MANAGEMENT OF THE SUCKING PEST COMPLEX, COCONUT ERIOPHYID MITE, COREID BUG AND BUTTON MEALY BUG, INFESTING COCONUT BUNCHES

BY

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THESIS
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DECLARATION

I hereby declare that this thesis entitled "**Management of the sucking pest complex, coconut eriophyid mite, coreid bug and button mealy bug, infesting coconut bunches**" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar title, of any other university or society.

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CERTIFICATE

Certified that this thesis entitled "**Management of the sucking pest complex, coconut eriophyid mite, coreid bug and button mealy bug, infesting coconut bunches**" is a record of research work done independently by Ms. Priya Mohan (99-11-16) under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

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Dedicated

to

My Parents

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Introduction

1. INTRODUCTION

Coconut palm, *Cocos nucifera* L. known as Kalpa Vriksha (Tree of Heaven) or Kera Vriksha is the traditional plantation crop of Kerala. Kerala contributes 44.30 per cent of total coconut production from a share of 53.40 per cent area in the country (Nair *et al.*, 2000a). Eventhough Kerala is the leading producer of coconut, the productivity is less than the national average mainly because of the dreadful root (wilt) disease. Besides this, coconut palm is subject to attack of a number of insect and non-insect pests which also affect the productivity.

Most of the pests of coconut affect productivity of the palm indirectly, by causing injuries to various parts of it other than the bunches. The last few decades have witnessed a tremendous increase in magnitude and diversity of sucking pests infesting coconut bunches. The coreid bug, *Paradasynus rostratus* Distant has been reported as an important sucking pest of coconut infesting the developing nuts (Kurien *et al.*, 1979). Radhakrishnan (1987) and CPCRI (1994) reported considerable yield loss in coconut by the attack of mealy bugs (*Pseudococcus* sp. and *Palmicultor* sp.). An exotic sucking pest, the coconut eriophyid mite, *Aceria guerreronis* K. was introduced to India during the later part of 1997 (Sathiamma *et al.*, 1998), compounding the loss caused by the other two pests. These three sucking pests viz., coconut eriophyid mite (CEM), coconut coreid bug (CCB) and coconut button mealy bug (CBM) are found to infest the palms either singling or in combinations.

Combined attack of coreid bug and mealy bug (Radhakrishnan, 1987) and coreid bug and mite (Mohan and Nair, 2000) was often recorded. Nair (2000) and Saradamma *et al.* (2000a) reported the evolution of a sucking pest complex consisting of CEM, CCB and CBM in Kerala especially in the southern districts.

These three pests attack the developing nuts and hence the damage caused by them reflects directly on yield. Infestation by coconut eriophyid mite resulted in 30-40 per cent crop loss (Nair *et al.*, 2000a) and 40 per cent yield loss in terms of copra output (Muthiah and Bhaskaran, 2000). The crop loss due to coconut coreid bug attack was assessed by CPCRI (1999) as 20 per cent. Nair *et al.* (1997) recorded a mean loss of 28.8 per cent in weight of copra due to infestation by coconut coreid bug. CPCRI (1994) reported that 25.9 per cent of bunches were damaged by coconut mealy bugs. Though the loss inflicted by individual sucking pests has been quantified, the extent of damage by the complex has so far not been worked out.

Separate management measures have been recommended against infestation of CEM, CCB and CBM. The present recommendations against coconut eriophyid mite are bunch spraying of dicofol (0.1 %), neem oil-garlic emulsion (2.0 %) or wettable sulphur (0.4 %) thrice a year (Saradamma *et al.*, 2000a). Spraying endosulfan (0.1%) or carbaryl (0.1 %) was recommended against coconut coreid bug (Ponnamma *et al.*, 1985; Kumar *et al.*, 1996) and monocrotophos (0.1 %) against coconut mealy bug (Radhakrishnan, 1987; CPCRI, 1994). However the present recommendations for the individual pest management are often not found successful in managing the pest complex and fails to achieve the final goal of yield loss reduction.

The present study focuses attention on the sucking pest complex infesting coconut bunches and is undertaken as an initial step towards developing a sustainable IPM strategy against them. The study is undertaken with the following major objectives.

* Assessment of nature and extent of damage caused by the sucking pest complex, CEM, CCB and CBM infesting coconut bunches
* Field evaluation of pesticides for the management of the sucking pest complex
* Identification of potential biological control agents of the sucking pests.

Review of Literature

2. REVIEW OF LITERATURE

India ranks first in coconut production with 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 44.3 per cent of production in the country from 53.4 per cent area (Nair *et al.*, 2000a). Coconut palm is subject to the attack of various pests throughout its life. The major insect pests include the red palm weevil, *Rhynchophorus ferrugineus* Oliv. (Curculionidae) the rhinoceros beetle, *Oryctes rhinoceros* Linn. (Scarabaeidae), the white grub, *Leucopholis coneophora* Burm. (Melolonthinae) and the leaf eating caterpillar, *Opisina arenosella* Walk. (Xylorictidae) (Nair *et al.*, 2000b). Recently productivity of coconut in Kerala is severely affected by the incidence of three sucking pests viz., coconut eriophyid mite (CEM), *Aceria guerreronis* Keifer. (Eriophyidae) coconut coreid bug (CCB), *Paradasynus rostratus* Distant. (Coreidae) and coconut button mealy bugs (CBM), *Pseudococcus* spp. and *Palmicultor* sp. (Pseudococcidae). More often a combined infestation of these pests are observed.

Mohan and Nair (2000) reported that the combined attack of coconut eriophyid mite and coreid bug was prevalent in Thiruvananthapuram District of Kerala.

Radhakrishnan (1987) reported heavy damage to coconut palms due to the combined attack of coreid bug and mealy bug.

Saradamma *et al.* (2000a) and Nair (2000) reported extensive damage by sucking pest complex viz., coconut eriophyid mite, coreid bug and mealy bugs in Kerala.

2.1 Coconut eriophyid mite *Aceria guerreronis* Keifer.

The CEM *Aceria guerreronis* is the most important mite pest of coconut causing severe economic loss in most of the coconut growing tracts of the world. *Aceria guerreronis* K. 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 in 1965 (Keifer, 1965). The attack of this pest was reported from Africa (Mariau, 1969) and subsequently from Togo, Nigeria, Cameroon and Ivory Coast (Mariau, 1977). Among the Asian countries it was first reported from Kerala, India (Sathiamma *et al.*, 1998). Following this ravages of this mite have been detected at far and wide localities of South India including Kerala, Tamil Nadu and Karnataka (Haq, 1999a). Reddy and Naik (2000) reported CEM attack in Andhra Pradesh. The occurrence of this pest was also reported from Sri Lanka (Fernando *et al.*, 2000) and Andamans (Prasad and Ranganath, 2000).

The spectacular invasive and establishment powers of the mite raised it to the status of a cosmopolitan pest throughout the coconut growing tracts of the world (Haq, 1999b).

Flechtmann (1989) reported *A. guerreronis* on a cocosoid palm, *Cocos weddelliana* in Brazil.

2.1.1 Morphology, biology and damage

Aceria guerreronis K. belongs to Fa: Eriophyidae. The mites have worm like elongated body measuring about 36-52 µm in width and 205-250 µm in length (Keifer, 1965; Julia and Mariau, 1979). They have two pairs of legs in the cephalothorax. The abdominal portion is studded with microtubercles in a series of rings. The anal opening is anteriorly placed below the leg base (Mohanasudaram, *et al.*, 1999).

According to Mariau (1977) CEM completes a development cycle from egg to adult in about 10 days. In confirmation Ramarethinum and Loganathan (2000) reported the development period as 10.50 ± 1.27 days under laboratory conditions.

Dispersal of the mite is mainly by wind or phoresy (Moore and Howard, 1996).

CEM feeds from below the perianth within a few weeks to a month after fertilization of female flowers (Ortega *et al.*, 1965; Mariau and Julia, 1970; Hall and Espinosa, 1981). Moore and Alexander (1987a) suggested the presence of mites on nuts upto 13 months after fertilization but the number was low after eight months. Maximum number of mites was observed under the tepals of fourth (Renjith *et al.*, 2001) and fifth (Mathew *et al.*, 2000) bunches.

A. guerreronis K. live and multiply under the perianth of tender coconuts and feed by piercing the meristematic zone of the nuts and sucking the sap (Julia and Mariau, 1979). The initial symptoms of attack includes appearance of typical triangular patches below the base level of the tepals and the tepals when removed show dusty areas with thousands of mites (Julia and Mariau, 1979). Feeding of the mites in meristematic zone causes uneven growth resulting in distortion and stunting (Moore *et al.*, 1989) due to necrosis and suberisation at feeding points (Moore and Howard, 1996).

Extensive premature nutfall was reported by Doreste (1968). Mohanasundaram *et al.* (1999) reported heavy button shedding due to severe infestation of CEM. Haq (1999b) suggested that premature nutfall incurred maximum loss. Haq (2000) revealed 41.36 per cent nutfall in infested palms. In Tanzania the losses due to premature nut fall were between 10-100 per cent with an average of 21 per cent (Seguni, 2000).

In contrast to be above reports Mariau and Julia (1970, 1979); Mariau (1977) stated that the loss due to premature nutfall was non-significant.

In Kerala the extent of damage varied from 20-60 per cent (Nair and Koshy, 2000). Nair *et al.* (2000c) reported crop loss due to mite infestation as 30-40 per cent and severe infestation resulted in more than 50 per cent loss in weight of kernel.

The estimated loss of copra was 10 per cent in Benin (Mariau and Julia, 1970), 16 per cent in Ivory Coast (Mariau and Julia 1979), 30 per cent in Mexico (Hernandez, 1977) and 11-28 per cent in St. Lucia (Moore *et al.*, 1989). Muthiah and Bhaskaran (2000) reported the yield loss in terms of copra output as 40 per cent.

2.1.2 Management

2.1.2.1 Chemical control

Hernandez (1977) recorded significant reduction in CEM damage by spraying dicrotophos, monocrotophos or chinomethionate onto bunches of developing fruits at 20 or 30 days intervals. Mariau and Tchibozo (1973) suggested spraying of acaricides at 15 days intervals to be effective against CEM. Stem injection of monocrotophos in every two months was effective in young dwarf plants (Julia and Mariau, 1979). Griffith (1984) claimed that single treatment of Kilvil (vamidothion) had given long lasting control. But Moore and Alexander (1987b) proved it to be ineffective.

Moore *et al.* (1989) proved the effectiveness of polybutene but the method was not economically viable. Moore and Howard (1996) stated that chemical control is not practicable for the management of CEM since repeated application at short interval was required for the treatment to be effective.

Mohanasundaram *et al.* (1999) observed that methyl demeton (Metasystox) @ 4 ml l^{-1}, phosalone (Zolone) @ 3 ml l^{-1} and triazophos (Hostathion) @ 5 ml l^{-1} were effective in checking CEM infestation. They suggested repeated application at 7-10 days interval. Root feeding with 40 % triazophos (Hostathion) was also reported to be effective. Triazophos, carbosulfan, endosulfan and wettable sulphur applied as spray on affected bunches controlled CEM infestation (CPCRI, 1999; CPCRI, 2000).

Nair *et al.* (2000a) proved the effectiveness of neem oil–Garlic (2 %) emulsion and alternatively dicofol (0.1 %) for the management of CEM.

Fenazaquin when applied by both topical spraying and root feeding methods was found to be superior to dicofol, monocrotophos and triazophos (Dey *et al.*, 2001). Bunch spraying of dicofol (0.1 %), micronized wettable sulphur (0.4 %) or neem oil - garlic emulsion (2 %) thrice a year was recommended by Saradamma *et al.* (2000b). Azadirachtin (Neemazal) @ 0.003 per cent was found to be a promising botanical pesticide when three sprayings at 45 days interval were given (Saradamma *et al.*, 2001).

2.1.2.2 Other methods of management

2.1.2.2.1 Innovative farmer practices

The farmers of the state have tried certain innovative practices to control mite infestation in their palms. Applying neem cake powder, garlic powder, turmeric powder etc on the crown, generating smoke from farm waste, garage waste, camphor etc in garden, hanging sticky traps on the crown, spraying salt water on infested bunches, spraying rice water and other sticky materials on the bunches were practiced (Nair *et al.*, 2000a).

2.1.2.2.2 Cultural Methods

Crown cleaning was recommended before the spraying of chemicals or botanicals for mite control (Nair *et al.*, 2000a). In Brazil, cultural control methods included removal of infested plant parts and avoidance of excessive irrigation and fertilizer use (Alencar *et al.*, 1999).

2.1.2.2.3 Biological control

Biological control has been considered as the most efficient suitable and economic means of control of CEM (Julia and Mariau, 1979; Hall *et al.*, 1980).

2.1.2.2.3.1 Predators

Moore and Alexander (1987a) observed that some predators were regularly associated with CEM occupying the meristematic zone of coconuts.

Julia and Mariau (1979) reported the presence of predatory mites *Bdella* sp., two phytoseiids and a tarsonemid in the CEM colonies. Two species of predatory mites (*Lupotarsonemus* sp.) were found to feed on CEM colonies causing significant reduction in their population (Hall *et al.*, 1980). Some predatory mites viz., *Bdella distincta* Baker and Balock, *Amblyseius largoensis* Muma, *Neoseiulus mumai* Denmark and *N. paspalivorus* De Leon were also observed in CEM colonies (Howard *et al.*, 1990). Saradamma *et al.* (2001) reported two predatory mites, *Amblyseius* sp. and *Bdella* sp. as predators of CEM.

2.1.2.2.3.2 Microbes

The acaropathogenic fungus *Hirsutella thompsonii* (Fisher) has been isolated from CEM samples collected from Tropical America and West Africa (Hall *et al.*, 1980). The pathogenicity and sporulation characteristics of Mexican strain of *H. thompsonii* were observed by Hall and Espinosa (1981).

Espinosa and Carrillo (1986) reported high mortality of CEM using *H. thompsonii* and its use as a potential biocontrol agent was discussed (Becerril and Sanchez, 1986, Gopal and Gupta, 2001). Eventhough good results were obtained under laboratory conditions, the fungus was not successful when used for field trials (Moore *et al.*, 1989). Lampedro and Rosas (1989) reported maximum mortality of 88.36 per cent for HtMOR strain, among the seven isolates of *H. thompsonii* tested. Integration of

H. thompsonii with other control methods resulted in reduction of damage by CEM in Cuba (Cabrera, 2000). Moore (2000) suggested the development of an integrated programme for CEM management with a mycoacaricide as its important component.

Another acaropathogenic fungus *H. nodulosa* Petch was found to be infective to *A. guerreronis* in Cuba (Cabrera and Dominguez, 1987).

In Kerala *H. thompsonii* var. *synnematosa* Samson, Mc Coy and O' Donnell was isolated from *A. guerreronis* K. (Beevi *et al.*, 1999). The fungus has already been described by Samson *et al.* (1980). Ramarethinam *et al.* (2000a) suggested the use of Nimbecidine in combination with one or more entomopathogenic fungi like *H. thompsonii*, *Verticillium lecani* (Zimm.) Veigas and *Paecilomyces* sp. for better mite control. A combination treatment involving Nimbecidine and Biocatch (*H. thompsonii* with spore count 10^7 ml^{-1}) at 500 ml and 1 kg respectively in 200 l of water was found to be effective in the control of CEM (Ramarethinam *et al.*, 2000b).

Project Directorate of Biological Control formulated the first mycoacaricide against CEM in India viz., Mycohit, based on *H. thompsonii* with the most effective strain *H. thompsonii* MF (Ag) 5 as active ingredient. The product having 2.5 x 10^8 CFU g^{-1} was reported to give 80 per cent control when sprayed on bunches infested with CEM (Kumar and Singh, 2000).

2.1.3 Other mites attacking coconut

Besides *A. guerreronis*, coconut palm is reported to be infested by a number of eriophyid mites. *Acarthrix trymatus* Keifer, *Acamina coconuciferae* Keifer, *Dialox stellata* Keifer, *Nacerimina gutierrezi* Kiefer, *Notostrix attenceata*

Keifer, *N. jamaicae* Keifer and *Scolocenus spiniferas* Keifer were found on the leaflets or foliage while *Colomerus novahebridensis* Keifer was found under the bracts of coconut buttons (Mohanasundaram and Kuruppuchamy, 1989).

Other mites recorded on coconut palm are *Raoiella indica* Hirst (fa : Tenuipalpidae) (Hirst, 1924), *Tetranychus hindustanicus* Hirst and *T. ludeni* Zacher (Tetranychidae) infesting the leaves, *T. fijiensis* and *Amenosius* sp. infesting flowers (Nair, 1978) and *Brevipalpus phoenicis* Geijkes on nuts (Chandra and Channabasavanna, 1976).

Sathiamma *et al.* (1985) reported *Dolichotetranychus vandergooti* (Oudemans) as perianth mite of coconut feeding under the perianth resulting in discolouration of the nut.

2.1.3.1 Management

Saradamma (1972) reported significant reduction in population of *R. indica* on palms treated with dimethoate and formothion. Dimethoate 0.05 per cent was effective in controlling the mites infesting coconut (Nair, 1978).

H. thompsonii was reported to be infective to *C. novahebridensis* and *Dolichotetranychus* sp. (Hall *et al.*, 1980). They reported predatory tarsonemids *Lupotarsonemus* spp. on *C. novahebridensis*.

2.2 Coconut Coreid bug (CCB) *Paradasynus rostratus* Dist.

Coconut coreid bug is an important sucking pest causing high economic loss to coconut growers in Kerala. In India, the coreid bug was first reported as a pest of coconut from Alleppey district of Kerala (Kurien *et al.*, 1972).

In 1976 the pest was identified and confirmed as *Paradasynus rostratus* Dist (Kurien *et al.*, 1976, 1979).

The pest was also recorded on other host plants like cashew (Nair and Remamony, 1964), Guava (Nair, 1975; Beevi *et al.*, 1989), Tamarind (Kurien *et al.*, 1979), Cocoa (CPCRI, 1999), Neem (Sundararaju and Babu. 1999) and passion fruit (Mohan and Nair, 2000).

2.2.1 Biology and Damage

Detailed study on the biology of the pest has been carried out on different host plants. The egg period was recorded as 8 to 10 days and the nymphal stage comprised of five instars with duration of 4-5, 5-7, 4-6, 4-6 and 8-10 days on coconut (Kurien *et al.*, 1979) 3-6, 3-8, 4-6, 3-6 and 8-10 days respectively in cashew (Nair and Remamony, 1964) and 3, 9.2, 4.9, 7.1 and 4.1 days respectively in guava (Beevi *et al.*, 1989). The insect took 5.4 days more to complete its nymphal period on mature cocoa pods. The survival percentage of nymphs was 15 per cent more in cocoa than coconut. Adults lived for 49-53 days and total life period was reported to be 82-97 days (CPCRI, 1999).

The nymphs and the adults feed on tender coconuts causing immature nutfall or malformation of nuts. The bugs while feeding on buttons insert their stylets through the perianth causing buttonfall and if retained the attacked nuts show feeding punctures as eye like spots which develop into necrotic lesions with furrows or crinkles and gummosis (Kurien *et al.*, 1979). Immature nutfall due to CCB ranged from 13.5 to 62.4 per cent (CPCRI, 1999).

