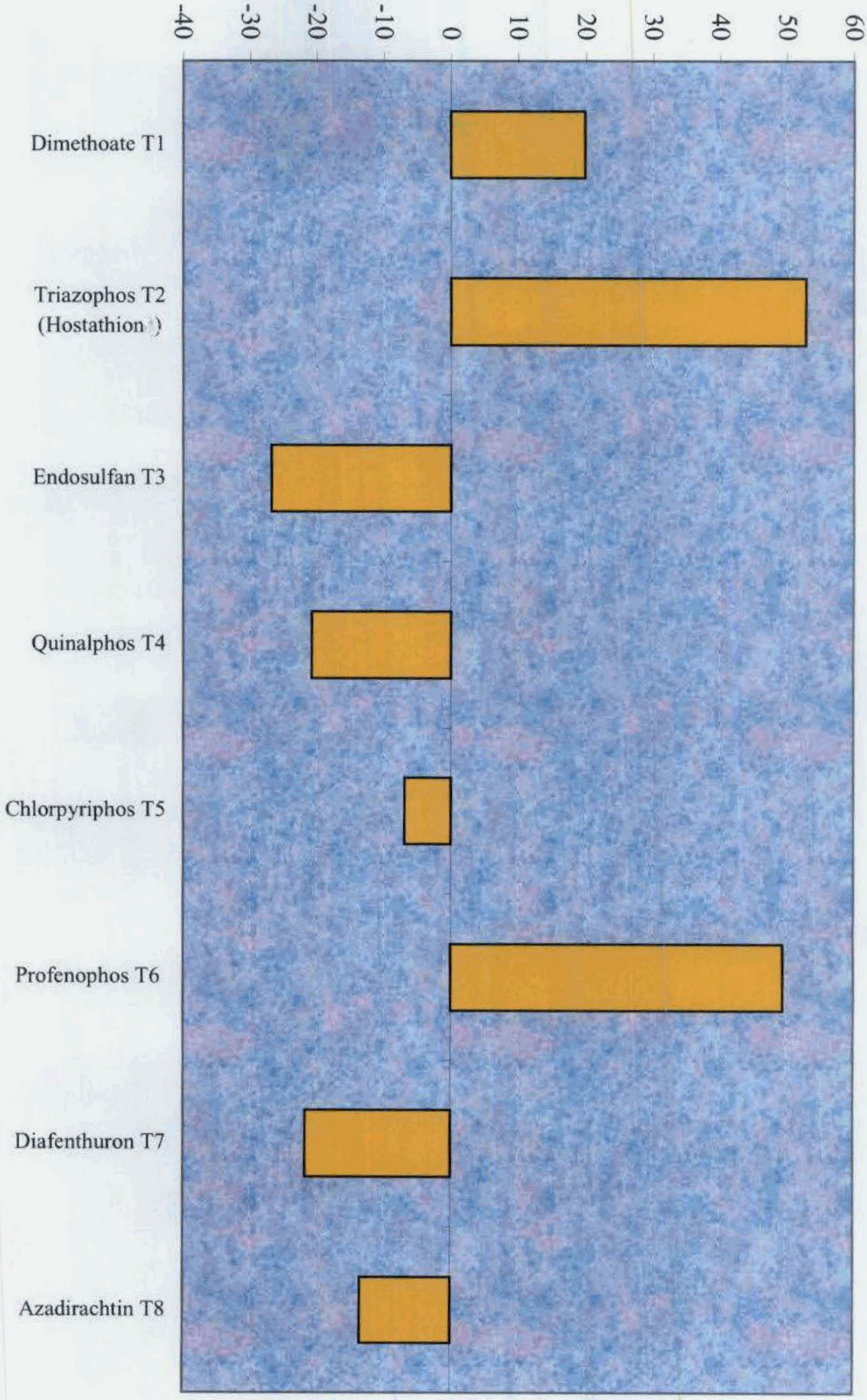


Fig . 7 Mean percentage reduction in damage due to PMB in five successively emerged bunches that received single spray at their ciritical stage, over corresponding control, at four MAS

Percentage reduction over corresponding control in the unsprayed bunches that emerged after spraying are presented in Table 25.