Nair *et al.* (1997) recorded the mean per cent loss in weight and volume of the nut as 17.99 and 19.96 per cent respectively. Crop loss due to CCB attack in harvested nuts was assessed by CPCRI (1999) as 20 per cent.

Survey conducted by Visalakshi *et al.* (1992) revealed that the infestation by *P. rostratus* was maximum (23.48 per cent) in Wynad followed by Kasargode and Thiruvananthapuram (5.09 and 4.82 per cent respectively).

2.2.2 Management

2.2.2.1 Chemical control

Kurien *et al.* (1976) reported that BHC 0.1 per cent and carbaryl 0.05 per cent were effective in controlling the pest. Spraying at bimonthly interval was recommended. According Ponnamma *et al.* (1985) carbaryl 0.05 per cent or Endosulfan 0.1 per cent was the effective treatment against CCB. The dosages of carbaryl and HCH were fixed as 0.1 per cent and 0.2 per cent respectively by Visalakshi *et al.* (1987), based on the results of multilocational field trials. Kumar *et al.* (1996) recommended spraying of carbaryl 0.1 per cent four times a year avoiding the rainy season.

CPCRI (1999) reported full protection of young bunches from coreid bug attack by placing two sachets of phorate 10G each containing 2.5 g of the insecticide in the corresponding leaf axil. They also reported reduction in the pest incidence by the application of carbaryl / endosulfan @ 0.1 per cent during May, August, October and November.

2.2.2.2 Biological control

Nair and Remamony (1964) recorded two species of egg parasitoids *Hadrophanurus* sp and *Anastatus* sp. as natural enemies of the pest. A reduviid predator *Endochus inornatus* Stal. was reported to be feeding on the nymphs (CPCRI, 1999). They also found that the pest incidence was low on the collateral host plants colonized with red ant, *Oecophylla* sp.

2.2.2.3 Trap Crop

Sundararaju and Babu (1999) suggested the use of Neem as a trap crop for CCB.

2.2.3 Other coreid bugs infesting coconut

The coreid bugs *Amblypelta cocophaga* China, *A. lutescens* Distant and *Pseudotheraptus wayi* Brown were reported as serious pests of coconut in the Solomon Islands, Papau New Guinea and East Africa, respectively (Lever, 1969).

The coreid bugs were reported to cause immature nutfall in coconut (Phillips, 1940 and Way, 1953).

2.2.3.1 Management

Repeated spraying of endosulfan was used for the control of *P. wayi* (Lohr and Oswald, 1990, Oswald, 1991).

Possibilities of the use of egg parasitoid *Oenocyrtus albicrus* (Prinsloo) (Hymenoptera, Encyrtidae) was discussed by Oswald (1990). Two egg parasitoids *Anastatus* sp. and a scelionid were reported to cause natural mortality of *P. wayi* (Neelthing and Joubert, 1994).

Colonization of coconut palms by predatory ant, *Oecophylla longinoda* Latr. significantly increased nut yield (Lohr and Oswald, 1990; Sporleder and Rapp, 1998).

2.3 Coconut button mealy bugs (CBM) *Pseudococcus* sp. and *Palmicultor* sp.

2.3.1 Nature of damage and biology

Mealy bugs infest almost all plant parts of coconut viz. leaves, spindle, inflorescence, buttons, mature nuts and roots. The mealy bugs *Pseudococous* sp. and *Palmicultor* sp. infesting coconut bunches caused heavy economic loss to coconut growers in Kerala (CPCRI, 1994). Earlier these pests were considered as minor pests of Kerala (Mathen *et al.*, 1962). Later the mealy bugs turned to be serious pests of coconut especially in south Kerala (Radhakrishnan, 1987, John, 1988).

Two species of mealy bugs viz., *Palmicultor palmarum* Ehrhon affecting spindle and *Pseudococcus cocotis* Maskell affecting spathe were found in coconut growing tracts of Kerala (CPCRI, 1994).

Palmicultor sp. was found to occur on the emerging fronds on coconut congregating in large numbers causing delayed emergence, yellowing and retarded growth. The larval period was 21.6 ± 1.8495 days for females, and the adult females and males lived for 18.27 ± 2.7156 and 2.8 ± 1.2293 days respectively (Jalaluddin and Mohanasundaram, 1993). It also attacks the unopened spadix and emerging inflorescence causing drying of inflorescence and shedding of buttons. On an average 25.9 per cent of bunches were affected in palms infested with mealy bugs (CPCRI, 1994). Barren bunches are often seen on mealy bug affected palms (Radhakrishnan, 1987). CPCRI (1994) recorded an average annual yield of 42.4 nuts palm^{-1} in mealy bug affected palms as against 46.4 nuts palm^{-1} in healthy ones.

2.3.2 Management

2.3.2.1 Chemical control

According to Radhakrishnan (1987) one spraying with dimethoate could check the pest in the inflorescence only for a short period of 30 days. Repeated spraying of carbaryl 0.2 per cent at 2-3 weeks interval on the heart leaves, spathe, buttons and nuts were found to be effective against CBM (John, 1988). CPCRI (1994) recommended the application of 0.1 per cent dimethoate or monocrotophos for effective control of mealy bug.

Jalaluddin *et al.* (1991) recorded cent per cent mortality of adult females of *Palmicultor* sp. 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 leaves of coconut in the laboratory.

Dakhinamurthy and Giridharan (1976) recommended soil application of thiodemeton (Disyston) 0.5 g a.i. plant^{-1} and methyldemeton (Metasystox) 0.05 per cent for the control of *Pseudococcus longispinus* T. infesting coconut seedlings.

2.3.2.2 Biological control

The common predators *Pullus* sp. (Coccinellidae) and *Spalgis* sp. (Lycaenidae) were observed feeding of coconut mealy bug. Natural enemies of coconut mealy bug newly recorded were *Scymnus* sp. (*Coccinellidae*), *Berginus maindroni* Grouvelle (Mycetophazidae), *Dicrodiplosis* sp. (*Cecidomyiidae*), *Cacoxenus* sp. (*Drosophilidae*) and *Homalotylus oculatus* Girault (*Encyrtidae*)(CPCRI, 1994).

2.3.3 Other mealy bugs infesting coconut

Williams (1981) reported *P. palmarum* infesting coconut in Micronesia, Hawaii and Bahamas. Williams (1994) reported distribution of Pacific coconut mealy bug *Dysmicoccus cocotis* (Maskell) and *Dysmicoccus finitimus* sp. nov. in Southern Asia.

A mealy bug *Rhizoecus* sp. was found infesting roots of coconut in the sandy tracts of Thiruvananthapuram district (Nair *et al.*, 1980).

2.4 Other sucking pests infesting coconut

Coconut scale *Aspidiotus distructor* Sign. (Diaspididae), *Lepidosaphes megregori* Banks (Diaspididae), plant hopper *Protista moesta* (Westwood) (Derbidae) lacewing bug, *Stephanitis typicus* (Dist.) (Tingidae) were reported as minor pests of coconut (Nair, 1978).

Jalaluddin and Mohanasundaram (1990) reported attack of coconut aphid (*Cerataphis variabilis* H.R.L.) in the nursery and suggested its management using methomyl (0.025 %).

2.5 Management of sucking pest complex in other crops

Sudhakar *et al.* (1998) evaluated certain selected insecticides against sucking pest complex on brinjal viz., whitefly [*Bemisia tabaci* (Genn.)] jassid (*Amrasca biguttula biguttula* (Ishida)) and redspider mite (Tetranychus sp.). Rinfenthrin 0.01 per cent recorded the highest percent reduction of whiteflies and jassids while carbaryl + dicofol combination resulted in the highest per cent reduction of mites.

Endosulfan + triazophos (500 + 500 g a.i. ha^{-1}) gave effective control of sucking pest complex (*Aphis gossypii* Glover, *A. bigutulla bigutulla* and *B. tabaci*) of 'H6' cotton (*Gossypium hirsutum* L.) (Patel *et al*., 1998).

A new type of thiourea derivative (GA 106630 (diafenthiuron) was reported to be effective in the control of sucking pest complex in cotton and other crops (Streibert, 1998).

Materials and Methods

3. MATERIALS AND METHODS

Coconut palms of variety West Coast Tall (WCT) in the Instructional Farm, Vellayani, having medium height, receiving fertilizers and manures as per Kerala Agricultural University recommendations (KAU, 1996) were selected for the conduct of experiments and observations. The palms with more or less uniform infestation of the three sucking pests viz., coconut eriophyid mite (CEM), coconut coreid bug (CCB) and button mealy bug (CBM) were selected.

3.1 Nature and extent of damage by sucking pests

3.1.1 Visual observation

The symptoms and damage caused by the three sucking pests individually and in combination were properly observed and documented.

3.1.2 Nut loss / Nutfall

Nutfall from six selected palms having more or less uniform infestation of sucking pests *viz.*, CEM, CCB and CBM was regularly monitored for one year starting from May 2000. The emerging bunches were serially labelled starting with No. 1. The buttons/ nuts fallen from each bunch due to sucking pest attack were counted and recorded at weekly intervals. The fallen nuts collected from the basins of the selected palms were taken to the laboratory for observations. The perianth of each button was removed and examined for infestation of sucking pests.

The presence of characteristic yellowish white or brown patches beneath the perianth indicated the presence of CEM attack. Coreid bug infested buttons show characteristic brownish sunken furrow beneath the perianth and crinkles at the points of feeding. Combined infestation if any were also recorded indicating the combination of attack. The fallen nuts exhibiting symptoms of attack of any of the sucking pests, either singly or in combinations were deemed to have fallen due to the attack of the pest(s). Fallen nuts without any symptoms of attack of the sucking pests were assumed to have fallen naturally hence the number was excluded from the study. Palm wise nutfall for each month due to sucking pest infestation was totalled and average of six palms was expressed as mean monthly nutfall. Data on mean monthly relative humidity, maximum temperature, minimum temperature, mean temperature and total rainfall were collected from the meteorological division of Department of Agronomy, College of Agriculture, Vellayani. Correlation Analysis was done to investigate the possible relationship of nutfall due to sucking pests with weather parameters.

3.1.3 Damage on retained nuts

The nuts retained in each labelled bunch were closely examined at the time of harvest and the symptoms of attack of the sucking pests individually or in combinations were described. The total number of retained nuts, the number of nuts infested with CEM, CCB and CBM were recorded on each bunch emerged from April 2000 to March 2001.

3.1.3.1 Yield loss in retained nuts

In order to assess the yield loss in retained nuts, the methodology followed by Julia and Mariau (1979) was adopted with modification to accommodate the attack of CCB along with CEM. A scale was developed in modification of the scale developed by Julia and Mariau giving 1-5 scores.

Score 1 No Damage

Score 2 1-10 per cent surface damage by CEM, 1-3% surface damage by CCB
Nut size not affected

Score 3 11-25% damage by CEM, 3-6 % damage by CCB
Nuts much smaller

Score 4 26-50 % damage by CEM, 6-9% damage by CCB
Nuts smaller with some distortion

Score 5 51-100% damage by CEM, >9 % damage by CCB
Nuts very small and greatly distorted.

Eight nuts belonging to each score were selected at random from the nuts harvested from the selected WCT palms. Total forty nuts were selected for observation and the following parameters were noted.

1. Surface area damage (cm^2)
2. Weight of whole nuts (g)
3. Circumference of nuts (cm)

   Top

   Center

   Bottom
4. Length of nuts (cm)
5. Weight of dehusked nut (g)
6. Circumference of dehusked nut (cm)
7. Weight of husk (g)
8. Thickness of kernel (cm)
9. Volume of nut water (ml)
10. Weight of nuts after water is removed (g)
11. Weight of copra (g)

3.1.3.1.1 Method of assessing surface area damage

The nut surface was divided into 3 faces and the surface area of each face was drawn on transparent paper using marker pen. The area damaged by each pest was also plotted separately. The area was found using a graph paper and expressed in cm^2.

3.1.3.1.2 Method of copra preparation

The broken dehusked nuts were dried under sun for 4-5 days for making copra till moisture was reduced to 4-5 per cent.

3.1.3.1.3 Statistical analysis

Each nut character was analysed within the scores 1–5 using simple ANOVA. Correlation analysis was performed to understand the relationship between surface damage by combined infestation of CEM and CCB and yield loss.

3.2 Evaluation of pesticides

3.2.1 Spraying of pesticides

Thirty palms of var. WCT having more or less uniform infestation of the three sucking pests CEM, CCB and CBM were selected in the Instructional Farm, Vellayani for the conduct of experiment. Each palm was labelled indicating treatments received and replication. Five bunches in each palm were labelled starting from the top excluding just opened ones. The experiment was laid out in completely randomised design (CRD) with ten treatments replicated thrice.

Treatments

1. Dimethoate 0.05 %
2. Triazophos 0.05%
3. Phosalone 0.05%
4. Endosulfan 0.1%
5. Neem oil – Garlic emulsion 2 %
6. Dimethoate 0.05 % + Wettable sulphur 0.4 %
7. Quinalphos 0.05% + Wettable sulphur 0.4%
8. Endosulfan 0.1 % + Wettable sulphur 0.4 %
9. Neem oil garlic emulsion 2 % + Endosulfan 0.1 %
10. Control

3.2.1.1 Preparation of spray solution

The insecticides were prepared to the required concentration. Six litres of spray fluid was prepared for each treatment.

3.2.1.2 Preparation of neem oil –garlic emulsion (2%)

For preparing one litre of neem oil garlic emulsion, five gram of ordinary bar soap was dissolved in 30 ml of lukewarm water. To this 20 ml of neem seed oil was added and stirred well. Twenty gram of garlic was made into a paste mixing with 50 ml of water. The garlic extract was added to neem oil soap solution and made upto one litre.

The pesticides were sprayed on all bunches except the just opened one. Two litres of spray fluid were used for each palm. Spraying was done using a rocker sprayer. The spray fluid was directed to the bunches using cone nozzle from the crown of the palm. Spraying was done upto the point of complete wetting of the buttons.

The effectiveness of the pesticides was evaluated by assessing the CEM population, nut loss due to the sucking pest infestation and different levels of damage on retained nuts.

3.2.2 Mite population assessment

Five month old CEM infested nuts were taken at random from all the treated palms one week after spraying, one month after spraying and 3 months after spraying. The population was assessed using the cello tape embedding technique developed by Girija *et al.* (2001). Population of mites under each tepal was counted immediately after removing the perianth without disturbing the colonies. Transparent cello tape of one inch width was used for this purpose. Cello tape was pressed gently over the mite colony to embed the whole population including eggs, nymphs and adults to the cello tape. Area of each colony was marked on the cello tape using a marker pen and was measured using graph paper. Cello tape embedded with mite colonies was pasted separately on microscopic slides. Population of eggs, nymphs and adults were counted in a calibrated microscope. Counts were taken from the randomly selected microscopic fields and the mean population per field was worked out. This was then projected to the actual area of the nut surface occupied by the colonies using the following formula.

$$\text{Mean population of mites in a colony} = \frac{\text{Mean population of mites in a microscopic field} \times \text{Area of mite colony (cm}^2\text{)}}{\text{Microscopic area (cm}^2\text{)}}$$

3.2.3 Nut loss

Nutfall in the labelled bunches of the treated palms due to the sucking pest infestation were recorded at weekly intervals as described in 3.1.2. The total number of barren /stunted/ dried retained nuts were recorded in treated bunches. Nut loss was calculated as the total of fallen nuts and the retained nuts which were completely barren/stunted or dried up.

3.2.4 Damage on retained nuts

3.2.4.1 CEM infestation – Mean intensity score

Score 1	Nuts with no mite damage
Score 2	Nuts with superficial mite damage (1-10%)
Score 3	Nuts with significant mite damage but not much smaller (11-25 %)
Score 4	Nuts with significant mite damage, nuts smaller with some distortion (26-50 %)
Score 5	Nuts very heavily attacked, very reduced in size and often greatly distorted (51-100%)

Mean intensity score was found by

$$\text{MIS} = \frac{\Sigma\ (\text{Score X number of nuts in that score})}{\text{Total number of nuts}}$$

Mean intensity score of each bunch was worked out.

3.2.4.2 CCB infestation – Percentage of nuts infested

Retained nuts showing CCB infestation were recorded from each labelled bunch. The percentage of total nuts infested by CCB was worked out.

3.2.5 Statistical Analysis

All the values were analysed using simple CRD after square root transformation. Mean intensity score was analysed as a factorial experiment with treatments and bunches as two factors.

3.3 Testing of entomo/acaropathogenic fungi for infectivity of CEM, CCB and CBM

Six entomopathogens viz., *Beauveria bassiana* (Balsamo) Vuill, *Metarhizium anisopliae* (Metchnikoff) Sorokin, *Fusarium pallidoroseum* (Cooke) Sacc., *Rhizopus oryzae* Went and Gerlings, *Paecilomyces farinosus* Dickson and *P. lilacinus* (Thom.) Samson were tested for infectivity against the sucking pests. Against CEM, three fungal cultures viz., *Verticillium chlamydosporium* (Goddard), *V. suchlasporium* W. Gams and Dackman and *Exiophiala psiciphila* Mc Ginnis and Ajello received from Tamil Nadu Agricultural University, Coimbatore, were also tested.

3.3.1 Screening against CEM

Mite infested nuts from the fifth bunch was excised along with rachis and fed with 10 per cent sucrose solution kept in plastic vials. The vials were kept on an iron frame provided with ant well.

The fungal cultures were grown on potato dextrose agar (PDA), in conical flasks. Spore suspensions prepared in sterile water were sprayed on the nut, completely wetting the nuts. Experiment was done as CRD with three replications.

The treated nuts were observed for mite population three days, five days and seven days after spraying. The mite population in 4 mm^2 area was estimated for all treatments and untreated control. Mites from treated nuts were observed under microscope for fungal infection (mycelial growth).

3.3.1 Per cent mortality of CEM by potential pathogens

The acaropathogenic fungus *V. suchlasporium* found to be pathogenic to CEM in the present study was compared to *H. thompsonii*, the specific pathogen of CEM. Spore suspensions of both pathogens were sprayed on to the CEM infested nuts. The experiment was replicated ten times and observations were recorded five days and seven days after spraying. The per cent mortality was estimated in each replication. The mean corrected mortality was found using Abbot's formula.

Corrected mortality (Abbot, 1925)

$$= \left(\frac{T - C}{100 - C} \right) x\ 100$$

T = mortality of treatment, C = Mortality in control

3.3.2 Screening against CCB

The nymphs and adults collected from the field or reared in the laboratory were used for the experiment. Spore suspension of the following entomopathogenic fungi viz., *B. bassiana, M. anisopliae, F. pallidoroseum, R. oryzae, P. farinosus* and *P. lilacinus* was sprayed to the nymphs. The adults were allowed to crawl over the culture for one hour. The percentage mortality was calculated. The pathogenicity was confirmed by observing Koch's postulates.

3.3.3 Screening against CBM

Tepals of coconut with high population of CBM were sprayed with the spore suspension of the above mentioned fungi. Mortality if any was recorded at regular intervals.

3.4 Survey on entomo / acaropathogenic fungi associated with bunch infesting sucking pests

A random survey was undertaken in the Instructional Farm, College of Agriculture, Vellayani to identify potent entomopathogenic fungi infecting coconut eriophyid mite, CCB and CBM.

CEM infested nuts were collected at random from the infested palms, at regular intervals. The tepals were removed and mite colonies were observed carefully under microscope for possible fungal infection. The tepals having mite colonies were also carefully examined.

In case of CCB and CBM, infested palms were observed at regular intervals for dead and mummified insects with fungal cover adhering to the nuts. Mass rearing of the insects was also done in laboratory conditions to record disease incidence if any.

3.4.1 Diagnosis of microbial infections

The infected mites were mounted in Hoyer's medium or stained with cotton blue in Lactophenol and examined carefully under microscope.

In case of the other two pests viz., CCB and CBM, the signs and symptoms of dying insects and postmortem changes were observed.

3.4.2 Isolation of pathogens

The fungal pathogens of mite were isolated by two methods.

3.4.2.1 Using cello tape

The infected mites were embedded on the cello tape piece. These pieces were surface sterilized using 0.1 per cent Mercuric chloride along with mites adhered to them and washed in two changes of sterile water and were transferred to PDA slants.

3.4.2.2 Direct transfer

The infected mites were individually picked under a microscope and placed immediately in PDA slants under sterile conditions. In the case of other pests, the dead insects were surface sterilized and placed in PDA in sterilized petridishes.

After one or two days when there is enough mycelial production, the fungus was brought to pure culture. Pathogenicity tests were conducted. The procedure followed was same as that described in 3.4.1 and 3.4.2.

3.4.3 Identification of the pathogen

The isolated fungal cultures in PDA slants were sent to Indian Type Culture Collection, IARI, New Delhi for species level identification.

3.5 Survey on egg parasitoids of CCB

A survey was conducted for egg parasitoids of CCB for a period from May 2000 to September 2001. Egg masses of CCB were collected from the field, kept in polythene bags and observed for nymph/parasitoid emergence.

3.5.1 Identification of parasitoids

The parasitoids obtained from CCB egg masses were sent to Systematic Insect Laboratory, University of Calicut, Kerala for identification.

3.5.2 Rearing of parasitoids

An attempt was made to develop laboratory rearing technique for the parasitoid and study the biology of the pest. Egg masses of CCB (*P. rostratus*), red cotton bug (*Dysdercus cingulatus* (Fb.)) and rice bug (*Leptocorisa acuta* (Tunb.)) were used for study. Coconut coreid bug and *D. cingulatus* were reared in the laboratory and fed with mature guava fruits and soaked cotton seeds respectively for collecting egg masses. Egg masses of rice bug were collected from the field.

Ten eggs of each pest were put in glass vials. Ten gravid females of the two parasitoids were released to individual glass vials. The experiment was replicated five times. Vials were kept and observed for nymph /parasitoid emergence. Honey-water solution (1: 1 mixture) streaked on the inner surface of glass vials served as food for the parasitoids.

Results

4. RESULTS

4.1 Nature and extent of damage by sucking pests

4.1.1 Visual observation

4.1.1.1 Damage by coconut eriophyid mite (*Aceria guerreronis* Keifer)

The coconut eriophyid mite (CEM) (Plate 1A) is a small microscopic organism measuring about 250 μ colonizing under the tepals of young coconut buttons. Thousands of mites were seen in colonies sucking sap form the soft tender meristematic zone. The infestation started 45-60 days after fertilization of buttons.

The first visual symptom appeared as yellowish white 'V' shaped marking (Plate 1B) extending below the perianth. When the tepals were removed irregular pale to light brown patches harbouring colonies of mites became visible. Surface of affected nuts became rough due to desapping and later turned brown in colour (Plate 1C). Epidermal cells in attacked portion get hardened and further distorted growth resulted in appearance of longitudinal cracks in the affected portion often showing 'T' like appearance (Plate 1D). Button fall started before the appearance of external symptoms and extended upto tender nut stage.

Some mite affected buttons were retained in the bunch and showed varying degrees of visible external symptoms depending on the severity of infestation as described by Juliau and Mariau (1979). In severely affected nuts

Plate 1 ***Coconut eriophyid mite (CEM) and its damage symptoms***

A. *Eggs, nymphs and adults of CEM*

B. **CEM infested nut with 'V' shaped yellowish white marking below the perianth**

C. **CEM infested nut with 'V' shaped brown marking below the perianth**

D. **'T' cut formed due to CEM attack**

E. **Mature nut with large wound and distortion due to CEM attack**

PLATE 1

A

B

C

D

E

the 'T' shaped cracks that had appeared in the early stages, developed into large cracks (Plate 1E).

4.1.1.2 Damage by coconut coreid bug (*Paradasynus rostratus* Distant.)

Coconut coreid bug (CCB) infestation was noticed on coconut buttons starting from the opening of the inflorescence and was found to extend upto five to six months. The adults and nymphs of coreid bug (Plate 2A, B, C) suck sap from tender portions of coconut. Desapping of buttons by the nymphs and adults of the bug was found to cause severe nutfall. Young fallen nuts with CCB attack did not show symptoms on the exposed nut surface. Dark sunken spots could be observed on the tender portion of the button below the perianth corresponding to the point of feeding (Plate 2D). Deep fissures were observed in some of the fallen nuts. CCB infested nuts that were retained in the bunches were found to develop varying degrees of surface damage, as deep constrictions on the husk (Plate 2E). Damage on a retained nut at the time of harvest is shown in Plate 2F.

4.1.1.3 Damage by coconut button mealy bug (*Pseudococcus* sp. and *Palmicultor* sp.)

Coconut button mealy bugs (CBM) were noticed colonising under the tepals of developing buttons, feeding from the perianth and tender portion of the nuts (Plate 3A, B, C, D). Infestation was noticed on nuts of different stages of growth starting from inflorescence stage. Development was found retarded resulting in stunted nuts either green or dried up (Plate 3E). Some affected nuts turned entirely barren. Bunches at the time of harvest (10-11 months old) were found to have both full sized healthy nuts as well as mealy

Plate 2 Coconut coreid bug (CCB) and its damage symptoms

A. Adult of CCB

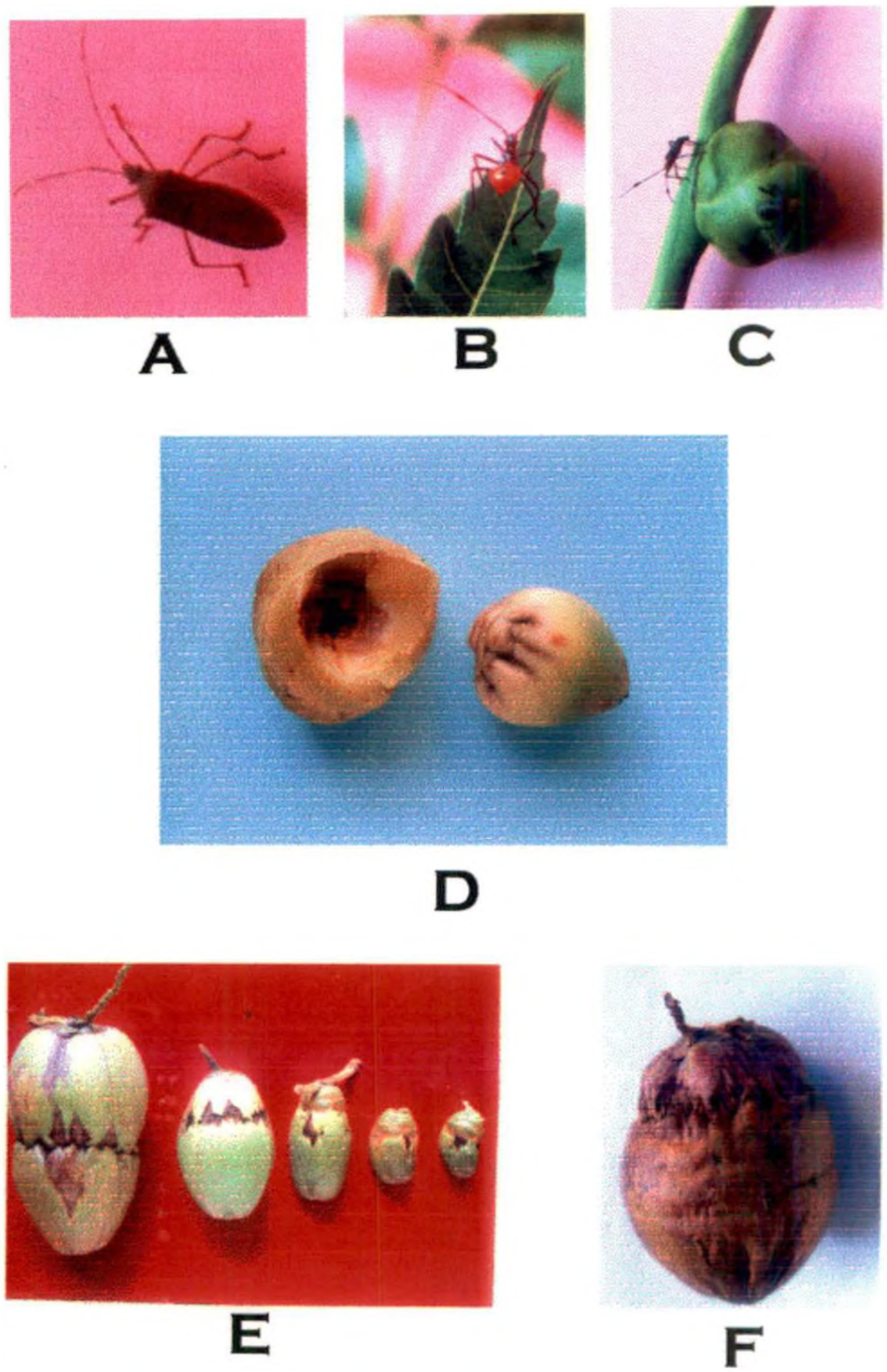
B, C. Nymphs of CCB

D. Fallen nut with damage symptom of CCB

E. Nuts at different stages of development showing damage symptoms of CCB attack

F. Mature nut with damage symptom of CCB

PLATE 2



bug affected stunted ones (Plate 3F). Ant colonies were observed constantly associated with CBM.

4.1.1.4 Damage by sucking pest complex

All the palms selected for observation exhibited combined attack of CEM, CCB and CBM. Various combinations of the three sucking pests viz., CEM and CCB; CEM and CBM; CCB and CEM; CEM, CCB and CBM were observed in individual nuts as well as in bunches. Both simultaneous and sequential attack of sucking pests were also observed.

4.1.1.4.1 Combined infestation of CEM and CCB

Combined attack of CEM and CCB was the most predominant combination observed. This combination often resulted in nutfall. Fallen nuts exhibited the symptoms of attack of both the pests (Plate 4A, B). Nut fall due to this combined infestation was observed only in coconut bunches of age two months and above. The nuts that survived the combined attack were retained with surface damage and distortion.

4.1.1.4.2 Combined infestation of CEM and CBM

Attack of CEM and CBM was observed together in individual nuts as well as in different nuts of the same bunch. Eventhough simultaneous presence of the two pests were observed in some of the retained nuts, fallen nuts showing their combined presence was less frequent. Retained nuts suffering from the combined attack of these two pests were either completely stunted or developed into undersized nuts with symptoms of attack of both (Plate 4 C, D).

Plate 3 Coconut button mealybug (CBM) and its damage symptoms

A. **Stunted nuts with CBM feeding below perianth**

B. **CBM inside tepals**

C. **CBM enlarged view (Dorsal side)**

D. **CBM enlarged view (Ventral side)**

E. **Damaged bunch showing stunted or barren nuts**

F. **Bunch at the time of harvest having both healthy mature nut and mealy bug affected stunted nuts**

PLATE 3

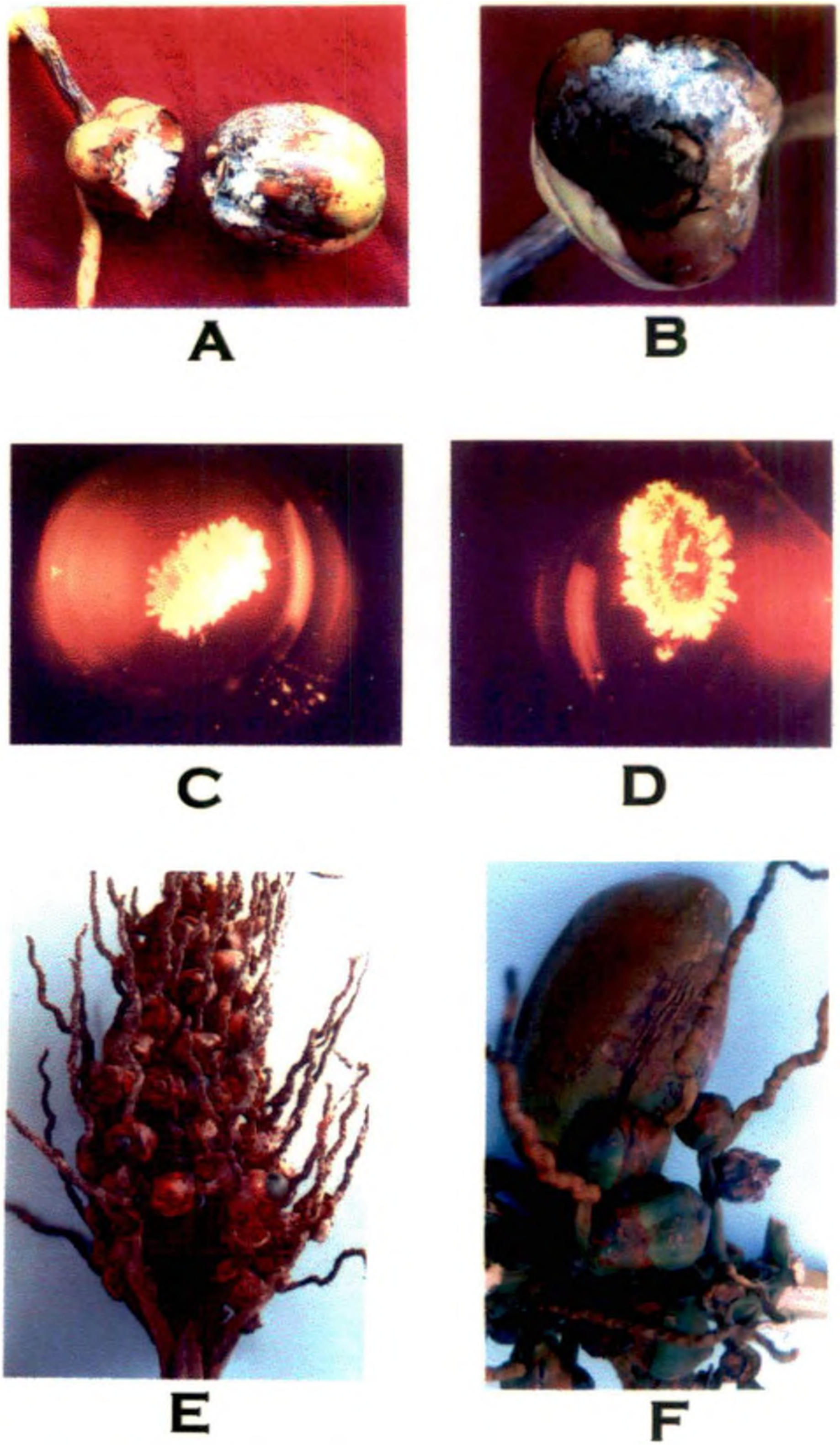


Plate 4 Combined attack of sucking pests

A. Fallen nuts exhibiting damage of combined attack of coconut eriophyid mite and coconut coreid bug

B. Gummosis in nuts attacked by coconut eriophyid mite and coconut coreid bug

C. Distorted nut showing damage symptoms of coconut eriophyid mite and coconut button mealybug

D. Distorted nut with coconut button mealybugs inside tepals

PLATE 4

A

B

C

D

4.1.1.4.3 Combined infestation of CCB and CBM

Combined attack of CCB and CBM was rarely observed. Combined infestation of the pests resulted in stunting and distortion of retained nuts.

4.1.1.4.4 Combined infestation of CEM, CCB and CBM

Combined attack of these three sucking pests was observed in individual nuts and bunches Retained nuts were found greatly distorted (Plate 5A, B) and often turned barren with no internal contents (Plate 5C, D). Symptoms and damage by the combined infestations on a bunch (Plate 5E) and a palm are also shown (Plate 5F).

4.1.2 Nutfall due to sucking pest complex infestation

Nutfall from the palms infested with the sucking pest complex was recorded as described in 3.1.2. Out of the total nutfall, those showing symptom of attack of CEM, CCB and CEM & CCB were recorded separately (Table 1). Since the fallen nuts with combined infestation of mite and coreid bug (MC) showed symptoms of attack of both, the total number of fallen nuts showing symptoms of mite infestation (M + MC) and coreid bug attack (C + MC) are also given. Eventhough much nutfall was observed during the first month after bunch opening, the data was not recorded since 70 per cent of total nuts naturally fall during this period.

The presence of mealy bug alone or in combination with other pests in fallen nuts was negligible and hence not shown in the table.

Significant difference was found to exist in nutfall caused in different months, by sucking pest infestation singly or in combination, except in case

Plate 5 Damage symptoms of sucking pest complex infestation

A. **Mature nut exhibiting damage by sucking pest complex**

B. **Distorted nut with symptoms of coconut eriophyid mite, coconut coreid bug and button mealybug**

C. **Barren nut formed due to sucking pest complex infestation**

D. **Comparison of healthy and barren nut**

E. **Bunch showing damage symptoms of sucking pest complex infestation**

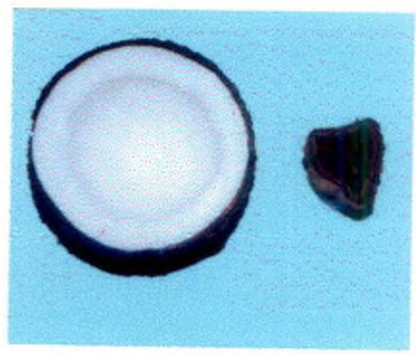
F. **Palm showing damage symptoms of sucking pest complex infestation**

PLATE 5

A

B

C



D

E

F

Table 1 Mean monthly nutfall due to infestation of the sucking pests

Month	Mean number of fallen nuts / palm					
	M	C	MC	T	M + MC	C + MC
May 2000	3.20 (2.05)	1.32 (1.52)	0.00 (1.00)	4.66 (2.38)	3.20 (2.05)	1.32 (1.52)
June 2000	3.98 (2.23)	0.14 (1.07)	0.14 (1.07)	4.31 (2.31)	4.18 (2.28)	0.30 (1.14)
July 2000	5.18 (2.49)	2.92 (1.98)	0.00 (1.00)	8.86 (3.14)	5.18 (2.49)	2.92 (1.98)
August 2000	2.08 (1.75)	2.40 (1.84)	2.15 (1.78)	7.47 (2.93)	4.56 (2.36)	5.09 (2.47)
September 2000	3.47 (2.11)	5.64 (2.58)	2.08 (1.76)	12.64 (3.69)	6.14 (2.67)	8.59 (3.09)
October 2000	3.71 (2.17)	3.58 (2.14)	4.46 (2.34)	13.25 (3.77)	8.81 (3.13)	8.52 (3.08)
November 2000	1.41 (1.55)	5.88 (2.62)	5.83 (2.61)	13.47 (3.80)	7.37 (2.89)	11.83 (3.58)
December 2000	1.86 (1.69)	5.54 (2.56)	6.24 (2.69)	14.88 (3.98)	8.88 (3.14)	12.44 (3.67)
January 2001	1.85 (1.69)	2.46 (1.86)	3.27 (2.07)	8.03 (3.01)	5.47 (2.54)	5.91 (2.63)
February 2001	2.46 (1.86)	0.53 (1.24)	1.15 (1.47)	4.38 (2.32)	3.76 (2.18)	1.69 (1.64)
March 2001	2.24 (1.80)	0.42 (1.91)	0.46 (1.21)	3.21 (2.05)	2.73 (1.93)	0.84 (1.36)
April 2001	1.94 (1.72)	1.06 (1.44)	0.14 (1.07)	3.29 (2.07)	2.13 (1.77)	1.19 (1.48)
CD (0.05)	NS	(0.825)	(0.526)	(0.636)	(0.527)	(0.762)

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

M	Fallen nuts with symptoms of CEM alone
C	Fallen nuts with symptoms of CCB alone
MC	Fallen nuts with symptoms of both CEM and CCB
T	Total fallen nuts with symptoms of CEM, CCB and both
M + MC	Fallen nuts with symptoms of CEM alone and in combination
C + MC	Fallen nuts with symptoms of CCB alone and in combination

of nutfall caused by mite alone. However the total fallen nuts infested by mites (i.e., M + MC) showed significant difference.