Table 25. Percentage reduction over corresponding control in the unsprayed bunches that emerged after spraying (based on 6 MAS)

Sl No.	Insecticide	Period of bunch emergence					
		Last week of December	Last week of January	Third week of February	Second week of March	Second week of April	Mean
T_1	Triazophos (0.05%)	17.03	12.66	-3.01	-11.69	-29.99	-3.00
T_2	Quinalphos (0.05%)	-15.00	-16.81	-5.14	-16.72	-18.53	-14.44
T_3	Endosulfan (0.05%)	-25.75	-14.54	-9.33	-3.59	-20.00	-14.64
T_4	Chlorpyriphos (0.05%)	-13.81	-18.25	-22.76	-20.00	-31.80	-21.32
T_5	Profenofos (0.05%)	-2.65	22.79	13.25	3.48	-8.51	5.67
T_6	Azadirachtin (3 ml/l)	15.76	2.27	-19.10	-30.19	10.74	-18.51
T_7	Diafenthuron (0.05%)	-38.13	-28.50	-18.00	-56.35	-39.00	-35.99
T_8	Dimethoate (0.05%)	39.20	-17.62	-19.46	-16.75	-14.90	-21.58
	Mean	-12.72	-7.25	-19.45	-18.97	-19.00	

CD (0.05) for bunch mean = 9.98

CD (0.05) for insecticide mean = 12.62

CD (0.05) for treatment mean = 10.18

In the bunch that emerged during last week of January (-7.25), mean percentage reduction over corresponding control was the highest and was on par with the bunch emerged during last week of December (12-72). The lowest mean percentage reduction over corresponding control was observed in the bunch that emerged during third week of February (-19.45) followed by the bunch that emerged during second week of April (-19.00) and second week of March (-18.97).

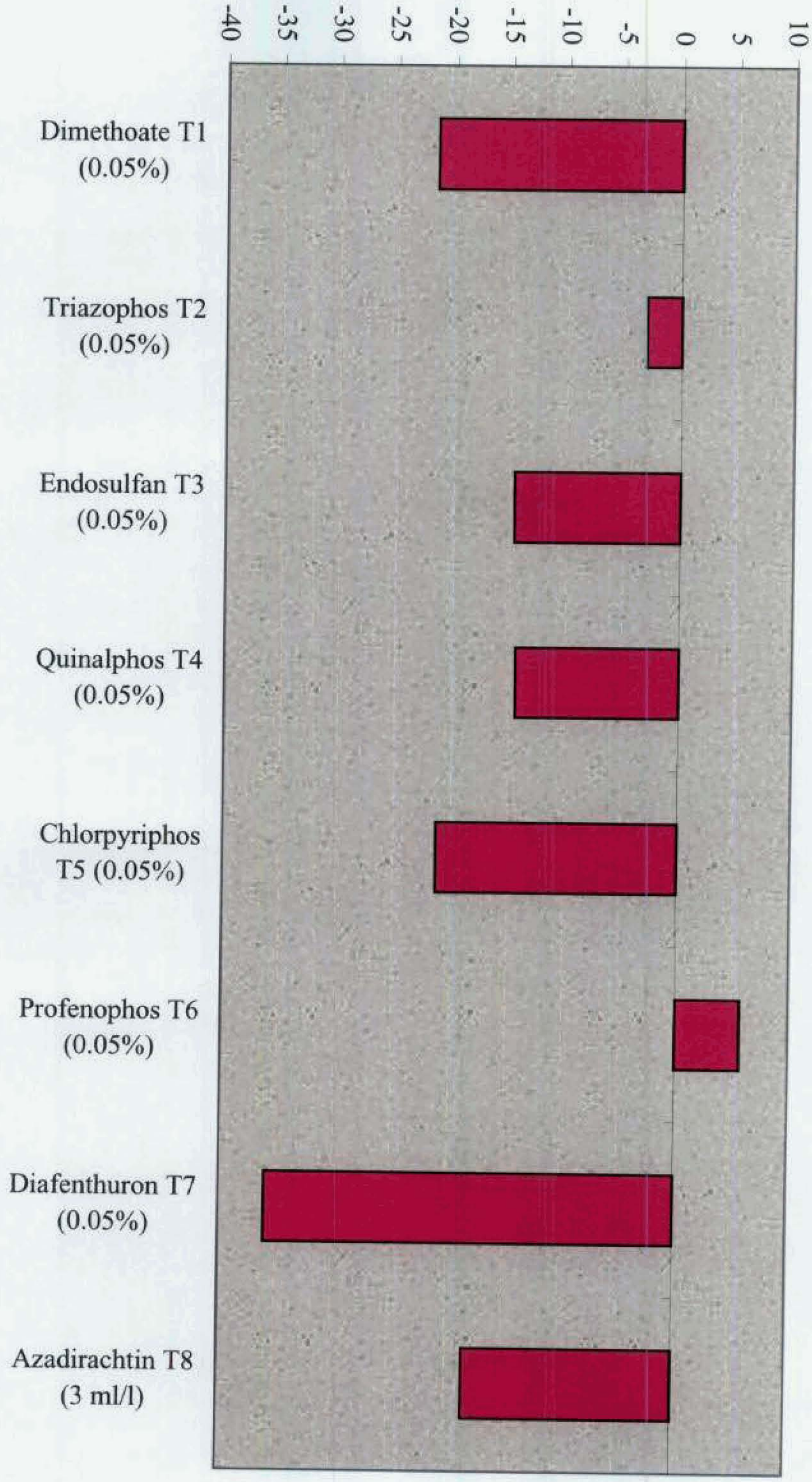


Fig. 8 Mean per cent reduction in damage due to PMB in five bunches that emerged successively after spraying, over corresponding control, at six MAS