4.1.2.1 Nutfall due to CEM infestation

There was no significant difference between months in case of nutfall due to mite alone. Significant difference in nutfall was observed between monthly averages of fallen nuts showing symptoms of damage of CEM (M + MC). Maximum nutfall was observed in December (8.88 nuts palm^{-1}) which was on par with that of October, November and September. Minimum nutfall was noticed in April (1.06 nuts palm^{-1}) (Table 1).

4.1.2.2 Nutfall due to CCB infestation

The mean number of fallen nuts showing symptoms of CCB alone was maximum in November (5.88 nuts palm^{-1}) and was on par with that of September, December, October, July, January and August. Minimum fall was recorded in the month of June (0.14 nuts palm^{-1}). Maximum number of fallen nuts showing symptoms of coreid bug (C + MC) was recorded in December (12.44 nuts palm^{-1}) and was on par with that of November, September and October.

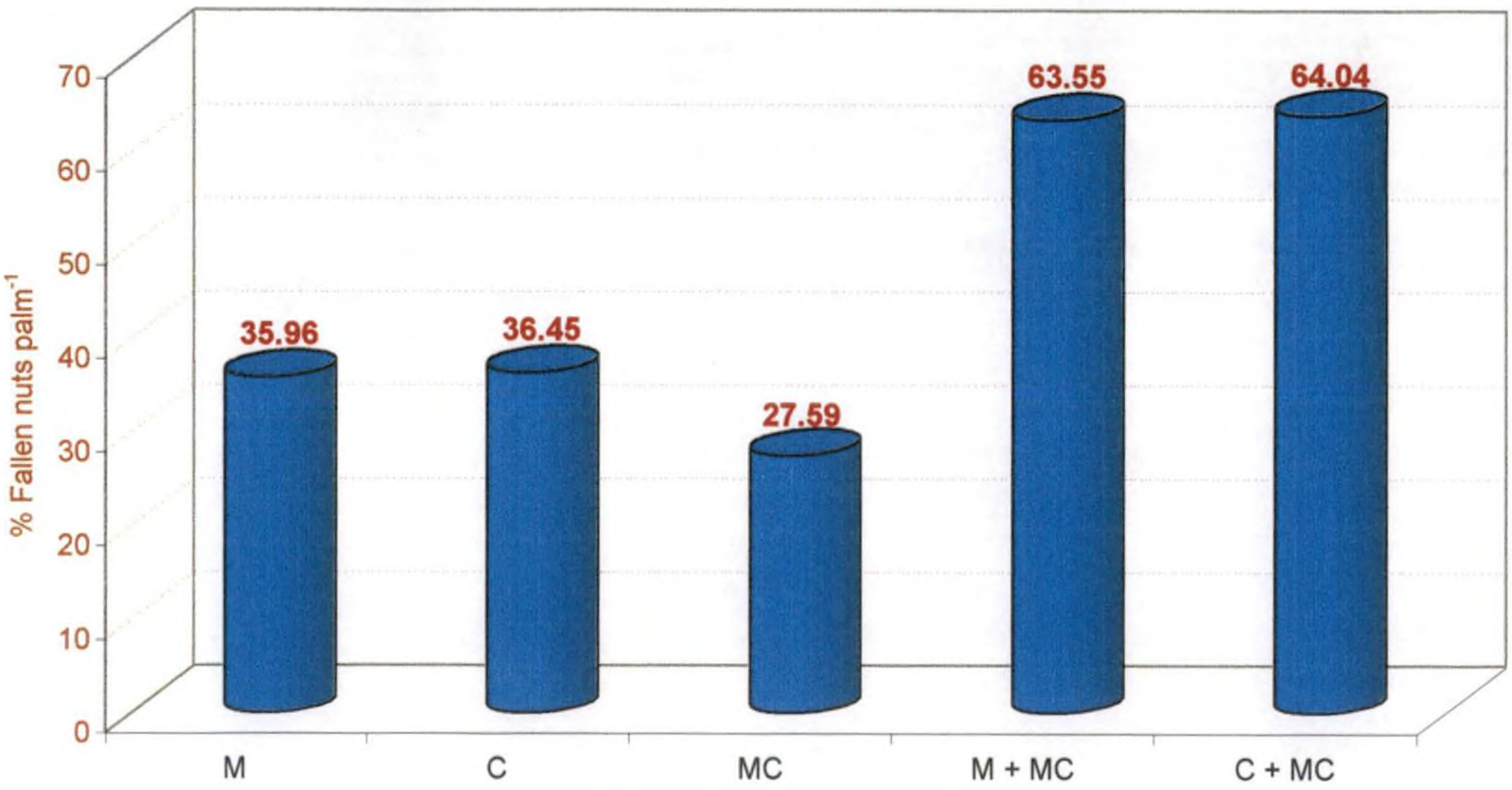
4.1.2.3 Nutfall due to combined infestation of CEM and CCB

Significant difference was found to exist between months in case of fallen nuts showing the symptoms of both the pests (MC) with maximum fall in December (6.24 nuts palm^{-1}) that was on par with that of November and October. Minimum nutfall was noticed in July and May.

4.1.2.4 Total nutfall due to sucking pest infestation

Total nutfall (T) was maximum in December (14.88 nuts palm^{-1}) and was on par with that of November, October and September. Nutfall due to the sucking pests was minimum in March (3.21 nuts palm^{-1}).

Fig. 1 Summary of nutfall due to sucking pests for one year from May 2000 to April 2001



M	Fallen nuts with symptoms of CEM alone
C	Fallen nuts with symptoms of CCB alone
MC	Fallen nuts with symptoms of both CEM and CCB
M + MC	Fallen nuts with symptoms of CEM alone and in combination
C + MC	Fallen nuts with symptoms of CCB alone and in combination

Out of the total nutfall (101.5 nuts palm^{-1} year^{-1}) 36.45 per cent was attributed to coreid bug alone and 35.96 per cent to mite alone whereas 27.59 per cent was due to the combined infestation of both the pests (Fig. 1). Damage symptoms of CCB was observed in 64.04 per cent of fallen nuts while that of CEM was observed in 63.55 per cent.

4.1.2.5 Correlation analysis

Results of correlation studies of nutfall due to sucking pest complex infestation with weather parameters are given in Table 2. Significant negative correlation was observed between fallen nuts showing infestation of both CEM and CCB and mean monthly minimum temperature (Fig. 2). The other weather parameters did not show significant correlation with the nutfall due to sucking pest complex.

4.1.3 Damage on retained nuts

The number of retained nuts bunch^{-1} in bunches that opened during April 2000 to March 2001 are presented in Table 3. Infestation percentage of CEM and CCB are also given.

Nut retention was minimum in bunches that opened during November and was on par with that of September, January, October and December during which period the percentage infestation of CEM ranged from 95.31 to 100 per cent whereas that by CCB ranged from 46.96 per cent to 100 per cent. Out of the total retained nuts 96.35 per cent showed damage symptoms of both the sucking pests.

Table 2 Correlation between weather parameters and nutfall

Weather parameters	× Nutfall			
	r values			
	MC	T	M + MC	C + MC
Relative humidity	0.2912	0.4642	0.4942	0.3641
Maximum temperature (^{0}C)	-0.2671	-0.4319	-0.4509	-0.3412
Minimum temperature (^{0}C)	-0.5823*	-0.3841	-0.4258	-0.4737
Mean temperature (^{0}C)	-0.5455	-0.5288	-0.5625	-0.5283
Total rainfall (mm)	0.0103	0.0418	0.0871	0.0029

*Significant at 5 % level

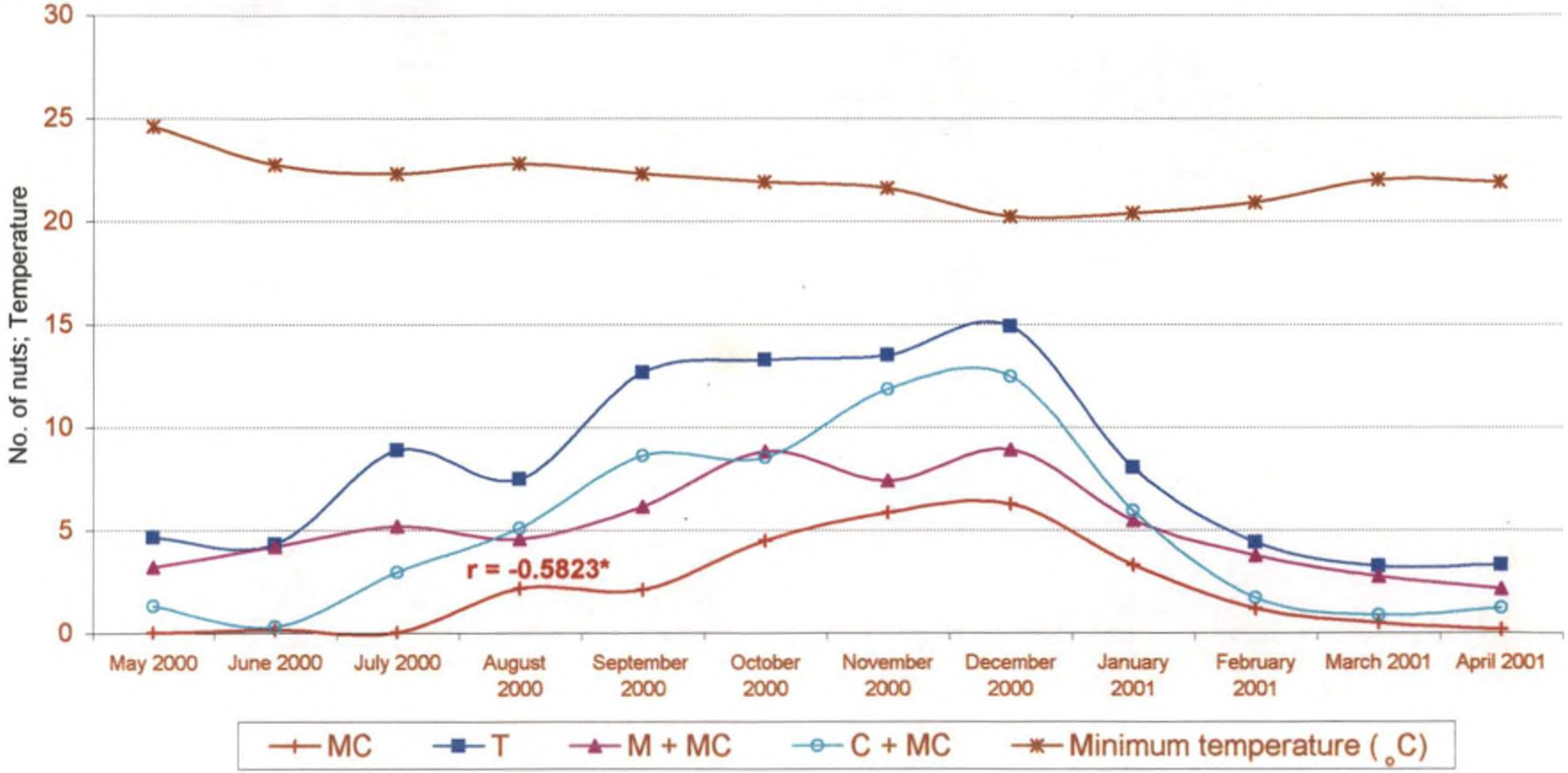
MC Fallen nuts with symptoms of both CEM and CCB

T Total fallen nuts with symptoms of CEM, CCB and both

M + MC Fallen nuts with symptoms of CEM alone and in combination

C + MC Fallen nuts with symptoms of CCB alone and in combination

Fig. 2 Relationship between minimum temperature and nut fall due to sucking pest infestation



MC	Fallen nuts with symptoms of both CEM and CCB
T	Total fallen nuts with symptoms of CEM, CCB and both
M + MC	Fallen nuts with symptoms of CEM alone and in combination
C + MC	Fallen nuts with symptoms of CCB alone and in combination

r : correlation coefficient

* significant at 5 % level

Table 3 Number and percentage of retained nuts in coconut bunches infested by sucking pests

Month of bunch opening	Total number of *retained nuts per bunch	CEM infested nuts		CCB infested nuts	
		No.	%	No.	%
April 2000	17.74 (4.33)	17.74 (4.33)	100.00	0.85 (1.36)	4.80
May 2000	14.96 (3.99)	14.96 (3.99)	100.00	2.66 (1.91)	17.78
June 2000	8.95 (3.15)	8.96 (3.15)	100.00	1.00 (1.41)	11.17
July 2000	10.28 (3.36)	9.98 (3.31)	97.08	4.57 (2.36)	44.45
August 2000	7.32 (2.88)	7.16 (2.86)	97.81	2.51 (1.87)	34.28
September 2000	3.21 (2.05)	3.21 (2.05)	100.00	2.69 (1.92)	83.80
October 2000	5.53 (2.56)	5.30 (2.51)	95.80	2.80 (1.95)	50.63
November 2000	2.15 (1.78)	2.15 (1.78)	100.00	2.15 (1.78)	100.00
December 2000	5.54 (2.56)	5.28 (2.51)	95.31	4.48 (2.34)	77.07
January 2001	5.26 (2.50)	4.80 (2.43)	92.96	2.47 (1.86)	46.66
February 2001	13.08 (3.75)	11.54 (3.54)	88.23	0.45 (1.21)	3.44
March 2001	10.95 (3.46)	9.74 (3.28)	88.95	0.45 (1.21)	4.11
CD (0.05)	(1.055)	(1.080)	-	NS	-

Figures in parentheses are transformed values $\sqrt{x+1}$
* Stunted / barren nuts were excluded

The infestation of mealy bug alone or in combination with other pests was observed in all barren / stunted nuts. The number of barren / stunted nuts was maximum in bunches that opened during November (10.81 nuts $bunch^{-1}$) and minimum in that opened during February (2.05 nuts $bunch^{-1}$) (Table 4).

4.1.3.1 Yield loss in retained nuts

The data on nut characteristics *viz.*, total surface area (cm^2), surface area damaged by CEM (cm^2), surface area damaged by CCB (cm^2), weight of whole nut (g), nut circumference (cm), nut length (cm), weight of dehusked nut (g), circumference of dehusked nut (cm), weight of husk (g), volume of nut water (ml), weight of dewatered nut (g), thickness of kernel (cm) and weight of copra (g) Scores 1-5 are presented in Table 5. Nuts belonging to the Scores 1-5 are shown in Plate 6A, B, C.

4.1.3.1.1 Total surface area

The total surface area of nuts differed significantly between scores except in case of Score 1 and 2, which were on par.

4.1.3.2 Weight of whole nut

The whole nut weight was maximum in Score 1 (1350.45g) and differed significantly from other scores. Score 2 and Score 3 were on par. Whole nut weight in Score 4 and 5 significantly differed from all the other scores and among each other. Minimum whole nut weight (725.77g) was recorded for Score 5.

Table 4 Barren / stunted nuts in coconut bunches infested by sucking pest complex

Month of bunch opening	No. of Barren / stunted nuts per bunch
April 2000	3.62 (2.15)
May 2000	4.16 (2.27)
June 2000	2.87 (1.97)
July 2000	3.91 (2.22)
August 2000	5.53 (2.56)
September 2000	6.56 (2.75)
October 2000	8.65 (3.11)
November 2000	10.81 (3.44)
December 2000	6.06 (2.66)
January 2001	6.30 (2.70)
February 2001	2.05 (1.75)
March 2001	2.93 (1.98)
CD (0.05)	(0.946)

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

Plate 6 Nuts belonging to score values 1 to 5 showing symptoms of combined infestation of CEM and CCB

A. Whole nuts representing score values 1 to 5 showing symptoms of combined infestation of CEM and CCB

B. Dehusked nuts belonging to Scores 1 to 5

C. Opened nuts belonging to Scores 1 to 5

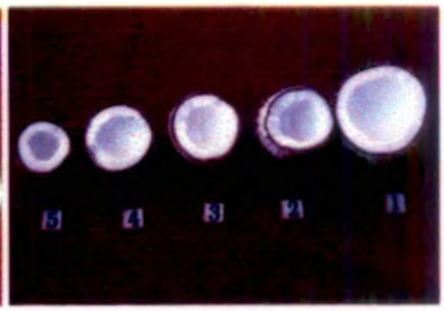
D. Comparison of Scores 1 and 5 – whole nuts

E. Comparison of Scores 1 and 5 – nuts cut opened

PLATE 6

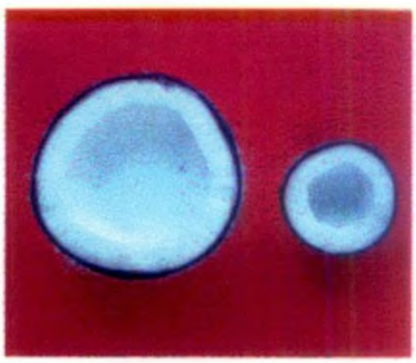
A

B



C

D



E

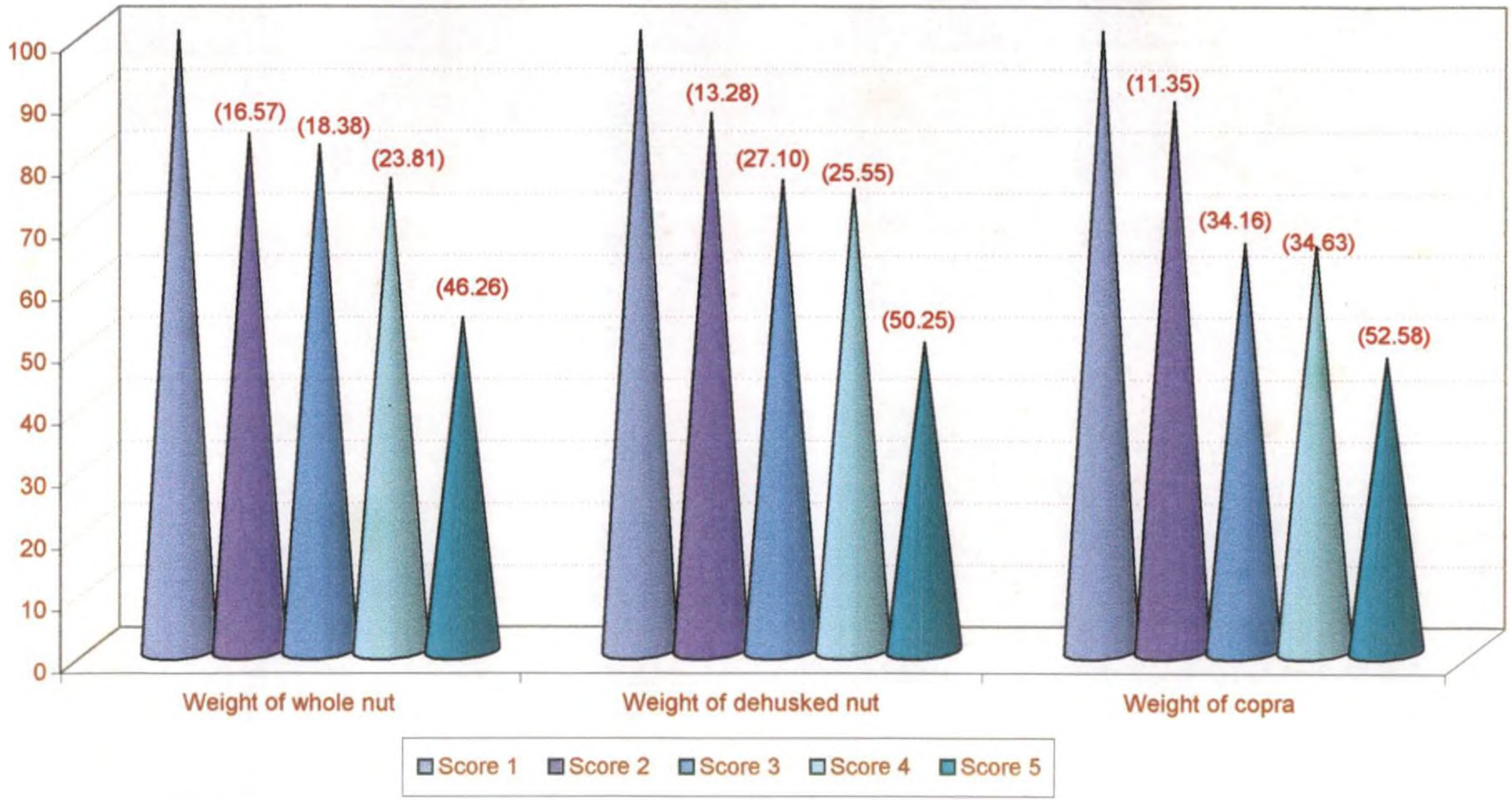
Table 5 Characteristics of nuts showing varying degrees of combined infestation of CEM and CCB

Nut characteristics	Scores					CD
	Score 1	Score 2	Score 3	Score 4	Score 5	
Total surface area in cm^2	1180.05 (34.37)	1087.94 (32.91)	983.48 (31.37)	815.85 (28.58)	526.86 (22.97)	(2.386)
Surface area damaged by CEM (cm^2)	5.61 (2.57)	101.23 (10.11)	179.37 (13.43)	277.60 (16.69)	434.72 (20.87)	(2.071)
Surface area damaged by CCB (cm^2)	2.54 (1.88)	19.95 (4.58)	48.13 (7.09)	56.26 (7.57)	62.02 (7.93)	(1.135)
Weight of whole nuts (g)	1350.45 (36.76)	1126.73 (33.58)	1102.24 (33.22)	1029.00 (30.10)	725.77 (26.95)	(2.978)
Nut circumference (cm) Top	42.76 (6.62)	37.98 (6.24)	40.59 (6.45)	31.95 (5.74)	30.34 (5.59)	(0.308)
" Centre	47.65 (6.98)	45.28 (6.80)	43.35 (6.66)	35.88 (6.07)	34.67 (5.97)	(0.242)
" Bottom	42.95 (6.63)	42.81 (6.62)	39.40 (6.36)	33.23 (5.85)	30.24 (5.58)	(0.320)
Nut length (cm)	27.83 (5.37)	24.66 (5.07)	25.16 (5.12)	20.66 (4.65)	21.42 (4.73)	(0.250)
Weight of dehusked nut (g)	596.92 (24.45)	517.61 (22.77)	435.18 (20.88)	444.38 (21.10)	296.95 (17.26)	(1.805)
Circumference of dehusked nut (cm)	32.85 (5.82)	31.64 (5.71)	28.53 (5.43)	28.58 (5.44)	24.43 (5.04)	(0.251)
Weight of husk (g)	683.87 (26.17)	603.67 (24.59)	663.09 (25.77)	564.11 (23.73)	431.22 (20.79)	(3.337)
Volume of nut water (ml)	192.92 (13.93)	126.19 (11.28)	86.52 (9.36)	115.75 (10.81)	53.78 (7.40)	(3.086)
Weight of dewatered nuts (g)	391.21 (19.80)	390.76 (19.79)	333.19 (18.28)	327.30 (18.12)	237.60 (15.45)	(1.471)
Thickness of kernel (cm)	1.29 (1.51)	1.22 (1.49)	1.15 (1.47)	1.19 (1.48)	1.26 (1.50)	NS
Weight of copra (g)	202.22 (14.26)	179.26 (13.43)	133.14 (11.58)	132.18 (11.54)	95.88 (9.84)	(0.632)

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

Score 1 : No Damage, by CCB, nuts very small and greatly distorted.

Fig. 3 Reduction in yield characters of nut belonging to different scores*



*Percentage reduction calculated taking nut characters of Score 1 as 100 %

Figures in parentheses denote per cent reduction over Score 1

4.1.3.3 Circumference of whole nuts

The top circumference of nuts in Score 1 was maximum (42.75 cm) and was on par with Score 2 and 3 whereas Score 4 and Score 5 were on par but differed significantly from all other scores.

The circumference at the middle portion of whole nuts between score 1, 2 and 3 did not show significant difference. Scores 4 and 5 differed significantly from other scores and were on par.

The bottom circumference in Scores 1, 2 and 3 were on par whereas Score 4 and 5 differed significantly each other and with other scores.

4.1.3.4 Length of whole nut

Maximum nut length (27.83 cm) was recorded in Score 1, which significantly differed from all other scores. Minimum nut length (21.42 cm) was observed in Score 5.

4.1.3.5 Weight of dehusked nuts

The weight of dehusked nuts of Score 1 and 2 were on par with a mean weight of 596.22 g and 517.61 g respectively. Score 2 and Score 3 showed significant difference while Score 3 and 4 were on par. Score 5 had minimum weight for dehusked nuts (296.95 g), which significantly differed from all the other scores.

4.1.3.6 Circumference of dehusked nuts

The circumference of dehusked nuts in Score 1 and Score 2 were on par and that of Score 3 and 4 were also on par. Mean circumference of 24.43 cm was observed in Score 5 and differed significantly from all other scores.

4.1.3.7 Weight of husk

Weight of husk was minimum in Score 5 (431.22 g) and was on par with Score 4 and differed significantly from other scores. Scores 1, 2 and 3 did not show any significant difference.

4.1.3.8 Volume of nut water

Volume of nut water was maximum in Score 1 (192.92 ml) and was on par with Score 2 (126.19 ml). Nut water content in Scores 2, 3 and 4 were on par. Score 5 had minimum nut water (53.78 ml) and differed significantly from other scores.

4.1.3.9 Weight of dewatered nut

Weight of dewatered nut was maximum in Score 1 (391.21 g) and was on par with Score 2 (390.76 g) whereas those of Score 3 and 4 were on par. Minimum nut weight was recorded for Score 5 (237.60 g) which differed significantly from all other scores.

4.1.3.10 Thickness of kernel

The thickness of kernel ranged from 1.26 to 1.29 cm in different scores with no significant difference.

4.1.3.11 Weight of copra

Significant difference in copra content was found between scores except in case of Score 3 and Score 4, which were on par. The maximum copra content (202.22 g) was observed in Score 1 while Score 5 had the least copra content (95.88 g).

4.1.3.12 Reduction in major yield components

Percentage reduction in economically important nut characters of coconut viz., weight of whole nut, weight of dehusked nut, and weight of copra in different scores were compared taking Score 1 as 100 per cent (Fig. 3).

Reduction in weight of whole nut, dehusked nut, and copra content was noticed in Scores 2-5. The nuts of Score 5 (Plate 6D, E) that suffered maximum damage by the sucking pests showed reductions of 47.04, 50.25, and 52.58 per cent for weights of whole nut, dehusked nut, and copra respectively.

4.1.3.13 Correlation analysis

The correlation studies revealed the existence of a negative correlation between surface damage due to CEM and CCB and economically important nut characters (Table 6).

As the area of pericarp damage increased, the nut characters such as weight of whole nut, dehusked nut, dewatered nut, nut water and copra content decreased. Significant negative correlation was obtained for these characters with r-value as -0.5813, -0.6465, -0.5791, -0.4788 and -0.8092 for mite damage and -0.522, -0.6437, -0.6383, -0.04221 and -0.8396 for CCB damage respectively.

4.2 Evaluation of pesticides against sucking pest complex

The effectiveness of pesticides was evaluated by assessing the CEM population, nut loss due to the sucking pest infestation and the levels of damage on the retained nuts in bunches.

Table 6 Correlation coefficient between the area of pericarp damaged (cm^2) by combined infestation of CEM and CCB and economically important nut characters

	× Nut characters	r value	
		CEM	CCB
Area of pericarp damaged by CEM and CCB in cm^2	Weight of whole nut	-0.5813**	-0.522**
	Weight of dehusked nut	-0.6465**	-0.6437**
	Weight of dewatered nut	-0.5791**	-0.6383**
	Volume of nut water	-0.4788**	-0.4221**
	Weight of copra	-0.8092**	-0.8396**

** Significant at 1 % degrees of freedom

4.2.1 Assessment of CEM population

The mean count of eggs, nymphs and adults of CEM, in nut samples collected from the palms treated with the pesticides recorded one week after spraying (WAS), one month after spraying (MAS) and 3 MAS are presented in Table 7.

4.2.1.1 Egg count

The egg count in treatments T_5 (neem oil-garlic emulsion 2%), T_6 (dimethoate 0.05 % + wettable sulphur 0.4 %), T_7 (quinalphos 0.05 % + wettable sulphur 0.4 %), T_8 (endosulfan 0.1 % + wettable sulphur 0.4 %), and T_9 (neem oil – garlic emulsion 2 % + endosulfan 0.1 %) was significantly lower than control when observed 1 WAS. One month after spraying the egg count in treatments T_5, T_9, T_6 and T_7 were found to be significantly lower than the control. Three MAS the egg count was found to be minimum in treatment 6 (Dimethoate 0.05 % + wettable sulphur 0.4 %), which was on par with T_7, T_5 and T_1. These treatments showed significant difference over the control.

4.2.1.2 Population of nymphs

Population of nymphs when observed 1 WAS, treatments T_6, T_5 and T_7 were found to be on par and differed significantly from control. Population of nymphs when observed 1 MAS, there was no significant difference between treatments. Nymph population in all the treatments differed significantly from control when observed 3 MAS. T_7 (quinalphos 0.05% + wettable sulphur 0.4%) recorded minimum nymph population and was on par with T_5 (Neem oil – Garlic emulsion 2 %) but differed significantly from other treatments.

Table 7 Effect of pesticide application on population of coconut eriophyid mite

Treatments	Egg count			Population of nymphs			Population of adults		
	1 WAS	1 MAS	3 MAS	1 WAS	1 MAS	3 MAS	1 WAS	1 MAS	3 MAS
T_1 Dimethoate (0.05 %)	1985.00 (44.57)	1260.18 (35.51)	1028.60 (32.09)	1547.60 (39.35)	991.34 (31.50)	1630.08 (40.39)	2120.45 (46.06)	1740.64 (41.73)	1659.07 (40.74)
T_2 Triazophos (0.05 %)	1635.42 (40.48)	1481.842 (38.51)	1758.51 (41.95)	2843.29 (53.33)	1984.18 (44.56)	2033.95 (45.11)	1687.36 (41.09)	2957.02 (54.39)	1900.37 (43.60)
T_3 Phosalone (0.05 %)	2199.46 (46.91)	1896.02 (43.55)	2296.10 (47.93)	2153.23 (46.41)	1678.00 (40.98)	2266.51 (47.62)	2845.18 (53.35)	1466.823 (38.31)	2933.26 (54.17)
T_4 Endosulfan (0.1 %)	1677.34 (40.97)	1210.70 (34.81)	1128.56 (33.61)	1844.24 (42.96)	1813.31 (42.59)	2335.88 (48.34)	3101.06 (55.70)	2519.123 (50.20)	3121.21 (55.88)
T_5 Neem oil-garlic emulsion (2 %)	462.99 (21.54)	793.843 (28.19)	867.82 (29.47)	380.57 (19.53)	668.49 (25.87)	1227.49 (35.05)	1102.49 (33.22)	2581.86 (50.82)	1807.80 (42.53)
T_6 Dimethoate (0.05 %) + Wettable sulphur (0.4 %)	394.75 (19.89)	642.42 (25.37)	484.25 (22.03)	322.42 (17.98)	987.62 (31.44)	1555.91 (39.46)	1971.38 (44.41)	1025.78 (32.04)	798.74 (28.58)
T_7 Quinalphos (0.05 %) + Wettable sulphur (0.4 %)	473.10 (21.77)	605.56 (24.63)	542.20 (23.31)	289.34 (17.04)	473.17 (21.78)	509.91 (22.58)	2151.98 (46.40)	764.76 (27.67)	867.51 (29.47)
T_8 Endosulfan (0.1 %) + Wettable sulphur (0.4 %)	670.41 (25.91)	2898.31 (53.85)	1622.12 (40.29)	2033.34 (45.10)	2445.62 (49.46)	1462.88 (38.26)	1494.27 (38.67)	2539.44 (50.40)	1940.54 (44.06)
T_9 Endosulfan (0.1 %) + Neem oil-garlic emulsion (2 %)	1398.77 (37.41)	686.19 (26.21)	1403.14 (37.47)	1528.15 (39.10)	1129.262 (33.62)	1863.22 (43.18)	2032.801 (45.10)	1509.69 (38.87)	1441.42 (37.98)
T_{10} Control	2673.23 (51.71)	2716.49 (52.12)	2803.21 (52.96)	4996.93 (70.70)	2298.84 (47.96)	3910.08 (62.54)	5126.66 (71.61)	5035.38 (70.96)	5537.45 (74.42)
CD (0.05)	(11.95)	(19.68)	(15.81)	(16.30)	NS	(15.195)	(17.52)	(19.00)	(12.81)

Figures in parentheses are transformed values $\sqrt{x}$

4.2.1.3 Population of adults

T_5 (neem oil-garlic emulsion 2%), T_8 (endosulfan 0.1 % + wettable sulphur 0.4 %), T_2 (triazophos 0.05 %), T_6 (dimethoate 0.05 % + wettable sulphur 0.4 %), T_9 (neem oil – garlic emulsion 2 % + endosulfan 0.1 %), T_1 (Dimethoate 0.05 %) and T_7 (quinalphos 0.05 % + wettable sulphur 0.4 %) were found to be on par and differed significantly from control when observed 1 WAS. T_7 recorded minimum adult population 1 MAS which was on par with T_6, T_3, T_9 and T_1 and were significantly different from control. Three MAS, T_6 (dimethoate 0.05 % + wettable sulphur 0.4 %) recorded minimum population and on par with T_7 (quinalphos 0.05 % + wettable sulphur 0.4 %) and T_9 (neem oil – garlic emulsion 2 % + endosulfan 0.1 %).

4.2.2 Nut loss

Data on nut loss due to sucking pest infestation in palms treated with pesticides are given Table 8.

Nut fall due to coreid bug was minimum in T_9 (neem oil – garlic emulsion 2 % + endosulfan 0.1 %) and significantly differed from that of all other treatments. The treatments T_8, T_4, T_3, T_5 and T_7 showed significantly lower nutfall as compared to the control.

Nut loss due to combined infestation of CEM and CCB was minimum in palms treated with neem oil – garlic emulsion 2 % + endosulfan 0.1 % (T_9) and neem oil garlic emulsion 2 % (T_5) and which were on par with T_7, T_8 and T_3. Nut fall was significantly lower in all pesticide treated palms as compared to the control palm.

Table 8 Effect of pesticide application on nut loss due to the infestation of the sucking pests

Treatments	Nut loss per palm			
	Nut fall due to CCB infestation (No.)	Nut fall due to CEM and CCB (No.)	Barren / stunted or dried nut (No.)	Total nut loss (No.)
T_1 Dimethoate (0.05 %)	5.05 (2.46)	4.39 (2.32)	14.45 (3.93)	24.24 (5.02)
T_2 Triazophos (0.05 %)	3.25 (2.06)	3.86 (2.20)	6.69 (2.77)	15.09 (4.01)
T_3 Phosalone (0.05 %)	1.40 (1.55)	3.32 (2.08)	10.15 (3.34)	15.18 (4.02)
T_4 Endosulfan (0.1 %)	1.31 (1.52)	3.86 (2.21)	12.02 (3.61)	17.79 (4.34)
T_5 Neem oil-garlic emulsion (2 %)	1.94 (1.72)	1.31 (1.52)	8.60 (3.10)	11.96 (3.60)
T_6 Dimethoate (0.05 %) + Wettable sulphur (0.4 %)	6.00 (2.65)	2.96 (1.98)	5.34 (2.52)	14.58 (3.95)
T_7 Quinalphos (0.05 %) + Wettable sulphur (0.4 %)	2.48 (1.87)	1.85 (1.69)	5.56 (2.56)	10.24 (3.35)
T_8 Endosulfan (0.1 %) + Wettable sulphur (0.4 %)	0.63 (1.28)	2.21 (1.79)	10.10 (3.33)	13.13 (3.76)
T_9 Endosulfan (0.1 %) + Neem oil-garlic emulsion (2 %)	0.29 (1.13)	1.31 (1.52)	8.42 (3.07)	10.38 (3.38)
T_{10} Control	7.04 (2.83)	9.6 (3.26)	24.74 (5.07)	41.94 (6.55)
CD (0.05)	(0.746)	(0.653)	(1.466)	(1.033)

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

The number of dried / barren nuts showing damage by sucking pests was minimum in T_6 (dimethoate 0.05 % + wettable sulphur 0.4 %). All the pesticide treatments were on par and differed significantly from control.

Palms which did not receive pesticide treatment lost maximum number of nuts (41.94 nuts palm^{-1}) which was found to be significantly higher than all the treatments. Total nut loss was minimum in T_7 and was on par with T_9, T_5, T_8, T_6, T_2 and T_3. The nut loss in these treatments were significantly lower than the control.

4.2.3 CEM infestation – Mean intensity score

The levels of damage by CEM on retained nuts was assessed by estimating the mean intensity score. Table 9 gives bunch wise data on mean intensity score of CEM infestation in each treatment. CEM damage on retained nuts was minimum in T_9 (neem oil–garlic emulsion 2 % + endosulfan 0.1 %) as evidenced by the lowest mean intensity score of 1.5. Treatments T_5, T_7 and T_8 were on par with T_9 and significantly differed from control.

No significant difference was observed between the mean intensity scores of different bunches in the pesticide treated palms.