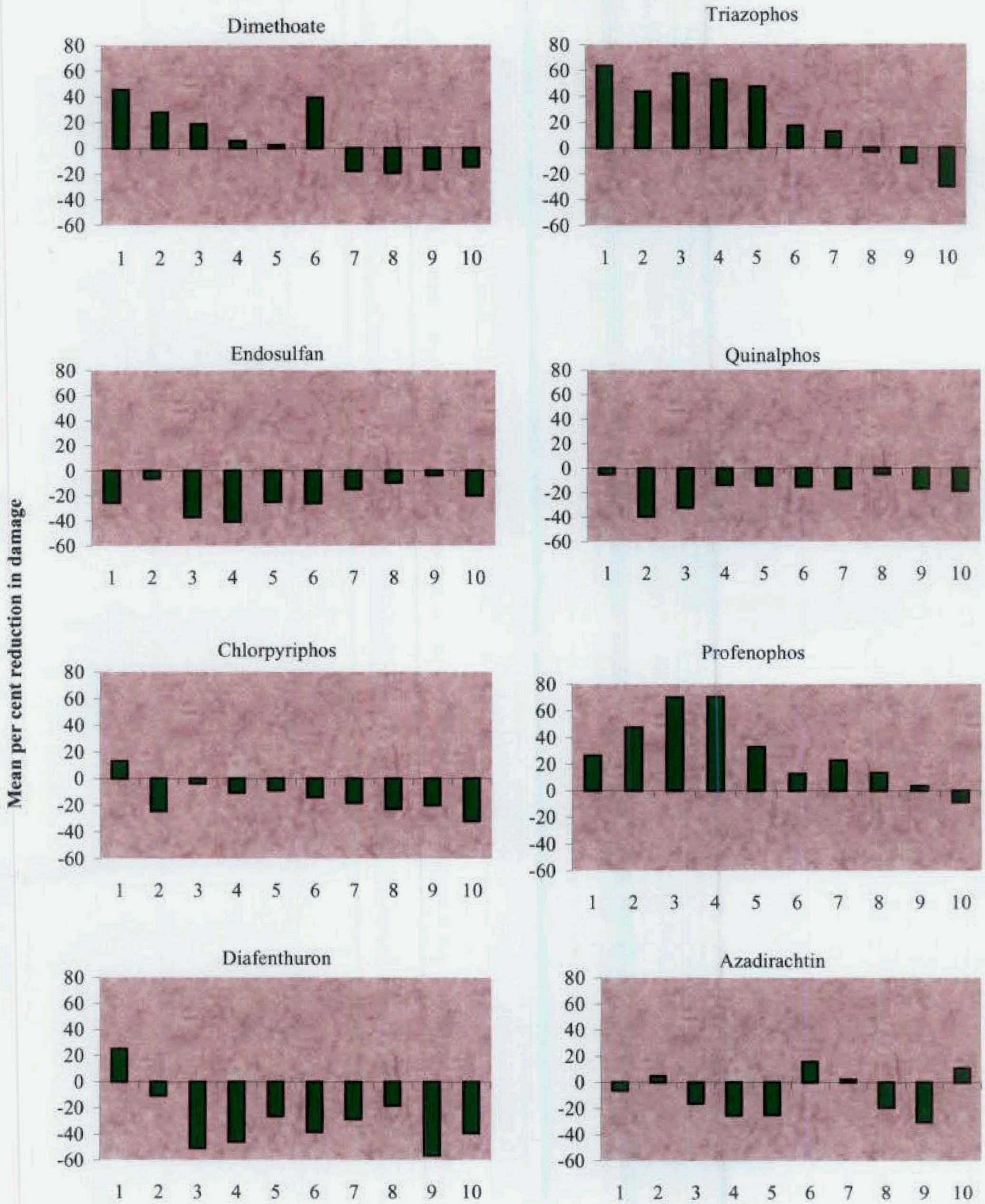


Fig. ¶ Effect of insecticides on the extent of reduction in damage due to PMB in ten successively emerged coconut bunches (five bunches in progresive stages of development after opening and five unopened spadices in progressive stages of development) that received a single spray

The treatment profenofos (5.67) significantly differed from control and was found to be on par with triazophos (-3.00). Control in quinalphos (-14.44), endosulfan (-14.64), chlorpyriphos (-21.32) and azadirachtin (-18.51) were on par with dimethoate (-21.58). Diafenthuron (-35.99) differed significantly from all other treatments.

The per cent reduction in damage over corresponding control was maximum in profenofos treatment (22.79), in the bunch that emerged during the last week of January followed by triazophos (17.03) and azadirachtin (15.76) in the bunches emerged during last week of December.

Mean per cent reduction in damage due to PMB, in five bunches that emerged successively after spraying, over corresponding control at six MAS is presented in Fig. 8.

The effect of insecticides on the extent of reduction in damage due to PMB in ten successively emerged coconut bunches (five bunches in progressive stages of development after opening and five unopened spadices in progressive stages of development) that received a single spray is presented in Fig. 9.

Among the various pesticides evaluated against PMBs, triazophos and profenofos were found to be effective in controlling the mealybugs.

DISCUSSION

5. DISCUSSION

In recent years the evolution of sucking pest complex comprising of the coconut eriophyid mite (CEM), coconut coreid bug (CCB) and coconut button mealybug (CBM) were observed on coconut in Kerala. The losses due to mealybugs in coconut buttons and immature nuts had assumed serious proportions resulting in economic hardship to the coconut growers. However, very little information is available on the species composition, bioecology of the predominant species and yield losses caused by perianth mealybugs (PMBs).

The correct identification of the species of mealybugs inhabiting the perianth and immature nuts was required to evolve suitable management measures to contain them. The present study was undertaken to address the above issues.

The results indicated that the mealybugs in the perianth of coconut buttons composed of two species. They were identified as *D. brevipes* and *P. longispinus*. *D. brevipes* is being reported for the first time in coconut. However, the species of mealybugs obtained from inflorescence and immature nuts of coconut in South India were earlier identified as *Palmicultor palmarum* and *Pseudococcus cocotis* by Ehrhorn (1916) and Ayyar (1919) respectively. *D. brevipes* has been reported as a pest of bromeliads, ornamentals and plantation crops (Frolich and Rodewald, 1970). Other *Dysmicoccus* spp. have been observed in coconut in South Asia (Williams, 1994).

P. longispinus is also being identified and reported in the perianth of coconut buttons for the first time. However, *P. longispinus* was early reported to congregate in the unopened leaves (Dakshinamurthy and

Giridharan, 1976) and inflorescence (Radhakrishnan, 1987 and CPCRI. 1994).

Other species of mealybugs have also been reported to infest coconut in the different coconut growing regions of the world.

Among the two species recorded in the present study, a pink coloured mealybug with plumpy and convex body had 17 pairs of lateral wax filaments and another species with a pair of wax thread "tails" that are as long or longer than the body were observed. The morphology of the two species were studied in detail. For easy reference, two common names are being proposed to describe the species *viz.*, Pink Perianth Mealy Bug and Two Tailed Perianth Mealy Bug that may be abbreviated as PPMB and TPMB respectively. Both the species of perianth mealybugs may be collectively referred by the abbreviation PMB.

The biology of *D. brevipes* was studied under laboratory condition after rearing on pumpkin fruits. The present study revealed that average larval duration and adult longevity of female PPMB were 36.0 and 103.3 days respectively. According to Beardsley (1965) duration of adult female life varied from 31.0 to 80.0 days, averaging about 56.0 days, in pineapple.

In the present study, observations on the fecundity showed that the number of larvae laid by the female ranged from 74.0 to 284.0 with a mean of 170.9 larvae per female. However, Beardsley (1965) observed the production upto 234.0 progeny per female of *D. brevipes*.

The adult female of *D. brevipes* had a mean pre larvi position period, larvi position period and post larvi position period of 24, 21 and 58.7 days respectively. The total life cycle took 139.5 days. It was observed that the larval duration, pupal duration and adult longevity (days) of male PPMB were 22.0, 4.2 and 3.6 days respectively.

Long tailed mealybugs do not produce an egg sac. The present study revealed the occurrence of three nymphal stages in the female and two nymphal plus one pre pupal and one pupal instar in males of pseudococcid mealybugs. It was observed that the mean fecundity, larval duration and longevity of female TPMB was 140.0, 26.0 and 57.0 days respectively. Twenty to 240 eggs have been observed per female under laboratory conditions (Mc Kenzie, 1967). It was also observed that larval duration, pupal duration and longevity of male TPMB were 16.0, 6.0 and 5.0 days respectively. The sex ratio observations showed that in a colony of crawlers, an average of seventy six per cent of *D. brevipes* and seventy eight per cent of *P. longispinus* developed into females.