4.2.4 CCB infestation – Percentage of nuts infested

Percentage of nuts infested by coreid bug in different treated palms showed significantly lower infestation than control in all treatments except T_1, T_3 and T_4 (Table 10). The lowest infestation of 0.35 per cent was observed in T_9 (neem oil – garlic emulsion 2 % + endosulfan 0.1 %). Infestation in T_8 (endosulfan 0.1 % + wettable sulphur 0.4 %), T_6 (dimethoate 0.05 % + wettable sulphur 0.4 %), T_5 (neem oil-garlic emulsion 2%) were on par with T_9.

Table 9 Mean intensity score of CEM infestation on retained nuts in pesticide treated palms

Treatment \ Bunch No.	1	2	3	4	5	Mean of five bunches
T_1 Dimethoate (0.05 %)	2.65 (1.63)	3.34 (1.83)	2.30 (1.52)	3.17 (1.78)	2.50 (1.58)	2.79 (1.67)
T_2 Triazophos (0.05 %)	3.68 (1.92)	2.47 (1.57)	3.08 (1.76)	2.84 (1.69)	2.25 (1.50)	2.86 (1.69)
T_3 Phosalone (0.05 %)	3.51 (1.87)	3.38 (1.84)	3.25 (1.80)	2.00 (1.42)	2.60 (1.61)	2.92 (1.71)
T_4 Endosulfan (0.1 %)	3.74 (1.93)	2.72 (1.65)	1.87 (1.37)	2.45 (1.57)	1.86 (1.37)	2.49 (1.58)
T_5 Neem oil-garlic emulsion (2 %)	2.25 (1.50)	1.91 (1.38)	1.67 (1.29)	1.99 (1.41)	2.03 (1.43)	1.96 (1.40)
T_6 Dimethoate (0.05 %) + Wettable sulphur (0.4 %)	2.50 (1.58)	1.93 (1.39)	1.97 (1.40)	1.80 (1.34)	1.91 (1.38)	2.02 (1.42)
T_7 Quinalphos (0.05 %) + Wettable sulphur (0.4 %)	2.27 (1.51)	2.25 (1.50)	1.79 (1.34)	1.63 (1.28)	1.81 (1.35)	1.96 (1.40)
T_8 Endosulfan (0.1 %) + Wettable sulphur (0.4 %)	1.85 (1.36)	1.78 (1.33)	3.03 (1.74)	1.55 (1.24)	1.37 (1.17)	1.88 (1.37)
T_9 Endosulfan (0.1 %) + Neem oil-garlic emulsion (2 %)	1.69 (1.29)	1.55 (1.24)	1.38 (1.17)	1.53 (1.24)	1.74 (1.32)	1.59 (1.26)
T_{10} Control	4.46 (2.11)	3.99 (1.99)	4.49 (2.12)	4.28 (2.06)	4.09 (2.02)	4.24 (2.06)
CD (0.05)	-	-	-	-	-	(0.139)

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

Table 10 Percentage infestation of CCB in retained nuts of palms treated with pesticides

Treatments	Per cent infestation
T_1 Dimethoate (0.05 %)	28.29 (5.41)
T_2 Triazophos (0.05 %)	22.36 (4.83)
T_3 Phosalone (0.05 %)	26.94 (5.29)
T_4 Endosulfan (0.1 %)	23.84 (4.98)
T_5 Neem oil-garlic emulsion (2 %)	6.95 (2.82)
T_6 Dimethoate (0.05 %) + Wettable sulphur (0.4 %)	2.59 (1.89)
T_7 Quinalphos (0.05 %) + Wettable sulphur (0.4 %)	15.67 (4.08)
T_8 Endosulfan (0.1 %) + Wettable sulphur (0.4 %)	2.46 (1.88)
T_9 Endosulfan (0.1 %) + Neem oil-garlic emulsion (2 %)	0.35 (1.16)
T_{10} Control	47.68 (6.98)
CD (0.05)	(2.091)

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

4.3 Screening of entomopathogenic fungi against sucking pests

4.3.1 Screening against CEM

The population of CEM taken at different intervals in the nuts treated with different entomopathogenic fungi is given in Table 11.

When observed three days after spraying, least population was observed in nuts sprayed with *Verticillium suchlasporium*, which was on par with those sprayed with *V. chlamydosporium*, *Paecilomyces lilacinus* and *Fusarium pallidoroseum*. Significantly low population was observed in nuts treated with *F. pallidoroseum, P. farinosus* and *V. suchlasporium* 5 DAS. When observed 7 DAS, the nuts treated with *V. suchlasporium* showed significant difference from control and other treatments.

When the dead mites were stained with cotton blue in lactophenol, infection could be observed only in nuts treated with *V. suchlasporium*. Infected mites with mycelial growth were observed (Plate 7 A, B).

V. suchlasporium, which was found to be infective on CEM in the present study, was compared for effectiveness with *H. thompsonii*, a pathogen reported to be effective against CEM (Table 12).

Table 11 Mean population of CEM in nuts treated with entomopathogenic fungi

Treatments	Mean CEM population (in 4 mm^2)			Fungal infection
	3 DAS	5 DAS	7 DAS	
Metarhizium anisopliae	112.49 (10.65)	102.50 (10.17)	111.42 (10.60)	Negative
Paecilomyces lilacinus	86.54 (9.36)	87.62 (9.41)	97.90 (9.95)	Negative
P. farinosus	94.41 (9.77)	58.74 (7.73)	66.85 (8.24)	Negative
Fusarium pallidoroseum	87.96 (9.43)	88.06 (9.41)	65.93 (8.18)	Negative
Verticillium chlamydosporium	83.77 (9.21)	88.37 (9.45)	105.18 (10.30)	Negative
V. suchlasporium	75.96 (8.77)	80.79 (9.04)	33.67 (5.88)	Positive
Beauveria bassiana	117.28 (10.88)	84.82 (9.26)	104.52 (10.27)	Negative
Rhizopus oryzae	141.02 (11.92)	133.63 (11.60)	127.67 (11.34)	Negative
Exiophiala psiciphila	117.12 (10.87)	123.55 (11.16)	91.13 (9.60)	Negative
Control	151.72 (12.36)	144.78 (12.07)	116.89 (10.86)	Negative
CD (0.05)	0.933	2.691	1.481	

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

Table 12 Comparison of *V. suchlasporium* and *H. thompsonii* against CEM

Pathogen	Corrected per cent mortality		Fungal infection
	5 DAS	7 DAS	
V. suchlasporium	27.8	30.8	Positive
H. thompsonii	20.6	56.8	Positive

Both the pathogens were found to be infective to CEM (Plate 7A, B, C, D) Comparable results were obtained after 5 DAS. But when observed 7 DAS, *H. thompsonii* gave higher per cent corrected mortality (56.80 %) while *V. suchlasporium* gave 30.80 per cent mortality.

4.3.2 Screening against CCB

Results of screening six entomopathogenic fungi against CCB are given in Table 13.

Table 13 Percentage mortality of CCB treated with entomopathogenic fungi

Fungi	Percentage mortality	Fungal infection
1) *Metarhizium anisopliae*	96.70	Positive
2) *Beauveria bassiana*	Nil	Negative
3) *Rhizopus oryzae*	Nil	Negative
4) *Fusarium pallidoroseum*	Nil	Negative
5) *Paecilomyces farinosus*	Nil	Negative
6) *P. lilacinus*	Nil	Negative
7) Control	Nil	Negative

Out of six fungi tested against CCB, *M. anisopliae* was found to be infective (Plate 8A,B, C) and caused 96.7 per cent mortality in treated adults (Table 13). Cent per cent mortality was observed in nymphs.

Plate 7 Coconut eriophyid mite infected by acaro pathogenic fungi

A, B . Coconut eriophyid mite infected by *Verticillium suchlasporium*

C, D. Coconut eriophyid mite infected by *Hirsutella thompsonii*

Plate 8 Coconut coreid bug infected by *Metarhizium anisopliae*

A, B, C. Dead coreid bug with mycelial growth

PLATE 7

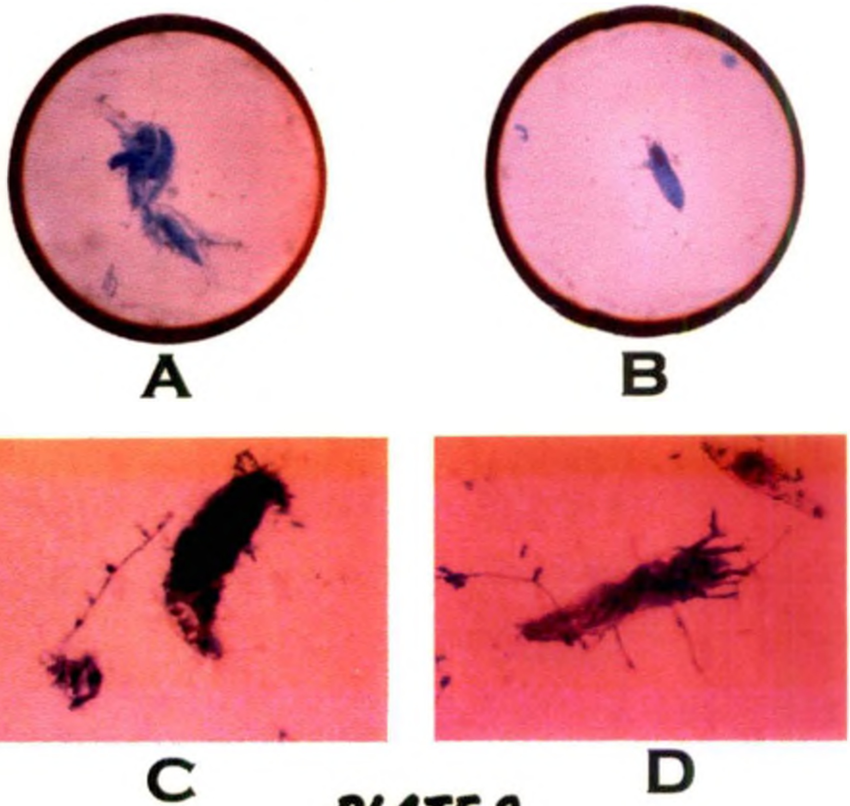
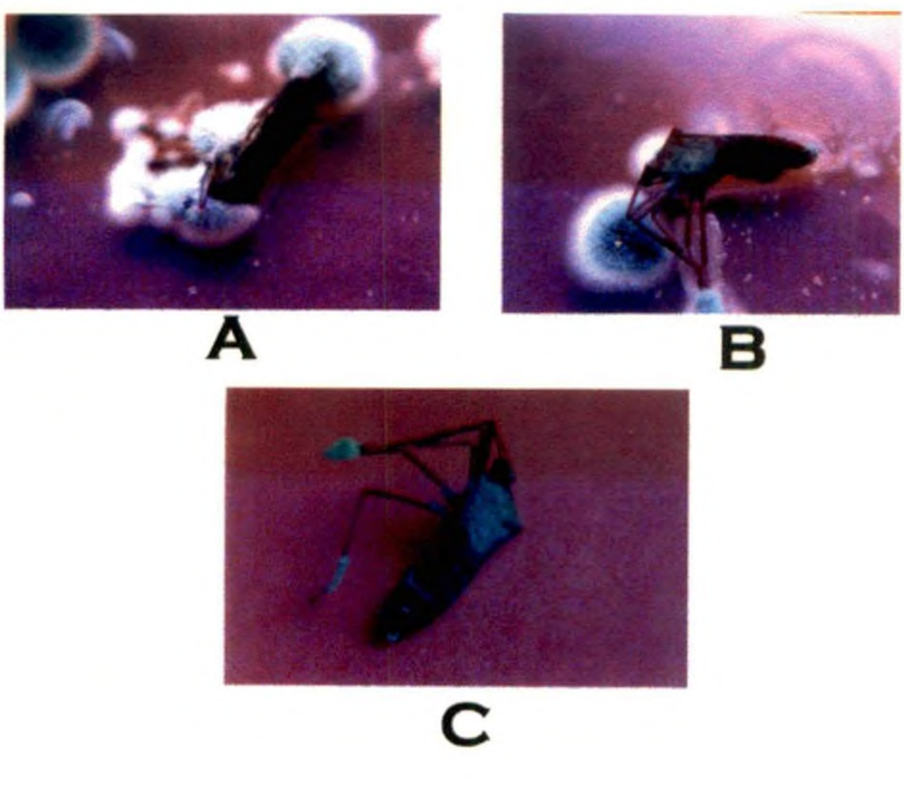


PLATE 8



4.3.3 Screening against CBM

Six fungal pathogens *viz.*, *Metarhizium anisopliae*, *Beauveria bassiana*, *Rhizopus oryzae*, *Fusarium pallidoroseum*, *Paecilomyces farinosus* and *P. lilacinus* were tried against CBM, but infection was not noticed in any of the fungi tested.

4.4 Survey on entomo / acaro pathogenic fungi associated with bunch infesting sucking pests

The details of the survey are given in Table 14. The four fungi isolated from CEM were identified as *Penicillium purpurogenum* Stoll., *Acremonium strictum* Gams., *Fusarium solani* (Martius) Sacc. and *Paecilomyces varioti* (Bainer). The fungus isolated from CBM (*Pseudococcus* sp.) was identified as *Fusarium moniliforme* Wollenw and Reink.

The spore suspensions of these pathogens were sprayed on the host species and were found to be infective.

The crowns of coreid bug infested palms were regularly observed for presence of fungal infected bugs but no dead mummified bugs having mycelial covering, could be detected.

4.5 Survey for egg parasitoids of CCB

Forty per cent of the total egg masses collected in the survey were found to be parasitised. Two parasitoids were obtained from these egg masses (Table 15). The parasitoids were identified as *Chrysochalcissa oviceps* Boucek (Torymidae) (Plate 9A, B) and *Gryon homeoceri* (Nixon) Scelionidae) (Plate 9C, D, E).

Table 14 Survey on entomo/acaro pathogenic fungi associated with sucking pests

Month	Number of nuts observed		Number of nuts with fungal infection		Number of pathogens isolated in pure culture	
	CEM infested	CBM infested	In CEM	In CBM	From CEM	From CBM
May 2000	26	12	2	-	-	-
June 2000	28	10	1	-	1	-
July 2000	32	10	5	1	1	1
August 2000	48	16	-	-	-	-
September 2000	38	12	-	-	-	-
October 2000	28	10	-	-	-	-
November 2000	32	16	1	-	1	-
December 2000	43	9	3	1	-	-
January 2001	24	16	-	-	-	-
February 2001	29	12	-	-	-	-
March 2001	22	16	-	-	-	-
April 2001	28	12	2	-	1	-

Table 15 Survey on egg parsitoids of CCB

Date of collection	Number of eggs in each egg mass	Number of parasitised eggs in an egg mass	Name of parasitoid
05.04.2000	32	32	*Chrysochalcissa oviceps*
10.05.2000	43	43	"
10.04.2001	52	52	"
21.06.2001	38	38	*Gryon homeoceri*
26.06.2001	42	38	*C. oviceps*
20.07.2001	32	32	*G. homeoceri* and *C. oviceps*
16.07.2001	46	46	*G. homeoceri*
13.09.2001	37	36	*C. oviceps* and *G. homeoceri*

Plate 9 Egg parasitoids of coconut coreid bug

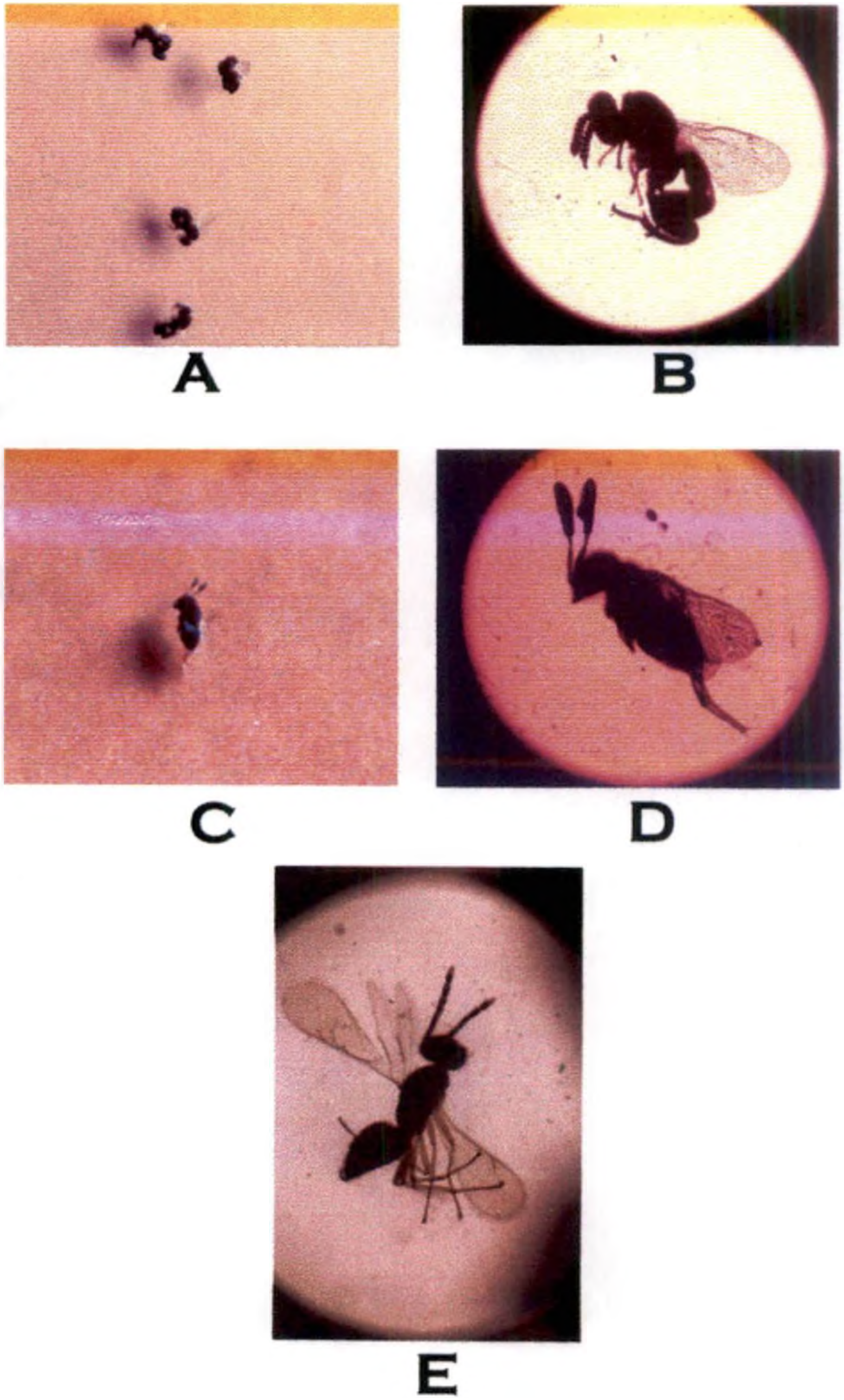
A. *Chrysochalcissa oviceps* Boucek

B. Enlarged view of *Chrysochalcissa oviceps* Boucek

C. *Gryon homeoceri* (Nixon)

D, E. Enlarged view of *Gryon homeoceri* (Nixon)

PLATE 9



4.5.2 Rearing of parasitoids

Chrysochalcissa oviceps and *G. homeoceri* parasitised only the eggs of CCB from among the egg masses of various insects tried. A comparison of healthy and parasitised egg masses of CCB revealed the following information. The unparasitised eggs were found to remain reddish orange until hatching (Plate 10A) whereas the parasitised eggs turned grey four to five days after parasitisation. These eggs turned completely black about seven days after parasitisation (Plate10B). The nymphs of CCB were observed to emerge from the healthy eggs by opening the black operculum of the egg while the parasitoid emerged by cutting open an irregular hole on the egg surface. The egg case of a healthy egg appeared glossy while that of the parasitised one black after emergence (Plate 10C, D). Plate 10E shows an adult female of *G. homeoceri* laying eggs on eggs of CCB. A comparison of some important characters of the two egg parasitoids of CCB, *viz., C. oviceps* and *G. homeoceri* are presented in Table 16.

Table 16 Comparison of some important characters of the two egg parasitoids of CCB

Character observed	*G. homeoceri*	*C. oviceps*
Legs	Legs longer and slender, Hind femur not enlarged	Legs short, Hind femur enlarged
Antennae	14segmented (Plate10F) with a long pedicel	10 segmented (Plate10G)
Egg to adult period	18-24 days	20-25 days
Adult longevity	38-40 days	30-34 days

The occurrence of both parasitoids was observed in the field from April to October.

Plate 10 Parasitised and unparasitised eggs of coconut coreid bug

A. Normal eggs of coconut coreid bug on guava leaf

B. Parasitised eggs of coconut coreid bug

C. Parasitised eggs after the emergence of parasitoids

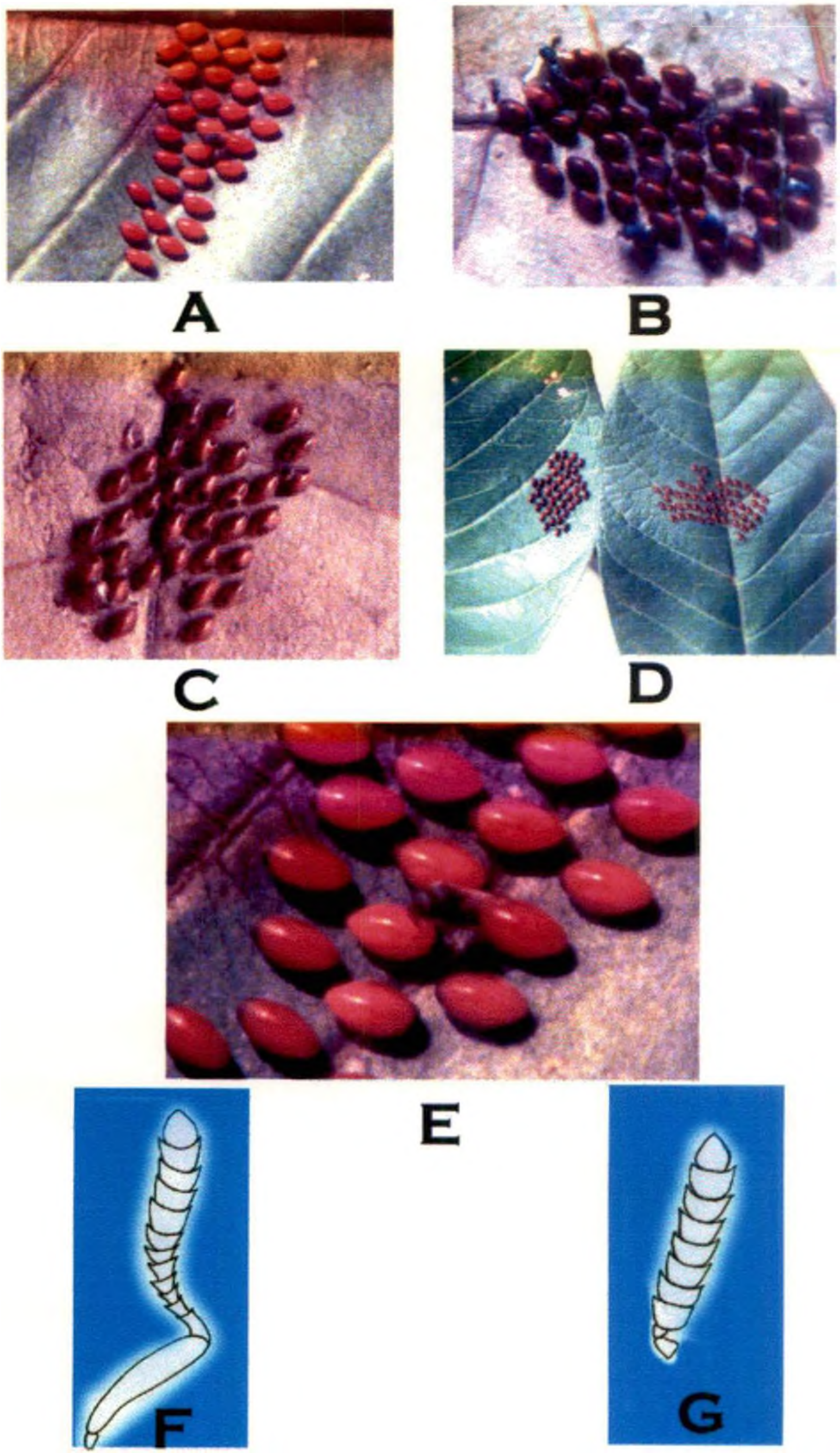
D. Egg cases of parasitised and un parasitised eggs of coconut coreid bug

E. Egg parasitoid *Gryon homeoceri* (Nixon) laying eggs on coconut coreid bug egg

F. Antennae of *G. homeoceri*

G. Antennae of *Chrysochalcissa oviceps*

PLATE 10



Discussion

5. DISCUSSION

The present study was undertaken to assess the nature and extent of damage caused by the infestation of sucking pest complex, viz., CEM, CCB and CBM infesting coconut bunches and to devise suitable insecticidal and microbial management measures against them. The experiments were conducted at the College of Agriculture, Vellayani from April 2000 to July 2001.

5.1 Nature and extent of damage

Coconut coreid bug (CCB) *Paradasynus rostratus* D., a pest which attacks, the most important economic part of coconut palm, the nuts, has been causing extensive loss to coconut cultivation in Kerala since 1972 (Kurien *et al.*, 1979). The economic loss to coconut cultivators got compounded with the introduction of an exotic bunch infesting sucking pest, the coconut eriophyid mite (CEM), *A. guerreronis* K. during later part of 1997 (Sathiamma *et al.*, 1998). Though mealy bugs infesting coconut were considered as minor pests earlier, of late, some species were found to infest the coconut bunches causing heavy economic loss (Radhakrishnan, 1987). Combined infestation of sucking pests viz., CEM, CCB and coconut button mealy bugs (CBM) was reported in coconut (Nair, 2000 and Saradamma *et al.*, 2000a) but little attention has been paid to investigate the nature and extent of damage of their combined infestation.

CEM and CCB were found to infest the palms either singly or in combination, sucking sap from the tender meristematic zone of developing buttons causing nutfall, with characteristic 'V' shaped marking below the perianth in case of the former and sunken spots beneath the perianth in case of the latter (Plate 1 and 2). The present study revealed that CEM and CCB were the most predominant combination of sucking pests infesting coconuts resulting in nutfall exhibiting symptoms of both (Plate 4). Mohan and Nair (2000) reported that the combined infestation of CEM and CCB was more prevalent in the district of Thiruvananthapuram.

Two species of button mealy bugs belonging to genera *Pseudococcus* and *Palmicultor* were found to infest developing buttons of coconut. Though there are many reports of mealy bugs affecting different parts of coconut palms (Radhakrishnan, 1987; Jalaluddin and Mohanasundaram, 1993) its attack on button/nuts leading to yield loss has rarely been accounted for. Observations revealed that the infestation of CBM *viz.*, *Pseudococcus* sp. and *Palmicultor* sp. on buttons resulted in retarded development making them barren or stunted (Plate 3). Radhakrishnan (1987) reported that the attack of mealy bugs resulted in barren bunches. In the present study also such damage was observed in some bunches. However most of the affected bunches at the time of harvest had full sized healthy nuts as well as mealy bug affected stunted ones. Nutfall due to mealy bug alone or in combination with other sucking pests were scarcely observed.

Combined attack of CEM and CBM as well as that of CEM, CCB and CBM could be observed frequently whereas the combination of CCB and CBM was observed rarely. This may be because infestation by CBM at an early stage prevents further development of the nut, making it a less preferred site of attack by the other two pests. Retained nuts that survive the attack of

CEM and CCB were later colonized by CBM resulting in nuts exhibiting damage symptoms of the sucking pest complex.

Efforts were made in this investigation to document the yield loss due to the attack of the sucking pests individually and in combinations. Combined infestation of CEM, CCB and CBM resulted in nutfall, size reduction, distortion, stunting and sometimes formation of barren nuts (Plate 5). Nutfall due to the combined infestation of sucking pest complex in coconut palm was documented for the first time in the present study. The consolidated data on nut loss for one year revealed that 101.5 nuts palm^{-1} year^{-1} fell due to sucking pest infestation and 5.3 nuts bunch^{-1} palm^{-1} turned barren (Table 1 and 2).

A comparison of nutfall in palms infested with sucking pests and uninfested palms could not be made because there were no palms without infestation of any one of the sucking pests in the study area during the period of study. Though there are many reports of premature nutfall caused by CEM (Doreste, 1968; Mohanasundaram, 1999; Haq, 2000; Nair, 2000) and CCB (Kurien *et al.*, 1979; CPCRI, 1999; Nair *et al.*, 2000c; Mohan and Nair, 2000), reports on nut loss due to infestation of sucking pest complex are lacking.

Out of the total damaged fallen nuts 35.96 per cent showed symptoms of CEM alone, 36.45 per cent CCB alone and 27.59 per cent both CEM and CCB (Fig. 1). Observations on month wise data on nutfall revealed that the nut fall due to the sucking pests was high in December (14.88 nuts palm^{-1}) September (12.64 nuts palm^{-1}), October (13.25 nuts palm^{-1}) and November (13.47 nuts palm^{-1}) (Table 1). This may be partly because of high population of CCB during this period which account for major share of the nutfall. CCB population was reported to be high during October and November (Visalakshi *et al.*, 1989; CPCRI, 1999). Seguni (2000) reported that premature nutfall by CEM was additionally influenced by attack of CCB.

Correlation studies were undertaken to understand the relationship between nutfall due to sucking pest infestation and weather parameters. Significant negative correlation was observed between minimum temperature and nut fall due to the combined attack of CEM and CCB (Table 2 and Fig. 2). Studies conducted by Visalakshi *et al.* (1989) revealed the existence of significant negative correlation between temperature and buttons damaged by CCB attack.

Number of fallen nuts with symptoms of infestation of either CEM or CCB during December was comparatively low. More than half of the damaged fallen nuts (50.16 %) during this period exhibited damage symptoms of combined infestation of CEM and CCB indicating the prevalence of these two pests in the area during the period.

High incidence of CEM infestation could be detected in the retained nuts throughout the one year period of study. During this period 88.23 per cent to 100 per cent of the nuts retained in bunches were found to be infested by CEM (Table 3).

On the other hand wide variation (3.44 % to 100 %) could be observed in the percentage of retained nuts attacked by CCB in bunches that opened from April 2000 to May 2001. Minimum infestation was observed during February 2001. This may be because of low population of CCB during

February – March. This is further evidenced by the low number of fallen nuts during March 2001 and April 2001. Cent per cent of the retained nuts in bunches that opened in November 2000 were infested by CCB which corresponds with high nutfall as well as low mean temperature during December 2000. However the variation in the number of retained nuts infested by CCB in different months was not significant (Table 3).

Barren / stunted nuts was found to be higher in bunches that opened from August to January and the maximum was in the bunch opened during November (10.81 nuts $bunch^{-1}$). Nuts turned barren/stunted when it is infested by CBM either singly or in combination with other pests. An increase in the number of barren / stunted nuts in bunches opened during November may be because of population flair up of CBM during this period (Table 4).

Studies conducted by CPCRI (1994) revealed maximum population of coconut mealy bugs in February. On the contrary in the present study the number of barren/stunted nuts with mealy bugs was maximum in bunches opened in November. This may be due to the influence of other two pests whose infestation is maximum in the month of November leading to secondary infestation by mealy bugs.

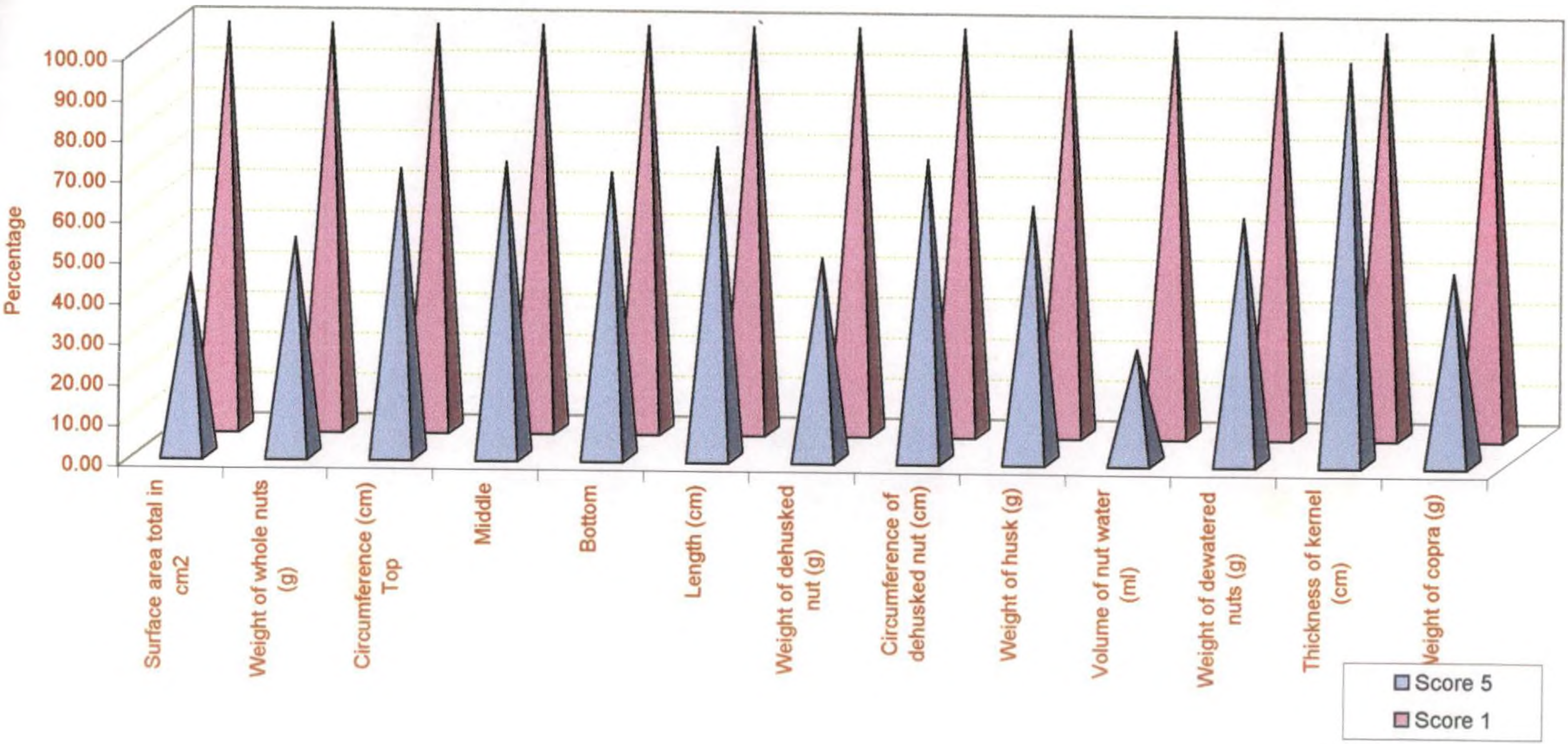
During November 2000, the nutfall due to sucking pest infestation was comparatively high indicating high population of CEM and CCB. The nuts that survived the attack of CEM and CCB might be colonized by CBM later contributing to the higher number of barren / stunted nuts. Radhakrishnan (1987) and CPCRI (1994) reported formation of barren / stunted nuts due to CBM infestation.

The yield loss in retained nuts damaged by combined infestation of CEM and CCB was investigated using a new scoring technique developed by modifying the one described earlier by Julia and Mariau (1979) and Moore *et al.* (1989). The nut characteristics viz., total surface area, weight of whole nuts, whole nut circumference, nut length, weight of dehusked nut, circumference of dehusked nut, weight of husk, volume of nut water, thickness of kernel weight of dewatered nuts and weight of copra were observed. Nuts belonging to Score 5 (having >50 % surface damage by CEM and $\geq$ 9 % surface damage by CCB) differed significantly from healthy nuts (Score 1) in all the nut characteristics investigated except the thickness of kernel (Fig. 4). Score 5 recorded 46.26 per cent, 50.25 per cent and 52.58 per cent reduction over Score 1 respectively for weight of whole nut, weight of dehusked nut and weight of copra. Nair *et al.* (1997) recorded a mean percentage loss of 17.99 per cent, 18.67 per cent and 23.80 per cent in weight of whole nut, dehusked nuts and weight of copra respectively in nuts infested by CCB alone.

In the present study when the nuts belonging to Scores 2 to 5 were compared with Score 1, 11.35 to 52.58 per cent reduction in weight of copra was observed.

The estimated loss of copra due to CEM attack was 10 per cent in Benin (Mariau and Julia, 1970), 16 per cent in Ivory Coast (Mariau and Julia, 1979), 30 per cent in Mexico (Hernandez, 1977) and 11.28 per cent in St. Lucia (Moore *et al.*, 1989). The present study indicated that the combined infestation of CEM and CCB incurred additional loss over and above the loss due to their individual attack.

Fig. 4 Comparison of nut characteristics of Score 5 and Score 1



Significant negative correlation was found to exist between the pericarp damaged by CEM and CCB and weight of whole nut, weight of dehusked nut, volume of nut water, weight of dewatered nut and weight of copra. Similar results were obtained in the correlation studies conducted in case of damage by CCB (Nair *et al.*, 1997) and CEM (Ambily, 2001). Thus the surface damage by the combined attack of CEM and CCB can be taken as an indication of the intensity of attack and the resultant yield loss.

5.3 Evaluation of pesticides against sucking pest complex

Coconut palms are more often subject to combined infestation of sucking pests rather than individual attack (Saradamma *et al.*, 2000a; Nair, 2000). There are effective chemical management practices against each pests. Management practices against one pest may not effective against another pest and hence fail to achieve the final goal of minimising yield loss. This failure may be due to the flair up of population of other sucking pests when only one of them is targeted. Besides, in a perennial tall crop like coconut which puts forth a new bunch every month it is cumbersome and expensive to spray different chemicals targeting individual pest. An attempt was made in the present study to evolve a management strategy which could reduce the damage and yield loss caused by the sucking pests viz., CEM, CCB and CBM which often attacks the palm as a complex. The treatments were fixed taking the present recommendation against the individual sucking pests into consideration (Ponnamma *et al.*, 1985; Radhakrishnan, 1987; CPCRI, 1994; Kumar *et al.*, 1996; Saradamma *et al.*, 2000a). Combinations of pesticides were included to check the attack of sucking pest complex. The effectiveness of the treatments were evaluated taking into consideration their ability to reduce yield loss due to infestation of sucking pests, individually or in combination. The parameters like nutfall, formation of barren nuts and intensity of infestation on retained nuts were considered. A consolidated chart of comparison of various treatments tried is presented in Fig. 5.