Studies on the fecundity of mealybugs on excised coconut buttons of different ages revealed that progeny production was maximum in the fourth bunch (B_4) and in the third bunch (B_3) for *D. brevipes* and *P. longispinus* respectively.

Fecundity of perianth infesting mealybugs as influenced by different host materials used for rearing (Fig. 1) revealed that pumpkin appeared to be the better host material when compared with potato, uninfested coconut button and excised tepals of buttons. Ripe pumpkin fruits were used to culture mealybugs by previous workers (Chacko *et al.*, 1978; Singh, 1978; Mani. 1988; CPCRI, 1994; Singh, 1994; Singh, 1995) in connection with mass production of predators and parasitoids. The results of the present study would be useful in mass culturing of natural enemies for biological control of PMBs.

Study on population dynamics and yield losses due to infestation of PMBs is very important to make economic decisions on pest management. The present investigation revealed that the annual yield loss in palms exhibiting high, medium and low levels of mealybug infestation were 46.4, 28.6 and 13.6 nuts per palm per year respectively. CPCRI (1994) recorded an average annual yield of 42.4 nuts $palm^{-1}$ in infested trees as against 46.4 nuts $palm^{-1}$ in healthy ones. A mean of 5.81 nuts $bunch^{-1}$ $palm^{-1}$ were found barren or stunted due to CBM infestation. The average annual yield loss in palms infested worked out to 29.53 nuts per palm. This was in contrast to the findings of the CPCRI (1994) where a yield loss of only four nuts per palm was observed due to mealybug infestation.

The present study revealed that the age of the nut was the most critical factor in the study of population dynamics. It was observed that highest mean percentage damage was observed in the fifth bunch (38.06) followed by fourth (36.52) and sixth (35.16). However, lowest mean percentage damage was noticed in the first bunch (0.55) followed by second (15.08) indicating initiation of colony buildup only from the second bunch onwards.

In the second bunch which appeared to be the most critical stage of entry by crawlers, the highest percentage damage was observed in the bunch which was second (B_2) in May (22.38) followed by the second bunch observed during April (20.92), March (18.40) and January (18.35) 2001. Mohan (2001) reported an increase in the number of barren/stunted nuts in bunches opened during November and reason for this was attributed to influence of coconut eriophyid mite and coreid bug which co-existed with CBM, whose infestation was maximum in the month of November leading to secondary infestation by mealybugs.

Study on the spatial and temporal distribution of PMBs revealed that maximum population was observed in the fifth bunch nuts in the upper most whorl of bunches which was on par with fourth in the upper most whorl and sixth, in the middle whorl. Minimum population was noticed in the first button followed by second, tenth and ninth. This indicated the scope for selective spraying of second to fifth bunches for control of PMBs.

The mean population of *D. brevipes* was maximum during May (1.31) followed by March (1.25), August (1.23), June (1.22), April (1.21), July (1.20), October (1.18) and February (1.18) 2001. The population of *D. brevipes* was minimum during November (1.11), followed by December (1.13) 2001.

Maximum population of *P. longispinus* was observed in the fifth bunch followed by sixth and fourth. Minimum population was observed in tenth, ninth, first and second bunches. The mean population of *P. longispinus* was maximum during March (1.13) followed by April (1.21) and February (1.11) 2001. The population was minimum during August (1.04), followed by June (1.05) 2001. Thus it could be concluded that the peak level of damage coincided with the fifth bunch stage. The damage by the mealybug was maximum during the month of June, whereas the mean population of both the species of the mealybugs was the highest during the month of May. However, the period of spadix opening (based on the month of the year) did not have any influence on the extent of damage by the mealybug.

Studies revealed that rainfall was most important factor having an adverse effect on mealybug population. The pest population was low during the rainy months. High infestation levels were associated with low relative humidity and maximum temperature. Population buildup of mealybugs on coconut started from November after the rains, reaching its peak in February and this level continued till onset of monsoon in May – June. Similar observations were made by Dakshinamurthy and Giridharan (1976), Radhakrishnan (1987), Santha –Cecila (1992) and CPCRI (1994).