The treatments that are effective in reducing the yield loss with respect to all the parameters tested were considered as superior treatments. Accordingly treatments T_5 (neem oil-garlic emulsion 2%), T_7 (quinalphos 0.05 % + wettable sulphur 0.4 %), T_8 (endosulfan 0.1 % + wettable sulphur 0.4 %) and T_9 (neem oil – garlic emulsion 2 % + endosulfan 0.1 %) were found to be superior. The population of CEM taken one week after spraying is presented in Fig. 6. It is evident that the population of eggs, nymphs and adults were low in all the above mentioned treatments when compared to control. Treatment 9 (neem oil – garlic emulsion 2 % + endosulfan 0.1 %) scored the best in four parameters viz., nutfall due to CCB, nutfall due to CEM and CCB and mean intensity score of CEM infestation and percentage infestation by CCB. However the cost involved for this treatment (T_9) was maximum among the superior treatments (Table 17).

Population of CEM, 1 MAS and 3 MAS were also assessed, to have an idea about the population build up of CEM after pesticide treatments. Eventhough population buildup was noticed in all the treatments, it was significantly lower compared to the control except in case of T_8 (endosulfan 0.1 % + wettable sulphur 0.4 %).

Saradamma *et al.* (2000b) reported significant reduction in mite population and intensity of damage in palms treated with neem oil – garlic emulsion (2 %). The present study indicated that this treatment was effective in

Fig. 5 Analytical chart showing effectiveness of pesticide treatments against the infestation of the sucking pests complex

Characteristics evaluated	Treatments									
	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10} (control)
Barren/dried nuts	•	•	•	•	•	◈	•	•	•	
Nutfall due to coreid bug infestation			•	•	•		•	•	◈	
Nutfall due to dual attack of coreid bug and mite			•		◈	•	•	•	◈	
Total nut loss		•	•		•	•	◈	•	•	
Percentage of nuts infested by coreid bug					◈	•	•	•	◈	
Intensity of damage by mite					•		•	•	◈	

◈ Treatment which gave best results

• Treatments which were on par with the best and statistically superior over control

T_1 Dimethoate (0.05 %)

T_2 Triazophos (0.05 %)

T_3 Phosalone (0.05 %)

T_4 Endosulfan (0.1 %)

T_5 Neem oil-garlic emulsion (2 %)

T_6 Dimethoate (0.05 %) + Wettable sulphur (0.4 %)

T_7 Quinalphos (0.05 %) + Wettable sulphur (0.4 %)

T_8 Endosulfan (0.1 %) + Wettable sulphur (0.4 %)

T_9 Endosulfan (0.1 %) + Neem oil-garlic emulsion (2 %)

T_{10} Control

Fig. 6 Population of coconut eriophyid mite in palms treated with pesticides (one week after spraying)

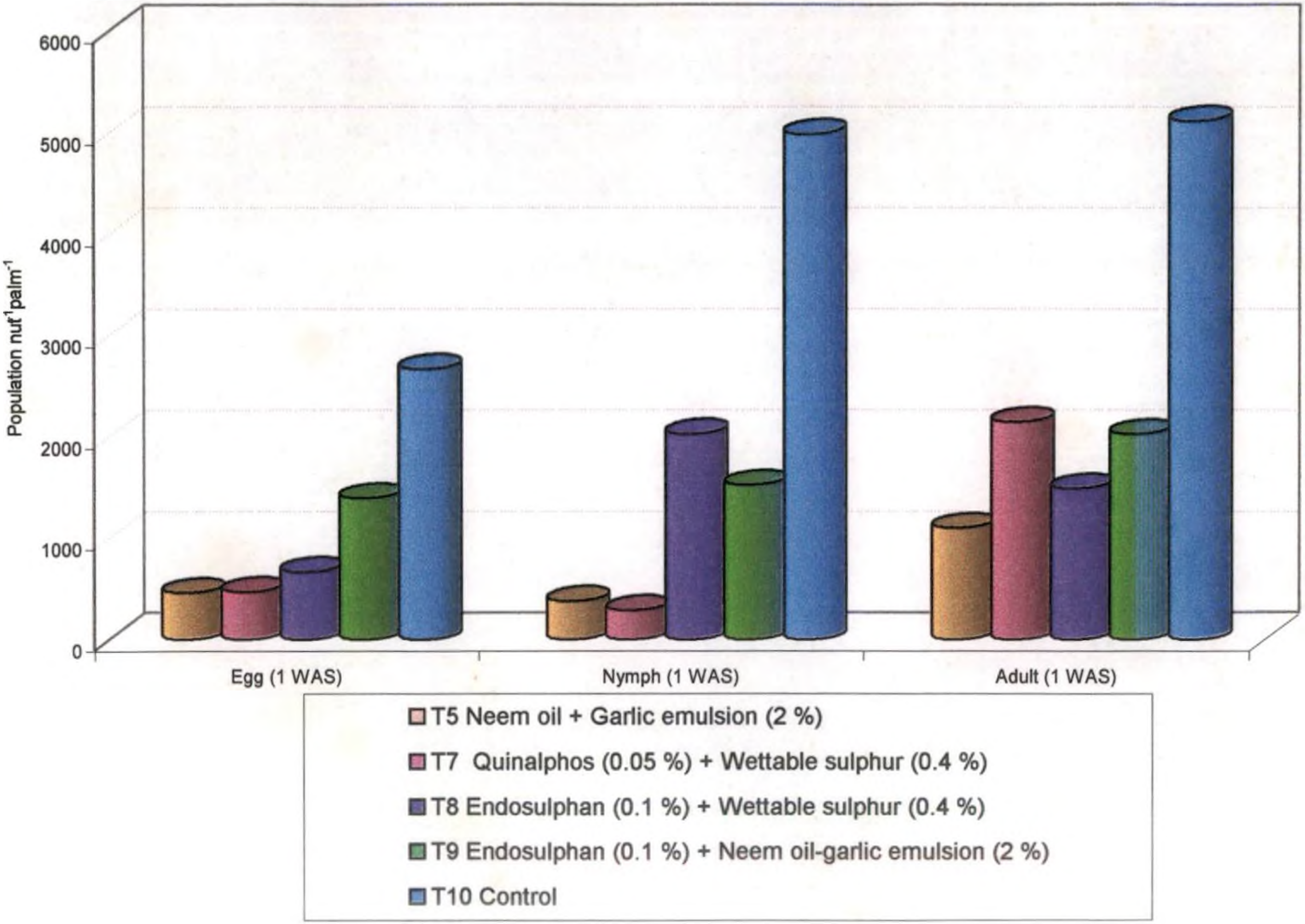


Table 17 Cost of superior treatments in experiment on pesticide evaluation

Treatments	Cost of spray solution required for 10 palms (Rs.)
Neem oil – garlic emulsion (2 %)	42.20
Neem oil – garlic emulsion (2 %) + endosulphan (0.1 %)	60.20
Quinalphos (0.05 %) + wettable sulphur (0.4 %)	23.50
Endosulphan (0.1 %) + wettable sulphur (0.4 %)	24.50

reducing the yield loss due to the sucking pest complex as a whole, eventhough the cost involved in this treatment was comparatively high. However this being a botanical pesticide is environmental friendly and is likely to cause least disturbance to the natural enemy complex of the sucking pests.

Endosulphan (0.1 %) was found to be effective against both CEM and CCB (Mohan and Nair, 2000). Wettable sulphur (0.4 %) was reported to reduce the intensity of damage of CEM (Saradamma *et al.*, 2000b). The present study revealed that the combination treatments of quinalphos (0.05 %) + wettable sulphur (0.4 %) as well as endosulphan (0.1 %) + wettable sulphur (0.4 %) were effective in reducing the yield loss due to sucking pest complex. The cost involved is comparatively less in these treatments (Table 17).

5.3 Screening of entomopathogens against bunch infesting sucking pests

One of the major considerations in applying biocontrol agents in pest management is the nature and habitat of the pest. Biological pest suppression strategies are very effective against gregarious sedentary pests (Hagen *et al.*, 1976). CEM and CBM being sedentary pests colonizing under the tepals of developing buttons biological control offers promise for their management. Many parasitoids, predators and pathogens have been tried against sucking pests (DeBach, 1964). Pathogens having the ability to cause natural epizooties among the pest population are the best suited in this regard (Moore and Howard, 1996; Moore, 2000).

However the mode of feeding of sucking pests preclude the attack of pathogenic viruses and bacteria (Charnely *et al.*, 1997). Fungi with the ability to cause infection by penetrating the cuticle could be successfully used against sucking pests (Hajek and Leger, 1994).

In this context some of the entomo/acaropathogenic fungi were evaluated for infectivity against CEM, CCB and CBM. *V. suchlasporium* and *M. anisopliae* infected CEM and CCB respectively causing 30.8 per cent and 96.7 per cent mortality. Rabindran *et al.* (2000) reported *V. suchlasporium* and *M. anisopliae* to be pathogenic to CEM. However in the present study *M. anisopliae* failed to cause any mortality to CEM. This may be because of the strain variation of the pathogens tested. Though significant reduction in population of CEM was observed in infested nuts treated with *F. pallidoroseum* and *P. farinosus*, fungal infection could not be detected. The reduction in population may be due to the effects of toxins produced by these fungi. *F. pallidoroseum* was reported to produce fusaric acid, toxic to cowpea aphid (Faizal, 1992 and Rejirani, 2001). *Paecilomyces* sp. was also reported to produce toxins (Hajek and Leger, 1994). *V. suchlasporium* was compared with *H. thompsonii*, an effective pathogen of CEM. Both pathogens caused mortality of CEM but *H. thompsonii* caused 56.8 per cent mortality as against 30.80 per cent by *V. suchlasporium* when observed seven days after spraying. The efficiency of *H. thompsonii* as fungal pathogen of CEM has already been proved (Julia and Mariau, 1979; Lampedro and Rosas, 1989; Beevi *et al.*, 1999).

5.4 Survey for fungal pathogens of bunch infesting sucking pests of coconut

With an aim to detect and isolate pathogenic fungi of local origin attacking sucking pests of coconut, a survey spanning over a period of one year was conducted in the study area. Natural fungal infection was detected in CEM and CBM whereas it could not be detected in CCB. Four fungal pathogens from CEM *viz.*, *Penicillium purpurogenum* Stoll., *Acremonium strictum* Gams., *Fusarium solani* (Martius) Sacc. and *Paecilomyces varioti* (Bainer) and one from CBM *F. moniliforme* Wollenw and Reink were successfully isolated. Entomopathogenic nature of these fungi was reported earlier. *P. purpurogenum* was reported to be pathogenic to *Anadevidia peponis* (Mathai *et al.*, 1997), *Fusarium solani* to pseudostem weevil, *Odoiporus longicollis*, (Anitha *et al.*, 1999), *Paecilomyces* spp. to many insect pests (Ibrahim and Low, 1993) and *F. moniliforme* to epilachna beetle (Beevi and Jacob, 1982).

The present study revealed the existence of pathogenic fungi which naturally regulate the population of CEM and CBM. Though CEM is an exotic pest the local fungal strains might have adopted to cause infection on it. The feasibility of employing fungal pathogens against CEM has already been discussed (Moore and Howard, 1996; Gopal and Gupta, 2001; Moore, 2000).

5.5.5 Survey on egg parasitoids of coconut coreid bug

Nair and Remamony (1964) reported two egg parasitoids of CCB *viz.*, *Hadrophanurus* sp. and *Anastatus* sp. But since then there has not been any reports on egg parasitoids of *P. rostratus* in India. According to Nair (2000) no effective natural enemies of CCB had been located so far. In the present study two hitherto unknown egg parasitoids of CCB *viz.*, *Chrysochalcissa oviceps* Boucek and *Gryon homeoceri* (Nixon) could be detected. Laboratory rearing of parasitoids on egg mass of *P. rostratus* was successful for many generations but no substitute host could be detected. Both parasitoids are potential biological control agents of CCB. Further research on mass rearing and release of these egg parasitoids could make it an important component of Integrated Pest Management in coconut.

The present investigation indicates the existence of sucking pests viz., CEM, CCB and CBM as a complex causing extensive yield loss in coconut. Pesticide treatments effective in reducing the yield loss caused by the sucking pest complex were evaluated. Four new fungal pathogens of CEM one of CBM and two new egg parasitoids of CCB were reported. The findings of the present study gives background information for further research for the development of a sustainable IPM strategy against bunch infesting sucking pest complex of coconut.

Summary

6. SUMMARY

The study entitled "Management of the sucking pest complex, coconut eriophyid mite, coreid bug and button mealy bug, infesting coconut bunches" was conducted at Instructional Farm, College of Agriculture, Vellayani during the period April 2000 to July 2001 with the objective of studying the nature and extent of damage of bunch infesting sucking pests on coconut and to devise suitable management measure against them.

The salient findings of present investigation are as follows.

1) Coconut bunches are attacked by three main sucking pests *viz.*, coconut eriophyid mite (CEM), coconut coreid bug (CCB) and coconut button mealy bug (CBM) either singly or in combinations. The most predominant combination being the combined attack of CEM and CCB.

2) The combined infestation of sucking pests resulted in extensive premature nutfall and varying degrees of damage on the retained nuts. In severe cases distortion and stunting of nuts and formation of barren nuts were observed.

3) Sucking pest complex infestation was found to cause a mean annual nutfall of 101.5 nuts/palm, the percentage share of CEM, CCB and their combination being 35.96, 36.45 and 27.59 per cent respectively.

4) Nutfall due to sucking pest infestation was maximum during December followed by November, October and September.

5) Significant negative correlation was found to exist between minimum temperature and mean number of fallen nuts having symptoms of dual attack of CEM and CCB.

6) Infestation of button mealy bug singly or in combination with other sucking pests retarded nut development resulting in formation of stunted/barren nuts. A mean of 5.81 nuts $bunch^{-1}$ $palm^{-1}$ were found barren or stunted due to CBM infestation.

7) Retention of nuts was minimum in bunches that opened during November. The infestation percentage of CEM on retained nuts ranged between 95.31 and 100 per cent while that of CCB ranged between 3.44 to 100 per cent during the one year period of study.

8) Out of the total retained nuts 96.35 per cent showed symptoms of damage by the sucking pests.

9) A new 1-5 scoring technique was developed to evaluate relationship between surface damage by both CEM and CCB and nuts characteristics. Significant negative correlation was observed between area of pericarp damaged and weight of whole nuts, weight of dehusked nut, weight of dewatered nut, volume of nut water and weight of copra. Significant reduction in the above mentioned nut characteristics was observed in higher scores with high intensity of surface damage as compared to healthy nuts (Score 1). Reduction in weight of whole nut, dehusked nut and copra ranged between 17 to 46 per cent, 13 to 50 per cent and 11 to 53 per cent respectively.

10) Among the various pesticides evaluated against the sucking pest complex, neem oil – garlic emulsion (2 %), quinalphos (0.05 %) + wettable sulphur (0.4 %), endosulfan (0.1 %) + wettable sulphur (0.4 %) and endosulfan (0.1 %) + neem oil garlic emulsion (2 %) were found to be effective in reducing the yield loss.

11) Entomopathogenic fungi, *Verticillium suchlasporium* (Goddard) and *Metarhizium anisopliae* (Metch.) Sorok were found to be infective to CEM and CCB respectively.

12) *V. suchlasporium* caused 30.8 per cent per cent mortality seven days after spraying as against 56.8 per cent by *Hirsutella thompsonii* F. under laboratory conditions.

13) The survey conducted to identify possible fungal pathogens of sucking pests revealed the existence of four pathogens of CEM and one of CBM which are hitherto unreported in these pests. The entomopathogenic fungi, *Penicillium purpurogenum* Stoll., *Acremonium strictum* Gams., *Fusarium solani* (Martius) Sacc. and *Paecilomyces varioti* (Bainer) were isolated from CEM and *Fusarium moniliforme* Wollenw and Reink from CBM.

14) Two egg parasitoids *viz.*, *Chrysochalcissa oviceps* Boucek and *Gryon homeoceri* (Nixon) hitherto unknown to parasitise the egg mass of CCB were reported for the first time.

The results of present study will aid in formulating an ecologically safe and economically viable IPM strategy against the sucking pest complex infesting bunches of coconut.

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*Original not seen

MANAGEMENT OF THE SUCKING PEST COMPLEX, COCONUT ERIOPHYID MITE, COREID BUG AND BUTTON MEALY BUG, INFESTING COCONUT BUNCHES

BY

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ABSTRACT

A study was conducted at the College of Agriculture, Vellayani from April 2000 to July 2001 to investigate the nature and extent of damage caused by the sucking pest complex, coconut eriophyid mite (CEM), coconut coreid bug (CCB) and coconut button mealy bugs (CBM) infesting coconut bunches and to devise suitable chemical and biological management measures against them.

CEM, CCB and CBM attack coconut bunches singly or in combinations, the combined attack of CEM and CCB being the most predominant. The coconut palms suffered heavy loss due to the combined infestation of these pests by way of premature nutfall, varying degrees of damage in retained nuts, distortion and stunting of nuts and formation of barren nuts. An annual premature nutfall of 101.5 nuts $palm^{-1}$ was observed due to sucking pest infestation, the share of nut fall due to CEM, CCB and the combined infestation of CEM and CCB being 35.96 per cent, 36.45 per cent and 27.59 per cent respectively. Maximum nutfall was observed in November. 5.81 nuts $bunch^{-1}$ $palm^{-1}$ were rendered barren or stunted due to infestation of button mealy bugs, singly or in combination with other pests. The infestation of CEM in retained nuts was more or less uniform all through the year whereas CCB showed wide fluctuation with maximum infestation in bunches that opened in November.

A new scoring technique was developed, based on surface damage by the pests to assess the loss incurred due to combined infestation of CCB and CEM. Significant negative correlation was observed between surface damage

and nut characteristics like weight of whole nut, weight of dehusked nut, weight of dewatered nut, volume of nut water and weight of copra. Significant reduction in the above nut characters was observed in higher scores with high intensity of surface damage as compared to healthy nuts (Score 1). Reduction in weight of whole nut, dehusked nut and copra ranged between 17 to 46 per cent, 13 to 50 per cent and 11 to 53 per cent respectively.

Among the various pesticides evaluated against the sucking pest complex, neem oil – garlic emulsion (2 %), quinalphos (0.05 %) + wettable sulphur (0.4 %), endosulfan (0.1 %) + wettable sulphur (0.4 %) and endosulfan (0.1 %) + neem oil garlic emulsion (2 %) were found to be effective in reducing the yield loss.

Verticillium suchlasporium (Goddard) and *Metarhizium anisopliae* (Metch.) Sorok. were found to be infective to CEM and CCB respectively. Four entomopathogenic fungi *Penicillium purpurogenum* Stoll., *Acremonium strictum* Gams., *Fusarium solani* (Martius) Sacc. and *Paecilomyces varioti* (Bainer) were identified causing natural mortality CEM population and one fungus, *Fusarium moniliforme* Wollenw and Reink, to CBM.

Two egg parasitoids *viz.*, *Chrysochalcissa oviceps* Boucek and *Gryon homeoceri* (Nixon), hitherto unknown to parasitise the eggs of CCB were identified.