Investigations were conducted on the mechanism of development of symptoms on immature nuts due to feeding injury by PMBs. Phytophagy by PMBs on immature nuts resulted in development of symptoms like drying of nut without drying of tepals, different grades of stunting, gummosis, development of cavities in place of embryo and a typical "tomato like" appearance of nuts with swollen or malformed pericarp. Radhakrishnan (1987) also reported that mealybugs infestation resulted in stunted nuts with tightly closed perianths. The present study revealed that nutfall is not at all conspicuous due to feeding injury by PMBs. Similar observations were made by Mohan (2001) on the nut fall due to mealybug.

Studies on the difference in polar circumference (PC) of the nuts in the different categories of the infested palms revealed that the highest mean percentage reduction was in the highly infested category whereas, the lowest percentage reduction was observed in the low infestation category palm. The same trend was observed when the equatorial circumference (EC) of the nuts in the three categories were examined. Consequently the reduction in weight of nuts was the maximum in the highly infested category of palms.

Study on population build up of different species of perianth infesting arthropods revealed the presence of thrips, scales, stem weevil, pink perianth mite, different species of ants, coconut eriophyid mite and coreid bug along with PMBs. In the present study higher population of thrips, scales and pink perianth mite was observed in the low and medium category of palms suggesting secondary infestation by PMBs. However, in the highly infested category of palms infestation of PMBs was mostly primary. Mohan (2001) opined that the nuts that survived the attack of Coconut Eriophyid Mite (CEM) and Coconut Coreid Bug (CCB) might be colonized by coconut button mealybugs (CBMs) later contributing to higher number of barren/stunted nuts. Nair (2000) and Saradamma *et al.* (2000) also observed combined infestation of sucking pests *viz.*, CEM, CCB and CBMs in coconut.

Population build up of PMB as influenced by morphological characters of immature nuts in the selected palms was also studied. It was observed that there is a strong positive relation between number of female flowers per spikelet and susceptibility to damage by PMBs. In the highly susceptible palms, mean number of female flowers/spikelet was from 2.0 to 3.5 while in low susceptible palms, it ranged from 0.3 to 1.6 only. More number of female flowers in close proximity may be a highly congenial condition for the survival, multiplication and dispersal of the mealybugs. This observation indicated the scope of easy identification of highly susceptible palms in a locality that may be advantageous in planning area wide control operations against pest complex infesting coconut.

Efforts were also made in this investigation to study the influence of colour of tepals on the population buildup of PMBs. Nutlets collected from third and fourth bunches with green and orange tepals recorded maximum population at 15 and 30 days after inoculation whereas buttons with yellow tepals recorded minimum progeny production. All the WCT palms selected under high category of palms in this experiment, invariably had green or orange coloured tepals.

In the present study, the ants found associated with PMBs were *C. nuda*, *T. albipes*, *A. longipes*, *C. compressus.*, *C. sericeus.*, *P. excrcita*, *C. paria* and *O. smaragdina*. Role of ants in the dispersal of PMBs was also studied. Ants provided the mealybugs shelter, protection from predators and parasites and kept them clean from detritus that could accumulate in the secreted honey dew and become deleterious to the colony. According to Rohrbach *et al.* (1988) the ants found associated with *D. brevipes* included *Pheidole megacephala*, *Iridomyrmex humilis* and *Solenopsis geminata*. CPCRI (1994) reported *O. smaragdina*, *Technomyrmex* sp. and *S. geminata* as symbionts of mealybug.

A series of laboratory and field experiments were conducted to evolve a management strategy which could reduce the damage and yield loss caused by PMBs. The effectiveness of the treatments were evaluated taking into consideration their ability to reduce yield loss due to infestation by PMBs. Experiments were conducted in the laboratory to assess the mortality of mealybugs released on excised undamaged buttons sprayed with selected insecticides. Based on the mean percentage mortality of mealybugs observed at 24 hours and 48 hours after release, it could be concluded that triazophos (0.05 %), profenofos (0.05 %), endosulfan (0.05 %) and dimethoate (0.05 %) were effective insecticides. Jalaludeen *et al*. (1991) also reported that organophosphorus insecticides caused heavy mortality of *Palmicultor* sp. under laboratory conditions.

In a field experiment conducted in the Instructional Farm, College of Agriculture, Vellayani, during 2001-2002, the efficacy of selected insecticides for management of PMBs were evaluated by spraying in December 2001 on five successively emerged coconut bunches.

The bunch which was fifth at the time of spraying (which emerged during second week of August 2001) showed highest mean percentage reduction in mealybug damage over corresponding control. The effect of treatments on this particular bunch differed significantly from the other bunches.

Triazophos at 0.05 per cent was observed to be the most effective treatment followed by profenofos 0.05 per cent and dimethoate 0.05 per cent when observed at four months after spraying. The recent recommendation in the POP, KAU (2002) for the control of mealybugs in coconut involves the use of insecticides like dimethoate 0.05 per cent. In this study, the newer organophosphorus insecticides *viz*., Triazophos and Profenofos were found to be more promising than dimethoate against mealybugs. Percentage reduction in mealybug damage over corresponding control in the unsprayed bunches that emerged after spraying was also studied. The percentage reduction in mealybug damage on bunches was the least in palms which received profenofos 0.05 per cent spray.

It was also observed that the mean population of *D. brevipes* was maximum during May and *P. longispinus* was maximum during March. Hence, it could be deduced that a bunch that emerged during first week of November or second week of October becomes susceptible to attack by PMBs in the months of February and January of the next year *i.e.*, when the bunches becomes third (B_3) or fourth (B_4). It was also observed that summer season favours increase in pest population build up. So spraying should be done taking into consideration of facts such as age of bunch and month of spraying.

The annual yield loss due to mealybug infestation worked out to be Rs.139/ palm and hence the cost of plant protection measures against the mealybug should be ideally less than the yield loss. Only then, the plant protection recommendations be viable and cost effective.

In the light of the present investigations on the bioecology and management of PMBs, the measures that can be recommended for management of the PMBs include surveillance during summer months is required to establish intensity of mealybug damage. If the pest population and damage is high, insecticide spray has to be given in February – March. At first, clean the crown of palms, remove dried and barren bunches and the insecticide profenofos or triazophos at 0.05 per cent have to be applied. Spraying should be concentrated on the younger bunches (second to fifth).

As ants tended mealybug colonies and were responsible for their dispersal, control measures should also be aimed at management of the ant species.

Future line of work suggested includes the study of life tables of the mealybugs. identification of their natural enemies and development of technologies to utilize them. This will go a long way in evolving IPM measures against the mealybugs.

SUMMARY

6. SUMMARY

The study entitled "Bio-ecology and management of perianth infesting mealybugs" has been carried out in the Instructional Farm, College of Agriculture, Vellayani during the period January 2001 to April 2002. The main objectives of the study were to generate basic information on bioecology of perianth infesting mealybugs *viz.*, pink perianth mealybug, *Dysmicoccus brevipes* and two tailed perianth mealybug, *Pseudococcus longispinus* and to assess their yield losses in coconut. The salient findings of this study are summarised below:

Biology of perianth infesting mealybugs, *D. brevipes* and *P. longispinus* were studied under laboratory condition on pumpkin fruits. Pumpkin was found to be a good host material for rearing mealybugs under laboratory conditions. *D. brevipes* did not lay eggs, but the eggs hatched within the female body and she gave birth to larvae (ovoviviparous) called crawlers. Soon after birth, the crawlers remained underneath the mother's body for protection. Within 24 hours of their emergence, they settled on the substratum (host surface). The number of larvae laid by or fecundity of *D. brevipes* ranged from 74 to 284 with a mean of 170.9 larvae per female. The life history included the pre larviposition, larviposition and post larviposition periods, the mean duration of each period being 24.00, 21.00 and 58.70 days respectively. *P. longispinus* laid eggs, the number ranged from 26 to 240 eggs with a mean of 140 eggs per female. The life cycle included the pre-viviparous, viviparous and post- viviparous periods, the mean duration of each period being 15.00, 14.00 and 27.50 days respectively.

Seventy six per cent of *D. brevipes* and seventy eight per cent of *P. longispinus* developed into females.

Progeny production of *D. brevipes* was maximum in the fourth bunch at 15 days after release (DAR) and for *P. longispinus* progeny production was maximum in the third bunch at 15 DAR.

Preliminary evaluation of 60 WCT coconut palms was conducted to identify palms showing low, moderate and high incidence of mealybugs.

Yield loss studies were conducted in terms of rupee for low, moderately and highly infested coconut palms. Annual yield loss in high, medium and low category infested palms were Rs. 139.20, Rs. 85.80 and Rs. 40.80 respectively.

The highest mean percent damage by mealybugs were observed in the fifth bunch (38.06) which was on par with the fourth (36.52) and sixth (35.16) bunches.

The mean population of *D. brevipes* was maximum during May and minimum during November to December. In the case of *P. longispinus* maximum mean population was recorded in March and minimum during August.

The mean population of *D. brevipes* was maximum in the nuts collected from the fifth bunch and mean population was minimum in the first button. In the case of *P. longispinus,* maximum population was observed in the nuts collected from the fifth bunch and minimum population was observed in the nuts collected from the tenth bunch. Studies on the susceptibility of stage of bunch to mealybug damage indicated that the peak level of damage was in the fifth bunch.

Among the weather parameters, rainfall was observed to be the most important factor affecting mealybug population. The mealybug population was low during the rainy months and high during the summer months. Consequently the maximum damage was observed in the month of June.

Mealy bug infestation inside the perianth resulted in the drying of the nuts and apparently there was no drying symptom in the tepals. The external appearance of the perianth was similar to that of a normal nut and nut fall due to the feeding of these mealybugs was not conspicuous.

Highest mean per cent reduction in polar circumference, equatorial circumference and weight of nuts was observed in the highly infested category of palms and lower per cent reduction was noted in the low category of palms.

Mealybug infested nuts showed a typical "tomato like appearance" with swollen or malformed pericarp and a cavity was formed in place of the embryo. Gummy exudation was observed in infested buttons and nuts.

A positive relationship was observed between number of female flowers per spikelet and susceptibility to mealybugs.

In WCT palms selected for study, the major varietal character, which influenced the population buildup, was colour of tepals. Fifteen and 30 days after release the number of crawlers produced by *D. brevipes* and *P. longispinus* was maximum in the immature nuts having green and orange coloured tepals.

It was evident that ants were responsible for the dispersal of the mealybugs. The important species associated with PMBs were *Cardioacondyla nuda* Mayr, *Technomyrmex albipes* Smith, *Anoplolepis longipes* Jerdon, *C. paria* Emery, *C. sericeus* Fabr., *Polyrachis exercita* Walker, *Oecophylla smaragdina* Smith.

Under laboratory conditions, the insecticides, triazophos, profenofos, endosulfan and dimethoate were found as effective insecticides considering the mortality of PMBs released on undamaged buttons sprayed with insecticides.

Among the various insecticides evaluated in the field against PMBs. triazophos (52.82) and profenofos (49.43) were most effective treatments in reducing the yield loss.

The mean per cent reduction in damage due to PMBs in five bunches that emerged successively after spraying, over corresponding control revealed that profenofos significantly differed from control and was found to be on par with triazophos.

The results of present study will aid in formulating management measures against PMBs on coconut and thereby reducing the yield losses caused by PMBs on coconut.

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*Original not seen

BIO-ECOLOGY AND MANAGEMENT OF PERIANTH INFESTING MEALY BUGS *Dysmicoccus brevipes* (Cockerell) AND *Pseudococcus longispinus* (Targioni-Tozzetti) ON COCONUT

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Abstract of the
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ABSTRACT

A study was conducted at the College of Agriculture, Vellayani from January 2001 to December 2001 to study the biology, species composition and symptomatology of perianth infesting mealybugs, *D. brevipes* and *P. longispinus* infesting the coconut palm and to assess the yield losses caused by the pest and to evolve management measures.

The biology of the two species was studied after rearing them on pumpkin fruits. The mean larval period and adult longevity of *D. brevipes* and *P. longispinus* when reared on pumpkin were 36 and 103.3 and 26 and 57 days respectively. The mean sex ratio of *D. brevipes* was 3.17 and of *P. longispinus* was 3.54. Pumpkin appeared to be a good host material for mass rearing PMBs.

Studies on the yield loss assessment revealed an annual yield loss of Rs 139.20/ palm in the highly susceptible palms whereas in the medium and low susceptible palms the yield losses were Rs. 85.80/palm and Rs. 40.80/ palm respectively.

When the influence of bunch age on the extent of damage by mealybugs was studied, highest mean per cent damage was observed in the fifth bunch followed by fourth and sixth bunches. Maximum population of PMBs were observed in the fifth nutlet. The mean population of *D. brevipes* was maximum during May (1.31) whereas the mean population of *P. longispinus* was maximum during March (1.13).

Studies on the susceptibility of stage of bunch to mealybug damage indicated that the peak level of damage was in the fifth bunch. Consequently the maximum damage was observed in the month of June.

Rainfall was observed to be the most important factor adversely affecting mealybug population.

Development of symptoms as a consequence of feeding injury by PMBs include drying of nut without drying of calyx, stunting, deformities in the buttons such as development of cavities in place of embryo and gummy exudation. The mean population of other perianth infesting arthropods found associated with highly infested category of palms was low when compared to medium and low category palms. A positive relation between number of flowers per spikelet and susceptibility to mealybugs was observed. A study on the reaction of nutlets of WCT variety to PMBs in terms of tepal colour revealed that orange and green coloured tepals were the most preferred by PMBs. Ant species *C. nuda, T. albipis* and *A. longipes* were seen closely associated with PMBs.

Among the various pesticides evaluated against PMBs, triazophos (0.05) and profenofos (0.05) were found to be effective in controlling the pest.